Operating Manual and
Programming Reference

IGC100
Ion Gauge Controller

Stanford Research Systems

Revision 2.5 (01/10/2020)

Certification

Stanford Research Systems certifies that this product met its published specifications at the time of shipment. Stanford Research Systems further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (NIST).

Warranty

This Stanford Research Systems product is warranted against defects in materials and workmanship for a period of one (1) year from the date of shipment.

Service

For warranty service or repair, this product must be returned to a Stanford Research Systems authorized service facility. Contact Stanford Research Systems or an authorized representative before returning this product for repair.

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Safety and Preparation For Use

CAREFULLY READ THE IMPORTANT SAFETY INSTRUCTIONS AND NOTES INCLUDED IN THIS SECTION BEFORE USING THE IGC100 ION GAUGE CONTROLLER AND ITS ACCESSORIES. SAFETY PAYS!

Within this section, the word **'product'** specifically refers to the **IGC100 Ion Gauge Controller and any of its accessories**.

Safety risks are associated with all research and production activities. Though long experience has proven high vacuum instrumentation to be remarkably safe, hazards are always associated with vacuum system operation. The most effective way to minimize risk to yourself and others is to read, and strictly follow, all safety instructions and warnings during the installation, operation and maintenance of the equipment connected to your vacuum system.

The intent of this section is to collect, in a single place, the most common risks associated to the installation, operation and maintenance of this product. The instructions are also repeated, with additional information, at the appropriate points throughout this manual.

This product has been designed with user-safety as a priority and has been proven to show reasonably safe operation provided it is installed, operated and serviced in strict accordance with all the safety instructions included in its manual

Safety Instructions and Warnings

- **SAFETY PAYS!** Safety instructions must be strictly followed during all stages of installation, operation and service of this product. Failure to comply with these precautions and warnings violates the safety standards expected of users of this product.
- If you have any doubts about how to use this product safely, contact Stanford Research Systems at the address listed in this manual.
- Retain these safety and operating instructions for future reference.
- Identify and adhere to all warnings posted on the product.
- Failure to comply with these instructions may result in serious personal injury, including death, as well as significant property damage.
- Due to the variety of vacuum system configurations and applications, it is impossible to account for all safety concerns that may arise during the installation, operation and maintenance of this product. Please contact the factory for any specific safety concerns not addressed directly by this manual.
- It is the installer's responsibility to ensure the safe operation of automated vacuum systems. Carefully check manual operation of the system and the setpoint programming instructions before switching to automatic operation.
- Provide for fail-safe operation wherever an equipment malfunction could lead to a hazardous situation.

Electrical Shock Risks

The most common risk associated with the operation of vacuum equipment is electrical shock.

- Dangerous voltages capable of causing injury and death are present during the operation of this product. **Do not remove the covers while the unit is plugged into a live outlet.**
- **Always operate the unit in its proper horizontal orientation.** Do not operate the unit on its side as foreign objects or liquids may enter through the ventilation slots, creating an unsafe condition.
- **Do not use this product if it has unauthorized modifications.** Unauthorized modifications may result in fire, electric shock and other hazards.
- Do not install substitute parts or perform any unauthorized modifications to this instrument.
- **The line fuse is internal to the instrument and may not be serviced by the user.** If the red 'Line' LED does not turn on when line power is provided, contact Stanford Research Systems. The fuse on the rear panel is for the ion gauge, NOT line power.
- The IGC100 has a detachable, three-wire power cord for connection to the power source and to a protective ground. The exposed metal parts of the instrument are connected to the outlet ground to protect against electrical shock. **Always use an outlet which has a properly connected protective ground.** Consult with an electrician if necessary. Be aware that grounding this product does not assure proper grounding of the rest of the vacuum system.
- The most important safety measure required to eliminate electric shock risks is to **provide an earth ground to all conductive parts of the vacuum chamber, gauges and controllers.**
- GFCI (Ground Fault Circuit Interrupter) protected outlets are often available in production and laboratory environments, particularly in proximity to water sources. GFCI's are generally regarded as an important defense against electrocution. However, **the use of a GFCI in conjunction with IGC100's and vacuum systems must not be regarded as a substitute for proper grounding and careful system design.** GFCI's must also be tested regularly to verify their functionality. Always consult an electrician when in doubt.
- Do not use accessories not recommended in this manual as they may be hazardous.
- 180 Vdc is present in the controller, on the cable and at the ionization gauge when the ionization gauge tube is turned on. This voltage increases to ≈ 500Vdc during degas operation. **Do not touch any cable connections when power is being applied to the unit.**
- **Always turn off the power to the instrument before connecting any cable to the controller or to an ionization gauge tube.**

- High-voltage ion-producing equipment such as a hot-cathode ionization gauge can, under certain circumstances, provide sufficient electrical conduction via a plasma to couple a high voltage potential to the vacuum chamber walls. Any exposed conductive parts of a gauge or vacuum chamber may attain high voltage potentials through this process if not properly grounded.
- All conductors in, on, or around the vacuum system that are exposed to potential high voltage electrical discharges must either be shielded at all times to protect personnel or must be connected to the system earth-ground at all times.
- All parts of a vacuum system utilized with this or any similar high voltage product must be maintained at earth ground for safe operation. There should be an **explicit heavy duty earth-ground connected to the vacuum chamber.** Check with an electrician if necessary. All electronic instrumentation must be connected to properly grounded electrical outlets and include a chassis grounding lug that must be tied to the common earth-ground of the vacuum system. Beware! Failure to safely ground your vacuum system can be fatal!
- The electrical insulation in this product may become less effective at preventing electrical shock after ten years of normal use (or even non-use). Products placed in harsh environments might deteriorate even faster. Inspect all electrical insulation periodically for signs of cracking and deterioration. Return the product to the factory for service if the insulation has become unsafe.
- To reduce the risk of fire and electrocution do not expose this product to rain or moisture. Be careful not to spill liquid of any kind onto or into the product.
- This product is intended for use only in a clean and dry laboratory environment. Operation in other environments may cause damage to the product and reduce the effectiveness of the safety features.
- Keep in mind that **O-ring seals without metal clamps or bolt connections can isolate big portions of a vacuum system from its safety ground.** Verify that the vacuum port to which any new component is mounted is electrically grounded. Use a ground lug on a flange bolt if necessary.
- Keep all electrical wiring in your vacuum system neatly organized and in good working conditions. Label and color-code all high voltage cables. Inspect all HV wires periodically for problems as part of your safety checkups.
- Use tie downs and cable channels to hold all electrical wiring in place (i.e. no dangling cables).
- Keep all electronic instrumentation neatly organized, and remove unconnected cables and connectors from the vacuum setup.
- If possible, rack mount your vacuum instrumentation.
- Only use instrumentation with high quality cables and connectors that properly shield all high voltage terminals. Eliminate homemade connections from your vacuum setups.
- High voltage cables from ion gauge controllers, ion guns, photomultiplier tubes, mass spectrometer probes, power supplies, etc , can be inadvertently damaged if pinched while tightening flange bolts. Keep all cables away from vacuum ports frequently opened to air.

- The voltages delivered by this product can be lethal, particularly during electron bombardment degas. Do not touch any of its connection pins even if the gauge is off.
- Do not push objects of any kind into this product through openings as they may come in contact with dangerous voltage points or short out parts that could result in a fire or electric shock.
- Verify that the vacuum port to which the ionization or Pirani gauge is mounted is electrically grounded. It is essential for personnel safety as well as proper operation that **the envelope of every ionization gauge be properly connected to the facility earth-ground.** Use a ground-lug on a flange bolt if necessary.
- **Perform regular electrical ground checkups** on your entire vacuum system, particularly if it is shared by multiple users running unrelated experiments. During a ground checkup carefully examine all vacuum system components: Are all exposed connectors and conductors on the vacuum chamber grounded? Are all ground connections properly connected to a solid earth (i.e. facility) ground? Some vacuum systems rely on water piping for the earth-ground connection. Proper ground connection can be easily lost by inadvertently inserting a plastic interconnect into the water lines. Refer to the step-by-step vacuum system grounding test procedure in Chapter 1 of this manual.
- Operation of this product with line voltages other than those accepted by the power supply can cause damage to the instrument and injury to personnel.

Burn Risks

Another common safety concern for vacuum system operators is burns.

- Filament based devices, such as Bayard-Alpert ionization gauges radiate heat to areas adjacent to the filament, sometimes making them too hot to touch.
- Do not touch hot-cathode Ionization Gauges during degassing operation. Serious burns can occur.
- Acetone, toluene and isopropyl alcohol are highly flammable and should not be used near an open flame or energized electrical equipment.

Explosion Risks

Injury due to explosion is another important safety concern during the operation of a vacuum system and gas manifold system.

Explosion is possible in systems that are routinely cycled from vacuum to pressures above atmosphere and can be caused by many different reasons. Dangerous overpressure conditions can be established if a pressure regulator is set to the wrong value, the wrong gauge or gauge calibration is used for positive pressure measurements or even if a bad setpoint value is programmed into an automated process control setup. Explosions can also occur if flammable or explosive gases are exposed to hot elements such as the hot filaments of a Bayard-Alpert gauge or the sensor wire of a Pirani gauge.

- Check that the right cylinders, with the right gases, are connected to the gas handling system before starting any process.
- **Check the pressure regulator settings** before starting any process.
- **Confirm that the right units were used** to program the setpoints of all automated process control channels.
- Install suitable devices that will limit the pressure to the level that the vacuum system, and its gas manifold, can safely withstand.
- Use pressure relief valves in the gas manifold and in the vacuum chamber, that will release pressure at a level considerably below that pressure which the system can withstand.
- **Do not use the product to measure the pressure of flammable, explosive, combustible or corrosive gases or mixtures of gases.** Turn off hot filament gauges during the exposure to flammable or explosive gases. Do not use this product to measure the pressure of unknown gases.
- The sensor wire of the Pirani gauge (PG105 or PG105-UHV) operates at about 120° C, but it is possible that controller malfunction might increase the sensor temperature above the ignition temperature of combustible gases. Turn off all PG105 gauges exposed to flammable or explosive gases.
- Avoid enhanced Pirani and thermocouple gauges for pressure measurements in systems routinely pressurized above atmosphere (capacitance diaphragm gauges are much safer and recommended instead).
- If used improperly, Pirani gauges can supply incorrect pressure readings. For example, using the N_2 calibration of a convection-enhanced Pirani gauge (i.e. PG105 or PG105-UHV) to pressurize a vacuum system above 1 Torr with certain other gases can cause dangerously high pressures and may lead to explosion.
- **Do not use compression fittings for positive pressure applications.** Pirani, thermocouple and even capacitance diaphragm gauges mounted in this fashion can be forcefully ejected and injure anybody in their path.

Implosion Risks

The risk of implosion must also be considered in high vacuum systems using glass windows, glass tubulation and glass-envelope ionization gauges. Dropping a tool on a gauge under vacuum, or pulling on the cables can easily break the glass. The resulting implosion may then throw glass fragments around the room injuring personnel.

- Glass-tubulated ionization gauges should not be treated roughly or be bumped.
- Install the ion gauge cable on glass tubulated gauges before the gauge reaches vacuum pressures.
- **Stress relief all cables attached to glass tubulated ionization gauges.**
- Do not allow the gauge tube temperature to exceed 100° C in glass tubulated gauges. Sustained high temperatures can damage the tube, causing air leakage into the vacuum system and increasing the chances of dangerous implosion.
- Make all glass windows as small and thick as possible.

- Wherever feasible, replace glass-tubulated gauges with all-metal ones.
- Protect all glass components with internal vacuum with tape or metal shields.

References

For additional information on vacuum technology safety recommendations consult:

1. Charles F. Morrison, "Safety Hazard From Gas Discharge Interactions with the Bayard-Alpert Ionization Gauge", J. Vac. Sci. Technol. A 3 (5) (1985) 2032.

2. R. N. Peacock, "Safety and Health Considerations Related to Vacuum Gauging", J. Vac. Sci. Technol. A 11(4) (1993) 1627.

3. John T. Yates, Jr., "Experimental Innovations in Surface Science. A Guide to Practical Laboratory Methods and Instruments", Springer-Verlag, New York, Inc., 1998: (1) Section 238, p. 832, titled: 'Electrical Shocks in the Laboratory'; and (2) Section 239, p. 836, titled: 'Accidental Electrical Charging From Ionization Gauge'.

4. Gerardo Brucker, "Prevention is Key to Vacuum System Safety", R&D Magazine, February 2001, p. 57.

5. Donald M. Mattox, "Safety Aspects of Vacuum Processing", Vacuum Technology and Coating Magazine, March 2001, p. 22.

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Front Panel Overview

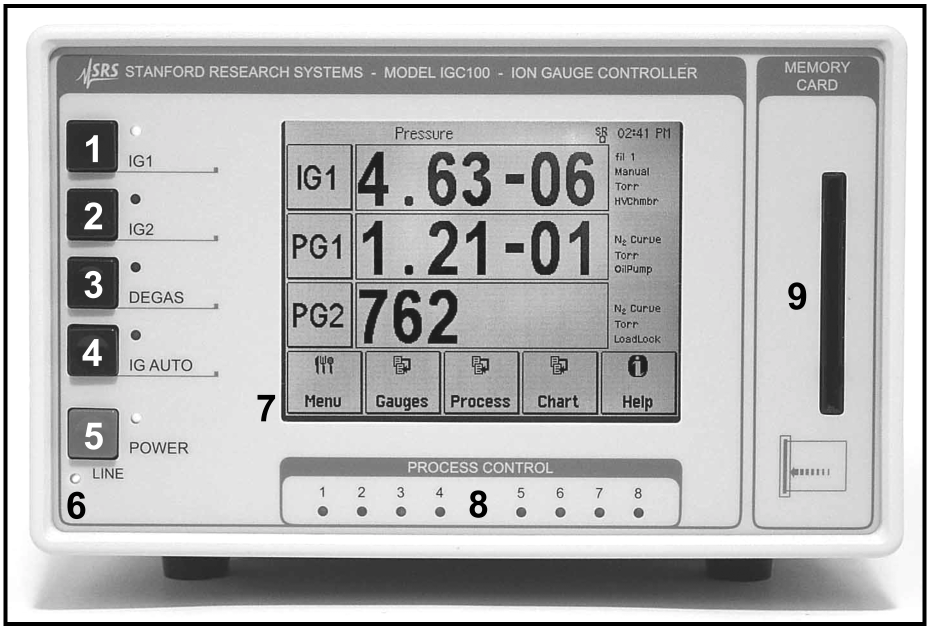
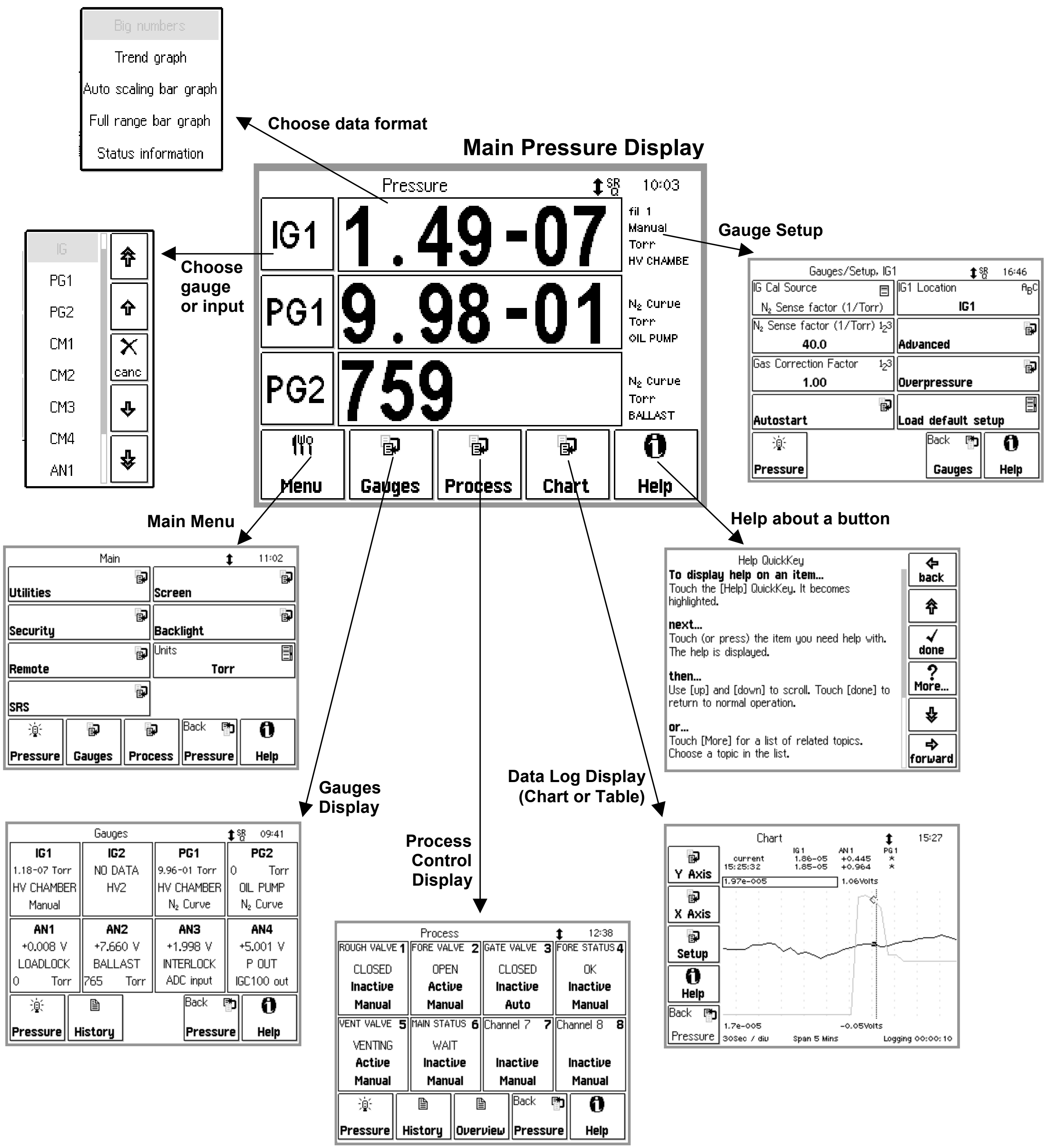


Figure i. IGC100 Front Panel.

1. IG1 BUTTON (Black w/green LED). Ionization gauge 1 power switch.
2. IG2 BUTTON (Black w/green LED). Ionization gauge 2 power switch.
3. DEGAS Button (Black w/red LED). Degas Power switch.
4. IG AUTO Button (Black w/yellow LED). IG AUTO-START switch.
5. POWER Button (Red w/green LED). Controller power switch.
6. LINE LED (Red). Line voltage indicator.
7. LCD Display (w/touchscreen). Pressure and menu display area.
8. PROCESS CONTROL LEDs (green). Process control channel indicator lights.
9. MEMORY CARD Module. Memory card slot.

Touchscreen Display Overview



Back Panel Overview

WARNING!

- Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.
- Read Chapter 1 for detailed instructions and safety information regarding the installation of the IGC100 and connection of gauges.

Figure ii. The IGC100 back panel.

1. Power - Power Entry Module, CHASSIS GND.
2. Ionization Gauge - ION GAUGE POWER.
3. Ionization Gauge - COLLECTOR (IG1 & IG2).
4. Pirani Gauge - PIRANI.
5. Capacitance Manometer – ±15 V AUX POWER.
6. Analog I/O - BNC Ports AN1-4
7. Computer Interfaces - RS-232, GPIB (IEEE-488) (Opt 01), and ethernet 10BASET (Opt 02).
8. Process Control (Opt. 03) - RELAY CONTACTS, DIGITAL I/O.

Connector Pinouts

WARNING!

- Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.
- Read Chapter 1 for detailed instructions and safety information regarding the installation of the IGC100 and connection of gauges.

Ion Gauge Power Connector

Use the 14-pin ION GAUGE connector to power an ionization gauge.

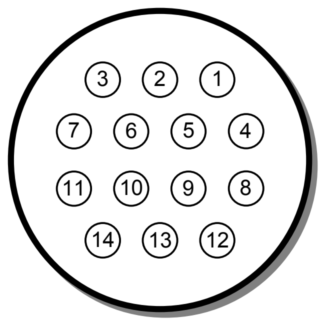


Figure iii. The ion gauge power connector.

Pin	Name	Description
1	O100IG_ID	This pin is used by the IGC100 to verify the presence of option O100IG (Dual Ion Gauge Connector Box)
2	unused	
3	O100IG_24V _SUPPLY	This pin provides 24 VDC (100 mA) to the relays of option O100IG when: (1) O100IG is detected (pin 1) and (2) IG2 is selected.
4	GND	Chassis Ground Connection
5	FIL_RETURN	Filament power return. Return path for the power provided by pins 8 and 11 (both filaments). +30 VDC bias, independently monitored through pin 6 at the gauge head.
6	BIAS_SUPPLY	Filament Bias Monitor +30 VDC bias.
7	O100IG_24V _RETURN	This pin provides the return path for the 24 VDC (100 mA) power provided by pin 3.
8	FIL2_SUPPLY	Filament 2 power supply [7 Amps DC, 7 VDC].
9	unused	
10	unused	
11	FIL1_SUPPLY	Filament 1 power supply [7 Amps DC, 7 VDC].
12	unused	
13	GRID_SUPPLY	Anode Grid Supply. +180 VDC (10 µA-12 mA), normal emission. ≈ 500 VDC (2-160 mA max), Degas.
14	unused	

1) Use only O100C1, O100C2 and O100C3 signal cables provided by Stanford Research Systems to connect ionization gauges to the IGC100 controller.
2) The ION GAUGE connector is also compatible with the STABIL-ION® gauge signal cables (part numbers 360112, 360114 or 360116) available directly from Granville-Phillips (Helix Corporation).
3) For maximum accuracy, independent of cable length, pins 5 and 6 of SRS ion gauge cables are connected together at the end that attaches to the gauge head.
4) Pins 1, 3 and 7 are for the optional Dual Ion Gauge Connector Box (O100IG). Do not make connections to those pins.

The ION GAUGE connector of a standard IGC100 is treated as the IG1 port. If the Dual Gauge Option (SRS# O100IG) is installed, this connector is used to power the option box. In this case, two gauges may be connected to the option box.

Pirani Gauge Connector

Use the DB-15 PIRANI port to connect up to two PG105 Pirani gauges to the IGC100 controller. Use only SRS# O105C4 Dual Pirani Gauge cables.

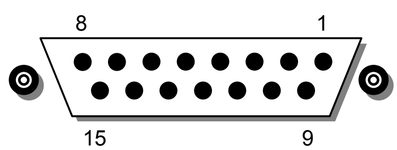


Figure iv. The dual Pirani gauge connectors

Pin	Pirani Gauge	Description
1		unused
2		unused
3	1	GND_Sense
4	1	GND_PWR
5	1	NULL (+) (filament side)
6	1	NULL (-) (divider side)
7	1	Vbr_PWR
8	1	Vbr_Sense
9	2	GND_PWR
10	2	GND_Sense
11	2	NULL (+) (filament side)
12	2	NULL (-) (divider side)
13	2	Vbr_PWR
14	2	Vbr_Sense
15		unused

±15 V AUX Power Connector

Use this 3-pin, ±15 V (100 mA max), connector to provide electrical power to standard (i.e. non-heated) capacitance manometers.

Process Control (Opt. 03)

Relay Contacts

Use these two 12-Position Terminal Block Plugs to connect to the eight process control relays. All relays are SPDT, form C, 5A/250VAC/30VDC, resistive load only.

Process Action	Relay Common Connected to	Rear Panel Label
INACTIVE	Normally Closed pin (NC)	I
ACTIVE	Normally Open pin (NO)	A

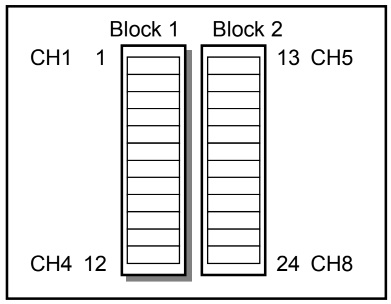


Figure v. The 2 12-position terminal blocks for process relay connections.

Block	Pin	Process Channel	Process Control Label	Relay Pin
1	1	1	Common (C)	C
	2		Inactive (I)	NC
	3		Active (A)	NO
	4	2	Common (C)	C
	5		Inactive (I)	NC
	6		Active (A)	NO
	7	3	Common (C)	C
	8		Inactive (I)	NC
	9		Active (A)	NO
	10	4	Common (C)	C
	11		Inactive (I)	NC
	12		Active (A)	NO
2	13	5	Common (C)	C
	14		Inactive (I)	NC
	15		Active (A)	NO
	16	6	Common (C)	C
	17		Inactive (I)	NC
	18		Active (A)	NO
	19	7	Common (C)	C
	20		Inactive (I)	NC
	21		Active (A)	NO
	22	8	Common (C)	C
	23		Inactive (I)	NC
	24		Active (A)	NO

DIGITAL TTL I/O

Use the female DB37 port to connect to the (1) eight Process Control TTL Outputs, (2) eight Process Control TTL inputs and (3) twelve Remote Control TTL inputs of the Process Control Board. A male DB37 connector is provided to facilitate connection to the controller.

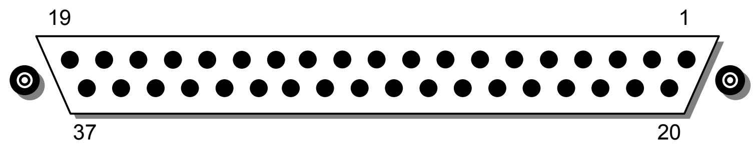


Figure vi. The DB37 TTL I/O connector.

Pin	Module	Name	Description
1		IGC100 Vcc	+5 V OUT
2	**Remote Control TTL IN**	ANODE COM	External User +5 V IN
3		IG1_On	Edge trigger: ↓=IG1 On, ↑=IG1 Off
4		IG2_On	Edge trigger: ↓=IG2 On, ↑= IG2 Off
5		Degas_On	Edge trigger: ↓= Degas On, ↑=Degas Off
6		IG_Lockout	Level: LOW=IG1 and IG2 emission Off
7		IG_Key_Disable	Level: LOW=Disable front panel IG Keypad.
8		PG1_Off	Edge trigger: ↓=PG1 Off, ↑=PG1 On
9		PG2_Off	Edge trigger: ↓=PG2 Off, ↑=PG2 On
10		Clear_Data_Log	Edge trigger: ↓=clear the data log
11		IG_Remote_Enable	Level: HIGH=Ignore IG1_On, IG2_On, Degas_On, FIL1_On, FIL2_On pins.
12		FIL1_On	Edge trigger: ↓=FIL1 ON, ↑=FIL1 Off
13		FIL2_On	Edge trigger: ↓= FIL2 ON, ↑= FIL2 Off
14		Front_Panel_Disable	Level: LOW=Disable Touchscreen and Keypad
15		IGC100 Vcc	+5 V OUT
16	**Process Control TTL OUT**	TTL_OUT_5	TTL OUT for Channel 5. LOW=ACTIVE
17		TTL_OUT_6	TTL OUT for Channel 6. LOW=ACTIVE
18		TTL_OUT_7	TTL OUT for Channel 7. LOW=ACTIVE
19		TTL_OUT_8	TTL OUT for Channel 8. LOW=ACTIVE

Pin	Module	Name	Description
20	**Process Control TTL IN**	ANODE COM	External User +5 V IN
21		TTL_IN_1	TTL Input Signal for Channel 1. Active LOW
22		TTL_IN_2	TTL Input Signal for Channel 2. Active LOW
23		TTL_IN_3	TTL Input Signal for Channel 3. Active LOW
24		TTL_IN_4	TTL Input Signal for Channel 4. Active LOW
25		TTL_IN_5	TTL Input Signal for Channel 5. Active LOW
26		TTL_IN_6	TTL Input Signal for Channel 6. Active LOW
27		TTL_IN_7	TTL Input Signal for Channel 7. Active LOW
28		TTL_IN_8	TTL Input Signal for Channel 8. Active LOW
29		unused	
30		IGC100 Ground	
31		IGC100 Ground	
32	**Process Control TTL OUT**	COM_EMTR_REF	External User Ground
33		COM_COLTR_PULLUP	External User +5 V IN
34		TTL_OUT_1	TTL OUT for Channel 1. LOW=ACTIVE
35		TTL_OUT_2	TTL OUT for Channel 2. LOW=ACTIVE
36		TTL_OUT_3	TTL OUT for Channel 3. LOW=ACTIVE
37		TTL_OUT_4	TTL OUT for Channel 4. LOW=ACTIVE

Note: ↓=HIGH-to-LOW, ↑=LOW-to-HIGH transition.

Process Control TTL OUT

These outputs are opto-isolated from the IGC100. For isolated operation of ALL outputs, connect pin 33 to the external +5 V supply and pin 32 to the external ground. For non-isolated operation of ALL outputs, connect pin 33 to IGC100 Vcc (pin 1 or 15) and pin 32 to IGC100 Ground (pin 30 or 31).

Process Control TTL IN

These inputs are opto-isolated from the IGC100. For isolated operation of ALL Process Control inputs, connect pins 2 and 20 to the external +5 V supply. Pull inputs to external ground for low inputs. For non-isolated operation of ALL Process Control inputs, connect pins 2 and 20 to IGC100 Vcc (pin 1 or 15) and pull inputs to IGC100 Ground (pin 30 or 31) for low inputs.

Remote Control TTL IN

These inputs are opto-isolated from the IGC100. For isolated operation of ALL Remote Control inputs, connect pins 2 and 20 to the external +5 V supply. Pull inputs to external ground for low inputs. For non-isolated operation of ALL Remote Control inputs, connect pins 2 and 20 to IGC100 Vcc (pin 1 or 15) and pull inputs to IGC100 Ground (pin 30 or 31) for low inputs.

RS-232 Connector

The IGC100 uses a DIN8 connector for its RS-232 port while most PC computers use DB9 connectors. A DIN8-DB9 connector adapter cable is provided with every IGC100 controller. The female DB9 connector of the DIN8-DB9 connector adapter cable is configured as a DCE.

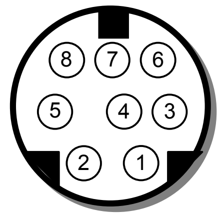


Figure 2-8. The IGC100 DIN8 RS-232 connector.

Pin	Signal
1	handshake out
2	handshake in
3	Transmit data
4	ground
5	Receive data
6	unused
7	unused
8	ground

Specifications

Specifications apply after 1 hour of warm-up and assume single filament (Fil1 or Fil2) ionization gauge operation with a signal cable shorter than 50 ft.

General

Pressure Range	1000 Torr to UHV (<10^{-11})
Compatible gauges	Bayard-Alpert type ionization gauges, convection enhanced Pirani gauges, capacitance manometers with 0 to 10 Vdc linear output.
Dual Pirani gauge	Simultaneous readout of two Pirani gauges (std.)
Dual ion gauge	Sequential readout of a second ion gauge (opt.)
Auto-Start	Use PG1 or PG2 to automatically turn IG1 or IG2 on/off when pressure goes through user-defined level.
Interfaces	RS-232 (std.), optional GPIB (opt. 01) or Ethernet interface with embedded web server (opt. 02)
Power	90 to 264 VAC, 47 to 63 Hz, 240 W
Operating temperature	0°C to 40°C, non-condensing Less than 90% humidity
Weight/Dimensions	15 lbs. / 8.5"x5.25"x16" (WHD)
Warranty	One year parts and labor

Display

Type	Back-lit, touchscreen LCD (4.7" diag)
Resolution	320 x 240 pixels
Modes	Numeric, bargraph, P vs. T
Units	Torr, mbar, bar, Pa and micron
Numeric resolution	3 digit mantissa plus exponent
Update rate	2 samples per second

Electrical (20°C to 30°C)

Electron Emission Current

Range	10 µA to 12 mA
Stabilization	Electronically controlled
Accuracy	±1% of setting

Anode

Potential	+180 Vdc
Accuracy	±0.3% of setting

Filament

Potential	+30 Vdc
Accuracy	±0.3% of setting
Filament power (max)	7 Amps DC, 7 Vdc

Degas

Mode	Electron bombardment
Power	1 to 75 W, adjusted in 1 Watt steps
Time	1 to 30 min., adjusted in 1 min. steps
Anode potential	500 Vdc
Emission current	2 to 150 mA
Display	Approximate pressure, degas power and remaining time

Electrometer

Accuracy	±1% of reading
Zero drift	0.4 pA

Analog I/O

Ports	4 configurable analog ports
Range	±12 Vdc
Resolution	14-bit (In), 12-bit (Out)
Update rate	2 Hz
Connector	BNC

Gauges

Ionization Gauge

Gauge type	Bayard-Alpert type ionization gauges including glass tubulated (std. and broad-range), nude, nude-UHV, STABIL_ION®, MICRO_ION®. Supports tungsten (W) and ThO_2 Ir filaments.
Pressure range	10^{-11} to 10^{-1} Torr Lower limit: X-ray limit of Bayard-Alpert gauge Upper limit: Maximum operating pressure specified by manufacturer
Pressure calculation	From sensitivity constant or full range calibration curve
Sensitivity constant	0.1/Torr to 100/Torr
Filament selection	Filament 1, Filament 2, or both
Overpressure protection	Programmable trip points, auto-start protection
Analog output	log, 1V/decade, 1 to 10 V

Convection Enhanced Pirani Gauge

Gauge type	PG105 & PG105-UHV Convection Enhanced Pirani gauges, CONVECTRON® and HPS/MKS Series 317 Convection-Enhanced Pirani gauges.
Pressure range	999 to 10^{-3} Torr. Lower pressure limit extends to 10^{-4} Torr w/ zero adjustment.
Gas type calibration	Direct readings for air, N_2 and Ar. Menu driven zero and atmospheric adjustments.
Analog output	log, 1V/decade, 1 to 8 V

Capacitance Manometer

Number of gauges	Simultaneous readout of up to four capacitance manometers using the auxiliary inputs.
Auxiliary power output	±15 Vdc, 100 mA (for CM power)

Process Control (opt. 03)

Number of channels	8 channels with programmable setpoint, polarity, hysteresis, delay, audio signal and text messages.
Input signals	Pressure (any gauge), voltage (I/O ports), time (internal clock), TTL and gauge status.
Output signals	Relay and TTL level
Relays	SPDT, form C, 5A/250VAC/30VDC, resistive load
TTL outputs	Active low, opto-isolated
Manual control	All channels can be operated from front panel.
Remote TTL control	12 opto-isolated TTL channels (Remote Enable, IG1 on/off, IG2 on/off, Degas on/off, Fil 1/Fil 2 select, IG lockout, IG Control keypad lockout, PG1 on/off, PG2 on/off, data logging time reset, touchscreen enable/disable)

Index of Commands

> **Important**
> Always use the GPMU command at the start of a program to ensure that the desired units are in effect. Use front panel lockout if a units change would result in system malfunction.
>
> Use VERB 0 to set the RS-232 serial interface to terse mode for computer programs. Use VERB 1 to use verbose mode for serial console communications.

Variables

i, j, d, n, p	integers
x	real number
s, t	text strings

Measurements

GPMU (?) {n} {s}	Pressure Units
GDAT ? p	Read Gauge/Port
GDTX ? p	Read Gauge/Port With Units
GPBA (?) n {, i}	Data Bar Assign
GPDF (?) n {, i}	Display Format

Gauges

GDES (?) p {, s}	Gauge Location
GSTA ? p	Gauge Status
GSTT ? p	Gauge Status Time

Ion Gauge Setup

GPOW (?) p {, i}	Power
CSEN (?) p {, x}	Sensitivity Factor
CGCF (?) p {, x}	Gas Correction Factor
CRVI (?) p {, i}	Calibration Source
IGEC (?) p {, x}	Emission Current
GFIL (?) p {, i}	Filament Select
GOSD (?) p (, i}	Overpressure Shutdown
GOTH (?) p {, x}	Overpressure Threshold
GODE (?) p {, n}	Overpressure Delay
GOAA (?) p {, i}	Overpressure Audio Alarm
DGAS (?) {i}	Degas On/Off
DENA (?) {i}	Degas Enable/Disable
DPOW (?) p {, n}	Degas Power
DTIM (?) p {, x}	Degas Time
AOPG (?) {i}	Auto-Start Pirani Gauge
AOIG (?) {i}	Auto-Start Ion Gauge
AOTH (?) {x}	Auto-Start Threshold
AOCN (?) {i}	Auto-Start On/Off
GHGF ?	Read Gauge History First
GHGN ?	Read Gauge History Next

Pirani Gauge Setup

GPOW (?) p {, i}	Power
CGCF (?) p {, x}	Gas Correction Factor
CRVP (?) n {, i}	Calibration Curve

Analog Port Setup

GADM (?) n {, i}	I/O Mode
GDAS (?) n {, i}	DAC Source
ANDF (?) n {, i}	Display Format
GDAV (?) n {, x}	Output Value
CMPX (?) n {, x}	CM PMax

Logging

PLDS (?) {i}	Chart/Table Display
PLCL	Clear Data Log
PLGF ?	Read Data Log First
PLGN ?	Read Data Log Next
PLIN (?) {n}	Logging Interval
PLWT (?) {n}	Log Length
PLEN (?) {i}	Logging Enable
PLDD (?) {i}	Display Date
PLTR (?) {i}	TTL Reset Enable

Charting

LCPN (?) {x}	Pmin
LCPX (?) {x}	Pmax
LCVN (?) {x}	Vmin
LCVX (?) {x}	Vmax
LCSA	Autoscale Y-Axis
LCRG (?) {n}	Time Range
LCSF	Scale X-Axis to Full

Process Control

RDES (?) d {, s}	Channel Description
RLCL (?) d {, s}	Channel Active Label
RLOP (?) d {, s}	Channel Inactive Label
RBEP (?) d {, i}	Channel Beep
RMOD (?) d {, i}	Channel Mode
RSTA (?) d {, i}	Channel State
RAMS (?) d {, i}	Channel Input
RGOS (?) d {, i}	Gauge Off State
RTRP (?) d {, x}	Pressure Setpoint
RPHY (?) d {, n}	Percent Hysteresis
RTRV (?) d {, x}	Voltage Setpoint
RVHY (?) d {, x}	Voltage Hysteresis
RPOL (?) d {, i}	Setpoint Activation
RDEL (?) d {, n}	Setpoint Delay
RTCL (?) d {,n} {,s}	Activation Time
RTOP (?) d {,n} {,s}	Deactivation Time
RTIL (?) d {, i}	TTL Activation Level
TTLL ?	Read TTL Inputs
RHGF ?	Read Process Log First
RHGN ?	Read Process Log Next
RHCL	Clear Process Log
RBAD ?	Relay Failure Status

Backlight	
BLEN (?) {i}	Backlight Saver Enable
BLIT (?) {i}	Backlight On/Off
BLOF (?) d {,n} {,s}	Backlight Turn-Off Time
BLON (?) d {,n} {,s}	Backlight Turn-On Time
BLTD (?) {n}	Backlight Delay

Security	
LOCK ?	Query Locked
PWDL i, s	Lock/Unlock
CPWD	Copy Password to Card
STPW s	Set Password.
SECF (?) d {, i}	Security Flags
WSEN (?) {i}	Web Server Enable

System	
NAME (?) {s}	System Name
SNUM?	Serial Number
TIME (?) {s}	Time
DATE (?) {s}	Date
VOLC (?) {n}	Volume
MENU d	Display Screen
MESG (?) {s}	Message
DHWR ? d	Detect Hardware
*TST ?	Self-Test
FREV ?	Firmware Revision
VRDT ?	Firmware Build

Interface	
VERB (?) {i}	Verbose RS-232
*IDN ?	Identification
*RST	Reset
*OPC (?)	Operation Complete
*WAI	Wait to Continue

Status	
*CLS	Clear Status
*PSC (?) {i}	Power-On Status Clear
*STB ? {i}	Read Serial Poll Status
*SRE (?) {i} {, j}	Serial Poll Enable
*ESR ? {i}	Read Standard Event Status
*ESE (?) {i} {, j}	Standard Event Enable
ERSW ? {i}	Read Error Status
ERSE (?) {i} {, j}	Error Status Enable
GSSW ? {i}	Read Gauge Status
GSSE (?) {i} {, j}	Gauge Status Enable
RSSW ? {i}	Read Process Status
RSSE (?) {i} {, j}	Process Status Enable

Damage Requiring Service

Caution

Do not use this product if it has unauthorized modifications. Unauthorized modifications may result in fire, electric shock and other hazards.

Do not use accessories not recommended in this manual as they may be hazardous.

Note

Within this section, the word 'product' specifically refers to the IGC100 Ion Gauge Controller, any of its accessories, or any SRS manufactured vacuum gauge.

Contact the factory for instructions on how to return the instrument for authorized service and adjustment.

Service of this product, by Authorized Service Personnel only, may be required under any of the following conditions:

- Any cable or plug is damaged.
- The product does not operate properly even after strictly following the operating instructions.
- The product exhibits a distinct change in performance.
- A liquid has spilled inside the product.
- The product has been exposed to rain or water.
- An object has fallen into the product.
- The product has been dropped or the enclosure has been damaged.
- The product contains unauthorized modifications. Do not substitute parts or modify the product. No user-serviceable parts are inside the controller. All service and repair information in this manual is for the use of Authorized Service Personnel only.
- If the product is a vacuum gauge, a Declaration of Contamination, describing the condition of the product and listing the gases it has been exposed to, must be submitted to Stanford Research Systems for review before a return authorization can be issued.
- The repair and/or service of products exposed to vacuum systems can only be carried out if a completed Declaration of Contamination has been submitted. Stanford Research Systems reserves the right to refuse acceptance of vacuum equipment where the Declaration of Contamination has not been fully or correctly completed. SRS also reserves the right to deny return authorizations for any vacuum equipment that could potentially be harmful to the personnel carrying out the repair and service of the product.

Declaration of Contamination of Vacuum Equipment

The repair and/or service of vacuum equipment or components can only be carried out if a completed **Declaration of Contamination** has been submitted to Stanford Research Systems (SRS). The completed declaration must be reviewed by qualified personnel before a return authorization number (RMA#) can be issued. Contact SRS to request additional copies of this form or if you have any questions regarding the contents of this declaration.

- SRS reserves the right to refuse acceptance of vacuum equipment submitted for repair or maintenance work where the declaration has been omitted or has not been fully or correctly completed.
- SRS reserves the right to refuse to service any vacuum equipment which could potentially be harmful to the personnel carrying out the repair and service of the equipment.
- SRS will not accept any equipment which has been radioactively or explosively contaminated.
- SRS will not service any equipment that might contaminate its vacuum calibration equipment.

Description of equipment

Equipment type/model: ____

Serial No.: ______________________ Date of Purchase: ______________

Reason for return (circle one): • Repair • Maintenance

Please describe symptoms and problems:

____

____

____

____

Equipment condition

Has the equipment been used ? (circle one) • Yes • No

Describe the operating environment the instrument was exposed to:

____

____

____

____

Page 1

Declaration of Contamination of Vacuum Equipment (cont.)

Was any of the equipment exposed to potentially harmful substances? (circle one)

• No

• Yes.
Please attach list of all known harmful substances including chemical name and symbol, precautions associated with the substance and first aid measures in the event of accident.

Were any of the harmful substances:

- Radioactive? • Yes • No
- Toxic? • Yes • No
- Corrosive? • Yes • No
- Explosive? • Yes • No

Was the equipment decontaminated/cleaned before being shipped to SRS?

• Yes • No • Not Applicable

Legally Binding Declaration

I hereby declare that the information supplied on this form is complete and accurate. The dispatch of equipment will be in accordance with the appropriate regulations covering Packaging, Transportation and Labeling of Dangerous Substances.

Name (print): ____

Job Title: ____

Organization: ____

Address: ____

Telephone: ______________________ Fax: ______________________

Email: ____________@______________

Legally binding signature: ____________________________ Date: __________

SRS Use Only.

RMA#:____________________

Form reviewed by:

Signature____________________

Name/Initials____________________

Date:____________________

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Chapter 1

Getting Started

This chapter provides instructions for

- unpacking, checking and installing the IGC100 Ion Gauge Controller and its gauges
- connecting the cabling between the controller and its gauges
- setting up the controller
- measuring pressures

In This Chapter

Unpacking

Before You Open the Box

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

Take a moment at this time to read the installation, operation and safety instructions for any ionization, capacitance manometer or Pirani gauges not purchased directly from Stanford Research Systems.

Read and strictly follow all installation instructions in this chapter to ensure that the performance of this instrument is not compromised by an incorrect installation.

Read and follow all safety and warning instructions in this manual to minimize the risk of injury and death to yourself and others.

Do NOT power up the instrument until specifically directed by the instructions.

Checklist

Open the box(es) and inspect all components of the IGC100 system.

Report any damage to Stanford Research Systems immediately.

Compare the contents of the shipping boxes against your original order and the checklist below. Report any discrepancies to Stanford Research Systems immediately.

Standard Equipment/Supplies

- ❑ IGC100 Ion Gauge Controller Box.
- ❑ Power cord.
- ❑ Operating Manual and Programming Reference.
- ❑ DIN8-DB9 Connector Adapter for Serial RS-232 Communication.
- ❑ Three (3) Position Terminal Block Plug for AUX ±15 Vdc output.
- ❑ Three (3) blank Password Cards.

Optional Equipment

- ❑ Dual Ionization Gauge Connector Box (SRS# O100IG)
- ❑ GPIB Computer Interface (Opt. 01). Preinstalled at the factory.
- ❑ Web Interface (Opt 02). Preinstalled at the factory.

- Process Control Board (Opt 03). Preinstalled at the factory.
  Includes: (1) one DB37 Digital I/O Connector (male)
  (2) two 12-position Terminal Block Plugs for relay connections.

- Rack Mount Shelf, for up to two IGC100's (SRS# O100IGRM).

- Bayard-Alpert Ionization Gauge(s).

- Ionization Gauge Signal Cable(s) (SRS# O100C1, O100C2 or O100C3).

- Cable Adapter(s) for Granville Phillips MICRO-ION® gauge (SRS# O100CA1).

- Convection-Enhanced Pirani Gauge(s) (PG105 or PG105-UHV).

- Pirani Gauge Signal Cable for PG105 and PG105-UHV (SRS# O105C4).

- Connector Adapter(s) for Granville Phillips Convectron® Pirani Gauge (SRS# O105CA1).

- Connector Adapter(s) for HPS® Series 317 Convection-Enhanced Pirani Gauge (SRS# O105CA2).

Installing the IGC100 Controller

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

Mounting Options

The IGC100 offers a variety of mounting options to fit your needs: (1) bench-top, (2) half-rack and (3) two units, side-by-side, in full-rack width.

Place the controller in a secure place on your bench-top or mount it into an equipment rack tray (SRS# O100IGRM, compatible w/standard 19 inch rack). In all cases, provide adequate ventilation for the control unit to dissipate heat - *≈1 inch clearance around the side ventilation slots is recommended.* Allow at least 6 inches at the back of the controller for cable routing. Do not mount the unit above other equipment that generates excessive heat. The IGC100 is designed to operate over the range 0-40°C. Ambient temperatures above that value may damage the instrument. For optimum electrometer stability (especially while using calibrated gauges) the ambient temperature should be 25±5°C.

Line Power Connection

Line Voltage Selection

The IGC100 operates from a 100 V, 120 V, 220 V, or 240 V nominal AC power source having a line frequency of 50 or 60 Hz.

Use the power entry module on the back panel of the IGC100 to power the unit from a wall outlet. Make sure that suitable power is available for the controller: 100-240 Vac, 50-60 Hz, 500 W. Use the three-wire power cord, provided by Stanford Research Systems, to connect the IGC100 to a **properly grounded** wall outlet. Contact Stanford Research Systems if a power cord compatible with your outlets was not included with your unit.

The connection of LINE power to the box is clearly indicated by a lighted LINE LED (red) located below the POWER button at the lower left corner of the front panel.

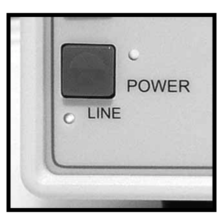


Figure 1-1. LINE LED below the POWER button indicates that Line Power is ***connected****.*

> **WARNING!**
> Do not switch on the power yet! Wait until instructed to do so later. Make sure that the green POWER LED is off.

Grounding

Connect a heavy duty ground wire, #12 AWG or larger, from the CHASSIS GND lug on the back of the IGC100 **directly to your facility earth ground**. This will provide an earth ground for the IGC100 in case the power cable is not in place. *Do not connect the CHASSIS GND lug to the vacuum system or other electrical component.* Connect it directly to the facility grounding system such as a grounded outlet box or a grounded copper water supply line. Do not rely on small metal water lines to ground a component. Get professional help from an experienced electrician if necessary.

WARNINGS!

- Connecting the power cord to a properly grounded outlet is necessary, but not sufficient with this (or any similar) high voltage producing vacuum equipment.
- Grounding the IGC100 does not and cannot guarantee that other components of the vacuum system are all maintained at earth ground.
- Perform a **Proper Grounding Test** on your vacuum system (described at the end of this chapter) if uncertain about the electrical safety of your vacuum setup. Consult an experienced electrician if necessary.

Figure 1-2. Power and chassis-ground connection on the back of the IGC100 controller.
1. Power entry module with power cord (connected to grounded wall outlet on the other end),
*2. CHASSIS GND lug with heavy gauge ground wire connected **directly** to facility earth ground.*

Before You Install a Vacuum Gauge

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

The IGC100 Ion Gauge controller measures pressures between 10^{-11} and 1000 Torr using a combination of gauges that includes: Ionization (hot-cathode, Bayard-Alpert type), Convection-Enhanced Pirani and Capacitance Manometers. It is not unusual for all of these types of gauges to coexist in a high-vacuum setup, each monitoring gas pressures in different sections of the system. To take advantage of the wide-pressure range of IGC100, only use gauges known to be fully compatible with this instrument.

This chapter describes the basic steps required for the safe and successful installation of the three types of gauges compatible with IGC100 onto a vacuum system. With the exception of capacitance manometers, the gauge installation information is tailored towards gauges purchased directly from Stanford Research Systems. Keep in mind that gauges purchased from third-party vendors will have specific installation and warning instructions and requirements that are not covered by these instructions.

WARNINGS!

- Take a moment at this time to review the specific installation, operation and safety instructions for any ionization, capacitance manometer or Pirani gauges purchased from third-party sources.
- It is the responsibility of the end-user to assure the safe installation and compatibility of third-party gauges with the IGC100 controller.

Recommendations and Warnings

- Perform a **Proper Grounding Test** on your vacuum system (as described at the end of this chapter). If you are uncertain about the electrical safety of your vacuum system, get professional help from an experienced laboratory electrician.
- **Do not use compression fittings for positive pressure applications.** The gauge may be forcefully ejected causing injury to personnel.
- For best results, locate gauges close to where the pressure needs to be measured.
- High pressure areas might develop around gas sources, such as valves, orifices and contaminated areas.
- If a gauge is placed near a pump, the pressure at the gauge might be much lower than in the rest of the system.
- Always maintain a high conductance connection between the gauge and the pressure being measured. Avoid small diameter tubulation. Eliminate all gas flow restrictions such as orifices.

- Minimize temperature effects by locating pressure gauges away from heat sources and in a region where the temperature is reasonably constant. This is particularly critical for measurements with calibrated gauges.

- If your vacuum system has an electron beam source, all ionization gauge tube electrodes must have a shield around them to keep spurious charged particles away.

- Gauges can get hot during normal operation. Keep your hands away from ionization gauges during use. Prevent low-temperature rated material, such as wire insulation, from touching the hot parts of your gauges.

- Verify that the vacuum port to which your gauge is being mounted is electrically grounded.

- To reduce the chances of contamination, do not remove pressure gauges from their protective shipping containers until moments before they are ready to be attached to the vacuum system.

- Follow good high-vacuum practice at all times. Avoid contaminating the vacuum gauges and your vacuum system. Wear gloves! Do not talk or breathe into open vacuum ports.

- Set aside a clean, dust free, work area next to the vacuum chamber before installation begins.

- To avoid leaks with ConFlat® flanges, use high tensile-strength stainless steel bolts and NEW, clean OFHC copper gaskets. Do not use non-metal gaskets.

- High voltage can couple through a gas to the internal electrodes of a gauge if a plasma discharge is established. Never touch the exposed pins of any gauge installed on a vacuum system where high voltage is present. Typical high voltage sources include plasma sources, ionization gauges, mass spectrometers and electron multiplier detectors.

- When high voltage is present, all exposed conductors of a gauge must be rigorously grounded or shielded from contact.

Installing an Ionization Gauge

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

This section describes the basic steps required for the safe and successful installation of ionization gauges compatible with IGC100 onto a vacuum system. Keep in mind that gauges purchased from third-party vendors will have specific installation and warning instructions and requirements that are not covered by these instructions.

Compatible Gauges

To take advantage of the full pressure range of IGC100, and to avoid the risks of injury and damage to equipment, you must always use compatible ionization gauges. Industry-wide standardization of the Bayard-Alpert Gauge (BAG) design allows the IGC100 to be compatible with virtually every commercially available Bayard-Alpert ionization gauge. This includes glass-tubulated, nude, nude-UHV, STABIL-ION® (Granville-Phillips) and MICRO-ION® (Granville-Phillips) products.

Appendix A includes detailed information on the principle of operation of Bayard-Alpert ionization gauges. Consult Appendix E regarding the selection of Bayard-Alpert ionization gauges for new applications.

SRS Gauges

The IGC100 is fully compatible with all Bayard-Alpert Ionization gauges available directly from Stanford Research Systems.

SRS Calibrated Gauges

IGC100 users may opt to have their new ionization gauges calibrated at the SRS High Vacuum Calibration Facility. The BAG response is calibrated below 10^{-3} Torr by comparison against a NIST-traceable secondary standard and the information is stored in a Memory Card that is provided with each calibrated gauge. The calibration curve, including all relevant controller setup information, can then be easily transferred into the IGC100 using the Memory Card. For details on ionization gauge calibration options, consult Appendix F of this manual.

Note
SRS calibrated ionization gauges include a Memory Card in their package. Keep the card in a safe place after gauge installation since it will be required later during IGC100 setup.

Third-Party Gauges

A manufacturer cross-reference table (Appendix B) lists some popular ionization gauges known to be compatible with the IGC100. The specifications of third-party ionization gauges should always be compared against the IGC100 specifications before a final connection is established. Stanford Research Systems is not responsible for changes in design or specifications of third-party products that might render them incompatible with the IGC100 controller. While checking for gauge compatibility, particular attention must be given to gauge sensitivity, grid bias voltage, filament bias voltage, recommended emission current settings, filament drive requirements and degas power specifications. The IGC100 can be programmed to accommodate a large range of gauge sensitivities, emission currents and degas power levels. The grid (+180 Vdc) and filament (+30 Vdc) bias potentials are not adjustable. Consult your gauge manufacturer and Stanford Research Systems if you are unsure about the compatibility of your third-party ionization gauges.

Installing a Glass-Tubulated Gauge

WARNING!
To reduce the risk of dangerous explosions, do not use glass-tubulated gauges in vacuum systems routinely pressurized above atmosphere.

Glass-tubulated gauges are fragile and present a safety hazard due to implosion if not adequately shielded. Place glass tubulated gauges where they cannot be bumped, use metal shields, and be very gentle during installation.

Most glass-tubulated gauges are connected to the vacuum system through an O-ring compression fitting. *The most common problem during gauge installation is crushed side tubes due to excessive tightening of compression fittings!* Whenever possible, use metal (i.e. Kovar) side tubulation to avoid this problem. Kovar side tubulation is most often welded to ConFlat® and Klein flanges for compatibility with standard vacuum ports. While slightly more expensive, flanged tubulated gauges offer better vacuum integrity and higher bakeout temperatures than standard compression fittings. To minimize the possibility of leaks in flanged connections, use only new and clean OFHC copper gaskets with ConFlat® Flanges. Pyrex is the material of choice when the side tube must be directly glass-blown on to the vacuum system.

If possible, install the gauge so that the filament is visible at all times- a quick visual check might save a tungsten filament from burnout during a venting or gas loading process.

The preferred mounting orientation is with the electrode assembly and filament in a *vertical position* to minimize electrode and filament distortion caused by gravity and thermal cycles. To avoid the possibility of excessive temperature at the electrical connector, it is best to install the gauge with *the electrical connection pins below the glass tube.*

WARNING!
Do not connect the glass-tubulated ionization gauge to the IGC100 cable until instructed to do so later in this chapter.

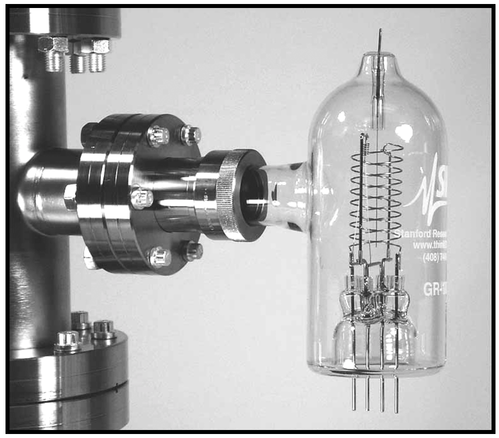


Figure 1-3. A glass-tubulated Bayard-Alpert gauge attached to a vacuum system through a compression fitting and mounted with the recommended vertical orientation - base pointing down.

Installing a Nude Gauge

In the nude Bayard-Alpert ionization gauge, the electrode structures are welded on to insulating feedthroughs mounted on a 2.75" ConFlat® Flange and inserted directly into the vacuum chamber environment. Before removing the nude Bayard-Alpert gauge from its shipping container, locate the SRS# O100C3 cable package. This cable is required to connect your nude ionization gauge to the IGC100 controller. Separate the metal ring from the package. Before you begin, make sure you also have: 1. a *new and clean* OFHC copper gasket (for 2.75" ConFlat® flanges) and 2. the required bolts (see Figure 1-4) and wrenches.

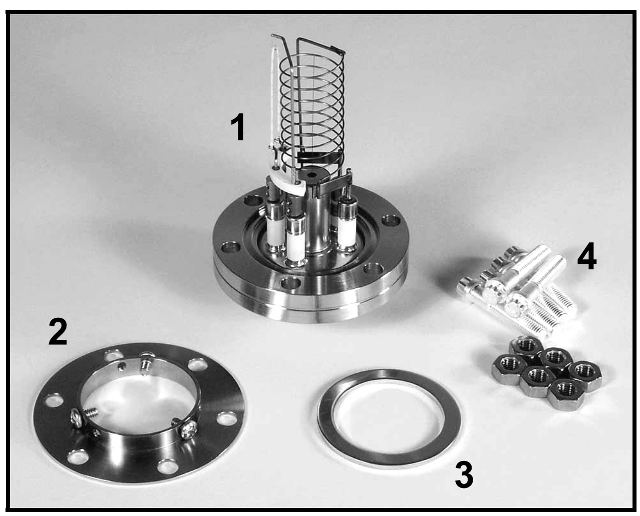


Figure 1-4. Nude-BAG Installation Hardware: 1. Nude-UHV gauge, 2. Metal ring (from O100C3 cable kit), 3. OFHC copper gasket (new and clean), 4. High tensile strength stainless steel bolts (wrench not shown).

Remove the gauge from its protective packaging. Position a new and clean OFHC copper gasket on the ConFlat® port of the vacuum system and carefully insert the nude gauge into the vacuum system port. Since the delicate electrodes are exposed, *be very careful* *during installation to avoid distorting and damaging the filament and/or anode grid structure.*

Place the O100C3 metal ring against the back of the feedthrough flange, as shown in Figure 1-5, and rotate the feedthru-flange and the ring until all six bolt-holes line up. Fasten the gauge and seal the port connection using high-tensile strength stainless steel bolts.

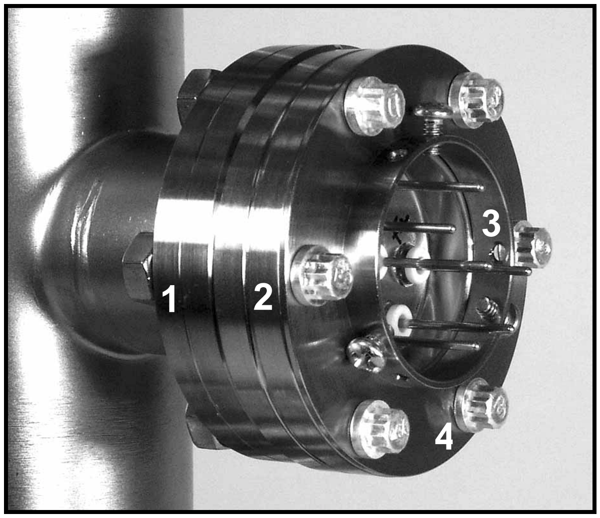


Figure 1-5. The nude ionization gauge attached to the vacuum system (2.75" ConFlat®) Port. 1. Vacuum system port, 2. Gauge feedthrough flange, 3. Metal ring, 4. Bolts (6 places).

WARNING!
Do not connect the ionization gauge to the IGC100 cable until instructed to do so later in this chapter.

Important

The sensitivity value of a nude gauge is dependent on the way it is mounted on the system. This is not new knowledge, but there is no widespread appreciation of the effect among many users of nude gauges. Fillipeli investigated the influence of envelope size and shape on the nitrogen sensitivity of conventional 'nude' BAGs (see A. R. Filippelli, "Influence of envelope geometry on the sensitivity of 'nude' ionization gauges", J. Vac. Sci. Technol. A 14(5) (1996) 2953). His report showed that changes in gauge envelope can result in measurement errors as large as 50% with some BAGs. Thus, *the envelope must be considered a part of an ionization gauge*, and a specification of 'nude' gauge sensitivity is not complete unless the geometry and potential of its envelope are also given. It is common practice to calibrate and operate nude ion gauges inside a nipple 38 mm ID x 100 mm long, with a metal screen at the input port.

Installing STABIL-ION® and MICRO-ION® Gauges

The IGC100 is fully-compatible with Granville Phillips' STABIL-ION® and MICRO-ION® gauges. Consult Appendix C or Appendix M for detailed installation, wiring and operating instructions.

Connecting an Ionization Gauge

Once the gauge and the controller are installed and properly grounded, the next step involves the connection of the IGC100 controller to the vacuum gauge through the signal cable. This section describes the connection of ionization gauges to the IGC100 controller using signal cables - SRS# O100C1, O100C2 and O100C3 - purchased directly from Stanford Research Systems. Both single and dual gauge connections are described.

WARNINGS!

- **Do not use homemade connections in your vacuum system.** The use of homemade gauge signal cables (i.e. not purchased directly from Stanford Research Systems) automatically voids the IGC100's warranty and can lead to dangerous operating conditions and expensive equipment damage.
- **Do not** switch the controller or gauge power on until instructed to do so. The green POWER LED on the IGC100 front panel should be off.
- Connect all gauge signal cables to the IGC100 controller *first*, before establishing a connection to the gauge heads.
- Do not attach signal cables to a glass-tubulated gauge pins while it is under vacuum. Accidental bending of the pins while pushing the connector plug may crack the glass base and cause a dangerous implosion of the gauge envelope.
- Cables, once installed, must be secured to provide strain relief for the gauge pins.

Cable Options (O100C1, O100C2 and O100C3)

There are three different signal cables for connecting ionization gauges to an IGC100 controller:

- O100C1 for a glass-tubulated ion gauge with single filament
- O100C2 for a glass-tubulated ion gauge with dual filaments
- O100C3 for a nude (all-metal) ion gauge with single or dual filaments.

Appendix B includes a list of the specific signal cables required by each ionization gauge model available from Stanford Research Systems, as well as for some third-party ionization gauges known to be electrically compatible with the IGC100 controller. All cables are identical at the end that connects to the IGC100, but different at the end that connects to the ionization gauge header. Separate instructions are required for the connection of each of the three signal cables to their respective ionization gauges.

WARNING!

Confirm the compatibility between your signal cable and your specific ionization gauge before proceeding further with these instructions. Consult Appendix B if necessary. Contact Stanford Research Systems if still in doubt!

Connecting to the IGC100 Controller (All Cables)

All signal cables are the same on the end that connects to the IGC100 controller (i.e. no gauge-specific instructions are required.)

Single Gauge Connection (IG1)

(i) Connect the signal cable's BNC connector to the upper COLLECTOR BNC (labeled '1'), located on the back of the IGC100. Push the BNC connector all the way into the BNC receptacle, then turn the connector one-quarter-turn clockwise until it clicks firmly into place

(ii) Connect the 7-pin plug to the ION GAUGE receptacle on the back of the IGC100 controller. Align the connector with the receptacle and then turn the plastic-ring clockwise to fasten the connection. Figure 1-6 shows the finalized connections on the back of an IGC100.

Figure 1-6. Single Ionization Gauge cable connection to the IGC100 controller. 1. 7-pin plug connection to ION GAUGE receptacle, 2. BNC connection to upper COLLECTOR input (labeled '1').

Note

The standard IGC100 has a single ionization gauge connector, labeled ION GAUGE, on its back panel and can control only one ionization gauge. When connected to a gauge, the ION GAUGE port is treated as 'IG1' by the IGC100 controller. This means that the IG1 Power button activates the gauge and the Pressure Display is set to 'IG1'.

Dual Gauge Connection (O100IG Option)

An optional Dual Ionization Gauge Connector Box (SRS# O100IG) can be plugged into the ION GAUGE receptacle, and used to simultaneously connect two ionization gauges (i.e. IG1 and IG2 port connections) to the back of the IGC100. This makes it possible for the controller to switch operation between two separate gauges (i.e. *sequential* operation) from the front panel, and measure pressure at two locations at a small fraction of the cost of a second instrument.

For information on the proper configuration and connection of the Dual Ionization Gauge Connector Box to the controller, consult the instructions provided with the Dual Ionization Gauge Connector Box (also included in Appendix L.)

Connecting a Single Filament Glass-Tubulated Ion Gauge, (O100C1 Cable)

WARNING!

- Make sure that the IGC100 is **NOT** turned on. The green POWER LED on the IGC100 front panel should be *off*.
- Connect the cable to a properly grounded IGC100 *before* attaching the cable to the gauge.

The SRS# O100C1 signal cable is specifically designed for connection to glass-tubulated ionization gauges with a single filament design.

Single filament, glass-tubulated gauges are easily identified by the in-line, 4-pin arrangement at the base connector of the gauge envelope.

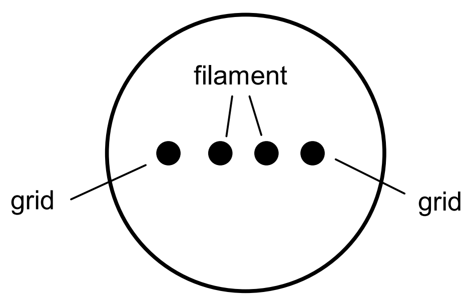


Figure 1-7. Pin Alignment for base connector of glass-tubulated gauge with single filament. IGC100 cable SRS# O100C1.

Connect the 4-pin cable connector to the base of the ion gauge as shown in Fig. 1-8. Align the connector with the pins, then gently push the connector onto the pins until it seats firmly in place.

Note

The 4-pin connector can attach to the ion gauge in two ways - one is rotated 180° from the other about the cylindrical axis of its plug. Since, the pin arrangement of glass-tubulated ionization gauges is symmetric, rotating from one connection orientation to the other *does not* affect the operation of the gauge.

Figure 1-8. O100C1 connection to a single filament, glass-tubulated, ionization gauge with 4-pin header configuration.

When the 4-pin connector is properly attached to the ionization gauge, it is recessed into the base of the gauge offering protection from the high voltages present on the pins.

Figure 1-9. O100C1 4-pin connector safely attached to the base of the glass-tubulated gauge.

Connect the remaining single-pin connector, attached to the coaxial cable, to the collector pin located on top of the ionization gauge envelope. Push the connector into the pin until it seats firmly in place.

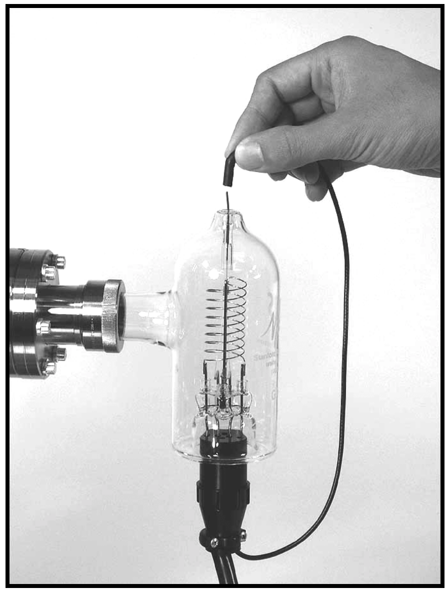


Figure 1-10. Single pin connection to the collector electrode.

The connectors of the O100C1 cable are specifically designed to completely shield the contact pins protecting vacuum users from dangerous high voltages. Once attached, the signal cable must be properly secured to provide strain relief for the gauge tube pins.

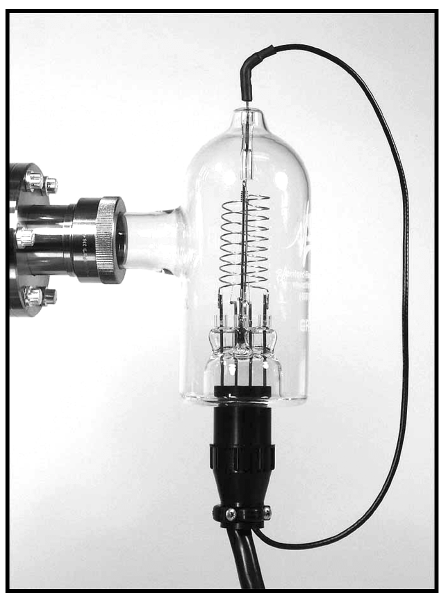


Figure 1-11. Picture of properly and safely connected glass-tubulated ionization gauge.

Connecting a Dual Filament Glass-Tubulated Ion Gauge, (O100C2 Cable)

WARNING!

- Make sure that the IGC100 is **NOT** turned on. The green POWER LED on the IGC100 front panel should be *off*.
- Connect the cable to a properly grounded IGC100 *before* attaching the cable to the gauge.

The SRS# O100C2 cable is specifically designed for connection to glass-tubulated ionization gauges with dual filament design.

Dual filament, glass-tubulated gauges are easily identified by the 6-pin connector pattern located at the base of the gauge envelope.

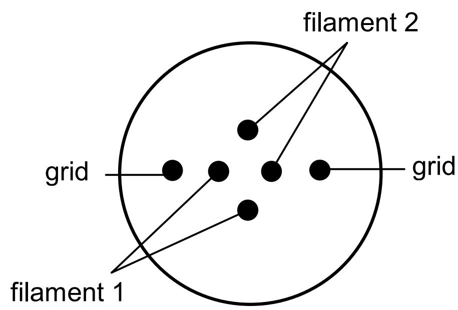


Figure 1-12. Pin alignment for base connector of a glass-tubulated gauge w/dual filament. IGC100 Cable SRS# O100C2

Connect the 6-pin cable connector to the base of the ion gauge as shown in Fig. 1-13. Align the connector with the pins, then gently push the connector onto the pins until it seats firmly in place.

Figure 1-13. O100C2 connection to a dual filament, glass-tubulated, ionization gauge with 6-pin connector header.

Note

The 6-pin connector can connect to the ion gauge in two ways - one is rotated 180° from the other about the cylindrical axis of the plug. Since, the pin arrangement of glass-tubulated ionization gauges is symmetric, rotating from one connection to the other simply switches the Fil1/Fil2 assignment for the filaments. This is important to keep in mind for calibrated ionization gauges since the sensitivity is usually slightly different for both filaments. In order to avoid errors, the use of *single* filament electrodes is often recommended for calibrated ionization gauges.

When the 6-pin connector is properly attached to the ionization gauge, it is recessed into the base of the gauge offering protection from the high voltages present on the pins.

Figure 1-14. O100C2 6-pin connector properly attached to the base of the glass-tubulated gauge.

Connect the single pin connector attached to the thin coaxial cable to the top of the Ion Gauge. Push the connector into the pin until it sits firmly in place.

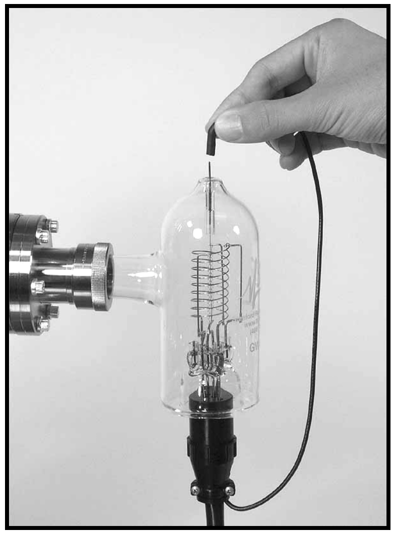


Figure 1-15. Single pin connection to the collector electrode of the gauge.

The connectors of the O100C2 cable are specially designed to completely shield the contact pins protecting vacuum users from dangerous high voltages. Once attached, the signal cable must be properly secured to provide strain relief for the gauge tube pins

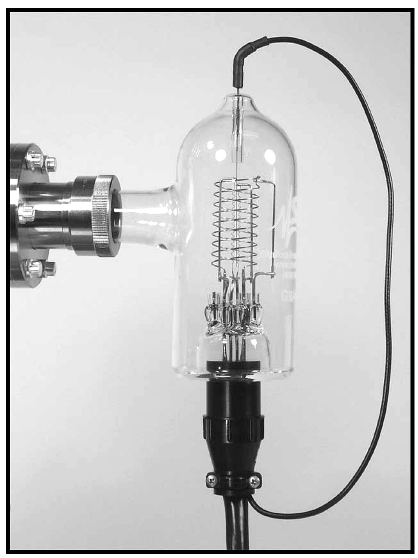


Figure 1-16. Picture of the properly and safely connected glass-tubulated ionization gauge.

Connecting a Nude Ionization Gauge, Single or Dual Filament (O100C3 Cable)

WARNING!

- Make sure that the IGC100 is **NOT** turned on. The green POWER LED on the IGC100 front panel should be *off*.
- Connect the cable to a properly grounded IGC100 *before* attaching the cable to the gauge.

The SRS# O100C3 cable is specifically designed for connection to nude (i.e. all-metal) ionization gauges with both single and dual filament electrode structures.

The end of the cable that connects to the gauge head has six (6) individual push-on connectors housed inside a plastic connector-shield. In order to easily identify which connector attaches to which pin on the ion gauge feedthru flange, five (5) of the connectors are labeled: GRID [red], FIL 1 [yellow], FIL 2 [green], FIL RET [black], and FIL RET [black]. The sixth connector, which connects to the collector pin located in the middle of the feedthru flange, is black, unlabeled and the only one attached to a black coaxial cable. A plastic connector-shield, specifically designed to mate with the metal ring mounted on the back of the gauge's flange (see Fig. 1-17), provides protection against the high voltages present on the electrical connectors during regular operation.

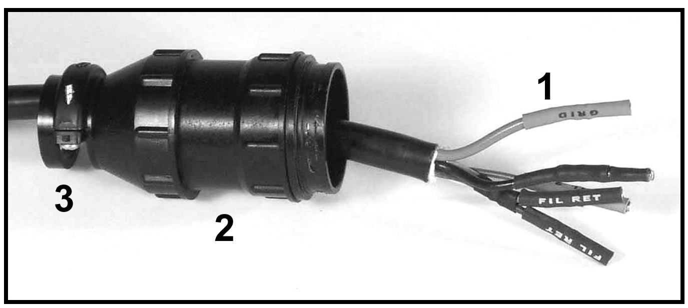


Figure 1-17. Gauge end of O100C3 signal cable: 1. Six (6) connector pins (labeled), 2. Plastic connector-shield, 3. Cable clamp w/screws. Note that the connector shield has been pushed back to expose the connectors and facilitate connection to the gauge pins.

Recommendation

In order to facilitate connection to the gauge, loosen the connector-shield cable clamp (3. in Fig. 1-17) with a #2 Phillips screwdriver and slide the entire assembly back until the connector ends are fully exposed and accessible before attaching them to the gauge pins.

Figure 1-18 describes the pin assignments for nude ionization gauges with one and two filament assemblies, viewed from the base.

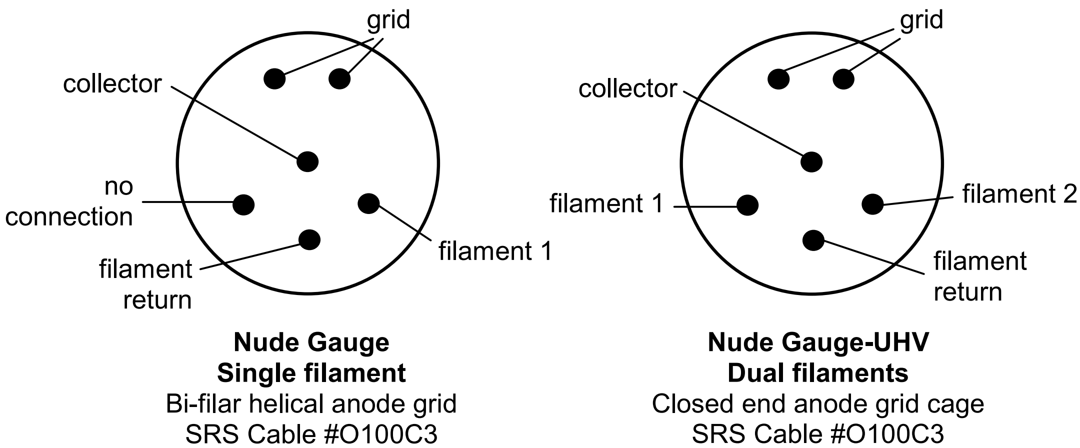


Figure 1-18. Pin assignments for nude ionization gauges, viewed from the base.

Connect the cable connectors to the appropriate pins on the base of the ionization gauge (consult Fig. 1-18). Both FIL-RET cable connectors are identical and only one needs to be connected to the gauge (fold the unconnected FIL RET cable connector back into the connector-shield with its end facing away from the metal flange). Push all connectors into the pins until they seat firmly in place.

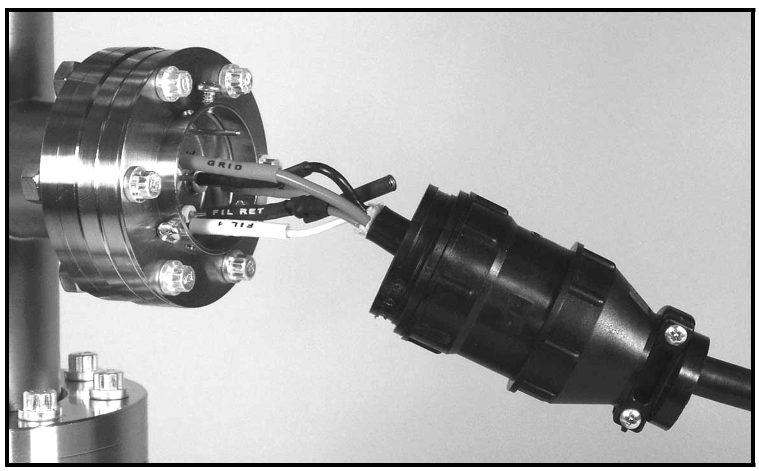


Figure 1-19. Cable connection to the base of a nude ionization gauge.

Slide the connector-shield assembly towards the gauge and fasten it to the metal ring on the gauge flange using its three side screws and a Phillips screwdriver. Fasten the connector-shield cable-clamp to firmly hold the entire connector assembly firmly in place.

Figure 1-20. Cable connection to the base of a nude ionization gauge with connector shield in place.

Connecting a STABIL-ION® or MICRO-ION® Gauge

IGC100 is fully-compatible with Granville Phillips' STABIL-ION® and MICRO-ION® gauges. Please consult Appendix C or Appendix M for detailed installation, wiring and operation instructions.

Installing a Pirani Gauge

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

Compatible Gauges

To take advantage of the full pressure range of IGC100, and to avoid the risks of injury and damage to equipment, you must always use compatible convection-enhanced Pirani gauges. The IGC100 is a generic controller, compatible with several commercially available Pirani Gauges, including: PG105 and PG105-UHV (SRS), HPS/MKS Series 317 and Convectron® (Granville-Phillips) models.

WARNING!
Do not connect a Pirani gauge to the IGC100 cable until instructed to do so later in this chapter.

SRS Gauges

SRS has developed its own line of convection-enhanced Pirani Gauges (PG105 and PG105-UHV) to complement the IGC100. Consult Appendix H of this manual for detailed information on the principle of operation, installation and operation of PG105 and PG105-UHV gauges. The installation instructions presented in this section are specific for PG105 and PG105-UHV gauges.

WARNING!
PG105 gauges should not be used in the presence of fluorine or mercury vapors. Both gases can react with the gold plated sensor and change its emissivity and/or overall diameter irreversibly. Consult Appendix H for additional gas compatibility details.

Third-Party Gauges

The IGC100 is also compatible with HPS/MKS Series 317 and Convectron® (Granville-Phillips) convection-enhanced Pirani gauges. Connector adapters (SRS# O105CA2 and O105CA1, respectively) are required to connect these gauges to the IGC100 dual connector cable (SRS# O105C4). The specifications of Pirani gauges manufactured by third-parties should always be compared against the IGC100 specifications before a connection is established. Stanford Research Systems is not responsible for changes in design or specifications of third-party products that might render them incompatible with the IGC100 controller. Consult your gauge manufacturer for specific gauge installation requirements and Stanford Research Systems if uncertain about the compatibility of IGC100 with your third-party Pirani gauge product.

Handling

WARNING!
All Pirani gauges include a very thin sensor wire that is easily damaged. Avoid dropping the gauge during installation.

Mounting Orientation

Below 1 Torr

The PG105 (-UHV) convection gauge will operate and report accurate pressures in any orientation.

Above 1 Torr

The PG105 (-UHV) convection gauge will accurately read pressures only while mounted with its axis horizontal.

WARNING!
- Erroneous readings can result in over or underpressure conditions which may damage equipment and/or injure personnel.
- In all cases, it is recommended that the gauge be installed with the port oriented *vertically downward* to ensure that no system condensates or other liquids collect inside the gauge tube. Care must be taken not mount the PG105 tube in a way such that deposition of process vapor impurities may occur through direct line-of-sight access from the vacuum chamber to the interior of the gauge.

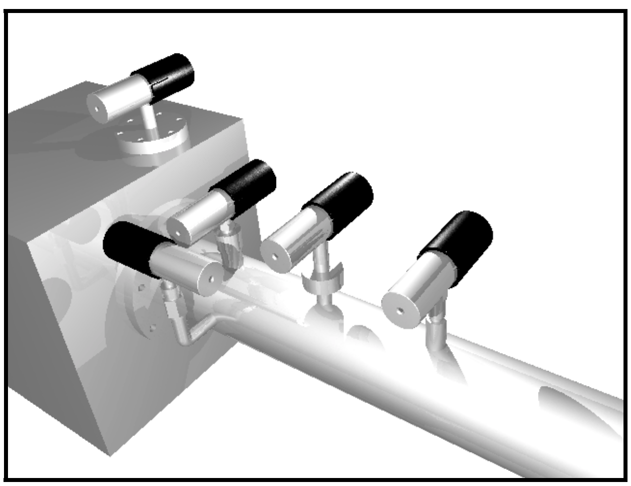


Figure 1-21. PG105 Gauge mounting examples.

Vibration Isolation

Mount PG105 gauges where they will not experience excessive vibrations. Vibration causes convection cooling of the sensor and results in high readings at the high pressure end. Damage to the filament is also possible.

Proper Grounding

Verify the proper electrical grounding of the vacuum port before connecting the PG105 gauge head to the vacuum system. *The gauge envelope must be properly grounded during operation.* If necessary, use a ground lug on a flange bolt to establish a dedicated connection to a facility ground. Alternatively, the gauge envelope may be grounded by using a metal hose clamp on the gauge connected to the system's safety ground by a #12 AWG copper wire.

Fitting Options

Compression fittings

The standard PG105 gauge port is designed to fit into any standard ½" compression fitting such as an Ultra-Torr® fitting.

WARNING!
Do not use compression fittings for positive pressure applications!

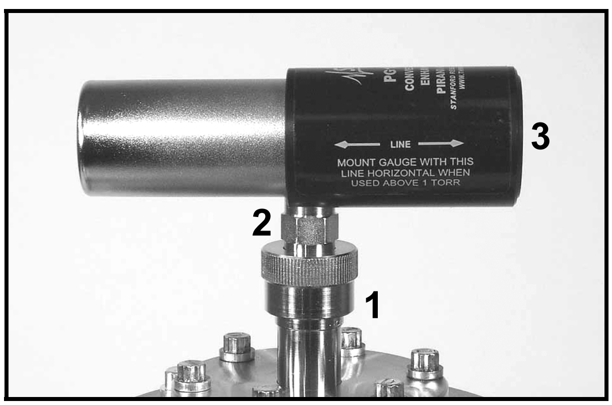


Figure 1-22. PG105 gauge mounted on a ½" compression fitting in the horizontal mounting orientation required for pressure readings above 1 Torr. 1. Ultra-Torr® fitting, 2. Side port tube (OD ½") with built-in nut, 3. PG105 Body.

1/8" NPT Fittings

The threads on the standard PG105 side port will fit a standard 1/8" NPT female fitting. Wrap the gauge threads with Teflon® tape and screw the gauge into the female fitting. Twist the gauge body by hand until the first sign of resistance is felt. *Do not use the body of the gauge as its own wrench past this point.* Instead, finish tightening with a wrench

(1/2" or 13 mm) applied to the nut built into the side tube until a proper seal is achieved. Do not overtighten as that might stress the tube port!

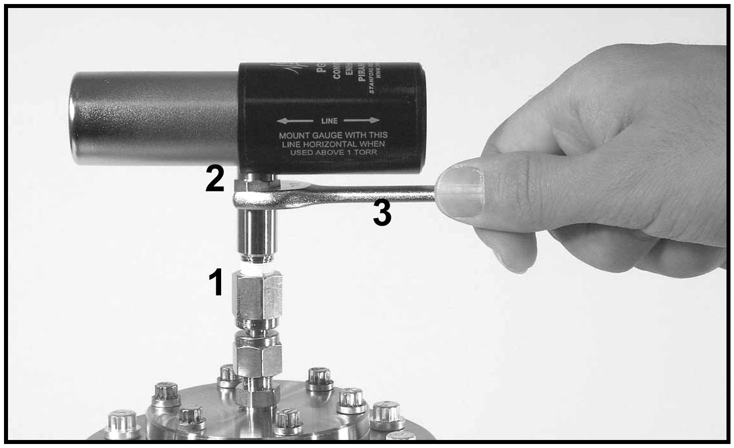


Figure 1-23. Proper installation of a PG105 gauge on a 1/8 NPT port. 1. Female 1/8 NPT Fitting, 2. built-in nut, 3. 1/2" (or 13 mm) wrench.

Other fittings

In addition to the standard tube, which provides a compression port and a 1/8" NPT male thread, a variety of other mounting options are available. They include: NW16KF, NW25KF, 1.33" and 2.75" ConFlat®, Cajon® SS-4-VCR and SS-6-VCO, etc. Consult Stanford Research Systems for additional information on available fittings.

Connecting a Pirani Gauge

Once the gauges and the controller are installed and properly grounded, the next step involves the connection of the IGC100 controller to the Pirani gauge through the signal cable. This section describes the connection of up to two Pirani gauges to the IGC100 controller using the O105C4 dual-gauge signal cable, optionally available from Stanford Research Systems.

WARNINGS!

- Connect all gauge signal cables to the IGC100 controller first, *before* establishing a connection to the gauge heads.
- **DO NOT** switch the controller or gauge power on until instructed to do so.
- Cables, once installed, must be secured to provide strain relief for the gauge pins.
- **Do not use homemade connections in your vacuum system**. The use of homemade gauge signal cables (i.e. not purchased directly from Stanford Research Systems) automatically voids the IGC100's warranty and can lead to dangerous operating conditions and expensive equipment damage.

SRS Gauges

SRS has developed its own line of convection-enhanced Pirani Gauges - models PG105 and PG105-UHV. These gauges use RJ-45 connector receptacles. The connection instructions presented in this section are specific for those gauges. Consult Appendix H of this manual for detailed information on the principle of operation, installation and operation of PG105 and PG105-UHV gauges.

The standard IGC100 box has a DB-15 receptacle on its back panel for interfacing up to two Pirani gauges with the controller (PG1 and PG2 ports). Accordingly, the O105C4 signal cable has a DB-15 plug on one end that leads to two separate connection cables. Each cable is terminated in a colored-coded RJ-45 connector plug at the other end:

RED	PG1 port
GREEN	PG2 port.

Third-Party Gauges

IGC100 is also compatible with Series 317 (HPS/MKS) and Convectron® (Granville-Phillips) convection-enhanced Pirani gauges. However, connector adapters (SRS# O105CA2 and O105CA1, respectively) are required to electrically connect those third-party gauges to the RJ-45 ends of the O105C4 signal cable.

Connection to IGC100 Control Unit

Push the DB-15 plug of the O105C4 signal cable into the DB-15 receptacle (labeled PIRANI) on the back plane of the IGC100 controller. Securely fasten the connector in place with its two locking screws (a small flat head screwdriver will be required).

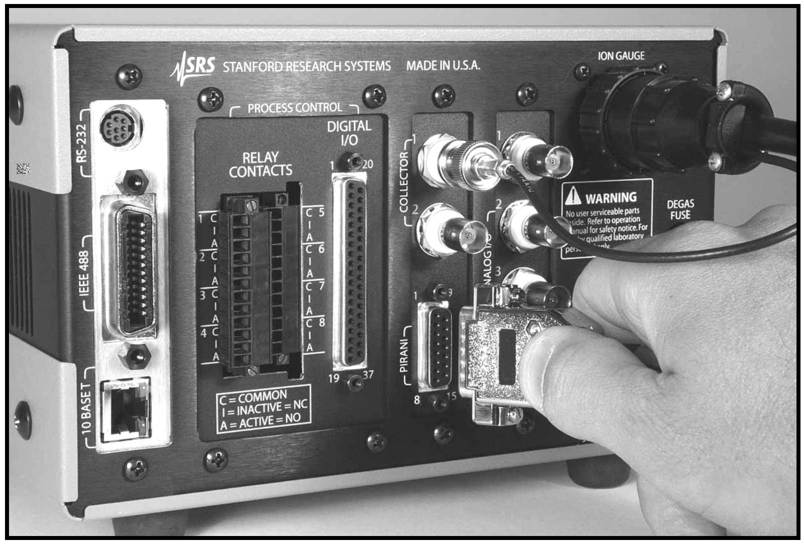


Figure 1-24. Pirani Gauge signal cable connection to the IGC100 controller: DB-15 plug connects to PIRANI receptacle.

Connection to Gauge Head(s)

PG1 Port (RED)

Push the RED RJ-45 connector into the matching receptacle located on the back-side of the detachable plastic connector of the first PG105 Pirani gauge.

Note

Data from the gauge connected to the red RJ-45 plug (PG1 port) is displayed on the PG1 Data Bar of the Pressure display window.

PG2 Port (GREEN)

For dual gauge operation, connect the GREEN RJ-45 connector into the second PG105 Pirani gauge.

Note

Data from the gauge connected to the green RJ-45 plug (PG2 port) is displayed on the PG2 Data Bar of the Pressure display window.

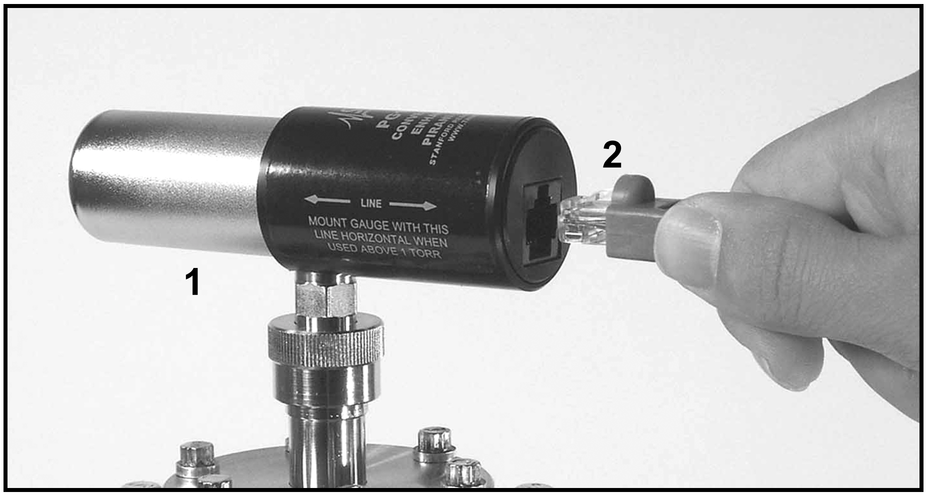


Figure 1-25. Pirani gauge signal cable connection to PG105 Pirani Gauge head.
1. PG105 Gauge, 2. RJ-45 connector (1of 2) on O105C cable.

Installing a Capacitance Manometer

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

Capacitance manometers are also called Capacitance Diaphragm Gauges.

The IGC100 can display pressure as measured from standard capacitance manometers (CMs). Up to four independent CM readings can be monitored simultaneously using the four ANALOG I/O ports located on the back panel of the controller. The IGC100 also supplies auxiliary power (±15 Vdc, 100 mA) sufficient to operate a pair of standard (i.e. non-heated) capacitance manometers. The IGC100 precisely measures the 0 to 10 Vdc linear output signal from the CM to determine pressure. Full-scale ranges up to 1000 Torr are supported by the controller.

CMs may be ordered from several commercial sources. The specifications of CMs should always be compared with the IGC100 specifications before a connection is established. Stanford Research Systems is not responsible for changes in design or specifications of third-party products that might render them incompatible with the IGC100 controller. Consult your gauge manufacturer for specific gauge installation requirements and Stanford Research Systems if uncertain about the compatibility of IGC100 with your third-party capacitance manometer.

It is generally recommended CMs be mounted with the inlet port pointing vertically downward. Although the gauge can be mounted in any orientation, mounting it as suggested allows any foreign matter entering the pressure port to fall away from the diaphragm. Isolate the unit from vibration as much as possible. While not susceptible to gas damping, the diaphragm may become susceptible to resonance. The low range transducers (≤1 Torr) are particularly sensitive and should be carefully isolated from any vibrations. Isolate the vibration through the cable as well as through the port.

WARNING!
Do not connect a capacitance manometer gauge to the IGC100 until instructed to do so later in this chapter.

Connecting a Capacitance Manometer

WARNINGS!

- Connect all gauge signal cables to the IGC100 controller first, *before* establishing a connection to the gauge heads.
- **DO NOT** switch the controller or gauge power on until instructed to do so.
- *The gauge chassis must be properly grounded* during operation to assure operator safety.
- Cables, once installed, must be secured to provide strain relief for the gauge pins.

This section describes the electrical connection of Capacitance Manometers (CM) to the IGC100 controller. Capacitance Manometers are also known as Capacitance Diaphragm Gauges. Up to four independent CM readings can be monitored, logged and displayed, simultaneously. Full-scale ranges up to 1000 Torr are supported by the controller software.

Unfortunately, there are a variety of conventions for connecting CMs. Consult your installation and operation manuals for gauge-specific information including connector type, pin assignments, electrical specifications, cable requirements and grounding recommendations.

In many cases, pin assignments are conveniently silk-screened on the gauge casing close to the electrical connector. *Be prepared to manufacture your own custom cables to interface CMs to the IGC100 controller.*

IMPORTANT!
General guidelines for the manufacturing of generic interface cables are often listed in the CM manual, or can be obtained directly from the gauge manufacturer.

Standard CMs require three basic connection steps**:**

- Grounding
- Pressure Signal Connection
- Power Connection

Grounding

The gauge chassis must be properly grounded during operation to assure operator safety. Most CMs feature a chassis grounding lug that must be directly connected to the facility ground by a #12 AWG copper wire. If necessary, use a ground lug on a flange bolt, or a metal hose clamp on the sensor port, to establish a dedicated connection to the facility ground.

IMPORTANT!
Consult the CM’s manual for gauge specific grounding requirements.

Pressure Signal Connection

To read CM pressures, the Pressure Output Signal must be connected to one of the four ANALOG I/O ports - BNC connectors labeled '1' through '4' on the back panel. Identify the two pins assigned to the pressure output signal on the gauge’s interface connector (typically labeled signal out (+) and signal common (-)). Construct a cable from these pins to a BNC connector, center pin connected to signal out (+) and outer shield connected to signal common (-). Other names for the signal pins are: PRESS OUT/OUTPUT RTN, Pressure Signal Output/Pressure Signal Output Return, SIGN OUT/SIGN COM, etc.

Power Connection

For convenience, the IGC100 also includes an auxiliary ±15 Vdc (100 mA) CM Power connector (3-position terminal block) on its back panel. This output is usually sufficient for the simultaneous operation of a pair of standard gauges (i.e. non-heated, ±15 Vdc, 35 mA typ.). Additional gauges or heated gauges will generally require help from an external source of power.

IMPORTANT!

Consult your CM manual or contact its manufacturer directly if you are uncertain about the power requirements of your gauges. Consult Stanford Research systems if uncertain about the compatibility of your CM(s) with the IGC100 controller.

Identify the three pins assigned to the ±15 Vdc power connection (typically labeled -15 VDC, +15 VDC, and Power Return) and use three wires to connect the gauge to the auxiliary ±15 VDC, 3-position, terminal block located on the back of the controller.

Figure 1-26. Capacitance Manometer Connection Ports.
1. Signal - Four ANALOG I/O BNC Ports. 2. Power - 3-position, terminal block.

Recommendation

Heated CMs often include additional pin connections assigned to heater status signals such as: 1. At Temperature Status/At Temperature Status Return pair and, 2. Heater Failure Status/ Heater Failure Status Return pair. In many cases these pin pairs act as semiconductor switches and their contact signals can be interfaced to the Process Control ports and used to trigger events in response to heater failure. This can be used to assure the reliability of your CM gauges at all times, and to protect delicate and expensive components sensitive to inaccurate pressure readings. Consult your gauge manual for availability of these options in your gauge heads.

Measuring Pressure

IGC100 Quick Setup

This section describes the setup steps required to prepare the IGC100 for accurate pressure measurements with ionization, Pirani and capacitance manometer gauges.

The steps in this section assume:

- The IGC100 box has been properly installed and grounded.
- Line power is connected to the controller (LINE LED on).
- The controller is turned off (POWER LED off)
- At least one gauge is connected to the controller, either an ionization gauge (IG1 port), a Pirani gauge (PG1 port) or a capacitance manometer (ANALOG I/O 1 = CM1 port).
- All pressure gauges are (1) mounted on the vacuum system, (2) properly grounded, (3) known to be compatible with the controller, and (4) safely connected to your IGC100 using Stanford Research System's cables (except for CMs).
- All ionization gauge(s) are exposed to a high vacuum environment with a known pressure < 10^{-3} Torr, and the gas composition is either: air, nitrogen or residual gas (i.e. typical base pressure composition of a clean high vacuum system).
- You are reasonably familiar with the general theory of operation of hot-cathode ionization and convection-enhanced Pirani Gauges (consult Appendices A and H, respectively, if necessary).
- The Relay and Logic Process Control ports (if available) are not physically connected to any devices or in a safe MANUAL mode status.
- The Remote Control TTL inputs are not connected or disabled.
- Manual gauge operation - i.e. the controller is not under the control of an external computer via one of its interfaces (RS232, GPIB or web).

Power-On Procedure

Power-up the controller. Press the red POWER button located at the lower left corner of the front panel. The green POWER LED turns on, a brief Power-On Self-Test procedure is executed, and the Pressure Display Screen is displayed on the touch-screen LCD.

For all new units (i.e. straight out of the shipping box) the Pressure Display Screen, preset at the factory, includes: (1) three Data Bars, corresponding to gauges connected to the IG1, PG1 and PG2 ports (top to bottom), plus (2) [Menu], [Gauges], [Process], [Chart], and [Help] QuickKeys lined up along the bottom of the screen (left to right.)

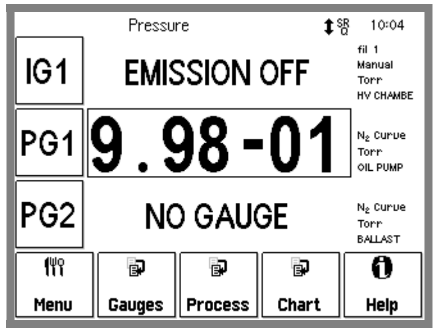


Figure 1-27. IGC100 Pressure Display Screen. IG, PG1 and PG2 Data Bars display pressures from gauges connected to the corresponding ports (Notice that no Pirani gauge is connected to the PG2 port and IG1 is off).

Reset

If your Pressure Display Screen does not appear like the one in Figure 1-27 at this point, it is possible to force the IGC100 to revert to its factory-preset settings by holding down the IG AUTO button during the Power-On procedure. However, keep in mind that this will also revert many other important settings of the instrument to factory default values (you might lose some important setup information). Holding down the IG AUTO Button should not be required for new instruments being powered right out of the shipping box.

As a factory default, all Pirani gauges connected to the controller become active during power-up and their pressures are displayed on the front panel. The PG1 and PG2 Data Bars display pressures from Pirani Gauges connected to the PG1 and PG2 ports, respectively. A "NO GAUGE" message (as displayed on the PG2 Data Bar of Figure 1-27) indicates that no gauge is physically connected (detected) at that port.

The IG1 Data Bar of your IGC100 should display an "EMISSION OFF" message at this time - the ionization gauge is not yet activated.

Gauge Setup Procedure

IGC100 is a generic instrument compatible with a large number of vacuum gauges. Individual setup information is required, and *must* be entered into the controller, for each new and/or replacement gauge connected to the: IG1, IG2, PG1, PG2, and CM1-4 interface ports.

IMPORTANT!

Setup of a new gauge requires knowledge of the gauge's operating parameters. Recommended parameters for third-party gauges are usually listed as part of the specifications provided by the gauge manufacturer. Contact the gauge manufacturer directly if specifications are not available.

IGC100 has a menu-driven user interface. All operating parameters are grouped into menus. Consult Chapter 3 of this manual for detailed menu information.

Help

Help for any menu button is available on screen by touching the [Help] QuickKey and then the menu button.

In order to enter new gauge setup parameters into the IGC100 controller, the user must follow the simple gauge setup procedure below. This procedure must be repeated for every new vacuum gauge connected to the controller.

Step 1

Starting from the Pressure Display Screen, touch the [Gauges] QuickKey to access the Gauge Display.

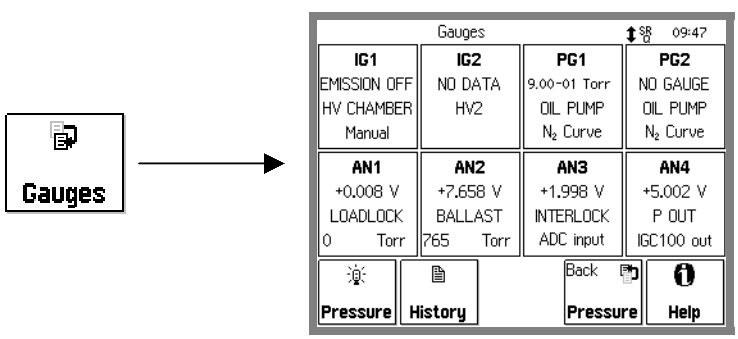


Fig 1-28. Gauge Display.

Step 2

Select a gauge port IG1, IG2, PG1, PG2, AN1-4 by touching its display button (Data Box). This brings up a Gauge Setup menu for the selected gauge port.

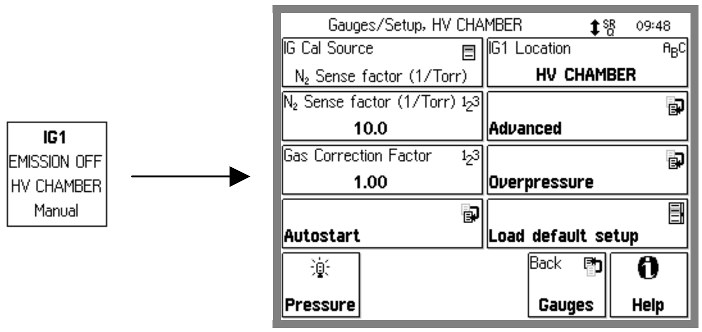


Figure 1-29. Gauge Data Box and Gauge Setup menu for the IG1 Port.

Step 3

Modify the gauge setup parameters for the selected port according to the gauge manufacturer's specifications. There are two basic approaches to this.

Setting Parameters Manually

Each gauge parameter can be modified individually (based on manufacturer’s recommended values) through the menu-driven user interface. See 'Setting Gauge Parameters' below for details.

Loading a Default Setup

All gauge parameters can be updated simultaneously by recalling a Default Setup File compatible with the gauge (where available).

Default Setup Files are pre-loaded at the factory and are accessed by the [Load Default Setup] button (where available) in a Gauge Setup menu. The use of Default Setup Files minimizes the chances of errors and is highly recommended whenever available as an option.

Default Setup Files are pre-loaded for commercially available ionization gauges of standard design only.

Individual parameters may still be modified after loading a Default Setup File.

Step 4

Once finished modifying parameters, touch the [Pressure] QuickKey 

to return to the original Pressure Display.

Setting Gauge Parameters

A different set of parameters must be considered for each type of gauge technology (i.e. ionization, Pirani or capacitance manometer) compatible with the IGC100 controller.

Uncalibrated Ionization Gauge (IG1, IG2)

The basic set of parameters that needs to be configured for any uncalibrated ionization gauge includes:

- IG Calibration Source (select N2 Sense Factor for uncalibrated gauges)
- N2 Sense Factor
- Gas Correction Factor
- Emission Current (Advanced submenu)
- Filament (Advanced submenu)
- Degas Power (Advanced submenu)
- Degas Time (Advanced submenu)
- Gauge Location
- Gauge Protection

These parameters depend on (1) gauge design (see Table 1-1) and (2) the type of gas being measured (Appendix D). The Gauge Location is an on-screen label to easily identify the position or function of the gauge in multiple gauge setups. The calculation of pressure from uncalibrated ionization gauges is based on their sensitivity factor (nominal or calibrated) - select N2 Sense Factor as the Calibration Source and enter the manufacturer recommended value for the N2 Sense Factor parameter before performing any measurements.

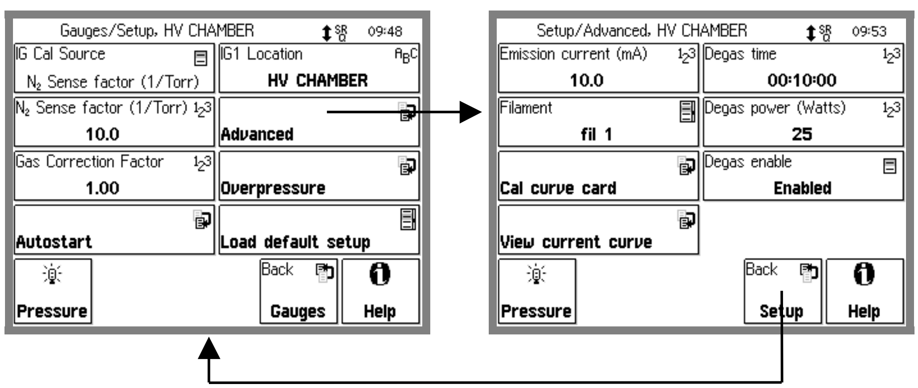


Figure 1-30. Touch [Advanced] to display the Advanced submenu, then [Back] to return.

Default Setup Files

Factory pre-loaded Default Setup Files are available for most commercially available Bayard-Alpert Ionization Gauge designs, including: Glass-Tubulated , Nude, Nude-UHV, Stabil-Ion®, Stabil-Ion® -UHV and Micro-Ion® gauges .

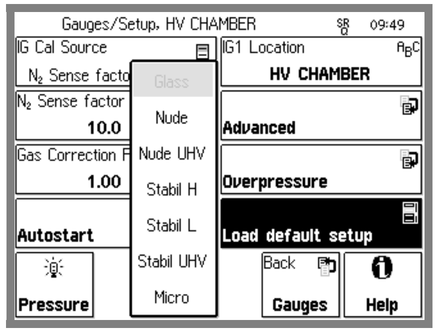


Figure 1-31. Default Setup Files for Ionization gauges. Touch the [Load Default Setup] button in the Gauge Setup menu to access the available choices.

Use Table 1-1 to select a file compatible with your ionization gauge(s). Consult Appendices B, C and M for additional details.

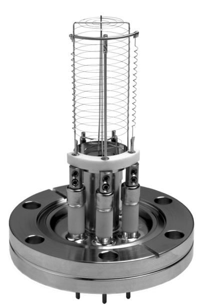
The parameter values used by the Default Setups in Table 1-1 are based on nominal specification numbers compiled from multiple commercial sources and known to be compatible with most modern Bayard-Alpert gauge designs. However, it is recommended to check your gauge manufacturer's specifications against the contents of the selected setup file to assure the safest and most accurate operation of your gauge(s). Consult your gauge manufacturer and Stanford Research Systems if unsure about the compatibility of IGC100 default setup files with your third-party ionization gauge products. Whenever available, replace the nominal sensitivity factor (N2 Sense Factor) provided by the default setup file with the actual (known or calculated) sensitivity factor for your gauge. Fil2 and Both are only available as Filament options for gauges with dual filament electrode design. Use Appendix D of this manual to obtain gas correction factors for pressure readings from gases other than nitrogen.

For More Information

Detailed recommendations for the proper operation of hot-cathode ionization gauges, have been compiled and reported by the Vacuum Group of the National Institute of Standards and Technology (Maryland, USA): C. R. Tilford, A. R. Filipelli and P. J. Abbott, “Comments on the stability of Bayard-Alpert Ionization Gauges”, J. Vac. Sci. Technol. A13(2) (1995) 485. Additional recommendations are also included in Appendix A.

For a very recent review of the state of ionization gauge technology, including essential practical information, consult J. H. Singleton, "Practical Guide to the use of Bayard-Alpert Ionization Gauges", J. Vac. Sci. Technol. A19(4) (2001) 1712.

Table 1-1. Default Setup Files for Common Ionization Gauges

Gauge Design	Setup File Name	N_2 Sense Factor [1/Torr]	Emission Current [mA]	Degas Time (min)	Degas Power (Watts)	Over Pressure Threshold (Torr)	Gauge Protection
Glass-Tubulated 	**GLASS**	10	10	10	40	$5x10^{-3}$	Normal
Nude (Bi-filar helix anode grid) 	**NUDE**	10	10	10	40	$5x10^{-3}$	Normal
Nude-UHV (closed end anode grid) 	**NUDE-UHV**	25	4	10	25	$2x10^{-4}$	Normal
STABIL-ION®-H (1) ($5x10^{-8}$ – $5x10^{-3}$ Torr) Use for P >10^{-4} Torr	**STABIL-H**	46	0.1	10	40	$2x10^{-2}$	Normal
STABIL-ION®-L (1) ($2x10^{-10}$ – $5x10^{-4}$ Torr) Use for P < 10^{-7} Torr	**STABIL-L**	42	4	10	40	$1x10^{-3}$	Normal
STABIL-ION® -UHV (2)	**STABIL-UHV**	21	4	10	25	10^{-4}	Normal
MICRO-ION® (3)	**MICRO**	20	0.02	2	3	$5x10^{-2}$	Micro-Ion

(1) Granville-Phillips Part# 360120 and 370120 ($5x10^{-10}$ - 10^{-3} Torr). See Appendix C.
(2) Granville-Phillips Part# 370121 ($5x10^{-11}$ - $2x10^{-5}$ Torr). See Appendix C.
(3) Granville-Phillips Part# 355001 (10^{-6} - $5x10^{-2}$ Torr). See Appendix M.

Calibrated Ionization Gauge (Memory Card)

Ionization gauges calibrated at the SRS High-Vacuum Calibration Facility, are the only gauges that do not require the Gauge Setup Procedure.

The IGC100 can store a single full-calibration curve for each ionization gauge port (IG1 and IG2) in its internal memory. Gauge-specific calibration data, including all relevant controller setup information, is stored at the factory in a memory card provided with the calibrated gauge. The calibration data is easily transferred into the controller through the MEMORY CARD interface of the front panel. Consult Chapter 6 of this manual for a step-by-step description of the procedure required to transfer gauge-specific calibration data from a memory card into the controller.

Once the calibration data is successfully loaded into the controller, choose Cal Curve as the IG Cal Source in the Gauge Setup menu, and the IGC100 will automatically be configured to match the setup conditions of the calibration data.

Important

The gauge setup parameters: (1) emission current, and (2) filament selection are fixed by the calibration data when Cal Curve is selected as the IG Cal Source. This is purposely done to assure the maximum accuracy of results obtained using Cal Curve data.

Pirani Gauge (PG1 and PG2)

Pirani gauges rarely require setup. The only setup parameters that might require adjustment include: (1) PG Calibration Curve (select between nitrogen and argon), (2) Power (on/off), (3) Gas correction factor, and (4) Gauge Location.

Calibration Curves

IGC100 is factory loaded with the required nitrogen and argon calibration curves required to convert Pirani Gauge signals into nitrogen-equivalent or argon-equivalent pressure readings. Use the PG Cal Curve parameter to select the appropriate calibration curve.

Power Off

Use the Power Off setting to cool down the Pirani gauge hot wire sensor while in the presence of explosive, flammable and combustible gases. There is no need to physically disconnect the gauge from the IGC100 during exposures to dangerous gases.

Gas Correction

Gas Correction factors (valid for pressure measurements below 1 Torr) are available in Appendix I of this manual to convert nitrogen-equivalent pressure readings to direct pressure readings for other gases.

Gauge Label

The Gauge Location label is very convenient and its use is highly recommended in multi-gauge setups. IGC100 allows you to assign a location name to each gauge port. Gauge locations are displayed next to their pressure readings. Use the Gauge Location to differentiate between identical gauges in a dual Pirani gauge setup.

Capacitance Manometer (CM1-4)

Configure an Analog Port

All Analog I/O ports are configured as inputs as a factory default. Configure an Analog port (AN1-4 corresponding to the 4 BNCs on the back) to read a capacitance manometer by touching the appropriate display button in the Gauges Display. This brings up the Analog I/O port setup menu. The I/O Mode should be set to Input (A/D) and the Input Signal should be set to CM Press Out. The two setup parameters that need to be adjusted for Capacitance manometers are:

Pmax

Pmax is the full scale range of the capacitance manometer (i.e. the pressure at which its pressure output signal =10 Vdc). Its value is usually indicated on the outer casing of the gauge head. The full scale ranges most commonly encountered in commercial capacitance manometers are: 50 and 100 mTorr, and 1, 2, 10, 100 and 1000 Torr. Consult your gauge manufacturer(s) directly if unsure about your gauge's full-scale range.

Gauge Location

The Gauge Location label is very convenient and its use is highly recommended in multi-gauge setups. IGC100 allows you to assign a location name for each gauge port. Gauge locations are displayed next to their pressure readings. Use the Gauge Location to differentiate between identical gauges in a multiple gauge setup.

Pressure Measurement

This section describes the steps required to measure and display pressures from ionization, Pirani and capacitance manometer gauges connected to the IGC100. This is the final step of the installation procedure.

It is assumed that at least one gauge – ionization (IG1), Pirani (PG1) or capacitance manometer (CM1) - is connected to the back ports, and that the controller has been completely configured, using the instructions of the previous section. Only manual operation of the gauges is discussed.

Readings may be displayed in various formats, in several different units and are continuously updated. When logging is enabled, data from all the gauges and analog inputs are stored in an internal data log at a user-programmable rate. The data log can be displayed in either table or chart (P vs. time) formats.

Warm-up times

The accuracy specifications of the IGC100 apply when the unit has warmed up for at least 1.5 hours and assume single filament operation (Fil1 **or** Fil2) of ionization gauges and signal cable lengths shorter than 50 ft. Longer warm-up times might be required by some capacitance manometers and even third-party Pirani gauges. Consult your gauge specifications and/or contact the gauge manufacturers for additional details.

To minimize temperature-induced drift in ionization gauge pressure readings, warm-up times must include operation of the filament at the selected emission current. Simultaneous operation of both filaments at high emission current settings in dual filament gauges can cause additional heating and may, in some cases, push the IGC100 slightly beyond its published accuracy specifications. This effect is aggravated by long signal cables, old filaments, the use of tungsten as filament material and operation at high pressures.

Recommendation

The accuracy specifications of the IGC100 should be relaxed by a factor of two for dual filament operation.

Ionization Gauge (IG1)

WARNING!

- Do not operate ionization gauges in the presence of explosive, flammable or combustible gases.
- Do not operate the ionization gauge at pressures $>10^{-3}$ Torr since that will significantly affect the filament's lifetime.

In order to perform pressure measurements with an ionization gauge, its filament must first be turned on. For manual operation, press the IG1 power button located on the front panel of the controller. The green IG1 LED to the right of the IG1 button lights up to indicate the presence of electron emission. *The filament current ramps up over a few seconds* minimizing pressure bursts in the vacuum system and emission current overshoot in the gauge head. As soon as full emission current is established, the pressure in the ionization gauge head is displayed on the IG1 Data Bar of the Pressure Display Screen. Press the IG1 power button again to turn the emission off – "EMISSION OFF" is displayed in the IG1 Data Bar.

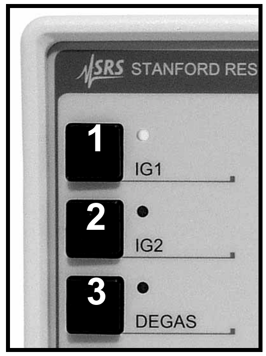


Figure 1-32. Front panel Ionization Gauge controls. 1. IG1 power button and emission LED, 2. IG2 power button and emission LED, 3. Degas button and LED

The amount of time required to establish full emission current in a gauge head depends on the emission current setting. As a rule-of-thumb, the larger the emission current, the shorter the turn on time. It is not unusual to experience turn on times of a few seconds at emission current settings <0.1 mA. This is considered normal and is designed to prevent large emission current overshoots that could overheat the gauge head damaging sensitive components inside the vacuum system. Turn on times are on the order of 1 second for emission current settings >1 mA.

A “WAIT” message is displayed in the IG1 Data Bar while electron emission current is being established, and all pressure readings are ignored until full (and stable) emission current is established. No process control action is performed based on ionization gauge readings during the time the emission current is established.

Dual Gauge Operation

If the dual ionization gauge option (SRS# O100IG) is installed, use the IG2 power button to turn on the second ionization gauge. *Only one gauge can be on at any time*. See Appendix L for more information.

Degassing an Ionization Gauge

WARNING!

- Degassing is not gentle on thoriated/iridium filaments. Experiment with Degas Time settings until you reach a good compromise between Degas Power and Degas Time. As a rule of thumb, choose the longest time you can wait and the minimum amount of power (under the manufacturer’s maximum specification) that will be compatible with your contamination tolerance. Maximum recommended degas powers for common gauge designs are listed in Table 1-1 of this chapter.

- Set the Degas Power and Time in the Advanced Gauge Setup described in the previous section.
- No process control action is performed based on ionization gauge readings while degassing takes place.

IMPORTANT!

To degas IG1 (or IG2), *the gauge must be on and the pressure must be under* $2x10^{-5}$ *Torr*, and Degas Enable (in the Advanced Gauge Setup) *must be set to Enabled*.

Press the DEGAS button on the front panel to degas the active ionization gauge. The red DEGAS LED next to the button turns on and an approximate indication of pressure and remaining degas time are displayed. Degassing may be stopped at any time by simply pressing the DEGAS button again. Observing the pressure indication rise, peak and then fall, is an excellent means of determining the optimum Degas Time. A setting of 10 minutes is adequate for most applications and should not be extended unless proven to be insufficient.

Figure 1-33. Front panel with Ionization Gauge 1 (IG1) degassing. 1. IG1 power switch with Emission LED on, 2. DEGAS Power Switch with DEGAS LED on, 3. Pressure Display Screen with approximate pressure and remaining degas time displayed.

The IGC100 employs electron bombardment degassing which is considered the most efficient means to remove contaminants from the gauge electrodes. During degassing, high energy electrons (500 eV) strike and heat the anode grid structure, removing impurities, while an increased filament temperature outgasses the filament surface. To complete the cleaning cycle, it is necessary to actively pump the outgassed molecules out of the gauge head. This requires pressures $<10^{-5}$ Torr for the removal process to be effective.

Degassing cannot be activated in the IGC100 unless (1) the ionization gauge is turned on and (2) the pressure is below the $2x10^{-5}$ Torr threshold. Degassing above this pressure threshold is inefficient and very damaging to the filament(s), and may cause pressure bursts that can strike an electrical gas discharge capable of coupling dangerous high voltages to the vacuum chamber wall. This creates an electrical-shock hazard if the system is not properly grounded.

An approximate indication of pressure within the ionization gauge head is available during degassing. Observing the pressure indication rise, peak out and then fall (see Trend Graph later in this chapter) is an excellent way to determine ideal degassing parameters such as Degas Time and Power. The Degas Power and the remaining Degas Time are displayed in the gauge's Port Info Box of the Pressure Display Screen (Fig. 1-33).

In order to remove pressure bursts and allow efficient removal of impurities, the degas power is ramped up slowly (i.e. 1W/sec) at the beginning of a degas cycle. For convenience and improved safety, degas power is carefully regulated throughout the entire degas process to prevent excessive pressure rise and reduce the possibility of striking a gas discharge. The degas power is immediately reduced if the pressure rises above the $2x10^{-5}$ Torr pressure threshold, and degas is aborted entirely if the pressure exceeds $5x10^{-5}$ Torr at any time. As a result of this power limitation feature, it is not unusual to see the Degas Power and pressure indications fluctuate significantly while degassing at pressures close to the $2x10^{-5}$ Torr threshold.

Recommendations

As a rule of thumb, pressure measurements below 10^{-8} Torr, require one degassing in the 10^{-6} Torr range followed by one more at or around the base pressure.

Degassing changes the surface conditions inside the gauge head. Allow sufficient time for new steady state conditions to be established before attempting to make accurate measurements.

If the pressure in the gauge is above the $2x10^{-5}$ Torr threshold, perform a bakeout of the ionization gauge applying an external heat source, to reduce the outgassing levels.

The recommendation from the NIST High Vacuum Group is to eliminate degassing by high temperature heating of the grid (whether resistive or electron bombardment). For baked systems, their observation is that gauges can be effectively outgassed by simply operating them at normal emission currents while the BAG and vacuum system are baked. For unbaked systems, the gauge can be baked and outgassed by thermally insulating it with fiberglass. Degassing by electron bombardment is only recommended if (1) the gauge is heavily contaminated or (2) after exposure to surface active gases such as O_2. Whenever possible minimize the emission current during degas and extend the degas time to compensate. For additional recommendations on the operation of ionization gauges, consult C. R. Tilford, A. R. Filipelli and P. J. Abbott, "Comments on the stability of B-A ionization gauges", J. Vac. Sci. Technol. A13(2) (1995) 485. See comments on second column of p. 486.

Degassing MICRO-ION® Gauges

Consult Appendix M for degassing information specific to MICRO-ION® gauges.

Pirani Gauge

By factory default, all Pirani gauges connected to IGC100 are automatically activated during power-up and their pressures are displayed on the front panel. *Pirani Gauge Power is On as the factory default*. The PG1 and PG2 Data Bars display pressures from Pirani Gauges connected to the PG1 and PG2 ports, respectively. A "NO GAUGE" message indicates that no gauge is detected by the controller on that port.

Use the Gauge Setup menu to turn Pirani gauge power on and off.

Capacitance Manometer

Displaying pressure readings from a capacitance manometer connected to an Analog I/O port requires assigning one of the Data Bars on the Pressure Display screen to the gauge's connection port (i.e. CM1 for a gauge connected to ANALOG I/O 1 port, and so on).

Each Data Bar consists of three boxes: Port ID (left), Port Data (center) and Port Info (right). Customize a Data Bar by touching the Port ID or the Port Data boxes.

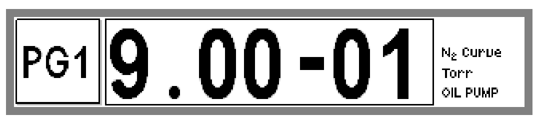


Figure 1-34. Data Bar: Port ID (left), Data Bar (center), and Info (right).

The Port ID box shows the source of the readings for the data bar, IG, PG1, PG2, CM1-4 or AN1-4. For example, the Data Bar in Fig. 1-34 displays pressure readings from the Pirani gauge connected to the PG1 port. Touch the Port ID box to select a different source (any gauge or analog input port) for that Data Bar. In the case of a capacitance manometer, identify the Analog I/O port (1-4) connection and choose the appropriate CM port (CM1-4). For example, choose CM1 for a capacitance manometer connected to the Analog I/O 1 port.

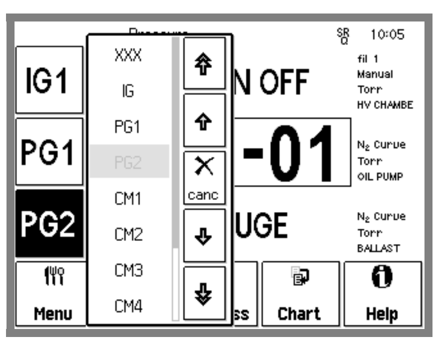


Figure 1-35. Select CM1 for the lower Data Bar.

Pressure Output Signal Display

It is also possible to display the pressure output signal (0-10 Vdc) of a capacitance manometer. Touch the Port ID box of the CM1-4 Data Bar and choose the appropriate

AN1-4 port as the Data Bar source. For example: choose AN1 for the CM1 capacitance manometer (CM connected to analog I/O 1 port). The Pressure Output signal is displayed in the Data Bar in units of Volts. This capability is very useful while debugging the proper connection and operation of a gauge and while calibrating capacitance manometer gauges.

Note

The analog and pressure output display will show 'OVERLOAD' if the Pressure Output signal exceeds 12 V.

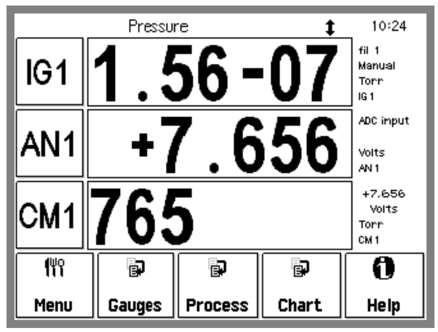


Figure 1-36. IGC100 displaying pressures from: IG1, AN1 and the CM pressure output signal at Analog I/O 1 port.

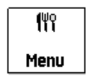
Pressure Display Formats

Use the [Pressure] QuickKey 

to bring up the IGC100 Pressure Display at any time.

Pressure Units

The factory default for pressure units is Torr (1 Torr = 1 mm Hg).

Use the [Menu] QuickKey 

to display the Main menu. Touch [Units] to choose a different units system: Torr, micron, mbar, bar, or Pascal.

Consult Appendix K for conversion factors between the different pressure units supported by IGC100.

Display Types

The Pressure Display has three Data Bars, each displaying a pressure (or analog input). Readings may be displayed in various formats and are updated twice a second.

Each Data Bar consists of three boxes (See Fig. 1-34): Port ID (left), Data (center) and Info (right). Customize a Data Bar by touching the Port ID or the Port Data boxes.

The Port Data area of the Data Bar is where the readings are displayed. Touch inside the Port Data box to choose a display format. Five (5) options are available:

Big Numbers

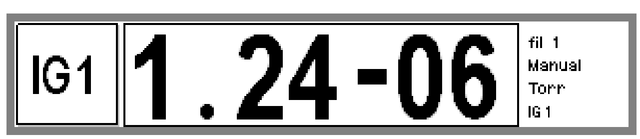


Figure 1-37. Big Numbers data display.

Best display for accurate, easy to view, pressure readings. Easily visible across the room.

Trend Graph

Figure 1-38. Trend Graph display.

Best display for trend analysis. A stamp-sized 'P vs. time' plot of the most recent 10 readings, sampled at the data logging interval (see 'Logging' below). It also includes a small instantaneous reading next to the plot. Use trend graphs to see pressure changes in time-dependent processes such as leak testing, pump downs, venting, bakeout, etc.

Auto Scaling Bar Graph

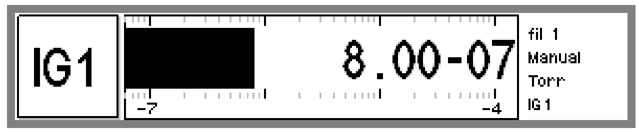


Figure 1-39. Auto Scaling Bar graph.

Best display to detect instantaneous changes in pressure readings. Three decade logarithmic bargraph display scaled about the current reading. Often used during leak testing procedures. This display preserves the 'feel' of the old analog needle displays preferred by some vacuum users.

Full Range Bar Graph

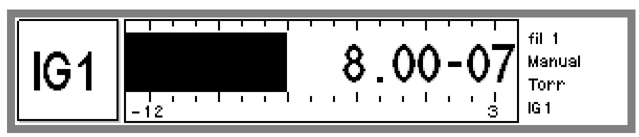


Figure 1-40. Full Range Bar Graph display.

Best display to view the overall status of your vacuum system at any given time. Fifteen decade logarithmic bargraph display, covering the entire useful range of the instrument (10^{-12} to 10^{3} Torr). The scale covers the entire range from UHV to atmosphere. For example, use the length of the bargraph of a Pirani Gauge measurement to quickly determine whether the system is pumped down or at atmosphere, without having to read actual pressure values.

Status Information

Figure 1-41. Status Information display.

Use this display to learn more about the state of a gauge. This is especially useful if the gauge is in a fault or error condition.

The lowest line in this display shows who last modified the status of the gauge (front panel user, remote user, etc.).

Logging

When Logging is enabled (factory default), data from all gauges and analog inputs are stored in a circular data buffer at a rate specified by a user adjustable Logging Interval.

The logged data for the three ports selected in the Pressure Display screen can be viewed at any time in the Data Log Display in either table or chart format. This allows users to switch readily between instantaneous and logged readings for the gauges of interest.

In order to access the Data Log display, follow these simple steps:

Step 1

Bring up the Pressure Display by touching the [Pressure] QuickKey 

.

Step 2

Touch the [Chart] or [Table] QuickKey to display the log in Chart/Table format.

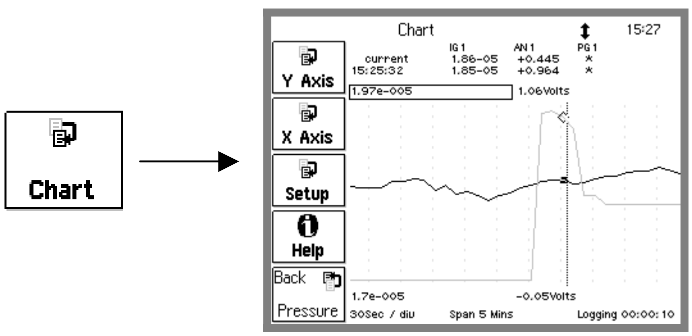


Figure 1-42. Press [Chart] to display the chart of the data log.

Step 3

Touch the [Setup] button to access the Logging Setup menu.

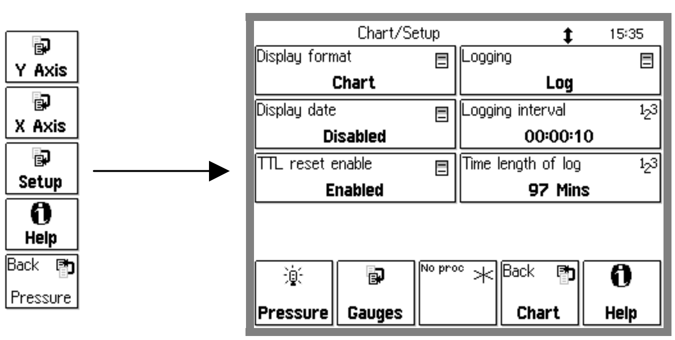


Figure 1-43. Logging Setup menu. Choose between Chart and Table display formats or adjust Logging Parameters.

Step 4

Select Table or Chart display format. Activate Logging or change the Logging Interval as required using the menu.

IG Auto-Start mode (IG AUTO)

The common combination of one ionization gauge and two Pirani gauges, standard in all IGC100 controllers, allows you to monitor system pressures between atmosphere and UHV without any blind spots.

If one of the Pirani gauges is exposed to the same gas environment as the ionization gauge, the IG AUTO mode automatically turns the ionization gauge ON when the Pirani pressure readings drop below a user programmed threshold. IG AUTO continues to protect the filament during subsequent operation. The ionization gauge will be turned OFF if the Pirani pressure rises above 1.2 times the threshold. For example, if the threshold is 1.0×10^{-3} Torr, the ion gauge turns on at 1.0×10^{-3} and shuts off if the pressure ever rises back above 1.2×10^{-3} Torr.

Auto-Start is used to provide complete unattended system control, and protect the ionization gauge filaments, during system pumpdowns and ventings. Auto-Start can also be activated remotely, through the computer interface.

The Auto-Start threshold and gauges are selected in the Gauge Setup menu of each ionization gauge. From the Gauge Setup menu, touch [Autostart] to display the Auto-Start setup menu.

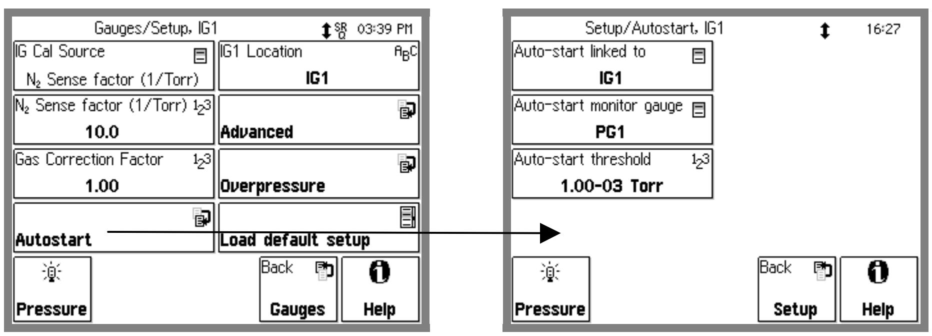


Figure 1-44. Touch [Autostart] in the Gauge Setup menu to display the Autostart Setup menu. Choose the Pirani Gauge, Ion Gauge and Threshold for Autostart operation BEFORE turning IG Auto on.

Choose which Pirani gauge is monitoring the Ion Gauge pressure and the safe pressure threshold for the Ion Gauge. In dual ionization gauge systems (with option O100IG) the Auto-Start function may be linked to either ionization gauge port. The user specifies the ionization gauge (IG1 or IG2) which will auto-start. Since the IGC100 only operates one ion gauge at a time, IG2 is automatically turned off if IG1 is put in Auto-Start (and vice-versa).

Auto-Start is activated/deactivated manually by pressing the IG AUTO button of the IG Control Keypad on the front panel. Pressing either IG1 or IG2 will deactivate IG AUTO operation.

RS232 Serial Cable Connection

The IGC100 is a stand-alone instrument - there is no need to connect the controller to an external computer for normal operation. However, a serial RS232 connection to a computer will be required for:

- External software control of the IGC100 and vacuum system (also available via optional GPIB or web interfaces).
- Download of firmware updates into the controller.
- Transfer of logged history and data into a PC for off-line analysis.
- Download of calibration data into the controller (also available via optional GPIB interface).

The IGC100 is delivered with a DIN8-DB9 Adapter cable for serial RS-232 communication with a PC. Connect the DIN8 (circular connector) end of the cable to the back of the IGC100 controller at this time.

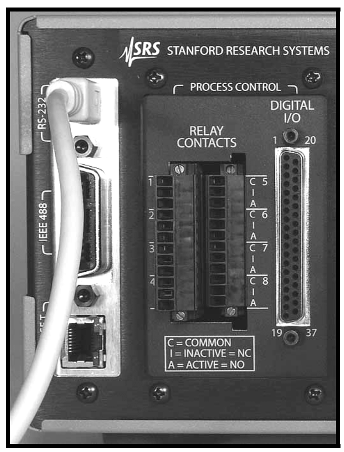


Figure 1-45. DIN8-DB9 Connector Adapter Cable, connected to the back of the IGC100 controller.

The DB-9 connector end of the cable provides a standard connection to serial connectors available in most PC computers. Use a DB-9 to DB-25 adapter if necessary.

Note

Attaching the cable to the controller at this time minimizes the chances of misplacing the cable in your lab, and not being able to find it when you really need it.

Proper Grounding Test Procedure

Read the entire **Safety and Preparation for Use** section of this manual before starting any installation procedure.

WARNING!

- Safe operation of any high-voltage, ion-producing vacuum equipment, including the IGC100, requires proper grounding of its electronics control unit and vacuum chamber. **LETHAL VOLTAGES** may be established under certain operating conditions if proper grounding is not assured.
- **This risk is not specific to the IGC100!**

As a rule-of-thumb, *all parts of a vacuum system* utilized with the IGC100, or any similar high voltage product, *must be maintained at earth-ground for safe operation*.

- **The vacuum chamber should be directly, and explicitly, connected to a heavy-duty earth-ground** (minimum 12 AWG ground lead wire).
- All electronic instrumentation must be connected to properly grounded 3-prong electrical outlets. **A chassis grounding lug must also be directly tied to an earth-ground electrode** (minimum 12 AWG wire). *Do not connect the controller's ground lug to the vacuum system or another component*. Connecting the power cord to a properly grounded outlet is a necessary, but not sufficient grounding condition with this (or any similar) high voltage producing vacuum equipment.
- **All conductors** in, on, or around the vacuum system that are exposed to potential high voltage electrical discharges **must either be shielded** at all times to protect personnel **or be permanently connected to the facility's earth-ground**. Consult an experienced electrician if necessary!!!
- High-voltage ion-producing equipment such as a hot-cathode ionization gauge can, under certain circumstances, provide sufficient electrical conduction via a plasma to couple a high-voltage potential to the vacuum chamber walls. *Any exposed conductive parts of a gauge or vacuum chamber may attain high voltage potentials through this process if not properly grounded.* Grounding the IGC100 does not and cannot guarantee that other components of the vacuum system are all maintained at earth ground.

Perform regular electrical ground-tests on your entire vacuum system, particularly if it is shared by multiple users who often perform custom modifications on the chamber's configuration.

Ground Test Procedure:

Step 1

Carefully examine your vacuum system:

- Are all exposed connectors and conductors on the vacuum chamber grounded?
- Are all ground connections properly connected to a solid earth or facility ground?
- Beware! Some vacuum systems rely on water piping for the earth-ground connection. Proper ground connection can be easily lost by inadvertently inserting a plastic interconnect into the water line.
- Keep in mind that the use of O-ring seals without metal clamps or bolt connection can isolate big portions of a vacuum system from its safety ground. Add metal clamps if necessary.
- Verify that the vacuum port to which any new component is about to be mounted is electrically grounded. Use a ground lug on a flange bolt if necessary.

Step 2

With the IGC100 controller turned off (but still plugged into an outlet):

- Test for both AC and DC voltages between the metal parts of the vacuum system and the controller's chassis. No voltage differences should be detected.
- If no voltages are detected, measure resistance between all parts of the vacuum system, and between the vacuum system and the controller: <2 Ohms assures a commonality of grounds between the different parts of the vacuum setup and prevents the development of high voltages between different sections of the vacuum setup in the presence of a high voltage plasma discharge.
- If AC or DC voltages exist or more than 2 ohms is detected, professional help is recommended.

Chapter 2

IGC100 Basics

This chapter describes the basic features and functionality of the IGC100 controller.

In This Chapter

IGC100 Overview

WARNING!

- Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.
- Read Chapter 1 for detailed instructions and safety information regarding the installation and connection of gauges.

The IGC100 Ionization Gauge Controller is a fully programmable, microprocessor-based vacuum system controller.

The IGC100 is a high accuracy controller that measures pressures from Bayard-Alpert ionization gauges, convection-enhanced Pirani gauges and capacitance manometers, providing uninterrupted pressure readings from 1000 Torr to UHV. The IGC100 has a touchscreen LCD display, pressure vs. time plots, built-in relays for vacuum system control and several multipurpose (analog and digital) I/O ports. An RS-232 computer interface is standard in all controllers with optional upgrades to GPIB and Web (ethernet) interfaces.

Controller operation is simple and intuitive via a menu-driven touchscreen user interface. The screen displays readings in a large, easy-to-read numeric format, as well as in bar graph and trend formats. Readings are updated twice a second and pressures can be displayed in several units systems. Data Logging and Pressure vs. Time plots allow you to follow pump down and venting cycles and keep track of process relay activity, analog input signals and gauge operations, to within a fraction of a second.

For applications that benefit from the accuracy of calibrated ionization gauges, the IGC100 also offers the ability to store and use *gauge-specific* calibration.

Complete controller specifications are included in the introductory pages of this manual.

This section details the main features of the IGC100.

Ionization Gauge (IG1)

The basic IGC100 Ionization Gauge Controller is designed to operate a single, hot-cathode, ionization gauge of Bayard-Alpert design within the 10^{-11} and 10^{-1} Torr pressure range supported by its electrometer. Pressure readings are updated at a rate of 2 Hz.

The IGC100 is compatible with most commercially available Bayard-Alpert ionization gauge designs, including: glass-tubulated, nude, nude-UHV, STABIL-ION® (Granville-Phillips, Helix Corporation) and MICRO-ION® (Granville-Phillips, Helix Corporation) gauges. The menu-driven interface allows the operator to easily program all required Gauge Setup parameters into the controller. Additional controls are provided for overpressure protection and Auto-Start operation (see Pirani Gauge Capabilities below).

The IGC100 is designed to be accurate and stable. All ion gauge bias voltages and emission current supplies are accurate to better than 0.3% (see 'Specifications'). The IGC100 has a low noise, autoranging electrometer that delivers high accuracy pressure readings into the UHV. A low noise, direct current supply powers the filament and establishes the emission current. Precision electronics eliminate controller-to-controller variations and the measurement uncertainties (up to 15%) associated with traditional instruments. When necessary, biasing voltages are measured directly at the gauge head (4 wire measurements) making them independent of cable lengths. The effective measurement range for ionization gauge readings is ultimately limited by the gauge design. The accuracy level of the pressure readings is defined by the accuracy of the calibration data available for the gauge. The high accuracy and long term stability of the IGC100 electronics, justifies the presence of three significant digits in the pressure display.

Pressure measurement with Bayard-Alpert ionization gauges requires that the filament be turned on. The IGC100 includes an IG Control Keypad (IG1, IG2, DEGAS and IG AUTO buttons w/LEDs) on its front panel for manual activation of pressure measurements and degassing. Ionization gauges can also be activated remotely through (1) software control, (2) Remote TTL control (requires Process Control board, Opt 03), and (3) web-interface (requires Web Interface, Opt. 02). An Auto-Start Mode (see below) is available for controllers also connected to Pirani Gauges (see below).

Degassing is by electron bombardment, with user-programmable degas power and degas time. To degas, the gauge must be on and the pressure must be under 2×10^{-5} Torr. In order to remove filament damaging pressure bursts, the degas power ramps up and down at the beginning and end of the degas procedure. For convenience, and improved safety, degas power is constantly regulated throughout the degas procedure to prevent excessive pressure rise and reduce the possibility of a gas discharge.

For applications that benefit from gauge-to-gauge reproducibility and the accuracy of calibrated gauges, SRS offers NIST-Traceable calibrated ionization gauges through its High-Vacuum Calibration Facility. Full-range calibrations are available with 6% and 3% accuracy. All calibrated gauges are delivered with a Memory Card which contains calibration data specific to the gauge. The calibration data is easily uploaded into the controller via the front panel Memory Card module. Of course, the IGC100 also operates with uncalibrated gauges. In that case, the user must simply configure the controller based on the manufacturer’s recommended parameter values or by recalling a factory pre-loaded Default Setup File compatible with the gauge.

Gauge connection cables must be purchased directly from Stanford Research Systems and are available for most gauge designs.

For More Information

Chapter 1 includes all the installation and setup information required to set up your IGC100 controller and its gauges. Chapter 3 describes, in detail, the menu-based user interface, including all menus required to configure the IGC100 for operation with ionization gauges. Chapter 6 provides a detailed description of the Memory Card module capabilities, including step-by-step instructions for uploading gauge calibration data into the controller. Consult Appendix A of this manual for general information on Bayard-Alpert ionization gauges, and Appendix B for a list of ionization gauges available directly from Stanford Research Systems (including detailed specifications, Manufacturer's Cross Reference Table, connection cables and available Default Setup Files). Appendix F lists the gauge calibration options available through the SRS High-Vacuum Calibration Facility.

Pirani Gauges (PG1 and PG2)

The standard IGC100 controller has the capability to simultaneously operate two convection-enhanced Pirani Gauges, providing mid-pressure measuring capabilities between 10^{-4} and 1000 Torr. Pressure readings are continuously updated, at a rate of 2 Hz.

To complement the IGC100, Stanford Research Systems has designed its own line of Pirani gauges, models PG105 and PG105-UHV. However, the IGC100 is also compatible with well-established, third-party products such as: Convectron® (Helix Corporation, Granville Phillips) and Series 317 (MKS/HPS) convection gauges. Note that connector adapters (O105CA1 and O105CA2, respectively) are required to connect these third party gauges to the O105C4 dual-Pirani gauge cable.

The PG105-UHV is the only commercially available convection-enhanced Pirani gauge that can be operated directly in UHV environments and can be baked to 250°C without any disassembly.

Following factory assembly, each PG105 gauge tube is individually calibrated for nitrogen, and temperature compensated between 10° and 40°C. Individual factory calibration of the gauge response provides true 'plug-and-play' convenience and eliminates the need to readjust the controller each time a new gauge tube is connected. PG105 gauges and IGC100 controllers are completely interchangeable without any need for instrument adjustments.

The IGC100 controllers are factory preloaded with nitrogen and argon specific calibration curves for all compatible convection gauges. Look-up tables are available (Appendix I) to convert nitrogen-equivalent readings to other gases.

The calibration data loaded into all IGC100 controllers is based on the response of a new gauge, free of contaminants. If a tube becomes contaminated or does not seem to read correctly, the front panel readings can often be readjusted through the menu-based interface using the ZERO and ATM calibration sub-menus included in the Gauge Setup menus. Consult Chapter 3 for details on these two adjustment procedures.

As a special feature, IGC100 users can turn off their Pirani Gauges from the front panel-without having to physically disconnect them from the controller, i.e. the hot wire sensor is cooled down and pressure readings are no longer available. This is convenient for fail-safe process control setups to prevent hot Pirani gauge sensor wires from coming in contact with flammable or explosive gases. The Pirani gauge sensor wire can be turned off manually (front panel), or remotely through the computer interface or the Remote TTL Control Module (requires Process Control Board, Opt. 03).

For More Information

Chapter 1 includes all the basic information required to install and set up your IGC100 controller and its gauges, including Pirani gauges. Chapter 3 describes, in detail, the menu-based user interface, including all menus required to turn Pirani gauges on/off, adjust Zero and ATM, and select N2/Ar cal curve. Consult Appendix H of this manual for general information on PG105 convection-enhanced Pirani gauges. Appendix I lists correction factors for some common gases.

IG Auto-Start mode (IG AUTO)

The common combination of one ionization gauge and two Pirani gauges, standard in all IGC100 controllers, allows you to monitor system pressures between atmosphere and UHV without any blind spots.

If one of the Pirani gauges is exposed to the same gas environment as the ionization gauge, the IG AUTO mode automatically turns the ionization gauge ON when the Pirani pressure readings drop below a user programmed threshold. IG AUTO continues to protect the filament during subsequent operation. The ionization gauge will be turned OFF if the Pirani pressure rises above 1.2 times the threshold. For example, if the threshold is $1.0x10^{-3}$ Torr, the ion gauge turns on below $1.0x10^{-3}$ and shuts off if the pressure ever rises back above $1.2x10^{-3}$ Torr.

The Auto-Start threshold and gauges are selected in the Gauge Setup menu of either ionization gauge. From the Gauge Setup menu, touch [Autostart] to display the Auto-Start setup menu. Choose which Pirani gauge is monitoring the Ion Gauge pressure and the safe pressure threshold for the Ion Gauge. In dual ionization gauge systems (with option O100IG) the user specifies the ionization gauge (IG1 or IG2) which will auto-start. Since the IGC100 only operates one ion gauge at a time, IG2 is automatically turned off if IG1 is put in Auto-Start (and vice-versa).

Auto-Start is activated/deactivated manually by pressing the IG AUTO button of the IG Control Keypad on the front panel. Pressing either IG1 or IG2 will deactivate IG AUTO operation. Auto-Start can also be activated remotely, through the computer interface.

Auto-Start is used to provide complete unattended system control, and protect the ionization gauge filaments, during system pumpdowns and ventings.

For More Information

Consult the 'Front Panel' section of this chapter for details on the IG AUTO button functionality, and Chapter 3 for information on the Auto-Start menu options available for ionization gauges.

Analog I/O Ports (AN1-4)

All IGC100 controllers have four analog input/output ports (BNC connectors) on the back panel. Their range is ±12 V with 14 bit input resolution and 12-bit output resolution. The update rate is 2 Hz. Each port is individually configured as an input or an output for complete I/O flexibility.

Input

Input signals (dc voltages) may be displayed on the Pressure or Gauge Display Screens, and monitored remotely through the computer and web interfaces. When Data Logging is enabled, all analog input voltages are stored in memory as part of the logging data set.

Use ANALOG I/O ports as inputs to read voltages from additional vacuum equipment such as capacitance manometers, thermocouples, mass flow controllers, turbo pump controllers, etc. Capacitance manometers must be connected to ANALOG I/O ports configured as inputs. Direct pressure readings are available only if their full scale pressure (Pmax) is programmed into the controller (see below).

Output

Analog output levels can be adjusted manually from the front panel, remotely through the computer interface, or they can be linked to the log pressure of the IG1, IG2, PG1 or PG2 gauges.

Use analog I/O ports as outputs to control auxiliary vacuum equipment such as heaters, actuators, ion sources, programmable logic controllers and throttle controllers.

For More Information

Consult Chapter 4 of this manual for a complete description of the ANALOG I/O capabilities of the IGC100, including specifications, connections, possible configurations, and capacitance manometer operation. Chapter 3 describes, in detail, the menu-based user interface, including all menus required to configure the IGC100 for proper operation of its ANALOG I/O ports.

Capacitance Manometers (CM1-4)

The standard IGC100 controller can display pressure as measured from standard capacitance manometers (CMs). Up to four independent CM readings can be monitored simultaneously using the four ANALOG I/O ports located on the back of the controller. Pressure readings are updated at 2 Hz. The IGC100 precisely measures the 0 to 10 Vdc linear output signal from the CM to determine pressure. Direct pressure readings are available only if the full scale pressure (Pmax) of the gauge is entered into the controller. Full-scale ranges up to 1000 Torr are supported by the controller.

For added convenience, the IGC100 also supplies an auxiliary (AUX) ±15 V, 100 mA power output. This is usually sufficient to operate up a pair of standard (i.e. non-heated) capacitance manometers.

For critical applications where repeatability, precision, and composition independent readings are required, a capacitance manometer gauge should be used to monitor and control the process pressure! This is particularly true if complex or changing gas mixtures are involved.

For More Information

Chapter 1 includes all the basic information required to install and set up your IGC100 controller and its gauges, including capacitance manometers. Consult Chapter 4 of this manual for further details on the operation of capacitance manometers and their proper connection to ANALOG I/O ports. Chapter 3 describes, in detail, the menu-based user interface, including all menus required to configure the IGC100 to display pressure readings from capacitance manometer gauges.

Data Logging (Charts and Tables)

All IGC100 controllers include Data Logging capabilities. When Data Logging is enabled, data from *all* gauges and *all* analog inputs are stored in a circular memory buffer at the rate specified by a user-programmable logging interval.

The logged data can be accessed through the touchscreen LCD - the logged data for the three Data Bars in the Pressure Display screen are presented in a single window. Both table and chart (P vs. Time) displays are available. The chart display includes convenient graphical tools such as (1) cursor, (2) zoom, (3) x,y scaling (manual and auto), and (4) cursor readings. Users can switch rapidly between current and logged readings for the pressures or analog signals of interest.

The data log can also be accessed remotely through the computer interface, or through the internet when using the optional embedded web server (Opt. 02).

The data log can be cleared manually, at any time, from the front panel (use Clear Log), remotely via the Remote TTL Control Module (requires Process Control board, Opt. 03), or via the computer interface.

Typical applications of the Data Logging capabilities include capturing pump-down or venting curves for vacuum system characterization, monitoring mass flow controller signals during deposition processes, and monitoring temperatures and other time dependent variables during bakeouts or heat treatments.

For More Information

Consult Chapter 3 of this manual for detailed information on the Data Logging capabilities of the IGC100 and Chapter 5 for information on the Remote TTL Control Module.

Security (Password Protection)

The IGC100 features password protection to prevent unauthorized users from altering important instrument parameters and vacuum system settings.

Use Security features to: (1) lock and unlock the system, (2) change the password, (3) use Password Cards, (4) password protect individual features.

As an example, a process supervisor might choose to lock the Process Control menus, or even the entire front panel, to prevent any changes by inexperienced or unauthorized operators.

For More Information

Chapter 3 describes, in detail, the menu-based user interface, including all menus required to program the security options and create Password cards. Consult Chapter 6 for additional information on Password Cards.

Display Formats

The IGC100 includes a very flexible Pressure Display that can present pressure and analog signals in a variety of numeric and graphical formats.

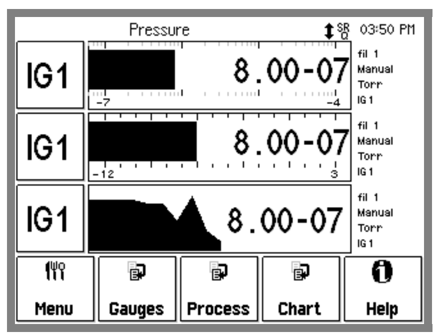


Figure 2-1. Pressure display using 3 different data display formats.

Big Numbers

Best for pressure readings. Easily visible across the room.

Trend Graph

A stamp-sized 'P vs. Time' plot of the most recent points, sampled at the logging interval. It also includes a small, instantaneous pressure display next to the plot. Best for trend analysis.

Auto Scaling Bar Graph

Three decade logarithmic bargraph display scaled about the current readings.

Full Range Bar Graph

Fifteen decade logarithmic bargraph display, covering the entire useful range of the instrument (10^{-12} to 10^{3} Torr). The scale covers the entire range from UHV to atmosphere.

Status Information
Display additional information about the gauge status. Use this to troubleshoot fault conditions.

For More Information
Consult Chapter 3 for a complete listing of menu items related to data display formats. Chapter 1 discusses examples of common applications of the different display formats in its Pressure Measurement section.

Pressure Units

The factory default for pressure units is Torr (1 Torr = 1 mm Hg). Users may choose a different units system (micron, mbar, bar, and Pascal) in the Main Menu.

For More Information
Consult chapter 3 for a guide to the menus required to change pressure units. Appendix K lists conversion factors for all the pressure units supported by the IGC100.

On-Screen Help

On-screen help is available in all IGC100 controllers. Extensive Help information is readily available for menus, buttons, displays and even hardware. From any screen where it is displayed, touch the [Help] button and then any button for which help is required.

For More Information
Touch [Help], then [Help] again, for a complete description of the IGC100 help system.

Backlight Saver

The IGC100 touchscreen LCD is illuminated by a fluorescent lightbulb (physically located to the side of the screen). Use the Backlight Saver to extend the life of the bulb. All IGC100 features remain functional while the backlight is off.

When the Backlight saver is enabled, the light turns off when the touchscreen is inactive for period longer than a user-specified period. Turn-off and turn-on times can also be programmed into the controller to keep the backlight off overnight.

For More Information
Consult Chapter 3 for menu options related to the Backlight saver capabilities.

RS-232 Computer Interface

The IGC100 controller comes standard with an RS-232 communications port (DIN8 connector on the back panel with DIN8 to DB9 cable included). A host computer connected to the instrument can easily configure, diagnose and operate the ionization gauge controller using simple ASCII commands. An intuitive command set facilitates integration of all controller functions into any processing or diagnostic software.

The RS-232 interface is easily configured through the front panel user interface. A variety of baud rates, byte framing and handshaking options are available. The IGC100 buffers the most recent characters received and transmitted over the communication interface (RS-232, GPIB and Web). The Queue can be displayed on the front panel at any time (Queue display mode) simplifying testing and debugging of communication programs.

Note that the IGC100 is a stand-alone instrument - there is no need to connect the controller to an external computer to access its full performance and functionality. All instrument functions and parameters are manually accessible and easily modified through the front panel.

Computer interfacing is only required for: (1) Computer monitor/control of the IGC100 and vacuum system, (2) Remote access to data-logs and history lists, (3) calibration data uploads, and (4) firmware upgrades (for controller and web-server).

RS-232 is the standard interface in all IGC100 controllers. An additional GPIB interface is available as an option (see below).

For More Information

Consult Chapter 7 of this manual for more detailed information on the available computer interfaces (RS-232 and GPIB), programming options, complete command set, and firmware upgrade procedures. Consult Chapter 3 for information on menu items related to configuration of the RS-232 interface. A complete Command Set is also listed at the beginning of this manual.

Dual Ionization Gauge Operation (IG2) (Opt. O100IG)

A Dual Ionization Gauge Connector Box (SRS# O100IG), is available to connect two ionization gauges (IG1 and IG2) simultaneously to the back of the IGC100 unit. This popular option allows the controller to switch operation between two separate gauges from the front panel (i.e. sequential operation), and measure pressure at a second location at a small fraction of the cost of a second instrument.

For More Information

Chapter 1 includes all the information required to connect and set up your IGC100 controller and its gauges, including a second ionization gauge (IG2). Chapter 3 describes the menu setup of the IGC100 for operation with a second ionization gauge. Appendix L provides gauge-to-controller connection information specific to the Dual Gauge Connector Box, Option O100IG.

GPIB Interface (Opt. 01)

A GPIB (IEEE-488) interface is available as an option for the IGC100. The GPIB interface uses the industry standard 24-pin connector.

The same command set is shared between the RS232 and GPIB interfaces.

For More Information

Consult Chapter 7 of this manual for detailed information on computer interfaces (RS-232 and GPIB), programming options, command set, and firmware upgrade procedures (controller and web-server). Consult Chapter 3 for information front panel configuration of the GPIB interface.

Embedded Web Server (Opt. 02)

The optional Embedded Web Server (EWS), option 02, connects the IGC100 to the internet.

The EWS is a TCP/IP compatible web server that resides inside the IGC100 box, continuously gathering data from the instrument. When connected to an ethernet network with an internet gateway, the EWS can deliver IGC100 data to a user anywhere on the world wide web using a standard browser. Users can monitor your vacuum system from anywhere in the world. E-mail notification can notify a client list of potential or real system problems.

The EWS provides the most convenient way to access IGC100 data from a computer without writing custom serial or GPIB based software. The EWS can be configured to allow access to process control functions, so that a user can control their vacuum process from anywhere in the world.

Use the web-interface to monitor your vacuum system from your office or from home without having to pay periodic visits to your lab while waiting for your system to pump down. Use the control capabilities to turn heating jackets on/off or activate/deactivate valves or pumps and gauges from the comfort of your office.

For More Information

The individual functions of the EWS are described in detail in Chapter 8 of this manual. Consult Chapter 3 for information on menu items related to configuration of the web-interface.

Process Control Option (Opt. 03)

The process control option of the IGC100 provides eight channels of process control.

Each channel has a relay closure output and corresponding opto-isolated TTL output signal, that may be linked to a variety of input sources with intuitive user-programmable rules. Each channel can be linked to any pressure gauge or analog input, the system clock, gauge status or a TTL input trigger signal. Channel Rules apply in AUTO mode, and include all variables required for full process automation, including setpoint (level, polarity and hysteresis), delay settings and audio and front panel notification.

The Process Control option also includes 12 opto-isolated TTL level inputs, used to remotely control gauge on/off, degas on/off, filament selection, IG lockout, datalogging reset and touchscreen enable/disable functions.

Programmable audio alarms and on-screen text messaging alert the user when process control activity takes place.

During process control, the status of all eight channels can be monitored directly in real time on the LCD display. Eight dedicated LEDs located below the screen provide across-the-room indication of channel status.

Manual override is available for all channels, making it possible to manually control channel relays and TTL output levels directly from the front panel. Manual relay control makes it possible to use the IGC100 as a standalone controller capable of manually or automatically controlling the operation of any standard vacuum system.

All process control events are automatically time stamped and recorded in memory (Event Log) so they can be reviewed at any time. Use the History button on the Process Control panel to access the Process Control Event Log at any time.

Why Use Process Control?

One of the best ways to improve process yield and reduce system failure is through system automation. This is especially important in complex systems or in systems operated by inexperienced personnel. The process control capabilities of the IGC100 make it unnecessary for the operator to be physically present to open valves and actuate switches at the proper time. In fact, an IGC100 with an embedded web server provides remote control capabilities from anywhere in the world.

Use the IGC100 Process Control Option to...

- Automatically control vacuum components such as valves, heaters, power supplies, shutters and other process equipment.
- Interlock process control operations with external signals that are related to time, pressure, temperature, gauge status, system status, TTL logic levels and other parameters.
- Automatically control pumpdown, venting and load-lock procedures.

- Signal when a process is complete or alert operators to system conditions that require their attention.
- Link process control channels together to create powerful system logic to control a wide variety of functions.
- Perform repetitive operations.
- Use e-mail notification to warn operators about possible system problems over the internet (requires web-interface).

For More Information

Consult Chapter 5 of this manual for detailed connection, configuration and operation information for the Process Control option. Consult Chapter 3 for information on menu items related to the configuration and operation of the Process Control module.

Front Panel

All IGC100 functions can be manually configured and controlled through the instrument's intuitive front panel graphical interface.

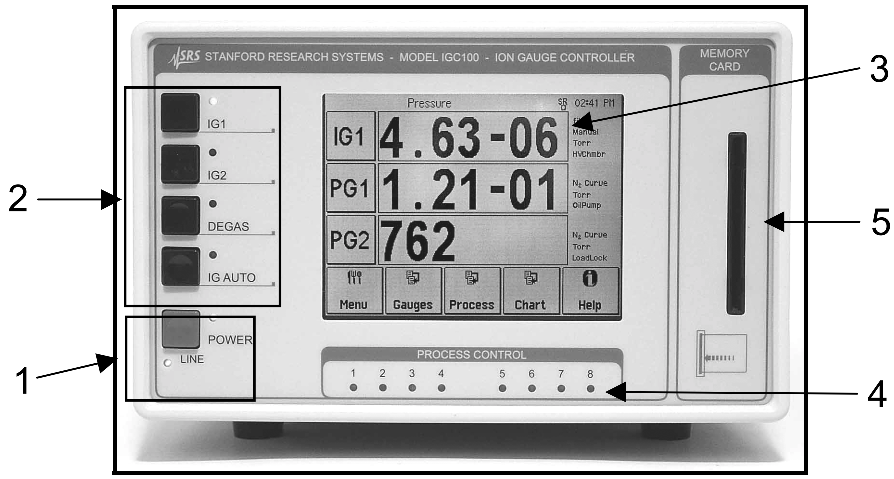


Figure 2-2. The IGC100 front panel.

Front panel components can be divided into five categories (see Figure 2-2) which are described individually in the following sections.

1. Power - LINE LED and POWER button with LED
2. IG Controls - IG1, IG2, DEGAS and IG AUTO buttons with LEDs
3. Touchscreen/LCD Display
4. Process Control LEDs
5. Memory Card Module

Power

LINE LED

The LINE LED (red) lights up to indicate that the IGC100 is connected to, and getting line power from, an AC outlet.

POWER Button and LED

Press the red POWER button to turn the IGC100 ON or OFF.

The green LED, located next to the POWER button, lights up to indicate that the IGC100 is fully powered and completely operational.

Reset

To reset the instrument to its default settings, turn the unit on (using the red POWER key) while holding down the IG AUTO key. This will erase all user entered parameters!

IG Controls

IG1 Button and LED

Press the black IG1 button to turn the IG1 filament emission on or off.

The green LED, located next to the button, lights up while the IG1 filament is emitting electrons and the unit is reading pressures from the ionization gauge IG1.

- The top Data Bar of the Pressure Display screen switches to IG1 when the IG1 button turns on a gauge.
- Filament emission must be turned on in order to acquire pressure readings with an ionization gauge.
- In units with a Dual Ionization Gauge Connector Box (O100IG) option, only one ionization gauge can be active at a time (i.e. sequential operation only).
- The IG1 button provides the *only* means to manually control the emission status of IG1.
- IG2 electron emission is automatically turned off when the IG1 button is pressed.

IG2 Button and LED

Press the black IG2 button to turn the IG2 filament emission on or off.

The green LED, located next to the button, lights up while the IG2 filament is emitting electrons and the unit is reading pressures from the ionization gauge IG2.

- The top Data Bar of the Pressure Display screen switches to IG2 when the IG2 button turns on a gauge.
- Operation of a second ionization gauge is optional in IGC100 controllers. See the Dual Ionization Gauge Connector Box (O100IG) option (Appendix L).
- Filament emission must be turned on in order to acquire pressure readings with an ionization gauge.
- In units with a Dual Ionization Gauge Connector Box (O100IG) option, only one ionization gauge can be active at a time (i.e. sequential operation only).
- The IG2 button provides the *only* means to manually control the emission status of IG2.
- IG1 electron emission is automatically turned off when the IG2 button is pressed.

DEGAS Button and LED

Press the black DEGAS button to start or stop degassing of the active ionization gauge.

The red LED, located next to the DEGAS button, lights up during ion gauge degassing.

- Degas must be Enabled in the Advanced Gauge Setup menu (IG1 or IG2).
- The ion gauge must be ON, emission established and the pressure read by the gauge must be <$2x10^{-5}$ Torr for degassing to start.
- The ion gauge pressure readings displayed during degas are only approximate and for reference only!
- Degassing is based on the electron bombardment method.
- No process control action is performed on based on ionization gauge readings while degassing.

IG AUTO Button and LED

Press the black IG AUTO button to activate, or deactivate, the IG Auto-Start mode.

- A Pirani gauge *must* share the same vacuum environment with the Ion Gauge for the IG Auto-Start mode to work correctly.
- See above for a quick description of the Auto-Start mode function.
- A specific ionization gauge (IG1 or IG2) must be linked to the Auto-Start mode whenever a Dual Ionization Gauge Connector Box (O100IG) option is installed. Consult Chapter 3 for details on this requirement.
- Pressing the IG1 or IG2 button will deactivate IG AUTO mode.
- While in IG AUTO mode, the ionization gauge is ON when the Pirani pressure is below the specified threshold and OFF when the Pirani pressure is more than 20% above the threshold.

Touchscreen/LCD Display

The IGC100 has a large backlit, touchscreen /LCD display. The resolution of the display is 320 x 240 pixels. Screen size is 4.7 in. (diagonal)

The LCD displays an intuitive menu-driven interface for instrument setup and operation. The pressure display shows large, easy to read, numeric readings from each gauge as well as bar graphs and trends. Full screen 'Pressure vs. Time' plots are available for all gauges and analog inputs.

Screen contrast is user adjustable and a screen saver is available to extend the life of the fluorescent backlight. A touchscreen calibration is available to align the touchscreen with the LCD display.

Use the Clean Screen menu to desensitize the touchscreen for 20 seconds while cleaning the touchscreen display.

Touchscreen Cleaning Procedure

For best results, use a clean, non-abrasive cloth towel and a commercial window cleaner to regularly clean the screen. The cleaning solution should be applied to the towel, not the surface of the touchscreen. Fluid may seep behind the panel if it is not cleaned properly. Perform the above procedure while the unit is off, or use the Clean Touchscreen menu, described in Chapter 3, to temporarily desensitize the touchscreen of a working instrument.

Process Control LEDs

The green Process Control LEDs are linked to the eight (8) process control channels available in units with the Process Control Option (Opt. 03).

Each LED is associated with a single process control channel and turns on to indicate when its channel output is ACTIVE. The LEDs are broken into two groups of four to facilitate visualization and channel identification from across the room.

Process Control channel status information can be quickly accessed on the LCD display by touching the [Process] QuickKey at any time. However, LEDs make it possible to view channel activities that might otherwise go undetected and have serious consequences on the vacuum system.

Memory Card Module

Insert Memory Cards into the MEMORY CARD slot, and follow the instructions in Chapter 6 to load ionization gauge calibration data or program and read Password cards.

Calibration Cards

For applications that benefit from gauge-to-gauge reproducibility and the accuracy of calibrated gauges, SRS offers NIST-traceable calibrated ionization gauges through its High Vacuum Calibration Facility. Full-range calibrations are available with 6% and 3% accuracy. All calibrated gauges are delivered with a Memory Card which contains calibration data specific to the gauge. The calibration data is easily uploaded into the controller via the front panel MEMORY CARD module.

See Appendix F for more information about calibrated ionization gauges.

Password Cards

Security passwords can be copied into special memory cards known as Password Cards. Password cards make it unnecessary to remember the password in order to unlock a controller. Simply insert the Password Card (loaded with the current password) into the memory card slot to unlock the controller. The controller returns to the locked state as soon as the card is removed

For More Information

Consult chapter 6 for detailed information on the MEMORY CARD module.

Back Panel

The back panel of the IGC100 includes all the electrical connectors required to (1) power and ground the controller, (2) power its gauges, (3) read pressure and analog signals, (4) connect the process control channels (relays and DIGITAL I/O) and remote TTL control pins and (5) interface to a host computer and/or the web. In addition, the back panel provides access to the DEGAS FUSE.

Back panel components specific to optional Dual Ionization Gauge Connector Box are described separately in Appendix L.

WARNING!

- Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.
- Read Chapter 1 for detailed instructions and safety information regarding the installation of the IGC100 and connection of gauges.

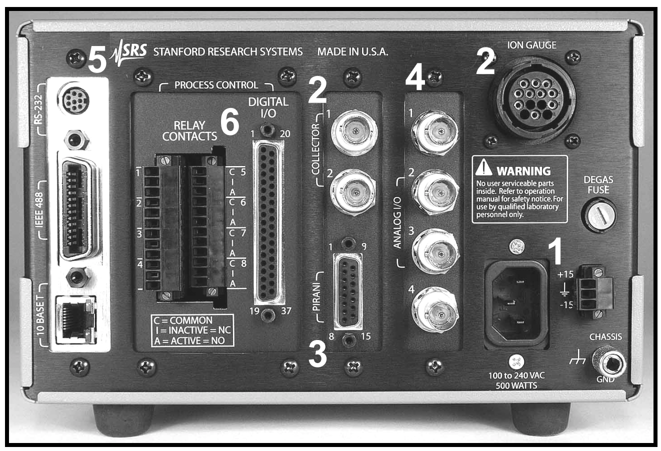


Figure 2-3. The IGC100 back panel.

Back panel components can be divided into six categories (see Figure 2-3) which are described individually in the following sections.

1. Power - Power Entry Module, CHASSIS GND, ±15 V (AUX power).
2. Ionization Gauge - COLLECTOR (BNC Ports 1 & 2), ION GAUGE.
3. Pirani Gauge - PIRANI.
4. Analog I/O - BNC Ports AN1-4
5. Computer Interfaces - RS-232, GPIB (IEEE-488) (Opt 01), and ethernet 10BASET (Opt 02).
6. Process Control (Opt. 03) - RELAY CONTACTS, DIGITAL I/O.

Power

Power Entry Module

Use the power entry module receptacle to power the IGC100 controller. Use the three-wire power cord provided by SRS to connect the instrument directly to a properly *grounded* AC outlet.

The IGC100 has a universal input (100 to 240 VAC, 46-63 Hz) and must have 500 W of power available.

WARNING!
Refer to Chapter 1 of this manual for instructions on connecting power to an IGC100 controller.

Chassis Gnd

Use this connector to safety ground the IGC100 chassis.

WARNING!

- The IGC100 *must* be grounded to the facility ground for safety. Do not rely on the power cord for this ground.
- Follow all the instructions in Chapter 1 for the proper grounding of the IGC100 controller.

±15 V (AUX power)

Use this 3-pin, ±15 V (100 mA max), connector to provide electrical power to standard (i.e. non-heated) capacitance manometers. For convenience, this connector includes a removable three (3) Position Screw Terminal Block Plug that can be detached from the back panel.

WARNING!
Follow all instructions in Chapter 1 for the proper connection of capacitance manometers to your vacuum system and the IGC100.

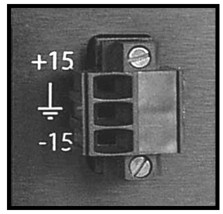


Figure 2-4. The AUX power connector.

Pin	Voltage (100 mA Max)
1	+15 Vdc
2	GND
3	-15 Vdc

Ionization Gauge

Collector (BNC Ports 1 & 2)

Figure 2-5. The Ion Gauge Collector BNC connectors.

Use the BNCs labeled COLLECTOR to connect the collectors of up to two ionization gauges to the IGC100. The upper connector is for IG1 (labeled '1'), the lower connector is for IG2 (labeled '2').

With a standard IGC100, use the upper IG1 connector only. If the Dual Gauge Option (SRS# O100IG) is installed, use both connectors.

For More Information

Consult Chapter 1 of this manual for complete ionization gauge connection details.

Ion Gauge Power

Use the 14-pin ION GAUGE connector to power an ionization gauge.

The ION GAUGE connector of a standard IGC100 is treated as the IG1 port. If the Dual Gauge Option (SRS# O100IG) is installed, this connector is used to power the option box. In this case, two gauges may be connected to the option box.

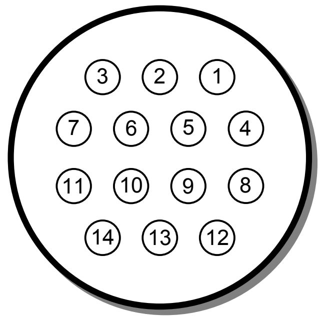


Figure 2-6. The Ion Gauge Power connector.

Pin	Description	Comments
1	O100IG_ID	This pin is used by the IGC100 to verify the presence of option O100IG (Dual Ion Gauge Connector Box)
2	unused	
3	O100IG_24V _SUPPLY	This pin provides 24 VDC (100 mA) to the relays of option O100IG when: (1) O100IG is detected (pin 1) and (2) IG2 is selected.
4	GND	Chassis Ground Connection
5	FIL_RETURN	Filament power return. Return path for the power provided by pins 8 and 11 (both filaments). +30 VDC bias, independently monitored through pin 6 at the gauge head.
6	BIAS_SUPPLY	Filament Bias Monitor +30 VDC bias.
7	O100IG_24V _RETURN	This pin provides the return path for the 24 VDC (100 mA) power provided by pin 3.
8	FIL2_SUPPLY	Filament 2 power supply [7 Amps DC, 7 VDC].
9	unused	
10	unused	
11	FIL1_SUPPLY	Filament 1 power supply [7 Amps DC, 7 VDC].
12	unused	
13	GRID_SUPPLY	Anode Grid Supply. +180 VDC (10 µA-12 mA), normal emission. ≈ 500 VDC (2-160 mA max), degas.
14	unused	

1) Use only O100C1, O100C2 and O100C3 signal cables provided by Stanford Research Systems to connect ionization gauges to the IGC100 controller.

2) The ION GAUGE connector is also compatible with the STABIL-ION® gauge signal cables (part numbers 360112, 360114 or 360116) available directly from Granville-Phillips (Helix Corporation), Longmont, CO, USA.

3) For maximum accuracy, independent of cable length, pins 5 and 6 of SRS ion gauge cables are connected together at the end that attaches to the gauge head.

4) Pins 1, 3 and 7 are for use by the optional Dual Ion Gauge Connector Box (O100IG). Do not make connections to those pins.

For More Information

Consult Chapter 1 for step-by-step ionization gauge connection instructions and warnings. Refer to Appendix A for details on the proper biasing and powering of a Bayard-Alpert ionization gauge. Consult Appendix L for the connection of a Dual Ionization Gauge Connector Box (Option O100IG) to the ION GAUGE port. Consult Appendix C for connection of the IGC100 to STABIL-ION gauges.

Pirani Gauge

PIRANI Connector

Use the DB-15 PIRANI port to simultaneously connect up to two PG105 Pirani gauges to the IGC100 controller.

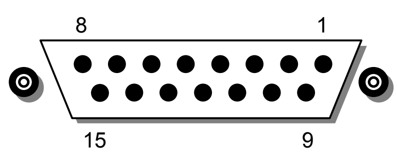


Figure 2-7. The Ion Gauge Power BNC connectors.

Pin	Pirani Gauge	Description
1		unused
2		unused
3	1	GND_Sense
4	1	GND_PWR
5	1	NULL (+) (filament side)
6	1	NULL (-) (divider side)
7	1	Vbr_PWR
8	1	Vbr_Sense
9	2	GND_PWR
10	2	GND_Sense
11	2	NULL (+) (filament side)
12	2	NULL (-) (divider side)
13	2	Vbr_PWR
14	2	Vbr_Sense
15		unused

Use only O105C4 Dual Pirani Gauge signal cables, available from Stanford Research Systems to connect PG105 Pirani Gauges to the IGC100 controller. Consult Chapter 1 for details.

For More Information

Chapter 1 includes all the basic information required to connect Pirani gauges to your IGC100 controller. Consult Appendix H of this manual for detailed electrical information on PG105 convection-enhanced Pirani gauges, including a full explanation of the pin nomenclature used in the table above.

Analog I/O

BNC Ports (AN1-4)

Use these four BNC ports to input (or output) analog signals into (or out of) the controller.

All IGC100 controllers have four analog input/output ports (BNC connectors) on the back panel. The range is ±12 V with 14 bit input resolution and 12-bit output resolution. The update rate is 2 Hz. Each individual port may be configured as an input or as an output for complete I/O flexibility.

Inputs

All inputs are logged in the Data Log, along with all pressure readings. These inputs may be displayed on the Pressure Display (in any format) and are available in either Table or Chart mode in the Data Log.

When used as inputs, these ports can read the output signals from standard capacitance manometers. The IGC100 will display the readings as pressures provided the full scale range (Pmax) of the gauge is programmed into the controller.

Inputs may be linked to Process Control channels (Opt. 03) to control relays or TTL outputs.

Outputs

All output voltages may be set manually or linked logarithmically to a pressure reading.

When an output port is linked to an ionization gauge (IG1 or IG2), the analog output behaves as follows:

$P\ (\text{Torr}) = 10^{V-12}$ for 10^{-11} Torr $\leq P \leq 10^{-1}$ Torr
0 V indicates gauge off
12 V indicates gauge fault

When an output port is linked to a Pirani gauge (PG1 or PG2), the analog output behaves as follows:

$P\ (\text{Torr}) = 10^{V-5}$ for 10^{-4} Torr $\leq P \leq 10{,}000$ Torr
0 V indicates gauge off
12 V indicates gauge fault

For More Information

Consult Chapter 4 of this manual for a complete description of the Analog I/O capabilities of the IGC100, including specifications, connections, possible configurations, and capacitance manometer operation. Chapter 3 all menus required to configure the

IGC100 for proper operation of its Analog I/O ports, including direct pressure display from capacitance manometers.

Degas Fuse

At pressures of $5x10^{-4}$ Torr and higher, a Bayard-Alpert ionization gauge can generate sufficient plasma that significant electrical coupling can occur between the anode grid and the metal parts of the vacuum system. The DEGAS FUSE is a safety device, built into the IGC100 to prevent the development of such electrical discharges inside the ionization gauge head during degassing.

WARNING!
Gas discharges in high voltage devices such as ionization gauges can be lethal in vacuum systems which are not properly grounded. Consult, Charles F. Morrison, "Safety hazard from gas discharge interactions with the Bayard Alpert ionization gauge", J. Vac. Sci. Technol. A 3(5) (1985) 2032, for a detailed explanation of this effect.

The DEGAS FUSE is connected in series with the anode grid, and is designed to burn out as soon as the electrical current through that electrode exceeds 250 mA. Removal of the bias voltage (500 Vdc degas, 180 Vdc normal) from the anode grid causes the filament to shut down, and extinguishes any discharge supported by the electrode structure.

A blown DEGAS FUSE is easily detected. Any attempt to establish an electron emission results in the "EMISSION FAIL" Error Message being displayed on the front panel instead of the expected pressure measurements.

Consult Chapter 9 for instructions for replacing the Degas Fuse.

Computer Interfaces

RS-232

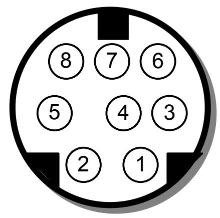


Figure 2-8. The DIN8 RS-232 connector.

Pin	Signal
1	handshake out
2	handshake in
3	Transmit data
4	ground
5	Receive data
6	unused
7	unused
8	ground

Most PC computers use DB9 ports for serial RS-232 communication. A DIN8-DB9 connector adapter cable is provided with every IGC100 controller. The female DB9 connector of the DIN8-DB9 connector adapter cable is configured as a DCE.

IMPORTANT

Make sure the adapter cable is connected to your controller at this time. Attaching the cable to the controller at this time minimizes the chances of misplacing the cable in your lab, and not being able to find it when you really need it.

For More Information

Consult Chapter 7 of this manual for information on the interfacing capabilities of the IGC100, including RS-232 communications.

GPIB/IEEE-488 (Opt. 01)

This port is available only in units containing the GPIB/IEEE-488 computer interface option (Opt. 01).

Use this 24-pin port (standard IEEE-488 connector) to interface your IGC100 to a host computer with a GPIB/IEEE-488 interface.

For More Information

Consult Chapter 7 of this manual for information on the interfacing capabilities of the IGC100, including GPIB communications.

Ethernet 10BASET (Opt. 02)

This port is only available in units containing the Embedded Web Server interface option (Opt. 02).

Use this RJ-45 Ethernet port to connect your IGC100 to your facility network (LAN) or directly to a host computer (cross-over cable). Use standard Ethernet cables, with RJ-45 connector ends, to connect your IGC100 to a network hub port.

For More Information

Consult Chapter 8 of this manual for information on networking the IGC100 and the capabilities of the Embedded Web Server.

Process Control (Opt. 03)

Relay Contacts

Use these two 12-Position Terminal Block Plugs to connect to the eight process control relays. All relays are SPDT, form C, 5A/250VAC/30VDC, resistive load only.

Each process control channel has a relay closure output (SPDT relay) associated to it.

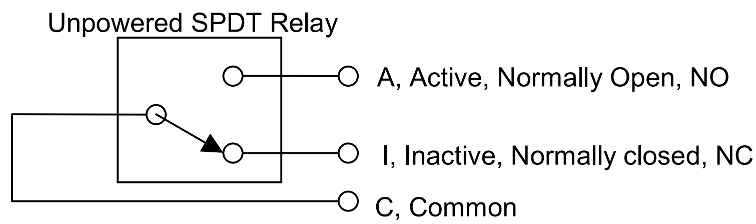


Figure 2-9. Process Control Relay connections.

When a process control channel is ACTIVE, the corresponding relay is powered, connecting its Common and Active (Normally Open, NO) pins. When a process control channel is INACTIVE, its relay is unpowered, connecting its Common and Inactive (Normally closed, NC) Pins. Inactive Pins are labeled 'I' and correspond to the NC pin of the relay. Active pins are labeled 'A' and correspond to the NO pin of the relay.

Process Action	Relay Common Connected to	Rear Panel Label
Inactive	Normally Closed pin (NC)	I
Active	Normally Open pin (NO)	A

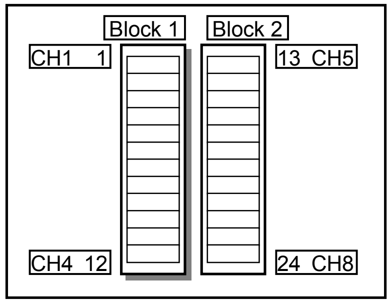


Figure 2-10. The 2 12-position terminal blocks for process relay connections.

Block	Pin	Process Channel	Process Control Label	Relay Pin
1	1	1	Common (C)	C
	2		Inactive (I)	NC
	3		Active (A)	NO
	4	2	Common (C)	C
	5		Inactive (I)	NC
	6		Active (A)	NO
	7	3	Common (C)	C
	8		Inactive (I)	NC
	9		Active (A)	NO
	10	4	Common (C)	C
	11		Inactive (I)	NC
	12		Active (A)	NO
2	13	5	Common (C)	C
	14		Inactive (I)	NC
	15		Active (A)	NO
	16	6	Common (C)	C
	17		Inactive (I)	NC
	18		Active (A)	NO
	19	7	Common (C)	C
	20		Inactive (I)	NC
	21		Active (A)	NO
	22	8	Common (C)	C
	23		Inactive (I)	NC
	24		Active (A)	NO

For More Information

Consult Chapter 5 of this manual for complete details on the Process Control Module, including connection to the relay ports. Chapter 3 includes full descriptions of the menus required to program the Process Control Rules.

DIGITAL I/O

Use the female DB37 port to connect to the (1) eight Process Control TTL Outputs, (2) eight Process Control TTL inputs and (3) twelve Remote Control TTL inputs of the Process Control Board. A male DB37 connector is provided to facilitate connection to the controller.

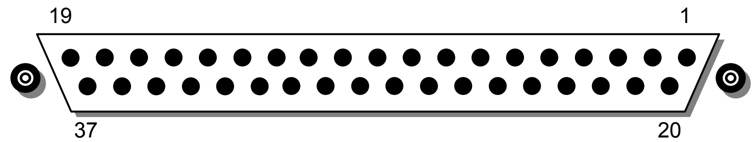


Figure 2-11. The DB37 DIGITAL I/O connector.

Pin	Module	Name	Description
1		IGC100 Vcc	+5 V OUT
2	**Remote Control TTL IN**	ANODE COM	External User +5 V IN
3		IG1_On	Edge trigger: ↓=IG1 On, ↑=IG1 Off
4		IG2_On	Edge trigger: ↓=IG2 On, ↑= IG2 Off
5		Degas_On	Edge trigger: ↓= Degas On, ↑=Degas Off
6		IG_Lockout	Level: LOW=IG1 and IG2 emission Off
7		IG_Key_Disable	Level: LOW=Disable front panel IG Keypad.
8		PG1_Off	Edge trigger: ↓=PG1 Off, ↑=PG1 On
9		PG2_Off	Edge trigger: ↓=PG2 Off, ↑=PG2 On
10		Clear_Data_Log	Edge trigger: ↓=clear the data log
11		IG_Remote_Enable	Level: HIGH=Ignore IG1_On, IG2_On, Degas_On, FIL1_On, FIL2_On pins.
12		FIL1_On	Edge trigger: ↓=FIL1 ON, ↑=FIL1 Off
13		FIL2_On	Edge trigger: ↓= FIL2 ON, ↑= FIL2 Off
14		Front_Panel_Disable	Level: LOW=Disable Touchscreen and Keypad
15		IGC100 Vcc	+5 V OUT
16	**Process Control TTL OUT**	TTL_OUT_5	TTL OUT for Channel 5. LOW=ACTIVE
17		TTL_OUT_6	TTL OUT for Channel 6. LOW=ACTIVE
18		TTL_OUT_7	TTL OUT for Channel 7. LOW=ACTIVE
19		TTL_OUT_8	TTL OUT for Channel 8. LOW=ACTIVE

Pin	Module	Name	Description
20	**Process Control TTL IN**	ANODE COM	External User +5 V IN
21		TTL_IN_1	TTL Input Signal for Channel 1. Active LOW
22		TTL_IN_2	TTL Input Signal for Channel 2. Active LOW
23		TTL_IN_3	TTL Input Signal for Channel 3. Active LOW
24		TTL_IN_4	TTL Input Signal for Channel 4. Active LOW
25		TTL_IN_5	TTL Input Signal for Channel 5. Active LOW
26		TTL_IN_6	TTL Input Signal for Channel 6. Active LOW
27		TTL_IN_7	TTL Input Signal for Channel 7. Active LOW
28		TTL_IN_8	TTL Input Signal for Channel 8. Active LOW
29		unused	
30		IGC100 Ground	
31		IGC100 Ground	
32	**Process Control TTL OUT**	COM_EMTR_REF	External User Ground
33		COM_COLTR_PULLUP	External User +5 V IN
34		TTL_OUT_1	TTL OUT for Channel 1. LOW=ACTIVE
35		TTL_OUT_2	TTL OUT for Channel 2. LOW=ACTIVE
36		TTL_OUT_3	TTL OUT for Channel 3. LOW=ACTIVE
37		TTL_OUT_4	TTL OUT for Channel 4. LOW=ACTIVE

Note: ↓=HIGH-to-LOW, ↑=LOW-to-HIGH transition.

Process Control TTL OUT

Each process control channel has a dedicated TTL output signal. Following common industry standards, all PC TTL output signals are Active Low: When a process control channel is ACTIVE, the corresponding TTL Output pin is logic LOW. INACTIVE means the channel's TTL Output pin is logic high.

These outputs are opto-isolated from the IGC100. For isolated operation of ALL outputs, connect pin 33 to the external +5 V supply and pin 32 to the external ground. For non-isolated operation of ALL outputs, connect pin 33 to IGC100 Vcc (pin 1 or 15) and pin 32 to IGC100 Ground (pin 30 or 31).

Process Control TTL IN

Each process control channel may be linked to a dedicated TTL Input signal. The user must program the channel rules to choose the polarity (HIGH or LOW) used to activate the channel during Channel Auto operation.

These inputs are opto-isolated from the IGC100. For isolated operation of ALL Process Control inputs, connect pin 20 to the external +5 V supply. Pull inputs to external ground for low inputs. For non-isolated operation of ALL Process Control inputs, connect pin 20 to IGC100 Vcc (pin 1 or 15) and pull inputs to IGC100 Ground (pin 30 or 31) for low inputs.

Remote Control TTL IN

The Process Control option also includes 12 logic inputs for remote, TTL control of various controller functions. Check the table above for pin-specific triggering specifications.

These inputs are opto-isolated from the IGC100. For isolated operation of ALL Remote Control inputs, connect pin 2 to the external +5 V supply. Pull inputs to external ground for low inputs. For non-isolated operation of ALL Remote Control inputs, connect pin 2 to IGC100 Vcc (pin 1 or 15) and pull inputs to IGC100 Ground (pin 30 or 31) for low inputs.

For More Information

Consult Chapter 5 of this manual for complete details on the Process Control module, including connection and use of the TTL IN, TTL OUT, and Remote Control TTL IN signals. Chapter 3 includes detailed explanations of the menus required to configure Process Control channels.

Maintenance and Service

1. The IGC100 does not have any user-serviceable parts and requires minimum routine maintenance.
2. Do not perform any unauthorized service, adjustment or modification of the controller.
3. Do not install any substitute parts.
4. Consult the 'Damage Requiring Service' section of this manual for instructions on how to return the instrument for authorized service and adjustment.

Chapter 3

Displays and Menus

The IGC100 has a menu driven, touchscreen user interface. To activate an on-screen button, simply touch the LCD display over the button area.

There are 5 main display screens – Pressure, Gauges, Logging, Process Control (optional) and Menus. These displays are the primary interface to the entire vacuum system. The Pressure Display presents the readings of 3 gauges or analog signals in a large, easy to read format. The Gauges Display shows the reading and state of all 8 ports (2 ionization and 2 Pirani gauges and 4 Capacitance Manometers or analog input/outputs). The Logging Display shows the stored Data Log in Table or Chart format. The Process Control Display shows the state of all 8 process control channels and relays. The Menu is used to setup various operating parameters of the IGC100 such as remote interfaces, time/date and security.

Displays are accessed via the QuickKeys displayed at the bottom of most displays. This allows fast access to the most critical information in the vacuum system. Within each display, the individual Data Boxes where the data is presented are also buttons. For example, touch a box in the Gauges Display to configure a gauge port.

Help for any button or box is available on screen by touching the [Help] QuickKey, then touch any button or box for help about its function. Touch [done] to exit help.

In This Chapter

QuickKeys

Each display includes five QuickKeys lined up across the bottom of the screen. The QuickKeys presented in the main Pressure Display (below) provide fast access to the most important displays – Menu, Gauges, Process, Table/Chart and Help. Within any of these other displays, the QuickKeys may provide access to additional displays. In each case, use the Pressure or Back QuickKeys to return to the Pressure Display.

Use the Pressure Display as the main starting point in operating the IGC100.

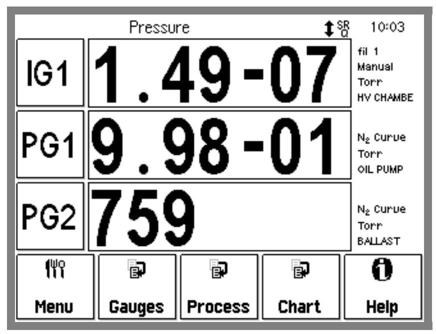
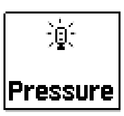


Figure 3-1. Pressure Display.

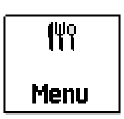
Pressure QuickKey



Show the main Pressure Display screen. The Pressure Display has three Horizontal Data Bars, each displaying a pressure (or analog input). Readings may be displayed in various formats and are updated twice a second.

The Pressure QuickKey is available in most displays.

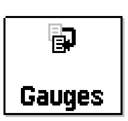
Menu QuickKey



Access the IGC100 Menu. Use the Menu to modify important IGC100 parameters such as units, communications, clock, touchscreen, backlight, password protection, audio, etc.

The Menu QuickKey is available *only* in the Pressure Display.

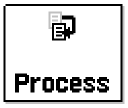
Gauges QuickKey



Show the Gauges Display. The Gauges Display shows the pressure and analog readings from all eight available ports. Touch an individual Gauge Data Box to modify the gauge settings or analog I/O setup parameters.

The Gauges QuickKey is available in most displays.

Process QuickKey



Show the Process Control Display. The Process Control Display shows the current state of all eight process control channels. Touch an individual Channel Data Box to control a channel or modify its configuration.

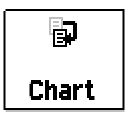
The Process QuickKey is available in most displays.

Important

Process Control *requires* the 8-channel Process Control board (option 03). This option provides eight channels of process control. Each channel has a relay closure output, with corresponding opto-isolated TTL output. While in AUTO mode, each channel can be linked to any pressure gauge or analog input, the system clock, gauge status or a TTL input trigger signal through user-programmable Rules. The Process Control Display allows editing of channel Rules and Labels, as well as manual control of all channels.

If option 03 is NOT present, the IGC100 will not display this key. Instead, a key labeled 'No Proc' will be displayed.

Table/Chart QuickKey

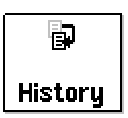


Display the Data Log in either Table or Chart format. Use the [Setup] button to choose the Default Display format, Table or Chart, and other data logging parameters.

The Table/Chart QuickKey is available *only* in the Pressure Display.

All IGC100 controllers include Data Logging. When Data Logging is enabled, data from all gauges and all analog inputs are stored in a circular memory buffer at the rate specified by the programmed logging interval.

History QuickKey



Display the Gauges or Process Control History log.

This key is available *only* in the Gauges and Process Control displays.

The IGC100 logs all important ion gauge events (power cycles, degasses, and overpressures) and all process control related events (manual/auto, de/activation) in two independent memory buffers. Use the information stored in these logs to track and diagnose system problems.

Important

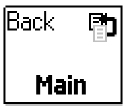
History event logs are erased whenever the IGC100 is turned off.

Overview QuickKey

Display a complete Process Control Overview. Use the Overview to quickly review the state and rules for all process control channels in a single display screen.

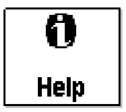
The Overview QuickKey is *only* displayed in the Process Control display.

Back to Previous QuickKey



Return to the previous menu screen indicated in the button.

Help QuickKey



On-screen Help provides information on the operation of the IGC100. Help information is available for menus, buttons, displays and hardware.

To display help on an item...

first... touch the Help QuickKey at the bottom-right corner of the screen. The button becomes highlighted.

next... touch the button or box you wish to learn about. The screen changes to the Help Display Window and help text is displayed.

then... use the [up] and [down] buttons to scroll through the text. Touch [done] to return to normal operation.

or... touch [More] for a list of related topics. Choose a topic in the list to display its help.

then... use [back] to display previous topics and [forward] to return to later topics.

Menu Buttons

The IGC100 uses various types of menu buttons identified by the icon in the upper right corner.

Submenu

Display a submenu.

Use the submenu to access setup parameters that do not fit (or belong) on the top menu.

Choose (multiple choices)

Display a multiple choice selection list.

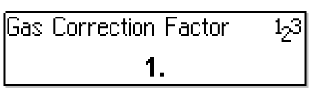
Touch an item from the list to choose it.

Choose (two choices)

Display a two choice selection list.

Touch one of the two items on the list to choose it.

Numeric Entry



Display the numeric entry keypad.

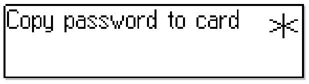
Enter a parameter value using the touchscreen keypad, then touch [accept] to store it. The parameter valid range and current units are shown in the numeric entry box. Touch [cancel] to quit entry with no change.

Text Entry

Display the text entry keypad.

Enter a text string using the touchscreen keypad, and touch [ok] to to store it. Touch [abort] to quit entry with no change.

Action



Perform the indicated action.

Touch the button to perform the action indicated. Further instructions may be presented on the screen.

Time/Date

Display the Time/Date entry keypad.

Enter the new time and date and touch [accept] to store the new settings. Touch [cancel] to quit entry with no change.

The clock is used ...

- to log pressure readings (data log)
- to log process control events (process history)
- to log gauge activity (gauge history)
- to trigger process control events at specific times.

The clock requires adjustment after daylight savings corrections take place.

Text Display

Display text data.

Touch the button to display text data on the screen. The text display includes scroll up/down and page up/down buttons.

This button is used to display large amounts of text information, such as annotated Data Log event entries (Table display format) and IGC100 configuration information (Utilities submenu).

Pressure Display

Use the Pressure Display as the main starting point in operating the IGC100. Use the [Pressure] or [Back to Pressure] QuickKeys to bring up the Pressure Display.

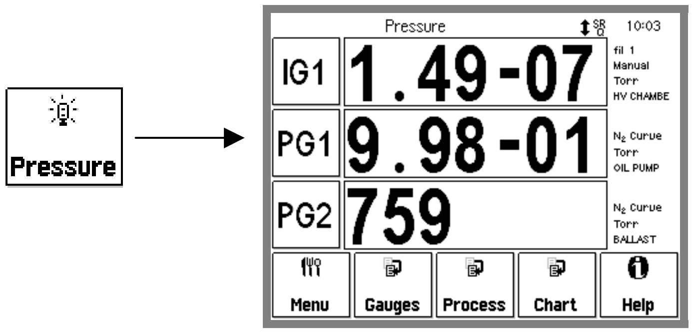


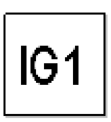
Figure 3-2. Use the [Pressure] QuickKey to bring up the Pressure Display.

This display has three horizontal Data Bars, each displaying a pressure (or analog input). Readings may be displayed in various formats and are updated twice a second.

Customize a Data Bar by touching the Port ID Box (left), the Port Data Box (center) or the Port Info Box (right).

The QuickKeys presented in the main Pressure Display provide fast access to the most important displays – Menu, Gauges, Process, Table/Chart and Help. Within any of these other displays, the QuickKeys may provide access to additional displays. In each case, use the Pressure or Back QuickKeys to return to the Pressure Display.

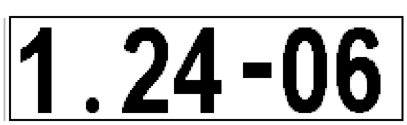
Port ID Box



The Port ID Box displays the source of the readings in the Data Bar. The source refers to a specific IGC100 port.

Touch the Port ID Box to display a list of available input ports. Select a port (any gauge or analog input) for the Data Bar.

Port Data Box



The Port Data Box displays the readings from the selected source.

Touch the Port Data Box to choose one of the five display formats.

Big Numbers

Figure 3-3. Big Numbers data display.

Best display for accurate, easy to view, pressure readings. Easily visible across the room.

Trend Graph

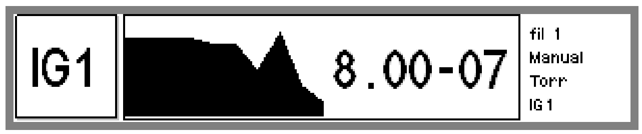


Figure 3-4. Trend Graph display.

Best display for trend analysis. A stamp-sized 'P vs. Time' plot of the most recent 10 readings, sampled at the data logging interval (see 'Data Logging'). It also includes a small instantaneous reading next to the plot. Use trend graphs to see pressure changes in time-dependent processes such as leak testing, pump downs, venting, bakeout, etc.

Auto Scaling Bar Graph

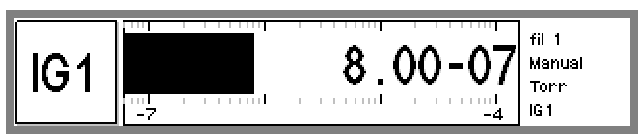


Figure 3-5. Auto Scaling Bar graph.

Best display to detect instantaneous changes in pressure readings. Three decade logarithmic bargraph display scaled about the current reading. Often used during leak testing procedures. This display preserves the 'feel' of the old analog needle displays preferred by some vacuum users.

Full Range Bar Graph

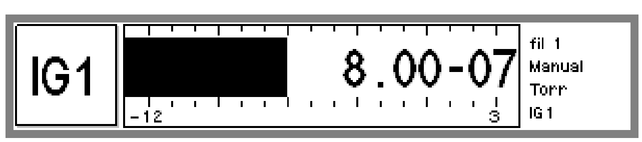


Figure 3-6. Full Range Bar Graph display.

Best display to view the overall status of your vacuum system at any given time. Fifteen decade logarithmic bargraph display, covering the entire useful range of the instrument

(10^{-12} to 10^{3} Torr). The scale covers the entire range from UHV to atmosphere. For example, use the length of the bargraph of a Pirani gauge measurement to quickly determine whether the system is pumped down or at atmosphere, without having to read actual pressure values.

Status Information

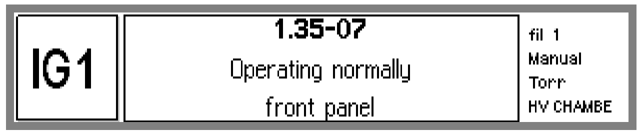
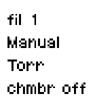


Figure 3-7. Status Information display.

Use this display to learn more about the state of a gauge. This is especially useful if the gauge is in a fault or error condition.

Port Info Box



The Port Info Box shows additional gauge information.

Touch the Port Info Box to access the Setup menu for the displayed input port. This allows easy access to all setup parameters for the displayed gauge. See 'Gauge Display' for more information on setting up IGC100 gauges/ports.

The Port Info Box includes ...

- ion gauge filament
- ion gauge Manual/Auto-start
- units (pressure or voltage)
- calibration type
- location
- degas power
- remaining degas time

Pressure Units

The factory default for pressure units is Torr (1 Torr = 1 mm Hg). To change the units of the Pressure Display, use the Menu QuickKey, then touch [Units] in the menu. Choose a units system – Torr, micron, bar, mbar, or Pascal. All three Data Bars use the same units system.

Consult Appendix K for conversion factors between the different pressure units supported by IGC100.

Gauges Display

Use the [Gauges] or [Back to Gauges] QuickKey to bring up the Gauges Display.

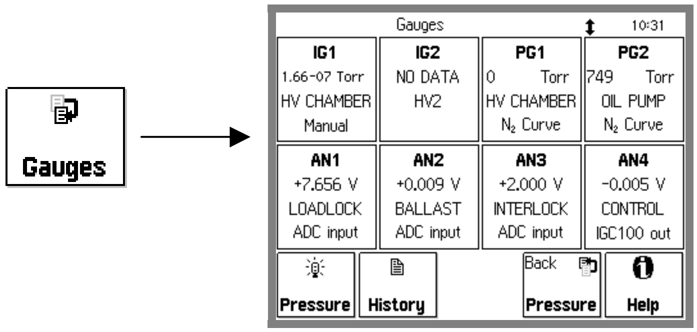


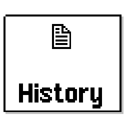
Figure 3-8. Gauges Display.

This display consists of eight rectangular Gauge Data Boxes, each displaying a pressure (or voltage) reading from a different signal port: IG1 and IG2 (ion gauges), PG1 and PG2 (Pirani gauges) and AN1-4 (analog I/O ports). Gauge location and important status/configuration information are also included in each box. This display allows fast access to the Gauge Setup menu of *any* IGC100 signal port. The Gauge Info Box in the main Pressure Display can only access the 3 displayed ports.

Touch a Gauge Data Box to display the Gauge Setup menu for that signal port. For example, touch the IG1 Data Box to modify the parameters used for operation of the ionization gauge connected to the IG1 port.

WARNING!
Gauge-specific information is required for the operation of any new, or replacement, gauge. Individual setup information is required for all gauges connected to the IGC100. Setup of a new gauge requires knowledge of the gauge's operating parameters. Recommended parameters should be listed in the specifications provided by the gauge manufacturer. Contact the gauge manufacturer directly for specifications.

Gauge History

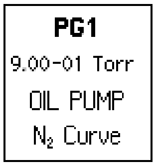


All ion gauge related events (such as power on/off, degas on/off, overpressure, gauge fault, etc.) are time stamped and stored in the Gauges/History log. Touch the [History] QuickKey in this display to show the contents of this log.

Important

History event logs are erased whenever the IGC100 is turned off.

Gauge Data Box



A Gauge Data Box displays the pressure (or analog voltage) reading and other relevant information from a gauge (or analog I/O) port.

Each Gauge Data Box contains four lines of information (top to bottom):

- Port name: IG1, IG2, PG1, PG2 or AN1-4.
- Reading/Status (port specific): pressure, voltage or gauge status.
- Location (user programmable): the gauge location string.
- Configuration/mode info (port specific).

IG1(or IG2):	Manual, Auto
PG1 (or PG2):	N2 Cal or Ar Cal
AN1-4:	ADC input, CM pressure or Manual, IG1, IG2, PG1, PG2 out

Touch a Gauge Data Box to display the Gauge Setup menu for its signal port. For example, touch the IG1 Data Box to modify the setup parameters used for operation of the ionization gauge connected to the IG1 port.

Ion Gauge Setup Menu (IG1/IG2)

> **WARNING!**
> Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.
>
> Read Chapter 1 for detailed instructions and safety information regarding the installation and connection of gauges.

Access the Ion Gauge Setup menu from the Gauges Display (touch an IG Data Box) or from the Pressure Display (touch the Port Info Box of an ion gauge Data Bar). Each ion gauge port (IG1 and IG2) has its own setup menu. For standard IGC100 units, only the IG1 port is used. With the Dual Ionization Gauge Option (O100IG), both IG1 and IG2 may be used.

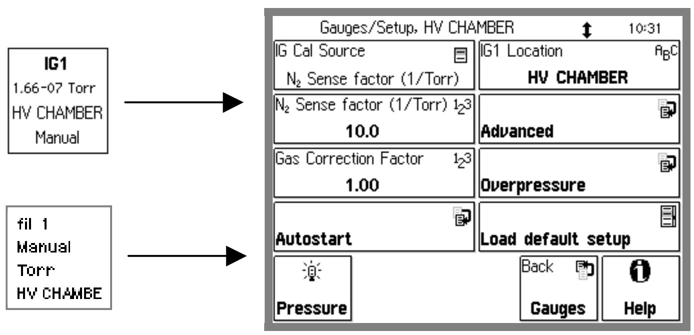


Figure 3-9. Ion Gauge Setup Menu.

For More Information

Chapter 1 includes all the installation and setup information required to set up your IGC100 controller and its gauges. Chapter 6 provides a detailed description of the Memory Card module capabilities, including step-by-step instructions for uploading gauge calibration data into the controller. Consult Appendix A of this manual for general information on Bayard-Alpert ionization gauges, and Appendix B for a list of ionization gauges available directly from Stanford Research Systems (including detailed specifications, Manufacturer's Cross Reference Table, connection cables and available Default Setup Files). Appendix F lists the gauge calibration options available through the SRS High-Vacuum Calibration Facility.

IG Cal Source

Select the calibration source used to calculate pressures from ion currents.

The calculation of pressure with a Bayard-Alpert ionization gauge relies on the knowledge of the gauge sensitivity factor, which is strongly dependent on (1) gauge geometry, (2) gas type, and, to a lesser extent , (3) pressure and (4) emission current.

Once the sensitivity factor is known, the pressure is calculated from the simple mathematical expression:

Pressure = (Ion Current) / [(Sensitivity Factor) x (Electron Current)]

A common approximation, adequate for many applications, is to treat the gauge sensitivity factor as a constant, independent of pressure and electron emission current. To choose this approach, select 'N2 Sense Factor (1/Torr)' as the Calibration Source. The pressure is then calculated from the single, pressure independent, nitrogen-based sensitivity factor displayed in the [N2 Sense Factor (1/Torr)] menu button.

For the highest pressure accuracy over the entire operating range of the gauge, it is necessary to use calibrated, pressure-dependent sensitivity factors. Full-range ion-gauge calibration curves can be stored in the IGC100. If a calibration curve is available, select Cal Curve as the Calibration Source to obtain gas-specific calibrated readings over the entire operating range of the gauge.

Note

The IGC100 stores a *single* calibration curve for each ion gauge port (IG1 and IG2). To use a different curve, load new calibration data using the Memory Card interface (Chapter 6).

N2 Sense Factor (1/Torr)

Enter the Nitrogen Sensitivity Factor for the ion gauge in units of 1/Torr (0.1 to 100). The Nitrogen Sensitivity Factor is used for pressure calculations when 'N2 Sense Factor (1/Torr)' is selected as the IG Cal Source.

Nominal nitrogen sensitivity factors for ionization gauges are available from all gauge manufacturers and are listed as part of the gauge specifications. Contact the gauge manufacturer directly for sensitivity data for your specific gauge. Nominal sensitivity factors for SRS Gauges (and for some cross-referenced third-party models) are listed in Appendix B.

Sensitivity factors can also be programmed into the controller by simply recalling a compatible Default Setup File (using [Load Default Setup]). Default Setup Files compatible with the most common commercial Bayard-Alpert gauge designs are pre-loaded at the factory.

Pressure readings based on the N2 Sense Factor are defined as nitrogen-equivalent readings and provide direct pressure measurements for N_2 *gas only.* A gas correction factor must be used to convert nitrogen-equivalent readings into direct readings for other gases.

Note

Nominal sensitivity factors provide reading accuracy adequate for rough pressure measurements (25 percent mid-range accuracy at best). For increased accuracy, calibrate the gauge’s mid-range sensitivity factor against a certified high vacuum standard. For the highest accuracy, use fully calibrated gauges and select the Cal Curve as the Calibration Source.

Gas Correction Factor

Enter a Gas Correction Factor value (0.01 to 10). The Gas Correction Factor is used to convert nitrogen-equivalent pressure readings into direct readings for other gases. The nitrogen-equivalent pressure reading is **divided** by the gas correction factor and displayed as the pressure. Use a value of 1.0 when detecting nitrogen.

Factors for a few common gases are included here:

He	0.18	Ne	0.30
H_2	0.35	N_2	1.00
Air	1.0	Water	1.12
NH_3	1.23	Ar	1.29
CO_2	1.42	Kr	1.94
Xe	2.87		

A listing of gas correction factors is available in Appendix D.

Note

Do not use Gas Correction factors for accurate pressure measurements. Use full-range, gas specific calibration data (Cal Curve) as the calibration source when high accuracy is required.

The Gas Correction factor can only be modified when 'N2 Sense Factor' is selected as the IG Calibration Source. When 'Cal Curve' is used, the Gas Correction factor is fixed at 1.0.

IG1 (IG2) Location

Enter the Gauge Location name.

The IGC100 assigns a location name (text string) for each signal port. Location names are displayed in the Port ID Box of the Pressure Display and also in the Gauge Data Boxes of the Gauges Display.

The use of distinctive gauge location names makes it easy to identify the different readings in multiple gauge setups.

The default location is the name of the port ("IG1" or "IG2").

Note

Use the Gauge Location to differentiate between identical gauges in a dual gauge setup. For example, consider a vacuum system with two ion gauges- one connected to the high vacuum load lock (and the IG1 port) and the other one connected to the UHV chamber (and the IG2 port). Give IG1 the location name, "LdLock", and IG2 the name, "UHV". This labels the two readings with meaningful names.

Load Default Setup

Select a Default Setup File compatible with your ion gauge design. This updates the following Gauge Setup parameters ...

- N2 Sense Factor
- Emission Current
- Degas Power
- Degas Time
- Overpressure Threshold

Pre-loaded Default Setup Files are available for most modern Bayard-Alpert gauge designs and are tabulated below.

Table 3-1. Default Setup Files for Common Ionization Gauges

Gauge Design	Setup File Name	N_2Sense Factor (1/Torr)	Emission Current [mA]	Degas Time (min)	Degas Power (Watts)	Over Pressure Threshold (Torr)	Gauge Protection
Glass-Tubulated	**GLASS**	10	10	10	40	$5x10^{-3}$	Normal
Nude (Bi-filar helix anode grid)	**NUDE**	10	10	10	40	$5x10^{-3}$	Normal
Nude-UHV (closed end anode grid)	**NUDE-UHV**	25	4	10	25	$2x10^{-4}$	Normal
STABIL-ION®-H (1) ($5x10^{-8}$ – $5x10^{-3}$ Torr) Use for P >10^{-4} Torr	**STABIL-H**	46	0.1	10	40	$2x10^{-2}$	Normal
STABIL-ION®-L (1) ($2x10^{-10}$ – $5x10^{-4}$ Torr) Use for P < 10^{-7} Torr	**STABIL-L**	42	4	10	40	$1x10^{-3}$	Normal
STABIL-ION®-UHV (2)	**STABIL-UHV**	21	4	10	25	10^{-4}	Normal
MICRO-ION® (3)	**MICRO**	20	0.02	2	3	$5x10^{-2}$	Micro-Ion

(1) Granville-Phillips Part# 360120 and 370120 ($5x10^{-10}$ - 10^{-3} Torr). See Appendix C.
(2) Granville-Phillips Part# 370121 ($5x10^{-11}$ - $2x10^{-5}$ Torr). See Appendix C.
(3) Granville-Phillips Part# 355001 (10^{-6} - $5x10^{-2}$ Torr). See Appendix M for additional setups.

IMPORTANT

Default Setup Files are compiled based on manufacturer’s recommendations. However, it is recommended to always double check your gauge's specifications against the contents of the selected setup file after file selection is made and make modifications if necessary. This will assure the safest and most accurate operation of your gauge(s).

Consult your gauge manufacturer and Stanford Research Systems, Inc. if unsure about the compatibility of IGC100 default setup files with your third-party ionization gauge products.

NOTE

Whenever available, for improved reading accuracy, replace the nominal sensitivity factor (N2 Sense Factor) provided by a default setup file with the actual (known or calculated) gas-specific sensitivity factor for your gauge.

Advanced Submenu

Display the Advanced Setup submenu for the selected ion gauge.

Important

Changes in the Advanced Setup submenu can affect the accuracy of pressure readings as well as the lifetime and long term stability of the ion gauge. Advanced gauge parameters should only be modified by experienced vacuum users who understand their potential effects on process control, filament lifetime and measurement accuracy.

Emission Current

Enter the emission current in mA (0.01 to 12).

Important

The Emission Current can only be modified when 'N2 Sense Factor (1/Torr)' is selected as the IG Calibration Source. When a Cal Curve is used as the IG Calibration Source, the emission current is fixed by the Calibration Curve data.

Recommendations

Emission current settings can be selected by simply recalling a compatible Default Setup File. Factory recommended emission currents for the most common Bayard-Alpert gauge designs are included in the Default Setup Files (see Table 3-1).

Most Bayard-Alpert gauges require electron emission currents between 0.1 and 10 mA. As a general rule, 1 mA emission current is a reasonable choice for most gauge designs. Lower emission currents, 0.1 mA or less, are recommended for pressures above 10^{-4} Torr.

Many users prefer to set emission currents of 10 mA for glass-tubulated and nude gauges with 10/Torr sensitivity, and 4 mA for UHV-extended nude gauges (with 25/Torr sensitivity). These higher currents result in higher operating temperatures that can sometimes help minimize outgassing and ESD effects.

The IGC100 uses the actual emission current to calculate pressures from the ion current.

Filament

Select the filament used for electron emission (fil1, fil2 or both).

For ion gauges with a single filament, 'fil1' is the only valid choice. In this case, the gauge filament *must* be connected to the FIL1 and FIL RET connector pins of the O100C3 Signal Cable.

For gauges with dual filaments, filament selection is ONLY available when 'N2 Sense Factor' is used as the Calibration Source. The filament selection is fixed by the calibration data when Cal Curve is selected as the IG Calibration Source. This assures the maximum accuracy of the results obtained using Cal Curve Data.

Use both filaments for emission if you are trying to avoid condensation of impurities on the cold filament wire. Avoid using both filaments in dual tungsten filament gauges since it defeats the ability of reserving the second filament as a backup in case of accidental filament burn-out.

Note

The sensitivity of a gauge can vary slightly when switching from one filament to the other in dual filament gauges. There will also be stabilization time requirement associated with the activation of any previously unused (or long retired) filament wire.

Important

The IGC100 does not know how many filaments an ion gauge has. The user is responsible for making sure only valid options are selected.

Degas Time

Enter the Degas Time (1 to 30 min).

To degas IG1 (or IG2), *the gauge must be on and the pressure must be under* $2x10^{-5}$ *Torr* and Degas Enable *must be set to Enable*.

The Degas Time specifies the duration of degassing for the ion gauge. Press the black [DEGAS] hardware button to initiate electron bombardment degassing. Degas power ramps up (1W/sec) to reduce pressure bursts. The remaining degas time is displayed on the screen during degas. Degas terminates after the Degas Time elapses or use the [DEGAS] hardware button to stop the degas process at any time.

Recommendation

A setting of 10 minutes is adequate for most applications and should not be extended unless proven to be insufficient.

Recommendation

Degas Time can be set by simply recalling a compatible Default Setup File. Factory recommended degas times for the most common Bayard-Alpert gauge designs are included in the Default Setup Files (see Table 3-1).

Degas is not gentle on thoriated filaments. Experiment with the Degas Time setting until you reach a good compromise between Degas Power and Degas Time. As a rule of thumb, choose the longest time you can wait and the minimum amount of power (under the manufacturer’s maximum specification) that will be compatible with your contamination tolerance.

Degas Power

Enter the Degas Power in Watts (1 to 80).

To degas IG1 (or IG2), *the gauge must be on and the pressure must be under* $2x10^{-5}$ *Torr* and Degas Enable *must be set to Enable*.

The Degas Power is the power dissipated by the electrons during the degas process in the gauge. Press the black [DEGAS] hardware button to initiate electron bombardment degassing. Degas power ramps up (1W/sec) to reduce pressure bursts. The remaining

Degas Time is displayed on the screen during degas. Degas terminates after the Degas Time elapses.

Use the [DEGAS] hardware button to stop the degas process at any time.

The electron bombardment power delivered by the IGC100 is controlled during degas by adjusting the emission current. The actual power dissipated inside the gauge is displayed in the Pressure Display (in the Port Info Box of an ion gauge Data Bar). It is not unusual to see the power decrease as the pressure increases above $2x10^{-5}$ Torr.

Warning
The default factory setting of 40 Watts is adequate for most standard gauges, but too high for UHV (25 W max) and miniaturized gauges. Tiny gauges usually require less than 5 Watts of Degas Power (see Appendix M for details). Degas power above 40 W are not recommended for gauges with ThO_2Ir filaments.

Recommended Degas Powers are listed as part of the nominal specifications supplied by gauge manufacturers. Contact the manufacturer directly for gauge specific information.

Degas Power can be set by simply recalling a compatible Default Setup (see Table 3-1). Factory recommended degas powers for the most common Bayard-Alpert gauge designs are included in the Default Setup Files.

The maximum degas power available from the IGC100 may be limited when using long cables (>10 ft) or low efficiency filaments.

Recommendation
Degas is not gentle on thoriated filaments. Experiment with the Degas Time setting until you reach a good compromise between Degas Power and Degas Time. As a rule of thumb, choose the longest time you can wait and the minimum amount of power (under the manufacturer's maximum specification) that will be compatible with your contamination tolerance.

Degas Enable

Enable or Disable the front panel [DEGAS] hardware button. To prevent accidental degas cycles, set this to Disable. Disable also prevents degas from the remote interface.

Cal Curve Card

Display the header information for the Calibration Data stored in the Memory Card currently inserted in the MEMORY CARD Module.

A Memory Card containing full calibration data must be present in the MEMORY CARD module or an error report is displayed when this button is pressed.

Recommendation
A preview of the header information stored in the memory card reduces the chances of errors. Check the model and serial numbers of the ionization gauge connected (or to be

connected) to the controller against the card's header information before loading the card's Calibration Data into the controller.

Use the [Back] button to return to the Advanced submenu WITHOUT making any changes to the calibration information stored inside the controller.

Press [Load cur] to transfer the calibration data stored in the memory card into the internal memory of the controller. Note that the new calibration data OVERWRITES any previous calibration information available in the controller for the corresponding ionization gauge port.

The IGC100 can store a single full-calibration curve for each ionization gauge port (IG1 and IG2) in its internal memory. Confirm that the calibrated gauge is connected to the correct port after the calibration is loaded into the controller.

To use this new calibration data, choose 'Cal Curve' as the IG Cal Source in the IG Setup menu.

Consult Chapter 6 of this manual for detailed information on Memory Cards, including a step-by-step description of the procedure required to transfer gauge-specific calibration data from a memory card into the controller.

View Current Curve

Display the header information for the ionization gauge calibration data currently available for either IG1 or IG2.

The header information includes model/serial number as well as emission current, gas, filament selection, calibration temperature and expiration date.

Important

An "Empty" message is displayed if no calibration data is available.

Gauge Protection

Gauge Protection limits the amount of power that can be delivered to the filament. This limit is gauge specific and intended to reduce the chance of filament burnout when using gauges with delicate filaments such as MICRO-ION® gauges. See Appendix M for more information about using MICRO-ION® gauges.

When using a MICRO-ION® gauge, set Gauge Protection to 'Micro-Ion'. For normal ionization gauges, choose 'Normal'.

Important

Using the 'Micro-Ion' setting while connected to a normal ionization gauge may prevent the gauge from operating.

Overpressure Submenu

Display the Overpressure submenu for the selected ion gauge.

Several protection safeguards, designed to avoid burn-outs and extend the lifetime of ion gauge filaments, are built into the IGC100 controller. Overpressure Shutdown is probably the most important filament protection function.

When Overpressure Shutdown is Enabled, the IGC100 automatically shuts down the ion gauge emission current when the pressure exceeds the user specified Overpressure Threshold.

Overpressure Shutdown

If an overpressure event occurs, the Overpressure Shutdown mechanism (with adjustable threshold and delay) will automatically shut off the ion gauge emission, protecting the filament wire from burn out.

Enabled means that Overpressure Shutdown is active. Electron emission will shut off when the pressure exceeds the Threshold for a time longer than the Delay.

Disabled means that Overpressure Shutdown is NOT active. Emission will remain on, even if the pressure around the filament exceeds the Overpressure Threshold. In this case, emission will stop only with excessive pressure or filament failure.

Recommendation

Overpressure protection should ALWAYS be Enabled for ion gauges that operate with tungsten filaments.

Overpressure Threshold

Enter the Overpressure Threshold value in Torr (10^{-11} to 10^{-1}).

The Overpressure Threshold is the pressure at which the ion gauge filament emission is shut off when Overpressure Shutdown is Enabled.

Overpressure Threshold settings can be set by recalling a compatible Default Setup File. Factory recommended overpressure thresholds for the most common Bayard-Alpert gauge designs are included in the Default Setup Files.

Recommendation

A recommended value, good for most gauges, is 10^{-3} Torr for tungsten filaments, and 10^{-2} Torr for thoriated filaments. Consult the manufacturer directly for gauge specific recommendations. As a rule of thumb, the service life of tungsten filaments is estimated to be 10-20 hours at 10^{-2} to 10^{-3} Torr and about 1000 hours at 10^{-6} Torr.

Overpressure Delay

Enter the Overpressure Delay in seconds (0 to 60).

The Overpressure Delay is the amount of time that an overpressure condition must be present before Overpressure Shutdown shuts off the ion gauge emission current. The factory default value is zero seconds (no delay)

Recommendation

Use a non-zero value of Overpressure Delay in systems known to experience brief pressure bursts during normal operation. The addition of a delay will eliminate unnecessary filament shutdowns and provide smoother operation of the vacuum system, especially when process control is linked to the ion gauge.

Examples include systems which have load locks. It is not unusual for the pressure in the main chamber to briefly overshoot when it is first exposed to the load lock. However, this overpressure situation is often very brief and might not require a filament shutdown. This would be especially true if a thoriated filament is being used.

Audio Alarm

Select overpressure Audio Alarm On or Off.

When Audio Alarm is On, the IGC100 sounds an audible alarm every time emission is shut down due to overpressure. When Audio Alarm is off, no alarm is sounded.

Recommendation

Use the Audio Alarm to call attention to overpressure conditions while you are not close to the controller.

Auto-Start Submenu

The common combination of one ionization gauge and two Pirani gauges ports, standard in all IGC100 controllers, allows you to monitor system pressures between atmosphere and UHV without any blind spots. If a Pirani gauge is exposed to the same vacuum environment as the ionization gauge, the Auto-Start function will turn ON the ionization gauge filament when the Pirani readings are below a user-adjustable safe threshold and turn OFF the ionization gauge when the Pirani readings are more than 20% above the threshold.

Auto-Start provides added protection for the filament(s). Its use is highly recommended when using tungsten filament gauges.

Auto-Start is activated and de-activated by pressing the black [IG AUTO] hardware button on the front panel. The LED next to the button is on indicating Auto-Start operation is active.

The user must choose a Pirani gauge (PG1 or PG2) and a threshold value in the Auto-Start submenu.

In dual ionization gauge controllers (option O100IG), the user also needs to specify which ionization gauge (IG1 or IG2) will Auto-Start when the [IG AUTO] button is pressed. Since the IGC100 can only operate one ion gauge at a time, IG2 is automatically turned off if IG1 is put in Auto-Start mode, and vice-versa.

Recommendation

Use Auto-Start and/or Overpressure shutdown functions to prevent filament burn-outs.

Auto-Start Linked To

Link the Auto-Start function to the ionization gauge IG1 or IG2.

Since the IGC100 can only operate one ion gauge at a time, IG2 is automatically turned off if IG1 is put in Auto-Start mode, and vice-versa.

Auto-Start Monitor Gauge

Select the Auto-Start Gauge (Pirani gauge PG1 or PG2). In Auto-Start operation, the ion gauge will be turned ON when the pressure reading of the Auto-Start Pirani Gauge is below the Auto-Start Threshold,. When the Pirani pressure is more than 20% above the Auto-Start Threshold, the ion gauge will be turned OFF. If the Pirani gauge is off (for any reason), then the ion gauge will be turned OFF also.

Important

The Pirani gauge chosen for Auto-Start operation **MUST** be exposed to the same vacuum environment as the ion gauge linked to Auto-Start. *Check your Pirani gauge operation before switching to Auto-Start operation.* For example, if PG1 is selected to Auto-Start IG1, make sure that the Pirani gauge connected to the PG1 port and the ion gauge connected to the IG1 port actually share the same vacuum environment, and also confirm that the Pirani gauge is working properly!

Recommendation

Use PG105-UHV Pirani gauges in high vacuum systems where UHV compatibility and/or bakeability are a requirement.

Auto-Start Threshold

Enter the Auto-Start threshold value in Torr (10^{-3} to 10^{-1}).

In Auto-Start operation, the ion gauge will be turned ON when the pressure reading of the Auto-Start Pirani Gauge is below the Auto-Start Threshold,. When the Pirani pressure is more than 20% above the Auto-Start Threshold, the ion gauge will be turned OFF.

Recommendation

The recommended Auto-Start Threshold is $2x10^{-3}$ Torr. Higher values can significantly compromise the lifetime of the ion gauge filament. Lower values cannot be accurately read with Pirani gauges, and require that the Pirani Gauge Zero be checked consistently.

Pirani Gauge Setup Menu (PG1/PG2)

WARNING!
Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.

Read Chapter 1 for detailed instructions and safety information regarding the installation and connection of gauges.

Access the Pirani Gauge Setup menu from the Gauges Display (touch a PG Data Box) or from the Pressure Display (touch the Port Info Box of a Pirani gauge Data Bar).

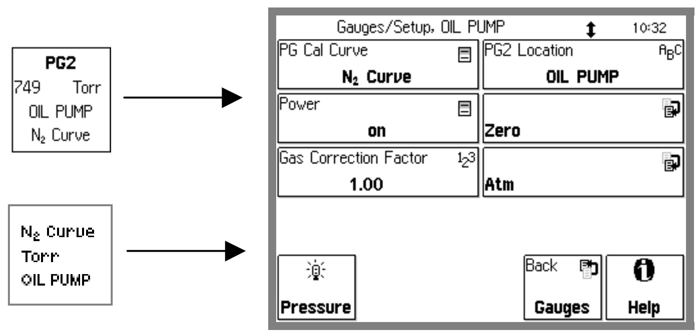


Figure 3-10. Pirani Gauge Setup Menu.

For More Information
Chapter 1 includes all the basic information required to install and set up your IGC100 controller and its gauges, including Pirani gauges. Consult Appendix H of this manual for general information on PG105 convection-enhanced Pirani gauges.

PG Cal Curve

Select the calibration used to calculate pressures from a Pirani Gauge signal (N_2 Curve or Ar Curve).

All IGC100 controllers are factory loaded with the required nitrogen and argon calibration curves required to convert Pirani gauge signals into nitrogen-equivalent or argon-equivalent pressure readings.

Use a Gas Correction Factor to convert readings for gases other than nitrogen or argon.

Gas Correction Factor

Enter a gas correction factor (0.01 to 10).

The IGC100 is factory-loaded with the calibration data required for direct Pirani gauge pressure measurements on N_2/Air or argon gases. At pressures below 1 Torr, a gas correction factor can be used to convert argon or nitrogen equivalent reading to direct readings for other gases. The nitrogen/argon equivalent reading is multiplied by the gas correction factor and displayed as the pressure.

The pressure reading is **multiplied** by the gas correction factor and displayed as the pressure.

Warning

Gas correction factors provide only rough accuracy results, and are only valid for pressure measurements in the pressure range from 10^{-3} to 1 Torr.

To convert nitrogen equivalent pressure into direct readings for other gases use the gas correction curves included in Appendix I.

PG1 (PG2) Gauge Location

Enter the Gauge Location name.

The IGC100 assigns a location name (text string) for each signal port. Location names are displayed in the Port ID Box of the Pressure Display and also in the Gauge Data Boxes of the Gauges Display.

The use of distinctive gauge location names makes it easy to identify the different readings in multiple gauge setups.

The default location is the name of the port ("PG1" or "PG2").

Note

Use the Gauge Location to differentiate between identical gauges in a dual gauge setup. For example, consider a vacuum system with two Pirani gauges - one connected to the high vacuum chamber (and the PG1 port) and the other one connected to the rough line (and the PG2 port). Give PG1 the location name, "HiVac", and PG2 the name, "Rough". This labels the two readings with meaningful names.

Power

Turn the Pirani gauge hot sensor wire On or Off.

When Power is On, the Pirani gauge sensor wire is powered and hot and the gauge is fully operational.

When Off, the Pirani Gauge sensor wire is turned off and no pressure readings are possible with the gauge.

When the Process Control Option is installed, a remote TTL input is available to control Pirani gauge power.

Recommendation

Use the Gauge Power Off setting to cool down the Pirani gauge hot wire while in the presence of flammable or explosive gases. This makes it possible to install Pirani gauges in systems that are intermittently filled with flammable gases. Manually turn off the gauge during exposure to dangerous gases instead of disconnecting the gauge from the controller.

Zero Submenu

Adjust the Pirani gauge Zero indication.

Follow the on screen directions to adjust the gauge readings at base pressure (<10^{-5} Torr) levels.

Periodic Zero adjustments of the controller readings, to compensate against background drift, are required for operation in the millitorr and sub-millitorr range.

Note

The calibration data loaded into all IGC100 controllers is based on the response of a new gauge free of contaminants. If a tube becomes contaminated or does not seem to read correctly, the front panel readings can often be readjusted using the Zero and Atm submenus.

Atm Submenu

Adjust the Pirani gauge Atmosphere indication.

Follow the on screen directions to adjust the gauge readings at atmospheric pressure levels.

Adjustment of the Atm indication should not be required unless compensating for contamination, extremely long cables or small deviations from horizontal in mounting orientation.

Note

The calibration data loaded into all IGC100 controllers is based on the response of a new gauge free of contaminants. If a tube becomes contaminated or does not seem to read correctly, the front panel readings can often be readjusted using the Zero and Atm submenus.

Analog I/O Setup Menu (AN1-4)

WARNING!
Read the entire **Safety and Preparation for Use** section of this manual before using the IGC100.

Read Chapter 1 for detailed instructions and safety information regarding the installation and connection of gauges.

Access the Analog I/O Setup menu from the Gauges Display (touch an ANalog I/O Data Box) or from the Pressure Display (touch the Port Info Box of an Analog Input Data Bar).

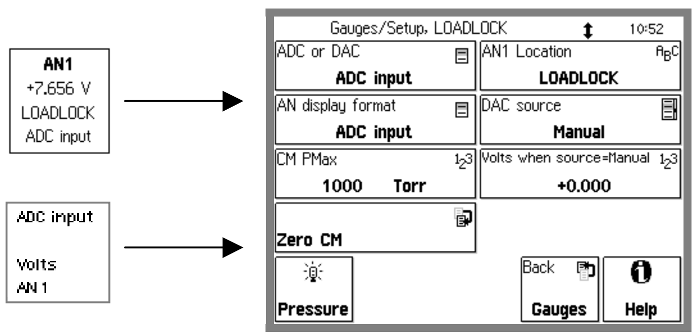


Figure 3-11. Analog I/O Setup Menu.

For More Information

Consult Chapter 4 for a complete description of the Analog I/O capabilities of the IGC100, including specifications, connections, possible configurations, and capacitance manometer operation.

About Capacitance Manometers

Capacitance Manometers (CMs), also known as capacitance diaphragm gauges, are the most accurate devices for measuring absolute and differential pressures of gases and vapors at the gauge's operating temperature. CM gauge heads are specified by their full scale pressure (Pmax). The gauge output is a dc voltage linearly related to the pressure. By industry standard , the output is 10 Vdc at Pmax. Dynamic range is typically 10^4.

Most gauge heads require ±15 Vdc (35 mA) to operate. Heated head assemblies require much higher power, and some models require higher voltages. Consult the gauge manual for power requirements and maximum pressure specifications. Most manufacturers list the maximum pressure, power requirements and connector pinouts right on the gauge body.

The IGC100 has a ±15 Vdc (100 mA) output connector on the back panel to directly power standard (non-heated) capacitance manometers.

Using capacitance manometers

The IGC100 is designed to read pressures from up to four capacitance manometers. To read CM pressures, the CM output signal must be connected to one of the four Analog I/O ports on the back panel. The analog port must be configured as an ADC input in the Analog I/O Setup menu. The full scale pressure of the CM (Pmax) must be set before pressure readings are correct.

CMs need to be periodically re-zeroed. A trim pot is built into most gauge heads for that purpose. However, if the trim pot is out of reach, use the Zero Manometer function in the Analog I/O Setup menu.

For More Information

Chapter 1 includes all the basic information required to install and set up your IGC100 controller and its gauges, including capacitance manometers. Consult Chapter 4 of this manual for further details on the operation of capacitance manometers and their proper connection to Analog I/O ports.

ADC or DAC

Configure the analog I/O port as either an ADC Input or a DAC Output.

ADC Input

When ADC Input is selected, the analog port is connected to a 14 bit , ±12 V full-scale, Analog-to-Digital Converter updated at 2 Hz. Input signals can be monitored through the Pressure Display (choose AN1-4 or CM1-4) or the Gauges Display.

Inputs may be linked to Process Control channels (Opt. 03) to control relays or TTL outputs.

All inputs are logged in the Data Log, along with all pressure readings.

Use analog inputs to read voltages from additional vacuum equipment such as capacitance manometers, thermocouples, mass flow controllers, turbo pump controllers, etc.

Capacitance manometers must be connected to Analog I/O ports configured as inputs. For direct pressure readings program the full scale pressure (Pmax).

DAC Output

When DAC Output is selected, the analog port is connected to a 12 bit , ±12 V full-scale, Digital-to-Analog Converter updated at 2 Hz.

Each DAC port may be programmed manually or linked to the log pressure readings of a gauge, either IG1, IG2, PG1 or PG2 (DAC Source). This provides logarithmic analog outputs compatible with programmable logic controllers and data loggers.

Use analog outputs to control auxiliary vacuum equipment such as heaters, actuators, ion sources and throttle controllers.

AN Display Format

Choose the display format for ADC Input readings.

Select ADC Input to display input signal levels as voltages (Vdc) in the Gauges Display. If a capacitance manometer is connected to the input, select CM Pressure to convert the input signal into a CM pressure reading and display the pressure in the Gauges Display.

In the main Pressure Display, choose AN1-4 in a Port ID Box to display voltage readings or CM1-4 to display CM pressure readings.

CM PMax

Enter the full scale range of the capacitance manometer (0-1000 Torr).

Note

The full scale ranges most commonly encountered in commercial CM gauges are 50 and 100 mTorr, and 1, 2, 10, 100 and 1000 Torr.

Important

Analog I/O ports connected to capacitance manometer signals must be configured as inputs (ADC Input) for pressure measurement to be possible. Direct pressure readings are possible only if PMax is programmed into the controller.

AN1-4 Location

Enter a Location name for the analog I/O port.

The IGC100 assigns a location name (text string) for each signal port. Location names are displayed in the Port ID Box of the Pressure Display and also in the Gauge Data Boxes of the Gauges Display.

The default location is the name of the port ("AN1").

Note

Use the Location name to differentiate between identical gauges in multiple gauge setups. For example, consider a vacuum system with two identical CM gauges- one connected to the High Vacuum Chamber (and the AN1 port) and the other one connected to the Rough Line (and the AN2 port). In this case, give the gauge connected to AN1 (CM1) the name "HiVac" and the CM2 gauge the name "Rough". This labels the two readings with meaningful names.

DAC Source

Link a DAC output to the pressure readings of IG1, IG2, PG1 or PG2 or choose Manual for front panel output level control.

The analog outputs may be linked to log pressure readings. These signals are often connected to devices such as programmable logic controllers, throttle valve controllers, and other common feedback controlled instruments.

When IG1 or IG2 is the DAC source, the analog output follows these parameters.

P (Torr) = 10^{V-12} for 10^{-11} Torr ≤ P ≤ 10^{-1} Torr
0 V indicates gauge off
12 V indicates gauge fault

When PG1 or PG2 is the DAC source, the analog output follows these parameters.

P (Torr) = 10^{V-5} for 10^{-4} Torr ≤ P ≤ 10,000 Torr
0 V indicates gauge off
12 V indicates gauge fault

When Manual is the DAC source, the analog output is set with the [Volts when source=Manual] menu button.

Volts When Source=Manual

Enter the voltage setting for the DAC Output when Source=Manual. The valid range is ±12V.

Zero CM Submenu

Adjust the Capacitance Manometer (CM) Zero indication.

Follow the on screen directions to adjust the zero of the capacitance manometer gauge.

Periodic Zero readjustments of the capacitance manometer readings, to compensate against background drift, are required for operation close to base pressures.

Important

Before making this adjustment, the CM must be connected to a vacuum system with a pressure lower than 0.01% of full scale (0.0001 x PMax).

Trim Pot Zero Adjustment

All capacitance manometers include a trim pot adjustment, used to adjust the output of the CM to zero at base pressure. Use the trim pot adjustment regularly to adjust the internal zero of the capacitance manometer head. The standard trim pot adjustment procedure is simple:

1. Connect the CM to a vacuum chamber with a pressure <0.01% of PMax
2. Switch the IGC100 to the Gauges Display.
3. Select AN Display Format = ADC Input for the appropriate Gauge Data Box (the analog port connected to the CM).
4. Turn the trim pot until the voltage displayed in the Data Box is zero.
5. Perform a Zero CM operation to adjust the IGC100 zero.
6. Switch the AN Display Format to CM Pressure to display pressure readings in the Gauges Display. The CM readings should be zero at base pressure.

Logging Display

Use the [Table] or [Chart] QuickKey to bring up the Logging Display. The data log is presented in either Table or Chart display formats. Select the format in the Logging Setup menu. This also changes the QuickKey between [Table] and [Chart].

The logged data for the three ports in the Pressure Display are displayed in a single screen. All inputs are logged – to display different ports, choose new ports in the Pressure Display (Port ID Boxes).

Chart

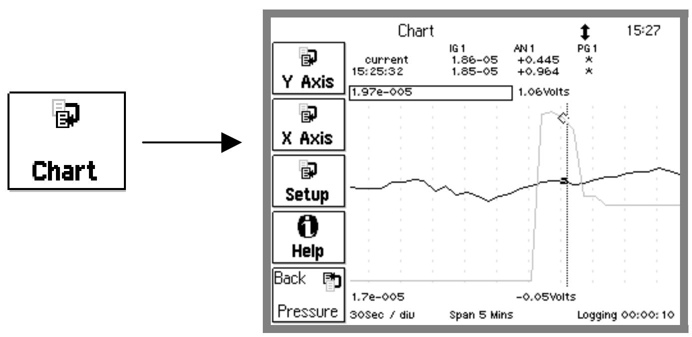


Figure 3-12. Chart Display.

Display the data log in graphical (P or V vs. Time) format.

The small table above the chart displays the most recent entry and the readings at the cursor position.

Pmax and Vmax are displayed above the graph, Pmin and Vmin below the graph.

The right edge is the most recent data point and the left edge is a Time Range ago. This resembles a chart recorder with new data appearing at the right edge. The X axis scale, span and logging interval are shown at the very bottom of the screen.

Touch [Setup] to display the Logging Setup menu. Touch [Y Axis] or [X Axis] to change the chart scales and time scale.

Moving the Cursor

To move the cursor, first touch the cursor readout above the graph (it highlights with a box). Touch the right half of the chart to move the cursor to the right, the left half to move it to the left. Touch close to the center to move slowly, farther from center to move quickly. Touch and hold to move continously.

Changing the Graph

The chart scale parameters can be modified within the chart display. To adjust the graph scales, first touch the displayed scale parameter (it highlights with a box). For Pmax, Pmin, Vmax and Vmin, touch the upper half of the chart to adjust the parameter up, the lower half to adjust the parameter down. For the Time Range, touch the left half of the chart to increase the range, the right half to decrease the range. In both cases, touch close to the center to make small changes, farther from center for large changes.

Touch [Y Axis] or [X Axis] to change the chart scales and time range numerically. Touch [Setup] to display the Logging Setup menu.

Table

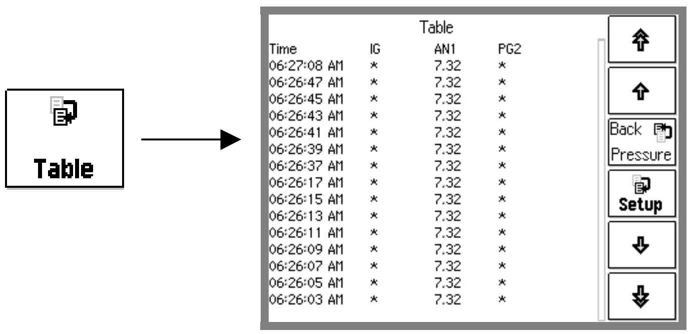


Figure 3-13. Table Display.

Column 1: The absolute time (and date) at which the readings were logged.

Columns 2, 3, 4: Pressure or voltage readings from the three Data Bars of the Pressure Display.

Use the up and down buttons to scroll through the entire log. Touch [Setup] to display the Logging Setup menu.

Logging Setup Menu

Touch [Setup] in either the Table or Chart Display to show the Logging Setup menu.

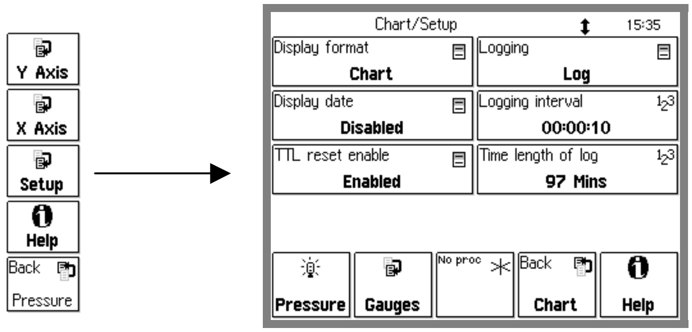


Figure 3-14. Logging Setup Menu.

Display Format

Select the log display format (Table or Chart). This also changes between the [Table] and [Chart] QuickKeys.

Important
The IGC100 always stores readings from *all* ports in the data log. However, the chart and table only show data from the three ports shown in the Pressure Display. To display other ports, change the Port ID Boxes in the Pressure Display.

Logging

Enable data logging (Log) or disable data logging (Pause).

Display Date

Enable or Disable the Date Display in the Table format.

Enabled means that the date will be included in the time stamp in the Table format display. This requires more lines per entry and fewer entries will be shown per page.

Disabled means that the date will not be included in the time stamp.

Enable this to keep track of the date through data logs that extend over more than one day.

Logging Interval

Enter the Logging Interval.

The Logging Interval is the time between data log entries. For example, a 5 minute setting indicates that a complete set of pressure and analog input readings are added to the data log every 5 minutes.

The Logging Interval affects the time length of the log. The data log stores a fixed number of entries, thus the Time Length of the data log and the Logging Interval are directly related. Use a small Logging Interval to record closely timed data points over a short period of time. Use a large Logging Interval to record data over a long period of time.

TTL Reset Enable

Enable or Disable data logging TTL Time Reset. This function requires the Process Control Option (opt. 03).

Enabled allows the Data Logging Time Reset input of the remote TTL control module to reset the data log.

Enable this to synchronize the start of the data log with an external event, such as the closing of a gate, the opening of a valve or the achievement of full speed in a turbo pump.

Disabled means that the Data Logging Reset input of the TTL control module does not have any effect on the data log.

Time Length of Log

This box displays the Time Length of the data log. This parameter can not be entered directly. The data log stores a fixed number of entries, thus the Time Length is determined by the Logging Interval.

The Time Length is the length of time covered by the data log. After this amount of time, the earliest data in the log will be overwritten by the newest data.

Chart Y Axis Menu

This button is only available from the Chart display.

Pmax
Pmin

Set the pressure corresponding to the top and bottom of the chart.

Note
All pressure readings are displayed with the *same* chart scale. The grid lines correspond to the values of Pmax and Pmin.

Vmax
Vmin

Set the voltage corresponding to the top and bottom of the chart.

Note
Voltage data from the analog I/O inputs is graphed according to Vmax and Vmin. *However, the grid lines correspond to the values of Pmax and Pmin.*

Autoscale

Autoscale the graph based on the data displayed in the graph.

This changes the values of Pmax, Pmin (and Vmax, Vmin) to use the entire vertical space of the chart display.

Chart X Axis Menu

This button is only available from the Chart display.

Chart Time Range

Set the time span of the chart.

The right edge of the chart is the most recent point, the left edge is a Time Range ago. The data moves across the chart as newer points are recorded, resembling a chart recorder.

Note
[Scale to Full] will set the Time Range to display all data points.

[Zoom to Cursor] will set the left edge of the chart to the cursor position. The right edge remains the most recent point.

Zoom to Cursor

Set the left edge of the chart to the cursor position. The right edge remains the most recent point.

Scale to Full

Set the Time Range to display all data points.

Process Control Display

Use the [Process] or [Back to Process] QuickKey to bring up the Process Control Display. *This is only available with the Process Control Option (opt. 03).*

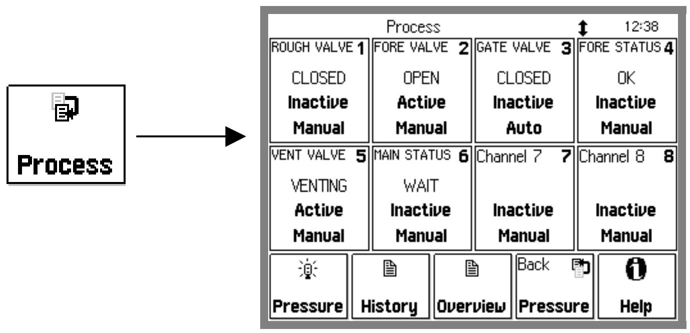


Figure 3-15. Process Display.

This display consists of eight rectangular Channel Data Boxes, each displaying state and mode information for a single process control channel. This display allows fast access to the state and configuration of all process control channels.

Touch a Channel Data Box to choose a channel state (Active, Inactive or Auto) or edit the channel rules and messages.

The 8 dedicated LEDs below the touchscreen provide across-the-room indication of channel output status (On = Active).

WARNING!
Using process control channels in your vacuum system requires careful programming and thorough testing. Double check all logic and wiring and use manual activation to test the action of each and every channel. Test all scenarios in a safe manner before relying on automatic, unattended operation.

About Process Control

The Process Control Option (Opt. 03) provides eight channels of process control. Each channel has a relay closure output, with corresponding opto-isolated TTL signal, that may be linked to a variety of input sources with intuitive user-programmable rules. Channel rules include all variables required for full process automation, including input source selection, activation threshold (level, polarity and hysteresis), delay settings and audio and text notification. The available input sources include any pressure gauge or analog input, the system clock, gauge emission status or a TTL input trigger signal.

This option also includes 12 opto-isolated TTL level inputs for triggering gauge on/off, degas on/off, fil1/fil2/both select, IG lockout, datalogging time reset and touchscreen enable/disable.

During process control, the output status of all eight channels can be monitored directly from the Process Control Display. In addition, the 8 dedicated LEDs below the touchscreen provide across-the-room indication of channel status.

Manual override is available for all channels, making it possible to control channel relays and TTL output levels directly from the front panel.

With this option, the IGC100 is a stand alone controller, capable of manual or automatic operation of any standard vacuum system.

All process control events are time stamped and recorded to be reviewed at any time. The process control log is also accessible remotely through the computer or web interfaces.

Active vs Inactive

When a process control channel is ACTIVE, the corresponding relay is powered, connecting the Common and Active (N.O.) relay pins, and the TTL output pin is logic low. INACTIVE means that the relay is unpowered, connecting the Common and Inactive (N.C.) relay pins, and the TTL output pin is logic high.

When a process control channel is in Auto mode, it becomes Active when the conditions specified by its rule's parameters are met. Rule parameters include setpoint, hysteresis, polarity (above or below), and delay.

Manual control of the channel output is also possible.

Process Control History

All process control events (channels active/inactive/auto) are time stamped and logged in the Process/History log. Touch the [History] QuickKey to display the contents of the process control event log.

Each line of the log is a change in either State or Mode of a process channel. For state changes (Active/Inactive), the bitfield shows the state of all channels (1=Active, 0=Inactive) starting with channel 1. For mode changes (Auto/Manual), the bitfield shows the mode of all channels (1=Auto, 0=Manual) starting with channel 1.

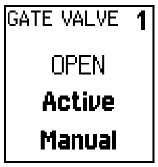
Important

History event logs are erased whenever the IGC100 is turned off.

Process Control Overview

Touch the [Overview] QuickKey to obtain a complete summary report of status and configuration information (including Rules) for all channels in a single screen.

Channel Data Box



A Process Control Data Box displays the state (Active/Inactive), mode (Auto/Manual) and message for a single process control channel. Touch the Data Box to access the channel's rules and messages or to manually control its output.

Each Data Box contains four lines of information (top to bottom):

- Channel Number and Description.
- Channel Active/Inactive Message.
- Output status (Active or Inactive).
- Mode (Manual override or Auto).

Touch a Channel Data Box and choose an option to:

- Switch to Auto mode (channel controlled by its Rules).
- Deactivate the channel (manual override).
- Activate the channel (manual override).
- Edit the channel's Rules (for Auto mode).
- Edit the channel's Messages.

Auto/Manual Channel Control

To control a channel state manually, touch a Channel Data Box and choose 'Active' or 'Inactive'.

To switch a channel to Auto mode (controlled by its Rules), touch a Channel Data Box and choose 'Auto'.

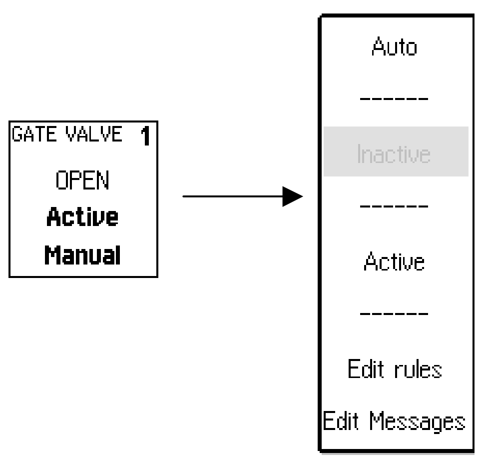


Figure 3-16. Manual Channel control.

Edit Rules Menu

Access the Edit Rules menu from the Process Control Display (touch a Channel Data Box) and choose 'Edit Rules'.

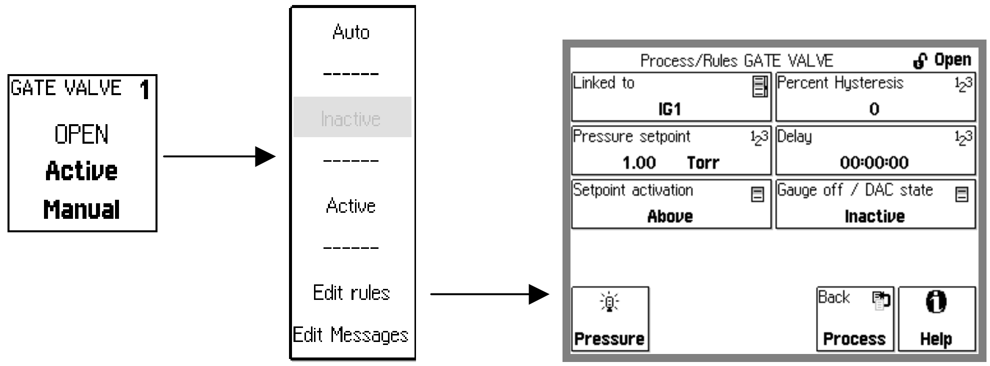


Figure 3-17. Edit Rules Menu.

Each process channel has its own rules. These rules determine the channel state when the channel is in Auto mode.

Linked To

Process control channels can be linked to

- any available pressure gauge (IG1, IG2, PG1, PG2, and CM1-4)
- any analog input port (AN1-4)
- the system clock (CLOCK)
- gauge status conditions (IG1 EMISSION, IG2 EMISSION, ANY IG EMISSION)
- the TTL channel input (TTL PIN)

For example, select PG1 to link the channel state to the readings of the Pirani gauge connected to the PG1 port.

Linked to IG1 (or IG2) EMISSION means that the channel remains ACTIVE as long as IG1 (or IG2) is turned on (i.e. electron emission is on). The channel becomes INACTIVE as soon as the gauge is turned off.

When using the Dual Ionization Gauge option (opt. O100IG),

- Linked to ANY IG EMISSION means that the channel is ACTIVE as long as either ion gauge (IG1 or IG2) is turned on. The channel becomes INACTIVE if both gauges are off.

Important

In addition to the Channel Source, the Pressure Setpoint, Setpoint Activation, Hysteresis, Delay and Gauge Off State must also be specified to complete the channel rules.

No process control actions take place based on ionization gauge readings while the gauge is degassing.

Pressure Setpoint

Enter the channel Pressure Setpoint (Torr) when the Channel Source is a pressure gauge (IG, PG or CM).

The Pressure Setpoint is the pressure threshold at which the channel becomes Active or Inactive. Set the Setpoint Activation to choose Active above or below this threshold. The Setpoint determines the exact level at which channel switching occurs. Use the channel Delay to ignore transient pressure levels.

Voltage Setpoint

Enter the channel Voltage Setpoint (Volts) when the Channel Source is an analog input (AD1-4).

The Voltage Setpoint is the voltage threshold at which the channel becomes Active or Inactive. Set the Setpoint Activation to choose Active above or below this threshold. The Setpoint determines the exact levels at which channel switching occurs. Use the Setpoint Delay to ignore transient voltages.

Setpoint Activation

Select the Setpoint Activation for the channel (Above or Below).

Above

The channel becomes ACTIVE when the pressure, or voltage, goes ABOVE the Setpoint.

The channel becomes INACTIVE when

the pressure goes BELOW {Setpoint / (1+Hysteresis_%/100)}

or

the input voltage goes BELOW {Setpoint – Hysteresis_V}.

Below

The channel becomes ACTIVE when the pressure, or voltage, goes BELOW the Setpoint.

The channel becomes INACTIVE when

the pressure goes ABOVE {Setpoint x (1+Hysteresis_%/100)}

or

the input voltage goes ABOVE {Setpoint + Hysteresis_V}.

Percent Hysteresis

Enter the Percent Hysteresis for the channel (0 to 999 %). Percent Hysteresis applies when the channel is linked to a pressure reading (IG, PG or CM). See 'Setpoint Activation' above for more information.

Hysteresis allows the process control channel to ignore normal, slow variations or drift in the readings. Use the Delay setting to ignore transient events.

Voltage Hysteresis

Enter the Voltage Hysteresis for the channel (0-12V). Voltage Hysteresis applies when the channel is linked to an analog input (AN1-4). See 'Setpoint Activation' above for more information.

Hysteresis allows the process control channel to ignore normal, slow variations or drift in the readings. Use the Delay setting to ignore transient events.

Delay

Enter the Setpoint Delay time.

The Setpoint Delay is the amount of time that a channel switching condition must be present before channel switching actually takes place.

Use the Setpoint Delay in systems known to experience brief pressure or voltage transients during normal operation. The addition of the delay eliminates unnecessary channel switching.

Gauge Off/DAC State

Specify the channel state (Active or Inactive) when the Channel Source pressure gauge is turned off or is in a fault condition (IG or PG) or when the analog port is overloaded or switched into DAC Output mode (while linked to CM or AN).

For Channel Sources IG1 and IG2, specify the desired channel state when the emission is turned off or a fault exists (no pressure readings available).

For Channel Sources PG1 and PG2, specify the desired channel state when the gauge is turned off or a fault exists (no pressure readings available).

For Channel Sources CM1-4, specify the desired channel state when its Analog I/O port is switched to DAC Output mode or the input is overloaded (no pressure readings available).

For Channel Sources AN1-4, specify the desired channel state when port is switched to DAC Output mode or the input is overloaded (no voltage readings available).

Activation Time
Deactivation Time

Enter the Channel Activation/Deactivation Time when the Channel Source is Clock.

The Activation Time is the exact time at which the channel switches to ACTIVE.

The Deactivation Time is the exact time at which the channel switches to INACTIVE.

All times are represented in 24hr format (18:30 is 6:30pm). The current time is displayed at the top of the screen in most displays.

Use the clock to control scheduled operations such as overnight system bakeouts. The channel Activation Time can start unattended system bakeout an hour after everybody leaves. Use the channel Deactivation Time to stop the bakeout, and allow the system to cool down, three hours before arriving in the morning.

Activate When TTL

Select the TTL Activation mode (High or Low).

Each channel has a dedicated TTL input pin (see Chapter 5). When the Channel Source is TTL, the level of this input controls the channel.

Activate When High means the channel is ACTIVE when the TTL input level is HIGH (and INACTIVE when LOW).

Activate When Low means the channel is ACTIVE when the TTL input level is LOW (and INACTIVE when HIGH).

Edit Messages Menu

Access the Edit Messages menu from the Process Control Display (touch a Channel Data Box) and choose 'Edit Messages'.

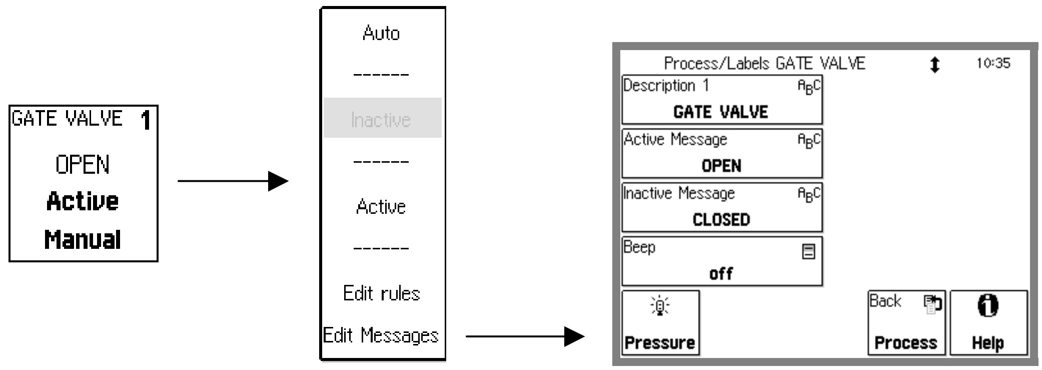


Figure 3-18. Edit Channel Messages Menu.

Each process channel has its own description and messages shown in the Channel Data Boxes. The messages are updated whenever the channel changes state.

Description

Enter a Channel Description.

The IGC100 assigns a Description (text string) to each process control channel. The Description is displayed at the top of each Channel Data Box (next to the channel #).

Assign Description to all channels used for process control. Descriptions such as "heater", or "gate valve" make it easier to visualize and control a system and minimize the chances of errors.

Recommendations

Combine Descriptions and Active/Inactive Messages to provide useful information about the status of your system. For example, for a channel controlling a gate valve (ACTIVE = valve open), use "gate valve" as the Description, "open" for the Active Message and "closed" for the Inactive Message. The Channel Data Box would then display "gate valve/open" or "gate valve/closed" depending on the state of the channel.

Active Message
Inactive Message

Enter the channel Messages.

The Active Message is displayed in the Channel Data Box whenever the channel is ACTIVE. The Inactive Message is displayed whenever the channel is INACTIVE.

Recommendations

Combine Descriptions and Active/Inactive Messages to provide useful information about the status of your system. For example, for a channel controlling a gate valve (ACTIVE = valve open), use "gate valve" as the Description, "open" for the Active Message and "closed" for the Inactive Message. The Channel Data Box would then read "gate valve / open" or "gate valve / closed" depending on the state of the channel.

Beep

Enable the Channel Beep (On or Off).

On means that a beep is sounded every time the channel changes states.

Off means that no beep is sounded.

Main Menu

Use the [Menu] or [Back to Main] QuickKey to bring up the Main Menu. This menu can only be accessed from the Pressure Display.

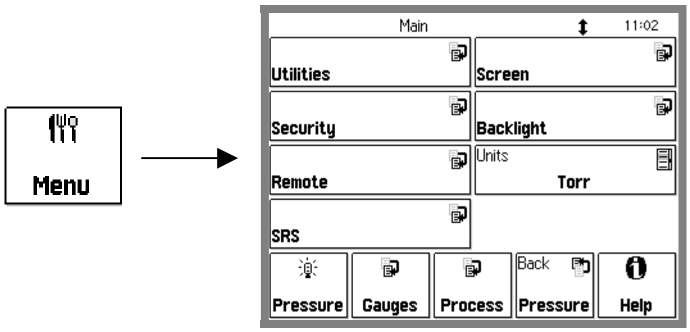


Figure 3-19. Main Menu.

The Main Menu provides access to many important IGC100 internal parameters and settings.

Units

Display the Units selection list.

Select from Torr, Micron, Bar, mbar or Pascal.

This units system is global to the IGC100. All pressure readings in the Pressure Display and data logs use these units. All pressure parameters in menus use these units.

This button is also available in the numeric entry keypad of pressure parameters.

See Appendix K for conversion factors.

SRS

Display contact information about Stanford Research Systems.

Utilities Menu

Touch [Utilities] in the Main menu to display the Utilities menu.

Time/Date

Adjust the time and date settings of the IGC100.

The clock is used to ...

- log pressure and voltage readings (data log).
- log process control events (process history).
- log gauge activity (gauges history).
- to trigger process control events at specific times.

All times are represented in 24hr format (18:30 is 6:30pm). The current time is displayed at the top of the screen in most displays.

The clock requires adjustment after daylight savings corrections take place.

Volume Control

Adjust the speaker volume (0 to 10).

The IGC100 speaker is used for different purposes, such as user interface feedback and sounding alarms during process control and overpressure events.

Configuration

Display the Configuration Report.

The Configuration Report shows a complete listing of all internal modules (standard and optional) detected when the unit was turned on.

Selftest Submenu

Display the Selftest menu.

System Selftest

Touch this button to perform the power-on test again. This also displays the firmware version and date.

Button & LED Test

Touch this button to test the BLACK hardware keys, the 8 process LEDS and the 4 ion gauge LEDS.

Xmit via RS-232

Transmit the string "SRS IGC100" over the RS-232 interface.

Security Menu

Touch [Security] in the Main menu to display the Security menu.

The IGC100 features password protection to prevent unauthorized users from altering important instrument parameters and vacuum system settings.

For example, a vacuum operator might need to lock the process control menus to avoid inadvertent switching of relays, while a supervisor might lock the entire front panel to avoid any unsupervised changes by inexperienced operators.

The security state of the IGC100 is indicated by an icon on the upper right corner of the screen. A padlock indicates that the system is locked and password protected.

WARNING!
When the system is locked, security settings **CAN NOT** be changed. All IGC100 functions/parameters protected in the Security Settings menu can not be changed.

Once the IGC100 is locked, the user *must* know the current password in order to modify any security settings in the IGC100. Alternatively, the user may insert a valid Password Card into the memory card slot to enable changes to the security settings.

If You Forget the Password

The password "SRS IGC100" always unlocks the system. This password is all uppercase and has a space after "SRS".

Password Cards

Security passwords can be copied into special memory cards known as Password Cards. Password Cards make it unnecessary to remember the password in order to unlock a controller. Simply insert the password card (loaded with the current password) into the Memory Card Slot to automatically unlock the controller. The controller returns to the locked state as soon as the card is removed.

Enter Password to Lock/Unlock

Enter the password to unlock or lock the system.

If the unit is unlocked, enter the password to lock the security system. Check the Security Settings submenu to ensure the desired functions become locked.

If the unit is locked, enter the password to unlock the security system. You can also use a Password Card to unlock a protected controller.

Important

Password recognition is case sensitive.

Set Password

Program a new password.

The system must be unlocked in order to enter a new password.

Important
Password recognition is case sensitive and may include numbers and letters.

Copy Password to Card

Load the current password into a Password Card.

Important
A password card must already be loaded into the Memory Card Slot AND the system must be unlocked before using this function. See Chapter 6 for details.

Following the password copy, the security system is locked when the Password Card is removed. Insert the card to unlock the system without manually entering the password.

Security Settings Submenu

Display the Security Settings menu. Use this menu to select the desired level of security.

Settings in this menu may not be altered when the system is locked.

Ion Gauge Buttons

Select the ion gauge protection mode (Normal or Protected).

Protected means that the black front panel IG1, IG2, DEGAS and IG AUTO buttons are not functional when the system is locked. Use this option to eliminate unintentional manual gauge shutdowns.

Normal means that the IG control buttons are not affected by the security system.

Gauge Setup

Select the Gauge Setup protection mode (Normal or Protected).

Protected means that all gauge setup menus, required for proper gauge operation, cannot be modified when the system is locked. Use this option to eliminate accidental parameter changes.

Normal means that the gauge parameters are not protected by the security system.

Calibration

Select the Calibration protection mode (Normal or Protected).

Protected means that user gauge calibrations, such as Pirani gauge Zero and Atmosphere, are protected. Use this option to lock all calibration settings and eliminate accidental changes.

Normal means that the user calibration functions are not protected by the security system.

Process Setup

Select the Process Setup protection mode (Normal or Protected).

Protected means that all Process Control rules, accessible via the Process Control QuickKey, cannot be modified when the system is locked. Use this option to lock the process control rules and eliminate accidental changes.

Normal means that the process control rules are not protected by the security system.

Process Manual

Select the Process Manual protection mode (Normal or Protected).

Protected means that the state of Process Control channels (Active/Inactive/Auto) cannot be changed from the front panel. Use this feature to prevent accidental state changes in the process control relays.

Normal means that the Process Control channels are not protected by the security system.

Units/Time/Date

Select the Units/Time/Date protection mode (Normal or Protected).

Protected means that the Time/Date and Units settings are locked when the system is locked.

Normal means that the time/day settings are not protected by the security system.

Local Access

Select the Local Access protection mode (Normal or Protected).

Protected means that all front panel actions (including Power Off) are disallowed, except for the required security functions, when the system is locked. This is the most powerful protection option available.

Normal means that front panel actions are not affected by the security system.

Remote Access

Select the Remote Access protection mode (Normal or Protected).

Protected means that remote commands may only query the settings/readings of the IGC100 when the system is locked. Any command which tries to change a setting will result in an error. Use this option to prevent remote control of your instrument. The remote user may still unlock the system via the password.

Normal means that remote control actions are not affected by the security system.

Remote Menu

Touch [Remote] in the Main menu to display the Remote menu.

System Name

Enter a system name for this IGC100.

The system name identifies this unit over the remote interfaces. In addition, the name is displayed on all web pages served by this unit.

RS-232 Submenu

Display the RS-232 configuration menu.

This menu also includes a Rx/Tx display button which shows receive/transmit activity on the RS-232 port.

Baud Rate

Select the RS-232 (Serial) interface Baud Rate [300 – 115.2k].

The available baudrates are: 300, 1200, 2400, 9600, 19200, 38400, 57600 and 115200.

Most PC's use 9600 as a default.

Word Length

Select the RS-232 (Serial) interface Word Length [7 bits, 8 bits].

8 bits is standard.

Parity

Select the RS-232 (Serial) interface Parity [None, Even, Odd].

None is standard.

Flow Control

Select the RS-232 (Serial) interface Flow Control [None, Xon/Xoff, Hardware].

None is standard. At high baud rates (>19200), flow control may be necessary to prevent data loss. Check the host serial interface for the type of flow control in use.

RS-232 Queue

Display the RS-232 transmit and receive buffers. The IGC100 buffers the most recent characters received and transmitted over the interface. The Queue display shows the interface history.

The Queue display may slow down communications and should be displayed only when testing or debugging a host program.

Press a QuickKey to exit from this display.

The upper half of the Remote Queue display is the Receive Queue. These are the most recent characters which have been received by the IGC100 (displayed in UPPER case). Commands which have already been executed are shown in normal text. Commands which have not yet been executed are shown with a gray background. Command errors are shown in inverse text.

The lower half of the Remote Queue display is the Transmit Queue. These are the most recent characters which have been placed in the output buffer. Characters which have already been sent over the interface are shown in normal text. Characters which are waiting to be sent are shown with a gray background.

GPIB Submenu

Display the GPIB (IEEE-488) configuration menu.

This menu also includes a Rx/Tx display button which shows receive/transmit activity on the GPIB port.

Address

Select the IGC100 Device Address (1 to 30).

Before attempting to communicate with the IGC100 over the GPIB interface, the IGC100's device address must be set.

GPIB Queue

Display the GPIB transmit and receive buffers. The IGC100 buffers the most recent characters received and transmitted over the interface. The Queue display shows the interface history.

The Queue display may slow down communications and should be displayed only when testing or debugging a host program.

Press a QuickKey to exit from this display.

The upper half of the Remote Queue display is the Receive Queue. These are the most recent characters which have been received by the IGC100 (displayed in UPPER case). Commands which have already been executed are shown in normal text. Commands which have not yet been executed are shown with a gray background. Command errors are shown in inverse text.

The lower half of the Remote Queue display is the Transmit Queue. These are the most recent characters which have been placed in the output buffer. Characters which have already been sent over the interface are shown in normal text. Characters which are waiting to be sent are shown with a gray background.

Web Submenu

Display the Web server configuration menu.

The parameters in this menu must be entered in order to use the web interface option (Opt. 02). This menu only applies if this option is installed. See Chapter 8 'Embedded Web Server' for more information on configuring the IGC100 for the internet.

Web Server

Enable or Disable the web server.

Important!
Use the web security measures in the Web/Control menu to prevent unauthorized control of the IGC100 via the web. Disable the server to prevent ALL web access to the IGC100.

IP Address

Enter the IP Address for the IGC100 web server.

Obtain a valid IP Address from your network administrator. Entering invalid addresses may disrupt your network.

When accessing the IGC100 from you browser, enter this IP address in the address box to display the web pages. Make a 'favorite' to provide one click access.

DNS

Enter a DNS Address for the IGC100 web server.

Obtain a valid Domain Name Server (DNS) Address from your network administrator.

The DNS is used by the web server's e-mail notification feature. The DNS allows e-mail addresses to be entered using full domain names.

Gateway

Enter a Gateway Address for the IGC100 web server.

Obtain a valid Gateway Address from your network administrator. The Gateway is used by the web server's e-mail notification feature.

Web Queue

Display the web transmit and receive buffers. The IGC100 buffers the most recent characters received and transmitted over the interface. The Queue display shows the interface history.

The Queue display may slow down communications and should be displayed only when testing or debugging a host program.

Press a QuickKey to exit from this display.

The upper half of the Remote Queue display is the Receive Queue. These are the most recent characters which have been received by the IGC100. Commands which have already been executed are shown in normal text. Commands which have not yet been executed are shown with a gray background. Command errors are shown in inverse text.

The lower half of the Remote Queue display is the Transmit Queue. These are the most recent characters which have been placed in the output buffer. Characters which have already been sent over the interface are shown in normal text. Characters which are waiting to be sent are shown with a gray background.

Port Number

Change the HTTP port number of the web server. The default port is 80 and should **NOT** be changed except in the following situations.

1. You are using multiple IGC100's in a network behind a NAT (network address translation) router. In this case, all of the IGC100's will appear at the same IP address to the outside world (they will have different IP addresses on the local network). Each IGC100 needs to be on a different port and the router must be configured to forward port requests to the correct IGC100. From the outside, each IGC100 is accessed at its own port number (but the same IP address).

2. If you are experiencing attacks on port 80 that block access to the IGC100. In this case, change the port to something else (like 8080). You will need to specify this port in your browser address window as 208.123.123.32:8080 where 208.123.123.32 is the IP address of the IGC100 and 8080 is the port number.

For more information about NAT routers and ports, see your network administrator.

Wait at least 30 seconds after changing the port number for the change to take effect.

Web Control Submenu

Display the Web/Control submenu.

The web server can disallow any user from controlling the IGC100 via the web. In this case, only monitoring is allowed from the web.

If web control is required, there are two types of security. Password security requires the user to enter the password from their browser and Trusted IP allows control only to those IP addresses entered in this menu. Both types can be used together.

See Chapter 8 'Embedded Web Server' for more information on configuring the IGC100 for the internet.

Web Control

Enable or Disable web control of the IGC100.

Disabled prevents any user from controlling the IGC100 via the web. In this case, only monitoring is allowed on the web. This provides the most security but only allows monitoring.

Enabled allows both monitoring and control of the IGC100.

Important

There are two types of security. Password security requires the user to enter the password from their browser and IP Checking allows access only to those IP addresses entered in this menu. Both types can used together. The IGC100 requires the use of at least one type of security.

Security Type

Choose the type of web security (Password, IP Checking or Both)

Password requires the entry of the Web Password from the user's browser before accessing any IGC100 web pages.

IP Checking only allows computers with trusted IP to access the web server. Only users with static IP addresses can use this feature. Do not use this if you use a dial-up account or DHCP account to access the internet. These accounts have dynamic (i.e. temporary) addresses.

Both requires the password AND a trusted IP address checking before web access to IGC100 is allowed.

Password

Enter a password for web access.

When accessing the IGC100 web server from your browser, it will ask for this password before any pages will be displayed.

Trusted IPs

Enter trusted IP addresses. When IP Checking security is enabled, the web server only allows access to those IP addresses entered in this menu.

A trusted range of IP addresses allows all users on a local network (or subnet) to access the web server. Use this in a laboratory environment where groups of computers and users are on a single subnet.

Enter individual IP addresses for remote users with static IP addresses.

IP Checking can not be used with users who have dial-up accounts. These accounts do not have a static, or permanent, IP address.

Start Trusted Range
End Trusted Range

Enter the Start and End of the Trusted IP Range.

Trusted IP Address

Enter individual Trusted IP addresses. Up to four individual addresses can be stored in the controller.

Screen Menu

Touch [Screen] in the Main menu to display the Screen menu.

Contrast Up
Contrast Down

Adjust the screen contrast according to your viewing needs.

Clean Touch Screen

Display the Touchscreen Cleaning display with countdown timer. This allows the user to clean the screen without turning the power off.

The cleaning display has no touch sensitive areas and can be wiped clean without changing any instrument settings. The touchscreen should be cleaned according to the procedure below and only while the Touchscreen Cleaning display is on (or the unit is off). The timer indicates the time remaining before returning to the menu.

Cleaning procedure

For best results, use a clean, non-abrasive cloth towel and a commercial window cleaner to regularly clean the screen. The cleaning solution should be applied to the towel, NOT the surface of the touchscreen. Fluid may seep behind the panel if it is not cleaned properly.

WARNINGS

Do not operate the touchscreen with the tips of pens or sharp objects that might permanently stain or damage the screen surface.

The surface of the touchscreen should be kept free of dirt, dust, fingerprints and other materials that could degrade its optical properties. Long term contact with abrasive materials will scratch the front surface and harm image quality.

Calibrate Touch Screen

Display the Touchscreen Calibration window.

If there is consistent misalignment between the LCD buttons and their touchsensitive areas, follow this calibration procedure to realign the LCD and touchscreen.

Test Touch Screen

Display the Touchscreen Test window. The cross-hairs on the screen should be aligned under the touch point across the entire screen. If the alignment is significantly off, use the Touchscreen Calibration window to re-calibrate.

Backlight Menu

Display the Backlight saver submenu.

The IGC100 has a back-lit LCD display. Backlighting is supplied by a fluorescent tube. Use the Backlight Saver feature to extend its useful lifetime by automatically turning it off after hours. Using the Backlight Saver can double the lifetime of the fluorescent tube.

All IGC100 controller functions remain functional while the backlight is off.

Backlight Saver

Select the Backlight Saver mode (Enabled or Disabled).

Disabled means that the backlight will never be turned off.

Enabled means that, between the Turnoff and Turnon times, the display backlight will turn off if the touchscreen is inactive for a period longer than the Backlight Saver Delay. All IGC100 controller functions remain functional while the backlight is off.

Important

Touch the LCD screen to restart the backlight.

Recommendation

Use the Backlight Saver to extend the life of the screen's backlight. Enable the backlight saver mode and program the on/off/delay times to shut off the light overnight.

Backlight Saver Delay

Enter the Backlight Saver Delay time.

If the Backlight Saver is enabled and the time of day is between the Turnoff and Turnon times, then the display backlight turns off if the touchscreen is inactive for the Backlight Saver Delay time.

TurnOff Time
Turnon Time

Enter the backlight Turnoff Time.

If the Backlight Saver is enabled and the time of day is between the Turnoff and Turnon times, then the display backlight turns off if the touchscreen is inactive for the Backlight Saver Delay time.

Recommendation

Set the Turnoff time to the time at which you leave the lab at night. Set the Turnon time to just before you return in the morning. There is no need to keep the light on when nobody is looking at the

Chapter 4

Analog Input/Output Ports

This chapter includes a complete description of the Analog I/O capabilities of the IGC100, including specifications, connections, possible configurations, and capacitance manometer operation.

In This Chapter

Analog I/O Ports (AN1-AN4)

All IGC100 controllers have four analog input/output ports (BNC connectors) on the back panel. Each port can be individually configured as an input or an output from the front panel or through the computer interface.

The specifications are identical for the four ports

Range	±12 V
Input resolution	14 bits
Input Impedance	1.2 MΩ
Output resolution	12 bits
Output impedance	100 Ω
Update Rate	2 Hz

Connection

The four Analog I/O ports are located on the back panel of the IGC100 and are easily identified as the vertical row of four BNC connectors, labeled ANALOG I/O 1 through 4.

Figure 4-1. Rear panel Analog I/O ports.

The BNC connectors are wired in the standard fashion, with the center pin connected to the signal (input or output) and outer shield connected to the signal return (ground).

Configuration

Each individual Analog I/O port may be programmed to perform one of many possible functions. To configure a port, touch the [Gauges] QuickKey to bring up the Gauges Display. Touch an analog port Data Box (AN1-AN4) to display the Analog Port Setup menu.

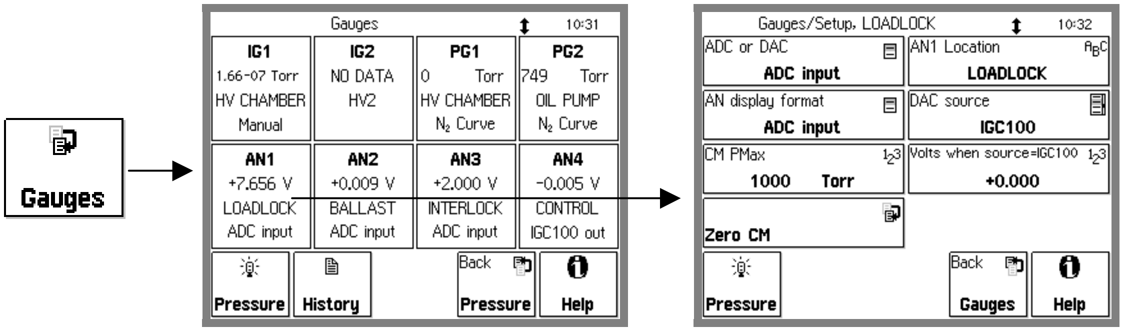


Figure 4-2. Analog I/O Port Setup.

The first, and most important, configuration option is selection of I/O mode, ADC Input (Analog to Digital Converter) or DAC Output (Digital to Analog Converter).

Input ports connected to the pressure signal of a capacitance manometer include the option to display the CM readings directly as pressures (AN Display Format), provided the full scale range (CM PMax) is programmed.

The level of a DAC output can be set manually (Volts When Source=Manual) or remotely (through the computer interface), or may be linked to the log pressure of the IG1, IG2, PG1 or PG2 gauges (DAC Source).

The IGC100 allows you to assign a descriptive Location name (text string) to each signal port. Locations are displayed in the Port Info box of the Pressure Display screen, and in the Port's Data Box of the Gauges Display. This makes it easy to identify the signal source.

For More Information

The menus used for Analog I/O port configuration are described in detail in the Gauges Display section of Chapter 3.

Analog Inputs

When an analog port is configured as an ADC Input, its signal levels (dc voltage or CM pressure) can be displayed on the front panel (Pressure and Gauges Display Screens) and/or monitored remotely through the computer and/or web interfaces.

When Data Logging is enabled, all analog input voltages are stored in memory as part of the data log.

Voltage levels beyond the ±12V range display the message 'OVERLOAD'.

Process Control Channels can be linked to ADC Input ports. Channel activation takes place above or below a user specified input signal level. For example, use the amplified voltage readings from a thermocouple gauge to prevent overheating of your sample during inductive heating.

Recommendation

Use Analog I/O ports as inputs to read voltages from additional vacuum equipment such as capacitance manometers, thermocouples, mass flow controllers, turbo pump controllers, throttle valve controllers, etc.

For More Information

Consult the Process Control Display section in Chapter 3 of this manual for information on how to link process control channels to analog input ports.

Analog Outputs

The level of a DAC output can be set manually (Volts When Source=Manual) or remotely (through the computer interface), or may be linked to the log pressure of the IG1, IG2, PG1 or PG2 gauges (DAC Source).

When IG1 or IG2 is the DAC source, the analog output follows these parameters.

P (Torr) = 10^{V-12} for 10^{-11} Torr $\leq$ P $\leq$ 10^{-1} Torr
0 V indicates gauge off
12 V indicates gauge fault

When PG1 or PG2 is the DAC source, the analog output follows these parameters.

P (Torr) = 10^{V-5} for 10^{-4} Torr $\leq$ P $\leq$ 10,000 Torr
0 V indicates gauge off
12 V indicates gauge fault

Recommendation

Use analog outputs to control auxiliary vacuum equipment such as heaters, actuators, ion sources and throttle controllers. Connect analog output signals to Programmable Logic Controllers to perform sophisticated process control.

Capacitance Manometers (CM1-CM4)

Basics

Capacitance manometers (CMs) are very accurate devices for measuring both absolute and differential pressures. They measure all gases and materials that are vapors at the gauge's operating temperature. Gauge heads are specified by their full scale range, Pmax (10,000 Torr - 0.1 Torr), and have a dynamic range of approximately 4 decades. The standard output is a dc analog voltage, independent of the gas, linear with pressure, and equal to 10 V at Pmax. Gauge volume is small, and response is fast. Capacitance manometers commonly offer accuracies of 0.25%, while high-accuracy products can offer 0.08%. Capacitance manometers are so accurate that gauge-head temperature variation is a critical source of error. The long-term accuracy of capacitance manometers (better than 1%) justifies their use as secondary standards and transfer gauges.

For critical applications where repeatability, precision, and composition independent readings are required, a capacitance manometer gauge should be used to monitor and control the process pressure! This is particularly true if complex or changing gas mixtures are involved.

Note

Capacitance manometers may be ordered from several commercial sources. Gauge heads can be purchased with two ports for differential measurements, or with an evacuated reference side for absolute pressure measurements.

Heated capacitance manometers, maintained at temperatures above ambient, are used extensively in chemical processes, gas handling systems, and semiconductor processing systems operating under two sets of conditions:

1. ambient temperature undergoes large fluctuations
2. system contains vapors that would otherwise condense on the sensor

Heated CMs are used in measuring pressures found in (1) chemical processes containing water vapor and organic materials that boil at modest temperatures, and (2) semiconductor manufacturing processes, particularly aluminum etching where $AlCl_3$ vapor exists.

When heated sensor heads are used, the temperature of the sensor usually is greater than that of the chamber whose pressure is to be measured. The pressure reading will be a few percent high under some conditions due to an effect known as thermal transpiration.

For More Information

For additional information on CMs and the thermal transpiration effect consult :

1. "Foundations of Vacuum Science and Technology", Ed. J. M. Lafferty, John Wiley and Sons, NY, 1998, p. 384.

2. R. W. Hyland and R. L. Shaffer, "Recommended Practices for the Calibration and Use of Capacitance Diaphragm gauges as transfer standards", J. Vac. Sci. Technol. A 9 (1991) 2843.

CM Connection

The standard IGC100 controller can display pressures measured from standard capacitance manometers (CMs). Up to four independent CM readings can be monitored simultaneously using the four Analog I/O ports. Pressure readings are updated at 2 Hz. The IGC100 precisely measures the 0 to 10 Vdc linear output signal from the CM to determine pressure. Direct pressure readings are accurate only if the full scale range (PMax) of the gauge is entered into the controller. Full-scale ranges up to 1000 Torr are supported by the controller.

An 'OVERLOAD' message is displayed when the output signal from the CM exceeds 12 V.

For added convenience, the IGC100 also supplies an auxiliary ±15 Vdc/100 mA power output. This power is usually sufficient to operate a pair of standard (i.e. non-heated) capacitance manometers.

For More Information

Chapter 1 includes all the basic information required to install and set up your IGC100 controller and its gauges, including capacitance manometers. Chapter 3 describes, in detail, all menus required to configure the IGC100 to display pressure readings from capacitance manometer gauges.

Tips For Using CMs

1. Avoid overpressurizing the gauge head. Use pressure relief and isolation valves whenever required.
2. Maintain a stable temperature around non-heated gauges.
3. Allow long warm up times for heated gauge heads. Consult manufacturer’s recommendations.
4. Avoid contamination and particulate buildup inside the gauge since that could affect diaphragm motion. Some gauge designs offer special features to avoid such buildup.
5. Avoid mechanical vibrations.
6. Eliminate any chances of mechanical stress to the gauges. Use bellows if necessary.
7. Recalibrate frequently. Rezero often.

Chapter 5

Process Control

This chapter provides the basic guidelines required to successfully interface and program the automation features built into the Process Control option (Opt. 03) of the IGC100 controller. If this option is installed, the [Process] QuickKey is available in the Pressure Display and all features described in this chapter are available. If this option is not installed, this QuickKey becomes [No Proc] and no process control features are available.

In This Chapter

Process Control Warnings

- It is the user's responsibility to ensure that the automatic control signals provided by the process control option (Opt. 03) of the IGC100 are always used in a safe manner.
- Carefully check the programming of the system, and test every individual channel connection under MANUAL control, before switching to AUTO Mode operation.
- When an equipment failure or power shutdown condition could cause a hazardous situation, always provide fail-safe precautions. As an example, a pressure relief check valve should be used in conjunction with an automated backfill valve when the risk of dangerous overpressure is possible.
- Use the security features built into the IGC100 to lock the Process Control Display and avoid potentially hazardous changes to your system by inexperienced users.
- Even if the control logic seems simple and obvious, we recommend that you always develop a logic diagram (flowchart) of the process control function you wish to implement. See the Automated Pumpdown Example at the end of this chapter.
- To minimize programming and connection errors, prepare a Specification Table which lists the rule parameters, measurement sources, and connection scheme for each channel. An example is presented in this chapter.
- Keep a copy of the circuit schematic, which illustrates how each piece of equipment is connected to the process control module, in this manual.
- Carefully consider the response of your process control setup during and after power losses. A properly wired setup should protect the system and operators from hazardous conditions whenever power is lost, and should remain in a safe state after power is reestablished.
- Keep in mind that all process control channels are set to Manual Mode, INACTIVE, every time the IGC100 controller is powered up (this should be considered a Fail-safe state). You must switch the appropriate channels to Auto Mode to restart automated operation after every power up.
- No process control actions take place based on ionization gauge readings while the gauge is establishing emission current or while the gauge is degassing.
- To prevent relay arcing, use transient absorbers when connecting inductive loads, such as motors or solenoids, to the process relays. It may be necessary in some cases to use an external power relay driven by a process relay to switch a device on and off.

Why Use Process Control?

Fully automatic vacuum system operation is universally recognized as the most effective way to provide:

- Reproducible process conditions → increased productivity
- Fault protection → decreased down-time
- Unattended operation → more efficient use of operators' time
- Safe operation in the hands of inexperienced users → reduced chances of errors and accidents
- System automation for repetitive processes → automate repetitive events such as sample loadings and pump downs

One of the best ways to improve process yield and reduce system failure is through automation. Process automation is most important in complex systems or in systems operated by inexperienced personnel. The process control capabilities of the IGC100 make it unnecessary for the operator to be physically present to operate valves and/or actuate switches at the right time. In fact, an IGC100 with an embedded web server (Opt. 02) provides remote control capabilities from anywhere in the world.

The IGC100 Process Control Option is commonly used to,

- Automatically control vacuum components such as valves, heaters, power supplies, shutters and other process equipment.
- Interlock process control operations with external signals that are related to time, pressure, temperature, gauge status, system status, TTL logic levels and other parameters.
- Automatically control pumpdown, venting and load-lock procedures.
- Signal when a process is complete or alert operators to system conditions that require their attention.
- Link process control channels together to create powerful system logic to control a wide variety of functions.
- Automate repetitive operations.
- Use e-mail notification to warn operators about possible system problems over the internet (requires Web-interface, Opt. 02).
- Control a system remotely through the computer or web interfaces.

Process Control Basics

An IGC100 controller fitted with a Process Control Board, Opt. 03, becomes a powerful and versatile vacuum system controller. The process control board provides eight independent channels for system automation. Each channel has a relay closure output, and associated opto-isolated TTL output logic signal, that may be linked to a variety of input sources through user-programmable rules.

When in AUTO mode, the state of a channel is linked to the readings from an input source. This input source can be:

- any pressure gauge or analog input
- the system clock
- ion gauge emission status
- a dedicated TTL input pin

Channel Rules define the exact conditions under which channels change state during automated operation. The parameters required to fully specify a rule include:

- input source
- setpoint (level, polarity and hysteresis)
- setpoint delay
- channel description and labels
- audio alerts

Process control programming is fast, straight-forward and designed for non-programmers. A complete listing of the Rule editing menus can be found in Chapter 3 of this manual, and will not be reproduced in this chapter.

During automated operation, the output status of all eight channels can be monitored in real time from the front panel (see Process Control Display in Chapter 3). Also, eight dedicated Process Control LEDs (located below the screen) and programmable audio alarms are available to announce process control events.

Manual Override is available for all channels. This allows channel relays and their TTL outputs to be operated directly from the front panel.

All process control events are automatically time stamped and recorded in the Process Control Log. Use the [History] QuickKey in the Process Control Display to review the log. Note that the log is erased when the power is turned off.

The Process Control option also includes 12 opto-isolated TTL inputs. These inputs can be used to remotely control various controller functions including:

- gauge on/off
- degas on/off
- IG filament select
- IG lockout
- Data Log reset
- touchscreen disable

ACTIVE vs INACTIVE

The state of a process control channel is either ACTIVE or INACTIVE.

ACTIVE

When a process control channel is ACTIVE,

- its TTL output is logic low
- its relay is energized or on - the Common and Active (normally open, N.O.) pins are connected together
- its channel LED on the front panel is ON

INACTIVE

When a process control channel is INACTIVE,

- its TTL output is logic high
- its relay is de-energized or off - the Common and Inactive (normally closed, N.C.) pins are connected together
- its channel LED on the front panel is OFF

When a process control channel is in Auto mode, it becomes ACTIVE when the conditions specified by its rule's parameters are met.

Manual operation of the channel output is possible using Manual Override from the front panel or over a computer interface.

Power-On State

All process control channels are set to Manual Mode and INACTIVE, when the IGC100 is powered up. The user must switch the required channels back to Auto Mode to restart automated operation every time the unit is powered up.

Programming Rules

The process control board provides eight independent channels for system automation. Each channel has a relay closure output and associated opto-isolated TTL output signal.

The channel state may be controlled (1) manually (Manual Override below) or
(2) automatically, by linking its state to an input source through user-programmable rules.

While in AUTO mode, the state of a channel can be linked to the readings from (1) any pressure gauge or analog input, (2) the system clock, (3) ion gauge status and (4) a dedicated TTL input pin.

Channel Rules define the exact conditions under which channel state activation or deactivation takes place during automated operation. The parameters required to fully specify a rule include (1) input signal (source), (2) activation setpoint (level, polarity and hysteresis), (3) delay and (4) audio alerts. For channels linked to gauges, the user must also specify a channel state for when the gauge is off or in a fault condition.

Process control programming is fast, straight-forward and designed for non-programmers. Rule editing menus do not require any prior programming experience, and present choices in a simple format.

The variety of signal sources available to every channel provides process control versatility that extends beyond what has been traditionally expected from vacuum gauge controllers. For example, one channel could open the main gate valve every time the PG1 readings from the main chamber drop below a user-specified level, while the next channel controls overnight bakeouts, by using the clock to power a heating envelope during off-hours.

For More Information

Consult Chapter 3 of this manual for a complete description of the Process Control menus, parameters and displays used to program, monitor and control the process control module. See Chapter 7 for information about controlling the process channels over a remote computer interface.

Manual Override

Manual Override is available for all channels, making it possible to manually operate channel relays and TTL outputs directly from the front panel.

Manual control of the channels is performed from the Process Control Display.

Use the [Process] or [Back to Process] QuickKey to bring up the Process Control Display screen. This display consists of eight Channel Data Boxes, each displaying state and configuration information for a process control channel.

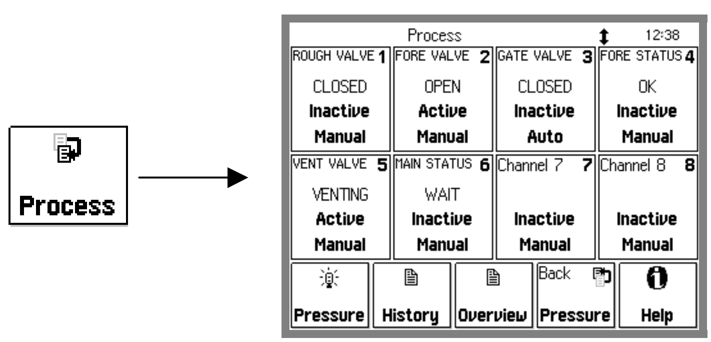


Figure 5-1. Process Control Display.

Touch a Channel Data Box to choose a channel state (Active, Inactive or Auto) or edit the channel rules and labels.

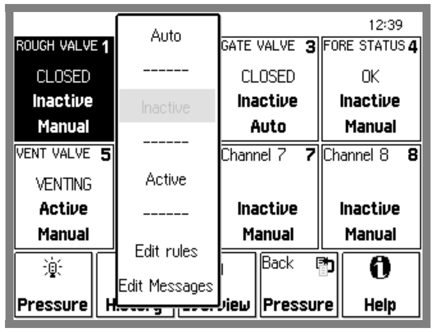


Figure 5-2. Channel Options.

Choose...

'Inactive' to manually DEACTIVATE the channel

'Active' to manually ACTIVATE the channel

'Auto' to switch the channel to Auto mode - its state is now controlled by the channel rules

'Edit Rules' to edit the channel rules

'Edit Labels' to edit the text and audio options for the channel

Recommendations

Always use Manual Operation to test your process control connections before switching to (and relying on) automatic rules for channel operation.

Use Manual Override to quickly switch an automated procedure to manual control in an emergency.

Use Channel Labels to display real system names and states for each channel. This eliminates confusion over which channel is connected to which device.

All process control channels default to Manual Mode, INACTIVE, when the IGC100 controller is first turned on.

For More Information

Consult the Process Control sections of Chapter 3, including descriptions of the Process Control Display, Channel Data Boxes and Rules Editing menus.

Fail-Safe Logic

WARNING!

When equipment malfunction or power loss could cause a hazardous situation, always provide fail-safe operation.

Fail-Safe logic must be very carefully planned, designed and tested before reliance on process automation is allowed.

IGC100 users must carefully consider the behavior of their process control setup during, and after,

- system failures
- equipment malfunctions
- operator errors
- power losses

Typical "unsafe" situations that must be anticipated and accounted for in logic designs, include,

- Gauges, used as input sources for process control channels, can turn off in the middle of a process due to overpressure, gauge failure, Auto-Start events or operator error.
- Input Analog I/O ports, used as channel sources, can be mistakenly switched into outputs in the middle of a process.
- Complete power loss can result in total system shutdown.

A properly designed process control setup must respond to all of the above conditions by immediately shifting the system into a fail-safe state.

A carefully wired and programmed fail-safe state should be available to protect the equipment and operators from danger under any one of the potentially dangerous events described above.

Fail-Safe logic must be very carefully planned, designed and tested before reliance on process automation is allowed.

The following guidelines MUST be considered during fail-safe logic design,

- Channels linked to gauge readings include the "Gauge-Off/DAC State" rule. *This must be specified* to provide the proper fail-safe response in case the gauge shuts down and no pressure readings are available to the channel.

- Channels linked to analog input readings (AN1-4 and CM1-4) also include the "Gauge Off/DAC State" rule. *This must be specified* to provide the proper fail-safe response in case the analog port is mistakenly configured into an output and no voltage or capacitance manometer readings are available to the channel. This rule also applies when the analog input is in overload.

- During a power shutdown all relays are de-energized and in the INACTIVE state - Common and Inactive pins connected. *This must be carefully considered* during the design and implementation of your process control setup, to assure proper fail-safe operation during and after power losses.

- The IGC100 controller *does not automatically turn back on* once power is re-established after power loss. Instead, the user must turn the unit back on manually. During this time, all relays are de-energized and in the INACTIVE state.

- *When the IGC100 is turned on, all channels are set to Manual Mode and INACTIVE. This is considered the fail-safe operating mode.* The user must set the required process control channels back to Auto to restart automated process control every time the IGC100 controller is turned on.

Relay Connections

Each process control channel has an associated relay. The relay specifications are:

Configuration	SPDT (Single Pole, Double Throw)
Contact Rating	5 A, 250 VAC/30 VDC, resistive load only
Contact Material	AgSnOInO

Use the two 12-Position Terminal Block Plugs located on the back panel to connect to the eight process control relays. Relay pins are labeled I (Inactive), C (Common) and A (Active) for easy association to channel states.

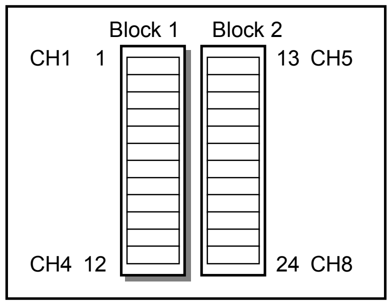


Figure 5-3. The 2 12-position terminal blocks for process relay connections.

Block	Pin	Process Channel	Process Control Label	Relay Pin
1	1	1	Common (C)	C
	2		Inactive (I)	N.C.
	3		Active (A)	N.O.
	4	2	Common (C)	C
	5		Inactive (I)	N.C.
	6		Active (A)	N.O.
	7	3	Common (C)	C
	8		Inactive (I)	N.C.
	9		Active (A)	N.O.
	10	4	Common (C)	C
	11		Inactive (I)	N.C.
	12		Active (A)	N.O.
2	13	5	Common (C)	C
	14		Inactive (I)	N.C.
	15		Active (A)	N.O.
	16	6	Common (C)	C
	17		Inactive (I)	N.C.
	18		Active (A)	N.O.
	19	7	Common (C)	C
	20		Inactive (I)	N.C.
	21		Active (A)	N.O.
	22	8	Common (C)	C
	23		Inactive (I)	N.C.
	24		Active (A)	N.O.

Note: Block #2 must be removed in order to be able to access its side screws.

Connection Basics

When a process control channel is ACTIVE its relay is energized, or on, connecting the Common and Active (N.O.) pins. Active Pins are labeled 'A' on the back panel, and correspond to the Normally Open pin of the SPDT relay.

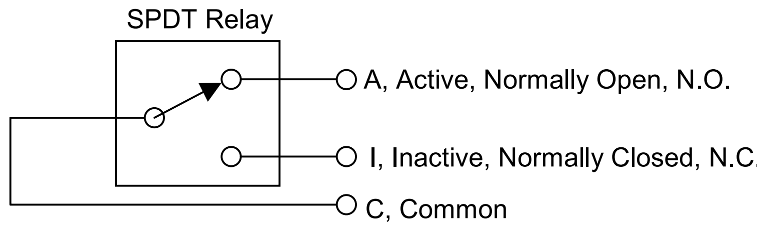


Figure 5-4. Active relay connection.

When a process control channel is INACTIVE its relay is de-energized, or off, connecting the Common and Inactive pins. Inactive Pins are labeled 'I' on the back panel, and correspond to the Normally Closed pin of the SPDT relay.

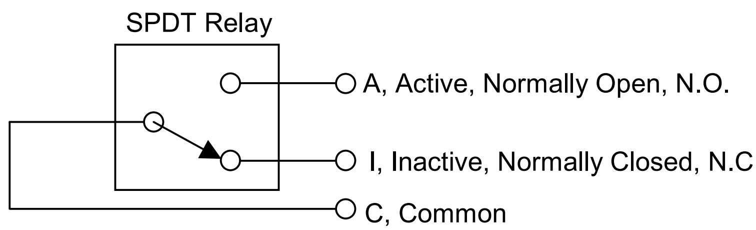


Figure 5-5. Inactive relay connection.

Connection Schemes

Process control relays have three pins and three connection schemes are possible.

Active-Common

The relay is wired as a single throw switch, with connections to the Active and Common pins only. Contact closure takes place during the ACTIVE state of the channel. Contact is open during the INACTIVE state of the channel and during power shutdowns. For example, use this connection to turn a heater on and off, using the relay as a power switch. Heat is available only when the channel state is ACTIVE.

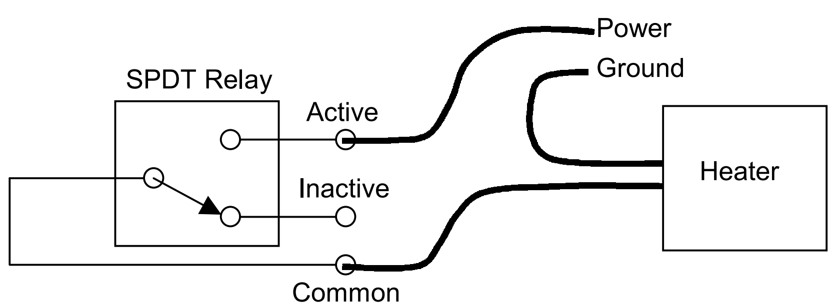


Figure 5-6. Using a relay as a power switch. (Shown in Inactive state.)

In this case, the Active and Common connections may be swapped. Connecting as shown prevents power from appearing on the Inactive pin when the channel is Inactive.

Inactive-Common

The relay is also wired as a single throw switch, but with connections to the Inactive and Common pins. Contact closure takes place during the INACTIVE state of the channel. Contact between the pins is also established during power shutdowns (fail-safe state). For example, use this connection scheme to turn an auxiliary power supply on after a main power failure. As the main power shuts down, the relay is deactivated, delivering backup power to the experiment. In general, use this connection scheme whenever you need a contact to open during the active state of the channel.

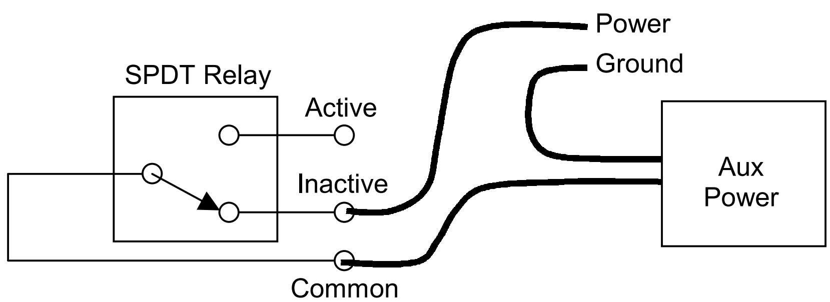


Figure 5-7. Using a relay as a back-up power switch. (Shown in Inactive, power-off state.)

In this case, the Inactive and Common connections may be swapped. Connecting as shown prevents power from appearing on the Active pin when the channel is Active.

Active-Common-Inactive

The relay is used as a true double throw switch, with connections to its three pins. As an example, consider a system where an electrical power source is shared between two instruments (#1 and #2), but only one instrument is powered at a time (sequential operation). In this scheme, the supply wire is connected to the Common pin and the Active and Inactive pins are connected to the power input pins of instruments #1 and #2, respectively. Switching the channel state between ACTIVE and INACTIVE redirects the power from instrument #1 to instrument #2.

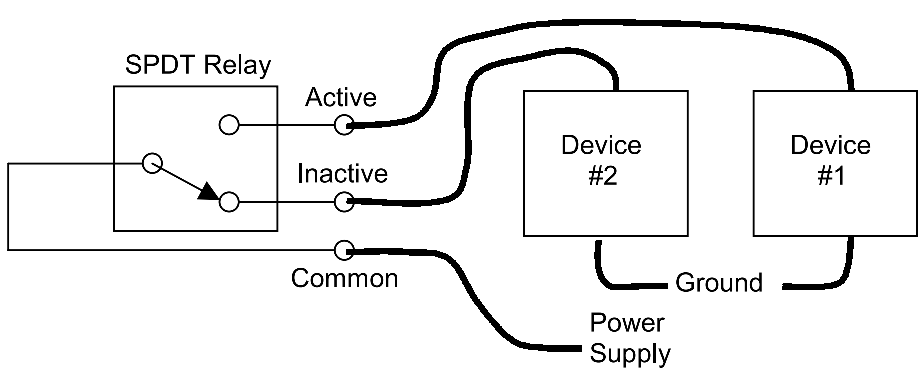


Figure 5-8. Using a relay as a power multiplexer. (Shown in Inactive, power-off state.)

A similar scheme could be used to monitor (sequentially) two separate sensors from a single-input reader (signal multiplexing). In this case, the reader's input is connected to Common, and sensors 1 and 2 connect to pins A and I of the relay, respectively. Activate the channel to monitor sensor 1, or deactivate the channel to switch to sensor 2.

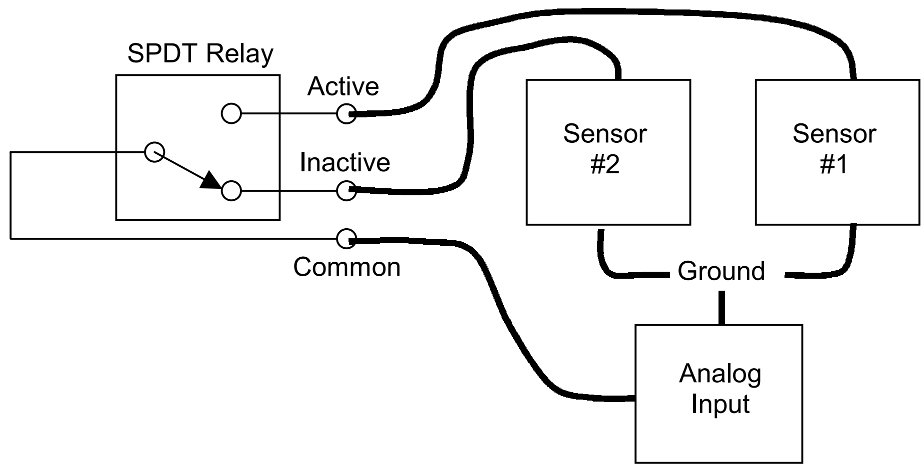


Figure 5-9. Using a relay as a signal multiplexer. (Shown in Inactive, power-off state.)

Connection Tips

- Both Terminal Block Plugs can be disconnected from the back panel, making it possible to transfer the controller to a different location without having to undo the relay connections. Spare Terminal Blocks are also available from Stanford Research Systems for lab environments where more than one wire connection scheme is used.
- Make sure all wire ends are securely fastened to the Terminal Block Plugs, always tighten the wire-lock screws.
- Block #2 (Relays 5-8) must be disconnected from the process control board in order to be able to access its side wire-lock screws. Gently pry the block out with a small screwdriver using the access slots in the panel above and below the connector.
- Relays are used in vacuum systems for many different purposes:
  - Power distribution/switching to system components such as gate valve actuators, heating jackets, etc.
  - Interlocking. Many pump controllers include relay closure detection ports designed for interlocking purposes.
  - Signal multiplexing. For example, it is not unusual to multiplex a single input temperature reader between two temperature sensors.
  - Sound alarms on/off.
  - Start/stop processes
- In order to prevent costly mistakes, label every cable connected to the process control relays with an unambiguous name. Include the pin#, pin label, and channel# in case the cable comes loose and needs to be reattached to the controller.

- Do not exceed the relay ratings: 5 A/250 VAC/30 VDC, resistive load, during operation.
- Use transient absorbers when connecting inductive loads, such as motors or solenoids, to the process relays. It may be necessary in some cases to use an external power relay driven by a process relay to switch a device on and off.
- Ensure that all process control channels are under manual control, and in the desired state, prior to connecting a wired terminal block plug into the process control board's receptacle.
- During a power shutdown, all relays are de-energized and switch to their INACTIVE state - i.e. Common and Inactive pins connected. This must be carefully considered during the design of your process control setup, to assure proper fail-safe operation during and after power losses.

Channel Linking

Process control relays can be linked together to create powerful system logic and control complicated functions. As an example, consider the implementation of an overnight bakeout system with over-temperature protection. Since heating jackets have been known to runaway and cause serious system damage, it is always a good precaution to add a safeguard system that will shut down the heating power if the temperature generated by the heater exceeds the maximum allowed threshold. This is easily implemented with the IGC100 if a thermocouple is attached to the vacuum system and its amplified voltage signal is monitored through one of the Analog I/O ports of the controller. A straightforward implementation of this function might be: (1) link channel 1 to the clock and program its activation period throughout the middle of the night, (2) link channel 2 to the AN1 thermocouple readings and program it to activate at voltage readings below the maximum allowed temperature value, (3) connect the channel 1 and channel 2 relays in series, using the Active-Common connection described above, and use the dual-switch combination as a power switch for the heater's power cord. Under this configuration, heating is only possible if channel 1 AND Channel 2 are both simultaneously Active. If the temperature exceeds the maximum specified value (channel 2 deactivated), or the bakeout time expires (channel 1 deactivated), no electrical power can flow into the heating jacket and the bakeout is interrupted.

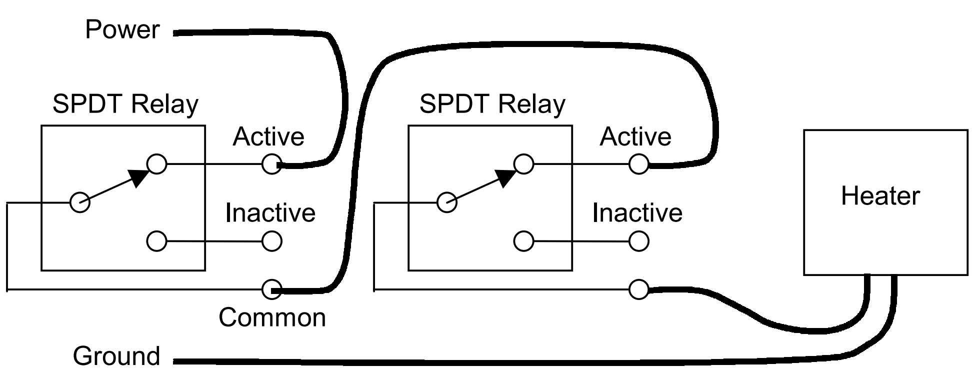


Figure 5-10. Using two relays in series to provide an interlock function. (Both relays shown in Active state.)

Remote Operation

Channel relays can be operated remotely through the computer (RS-232 or GPIB) and web (Opt. 02) interfaces. Use this convenient feature to control experiments or processes from anywhere in the world. For example, turn off your bakeout jackets from home before leaving for work, so that the system can cool down during your commute and is ready to start an experiment as you get into the lab.

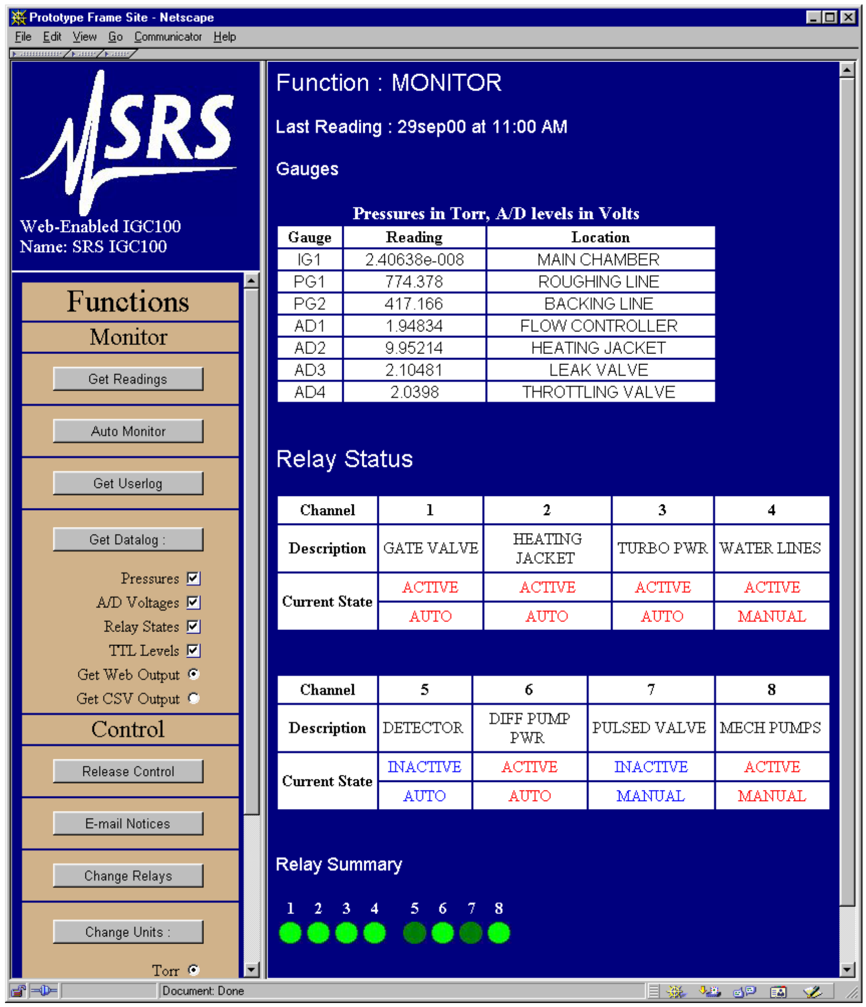


Figure 5-11. IGC100 web page showing relay status and control via the internet.

Digital I/O Module

The DIGITAL I/O module included with the Process Control board supports three types of logic signals. The TTL signals are opto-isolated from the IGC100 chassis. The inputs may be electrically floated as a group. The outputs may be electrically floated as a group, separate from the inputs.

TTL Input (8 pins)

Each process control channel has a dedicated TTL input pin. While in AUTO mode, channel control can be linked to this TTL input. The logic level (TTL HIGH or LOW) responsible for channel activation must be specified by the user (factory default setting is active low, meaning that the channel is ACTIVE when the logic level on the pin is LOW.)

TTL Output (8 pins)

Each process control channel has a dedicated TTL output signal. Following common industry standards, all process control TTL output signals are Active Low - when a process control channel is ACTIVE, the corresponding TTL output is logic LOW. INACTIVE means the channel's TTL output pin is logic high.

Remote Control Input (12 pins)

The Process control option also includes 12 TTL logic inputs for remote logic control of various controller functions.

- Ionization gauge IG1/IG2 On/Off
- Degas On/Off
- Ionization gauge filament selection
- Ionization gauge lockout
- Ionization gauge keypad disable
- Pirani gauge PG1/PG2 On/Off
- Data log clear/reset
- Touchscreen disable

Recommendation

Use the Remote Control TTL inputs to control important IGC100 functions remotely, without the need for a computer interface. A common application is clearing the data logging buffer to synchronize the start of the data log with a particular event, such as (1) the opening of a gate valve or (2) the achievement of full speed by a turbo pump. Gate valve and turbo pump controllers often provide logic outputs compatible with the remote control module. Remote control inputs can also be interfaced with Programmable Logic Controllers' signals.

Digital I/O Connections

Use the female DB37 port located on the back panel of the IGC100 controller (labeled DIGITAL I/O) to connect to the (1) eight PC TTL Output, (2) eight PC TTL input, and (3) 12 Remote Control TTL input pins of the Process Control Board.

Note

A Male DB37 connector is included with every IGC100 controller shipped directly from Stanford Research Systems to facilitate interfacing of the TTL I/O port to your system.

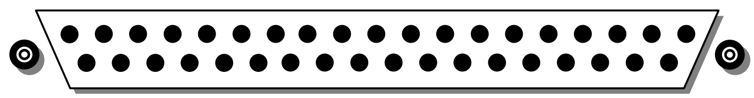


Figure 5-12. DB37 TTL I/O connector.

TTL I/O Pin Assignments

Pin	Module	Name	Description
1		IGC100 Vcc	+5 V OUT
2	**Remote Control TTL IN**	ANODE COM	External User +5 V IN
3		IG1_On	Edge trigger: ↓=IG1 On, ↑=IG1 Off
4		IG2_On	Edge trigger: ↓=IG2 On, ↑= IG2 Off
5		Degas_On	Edge trigger: ↓= Degas On, ↑=Degas Off
6		IG_Lockout	Level: LOW=IG1 and IG2 emission Off
7		IG_Key_Disable	Level: LOW=Disable front panel IG Keypad.
8		PG1_Off	Edge trigger: ↓=PG1 Off, ↑=PG1 On
9		PG2_Off	Edge trigger: ↓=PG2 Off, ↑=PG2 On
10		Clear_Data_Log	Edge trigger: ↓=clear the data log
11		IG_Remote_Enable	Level: HIGH=Ignore IG1_On, IG2_On, Degas_On, FIL1_On, FIL2_On pins.
12		FIL1_On	Edge trigger: ↓=FIL1 ON, ↑=FIL1 Off
13		FIL2_On	Edge trigger: ↓= FIL2 ON, ↑= FIL2 Off
14		Front_Panel_Disable	Level: LOW=Disable Touchscreen and Keypad
15		IGC100 Vcc	+5 V OUT

Pin	Module	Name	Description
16	**Process Control TTL OUT**	TTL_OUT_5	TTL OUT for Channel 5. LOW=ACTIVE
17		TTL_OUT_6	TTL OUT for Channel 6. LOW=ACTIVE
18		TTL_OUT_7	TTL OUT for Channel 7. LOW=ACTIVE
19		TTL_OUT_8	TTL OUT for Channel 8. LOW=ACTIVE
20	**Process Control TTL IN**	ANODE COM	External User +5 V IN
21		TTL_IN_1	TTL Input Signal for Channel 1. Active LOW
22		TTL_IN_2	TTL Input Signal for Channel 2. Active LOW
23		TTL_IN_3	TTL Input Signal for Channel 3. Active LOW
24		TTL_IN_4	TTL Input Signal for Channel 4. Active LOW
25		TTL_IN_5	TTL Input Signal for Channel 5. Active LOW
26		TTL_IN_6	TTL Input Signal for Channel 6. Active LOW
27		TTL_IN_7	TTL Input Signal for Channel 7. Active LOW
28		TTL_IN_8	TTL Input Signal for Channel 8. Active LOW
29		unused	
30		IGC100 Ground	
31		IGC100 Ground	
32	**Process Control TTL OUT**	COM_EMTR_REF	External User Ground
33		COM_COLTR_PULLUP	External User +5 V IN
34		TTL_OUT_1	TTL OUT for Channel 1. LOW=ACTIVE
35		TTL_OUT_2	TTL OUT for Channel 2. LOW=ACTIVE
36		TTL_OUT_3	TTL OUT for Channel 3. LOW=ACTIVE
37		TTL_OUT_4	TTL OUT for Channel 4. LOW=ACTIVE

Note

↓=HIGH-to-LOW, ↑=LOW-to-HIGH

Unconnected inputs are HIGH.

Input Circuit

The TTL inputs are opto-isolated from the IGC100. The schematic of a TTL input is shown below.

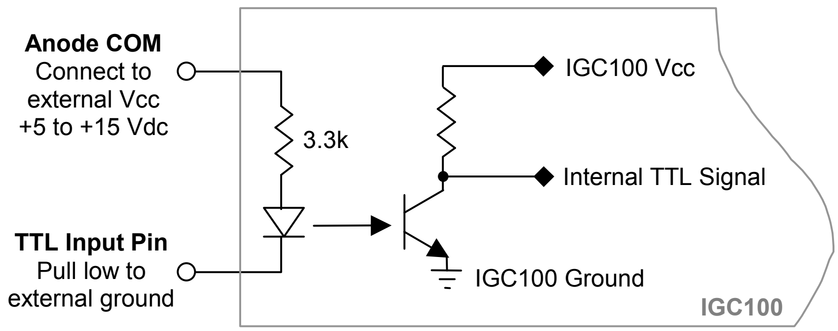


Figure 5-13. TTL input pin schematic.

For isolated operation of ALL TTL inputs, connect ANODE_COM (pins 2 and 20) to the external Vcc supply (+5 to +15 Vdc). Pull inputs to external ground for low inputs.

For non-isolated operation of ALL TTL inputs, connect ANODE_COM (pins 2 and 20) to IGC100 Vcc (pin 1 or 15) and pull inputs to IGC100 Ground (pin 30 or 31) for low inputs.

In both cases, leaving an input unconnected or open is equivalent to a HIGH input.

Output Circuit

The TTL outputs are opto-isolated from the IGC100. The schematic of a TTL output is shown below.

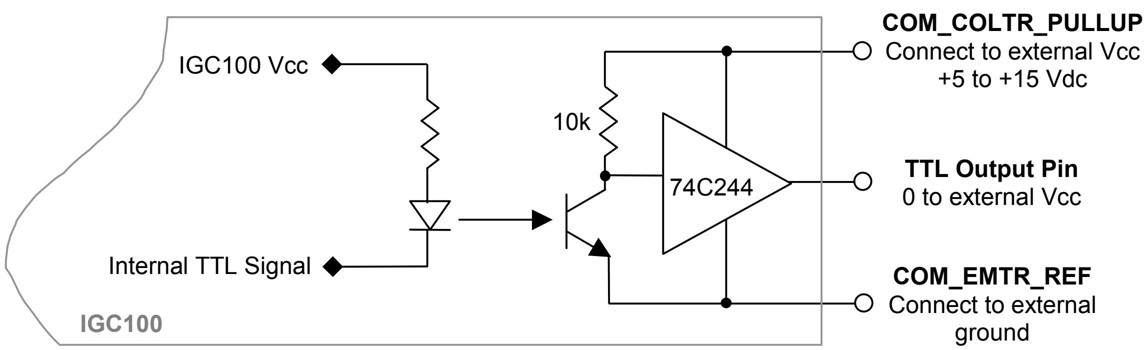


Figure 5-14. TTL output pin schematic.

For isolated operation of ALL TTL outputs, connect COM_COLTR_PULLUP (pin 33) to the external Vcc supply (+5 to +15 Vdc) and COM_EMTR_REF (pin 32) to the external ground. The TTL output will be external 0 V or Vcc (low or high).

For non-isolated operation of ALL TTL outputs, connect COM_COLTR_PULLUP (pin 33) to IGC100 Vcc (pin 1 or 15) and COM_EMTR_REF (pin 32) to IGC100 Ground (pin 30 or 31). The TTL output will be external 0 V or 5 V (low or high).

Connection Tips

- All TTL inputs may be connected to respond to relay closure signals, such as those provided by the mechanical position indicators of gate valves, or full speed indicators of turbomolecular pump controllers.
- Input and output pins can be linked together to create powerful system logic and control a wide variety of system functions. For example, Process Control TTL outputs can be connected to Remote Control TTL inputs and used to control functions such as powering gauges on/off or clearing the Data Log.
- The use of external TTL logic circuitry to provide additional logic manipulation of the TTL I/O signals complements the process control capabilities of IGC100. For example, connect the TTL I/O pins to an external PLC (programmable logic controller) or a home-built logic circuit to extend the capabilities of the process control ports.
- Use the TTL output signals to operate external relays, with ratings exceeding those of the built-in relays.
- Use the TTL outputs to indicate the status of the individual process control channels to external devices such as computers, logic analyzers and PLCs.

Debounce Time

A 50 ms debounce time is standard for ALL TTL inputs (Process Control and Remote Control). This prevents spurious glitches on the TTL lines from triggering process control events or controller functions.

For a level-triggered input, the debounce time is the minimum amount of time the input signal must remain unchanged, at the new logic level, before that level is recognized by the IGC100 and triggers a process control event or controller function.

For an edge-triggered Remote Control input, the debounce time is the length of time during which the input signal must remain unchanged following a level transition, before the edge is validated by the IGC100 and triggers a controller function.

Remote Control Inputs

IG_On

Pins: 3 for IG1; 4 for IG2
Trigger mode: Edge, ↓= ON, ↑= OFF
Debounce time: 50 ms

Prerequisites:

- Pressure in the IG is adequately low
- IG_Remote_Enable is logic LOW
- IG_Lockout is logic HIGH

Pulling an IG_On control line LOW, after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, turns the gauge on. The input must remain LOW until it is required to turn the IG off.

Either IG can be turned off through the remote input by

- Switching the IG_On input HIGH after it has been LOW for at least 50 ms
- Turning the other ionization gauge on
- Pulling the IG_Lockout pin LOW

Degas_On

Pin: 5
Trigger mode: Edge, ↓= ON, ↑=OFF
Debounce time: 50 ms

Prerequisites:

- IG is turned on
- IG pressure is below $5x10^{-5}$ Torr
- IG_Remote_Enable is logic LOW
- IG_Lockout is logic HIGH

Pulling the Degas_On control line LOW, after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, starts the degassing process on the active IG. The input must remain LOW for the duration of the degas process. Degassing takes place for a period specified by the Degas Time.

Degas can be terminated before the Degas Time has elapsed through the remote input by

- Switching the Degas_On input HIGH after it has been LOW for at least 50 ms
- Turning the ionization gauge off
- Pulling the IG_Lockout pin LOW.

IG_Lockout

Pin: 6
Trigger mode: Level. LOW = IG1 and IG2 off, HIGH = Normal IG operation.
Debounce time: 50 ms

Prerequisites:

- IG_Remote_Enable is logic LOW

HIGH allows normal IG operation (unconnected default).

LOW forces the IGs to turn off, and stay off - any request to turn an IG on is denied as long as the IG_Lockout line remains LOW. This applies to requests from the front panel keys and the computer interfaces.

Recommendation

IG_Lockout is one of the most useful remote control lines and is often used to interlock IG emission. For example, the IG_Lockout line is often connected to the logic output of the mechanical position indicator of a load lock's vent valve. If the vent valve is opened (indicating that high pressure is present in the load lock chamber), the IG shuts down, and any attempt to turn it back on is denied, effectively protecting its filament.

Fil_On

Pins: 12 for Filament 1; 13 for Filament 2
Trigger mode: Edge, ↓= ON, ↑=OFF
Debounce time: 50 ms

Prerequisites:

- IG_Remote_Enable is logic LOW

Pulling the Fil1_Onf control line LOW after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, selects Filament 1 for IG emission. The input must remain LOW until it is required to turn the filament off.

Pulling the Fil2_On remote control line LOW after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, selects Fil2 for IG emission. The input must remain LOW until it is required to turn the filament selection off.

Select Filament 1 and Filament 2, as described above, to use both filaments in the IG emission.

Turning both filaments off turns off the gauge.

IG_Remote_Enable

Pin:	11
Trigger mode:	Level. HIGH = ignore IG1_On, IG2_On, Degas_On, Fil1_On and Fil2_On pins.
Debounce time:	50 ms

Prerequisites:

- None

The IG_Remote_Enable line must be LOW for the IGC100 Remote Control Module to acknowledge the edge triggers from the IG1_On, IG2_On, Degas_On, Fil1_On and Fil2_On pins.

If unconnected, this pin will be HIGH and remote control is disabled (default).

Recommendation

This pin is often used to enable/disable Remote Control of ionization gauge functions. For example, it might be useful to lock the remote control signals during an electrically noisy process to prevent logic glitches from accidentally affecting IG operation.

IG_Key_Disable

Pin:	7
Trigger mode:	Level, LOW = Disable front panel IG Keypad.
Debounce time:	50 ms

Prerequisites:

- None

HIGH allows manual operation of ionization gauges from the front panel IG Keypad (IG1, IG2, DEGAS, and IG AUTO buttons).

If unconnected, this pin will be HIGH and the IG Keypad is operational (default).

LOW locks out the IG keypad: the IG1, IG2, DEGAS and IG AUTO keys have no function as long as this line remains LOW.

Recommendation

IG_Key_Disable is often used to lock the front panel IG keypad during a process or experiment, and block inexperienced users from ruining a run.

PG_Off

Pins: 8 for PG1; 9 for PG2
Trigger mode: Edge, ↓= PG OFF, ↑= PG ON
Debounce time: 50 ms

Pulling the PG_Off control line LOW after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, turns the Pirani gauge off. The input must remain LOW until it is required to turn the PG on.

The Pirani gauge can be turned on by switching the PG_Off control line HIGH after it has been LOW for at least 50 ms. The input must remain HIGH until it is required to turn the PG off.

Recommendation

Use the PG_Off lines to control Pirani gauges in the presence of dangerous gases. For example, connect the PG_Off line to the mechanical position indicator of a valve used to deliver flammable gases, so that the PG is turned off whenever flammable gas is flowing into the chamber.

Clear_Data_Log

Pin: 10
Trigger mode: Edge, ↓= Clear the data log.
Debounce time: 50 ms.

Pulling the Clear_Data_Log control line LOW after it has been high for at least 50 ms, and holding the line LOW for at least 50 ms, clears and resets the data log.

Recommendation

Use this input to synchronize the start of data logging with an important event such as a gate valve closing, a turbo pump achieving full rotational speed or a heating cycle getting started. For example, connect the Clear_Data_Log line to the logic output of your gate valve's mechanical position indicator to restart the data log buffer every time the gate valve is opened. This is useful for the collection of pump down curves. Connect the Clear_Data_Log line to a logic signal from your temperature controller indicating the start of a heating ramp, to monitor the entire temperature profile of a TPD experiment.

Front_Panel_Disable

Pins: 14
Trigger mode: Level, LOW = Disable front panel touch screen LCD and keypad
Debounce time: 50 ms

HIGH allows normal operation of the touchscreen display (unconnected default).

LOW locks the touchscreen LCD. The display does not respond to touches.

Recommendation

The Front_Panel_Disable signal is often used to lock the front panel and block unauthorized changes to the controller during a process or experiment.

Automated Pumpdown Example

The following example is intended to provide ideas on how to use the IGC100 process control capabilities to automate vacuum system procedures.

The same basic control concepts can be applied to almost any kind of system ranging from the simple experimental setups found in research labs to the more complex vacuum equipment used in production environments.

> **WARNING**
> Since the operating conditions of a process vary according to (1) the application, (2) the system configuration and (3) the user's preferences, the example provided should only be used as general guideline and should not be applied without the appropriate modifications to any real system.

Recommendation

The process control capabilities of the IGC100 are not limited to vacuum system control only. IGC100 controllers are also routinely used to automate, and/or control, many other lab related processes such as (1) laser firing and interlocking, (2) mass spectrometer sample loading and automated data acquisition, (3) mass spectrometer detector and ionizer protection, (4) heat treatment cycles, (5) signal multiplexing in multiple input measurements, etc. It is very likely that many repetitive procedures you currently perform during your daily lab routine could be automated, and even controlled remotely, with the help of an IGC100.

Pumpdown Automation

This example is intended to provide ideas on how to automate the most universal high vacuum repetitive procedure - Main Chamber Pumpdown from atmosphere.

The steps controlled by the IGC100 involve:

1. Roughing the chamber
2. Switching to turbo pumping at the cross-over pressure
3. Turning the ionization gauge on
4. Sending e-mail notification when the chamber pressure goes below $2x10^{-5}$ Torr or when dangerous overpressure is detected in the foreline (requires Web interface Opt. 02).

When implemented properly, a procedure such as this will allow any IGC100 user to start a main chamber pumpdown and then walk-away, while the IGC100 does all the work. Pumpdown completion is notified via e-mail. There is no need to constantly revisit the lab to check on the pressure. Use any internet browser to check on the system while pump down is in progress. As examples, automated pumpdown is very useful in a mass spectrometer after a new sample is loaded into the vacuum chamber, and also in a processing setup after a new substrate is loaded into a coating machine.

Vacuum System Diagram

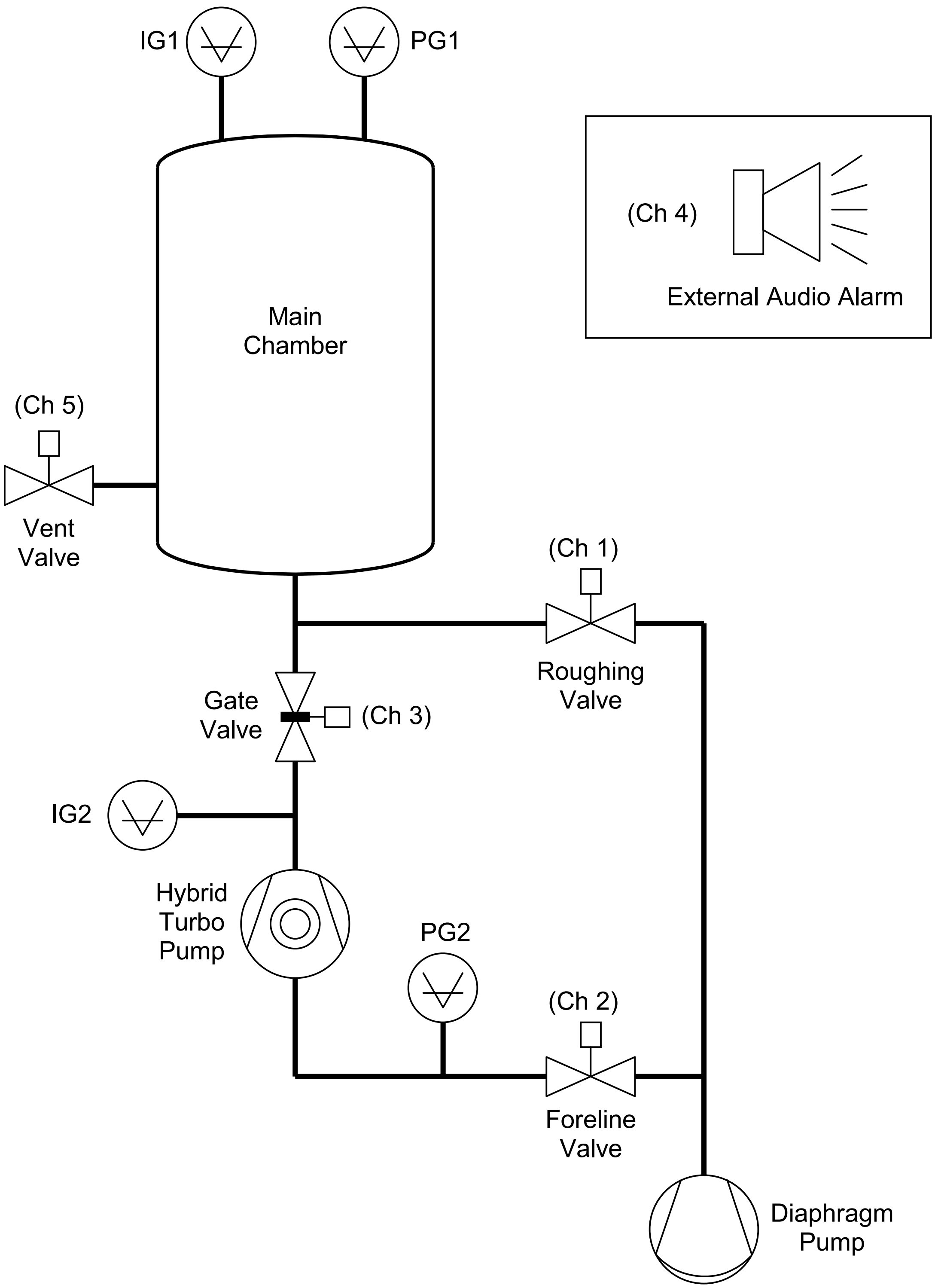


Figure 5-15. Example vacuum system diagram.

Components

PG1 - Pirani Gauge - Main Chamber

Monitors the Main Chamber pressure between 10^{-4} and 1000 Torr. A PG105-UHV gauge is used for compatibility with UHV construction.

IG1 - Ionization Gauge - Main Chamber

Monitors the Main Chamber pressure between $2x10^{-10}$ and $2x10^{-3}$ Torr. Operated in Auto-Start mode, its filament turns on automatically when PG1 pressure falls below $2x10^{-3}$ Torr during automated pumpdown.

IG2 - Ionization Gauge – Turbo Pump

Monitors the Turbo Pump pressure below the Gate Valve. It is not used by the automated pumpdown procedure, but is an essential component of this vacuum setup.

PG2 - Pirani Gauge - Foreline

Monitors the Foreline pressure, which should never exceed 1 Torr (except briefly) in this system.

Roughing Valve

Pneumatically actuated valve controlled by process channel 1, programmed to close automatically after PG1 pressure drops below 0.1 Torr (cross over pressure) while in Auto mode. Channel description: Rough Valve

Foreline Valve

Pneumatically actuated valve controlled by process channel 2, programmed to open 30 seconds after the PG1 pressure drops below 0.1 Torr (cross over pressure) while in Auto mode. The 30 second delay avoids pressure surges into the back of the turbo pump after the valve is opened. Channel Description: Fore Valve

Gate Valve

Pneumatically actuated valve controlled by process channel 3, programmed to open 60 seconds after PG1 pressure drops below 0.1 Torr (cross over pressure) while in Auto mode. The 60 second delay provides 30 seconds additional delay from the time the foreline valve is opened, and assures complete stabilization of the turbo pump speed before its inlet is exposed to the main chamber. Channel description: Gate Valve.

External Audio Alarm

Controlled by process channel 4, programmed to sound a loud alarm when the PG2 pressure exceeds 1 Torr for longer than 30 seconds. This warns of potential problems, since such large foreline pressures should never develop during normal pumpdown. An e-mail notification message should also be linked to channel 4 activity if a Web Interface connection is available and the user is planning to be away from the vacuum lab during parts of the process.

Vent Valve

Pneumatically actuated valve controlled by process channel 5, operated manually and only opened to pressurize the main chamber to atmosphere during ventings. This valve remains closed and under Manual control throughout the entire Pumpdown procedure. Channel Description: Vent Valve.

Connections

All valves used in the system considered here are pneumatically actuated and require +24 Vdc power to be delivered to the air control solenoid valve to open. All valves are connected following the Active-Common scheme (described earlier), with the channel relay acting simply as a switch between the +24 Vdc line from the power supply and the solenoid valve. The +24 Vdc power supply wire connects to the Active pin and the solenoid power input is connected to the Common pin of the relay. As a result, all valves are OPEN in the ACTIVE state of their channel. When the power is off, all channels are INACTIVE and all valves will be CLOSED.

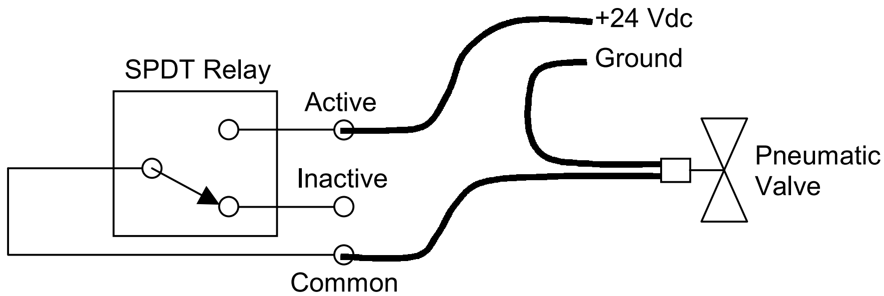


Figure 5-16. Pneumatic valve to relay connections (shown in INACTIVE or closed state).

The external alarm is controlled by channel 4 and requires +24 Vdc power to sound. It is connected to the relays in the same way as the valves - the alarm sounds when the channel goes ACTIVE.

Process Specification Table

The following table lists the parameter values used to program the rules of the six process control channels used by the Automated Pumpdown Procedure.

The channel descriptions and ACTIVE/INACTIVE messages are selected to be informative of the status of the process. For example, channel 1 is described as "Rough Valve" and programmed to display a "Roughing" message while its valve is open. Similarly, channel 6 is described as "Main Status" and displays a "Wait" message while the pressure in the Main Chamber remains above the $2x10^{-5}$ Torr setpoint.

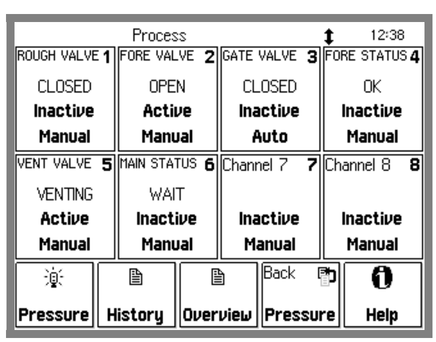


Figure 5-17. Process Control Display showing Channel Data Boxes with messages and descriptions for this example.

No electrical connections are made to the channel 6 outputs since it is only used for status notification through the front panel and e-mail messaging.

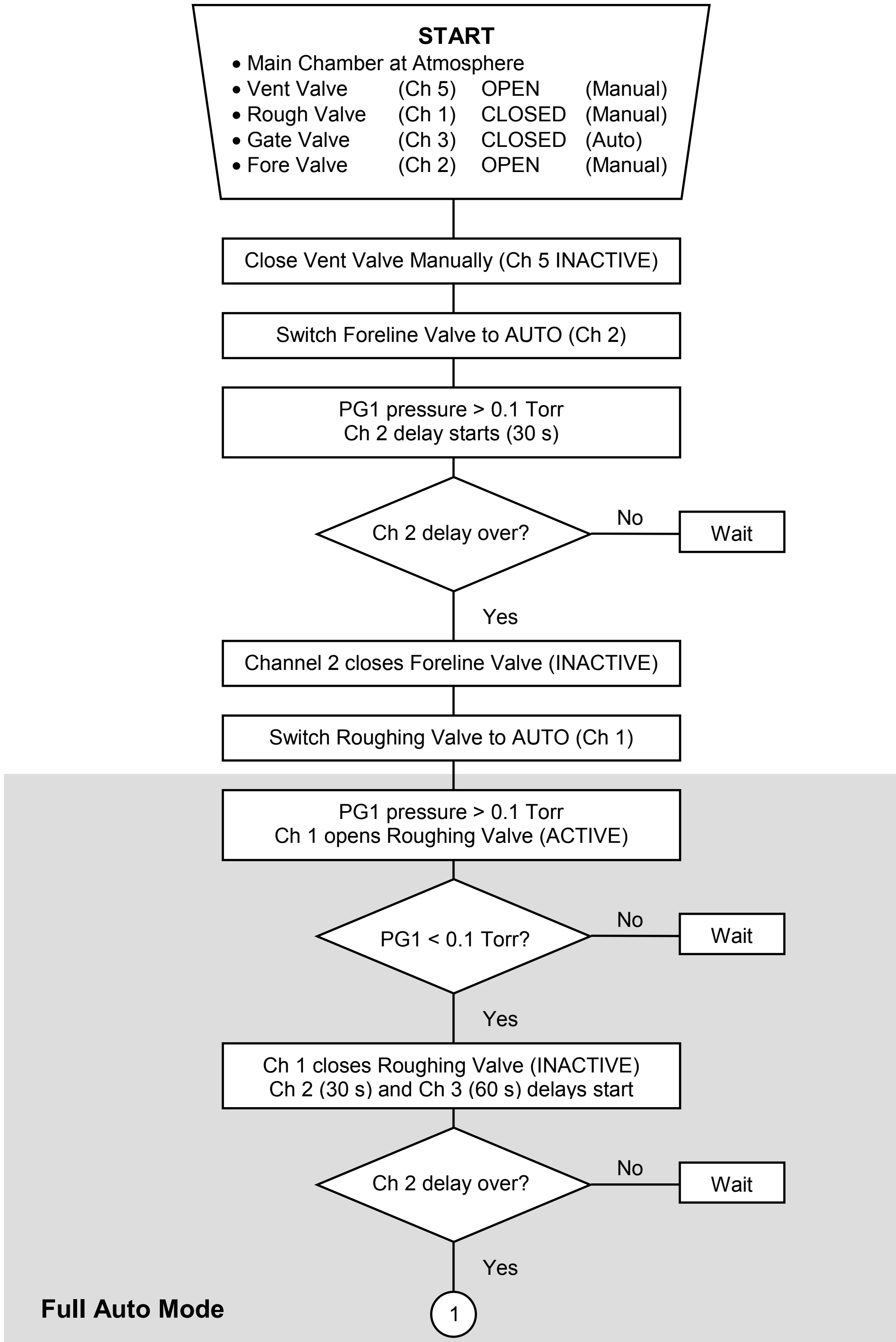
Channel 4 controls a loud external alarm and sends an e-mail message when it goes ACTIVE. E-mail notification through the Web interface (requires Option 02 installed) makes it possible to be away from the lab while the pump down takes place.

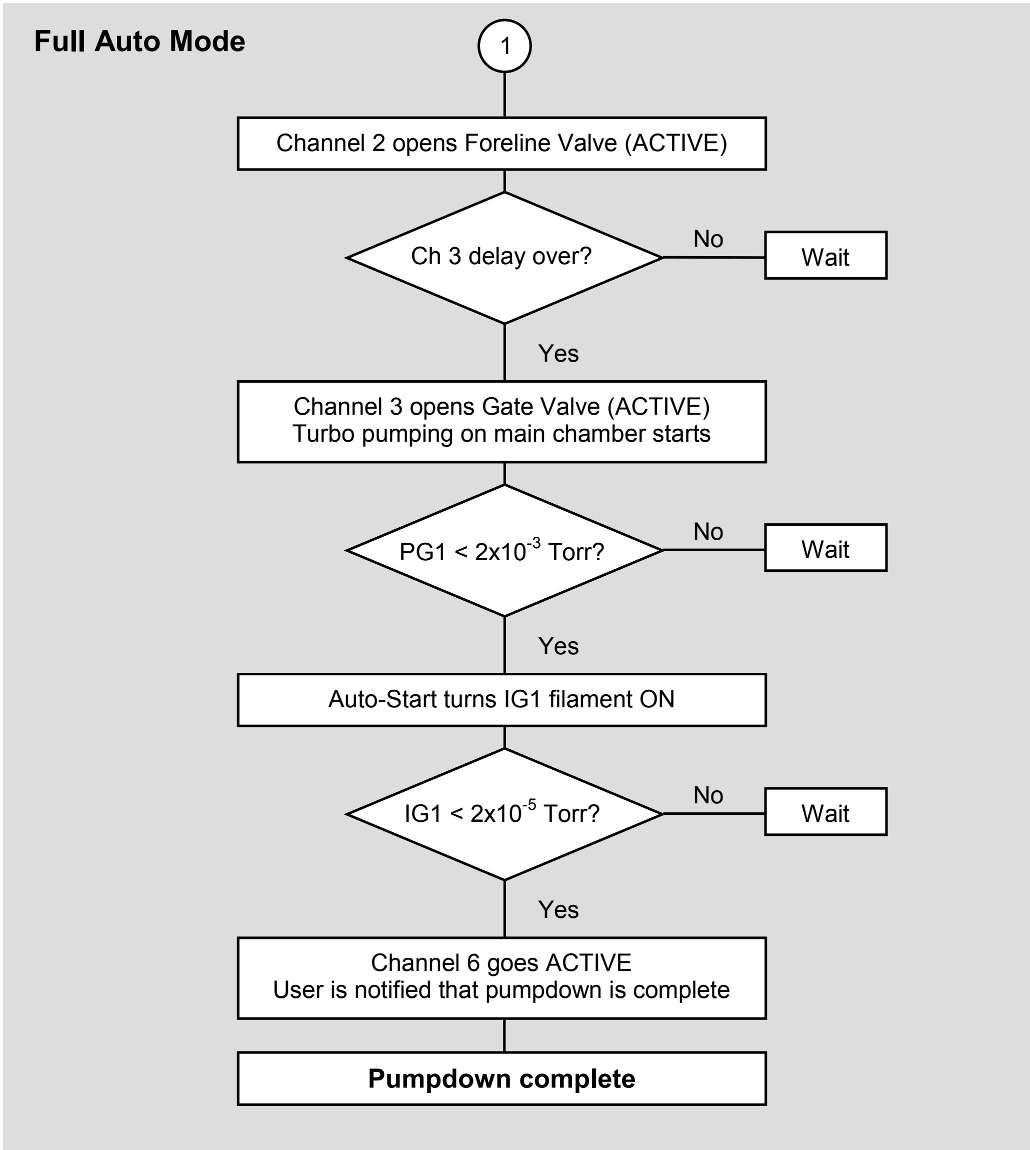
Process Name: **Pumpdown**										
Channel# (Description)	**Linked to…**	**Setpoint (above / below)**	**Hyst (%)**	**Delay (sec)**	**Off-State**	**E-mail (✓)**	**Beep (✓)**	**Active Msg**	**Inactive Msg**	**Relay Wiring pin**
1 (Rough Valve)	PG1	0.1 Torr (above)	0	0	INACTIVE		✓	Roughing	Closed	1 (C) Solenoid
										2 (I)
										3 (A) +24Vdc
2 (Fore Valve)	PG1	0.1 Torr (below)	0	30	INACTIVE		✓	Open	Closed	4 (C) Solenoid
										5 (I)
										6 (A) +24Vdc
3 (Gate Valve)	PG1	0.1 Torr (below)	0	60	INACTIVE		✓	Open	Closed	7 (C) Solenoid
										8 (I)
										9 (A) +24Vdc
4 (Fore Status)	PG2	1 Torr (above)	0	30	INACTIVE	✓	✓	Problem	OK	10 (C) Alarm pwr
										11 (I)
										12 (A) +24Vdc
5 (Vent Valve)	Manual mode only	( )					✓	Venting	Closed	13 (C) Solenoid
										14 (I)
										15 (A) +24Vdc
6 (Main Status)	IG1	$2x10^{-5}$ Torr (below)	0	0	INACTIVE	✓	✓	Ready	Wait	16 (C)
										17 (A)
										18 (I)
7 ( )		( )								19 (C)
										20 (A)
										21 (I)
8 ( )		( )								22 (C)
										23 (I)
										24 (A)

Process Flow Diagram

IMPORTANT

No matter how simple a process appears to be, it is always recommended to develop a logic diagram to check and step through the process.




Full Auto Mode
1
Channel 2 opens Foreline Valve (ACTIVE)
Ch 3 delay over?
No
Wait
Yes
Channel 3 opens Gate Valve (ACTIVE)
Turbo pumping on main chamber starts
PG1 < 2x10^-3 Torr?
No
Wait
Yes
Auto-Start turns IG1 filament ON
IG1 < 2x10^-5 Torr?
No
Wait
Yes
Channel 6 goes ACTIVE
User is notified that pumpdown is complete
Pumpdown complete

Process Steps

1. The sequence is started by closing the Vent valve manually and switching the Foreline valve (Ch 2) to AUTO mode.
2. Since the pressure on PG1 is at atmosphere (above the Ch 2 setpoint), the Foreline valve automatically closes after 30 seconds (Ch 2 INACTIVE).
3. Once the Foreline Valve closes, switch the Roughing Valve (Ch 1) to AUTO.
4. Since the pressure at PG1 is atmosphere (above the Ch 1 setpoint) the Roughing valve is automatically opened (Ch 1 ACTIVE) and rough pumping of the Main Chamber starts. The Gate valve and the Foreline valve remain safely closed while the chamber pumps down. *At this point the IGC100 automation capabilities take over and no more user involvement will be required.* The Roughing, Foreline and Gate valves are under full automatic control.
5. The pressure in the main chamber drops as it is pumped out through the roughing line. As soon as the pressure on PG1 goes below the cross over value, (0.1 Torr), the Roughing valve is closed (Ch1 INACTIVE), and delays are triggered for the Fore valve (Ch2, 30 seconds) and Gate valve (Ch 3, 60 seconds).
6. After a 30 second delay, the Foreline valve is opened, switching the roughing line to the back of the turbo pump (Ch 2 ACTIVE). The short delay is enough to assure proper stabilization of the roughing line pressure before exposing the turbo pump to the diaphragm pump.
7. After an additional 30 seconds, and once the turbo pump speed has stabilized, the Gate valve opens exposing the main chamber to the turbo pump inlet (Ch 3 ACTIVE).
8. At this point the system starts pumping down towards its $2x10^{-5}$ Torr target, monitored through channel 6.
9. Once the pressure in the main chamber reaches the $2x10^{-3}$ Torr value (as measured by PG1), the IG Auto-Start turns on the IG1 filament and pressures are now tracked through the ionization gauge. Note that this does not involve any process control channels.
10. As soon as the main chamber pressure measured by IG1 drops below the $2x10^{-5}$ Torr target, channel 6 activates and an e-mail message is sent out to the prespecified address list to announce the achievement of base pressure. The process is now completed.
11. Upon completion of pumpdown, it is common practice in this system to switch the Roughing valve (Ch 1) to Manual Control and INACTIVE, so that the Roughing valve remains closed if the Vent valve is accidentally opened. It is also recommended to eliminate the delays from channels 2 and 3 to provide immediate Gate valve and Foreline shutdowns (pressure interlock) in the event of an overpressure.

Process Control Worksheet

Process Name:										
Channel# (Description)	**Linked to…**	**Setpoint (above / below)**	**Hyst (%) (V)**	**Delay (sec)**	**Off-State**	**E-mail (✓)**	**Beep (✓)**	**Active Msg**	**Inactive Msg**	**Relay Wiring pin**
1										1 (C)
										2 (I)
										3 (A)
2										4 (C)
										5 (I)
										6 (A)
3										7 (C)
										8 (I)
										9 (A)
4										10 (C)
										11 (I)
										12 (A)
5										13 (C)
										14 (I)
										15 (A)
6										16 (C)
										17 (A)
										18 (I)
7										19 (C)
										20 (A)
										21 (I)
8										22 (C)
										23 (I)
										24 (A)

Chapter 6

Memory Card

IGC100 includes a MEMORY CARD module on its front panel. This module consists of a long vertical slot specifically designed to accept a special type of information storage device referred to as Memory Card throughout this manual.

In This Chapter

Introduction

Figure 6-1. Front panel Memory Card module.

There are two kinds of Memory Cards compatible with IGC100:

Calibration Cards

For applications that benefit from gauge-to-gauge reproducibility and the accuracy of calibrated gauges, SRS offers NIST-traceable calibrated ionization gauges through its High-Vacuum Calibration Facility. Full-range calibrations are available with 6% and 3% accuracy. Gauge-specific calibration data, including all relevant controller setup information, is factory loaded into a Memory Card provided with the calibrated gauge. The calibration data is easily uploaded into the controller via the front panel MEMORY CARD module. See Calibration Storage in the IGC100 and Cal Curve Loading sections below for additional details.

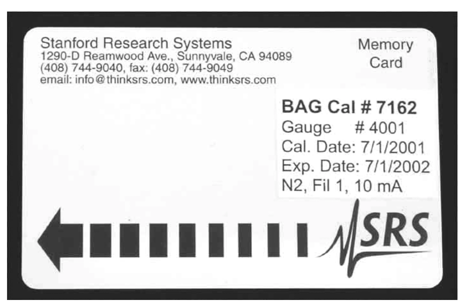


Figure 6-2. Calibration Card.

Password Cards

Security Passwords can be copied into special memory cards known as Password Cards. Password cards make it unnecessary to remember the password in order to unlock a controller. Simply insert the Password Card (preloaded with the current password) into the memory card slot to unlock the controller at any time. The controller returns to the locked state as soon as the card is removed.

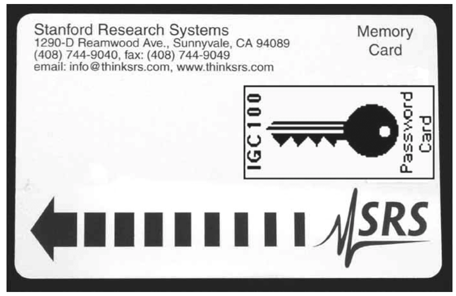


Figure 6-3. Password Cards.

TIP

Three blank Password Cards are provided with every IGC100 controller. Consult the Security Menu section of chapter 3 for details on the security options built into the IGC100 controller.

Calibration Storage in the IGC100

The IGC100 controller has the capability to store in memory a full-range calibration curve and a sensitivity constant (for nitrogen) for each ionization gauge connected to its back panel. An intuitive, front-panel menu selection allows the user to switch effortlessly between the two calibration sources during pressure measurements.

IGC100 users can have their ionization gauges calibrated at the certified SRS High Vacuum Calibration Facility. The BAG response is calibrated below10^{-3} Torr by comparison against a NIST-traceable secondary standard and the information is stored in a Memory Card that is returned to the user with the gauge. The calibration curve, including all relevant instrument setup information, can then be easily transferred into the controller using the Memory Card Module built into the front panel of the instrument. For details on calibration options consult the Calibration Procedure section of appendix F.

Since all SRS IGC100 instruments offer identical electrical performance, calibrated gauges can be operated from any IGC100 controller without any significant change in the accuracy of the results. For the same reason, the actual IGC100 controller used for real measurements does not need to be present at the SRS High Vacuum Calibration Facility during the calibration procedure.

IGC100 uses full-range calibration data to display accurate pressure readings in real time without the need for pressure-dependent corrections outside the box. The estimated expiration date for the gauge calibration is stored in the memory card and transferred to the controller along with the rest of the calibration header information.

Although in principle it should be possible to calibrate a gauge for one gas and use this calibration for another by simply multiplying by the corresponding gas correction factor, investigations have shown that this is not the case if high accuracy (<10%) is required. Specific calibration for each specific gas is recommended in that case.

Loading a Calibration Curve

The IGC100 controller has the capability to store in memory a full-range calibration curve for each ionization gauge connected to a back panel port (IG1 or IG2).

All calibrated ionization gauges are delivered from the factory with a Memory Card which contains calibration data specific to the gauge. The calibration data stored in a Memory Card is easily transferred into the controller through the MEMORY CARD interface of the front panel using the step-by-step procedure described below:

Step 1. Insert the gauge's Memory Card into the MEMORY CARD slot located on the front panel of the instrument.

Figure 6-4. Insert the card into the controller.

Step 2. Starting from the Pressure Display Screen, touch the [Gauges] QuickKey to access the Gauge Display.

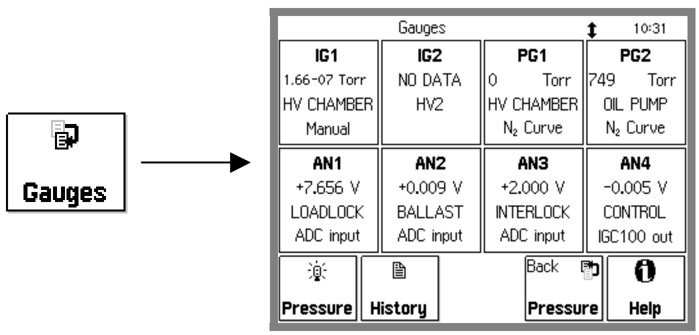


Figure 6-5. Gauge Display.

Step 3. Select the gauge's port (IG1 or IG2) by touching its display button (Data Box). This brings up a Gauge Setup menu for the ionization gauge's port.

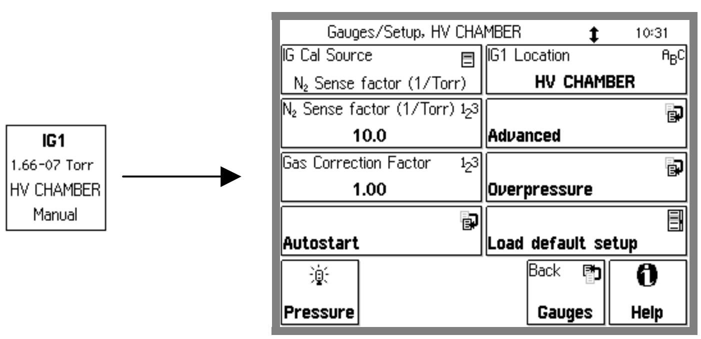


Figure 6-6. Gauge Setup menu.

Step 4. Touch [Advanced] to display the Advanced submenu for the gauge's port.

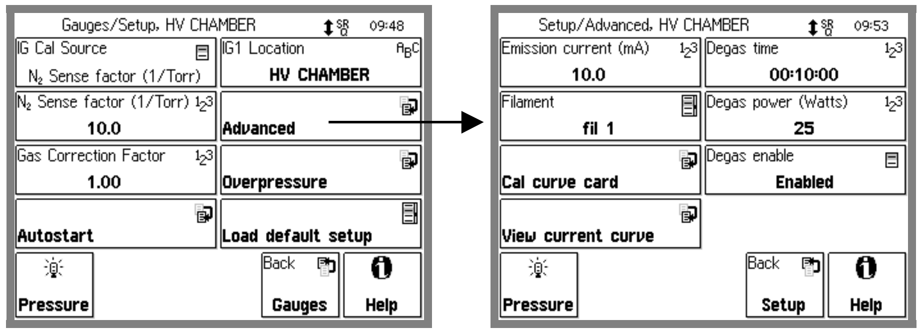


Figure 6-7. Advanced Ion Gauge Setup menu.

Step 5. Touch [Cal Curve Card] to display header information for the Calibration data stored in the memory card.

TIP

A preview of the header information stored in the memory card is a very convenient feature designed to eliminate the chances of errors. Check the model and serial numbers of the ionization gauge connected (or to be connected) to the controller against the card's header information before uploading the card's Calibration Data into the controller.

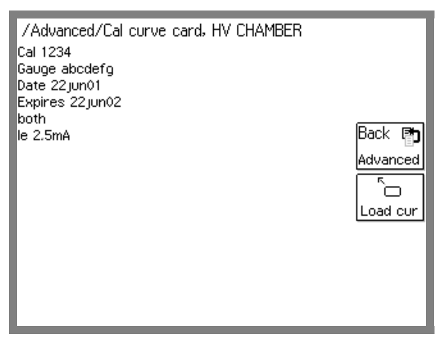


Figure 6-8. Preview the Calibration Card header info.

Step 6. Touch [Load Cur] to transfer the Calibration data into the controller's memory.

Step 7. Pull the Memory Card out of the front panel and store it in a safe place.

Once the calibration data is successfully loaded into the controller, choose Cal Curve as the IG Cal Source in the gauge setup menu of the port, and the IGC100 will automatically be configured to match the setup conditions required for the calibration data.

TIP

Consult appendix F of this manual for details on the ionization gauge calibration options available from the High Vacuum Calibration Facility at Stanford Research Systems.

Password Card Programming

Security Passwords can be copied into special memory cards known as Password Cards using the procedure described below.

IMPORTANT

The security system must be unlocked before using this function. Unlock the security system at this time if necessary . Follow the instructions in the Security Menu section of Chapter 3 to unlock the system.

Step 1. Insert a blank Password Card into the MEMORY CARD module slot.

Step 2. Starting from the Pressure Display Screen, touch the [Menu] QuickKey to access the Main Menu.

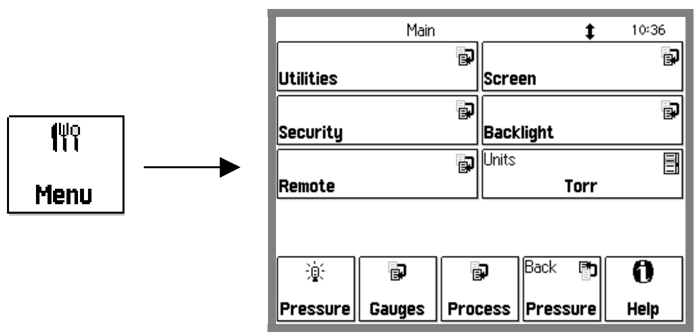


Figure 6-9. Main Menu.

Step 3. Touch [Security] to display the Security submenu.

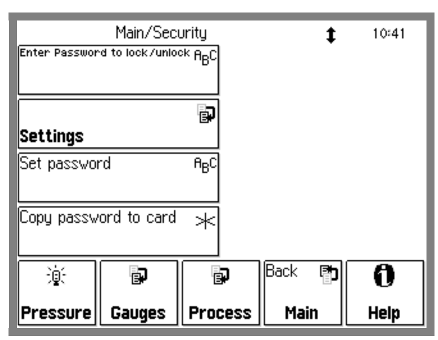


Figure 6-10. Security menu.

Step 4. Touch [Set Password] and enter a new password using the alphanumeric keypad.

Step 5. Touch [Copy Password to card] to store a copy of the password in the memory card (i.e. password card).

Step 6. Remove the card from the MEMORY CARD Slot. The controller reverts to a locked state as soon as the card is removed.

Password cards make it unnecessary to remember the password in order to unlock a controller. Simply insert the Password Card (preloaded with the current password) into the memory card slot to unlock the controller at any time. The controller returns to the locked state as soon as the card is removed. A unit locked after removing a password card can also be unlocked by manually typing the password through the security menu.

Chapter 7

Remote Programming

In This Chapter

Index of Commands

Important
Always use the GPMU command at the start of a program to ensure that the desired units are in effect. Use front panel lockout if a units change would result in system malfunction.

Use VERB 0 to set the RS-232 interface to terse mode for computer programs. Use VERB 1 to use verbose mode for console communications.

Variables

i, j, d, n, p	integers
x	real number
s, t	text strings

Gauges and Measurement

GPMU (?) {n} {s}	7-17	Pressure Units
GPBA (?) n {, i}	7-17	Data Bar Assign
GPDF (?) n {, i}	7-17	Display Format
GDAT ? p	7-18	Read Gauge/Port
GDTX ? p	7-18	Read Gauge/Port With Units
GDES (?) p {, s}	7-18	Gauge Location
GSTA ? p	7-18	Gauge Status
GSTT ? p	7-19	Gauge Status Time

Ion Gauge Setup

GPOW (?) p {, i}	7-20	Power
CSEN (?) p {, x}	7-20	Sensitivity Factor
CGCF (?) p {, x}	7-20	Gas Correction Factor
CRVI (?) p {, i}	7-20	Calibration Source
IGEC (?) p {, x}	7-20	Emission Current
GFIL (?) p {, i}	7-21	Filament Select
GPLV (?) p {, i}	7-21	Gauge Protection
GOSD (?) p (, i}	7-21	Overpressure Shutdown
GOTH (?) p {, x}	7-21	Overpressure Threshold
GODE (?) p {, n}	7-21	Overpressure Delay
GOAA (?) p {, i}	7-22	Overpressure Audio Alarm
DGAS (?) {i}	7-22	Degas On/Off
DENA (?) {i}	7-22	Degas Enable/Disable
DPOW (?) p {, n}	7-22	Degas Power
DTIM (?) p {, x}	7-22	Degas Time
AOPG (?) {i}	7-23	Auto-Start Pirani Gauge
AOIG (?) {i}	7-23	Auto-Start Ion Gauge
AOTH (?) {x}	7-23	Auto-Start Threshold
AOCN (?) {i}	7-23	Auto-Start On/Off
GHGF ?	7-23	Read Gauge History First
GHGN ?	7-23	Read Gauge History Next

Pirani Gauge Setup

GPOW (?) p {, i}	7-24	Power
CGCF (?) p {, x}	7-24	Gas Correction Factor
CRVP (?) n {, i}	7-24	Calibration Curve

Alphabetical List of Commands

Important
Always use the GPMU command at the start of a program to ensure that the desired units are in effect. Use front panel lockout if a units change would result in system malfunction.

Use VERB 0 to set the RS-232 interface to terse mode for computer programs. Use VERB 1 to use verbose mode for console communications.

Variables

i, j, d, n, p	integers
x	real number
s, t	text strings

Introduction

The IGC100 Ion Gauge Controller may be remotely programmed via either the standard RS-232 serial interface or the optional GPIB (IEEE-488) interface. Any computer supporting one of these interfaces may be used to program the IGC100. All installed interfaces are active at all times.

WARNING!
The VERB command sets the instrument's RS-232 verbosity level. When set to 0 (FALSE), the instrument uses terse return values and error messages for RS-232 computer programs. When set to 1 (TRUE) the instrument uses descriptive return values and error messages for human remote operators. *Set VERB first when connecting to the instrument via RS-232.*

Communicating With RS-232

The IGC100 uses a DIN8 connector for serial communications. Most PC computers use DB9 ports. Use the DIN8-DB9 adapter cable provided with the IGC100 to connect to a PC. The female DB9 connector is configured as a DCE (transmit on pin 2, receive on pin 3) device and supports CTS/DTR hardware handshaking. The CTS signal (pins 1, 6 and 8) is an output indicating that the IGC100 is ready, while the DTR signal (pin 7) is an input that is used to control the IGC100's data transmission. Ground is pin 5. If desired, the handshake pins may be ignored and a simple 3 wire interface (pins 2, 3 and 5) may be used. The RS-232 interface Baud Rate, Word Length, Parity and Flow Control must be set in the Main/Remote/RS-232 menu.

Communicating With GPIB

With Option 01 installed, the IGC100 supports the IEEE-488.1 (1978) interface standard. It also supports the required common commands of the IEEE-488.2 (1987) standard. Before attempting to communicate with the IGC100 over the GPIB interface, the IGC100's Device Address must be set in the Main/Remote/GPIB menu.

Screen Indicators And Queues

To assist in programming, the IGC100 has an interface activity indicator displayed in the upper right corner of the screen (next to the time). The arrow symbol ⬍ flashes whenever there is interface activity (transmit or receive). The **X** symbol indicates a computer interface error has occurred, such as an illegal command or out of range parameter is received. The **SRQ** indicator is on when the IGC100 generates a GPIB service request. **SRQ** stays on until a GPIB serial poll is completed.

To help find program errors, the IGC100 can display the interface buffers on the screen. This screen is accessed by touching [Queue] in the Main/Remote/RS-232 or GPIB menus. The Queue display may slow down communications and should be displayed only when testing or debugging a host program. Press a QuickKey to exit from this display.

The upper half of the Queue display is the Receive Queue. These are the most recent characters which have been received by the IGC100 (displayed in all UPPER case). Commands which have already been executed are shown in normal text. Commands which have not yet been executed are shown with a gray background. Command errors are shown in inverse text.

The lower half of the Queue display is the Transmit Queue. These are the most recent characters which have been placed in the output buffer. Characters which have already been sent over the interface are shown in normal text. Characters which are waiting to be sent are shown with a gray background.

Command Format

Communications with the IGC100 uses ASCII characters. Commands may be in either UPPER or lower case. A command to the IGC100 consists of a four character command mnemonic with optional ?, arguments if necessary, and a command terminator. The command, arguments and terminator may be separated by spaces. The terminator must be a linefeed <lf> or carriage return <cr> on RS-232, or a linefeed <lf> or EOI on GPIB. No command processing occurs until a terminator is received. Commands function identically on GPIB and RS-232 whenever possible. Command mnemonics beginning with an asterisk '*' are IEEE-488.2 (1987) defined common commands. These commands also function identically on RS-232 whenever possible. Commands may require one or more parameters. Multiple parameters are separated by commas (,).

Multiple commands may be sent on one command line by separating them with semicolons (;). In this case, no commands are executed until a terminator is received.

There is no need to wait between commands. The IGC100 has a 256 character input buffer and processes commands in the order received. If the buffer fills up, the IGC100 will hold off handshaking on the GPIB and attempt to hold off handshaking on RS-232. Similarly, the IGC100 has a 256 character output buffer to store output until the host computer is ready to receive it. If either buffer overflows, both buffers are cleared and an error reported.

The present value of a particular parameter may be determined by querying the IGC100 for its value. A query is formed by appending a question mark '?' to the command mnemonic and omitting the desired parameter from the command. Values returned by the IGC100 are sent as a string of ASCII characters terminated by a carriage return <cr> on RS-232 and by a line-feed <lf> on GPIB. If multiple query commands are sent on one command line (separated by semicolons, of course), the answers will be returned individually, each with a terminator.

Examples of Commands

GADM 4, 1 <lf>	Set Analog Port 4 to DAC output mode
GADM? 4 <lf>	Query the mode of Analog Port 4
GDAT? 1 <lf>	Query the reading of IG1
*IDN ? <lf>	Query the Device Identification String

Command Synchronization

IFC (Interface Ready, bit 7) in the Serial Poll status signals that the IGC100 is ready to receive and execute a command. When a command is received, this bit is cleared, indicating that command execution is in progress. No other commands will be processed until this command is completed. Commands received during this time are stored in the buffer to be processed later. Only GPIB serial polling will generate a response while a command is in progress. When all pending commands have executed, the IFC bit is set again. By checking IFC with serial polls, a host computer can ensure that all previously sent commands have finished before sending a new command.

Since most commands execute very quickly, the host computer does not need to continually check the IFC bit. Commands may be sent one after another and they will be processed immediately.

However, some commands, such as memory card and data transfer operations, may require a long time to execute. In addition, the host program may need to check that these operations executed without error. In these cases, after the command is sent, the status should be queried.

When using the GPIB interface, serial polling may be used to check the IFC bit in the Serial Poll status while an operation is in progress. After the IFC bit becomes set, signaling the completion of the command, then the ESB (Event Status) bit may be checked to verify successful completion of the command.

If the RS-232 interface is used, or serial polling is not available, then the *STB? query command may be used to read the Serial Poll status word. However, *STB *NEVER* returns the IFC bit set (since *STB is itself a command).

Since the IGC100 processes one command at a time, status queries will not be processed until the previous operation is finished. Thus a response to a status query in itself signals that the previous command is finished. The query response may then be checked for various errors.

Command Syntax

The four letter mnemonic (shown in CAPS) in each command sequence specifies the command. The rest of the sequence consists of parameters. Parameters shown in { } are not always required. Generally, parameters in { } are required to set a value in the IGC100. Multiple parameters are separated by commas. Multiple commands may be sent on one command line by separating them with semicolons (;).

The present value of a parameter may be determined by sending a query command.

- Commands that MAY be queried show a question mark in parentheses (?) after the mnemonic.
- Commands that are ONLY queries have a '?' after the mnemonic, with no parentheses.
- Commands that MAY NOT be queried have no '?'.

A query is formed by including the question mark ? after the command mnemonic and omitting the queried parameter from the command. The query parameters shown in { } are NOT sent with a query. The query returns the value of these parameters. Values are returned as a string of ASCII characters (unless otherwise noted).

Do NOT send ( ) or { } as part of the command.

For example, the command sequence GADM (?) i {, j} is used as follows.

GADM 1, 0	Set the Analog Port 1 to ADC Input mode.
GADM ? 1	Query the mode of Analog Port 1.

Variables are defined as follows.

i, j, d, n, p	integers
x	real number
s, t	text strings

Commands to set values which may be different for each port require the p parameter. These values must be queried separately for each port.

All numeric variables may be expressed in integer, floating point or exponential formats (i.e. the number five can be either 5, 5.0, or 0.5E1). Strings are sent as a sequence of ASCII characters.

Pressure Units

The entire IGC100 operates with a **SINGLE** units system. All commands that query or set pressure parameters use the global units system of the IGC100. The units may be changed in the Main Menu or with the GPMU command.

For example, if the IGC100 units are Torr, all commands that query pressures will return values in Torr. All commands that set pressures must send values in Torr.

All pressure parameters have minimum and maximum allowed values. These values are converted to the current units and may not be exceeded in a command. These limits are displayed in the entry screen when entering new values from the front panel.

WARNING!
Always use the GPMU command at the start of a program to ensure that the desired units are in effect. Use the Local Access Security feature if a units change would result in system malfunction. See Chapter 3 (Security Menu) for details.

Gauge and Measurement Commands

GPMU (?) {n} {s}

Pressure Units

The GPMU command sets (queries) the system pressure units. The parameter n selects the units system below, or use string s ("micron", "bar", etc.). Do not use both n and s.

n	units
0	Torr
1	micron
2	bar
3	mbar
4	Pascal

Example

GPMU?	Returns the pressure units n.
GPMU 1	Sets the pressure units to microns.
GPMU pascal	Sets the pressure units to Pascal.

GPBA (?) n {, i}

Data Bar Assign

The GPBA command sets (queries) the Data Bar assignments in the Pressure Display (Port ID). The parameter n selects Upper (0), Middle (1) or Lower (2) Data Bar and is required. The parameter i selects a signal port below.

i	port	i	port	i	port
1	IG	4	CM1	8	AN1
2	PG1	5	CM2	9	AN2
3	PG2	6	CM3	10	AN3
		7	CM4	11	AN4

Example

GPBA? 0	Returns the Port ID i of the upper Data Bar.
GPBA 2, 3	Sets the lower Data Bar to PG2.

GPDF (?) n {, i}

Display Format

The GPDF command sets (queries) the Display Format of a Data Bar. The parameter n selects Upper (0), Middle (1) or Lower (2) Data Bar and is required. The parameter i selects a Display Format below.

i	format
0	Big Numbers
1	Trend Graph
2	Auto Scaling Bar Graph
3	Full Range Bar Graph
4	Gauge Status Information

Example

GPDF? 0	Returns the display format i of the upper Data Bar.
GPDF 2, 3	Sets the lower Data Bar to Full Scale Bar Graph.

GDAT ? p

Read Gauge/Port

The GDAT? query returns the reading from port p in the current units. The parameter p selects a signal port below and is required.

p	port	p	port	p	port
1	IG1	5	CM1	9	AN1
2	IG2	6	CM2	10	AN2
3	PG1	7	CM3	11	AN3
4	PG2	8	CM4	12	AN4

The returned string has the form "1.00" with current units implied.

Example

GDAT? 1 Returns the reading of IG1 in the current units.

GDTX ? p

Read Gauge/Port With Units

The GDTX? query returns the reading from port p with units. The parameter p selects a signal port below and is required.

p	port	p	port	p	port
1	IG1	5	CM1	9	AN1
2	IG2	6	CM2	10	AN2
3	PG1	7	CM3	11	AN3
4	PG2	8	CM4	12	AN4

The returned string has the form "1.00 micron".

Example

GDTX? 1 Returns the reading of IG1 *with* the current units.

GDES (?) p {, s}

Gauge Location

The GDES command sets (queries) the Gauge (Port) Location string. The parameter p selects a gauge port below and is required. The string s is the location name.

p	port	p	port	p	port
1	IG1	5	CM1	9	AN1
2	IG2	6	CM2	10	AN2
3	PG1	7	CM3	11	AN3
4	PG2	8	CM4	12	AN4

Example

GDES 3, pump Sets the location name of PG1 to "PUMP".
GDES? 3 Returns the location name of PG1 ("PUMP" in this case).

GSTA ? p

Gauge Status

The GSTA? query returns the status of gauge port p. The parameter p selects a gauge port below and is required.

p	port	p	port	p	port
1	IG1	5	CM1	9	AN1
2	IG2	6	CM2	10	AN2
3	PG1	7	CM3	11	AN3
4	PG2	8	CM4	12	AN4

The returned value is an integer n described below.

n	description
0	The gauge is operating normally.

Values greater than 1 – gauge/port may still operate.

2	The gauge reading is underrange.
3	The gauge reading is overrange.
4	The gauge reading is not yet accurate.
5	There is no data from the gauge.

Values greater than 6 – gauge displays no data.

7	ADC is overloaded.
8	The A/D is in DAC output mode. CM gauge not running.
9	No Pirani gauge detected.

Values greater than 10 – gauge shuts down.

11	There is no data to display.
12	The Pirani gauge is off.
13	All ion gauges are off.
14	No IG filament is detected.
15	Auto-Start PG is off.

Values greater than 16, IG Auto-Start turned off.

17	An IG overpressure condition occurred.
18	The controller cannot establish IG emission current.
19	A TTL port was used to turn the gauge off.
20	The controller detected a fault.
21	There is no hardware to run the gauge.

See the GSTT? command.

Example

GSTA? 1 Returns 0 if IG1 is operating normally.

GSTT ? p

Gauge Status Time

The GSTT? query returns the time and date that gauge p last changed status. The parameter p selects a gauge port below and is required.

p	port	p	port	p	port
1	IG1	5	CM1	9	AN1
2	IG2	6	CM2	10	AN2
3	PG1	7	CM3	11	AN3
4	PG2	8	CM4	12	AN4

See the GSTA? command.

Example

GSTT? 1 Returns a string of the form "10:22 AM 22may01".

Ion Gauge Setup Commands

GPOW (?) p {, i}

Power

The GPOW command sets (queries) the power state for gauge port p. The parameter p selects IG1 (1), IG2 (2), PG1 (3) or PG2 (4) and is required. The parameter i selects ON (1) or OFF (0).

Note
IG1 and IG2 can not be on simultaneously.

Example

GPOW? 1	Returns 1 if IG1 is on, 0 if IG1 is off.
GPOW 1, 1	Turns on IG 1.

CSEN (?) p {, x}

N2 Sensitivity Factor

The CSEN command sets (queries) the N2 Sensitivity Factor for ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter x is the Sensitivity Factor in $Torr^{-1}$.

Example

CSEN? 2	Returns the N_2 Sensitivity Factor x of IG2 in $Torr^{-1}$.
CSEN 1, 10.0	Sets the IG1 N_2 Sensitivity Factor to 10.0 $Torr^{-1}$.

CGCF (?) p {, x}

Gas Correction Factor

The CGCF command sets (queries) the Gas Correction Factor for gauge p. The parameter p selects IG1 (1), IG2 (2), PG1 (3) or PG2 (4) and is required. The parameter x is the Gas Correction Factor (unitless).

Example

CGCF? 2	Returns the Gas Correction Factor x of IG2.
CGCF 1, 2.0	Sets the IG1 Gas Correction Factor to 2.0.

CRVI (?) p {, i}

Calibration Source

The CRVI command sets (queries) the Cal Source for ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter i selects N_2 Sense Factor (0) or Cal Curve (1).

Example

CRVI? 2	Returns the Cal Source i of IG2.
CRVI 1, 0	Sets the IG1 Cal Source to N_2 Sense Factor.

IGEC (?) p {, x}

Emission Current

The IGEC command sets (queries) the Emission Current of ion gauge port p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter x is the emission current (milliamps) from 0.01 to 12.0.

Example

IGEC? 2	Returns the Emission Current x of IG2 in mA.
IGEC 1, 1.00	Sets IG1 Emission Current to 1.00 mA.

GFIL (?) p {, i}

Filament Select

The GFIL command sets (queries) the Filament of ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter i selects Filament 1 (0), Filament 2 (1) or Both (2).

Example

GFIL? 1	Returns the filament i of IG1.
GFIL 2, 0	Sets IG2 to use Filament 1.

GPLV (?) p {, i}

Gauge Protection

The GPLV command sets (queries) the Gauge Protection of ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter i selects Normal (0) or Micro-Ion (1).

Example

GPLV? 1	Returns the protection level i of IG1.
GPLV 2, 1	Sets the protection of IG2 to Micro-Ion.

GOSD (?) p (, i}

Overpressure Shutdown

The GOSD command sets (queries) the Overpressure Shutdown of ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter i selects Disabled (0) or Enabled (1).

Example

GOSD? 1	Returns Overpressure Shutdown mode i of IG1.
GOSD 1, 1	Enables Overpressure Shutdown for IG1.

GOTH (?) p {, x}

Overpressure Threshold

The GOTH command sets (queries) the Overpressure Threshold of ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter x is the Overpressure Threshold expressed in the current system units.

Example

GOTH? 1	Returns the Overpressure Threshold for IG1 in the current units.
GOTH 1, 1.2E-3	Sets the Threshold of IG1 to 0.0012 in the current units.

GODE (?) p {, n}

Overpressure Delay

The GODE command sets (queries) the Overpressure Delay of ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter n is the Overpressure Delay in milliseconds.

Note

Times are stored in milliseconds, but this timer is only accurate to within a second.

Example

GODE? 1	Returns the Overpressure Delay for IG1 in ms.
GODE 1, 60000	Sets the Delay of IG1 to 1 minute (60,000 ms).

GOAA (?) p {, i} — Overpressure Audio Alarm

The GOAA command sets (queries) the Overpressure Audio Alarm mode for ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter i selects Off (0) or On (1).

Example

GOAA? 1	Returns the Audio Alarm mode i for IG1.
GOAA 1, 1	Turns IG1 Audio Alarm On.

DGAS (?) {i} — Degas On/Off

The DGAS i command turns Degas On (i=1) or Off (i=0). An ion gauge must be on for degas to turn on. In a dual ion gauge system, whichever ion gauge is on is degassed. Degas will not turn on unless the pressure is below $2x10^{-5}$ Torr. DGAS? queries whether degas is on or off.

Degas will not turn on until the ion gauge is on and stabilized. Do not issue the DGAS 1 command immediately after turning a gauge on. Wait until the pressure readings have stabilized.

Example

DGAS?	Returns 1 if Degas is on, 0 if Degas is off.
DGAS 1	Turns Degas on for the active ion gauge.

DENA (?) {i} — Degas Enable/Disable

The DENA i command Enables Degas (i=1) or Disables Degas (i=0). When disabled, degas cannot be turned on from the front panel or remote command. DENA? queries whether degas is enabled or disabled.

Example

DENA?	Returns 1 if Degas is enabled, 0 if Degas is disabled.
DENA 1	Enables Degas.

DPOW (?) p {, n} — Degas Power

The DPOW command sets (queries) the Degas Power for ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter n is an integer number of Watts.

Example

DPOW? 1	Returns the Degas Power for IG1 in Watts.
DPOW 1, 20	Sets the Degas Power for IG1 to 20 Watts.

DTIM (?) p {, x} — Degas Time

The DTIM command sets (queries) the Degas Time for ion gauge p. The parameter p selects IG1 (1) or IG2 (2) and is required. The parameter n is the Degas Time in milliseconds.

Note

Times are stored in milliseconds, but this timer is only accurate to within a second.

Example

DTIM?	Returns the Degas Time in ms.
DTIM 1, 600000	Sets the IG1 Degas Time to 10 minutes (600,000 ms).

AOPG (?) {i}

Auto-Start Pirani Gauge

The AOPG command sets (queries) the Auto-Start Pirani Gauge. The parameter i selects PG1 (0) or PG2 (1).

Example

AOPG?	Returns the IG1 Auto-Start Pirani Gauge i.
AOPG 0	Sets the IG1 Auto-Start Pirani Gauge to PG1.

AOIG (?) {i}

Auto-Start Ion Gauge

The AOIG command sets (queries) the Auto-Start Ion Gauge. The parameter i selects IG1 (0) or IG2 (1). This is the ion gauge which will auto-start when the Auto-Start Pirani Gauge pressure is below threshold.

Example

AOIG?	Returns Auto-Start Ion Gauge i.
AOIG 0	Sets the Auto-Start Ion Gauge to IG1.

AOTH (?) {x}

Auto-Start Threshold

The AOTH command sets (queries) the Auto-Start Threshold. The parameter x is the Auto-Start Threshold expressed in the current system units.

Example

AOTH?	Returns the Auto-Start Threshold for IG1 in the current units.
AOTH 1.2E-3	Sets the Auto-Start Threshold of IG1 to 0.0012 in the current units.

AOCN (?) {i}

Auto-Start On/Off

The AOCN i command turns Ion Gauge Auto-Start On (i=1) or Off (i=0). When Auto-Start is On, the IG AUTO LED is on. AOCN? queries whether IG Auto-Start is on or off.

Example

AOCN?	Returns 1 if Auto-Start is on, 0 if off.
AOCN 1	Turns IG Auto-Start On.

GHGF ?
GHGN ?

Read Gauge History

The IGC100 logs all ion gauge events in the Gauges/History. To read the log, use the GHGF? query to return the most recent entry in the log. Then issue GHGN? repeatedly to get the rest of the entries, until the string "&" is returned, signaling that all entries have been read.

This command pair retrieves the history as it was when the GHGF? command was received. Log entries created while you download the log do not appear in it. If you try to retrieve history over two interfaces at the same time you will not get the complete history on either.

The returned string is in CSV spreadsheet format, "<date>, <time>, <event description>".

Example

GHGN?	Returns a string of the form: "01jan01, 06:22 AM, Instrument turned on"

Pirani Gauge Setup Commands

GPOW (?) p {, i}	**Power**

The GPOW command sets (queries) the power state for gauge port p. The parameter p selects IG1 (1), IG2 (2), PG1 (3) or PG2 (4) and is required. The parameter i selects ON (1) or OFF (0).

Example

GPOW? 3	Returns 1 if PG1 is on, 0 if PG1 is off.
GPOW 3, 1	Turns on PG1.

CGCF (?) p {, x}	**Gas Correction Factor**

The CGCF command sets (queries) the Gas Correction Factor for gauge p. The parameter p selects IG1 (1), IG2 (2), PG1 (3) or PG2 (4) and is required. The parameter x is the Gas Correction Factor (unitless).

Example

CGCF? 3	Returns the Gas Correction Factor x of PG1.
CGCF 3, 2.0	Sets the PG1 Gas Correction Factor to 2.0.

CRVP (?) n {, i}	**Calibration Curve**

The CRVP command sets (queries) the Cal Source for Pirani gauge n. The parameter n selects PG1 (1) or PG2 (2) and is required. The parameter i selects N_2 Curve (0) or Ar Curve (1).

Example

CRVP? 2	Returns the Cal Source i of PG2.
CRVP 1, 0	Sets the PG1 Cal Source to N_2 Curve.

Analog Port Setup Commands

GADM (?) n {, i} — **I/O Mode**

The GADM command sets (queries) the I/O Mode of analog port n. The parameter n (1-4) selects AN1-AN4 and is required. The parameter i selects ADC Input (0) or DAC Output (1).

Example

GADM? 4	Returns the AN4 I/O Mode i.
GADM 4, 1	Sets AN4 into DAC Output mode.

GDAS (?) n {, i} — **DAC Source**

The GDAS command sets (queries) the DAC Source for analog port n. The parameter n (1-4) selects AN1-AN4 and is required. The parameter i selects Manual (0), IG1 (1), IG2 (2), PG1 (3) or PG2 (4).

Example

GDAS? 1	Returns the AN1 DAC Source i.
GDAS 1, 2	Sets the AN1 DAC Source to IG2.

ANDF (?) n {, i} — **Display Format**

The ANDF command sets (queries) the AN Display Format for analog port n. The parameter n (1-4) selects AN1-AN4 and is required. The parameter i selects CM (0) or ADC (1).

Example

ANDF? 1	Returns the AN1Display Format i.
ANDF 1, 0	Sets the AN1 Display Format to CM.

GDAV (?) n {, x} — **Output Value**

The GDAV command sets (queries) the DAC output value for analog port n. This is the output voltage when the analog port is a DAC Output and the DAC Source is Manual. The parameter n (1-4) selects AN1-AN4 and is required. The parameter x is an output voltage (in Volts).

Example

GDAV? 1	Returns the AN1 DAC output value in Volts.
GDAV 1, 2.5	Sets the AN1 DAC output value to 2.5 V.

CMPX (?) n {, x} — **CM PMax**

The CMPX command sets (queries) the Maximum Pressure (Pmax) of capacitance manometer n (1-4 for CM1-4). The parameter x is the pressure Pmax in the current units.

Example

CMPX 1, 100.0	Set Pmax of CM1 to 100.0 in the current units.
CMPX? 1	Return the value of Pmax for CM1 in the current units.

Logging Commands

PLDS (?) {i}

Chart/Table Display

The PLDS command sets (queries) the Log Default Display to Chart (i=0) or Table (i=1).

Example

PLDS 0	Sets the log display to Chart.

PLCL

Clear Data Log

The PLCL command clears the Data Log. All entries in the Data Log are lost after sending the PLCL command.

PLGF ?
PLGN ?

Read Data Log

The IGC100 logs all gauge readings in the Data Log. To read the log, use the PLGF? query to return the most recent entry in the log. Then issue PLGN? repeatedly to get the rest of the entries, until the string "&" is returned, signaling that all entries have been read.

This command pair retrieves the log as it was when the PLGF? command was received. Log entries created while you download the log do not appear in it. If you try to retrieve history over two interfaces at the same time you will not get the complete history on either.

WARNING!
The Embedded Web Server continually issues PLGF and PLGN. If you have the web server option, you must disable it (from the Remote/Web menu or with the WSEN command) to use these commands.

These commands return a string with the following fields separated by commas:

- Date in format "30oct01".
- Time in format "06:42 PM".
- IG1 data.
- IG2 data.
- PG1 data.
- PG2 data.
- CM1 data.
- CM2 data.
- CM3 data.
- CM4 data.
- AN1 data.
- AN2 data.
- AN3 data.
- AN4 data.

- Process control bitfield. The first digit is channel 8, the last digit is channel 1. A '1' means the channel is active, '0' means inactive.
- TTL input bitfield. The first digit is channel 8, the last digit is channel 1. A '1' means the input is high, '0' means low.

Data that isn't available shows up as an asterix '*'.

All pressure readings are expressed in the current units. All ADC inputs are in Volts.

Example
The returned string

"30oct01,06:42 PM,1.64-06,*,*,2.34-01,*,*,*,*,0.046,7.34,-0.029,-0.029, 00000100,1111111"

has the following interpretation:

- This data was sampled at 6:42 PM on October 30, 2001.
- IG1 read 1.64e-6 in the current units.
- IG2 and PG1 were off (no data available).
- PG2 read 2.34e-1 in the current units.
- All capacitance manometers were off.
- AN1 read 0.046V.
- AN2 read 7.34 V.
- AN3 and 4 read –0.029 V
- Process control channel 3 is active, all others are inactive.
- All Process TTL inputs are high (inactive).

PLIN (?) {n}

Logging Interval

The PLIN command sets (queries) the Logging Interval. The parameter n is the Logging Interval in milliseconds. This command will change the Log Length as well.

Note
Times are stored in milliseconds, but this timer is only accurate to within a second.

Examples

PLIN?	Returns the Logging Interval n in ms.
PLIN 60000	Sets the Logging Interval to 1 minute (60,000 ms).

PLWT (?) {n}

Log Length

The PLWT command sets (queries) the Log Length. The parameter n is the Log Length in seconds. This command will change the Logging Interval.

Examples

PLWT?	Returns the Log Length n in seconds.
PLWT 3600	Sets the Log Length to 1 hours (3600 sec).

PLEN (?) {i}

Logging Enable

The PLEN command sets (queries) whether Data Logging is enabled. The parameter i selects Log/Enabled (1) or Pause/Disabled (0).

Examples

PLEN?	Returns 1 if logging is enabled, 0 if disabled.
PLEN 1	Turns data logging on.

PLDD (?) {i}

Display Date

The PLDD command sets (queries) whether Date Display (in Table display format) is Enabled (i=1) or Disabled (i=0).

Examples

PLDD?	Returns 1 if Date Display is enabled, 0 if disabled.
PLDD 1	Turns Date Display on.

PLTR (?) {i}

TTL Reset Enable

The PLTR command sets (queries) whether the TTL Log Reset input is Enabled (i=1) or Disabled (i=0).

Examples

PLTR?	Returns 1 if TTL Log Reset input is enabled, 0 if disabled.
PLTR 1	Enables TTL Log Reset input.

Charting Commands

LCPN (?) {x}

Pmin

The LCPN command sets (queries) the value of the Chart Y-Axis Pmin. The parameter x is a pressure expressed in the current units.

Examples

LCPN?	Returns the value of Pmin in the current pressure units.
LCPN 1.3e-10	Sets Pmin to 1.3×10^{-10} in the current units..

LCPX (?) {x}

Pmax

The LCPX command sets (queries) the value of the Chart Y-Axis Pmax. The parameter x is a pressure expressed in the current units.

Examples

LCPX?	Returns the value of Pmax in the current pressure units.
LCPX 1.3e-6	Sets Pmax to 1.3×10^{-6} in the current units.

LCVN (?) {x}

Vmin

The LCVN command sets (queries) the value of the Chart Y-Axis Vmin. The parameter x is expressed in Volts.

Examples

LCVN?	Returns the value of Vmin in Volts.
LCVN –10.0	Sets Vmin to -10.0 Volts.

LCVX (?) {x}

Vmax

The LCVX command sets (queries) the value of the Chart Y-Axis Vmax. The parameter x is expressed in Volts.

Examples

LCVX?	Returns the value of Vmax in Volts.
LCVX 10.0	Sets Vmax to +10.0 Volts.

LCSA

Autoscale Y-Axis

The LCSA command Autoscales the Chart Y-Axis. This command has no effect unless the chart display is on the screen. This command has no parameters and no query.

LCRG (?) {n}

Time Range

The LCRG command sets (queries) the Chart X-Axis Time Range. The parameter n is a number of seconds.

Examples

LCRG?	Returns the X-Axis Time Range in seconds.
LCRG 600	Sets the X-Axis Time Range to 10 minutes (600 s).

LCSF

Scale X-Axis to Full

The LCSF command Scales the X-Axis to Full. This sets Time Range to display all of the data in the log. This command has no effect unless the chart display is on the screen. This command has no parameters and no query.

Process Control Commands

These commands require the Process Control Option installed in the IGC100.

RDES (?) d {, s}

Channel Description

The RDES command sets (queries) the process channel Description string. The parameter d selects a process channel (1-8) and is required. The string s is the channel description.

Example

RDES 3, pump	Sets the Description of process channel 3 to "PUMP".
RDES? 3	Returns the Description of channel 3 ("PUMP" in this case).

RLCL (?) d {, s}

Channel Active Message

The RLCL command sets (queries) the process channel Active Message. The parameter d selects a process channel (1-8) and is required. The string s is the label.

Example

RLCL 1, on	Sets the Active Label of process channel 1 to "ON".
RLCL? 1	Returns the Active Label of channel 1 ("ON" in this case).

RLOP (?) d {, s}

Channel Inactive Message

The RLOP command sets (queries) the process channel Inactive Message. The parameter d selects a process channel (1-8) and is required. The string s is the label.

Example

RLOP 1, off	Sets the Inactive Label of process channel 1 to "OFF".
RLOP? 1	Returns the Inactive Label of channel 1 ("OFF" in this case).

RBEP (?) d {, i}

Channel Beep

The RBEP command sets (queries) whether the Beep (channel audio alert) is On (i=1) or Off (i=0). The parameter d selects a process channel (1-8) and is required.

Example

RBEP? 1	Returns 1 if channel 1 Beep is on, 0 if off.
RBEP 1, 1	Turns channel 1 Beep on.

RMOD (?) d {, i}

Channel Mode

The RMOD command sets (queries) whether the mode of process channel d is Auto (i=1) or Manual (i=0). The parameter d selects a process channel (1-8) and is required. If the channel is Auto, its state is controlled by its process rules. If the channel is Manual, use the RSTA to set the channel state active or inactive.

Example

RMOD? 2	Returns 1 if channel 2 is Auto, 0 if Manual.
RMOD 2, 1	Sets channel 2 to Auto mode.

RSTA (?) d {, i}

Channel State

The RSTA command sets (queries) the state of process channel d when its mode is Manual. The parameter d selects a process channel (1-8) and is required. The parameter i selects Inactive (0) or Active (1). This command requires that channel d is in Manual mode (RMOD command).

Example

RSTA? 7	Returns 0 if channel 7 is Inactive, 1 if Active.
RSTA 7, 0	Deactivates process control channel 7.

RAMS (?) d {, i}

Channel Input

The RAMS command sets (queries) the process control input (channel Linked To) for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter i selects a control input below.

i	input
0	IG1
1	IG2
2	PG1
3	PG2
4	CM1
5	CM2
6	CM3
7	CM4
8	AN1
9	AN2
10	AN3
11	AN4
12	CLOCK
13	TTL PIN
14	ANY IG EMISSION
15	IG1 EMISSION
16	IG2 EMISSION

Examples

RAMS? 2	Returns the control input i for process channel 2.
RAMS 2, 3	Sets the control input for channel 2 to PG2.

RGOS (?) d {, i}

Gauge Off State

The RGOS command sets (queries) the Gauge Off State for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter i selects Inactive (0) or Active (1).

Example

RGOS? 2	Returns 1 if channel 2 Gauge Off State is Active, 0 if Inactive.
RGOS 2, 1	Sets channel 2 Gauge Off State to Active.

RTRP (?) d {, x}	**Pressure Setpoint**

The RTRP command sets (queries) the Pressure Setpoint for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter x is the Pressure Setpoint expressed in the current units.

Example

RTRP? 8	Returns the Pressure Setpoint for channel 8 in the current units.
RTRP 8, 1.0e-3	Sets the Pressure Setpoint for channel 8 to 1.0×10^{-3} in the current units.

RTRV (?) d {, x}	**Voltage Setpoint**

The RTRV command sets (queries) the Voltage Setpoint for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter x is the Voltage Setpoint in Volts.

Example

RTRP? 8	Returns the Voltage Setpoint for channel 8 in Volts.
RTRP 8, 5.2	Sets the Voltage Setpoint for channel 8 to 5.2 V.

RPHY (?) d {, n}	**Percent Hysteresis**

The RPHY command sets (queries) the Percent Hysteresis for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter n is the hysteresis percentage.

Example

RPHY? 8	Returns the hysteresis percentage for channel 8.
RPHY 8, 10	Sets the Setpoint Hysteresis for channel 8 to 10%.

RVHY (?) d {, x}	**Voltage Hysteresis**

The RVHY command sets (queries) the Voltage Hysteresis for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter x is the hysteresis voltage.

Example

RVHY? 8	Returns the hysteresis percentage for channel 8.
RVHY 8, 1.2	Sets the Voltage Hysteresis for channel 8 to 1.2V.

RPOL (?) d {, i}	**Setpoint Activation**

The RPOL command sets (queries) the Setpoint Activation for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter i selects Active Below (0) or Above (1).

Example

RPOL? 6	Returns 1 if channel 6 is active Above, 0 if Below.
RPOL 6, 1	Sets channel 6 to Active Above the setpoint.

RDEL (?) d {, n}	**Setpoint Delay**

The RDEL command sets (queries) the Setpoint Delay for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter n is the Delay in milliseconds.

Note
Times are stored in milliseconds, but this timer is only accurate to within a second.

Example

RDEL? 5	Returns the Setpoint Delay of channel 5 in ms.
RDEL 5, 10000	Sets Setpoint Delay of channel 5 to 10 seconds (10,000 ms).

RTCL (?) d {,n} {,s}	**Activation Time**

The RTCL command sets (queries) the Activation Time of day for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter n is the time of day in milliseconds from midnight or the string s is the time in the format "9:30PM". Do not use both n and s in the command. The RTCL? query returns the value n in ms.

Example

RTCL? 4	Returns the Activation Time of channel 5 in ms.
RTCL 4, 9:30pm	Sets the Activation Time of channel 4 to 9:30 PM.
RTCL 4,77400000	Sets the Activation Time of channel 4 to 77,400,000 ms after midnight (9:30 PM).

RTOP (?) d {,n} {,s}	**Deactivation Time**

The RTOP command sets (queries) the Deactivation Time of day for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter n is the time of day in milliseconds from midnight or the string s is the time in the format "9:30PM". Do not use both n and s in the command. The RTOP? query returns the value n in ms.

Example

RTOP? 4	Returns the Deactivation Time of channel 5 in ms.
RTOP 4, 9:30pm	Sets the Deactivation Time of channel 4 to 9:30 PM.
RTOP 4,77400000	Sets the Deactivation Time of channel 4 to 77,400,000 ms after midnight (9:30 PM).

RTIL (?) d {, i}	**TTL Activation Level**

The RTIL command sets (queries) the TTL Activation Level for process channel d. The parameter d selects a process channel (1-8) and is required. The parameter i selects Active when TTL input Low (0) or High (1).

Example

RTIL? 3	Returns 1 if channel 3 is active when TTL Input High, 0 if Low.
RTIL 3, 1	Sets channel 3 to active when TTL Input High.

TTLL ?

Read TTL Inputs

The TTLL? query returns the decimal value of a 24 bit binary number representing the state of the process control TTL Inputs as listed below.

Each bit is 0 if the input is TTL low, and 1 if the input is TTL high. All unused bits are 0.

bit	description
0	IG1_On
1	IG2_On
2	Degas_On
3	IG_Lockout
4	IG_Key_Disable
5	PG1_Off
6	PG2_Off
7	Clear_Data_Log
8	IG_Remote_Enable
9	Fil1_On
10	Fil2_On
11	Front_Panel_Disable
12	unused
13	unused
14	unused
15	unused
16	Process control TTL input #1
17	Process control TTL input #2
18	Process control TTL input #3
19	Process control TTL input #4
20	Process control TTL input #5
21	Process control TTL input #6
22	Process control TTL input #7
23	Process control TTL input #8

Example
If the returned value is 197136, the hex equivalent is 030210H indicating that all bits are low except bits 4, 9, 16 and 17.

RHGF ?
RHGN ?

Read Process Log

The IGC100 logs all process control events. To read the process log, use the RHGF? query to return the most recent entry in the log. Then issue RHGN? repeatedly to get the rest of the entries, until the string "&" is returned, signaling that all entries have been read.

This command pair retrieves the log as it was when the RHGF? command was received. Log entries created while you download the log do not appear in it. If you try to retrieve history over two interfaces at the same time you will not get the complete history on either.

WARNING!
The Embedded Web Server continually issues RHGF and RHGN. If you have the web server option, you must disable it (from the Remote/Web menu or with the WSEN command) to use these commands.

The returned string has one of the formats below.

State or Mode change:
When a channel changes state or mode, an entry is returned with the following format.

"<date> <time> <StateBits (LSB first)> <ModeBits (LSB first)> <channel #> <State or Mode> <new State or Mode>"

For example, the returned string

"23jun01 12:15:49 PM 10100000 01000000 #2 Mode Auto"

indicates the date/time that channel 2 was switched to Auto mode. The first bitfield shows 2 channels are active (1 and 3). The second bitfield shows that only channel 2 is in Auto mode.

Another example, the returned string

"23jun01 10:42:35 AM 10000000 00000000 #1 State Active"

indicates the date/time that channel 1 switched to the Active state. The first bitfield shows that only channel 1 is active. The second bitfield shows that no channels are in Auto mode.

Event format:
When an event occurs, an entry is returned with the following format.

"<date> <time> <event description>"

For example, the returned string

"22may01 04:36:25 PM Instrument turned on"

indicates the date/time that the unit was turned on.

RHCL **Clear Process Log**

The RHCL command clears the Process Log. All entries in the Process Log are lost after sending the RHCL command.

RBAD ? **Relay Failure Status**

RBAD? query returns the decimal value of an 8 bit binary number representing the state of the process control relays. Bit 0 corresponds to Channel 1 and bit 7 corresponds to Channel 8. If the bit is 0, the relay is ok. If the bit is set, the relay is not trustworthy.

Backlight Commands

BLEN (?) {i}

Backlight Saver Enable

The BLEN command sets (queries) the Backlight Saver. The parameter i selects Disabled (0) or Enabled (1).

Example

BLEN?	Returns 1 if the Backlight Saver is Enabled, or 0 if Disabled.
BLEN 1	Enables the Backlight Saver.

BLIT (?) {i}

Backlight On/Off

The BLIT command sets (queries) the state of the LCD screen backlight. The parameter i selects On (1) or Off (0).

Example

BLIT?	Returns 1 if the backlight is On, or 0 if Off.
BLIT 1	Turns the screen backlight On.

BLOF (?) {n} {s}

Backlight Turn-Off Time

The BLOF command sets (queries) the Backlight Turn-Off Time of day. The parameter n is the time of day in milliseconds from midnight or the string s is the time in the format "9:30PM". Do not use both n and s in the command. The BLOF? query returns the value n in ms.

Example

BLOF?	Returns the Turn-Off Time in ms.
BLOF 9:30pm	Sets the Turn-Off Time to 9:30 PM.
BLOF 77400000	Sets the Turn-Off Time to 77,400,000 ms after midnight (9:30PM).

BLON (?) {n} {s}

Backlight Turn-On Time

The BLON command sets (queries) the Backlight Turn-On Time of day. The parameter n is the time of day in milliseconds from midnight or the string s is the time in the format "9:30PM". Do not use both n and s in the command. The BLON? query returns the value n in ms.

Example

BLON?	Returns the Turn-On Time in ms.
BLON 9:30pm	Sets the Turn-On Time to 9:30 PM.
BLON 77400000	Sets the Turn-On Time to 77,400,000 ms (9:30PM).

BLTD (?) {n}

Backlight Delay

The BLTD command sets (queries) the Backlight Saver Delay. The parameter n is the Delay in milliseconds.

Example

BLTD?	Returns the Backlight Saver Delay in ms.
BLTD 300000	Sets Delay to 5 minutes (300,000 ms).

Security Commands

LOCK ?

Query Locked

The LOCK? query returns the security state of the unit, Locked (1) or Unlocked (0). This is a query only command.

PWDL i, s

Lock/Unlock

The PWDL command locks and unlocks the unit. The parameter i selects the action Switch State (0), Unlock (1) or Lock (2). The string s is the password.

The string s is converted to UPPER case. If you enter the password from the front panel, be sure that the password is all UPPER case before using this command.

Example

PWDL 1, secret	Unlocks the system if the password is "SECRET".
PWDL 0, secret	Switches the state (Locks if unlocked, unlocks if locked) if the password is "SECRET".

CPWD

Copy Password to Card

The CPWD command copies the password to a Memory Card. This card can then be used as a key to unlock the unit without knowing the password.

A memory card must be inserted in the card reader before sending this command.

STPW s

Set Password.

The STPW s command sets the password to the string s. This is a set only command. The password may not be queried.

Passwords may include letters and numbers. The string s is converted to UPPER case.

This command has no effect unless the unit is UNLOCKED.

Example

STPW secret	Sets the password to "SECRET".

SECF (?) d {, i}

Security Flags

The SECF command sets (queries) the security setting for feature d listed below. The parameter i selects Normal (0) or Protected (1).

Protected features may not be changed when the system is locked. Normal features are not affected by system locking.

d	feature
0	Ion gauge control keys
1	Gauge setup.
2	Gauge calibration.
3	Process control setup.
4	Process control operation.
5	Time & Date.
6	Local user lockout. Prevents changes from the touch screen.
7	Remote user lockout. Prevents changes from the remote interfaces.

Note
Do not lock out the remote interface (d=7) from a computer program.

Example

SECF? 3	Returns 1 if process control setup is Protected, 0 if Normal.
SECF 0, 1	Sets Ion Gauge Control to Protected.

WSEN (?) {i}

Web Server Enable

The WSEN command sets (queries) whether the Web Server Option is Enabled (i=1) or Disabled (i=0). Disable the web server to prevent web users from interfering with local computer control. It may take up to 10 seconds for this to take effect.

Example

WSEN?	Returns 1 if web server is Enabled, 0 if Disabled.
WSEN 0	Disables the web server option.

System Commands

NAME (?) {s}	**System Name**

The NAME command sets (queries) the System Name. The string s is the name and is converted to UPPER case.

Example

NAME?	Returns the System Name.
NAME my igc	Sets the Name to "MY IGC".

SNUM ? — **Serial Number**

The SNUM? query returns the unit serial number.

TIME (?) {s} — **Time**

The TIME command sets (queries) the System Time of day. The string s is the time in the format "9:30PM".

Example

TIME 9:30pm	Sets the system time to 9:30 PM.
TIME?	Returns "09:30 PM".

DATE (?) {s} — **Date**

The DATE command sets (queries) the System Date. The string s is the date in the format "ddMMMyy" where "MMM" are the first 3 letters of the month (jan, feb, mar, etc.).

Example

DATE 23may01	Sets the system date to May 23, 2001.
DATE?	Returns "23may01".

VOLC (?) {n} — **Volume**

The VOLC command sets (queries) the system audio Volume. The parameter n is the volume setting from 0 to 10.

Example

VOLC?	Returns the Volume setting.
VOLC 9	Sets the Volume to 9 (loud).

MENU d — **Display Screen**

The MENU d command changes the screen to the display listed below.

d	feature
0	Pressure Display
1	Gauges Display
2	Process Display
3	Chart Display
4	Table Display

Example

MENU 2	Shows the Process Display on the screen.

MESG (?) {s}

Message

The MESG s command sends the message string s to the screen. The user must clear this message by touching a button.

The MESG? query returns 1 if the message has not been cleared and 0 if all messages have been cleared.

Example

MESG warning	Displays the message "WARNING" on the screen.
MESG?	Returns 1 if until the message has been cleared from the front panel, and 0 when all messages have been cleared.

DHWR ? d

Detect Hardware

The DHWR? d command returns 1 if component d (listed below) is present, 0 if not installed. This is a query only command.

d	component
6	Process Control option
9	RS-232 interface
14	GPIB (IEEE-488) interface
17	Web Server

Example

DHWR? 6	Returns 1 if the Process Control Option is installed.

***TST ?**

Self-Test

The *TST ? query performs a self-test and returns 0 if the test passes.

Returned values which are warnings are listed below.

value	description
1	Unable to perform all tests
2	Flash memory needs to be programmed
3	Excess load on Aux ±15 V supply
4	Relay failure
5	Communication port problem

If *TST ? returns any other value contact Stanford Research Systems for further instructions.

FREV ?

Firmware Revision

The FREV? query returns the IGC100 firmware revision code.

VRDT ?

Firmware Build

The VRDT? query returns the date of the IGC100 firmware revision.

Interface Commands

VERB (?) {i}

Verbose RS-232

The VERB command sets (queries) the verbose serial communication mode. The parameter i selects Verbose (1) or Terse (0). This command only affects the RS-232 interface. The GPIB interface is always in Terse mode.

Use Terse for programming. All responses to queries are as documented in this chapter. **Use the Verb 0 command at the start of all programs.**

Use Verbose for terminal applications or debugging. All terse responses are followed with a verbose message which explains the response.

For example, a query might return "0" (terse) or "0 off" (verbose).

Example

VERB?	Returns 1 if verbose mode, 0 if terse mode.
VERB 0	Use terse responses.

***IDN ?**

Identification

The *IDN ? query returns the IGC100's device identification string. This string is in the format "Stanford_Research_Systems,IGC100,s/n0,ver001". In this example, the serial number is 0 and the firmware version is 001.

***RST**

Reset

The *RST command resets the IGC100 to its default configurations. The communications setup is not changed. All other modes and settings are set to their default conditions and values. This command takes some time to complete.

Do not send other commands on the same command line after *RST. Do not send another command until *RST is complete. This takes about 10 seconds. You can send a query command (like *OPC?) and wait for the response. When the response comes, the unit is ready.

***OPC (?)**

Operation Complete

*OPC is a GPIB command which is implemented for compatibility with the IEEE-488 standard. It is for operations that take time to complete. Upon receipt of the *OPC command, the instrument should set the OPC bit in the Standard Event Status register (bit 0) when all pending operations have been completed.

If the host sends *OPC, the IGC100 sets the OPC bit when all pending operations complete. Since the IGC100 completes all commands in the order received, the bit is set when the *OPC command completes.

The *OPC ? query returns 0 if any previous commands are still executing, 1 if all previous commands are complete. Since the IGC100 completes all commands in the order received, the *OPC ? query always returns 1. For commands that take a long time to complete execution, follow the command with a *OPC? query. The response (1) signals that the previous command is completed.

***WAI** **Wait to Continue**

The *WAI command prevents the instrument from executing any other commands or queries until all pending commands and queries are complete. Since the IGC100 executes commands to completion in the order received, the IGC100 operates in this manner for all commands (not just *WAI). This command has no parameters or return value.

Status Reporting

The IGC100 reports on its status by means of five status registers: the Serial Poll, Standard Event, Error, Gauge and Process Control status registers.

Status Registers

In the IGC100, a status register is a read-only, 16 bit word where the state of each bit indicates a specific instrument state or condition.

Bits in status registers are set when their corresponding condition or status is met. Once set, bits remain set until cleared by reading them with the appropriate status reporting command. *Whenever a status bit is set, it remains set until read.*

Some status bits report that a bit is set in another status register.

Resetting the IGC100, turning it off, or issuing *RST do not clear the status registers. Reading the status registers or issuing *CLS clears the status registers. Powering-up with *PSC enabled also clears the status registers.

This instrument extends the IEEE-488 specification by allowing you to check and clear individual bits in a status register.

Status Enable Registers

Status enable registers let you decide which conditions you care about and check them all with one *STB? query or GPIB serial poll.

The Standard Event, Error, Gauge and Process status registers all have a corresponding status enable register. Each bit in the enable register matches with a bit in the corresponding status register. Bits in the enable registers are set with the status enable commands. The enable bits do not affect the value of the status register and are not affected by status reads.

When a bit in *BOTH* a status register *AND* its enable register are set, then a bit in the Serial Poll Status register will become set. This mechanism reports underlying status conditions to a single status register (Serial Poll Status).

Serial Poll Status Register

The Serial Poll Status register is a special status register. It is a single byte (8 bits) and contains bits corresponding to the other four status registers. When a status bit (in another status register) *and* the matching enable bit (in its corresponding enable register) are *both* set, a bit is set in the Serial Poll Status register. This allows a single read of the Serial Poll Status to determine if any enabled bits in *all* of the other status registers is set. These bits in the Serial Poll Status *are not* cleared by reading. They remain set as long as the enabled bit in the other status register is set. Read the other status registers to determine which bit(s) are set and clear them.

The Serial Poll Status register has a matching Serial Poll Enable register. When a bit in *both* becomes set, the Service Request, or SRQ, bit will be set. This causes an IEEE-488 bus service request. When an enabled Serial Poll bit becomes set, a single service request is generated.

*STB? to Read the Status

The Serial Poll Status register is *NOT* cleared by reading the status using *STB?. A bit stays set as long as the status condition exists. This is true even for bit 6 (SRQ). Bit 6 will be set whenever the same bit in the Serial Poll Status *AND* Serial Poll Enable registers is set.

Serial Poll to Read the Status

Except for SRQ, a bit in the Serial Poll Status is *NOT* cleared by GPIB serial polling the status register. A bit stays set as long as the status condition exists.

When reading the status using a GPIB serial poll, the SRQ bit signals that the IGC100 is requesting service. The SRQ bit will be set the *first* time the IGC100 is polled following a service request. The serial poll automatically clears the service request. Subsequent serial polls will return SRQ cleared until another service request occurs. Polling the status word and reading it with *STB? can return different values for SRQ. When serial polled, SRQ indicates a service request has occurred. When read with *STB?, SRQ indicates that an enabled Serial Poll Status bit is set.

Service Request

A GPIB service request (SRQ) will be generated whenever a bit in both the Serial Poll Status register *AND* Serial Poll Enable register is set. Use *SRE to set bits in the Serial Poll Enable register.

A service request is only generated when an enabled Serial Poll Status bit becomes set (changes from 0 to 1). An enabled status bit which becomes set and remains set will generate a single SRQ. This prevents a single, persistent condition, such as overload, from generating an endless stream of service requests.

If another service request from the same status bit is desired, the requesting status bit must first be cleared. In the case of the PCSQ, GERR, IERR and ESB bits, this means clearing the enabled bits in the Process, Gauge, Error or Standard Event Status registers (by reading them) or clearing the appropriate bits in the corresponding enable registers. Multiple enabled bits in these status registers will generate a single SRQ. Another SRQ (from PCSQ, GERR, IERR or ESB) can only be generated after clearing the PCSQ, GERR, IERR or ESB bits in the Serial Poll Status.

The controller should respond to the SRQ by performing a serial poll to read the Serial Poll Status to determine the requesting status bit. Bit 6 (SRQ) will be reset by the serial poll. The controller should then investigate the appropriate status register to find the requesting status bit. The SRQ handler should deal with the actual problem (e.g. removing an overload condition), NOT just clear the bit and continue. This can lead to repeated SRQ events.

Power-On Status

Powering on does not clear the status registers. Reading status registers or issuing *CLS clears status registers.

Upon power-on, the IGC100 may either clear all of its status *enable* registers or maintain them as they were on power-off. The *PSC command determines which action will be taken.

Status Reporting Commands

***CLS**

Clear Status

The *CLS command clears all status registers. The enable registers are *not* changed.

***PSC (?) {i}**

Power-On Status Clear

The *PSC command sets the value of the power-on status clear bit.

If i=1 the power-on status clear bit is set and all status registers and enable registers are cleared on power up.

If i=0 the bit is cleared and all enable registers are stored at power down. The status registers are cleared and the enable registers are restored to their stored values on power up. This allows a service request to be generated at power up.

The default value is 0.

***STB ? {i}**

Read Serial Poll Status

The *STB? query returns the value of the Serial Poll Status register. The value is returned as a decimal number from 0 to 255. The *STB? i query returns the value (0 or 1) of bit i (0-7). The conditions for each bit are listed below.

bit	name	set when
0	PCSQ	An enabled bit in the Process Control Status is set.
1	IERR	An enabled bit in the Error Status is set.
2	GERR	An enabled bit in the Gauge Status is set.
3	Unused	never
4	MAV	Data is available in the GPIB output buffer.
5	ESB	An enabled bit in the Event Status is set.
6	SRQ	Service request occurs.
7	IFC	No Command Execution is in progress.

The value of bit 6 (SRQ) when read using *STB? returns 1 if a bit is set in BOTH the Serial Poll Status register AND the Serial Poll Enable register. This is independent of serial polling and GPIB service requests. Bit 6 is the SRQ bit only when serial polled.

*STB? has no effect on the value of the Serial Poll Status register. To clear a bit in the Serial Poll Status, the condition which causes it to be set must be cleared. For the PCSQ, GERR, IERR or ESB bits, this is accomplished by clearing the enabled status bits in the Process, Gauge, Error or Standard Event status words (by reading them).

Example

*STB?	Returns the Serial Poll Status register (0-255).
*STB? 2	Returns 0 if bit 2 (GERR) is clear, 1 if it is set.

***SRE (?) {i} {, j}**

Serial Poll Enable

The *SRE i command sets the Serial Poll Enable register to the decimal value i (0-255). The *SRE i, j command sets bit i (0-7) to j (0 or 1).

The *SRE? query returns the value (0-255) of the Serial Poll Enable register. The *SRE? i query returns the value (0 or 1) of bit i (0-7).

When a bit becomes set in BOTH the Serial Poll Status register AND the Serial Poll Enable register, an SRQ (GPIB service request) is generated. The SRQ is cleared by performing a serial poll. The bit in the Serial Poll Status which caused the SRQ must be cleared before this bit can cause another SRQ. To clear this bit, the condition which causes it to be set in the Serial Poll Status needs to be cleared. For the PCSQ, GERR, IERR or ESB bits, this is accomplished by clearing the enabled status bits in the Process, Gauge, Error or Standard Event status words (by reading them).

Example

*SRE?	Returns the Serial Poll Enable register (0-255).
*SRE? 2	Returns 0 if bit 2 is clear, 1 if it is set.
*SRE 40	Sets the Serial Poll Enable register to 40 decimal (bits 3 and 5 set).
*SRE 1, 0	Clears bit 1 of the Serial Poll Enable register.

***ESR ? {i}**

Read Standard Event Status

The *ESR? query returns the value of the Standard Event Status register. The value is returned as a decimal number from 0 to 255. The *ESR? i query returns the value (0 or 1) of bit i (0-7).

*ESR? clears the entire register while *ESR? i clears just bit i.

The conditions for each bit are listed below.

bit	name	set when
0	OPC	The *OPC command completes.
1	Unused	
2	Unused	
3	Unused	
4	EXE	A command cannot be executed.
5	CME	A command syntax error occurs.
6	Unused	
7	PON	Unit turns on.

The Standard Event Status is defined by IEEE-488.2 (1987) and is used primarily to report errors in commands received over the interface. These bits remain set until read, cleared by *CLS or power-up with *PSC enabled.

Example

*ESR?	Returns the Standard Event Status register (0-255).
*ESR? 5	Returns 0 if bit 5 (CME) is clear, 1 if it is set.

***ESE (?) {i} {, j}**

Standard Event Enable

The *ESE i command sets the Standard Event Enable register to the decimal value i (0-255). The *ESE i, j command sets bit i (0-7) to j (0 or 1).

The *ESE? query returns the value (0-255) of the Standard Event Enable register. The *ESE? i command queries the value (0 or 1) of bit i (0-7).

When a bit becomes set in BOTH the Standard Event Status register AND the Standard Event Enable register, bit 5 (ESB) of the Serial Poll Status is set. This causes an SRQ if bit 5 in the Serial Poll Enable register is set. To clear a bit in the Standard Event Status, use *ESR?.

Example

*ESE?	Returns the Standard Event Enable register (0-255).
*ESE? 2	Returns 0 if bit 2 is clear, 1 if it is set.
*ESE 48	Sets the Standard Event Enable register to 48 decimal (bits 4 and 5 set).
*ESE 7, 0	Clears bit 7 of the Standard Event Enable register.

ERSW ? {i}

Read Error Status

The ERSW? query returns the value of the Error Status register. The value is returned as a decimal number from 0 to 65535. The ERSW? i query returns the value (0 or 1) of bit i (0-15).

ERSW? clears the entire register while ERSW? i clears just bit i.

The conditions for each bit are listed below.

bit	name	set when
0	Tst_Err	Selftest fails.
1	Math_Err	An internal math error occurs.
2	RAM_Err	The RAM checksum fails.
3	ROM_Err	The ROM checksum fails.
4	Batt_Err	Data in battery backed-up RAM was lost.
5	Stk_Err	An internal stack error occurs.
6	Heap_Err	An internal heap error occurs.
7	Rly_Err	A process control relay failure is detected.
8	Com_Err	An error with a communications port occurs.
9	Mnt_Err	A selftest requests routine maintenance.
10	Elec_Err	An internal electronics fault occurs.
11	PG1_Err	PG1 has a controller electronics fault.
12	PG2_Err	PG2 has a controller electronics fault.
13	Reset_Err	A Watchdog timer reset has occured.
14-15	Unused	

These bits **REMAIN SET** until read, cleared by *CLS or power-up with *PSC enabled.

Example

ERSW?	Returns the Error Status register (0-65535).
ERSW? 10	Returns 0 if bit 10 (Flt_Err) is clear, 1 if it is set.

ERSE (?) {i} {, j}

Error Status Enable

The ERSE i command sets the Error Status Enable register to the decimal value i (0-65535). The ERSE i, j command sets bit i (0-15) to j (0 or 1).

The ERSE? query returns the value (0-65535) of the Error Status Enable register. The ERSE? i query returns the value (0 or 1) of bit i (0-15).

When a bit becomes set in BOTH the Error Status register AND the Error Status Enable register, bit 1 (IERR) of the Serial Poll Status is set. This causes an SRQ if bit 1 in the Serial Poll Enable register is set. To clear a bit in the Error Status, use ERSW?.

Example

ERSE?	Returns the Error Status Enable register (0-65535).
ERSE? 2	Returns 0 if bit 2 is clear, 1 if it is set.
ERSE 48	Sets the Error Status Enable register to 48 decimal (bits 4 and 5 set).
ERSE 12, 0	Clears bit 12 of the Error Status Enable register.

GSSW ? {i}

Read Gauge Status

The GSSW? query returns the value of the Gauge Status register. The value is returned as a decimal number from 0 to 65535. The GSSW? i query returns the value (0 or 1) of bit i (0-15).

GSSW? clears the entire register while GSSW? i clears just bit i.

The conditions for each bit are listed below.

bit	name	set when
0	IG_Lock	IG TTL lockout occurs.
1	IG_Rng	IG reading is out-of-range.
2	IG_Err	IG fault occurs, perhaps an open or shorted gauge.
3	IG_Over	IG overpressure shutdown occurs.
4	AN1_Rng	AN1 reading is out-of-range.
5	AN2_Rng	AN2 reading is out-of-range.
6	AN3_Rng	AN3 reading is out-of-range.
7	AN4_Rng	AN4 reading is out-of-range.
8	Unused	
9	PG1_Rng	PG1 reading is out-of-range.
10	PG1_Err	PG1 fault occurs, perhaps an open or shorted gauge.
11	Unused	
12	Unused	
13	PG2_Rng	PG2 reading is out-of-range.
14	PG2_Err	PG2 fault occurs, perhaps an open or shorted gauge.
15	Unused	

These bits **REMAIN SET** until read, cleared by *CLS or power-up with *PSC enabled. For example, if AN1 is out-of-range, bit 4 will become set. Reading this status register will clear the bit. However, if AN1 remains out-of-range, then bit 4 will become set again (within 0.5 second). This can lead to repeated SRQs if the appropriate enable bits are set. In this case, the SRQ handler should not just read the status to clear the bit but also deal with the actual cause, in this case, why is the signal at AN1 out of range?, and remove the source of the problem.

Example

GSSW?	Returns the Gauge Status register (0-65535).
GSSW? 10	Returns 0 if bit 10 (PG1_Err) is clear, 1 if it is set.

GSSE (?) {i} {, j}

Gauge Status Enable

The GSSE i command sets the Gauge Status Enable register to the decimal value i (0-65535). The GSSE i, j command sets bit i (0-15) to j (0 or 1).

The GSSE? query returns the value (0-65535) of the Gauge Status Enable register. The GSSE? i query returns the value (0 or 1) of bit i (0-15).

When a bit becomes set in BOTH the Gauge Status register AND the Gauge Status Enable register, bit 2 (GERR) of the Serial Poll Status is set. This causes an SRQ if bit 2 in the Serial Poll Enable register is set. To clear a bit in the Gauge Status, use GSSW?.

Example

GSSE?	Returns the Gauge Status Enable register (0-65535).
GSSE? 2	Returns 0 if bit 2 is clear, 1 if it is set.
GSSE 48	Sets the Gauge Enable register to 48 decimal (bits 4, 5 set).
GSSE 12, 0	Clears bit 12 of the Gauge Status Enable register.

RSSW ? {i}

Read Process Status

The RSSW? query returns the value of the Process Status register. The value is returned as a decimal number from 0 to 65535. The RSSW? i query returns the value (0 or 1) of bit i (0-15).

RSSW? clears the entire register while RSSW? i clears just bit i.

The conditions for each bit are listed below.

bit	name	set when
0	Ch1_Chg	Process control channel 1 changes state.
1	Ch2_Chg	Process control channel 2 changes state.
2	Ch3_Chg	Process control channel 3 changes state.
3	Ch4_Chg	Process control channel 4 changes state.
4	Ch5_Chg	Process control channel 5 changes state.
5	Ch6_Chg	Process control channel 6 changes state.
6	Ch7_Chg	Process control channel 7 changes state.
7	Ch8_Chg	Process control channel 8 changes state.
8	Ch1_Act	Process control channel 1 is active.
9	Ch2_Act	Process control channel 2 is active.
10	Ch3_Act	Process control channel 3 is active.
11	Ch4_Act	Process control channel 4 is active.
12	Ch5_Act	Process control channel 5 is active.
13	Ch6_Act	Process control channel 6 is active.
14	Ch7_Act	Process control channel 7 is active.
15	Ch8_Act	Process control channel 8 is active.

The Process Control Status reflects the current process control state and indicates channels that have changed state (1 or more times) since the last time the status was read.

The lower 8 bits are set when a channel changes state and **REMAIN SET** until read, *CLS executes, or power-on with *PSC enabled. These bits can be enabled to generate an SRQ. Reading this register will clear these bits and they will remain cleared until the relay changes state again.

The upper 8 bits always reflect the state of the process control channels **at the time this status is read.** These bits should **NOT** be enabled to generate an SRQ. Reading this register will clear these bits but if the relay remains active, the bit will immediately be reset and generate another SRQ.

Example

RSSW?	Returns the Process Control Status register (0-65535).
RSSW? 10	Returns 0 if bit 10 (Ch3_Act) is clear, 1 if it is set.

RSSE (?) {i} {, j} — Process Status Enable

The RSSE i command sets the Process Status Enable register to the decimal value i (0-65535). The RSSE i, j command sets bit i (0-15) to j (0 or 1).

The RSSE? query returns the value (0-65535) of the Process Status Enable register. The RSSE? i query returns the value (0 or 1) of bit i (0-15).

When a bit becomes set in BOTH the Process Status register AND the Process Status Enable register, bit 0 (PCSQ) of the Serial Poll Status is set. This causes an SRQ if bit 0 in the Serial Poll Enable register is set. To clear a bit in the Process Status, use RSSW?.

Example

RSSE?	Returns the Process Status Enable register (0-65535).
RSSE? 2	Returns 0 if bit 2 is clear, 1 if it is set.
RSSE 48	Sets the Process Status Enable register to 48 decimal (bits 4 and 5 set).
RSSE 12, 0	Clears bit 12 of the Process Status Enable register.

Chapter 8

Embedded Web Server (EWS)

The embedded web server (EWS) is a factory installed option for the IGC100. The EWS provides an ethernet connection between the IGC100 and a network. The EWS allows monitoring and control of the IGC100 (and vacuum system) from a local network or the world wide web.

The EWS allows you to

- Monitor and control the IGC100 from virtually anywhere in the world.
- View vacuum system data using a standard web browser.
- Get log data from the IGC100 without writing a custom program.

In This Chapter

EWS Quick Start

If you are comfortable with networking and wish to get your EWS up and going as quickly as possible, use the Quick Start instructions here. Please read the rest of this chapter for a more complete description of the EWS features and capabilities.

Connect the IGC100 to Your Network

Warning!

- Connecting your vacuum system to the world-wide-web can expose it to unauthorized access, resulting in harm to personnel as well as equipment.
- Network security is a serious matter. Consult your network administrator for more information about using web-enabled instruments in your lab.

Use a CAT5 ethernet cable to connect your hub or switch to the ethernet connector on the back of the IGC100 (with EWS installed). *Do not use a crossover cable*.

Bring up the Web setup menu by pressing the [Menu] QuickKey (in the Pressure Display), choosing [Remote] and then [Web].

Set the Network Addresses

For full use of the EWS, you will need a static IP (Internet Protocol) address, subnet mask, DNS (Domain Name Server) address, and gateway address. See your network administrator to obtain addresses appropriate for your network environment. If you already know the IP address you will be using, you may be able to find your subnet mask and gateway by typing "ipconfig" from your workstation's command line prompt.

Enter these values in the Main/Remote/Web menu of the IGC100.

Set the Security Level

To quickly allow access to all EWS features, go to the Main/Remote/Web/Control submenu and set Web Control to Enabled and Security Type to Password. The default password is "igc100".

Read the section 'Configuring EWS Security' later in this chapter for a complete description of EWS security features.

Enable the EWS

Return to Main/Remote/Web and set Web Server to Enabled. Your EWS stores the network addresses into non-volatile memory, then gathers data on your IGC100 setup (gauge and relay descriptions, etc.). Allow the EWS about 30 seconds before continuing.

To make sure the EWS is functioning, touch the [Web Queue] button. If commands are streaming across the display, the EWS is communicating with the IGC100.

Access the Web Page

Start your web browser and in the location (URL) bar, type the IP address you assigned to the EWS. Make sure JavaScript is not disabled in your browser. You should see a web page similar to below. Relay status is displayed only if Option 03 (Process Control) is installed in the IGC100.

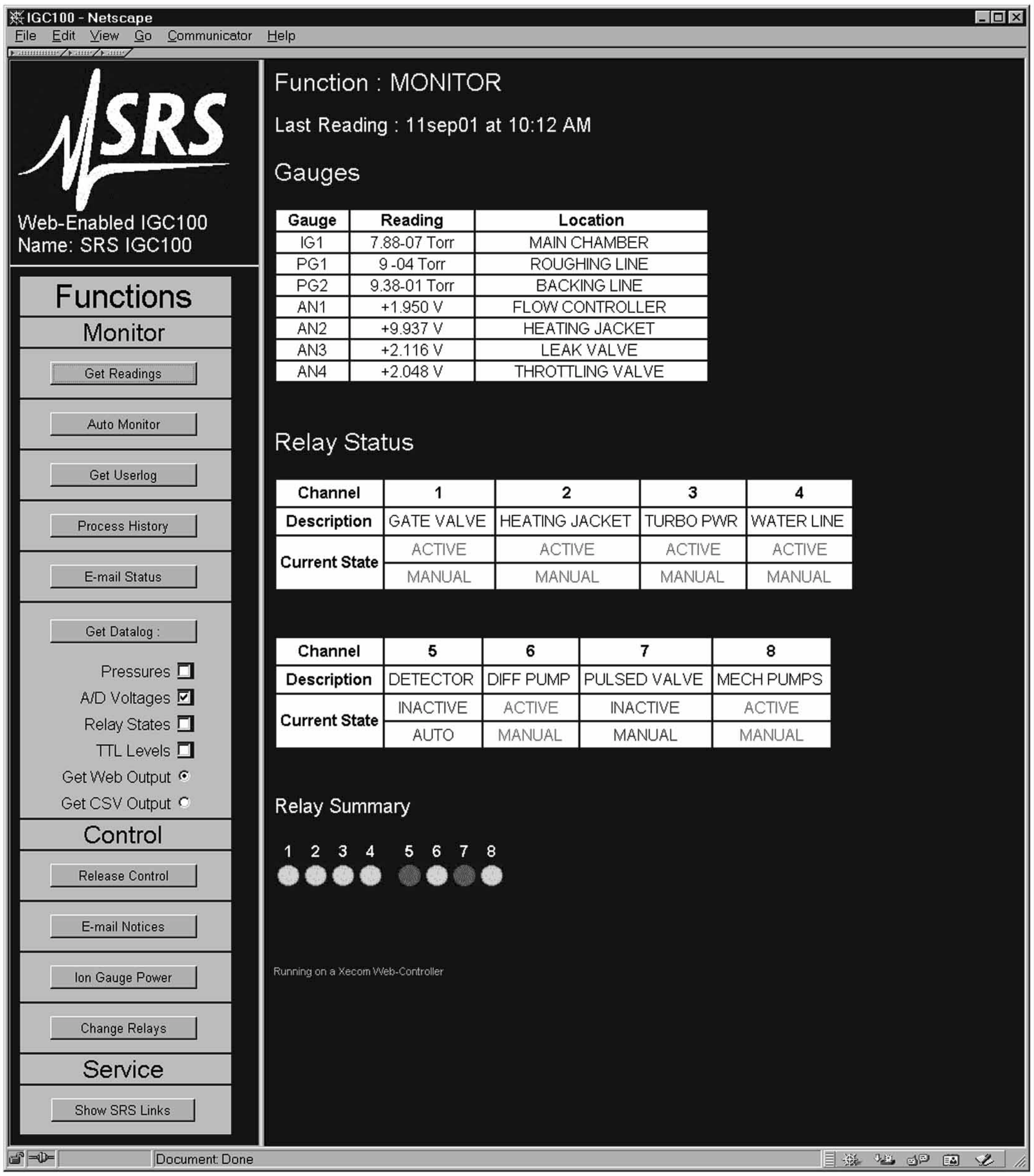


Figure 8-1. EWS web page.

Installing the EWS

This section covers the network installation and configuration of the Embedded Web Server option. While this option adds powerful functionality to the IGC100, *connecting your vacuum system to the world-wide-web can expose it to unauthorized access, resulting in harm to personnel as well as equipment.*

Warning!
Network security is a serious matter. Consult your network administrator for more information about using web-enabled instruments in your lab.

Network Administration Concerns

Your network administrator has a difficult job. In addition to making sure your network is always running smoothly, she also needs to keep track of which IP addresses are assigned to which machines. This prevents IP address collisions (where more than one computer has the same IP address), as well as maintains the security of the network.

Your administrator may have a limited number of free IP addresses, and may show concern about having an instrument on the network in the first place.

Some of the first questions she may ask include:

- Why does an instrument need an IP address?
- Why does it need a static IP address?
- What happens if everyone in the department wants instruments with IP addresses?
- What is the MAC address for this instrument?
- What kind of security measures are in place?

These are all very valid concerns. You will need to explain what you want to do, and allow your administrator enough leeway to accomplish your goals while still satisfying theirs. Some of the information in this chapter may help you both.

Static IP

The reason your instrument needs a static IP address is because it is a *server*. You need your server to be at the *same* address all the time, so you always know where to point your browser. The server does not use a conventional file system. It is likely that once your instrument is running, it will remain on 24 hours a day, 7 days a week. This makes using a dynamic IP address (one that changes with each power up sequence) somewhat infeasible.

Port Number

The default port is 80 and should **NOT** be changed except in the following situations.

1. If IP addresses are scarce in your network environment, consider using a network address translation (NAT) router. With such a device, several IGC100's can 'share' a single IP address. Each IGC100 is assigned a 'fictitious' IP address and the router presents a single IP address to the rest of the world. In this case, all of the IGC100's will appear at the same IP address to the outside world (they will have different IP addresses on the local network). Each IGC100 needs to be on a different port and the router must be configured to forward port requests to the correct IGC100. From the outside, each IGC100 is accessed at its own port number (but the same IP address).

2. If you are experiencing attacks on port 80 that block access to the IGC100. In this case, change the port to something else (like 8080). You will need to specify this port in your browser address window as 208.123.123.32:8080 where 208.123.123.32 is the IP address of the IGC100 and 8080 is the port number.

For more information about NAT routers and ports, see your network administrator.

Setting Network Addresses

To enter network addresses into the IGC100, press the [Menu] QuickKey from the Pressure Display, then choose [Remote] from the Main Menu. Finally, choose [Web] in the Remote Menu.

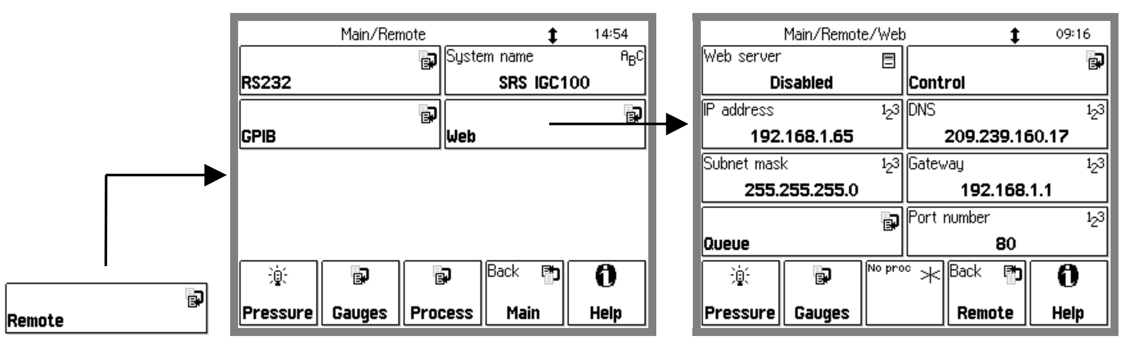


Figure 8-2. Getting to the Web menu.

In order to use the EWS option, you will need to have a connection to the internet and some information about your network environment.

The best source of information about your network environment is your network administrator. Here is a list of information you will need from that person:

1) An IP (Internet Protocol) address for the instrument
2) The IP address of a domain name server (DNS)
3) The IP address of the gateway
4) The IP address of a simple mail transfer protocol (SMTP) server
5) The Subnet mask

An IP address is made up of four bytes. It is often expressed as a set of three digit numbers separated by a '.' such as 209.239.160.084. The Internet protocol maps each machine's individual media access control (MAC) address to an IP address. Every page you are served from the world wide web is actually from a machine with a particular IP address.

People have a difficult time remembering and using long strings of numbers, so domain name servers (DNS) are in use. You can think of these machines as a kind of telephone book; they associate a particular IP address (209.239.160.084) with a string of characters (www.thinksrs.com). A DNS is not required to use the EWS, but it can make your life a little easier.

Next we need to consider the gateway. The gateway is simply the machine that connects your network to the outside world. It is the link between two networks, routing data traffic between those networks. For this reason, a gateway is sometimes referred to as a router. Its IP address is required for you to be able to send email from the EWS. If you will not be using the email notices feature of the EWS, and you will always be contacting the EWS from a machine on the same network, this IP address is not required.

A simple mail transfer protocol (SMTP) server often has one purpose in life: to relay email from one machine to another. It follows some simple rules for how the information that makes up the email is exchanged between the machine sending the email and the machine that will relay the message to its destination. This address is not required if you will not be using the email feature of the EWS.

Lastly, the subnet mask is required. In a network, there are quite often sub-networks. The subnet mask is required to let the EWS know which subnet it will be on.

Enable the EWS

After entering network addresses, set the Web Server to Enabled. Your EWS stores the network addresses into non-volatile memory, then gathers data on your IGC100 setup (gauge and relay descriptions, etc.). Allow the EWS about 30 seconds before continuing.

To make sure the EWS is functioning, touch the [Web Queue] button. If commands are streaming across the display, the EWS is communicating with the IGC100.

Important

Whenever network setup information is changed, you must wait at least 5 seconds for the changes to take effect.

System Name

The System Name (Menu/Remote/System Name) identifies this IGC100 on the web. This is important if your setup includes multiple web-enabled IGC100's. The system name is displayed in the web pages to identify the source of the data.

MAC Address

Your administrator may want to know the media access control (MAC) address of your instrument. The MAC is a unique address used at a lower layer of the internet protocol. Each IP address is mapped to a unique MAC address. Administrators often like to know this address as a crosscheck for the IP address (both should be unique). Knowing the MAC address also provides some extra security; if the administrator finds a MAC address that isn't listed in their directory, it could be an unauthorized user. When you put a server on a network, you are essentially inviting people to come and get information. Your administrator will want to make sure that this server doesn't create a security risk for the rest of the network.

To find the MAC address of your IGC100 from a networked PC (which can access the IGC100 via the web) :

Type in the IGC100's IP address (and port if not 80) in your browser's address window. This should bring up the IGC100 web page. Click on "Get Userlog" on the left. This displays the network settings of the IGC100 including its MAC address.

Choosing a Network Configuration

This section illustrates some possible network configurations for the EWS. This may help in choosing the best network configuration for your EWS.

Crossover Cable Configuration

This setup uses a crossover ethernet cable that allows the EWS to connect to a single computer without a network. A crossover cable is wired differently than regular network cables. A normal ethernet cable is wired 'straight through' (Tx to Tx, Rx to Rx), while a crossover cable is connects transmit to receive (Tx to Rx, Rx to Tx). *To use this configuration, make sure you use a crossover cable!*

This configuration will **NOT** allow email, use of a DNS, or access from more than one computer. It will **NOT** allow the computer connected to the IGC to connect to the internet. However, it does allow you to use a standard web browser to monitor, control and receive data from the IGC100.

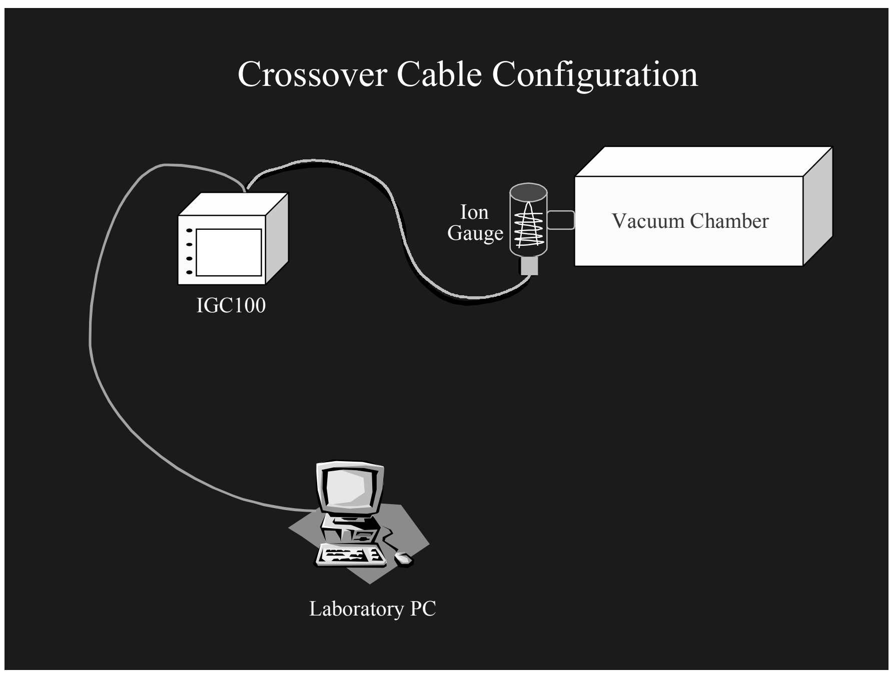


Figure 8-3. Crossover Cable Configuration

This configuration does **NOT** allow access to the IGC100 from the outside world. However, if security is a concern, this limitation is a strong reason for its use. The only security question to ask is "who will have access to this computer?". Since there is no intermediate connection, or dependence on outside hardware, this is also a very reliable connection. Furthermore, since the EWS will not actually be on the internet, you do not need a 'real' IP address. You can simply choose your own IP (on the same subnet as the PC).

Internal LAN Configuration

You can retain the security of the crossover connection and still allow more than one computer to access the IGC100. An ethernet hub will allow you to make a local area network (LAN) that can use fictitious IP addresses in order to access the instrument (as well as other computers on the LAN). The figure below shows a conceptual diagram of this configuration. While the IP addresses are fictitious, other networking parameters are still required and your network administrator can help you set up this type of LAN.

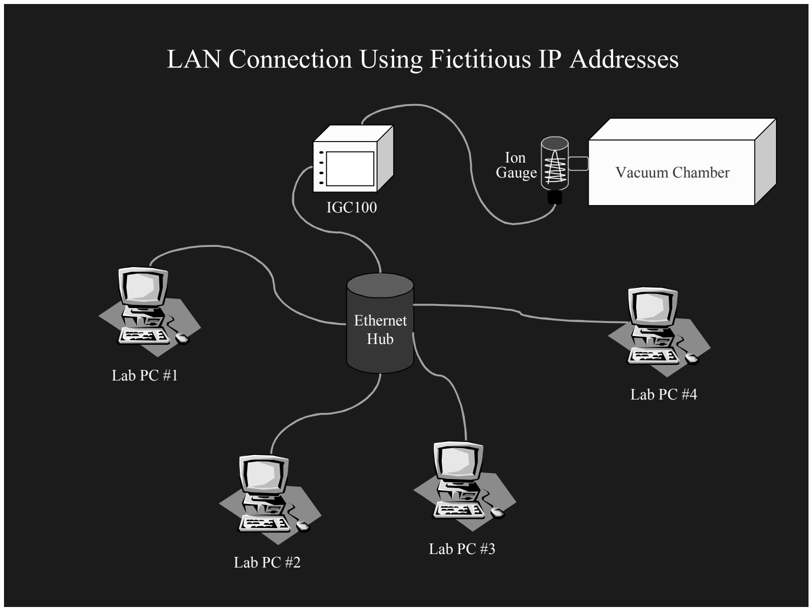


Figure 8-4. Internal LAN Configuration

Note that no connection to the internet is made in this LAN. The network is completely within your laboratory or plant floor, so security from an outside attack on this LAN is not a concern. Of course this also means that *you* cannot access the LAN outside of the workplace. However, the IGC100 *can* be accessed from other computers on the same LAN.

Conventional LAN Configuration

Chances are good that you are currently using a LAN with real IP addresses that is also connected to the internet through a firewall. A firewall is a piece of hardware designed to exclude unwanted data traffic coming from the outside world. A gateway is often employed in order to allow data traffic from the LAN to reach the outside world. Within a LAN that is using real IP addresses, you need to contact your network administrator in order to set up your EWS. For details, see the section 'Network Administration Concerns'.

This configuration allows anyone on your LAN to use the EWS. With a gateway in place, it also allows the EWS to send out email to a computer which is outside the LAN. However, this configuration may not allow you to monitor or control your vacuum system from outside your workplace. Talk with your network administrator for their advice on setting up this configuration to allow outside access to the IGC100. To maintain the security of the LAN, your administrator may wish to place the IGC100 outside the firewall, as described in the next section.

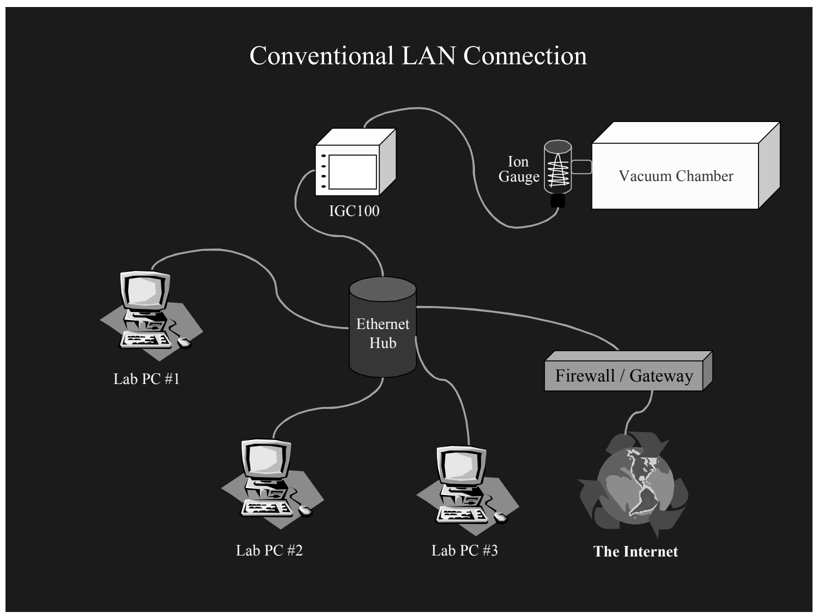


Figure 8-5. Conventional LAN Configuration

Outside Firewall Configuration

Here, the IGC100 is connected to the world wide web via a router outside the workplace firewall. This connection requires setting up real network parameters (as discussed in the previous sections) and your network administrator should work with you to set this type of connection. This configuration allows you to interact with your instrument from any computer, anywhere on the internet, via a standard browser. You can monitor your data, control relay states, and even receive email notification about relay state changes, from any location. There is a trade-off for all this flexibility and power. Once your instrument is accessible throughout the world, security issues must be addressed. See 'Configuring EWS Security' later in this chapter.

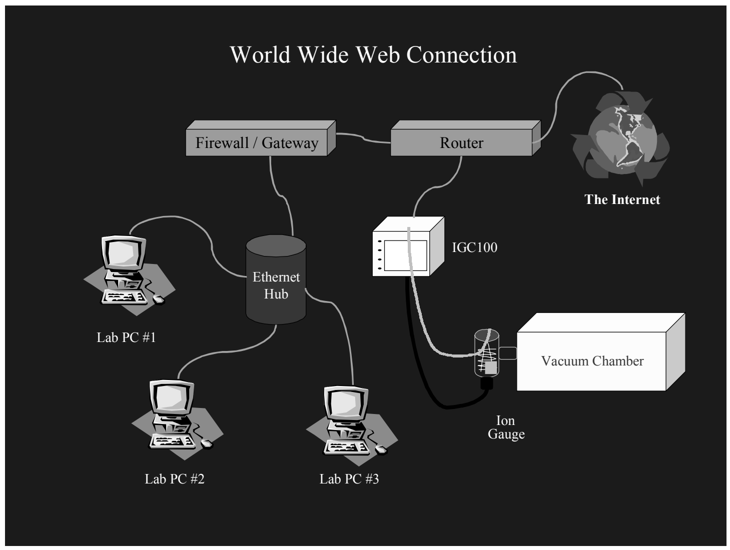


Figure 8-6. Outside Firewall Configuration

Testing with a Crossover Cable

Before putting your instrument on the web, it is best to test it via a direct PC to instrument connection. You will need an ethernet crossover cable, and a computer with a network card, already configured with network parameters. If you need to set up a computer for networking, contact your network administrator. Please do not contact SRS for support of your network. A workstation attached to the same network you wish to use the EWS with is ideal for this test. If the computer is already hooked up to a network, make sure disconnecting it will not cause problems for others on that network.

In this crossover configuration, real networking parameters (Subnet mask, DNS, Gateway) are not required.

1) Make sure the IGC100 is powered up and running normally.
2) Disconnect the computer from its ethernet network.
3) Connect the IGC100 EWS to the computer using a crossover cable.
4) From the command line prompt of your workstation, enter the command 'ipconfig'. This command will report the workstation's IP address.
5) On the IGC100, go to the Main/Remote/Web menu. Make sure the EWS is Disabled.
6) For this test, the IP address can be 'fictitious'. Set the EWS to use a fictitious address by subtracting one from the IP address of your workstation. For example, if your workstation IP address was reported as 111.111.111.111, use 111.111.111.110 for your fictitious EWS IP address. This is the only networking parameter required for this crossover test.
7) In the IGC100 Main/Remote/Web menu, set EWS to Enabled. This sets the IP addresses in the EWS and starts the EWS.
8) Under Main/Remote/Web, touch [Web Queue]. This screen should show web server activity as it queries the IGC for information. Allow the web server to gather information from the IGC for several seconds.
9) Run a web browser on your workstation. At the browser's "http://" prompt, type the fictitious IP address you set on the IGC100 front panel and hit the return key. In a moment, you should see the opening screen of the web page.

If you did not see the opening screen within a few seconds, make sure of the following:

- The web server is enabled. Check Main/Remote/Web/Web Queue (see above) for activity.
- When the cable is plugged in and the server is enabled, a green activity light on the ethernet connector on the rear panel should be illuminated. Verify this light is on. If it does not light, there may be a hardware problem with the crossover cable or your PC network card.
- The IP address on the front panel of the IGC100 matches the IP address you typed in on your browser.
- The crossover cable is connected directly from the PC to the IGC (no hub or switch is in the path).

- The cable is wired as a crossover cable.
- If the web page display seems garbled or if parts are incomplete, try waiting a few seconds and reloading the page in your browser. The most likely cause for this problem is that the web server has not had time to initialize.

Testing Within a Network

In order to test your EWS with a real network, you will need an IP address from your network administrator. You will also need the subnet mask, and IP address of the default gateway machine. You can get these addresses from the administrator. If you wish to use electronic mail, you may also wish to obtain the address of a domain name server (DNS).

1) Make sure the EWS is Disabled (Go to the Main/Remote/Web menu on the IGC100 if necessary).
2) Set the IP address.
3) Set the gateway address and subnet mask.
4) Connect the IGC100 EWS to a hub (or other network connection) with a standard ethernet network cable. *Do not use a crossover cable*.
5) In the IGC100 Main/Remote/Web menu, set EWS to Enabled. This sets the IP addresses in the EWS and starts the EWS.
6) Under Main/Remote/Web, touch [Web Queue]. This screen should show web server activity as it queries the IGC for information. Allow the web server to gather information from the IGC for several seconds.
7) Run a web browser on your computer. At the browser's "http://" prompt, type the IP address you entered on the IGC100 front panel and hit the return key.

If you did not see the opening screen within a few seconds, make sure of the following:

- The web server is enabled. Check Main/Remote/Web/Web Queue (see above) for activity.
- When the cable is plugged in and the server is enabled, a green activity light on the ethernet connector on the rear panel should be illuminated. Verify this light is on. If it does not light, there may be a hardware problem with the crossover cable or your PC network card.
- The IP address on the front panel of the IGC100 matches the IP address you typed in on your browser.
- The ethernet cable is connected from the IGC100 to a hub or other ethernet port (not directly to a PC).
- The cable is *NOT* a crossover cable.
- If the web page display seems garbled or if parts are incomplete, try waiting a few seconds and reloading the page in your browser. The most likely cause for this problem is that the web server has not had time to initialize.

Note
Your local network environment may prohibit your ability to get web pages from the EWS from outside your facility. See the section below entitled 'Network Configurations' and consult your network administrator for possible solutions.

Configuring EWS Security

You must decide if the IGC100/EWS offers enough security for your application. The EWS employs a number of security measures, however*, no network can be made entirely secure!* All security measures are implemented from the front panel of the IGC100 and cannot be changed via the web interface. This ensures that only authorized users set security levels.

Monitoring of the IGC100 through the EWS is allowed from all users. The security measures are designed to prevent unauthorized users from making changes to the IGC100 settings.

Web Server Enable

If you use your EWS only during certain hours, simply disable it when not in use. No web monitoring or control of the IGC100 is possible when the EWS is disabled. This setting can only be changed from the front panel.

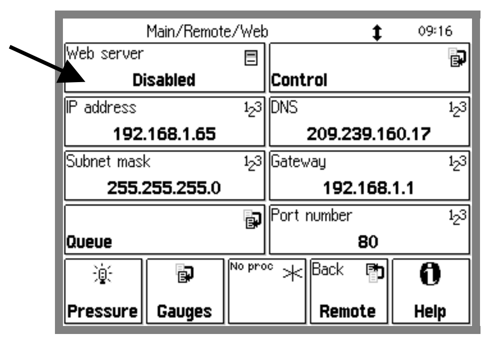


Figure 8-7. Web server enable/disable.

Important
Whenever network setup information is changed, you must wait at least 5 seconds for the changes to take effect.

Web Control Enable

If you only wish to monitor your vacuum system from the web, you should disable Web Control. Web Control of the IGC100 includes setting relay states and turning ion gauges on and off. When control is disabled, the EWS does not allow changes to the IGC100 settings. If you allow web control, make sure that the security features below are enabled.

Touch [Control] in the Main/Remote/Web menu to access the control and security features of the EWS.

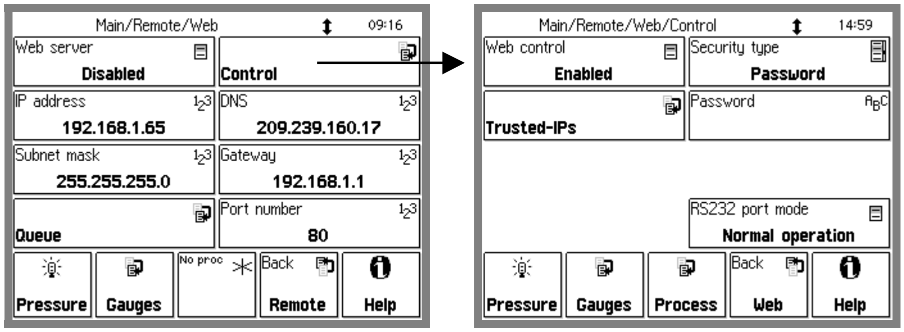


Figure 8-8. Web Control menu.

Security Type

The IGC100 offers a choice of security options when web control is enabled.

IP Checking

Within a networking environment in which the IP addresses do not change (the IP addresses are static), you can limit who has access to the instrument by checking the IP address of users asking for data.

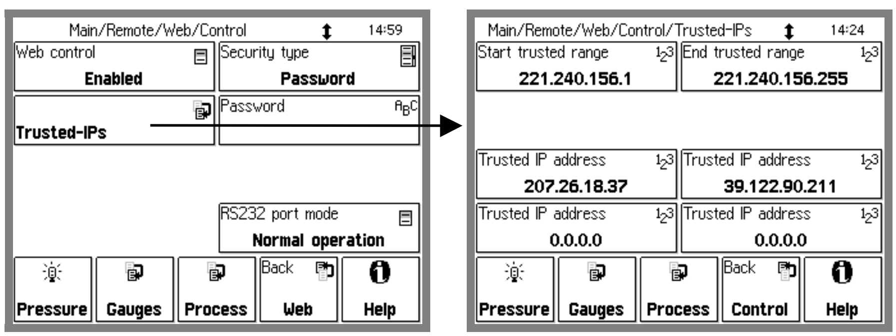


Figure 8-9. Trusted-IP setup menu.

The IGC100 allows you to specify the IP addresses that will be allowed to access the instrument over the web. You may specify a range of addresses as well as four addresses that are outside that range. The addresses outside the range are for trusted users outside the local network with static IP addresses. If your network uses dynamic IP addresses, but they always fall in the same range, you can still use IP checking security. If you do not require access to the EWS via a dial-up connection, this is the security measure to use.

Note that no password is required - if the IP address is trusted, control access is granted.

IP and Password Checking

As an extra measure of security in addition to IP checking, you can also assign a password to gain access to control of the IGC100. If you have set special parameters that are to remain unchanged even by in-house personnel, this is this measure to use.

Password Checking Only

This is the lowest level of security for the IGC100's control functions. However, if you require access to the control functions over a dial-up connection to the instrument, this is the method to use. A dial-up connection almost always assigns a different IP address to your connection each time you log on to your internet service provider (ISP). This means IP checking is not a feasible option.

Note

The password exchange is not encrypted. This means that if someone is monitoring your communication with the EWS, they will see your password.

Using the EWS

To view the EWS web pages, simply type the IP address of the EWS into your web browser.

Figure 8-10. Enter the IGC100's IP address into your browser.

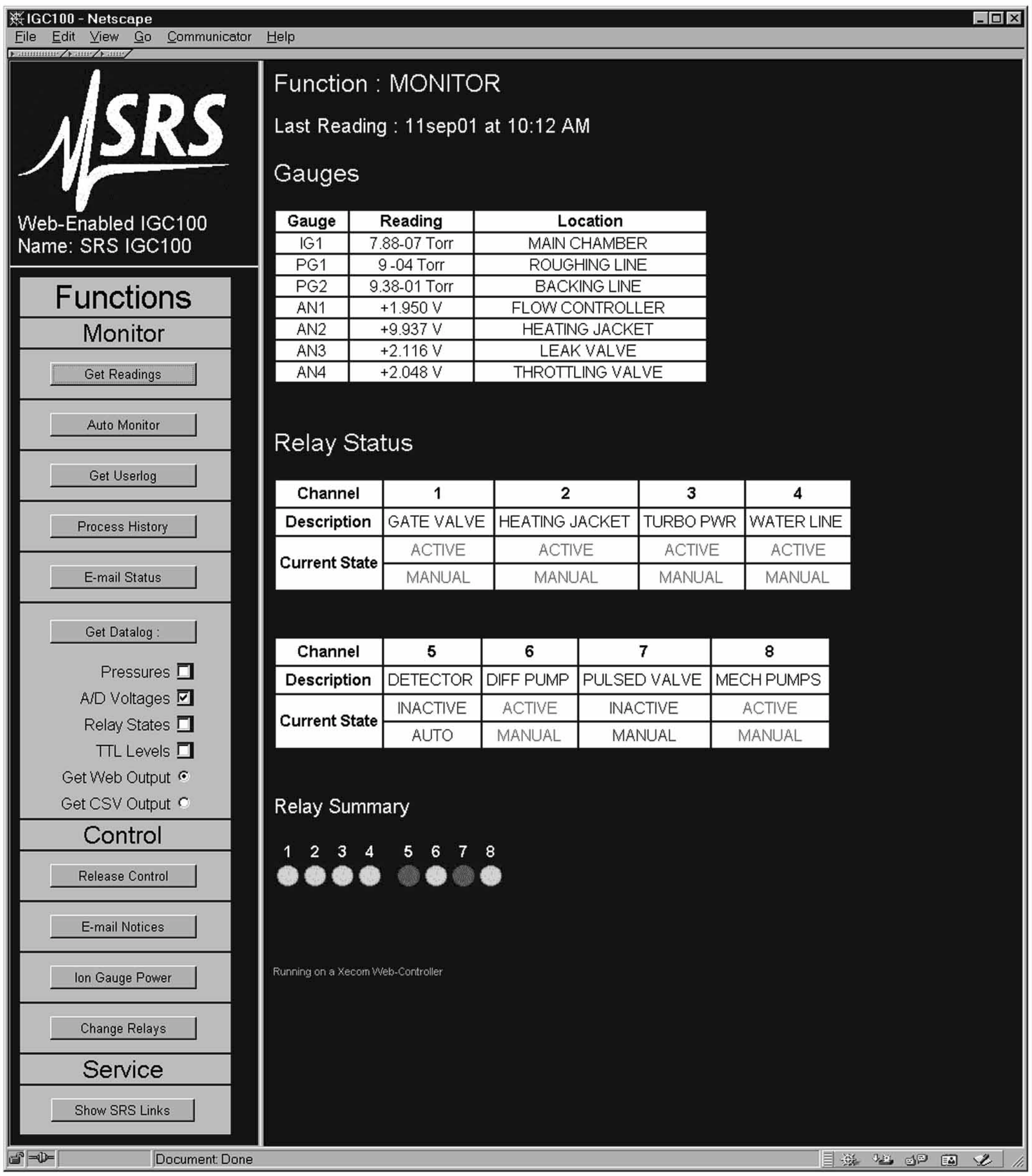


Figure 8-11. Main EWS web page.

Bookmarking the IGC100

You can add a bookmark to the IGC100 in your browser. Be sure to rename the bookmark to something meaningful. If you are accessing multiple IGC100's, make sure each bookmark is unique.

Monitoring the IGC100

The simplest use of the EWS is to monitor your data. The EWS offers three distinct ways to monitor.

- Display a page with all active gauges and current relay states
- Monitor selected parameters in an automatically updated window
- Display the data log to see how your system is behaving over time.

Get Readings

Get Readings reports the value of all inputs that are not in an error state as well as the process control relay states. If a gauge reading does not appear, use the Auto Monitor function described below to display the error state of the gauge. Note that all analog ports which can be converted to capacitance manometer readings are listed twice, as the analog voltage and the corresponding pressure value.

The system name (default "SRS IGC100") can be changed in the Main/Remote menu of the IGC100. This is important if you are monitoring multiple units.

This screen only updates when you click Get Readings. For continuous updates, use Auto Monitor.

Auto Monitor

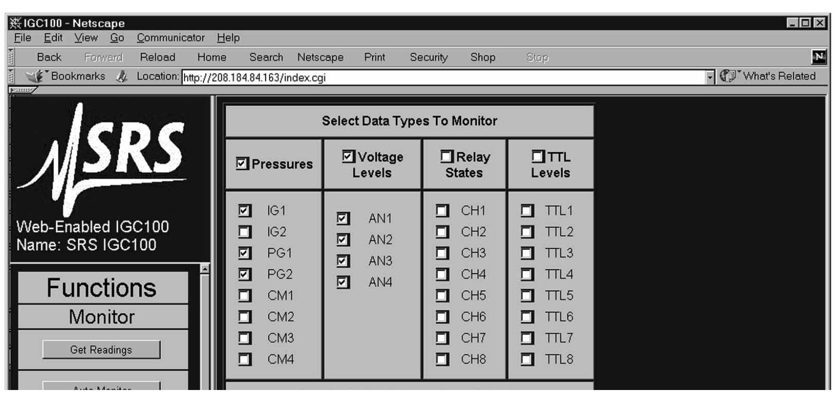


Figure 8-12. Auto Monitor menu.

This function allows automatic monitoring of specific inputs or values. Select the quantities you wish to monitor from the menu and how often you wish the display to update. A new browser window will be created displaying only the selected data. This window will refresh every 20 seconds (depending upon network availability). The auto monitor function will show the status of a gauge that cannot report a value.

The auto monitoring window can be on your desktop while you work, allowing you to keep tabs on critical parameters (see below). You can create multiple windows to group critical parameters by type, or use a single window and look at several types of data at once. This feature can be especially useful when a relay state is tied to a pressure reading; you can make absolutely sure that the relays are functioning correctly with the given pressure input. These same ideas can be applied to the analog inputs to monitor parameters such as temperature.

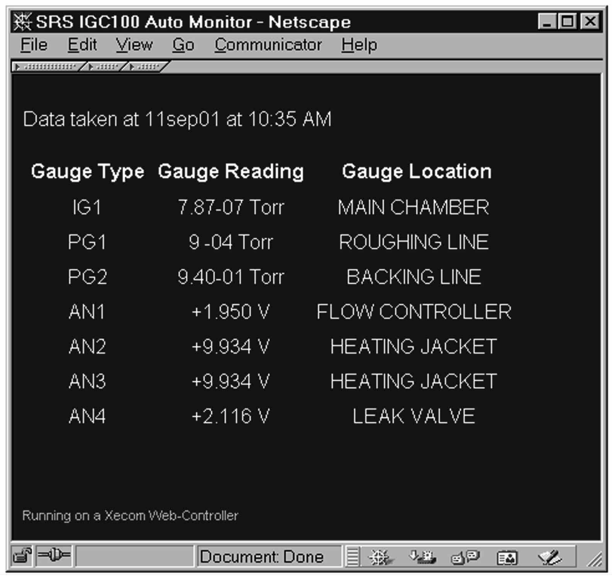


Figure 8-13. Auto Monitor window.

Process History

If your IGC100 is equipped with a Process Control option, this function will return up to the last 20 events in the process history. Each entry of the history has a timestamp, a listing of what relays were active at that moment, a listing of what relays were under automatic control at that moment, and what change took place at that moment. By examining the process history, you can trace how your vacuum system arrived in its current state. Often, you can quickly diagnose a problem in your vacuum system when you learn which interlocks were activated and the order in which they were activated.

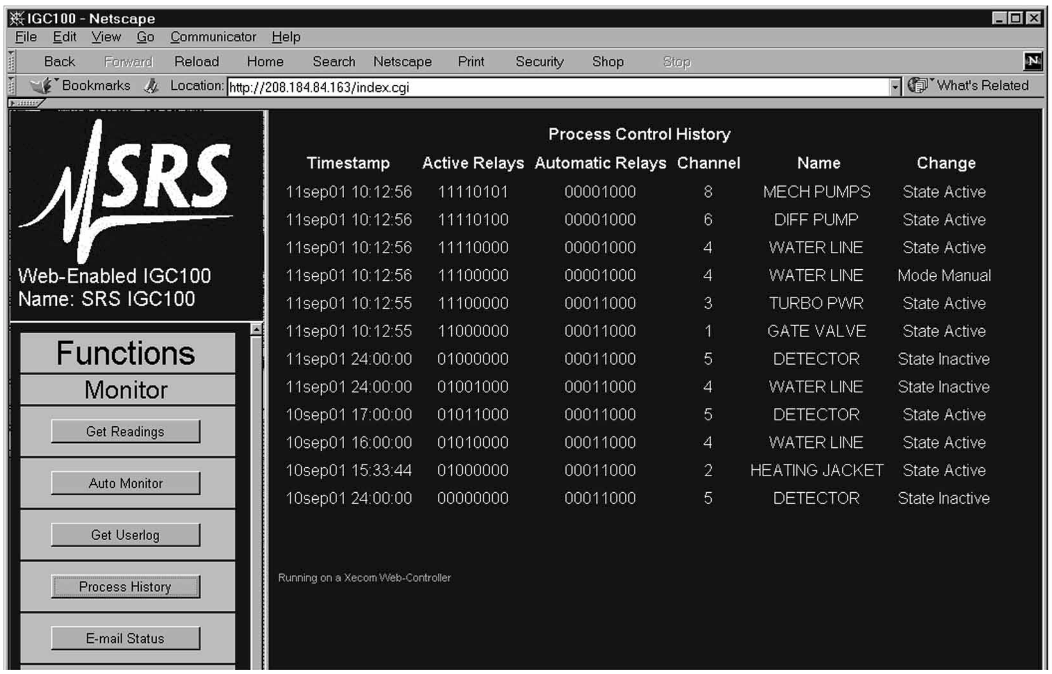


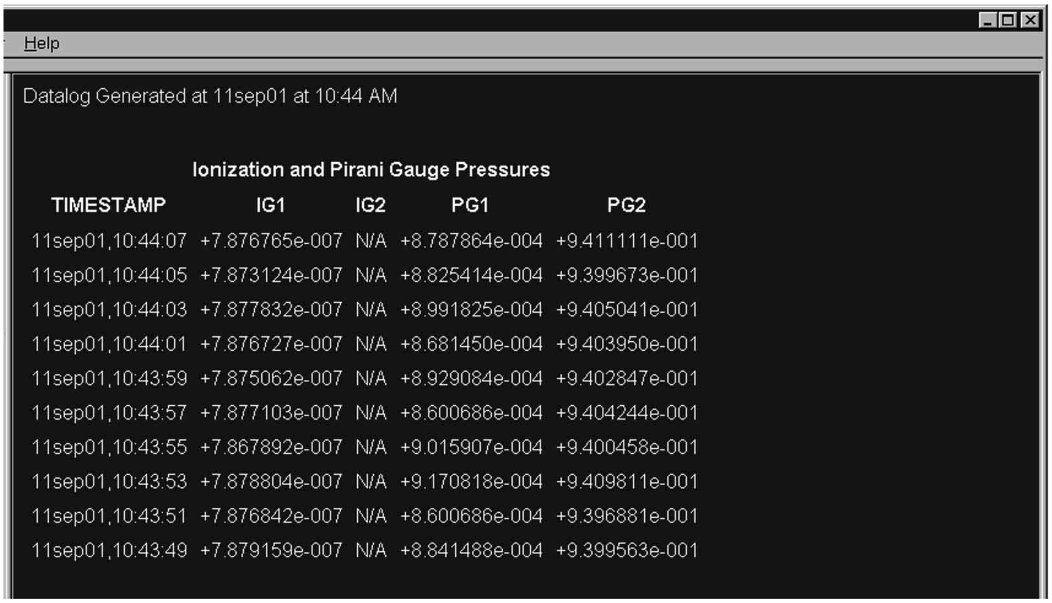
Figure 8-14. Process History.

Get Datalog

The Get Datalog function downloads IGC100 log data to your computer, via the web. You can select data from four categories, pressures, analog port values, relay states, and TTL levels. The data is downloaded either as a web page or as a comma separated variable (.csv) file compatible with Microsoft Excel.

Web Output

The number of log points in a web page is fixed at 10 points per data type.


Help

Datalog Generated at 11sep01 at 10:44 AM

Ionization and Pirani Gauge Pressures

TIMESTAMP	IG1	IG2	PG1	PG2
11sep01,10:44:07	+7.876765e-007	N/A	+8.787864e-004	+9.411111e-001
11sep01,10:44:05	+7.873124e-007	N/A	+8.825414e-004	+9.399673e-001
11sep01,10:44:03	+7.877832e-007	N/A	+8.991825e-004	+9.405041e-001
11sep01,10:44:01	+7.876727e-007	N/A	+8.681450e-004	+9.403950e-001
11sep01,10:43:59	+7.875062e-007	N/A	+8.929084e-004	+9.402847e-001
11sep01,10:43:57	+7.877103e-007	N/A	+8.600686e-004	+9.404244e-001
11sep01,10:43:55	+7.867892e-007	N/A	+9.015907e-004	+9.400458e-001
11sep01,10:43:53	+7.878804e-007	N/A	+9.170818e-004	+9.409811e-001
11sep01,10:43:51	+7.876842e-007	N/A	+8.600686e-004	+9.396881e-001
11sep01,10:43:49	+7.879159e-007	N/A	+8.841488e-004	+9.399563e-001

Figure 8-15. Web Output of datalog.

CSV Output

The CSV file is downloaded when you click Get Datalog. If the browser is not setup to automatically handle a .csv file, the data will be displayed in the browser. Users of Netscape Navigator can easily configure the browser to automatically launch Excel (or another graphing program) whenever a .csv file is downloaded.

In Navigator:

1) Go to Edit in the menu bar, and choose Preferences.
2) In the Category pane, double click on Navigator, then click on Applications.
3) Click on New Type. Enter the description "comma separated values", file extension "csv", MIME type "text" and browse to your application. Do not type the quote symbols!
4) Click OK.
5) Download the CSV data and your chosen application should open. Remember, the application must be able to handle data in this format!

Internet Explorer uses the Windows file associations. Installing Excel usually associates .csv files to Excel. If you need to add the association, go to Windows Explorer or My Computer. Go to View in the menu bar, then choose Options. Click on the File Types tab. Either edit an existing entry or add a new one.

If Internet Explorer will not automatically open Excel, try saving the downloaded csv data to a file. To do this, right-click on the downloaded data frame and choose view source. This usually opens a Notepad window with the data in it. Save this file to disk. Either double-click on this file to launch Excel or open it from within Excel.

Note

The EWS is limited in how much data it can send out at a time. Selecting fewer quantities (for example, pressures only instead of pressures and relay states) will increase the number of log points you acquire in a single CSV download.

Get Userlog

This feature is simply for security purposes. It displays the recent activity on the EWS and it shows the IP address and files accessed.

The network settings of the IGC100 are also displayed, including the MAC address.

E-Mail Status

E-mail notification is available in units with the Process Control option.

This page displays information about e-mail notification including a summary of the e-mail setup and a list of e-mails which have been sent from the IGC100. In addition, the number of messages sent is shown along with the maximum number allowed.

For more information about setting up e-mail, see the next section 'Controlling the IGC100'.

Controlling the IGC100

The world wide web allows the ultimate in remote control. You can change parameters of the instrument from virtually any location. For security purposes, the EWS only allows control of relay states, email configuration, and ion gauge power. All the control functions are under the security layer and require either the correct trusted IP address and/or password in order to gain access.

Request Control

If web control is disabled from the front panel of the IGC100, the control functions do not appear on the EWS web pages. If control is disabled while someone is browsing the page, the control functions will still be in the web page, but any control operation is prevented.

You must logon as the controller before any of the control functions can be accessed. Click this button to logon as the controller. Once you log in, the page reloads, and this button is re-drawn as 'Release Control'. *Only one user can have control of the EWS at a time.*

The logon prompt depends upon the type of security selected on the IGC100. If you have selected password or both password and IP checking security, you will have to enter the password. If you are just using IP checking for security, no password is required. In both cases, you will need to enter a controller name for identification purposes.

If someone is already controlling the instrument, you will be informed of their logon name, their IP address, and how long it has been since that controller performed a control function (their idle time). If the current controller has been idle for hours, it is likely they simply forgot to logout by clicking 'Release Control'. For this reason, *you are allowed to take control from an idle user, provided you know the password and/or have a trusted IP.*

Release Control

Click this button to logoff as the controller of the instrument.

Note

E-mail notification will remain enabled after control is released.

E-Mail Notices

This function allows configuration of the e-mail notification feature. In order to use e-mail, you must have entered a valid gateway address in the IGC100. A valid Simple Mail Transfer Protocol server (SMTP) address is also required. The gateway address is required so the EWS can access the SMTP server. The SMTP server is the machine (typically outside your network) that accepts e-mail and routes it to the appropriate address. These addresses should be obtained from your local network administrator.

Remember, e-mail is inherently unreliable - SMTP servers fail, delivery time is inconsistent, you don't read your mail regularly, etc. *Use e-mail notification as a backup* to an interlock system, not in replacement of one. Since the only purpose of e-mail is to alert users to process control changes, this button will be functional only if the IGC100 has the Process Control option.

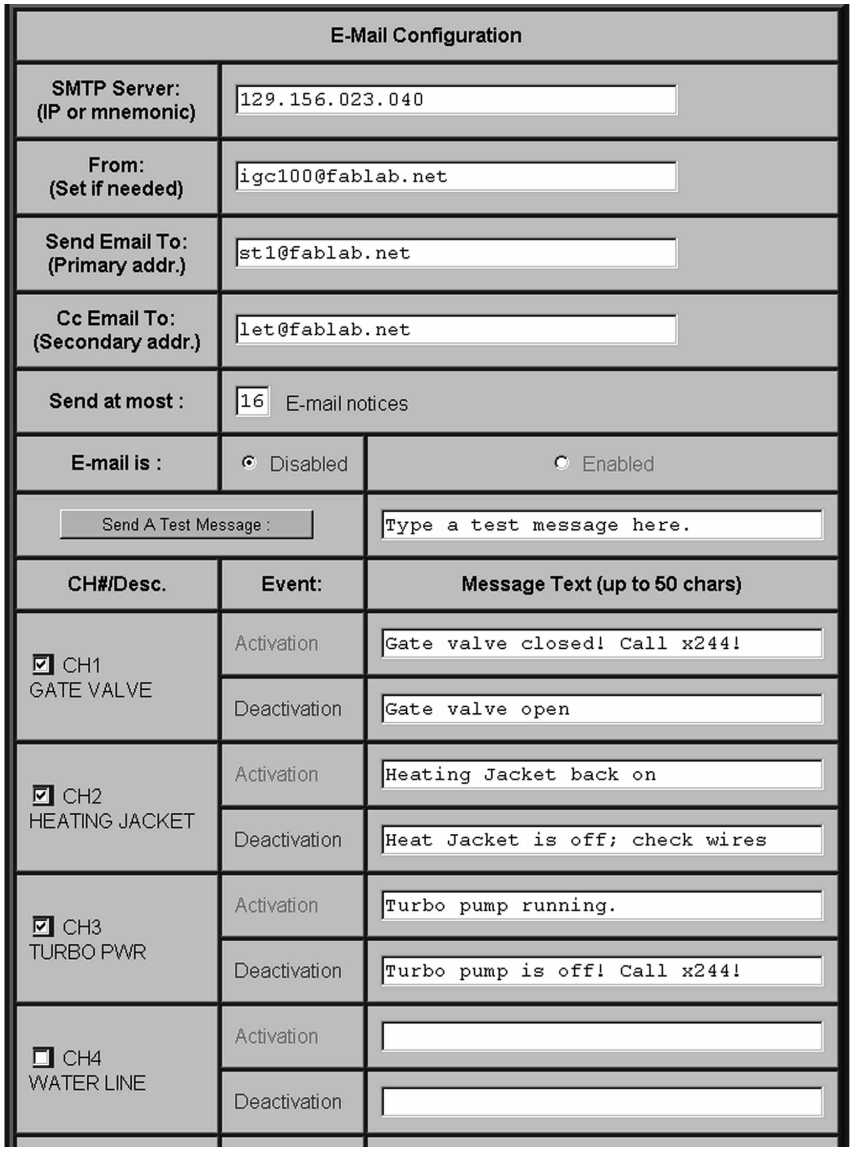


Figure 8-16. E-Mail configuration web page.

Testing the E-Mail Function

It is very important to test the e-mail function before using it routinely. If any address is incorrect, you will never get an e-mail notice.

1. Set the SMTP address. Make sure you type it correctly. If you are using a verbose address (relay.mailhandling.com), make sure the DNS address was entered correctly on the IGC100.
2. Set the "from" address. The SMTP may require a "from" address that has a certain domain name. The domain name is typically the string after the '@' sign in an e-mail

address. For example, if your e-mail address is me@mycompany.com, you may wish to use igc100@mycompany.com as the "from" address. Ask your network administrator if a particular domain name is required is required to use your SMTP server.

3. Set the "to" address; this is the e-mail address where you want notifications to be sent.
4. Click the 'Send A Test Message' button.

To learn the fate of your e-mail message, click 'E-Mail Status'. Your sent e-mail and the reply from the SMTP server will be listed there. Any reply other than "250 - OK" is an error. Click 'E-Mail Status' again to refresh the status if it was listed as "-2 -Awaiting reply". If the SMTP reply is "-1 : No Reply", a connection to the SMTP server was never made. Re-check your physical network connection as well as the gateway and SMTP addresses. If no error occurs, but you still do not receive the email, check the "from" and "to" addresses used.

Using the E-Mail Function

Once you have successfully tested the e-mail function, you can set a carbon copy (CC) address to send a copy of the notice to another user. Use only one e-mail address in the CC field.

1. Set the e-mail notices to "Enabled". A test message can always be sent by clicking the "Send A Test Message" button, even if e-mail notification is disabled. If you will be unable to receive e-mail for an extended period, it is a good idea to disable relay-linked e-mail notification.
2. Set the maximum number of relay-linked e-mail notices the EWS is allowed to send. This feature prevents accidental flooding of your mailbox. The default is 16. You probably wish to limit this number even further. The maximum cannot be set higher than 32.
3. Link process relays to e-mail notices by clicking their checkboxes. The subject line of each e-mail will be the channel number of the relay that changed and its new state, e.g. "Channel 1 : Inactive".
4. Enter a message you wish to send in the notification for both the activation and deactivation of the relay. Note the message cannot be more than 50 characters long.
5. Click "Use This E-Mail Configuration" to store your e-mail setup in the EWS. Verify the configuration is correct by clicking "E-Mail Status".
6. Test that your configuration by manually changing the state of a linked relay from the front panel.

If you wish to clear the configuration when you begin a new process, click "Erase This E-Mail Configuration".

To reset the e-mail count after a number of e-mails have been sent, disable then re-enable e-mail.

Note

E-mail notification remains enabled after control is released.

Ion Gauge Power

> **Warning!**
> Turning an ion gauge on or off from a remote interface can be dangerous. Make sure you understand your vacuum system and any process controls that depend upon ion gauge data before using this feature.

This function allows you to turn an ion gauge on or off, as well as choose the filament usage mode.

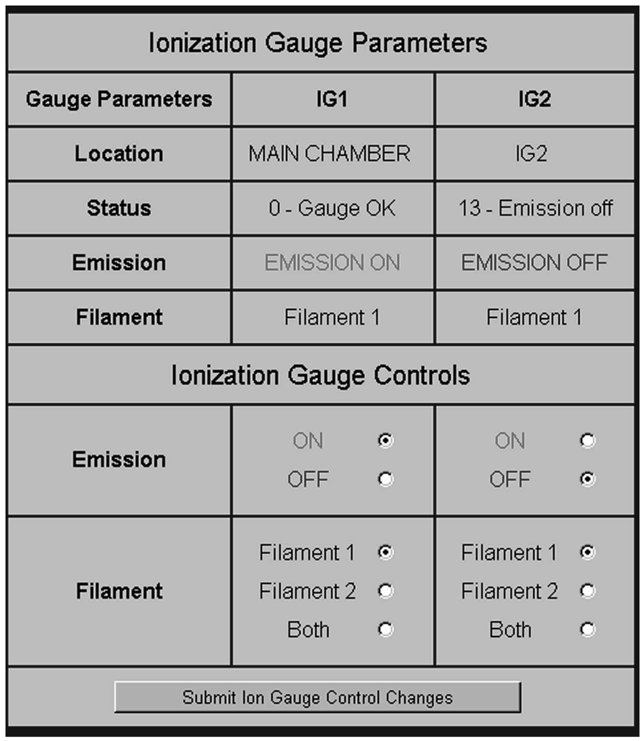
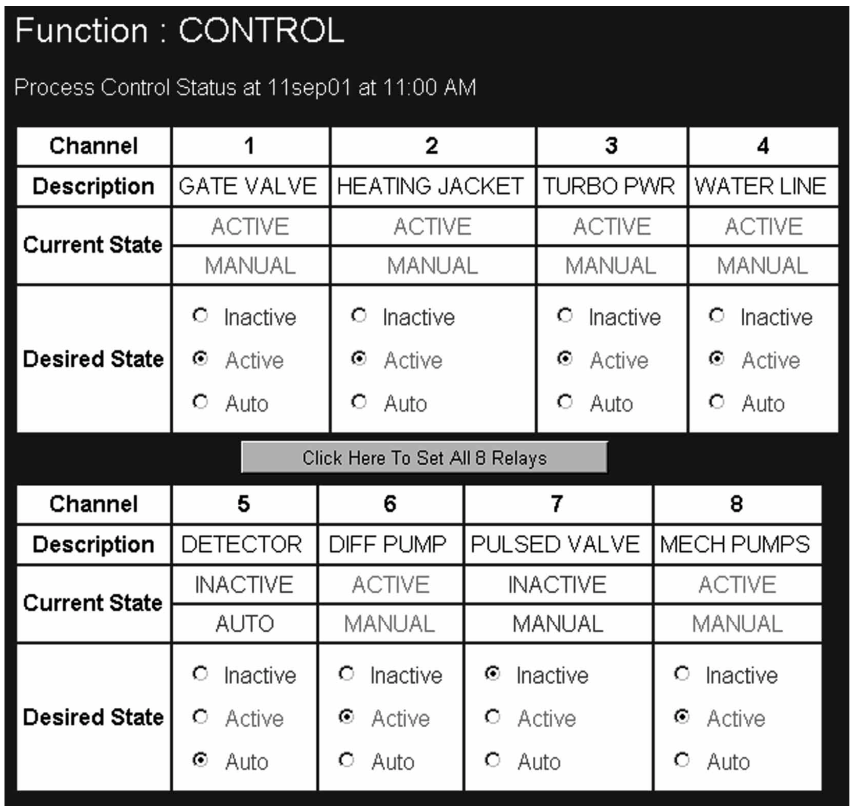


Figure 8-17. Controlling the Ion Gauge.

Change Relays

Warning!
Changing relay states from a remote interface can be dangerous. Make sure you understand your vacuum system and all process controls you have in place before using this feature. This feature will not be functional if the IGC100 does not have the process control option.

By clicking this button, you receive a web page showing the current state of all eight relays of process control. You can set a relay to be active, inactive, or under automatic control. To send your desired relay states to the IGC100, click the button labeled "Click Here To Set All 8 Relays".


Function : CONTROL

Process Control Status at 11sep01 at 11:00 AM

Channel	1	2	3	4
Description	GATE VALVE	HEATING JACKET	TURBO PWR	WATER LINE
Current State	ACTIVE	ACTIVE	ACTIVE	ACTIVE
	MANUAL	MANUAL	MANUAL	MANUAL
Desired State	○ Inactive ● Active ○ Auto	○ Inactive ● Active ○ Auto	○ Inactive ● Active ○ Auto	○ Inactive ● Active ○ Auto

Click Here To Set All 8 Relays

Channel	5	6	7	8
Description	DETECTOR	DIFF PUMP	PULSED VALVE	MECH PUMPS
Current State	INACTIVE	ACTIVE	INACTIVE	ACTIVE
	AUTO	MANUAL	MANUAL	MANUAL
Desired State	○ Inactive ○ Active ● Auto	○ Inactive ● Active ○ Auto	● Inactive ○ Active ○ Auto	○ Inactive ● Active ○ Auto

Figure 8-18. Relay control web page.

Networking Terms

Some terms that are used throughout this chapter are defined here.

Server
A server is simply a computer capable of delivering data to another computer. Typically, the server is *only* used to deliver data and all its resources are allocated to that task.

IP Address
Each computer that is connected to the world wide web needs to have a unique address in order for other machines to access that computer. An IP address is made up of four bytes. It is often expressed as a set of three digit numbers separated by a '.', e.g. 209.239.160.084.

Static IP Address
A static IP address never changes. Static IP addresses are often used for servers, so that computers on the web can find them.

Dynamic IP Address
A dynamic IP address changes frequently. Often, clients have dynamic IP addresses that are assigned to them when they boot up. When you use a dial-up connection, an IP address is assigned to you each time. This means you get a different IP address every time you logon from a dial-up connection.

Fictitious IP Address
Networks that are not directly connected to the world wide web sometimes use fictitious IP addresses valid only for local communication. Machines connected to this type of network are not directly accessible from outside that network. This improves security of the network and conserves the number of real IP addresses required for a facility. A network of fictitious addresses can be connected to the web using a router.

MAC Address
The media access control (MAC) address is another unique address that belongs to the physical network interface card. It is sometimes called an 'ethernet address'. It is often expressed as a series of hexadecimal codes separated by a dash (for example, 00-00-1A-18-FF-00). The Internet Protocol (IP) maps each machine's individual MAC address to an IP address.

DNS Address
People have a difficult time remembering and using long strings of numbers, so domain name servers are in use. You can think of these machines as a kind of telephone book - they associate a particular IP address (209.239.160.084) with a string of characters (www.thinksrs.com). A DNS is not required to use the EWS, but it can make your life a little easier.

SMTP Address
In order to send e-mail, a special machine called a Simple Mail Transfer Protocol server is often used. These servers respond to commands for sending e-mail and will forward your messages to the recipient’s local mail handling machine.

Chapter 9

Troubleshooting and Maintenance

Troubleshooting a vacuum system can be a complex and daunting task. This chapter contains troubleshooting information for the IGC100 and some typical gauges. Please read and follow all warnings presented in this chapter. See 'Safety and Preparation for Use' at the beginning of this manual to remind yourself of some of the dangers involved in working with vacuum systems.

In This Chapter

Warnings

- **Read and follow all 'Safety and Preparation for Use' warnings before handling this product (see front of this manual).**
- Dangerous voltages, capable of causing injury or death, are present in this instrument. Use extreme caution whenever troubleshooting any of its parts.
- Do not substitute parts or modify the instrument. Do not use the product if it has unauthorized modifications. Return the product to Stanford Research Systems for service and repair to ensure that safety features are maintained.
- Use only SRS supplied replacement/accessory parts.
- The IGC100 controller does not have any serviceable parts other than the Degas Fuse.
- Consult the 'Damage Requiring Service' section at the end of this chapter for instructions on how to return the instrument for authorized service and adjustment.

Resetting the IGC100

If the unit appears to be 'hung' and unresponsive to front panel inputs, disconnect and then reconnect line power.

To reset the instrument to its default settings, turn the unit on (using the red POWER key) while holding down the IG AUTO key.

Error Detection

Important
Diagnose and troubleshoot problems as soon as they are detected.

Even though the hardware tests built into the IGC100 can test the instrument for a large variety of problems, they cannot detect all possible error conditions.

If system downtime is of prime concern, it is recommended that a spare IGC100 unit be available for immediate replacement in the cause of failure or problems.

Built-in Checks

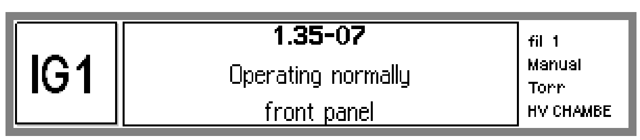
Several built-in hardware test procedures automatically check the IGC100 when the instrument is turned on, and continuously monitor the internal workings of the unit during operation.

All detected errors are immediately reported through on-screen messages, audio alarms or over the computer interfaces.

Error Messages

Text error messages are shown in the Data Bars and Data Boxes of the IGC100 display. Consult the 'Error Messages' section of this chapter for more information.

Touch the Data Box and choose 'Status Information' to display an explanation of the gauge status.



Audio Alarms

Sounds are used to draw the user's attention to potentially serious problems.

Error Status Words

Internal status words signal all status and error conditions through the computer interfaces.

Event Logging

All gauge related events (such as power on/off, degas on/off, overpressure shutdown, etc.) are stored in the Gauge History log. Use the [History] QuickKey in the Gauges Display to trace the gauge history and diagnose gauge failures and problems.

All Process Control events are stored in the Process History log. Use the [History] QuickKey in the Process Control Display to trace all channel actions and debug your process control settings. Use the [Overview] QuickKey to list the state and rules for all the Process Control channels.

Filament Protection

Use 'Overpressure Shutdown' and/or 'IG Auto-Start' to provide effective protection of delicate ion gauge filaments against accidental overpressure.

For More Information

Consult Chapter 3 for details on the proper implementation of 'Overpressure Shutdown' and 'IG Auto-Start'.

Remote Status Checking

Status reporting commands are available to query the Gauge and Process Control Status through the computer interfaces. Users developing their own control software should integrate status checking commands into their programs and use them to monitor the condition of their system. Status checking and error reporting should be an integral part of any custom-built control software.

For More Information

Consult Chapter 7 for a complete listing of the error checking commands and status registers.

Interface Queues

The IGC100 buffers the most recent characters received and transmitted over the RS-232, GPIB and Web interfaces. A Queue Display, accessed through the Remote submenu of the Main Menu, shows the interface history for both transmitted and received data. Use this feature to troubleshoot communications during the development of your custom control software.

For More Information

Consult the RS-232, GPIB and Web Queue menu items in Chapter 3 of this manual. Consult Chapter 7 for communications troubleshooting information.

Error Messages

Error Messages alert IGC100 users of instrument malfunctions detected during normal operation. They are short descriptive messages (one or two words) displayed within a Port Data Box or Data Bar where measurements are normally displayed. Touch the Data Box and choose 'Status Information' to display a more complete description of the problem.

The following tables list all Error Messages, along with possible causes and recommended solutions.

Pressure/Voltage Display

Error Message	Cause	Solution
UNDERRANGE	The IGC100 cannot display a number this small.	
OVERRANGE	The reading exceeds the range of the controller.	Reduce the pressure or voltage in your system.
NEGATIVE	The IGC100 cannot display negative numbers in this display mode.	Rezero the controller. Choose a different display mode.
OVERLOAD	The input voltage is beyond the ±12V range of the analog I/O port.	Limit the voltage range of the input signal. Use a voltage divider if necessary. Reduce the pressure of the capacitance manometer connected to the port.
FAULT	There is a serious system hardware problem in the controller that needs immediate attention.	Contact SRS. Do NOT use the IGC100 until the problem is diagnosed.
RESET	There has been no data to display since the unit was turned on.	Contact SRS.
ADC PROBLEM	The CM is connected to an analog I/O port configured as an output.	Configure the capacitance manometer port as an input so that you can read pressures directly.
WAIT	The controller is computing the answer. Emission current is being established in the ionization gauge.	Wait for the answer. Wait for the emission current to stabilize.
NOT SELECTED	The gauge has not been selected.	Select the gauge.

Gauges

Error Message	Cause	Solution
NO HARDWARE	The hardware required to operate the gauge is not present, or is not being recognized by the controller.	Contact SRS.
NO GAUGE	No Pirani gauge is detected.	Connect a gauge.
	Pirani gauge is unplugged.	Plug in the gauge.
	Signal cable (O105C4) is damaged or not properly connected.	Check the cable connection at both ends. Switch connectors (dual cable). Try a different O105C4 cable if available.
	Open sensor wire.	Perform Gauge Test Procedure (see Maintenance).
		Replace gauge head.
POWER OFF	Pirani Gauge power is turned off. No pressure readings are available.	Turn Pirani Gauge on from its Gauge Setup menu. (NOT in the presence of flammable or explosive gases).
EMISSION OFF	All ionization gauges are turned off.	Turn an ionization gauge on using the IG1 (or IG2) button on the front panel.
NO FILAMENT	IGC100 failed to detect a filament after the gauge emission was turned on.	IMPORTANT! Use only ionization gauge signal cables provided by Stanford Research Systems.
	Ionization gauge is unplugged.	Connect the gauge to the controller using proper signal cable.
	Nude ionization gauge pins improperly connected to O100C3 signal cable connectors.	Check instructions in Chapter 1 for proper connection of O100C3 cable to a nude gauge.
	Wrong signal cable is being used.	Use Appendix B to find the correct signal cable for your gauge.
	Defective Signal cable or connector.	Check for continuity between both ends. Try a different cable if available.
	Open filament in the gauge.	Inspect the filament visually (glass gauge), or with an ohmmeter (nude gauge) Consult appendix B for pin assignments. Try the second filament in a dual gauge system. Replace the filament assembly if possible. Get a new gauge if necessary.
	Defective Gauge tube.	Replace the gauge.
PG OFF	The Pirani gauge linked to Auto-Start function was off when the IG AUTO button was pressed.	Turn the PG on, and press the IG AUTO button again.

Error Message	Cause	Solution
EMISSION FAIL	IG will not turn on or turns on briefly then shuts off.	
	Badly contaminated filament will not support the emission.	Bakeout the gauge overnight (if possible). Replace the filament or the gauge if emission still cannot be turned on. Identify the contamination source and eliminate it.
	Badly damaged filament will not support the emission.	Replace the filament or the gauge. Filaments are easily damaged during degas and in the presence of corrosive and reactive gases. Check gauge history for overuse of degas cycles and recurring overpressures.
	IG at too high pressure.	Reduce the pressure in your system. Check for leaks and contamination sources, use an RGA or leak tester if available.
	Defective Gauge tube.	Try another tube.
	Gauge cable too long.	Use a shorter cable.
	Degas power too high.	Reduce degas power setting. Reduce ion gauge cable length. Switch to single filament operation in the ionization gauge.
	Degas Fuse is blown.	Replace the Degas Fuse. See Maintenance for procedure.
	Incorrect Gauge Protection Mode.	Use the proper Gauge Protection setting for the gauge.
	Controller failure.	Contact SRS
OVERPRESSURE	Overpressure Shutdown function is turning off the gauge.	Increase the Overpressure Threshold. Increase the Overpressure Delay to ignore short pressure bursts. Eliminate the source of the pressure burst.
TTL LOCKOUT	The ionization gauges are turned off by the IG_Lockout pin of the TTL Remote Control Module (opt 03). The IG1 and IG2 gauges remain off as long as this pin is held LOW, and IG_Remote_Enable is LOW.	Set the IG_Lockout pin high or disable Remote Control (set IG_Remote_Enable=High).

Basic Troubleshooting

This section documents symptoms, causes and possible solutions for some of the common problems encountered during the operation of an IGC100 controller.

Note
The problems listed below DO NOT GENERATE Error Messages.

Input Power

Power Problems		
Symptom	**Possible Cause**	**Solution**
LINE LED is off	No AC power available to the controller	Check your connection to the AC power outlet. Look for defective power outlet, defective power cord or power cord not connected.
	Defective internal power supply module	If AC power is available to the controller but the LED is still off, contact SRS.

Ionization Gauge

Ionization Gauge Problems		
Symptom	**Possible Cause**	**Solution**
Pressure reading is very inaccurate	Defective collector cable	Try a different cable.
	Electrical leakage in the gauge head	Bakeout the gauge. Replace the gauge if no change.
	Defective electrometer circuit	Contact SRS.
	Tube sensitivity improperly programmed	Reprogram the gauge’s sensitivity factor.
	Incompatible gauge settings	Select settings compatible with your gauge.
	Contaminated gauge head	Bakeout and/or degas the gauge. Replace the gauge if no change.
	Unknown gas composition	Use an RGA to analyze gas composition. Use Gas Correction Factor to adjust readings to the gas. Look for leaks or contamination sources
	Poor conductance in gauge’s connection to vacuum system	Move the gauge to the point-of-measure and/or increase conductance.
	Cross-talk with other ion sources	Separate the ionization gauge from other ion sources such as magnetrons, RGA's, ion pumps, ion guns, etc.

Ionization Gauge Problems		
Symptom	**Possible Cause**	**Solution**
Pressure reading too low	Collector cable disconnected or damaged	Check the signal cable connections. Replace the cable if necessary.
	Defective electrometer circuit	Contact SRS.
	Defective gauge head	Replace the gauge.
Pressure readings erratic	Gauge head badly contaminated	Bakeout, and/or degas, Replace the gauge if no change.
	Improper grounding	Perform a Proper Grounding Test (see Chapter 1).
	Bad collector cable or connection	Check connection or try a different cable.
	Faulty electrometer	Contact SRS.
	Cross-talk with other ion sources	Turn off all other sources of ions. Separate/shield the gauge from other ionization gauges, RGA's, ion pumps, etc.
Filament is unusually bright as soon as power is applied to IG	Contaminated filament	Bakeout, degas or replace the gauge. Try alternate filament if available. Identify and eliminate any source of contamination.
	Pressure is too high	Reduce the pressure at the gauge.
	Defective power supply	Contact SRS.
Degas will not turn on	IG not turned on	Turn on the ionization gauge before pressing the DEGAS switch.
	Pressure is above $2x10^{-5}$ Torr	Degas will not start if the pressure is above $2x10^{-5}$ Torr.
	Defective switch or power supply	Contact SRS.
IG shuts off after degas is initiated	Badly damaged filament	Replace the filament assembly or the gauge.
	Pressure rises above $5x10^{-5}$ Torr during degas	Reduce the initial pressure at the gauge.
	Badly contaminated tube	Bakeout or replace the tube.
	Degas power too high for gauge	Lower the degas power setting.
		Switch to single filament operation.
		Reduce the cable length.
	Incorrect Gauge Protection setting	Choose the proper Gauge Protection setting for the gauge.
	DEGAS FUSE blown	Replace the fuse (See Maintenance).
Degas power fluctuates during degas	Pressure rises above $2x10^{-5}$ Torr during degas	Reduce initial pressure at the gauge.

Pirani Gauge

Pirani Gauge Problems		
Symptom	**Possible Cause**	**Solution**
Pressure reading grossly in error	Gauge contaminated	Perform Pirani Gauge Cleaning Procedure and/or Bakeout the gauge (PG105-UHV only).
	Unknown gas type	Identify the gases in your system, use an RGA if available.
	Improper tube orientation	Mount tube horizontally for pressure readings above 1 Torr.
	Sensor damaged	Replace the tube.
	Excessive mechanical vibration	Remove the vibrations or mechanically isolate.
	Out of range temperature.	Control the temperature around the gauge.
	Wrong calibration curve	Check the calibration source.
	Poor conductance in gauge's connection to vacuum system	Move the gauge to the point-of-measurement, or increase conductance.
	Controller out of calibration or faulty electronics	Contact SRS.
Gauge zero reading is off	Gauge out of calibration	Adjust ZERO setting (using the Gauge Setup menu).
	Gauge contaminated	Perform Pirani Gauge Cleaning/Bakeout Procedure. See Maintenance.
Gauge atmosphere reading is off	Gauge out of calibration	Adjust ATM setting (using the Gauge Setup menu).
	Gauge not mounted horizontally	Mount gauge horizontally.
	Excessive vibration	Isolate the gauge from the source of vibrations.
Gauge Zero out of calibration range	The gauge is severely contaminated and the ZERO adjustment can no longer compensate for drift.	Perform Pirani gauge Cleaning/bakeout Procedure, or replace the gauge.
	The controller is faulty	Contact SRS.

Capacitance Manometer

Capacitance Manometer Problems		
Symptom	**Possible Cause**	**Solution**
Pressure reading grossly in error	Gauge contaminated or damaged	Consult your gauge manual or manufacturer for possible solutions.
	Excessive mechanical vibration	Remove the vibrations or mechanically isolate.
	Wrong full range (CM Pmax) setting	Check the CM Pmax value, and adjust if necessary.
	Poor conductance in gauge's connection to vacuum system	Move the gauge to the point-of-measurement, or increase conductance.
	Gauge needs to warm up	Temperature compensated gauges need up to one hour to completely warm up.
	Controller out of calibration or faulty gauge electronics	Contact SRS.
	Wrong supply voltage	Check power supply voltage and current limit settings. Do not use the AUX ±15V supply for heated gauges.
Gauge zero is off	Zero drifted off	Adjust the Zero calibration (using the Gauge Setup menu). Perform a Trim-Pot Zero Adjustment. Consult Chapter 3 for details.
Gauge Pmax reading is Off (Vout ≠10V when P=Pmax)	The gauge's gain calibration has drifted. This is a rare problem.	Follow the manufacturer's recommendations to adjust your gauge's calibration trim pots.
Gauge reading is too low and unresponsive to pressure changes	Gauge is unpowered	Check your cable and connections, check the current limit in your power supply, check the power supply operation.
	Gauge output circuit is faulty	Contact the gauge manufacturer.
Gauge reading is 'OVERLOAD'	The pressure output signal from the CM exceeds 12V	Reduce the pressure at the CM until it is below Pmax.

Process Control

Process Control Problems		
Symptom	**Possible Cause**	**Solution**
Channel output does not respond to input signal	Incorrect rules Bad connection Delay is too long Hysteresis is too large	Review the Channel Rules. Check the channel connections. Reduce the Delay setting. Reduce the Hysteresis setting.
Channel activates at wrong setpoint or time	Incorrect rule	Check the Channel Rules – Setpoint, Hysteresis and Delay settings
Relay closure does the opposite of what is expected	Wrong connection	Check the relay connection. Each SPDT relay has three connection pins, make sure you are connected to the right ones.
Relay contact opens and closes intermittently around the setpoint	Hysteresis percentage setting is too small	Increase the Hysteresis Percentage setting. Check for excessive noise in the input signal. Filter if necessary.

Analog I/O

Analog I/O Problems		
Symptom	**Possible Cause**	**Solution**
The analog output does not follow the log of the pressure of the gauge	The Analog I/O port is not configured properly.	Make sure the analog I/O port is configured as an Output and linked to the right gauge.
Analog reading is 'OVERLOAD'	The input signal exceeds ±12V range.	Reduce the input voltage until it is between –12V and +12V.

Maintenance

IGC100 Controller

IMPORTANT
The IGC100 controller box does not have any serviceable parts (other than the Degas Fuse) and requires no scheduled maintenance.

The IGC100 is only recommended for use in a clean, dry laboratory environment. Operation in other environments may cause damage to the controller and reduce the effectiveness of the safety features.

In all cases provide adequate ventilation for the control unit to dissipate heat - ≈1 inch clearance around the side ventilation slots is recommended. Allow at least 6 inches at the back of the controller for cable routing. Do not mount the unit above other equipment that generates excessive heat.

The IGC100 is designed to operate over the range 0-40°C. Ambient temperatures above that value might damage the product. For optimum electrometer stability (particularly while using calibrated gauges) the control unit ambient temperature should be 25±5°C.

Touchscreen

The surface of the touchscreen should be kept free of dirt, dust, fingerprints and other materials that could degrade its optical properties. Long term contact with abrasive materials will scratch the front surface and harm image quality.

Do not operate the touchscreen with the tips of pens or sharp objects that might permanently stain or damage the screen surface.

Use a clean, non-abrasive cloth towel and a commercial window cleaner to regularly clean the screen. The cleaning solution should be applied to the towel, NOT the surface of the touchscreen. Fluid may seep behind the panel if it is not cleaned properly. Turn off the unit or activate the Clean Touchscreen (Main menu, then Screen menu) while wiping the screen's surface.

Degas Fuse Test/Replacement

At pressures of $5x10^{-5}$ Torr and higher, a Bayard-Alpert ionization gauge can generate sufficient plasma that significant electrical coupling can occur between the anode grid and the metal parts of the vacuum system. The DEGAS FUSE is a safety device, built into the IGC100 to prevent the development of such electrical discharges inside the ionization gauge head during degassing.

WARNING!
Gas discharges in high voltage devices such as ionization gauges can be lethal in vacuum systems which are not properly grounded. Consult, Charles F. Morrison, "Safety hazard from gas discharge interactions with the Bayard Alpert ionization gauge", J. Vac. Sci. Technol. A 3(5) (1985) 2032, for a detailed explanation of this effect.

The DEGAS FUSE is connected in series with the anode grid, and is designed to burn out as soon as the electrical current through that electrode exceeds 250 mA. Removal of the bias voltage (500 Vdc degas, 180 Vdc normal) from the anode grid causes the filament to shut down, and extinguishes any discharge supported by the electrode structure.

A blown DEGAS FUSE is easily detected. Any attempt to establish an electron emission results in the "EMISSION FAIL" Error Message being displayed on the front panel instead of the expected pressure measurements.

In order to test and/or replace the DEGAS FUSE:

1. Disconnect the unit from its AC power cord.
2. Using a flat head screwdriver, remove the plug from the DEGAS FUSE receptacle on the back panel (quarter turn counterclockwise).
3. Remove the fuse, and use an ohmmeter to test electrical continuity between its ends.
4. If continuity is intact (i.e. fuse is OK) the emission problem is somewhere else. Consult the Troubleshooting section above.
5. If the fuse is blown (i.e. no electrical continuity between its ends) replace the fuse with a new one: DEGAS FUSE: 250mA, NB, Littelfuse 312.250
6. Replace the fuse plug and then the AC power cord.
7. Try turning a filament on to make sure emission is now possible.

Note

If the new fuse burns out as soon as emission is established, do not insert a new one until the cause for the failure is identified first. Contact Stanford Research Systems for additional help.

If emission is still not possible after replacing the fuse, consult the troubleshooting section above.

Ionization Gauges

Filament replacement, overnight bakeout and sensitivity adjustment are the three typical maintenance procedures performed on ionization gauges.

Filament Replacement

Since the electrodes are exposed, and easily accessible, most Nude ionization gauges are designed with replacement filament assemblies. This allows filaments to be replaced after a burnout without having to dispose of the entire gauge (an important cost saving feature!).

Contact Stanford Research Systems or your gauge manufacturer directly to order filament replacement kits for your gauges. Gauge refurbishing services, including both filament and electrode replacement options, are available from several vacuum hardware vendors.

Warning

Replacing the filament assembly in a nude ionization gauge will generally affect the sensitivity of the gauge.

Recommendation

Dual filament assemblies provide security against filament burnout if the system cannot be brought to atmosphere to change the filament or the gauge. They are the most cost-effective alternative for glass tubulated gauges where filament replacement is not an option. Do not expect both filaments to give identical readings in a dual filament gauge unless a high-accuracy gauge is being used.

Consult Appendix A of this manual for an in-depth discussion of the merits of different filament materials.

Use the Overpressure Shutdown and IG Auto-Start functions described in Chapters 2 and 3 to protect tungsten filaments against overpressures.

Bakeout

Outgassing is a pervasive effect that is observed in even the most carefully handled ionization gauges. An aggressive and prolonged degassing and/or bakeout can dramatically reduce gauge outgassing, but it will rarely completely eliminate it.

The most effective way to reduce the contribution of gauge outgassing is to bake out the gauge, along with as much of the rest of the vacuum system as possible, for an extended period of time (i.e. overnight typical).

Maximum recommended bakeout temperatures are: 450°C max for nude (all-metal) gauges, and 250°C for glass-tubulated gauges. Consult your gauge's specifications, or contact the manufacturer directly, for bakeout recommendations.

Frequently, an ion gauge is automatically degassed and/or the system baked after the gauge is exposed to ambient, or after surface contamination is suspected. Gauges will be unstable for several hours following degassing until the chemical composition and adsorbed layers on the newly cleaned surfaces reach equilibrium. This effect must be carefully considered for high accuracy measurements.

Degas or Bake Out?

The recommendation from the NIST High Vacuum Group is to eliminate degassing by high temperature heating of the grid (whether resistive or electron bombardment). For baked systems, their observation is that gauges can be effectively outgassed by simply operating them at normal emission currents while the gauge and vacuum system are baked. For unbaked systems, the gauge can be baked and outgassed by thermally insulating it with fiberglass or similar material. Degassing by electron bombardment is only recommended if (1) the gauge is heavily contaminated or (2) after exposure to surface active gases such as O_2 .

Sensitivity Adjustments

As an ionization gauge ages, its sensitivity drifts and its measurements become inaccurate. Long-term stability of its readings is affected by the gauge design, but most importantly, by its usage history. In most cases, ionization gauge sensitivity decreases with time.

It is highly recommended to check the accuracy of ionization gauge readings on a regular basis, by comparison against a secondary or working standard, and to keep track of the changes in sensitivity of each gauge with time. Sudden changes in the sensitivity may be indicative of increases in vacuum system contamination levels.

In order to check and/or readjust the sensitivity of your gauge, the following steps must be followed. Depending on the circumstances: (1) connect the secondary or working standard to your gauge's vacuum system, or (2) transfer your test gauge to a separate vacuum system (i.e. calibration station) containing the secondary or working standard. Make sure your gauge and the standard are exposed to the same pressure (within the tolerance of your measurements).

Pressurize the vacuum system with nitrogen up to a pressure level around the mid-range of your gauge. Typical pressures used are around 5×10^{-6} to 10^{-5} Torr (and at least 2 decades above base pressures)

Compare your test gauge readings (P_{gauge}) against those of the standard (P_{std}).

Uncalibrated Gauges

Uncalibrated gauges rely on the mid-range N2 Sense factor (stored in the controller) to calculate pressures from ion currents. Small drifts in sensitivity are common and can be easily compensated by adjusting the value of the sensitivity factor.

After recording the pressure measurements of your gauge against the calibration standard, calculate the sensitivity factor value for the test gauge based on the equation below and enter the new N2 Sense Factor into the controller.

$$N_2 \text{ Sense Factor (new)} = N_2 \text{ Sense Factor (old)} \times (P_{gauge} - P_{0g} / P_{std} - P_{0std})$$

where P_{0g} and P_{0std} are the background pressure as measured by the gauge and the standard. Note that this same procedure can be used to calibrate the N2 Sense Factors for gauges (1) when only nominal values (as provided by the manufacturer) are known or (2) where calibration for a different gas is required.

Tip

For maximum accuracy and to eliminate the effects of background gases, use pressure steps in the above equation to calculate the new sensitivity factor.

Calibrated Gauges

Calibrated gauges rely on data downloaded from a Memory Card to provide accurate pressures from ion signals. Small drifts in sensitivity with time are unavoidable, and are accepted as long as they do not extend beyond the accuracy tolerance of your measurement scheme. However, if comparison against a secondary or working standard indicates large drops in sensitivity, beyond acceptable levels, the gauge will need to be recalibrated. For information on ionization gauge calibration options available from Stanford Research Systems, consult appendix F of this manual.

Pirani Gauges

Zero and ATM adjustments.

The PG105 Pirani gauge calibration data loaded into all IGC100 controllers is based on the response of a new gauge free of contaminants. If a tube becomes contaminated or does not seem to read correctly, the front panel readings can often be adjusted using the 'ZERO and 'ATM' calibration menus. The ZERO and ATM adjustments built into the IGC100 make it possible to accommodate considerable drifts in PG105 calibration while retaining acceptable measurement accuracy.

To access the Zero and Atm calibration menus, bring up the Gauge Setup menu for the Pirani gauge port (PG1 or PG2), then touch [Atm] or [Zero] and follow the on-screen instructions.

Note

For accurate results in the 10^{-4} Torr range, ZERO readjustments of the gauge's readings should be performed periodically.

Use the Cleaning and Bakeout procedures described below if the calibration adjustments fail to correct for drifts in the calibration.

Cleaning Procedure

IMPORTANT!

- This cleaning procedure should only be used on severely contaminated gauges, when the ZERO and ATM calibration adjustments can no longer correct for drifts in the calibration.
- Stanford Research Systems does not guarantee that this procedure will remove contamination from a PG105 convection gauge.
- Use this cleaning method as a last resort only!

> **Warning!**
> The fumes from acetone and isopropyl alcohol can be dangerous to your health if inhaled and are highly flammable. Work in well ventilated areas and away from ignition sources!

Materials:

- Isopropyl alcohol or acetone, electronic grade or better.
- Wash bottle with long thin neck

Procedure

1. Disconnect the gauge from the O105C4 cable and from the vacuum system port. Disconnect the detachable plastic connector from the back of the gauge tube and store it in a safe and clean place. See Figure 9-1.

2. Hold the metal gauge tube in a horizontal position with the side port pointing upwards at a 45° angle. Slowly fill the volume of the gauge with solvent using the wash bottle to squirt the liquid into the side tube. Let the solvent stand inside the gauge for at least 10 minutes. Do not shake the gauge, since that might cause damage to the sensor wire. To drain the gauge, position it horizontally with the side port facing downward. Slightly warming the gauge will help dry the gauge. Allow the gauge tube to dry overnight with the port facing downward. Before reattaching the gauge to the system, be certain no solvent odor remains.

3. Viton O-rings soaked in organic liquids can outgas solvent molecules for extended periods of time. Solvent outgassing rates can be significantly diminished: (a) baking the gauge tube overnight in a vacuum oven between 100-110°C before gauge installation or (b) baking out the gauge while attached to the vacuum system and before reconnecting its plastic connector.

Bakeout Procedure

WARNING!
The detachable plastic connector must be physically disconnected from the PG105 gauge head during bakeout.

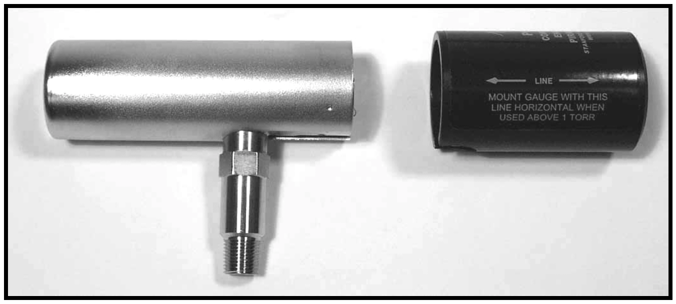


Figure 9-1. Side view of the PG105 gauge tube with the detachable plastic connector disconnected.

Periodic, overnight, gauge bakeouts provide an effective way to minimize contamination buildup problems. Maximum bakeout temperatures are 110°C for standard (i.e. Viton O-ring sealed) heads, and 250°C for metal-gasket sealed tubes (PG105-UHV) used in UHV or low contamination applications.

NOTE
An overnight bakeout, at 200-250°C, is the only recommended cleaning procedure for PG105-UHV gauges in direct contact with ultra high vacuum environments.

PG105 Gauge Test Procedure

Breakage of the small diameter sensor wire located inside the tube is a common failure mechanism for all Pirani gauges. Fortunately it is very easy to test the PG105 gauges for electrical continuity, to determine the integrity of both the sensor and temperature compensation wires.

WARNING!
Use an ohmmeter that cannot apply more than 0.1 V when the gauge is at vacuum or 2 V when at atmospheric pressure.

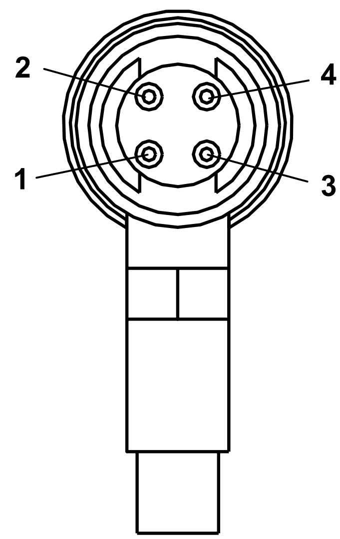


Figure 9-2. Back view of the PG105 tube, with the plastic connector removed.

1. Disconnect the Detachable Plastic Connector from the PG105 gauge head. Four feedthru connector pins are now easily accessible from the back of the gauge tube as schematically represented in Fig. 9-2.

2. Following the pin assignments of Fig. 9-2, measure the resistance between pins 1 and 4 and between pins 2 and 3. The nominal wire resistances are:

Pins	Wire	Expected value (Ohms)
1 to 4	Sensor	20 – 22
2 to 3	Compensate	35 - 40

3. Gauge wires are not replaceable! Replace the gauge head if the wire resistance values do not fall within the ranges specified above.

Damage Requiring Service

Caution

Do not use this product if it has unauthorized modifications. Unauthorized modifications may result in fire, electric shock and other hazards.

Do not use accessories not recommended in this manual as they may be hazardous.

Note

Within this section, the word 'product' specifically refers to the IGC100 Ion Gauge Controller, any of its accessories, or any SRS manufactured vacuum gauge.

Contact the factory for instructions on how to return the instrument for authorized service and adjustment.

Service of this product, by Authorized Service Personnel only, may be required under any of the following conditions:

- Any cable or plug is damaged.
- The product does not operate properly even after strictly following the operating instructions.
- The product exhibits a distinct change in performance.
- A liquid has spilled inside the product.
- The product has been exposed to rain or water.
- An object has fallen into the product.
- The product has been dropped or the enclosure has been damaged.
- The product contains unauthorized modifications. Do not substitute parts or modify the product. No user-serviceable parts are inside the controller. All service and repair information in this manual is for the use of Authorized Service Personnel only.
- The repair and/or service of products exposed to vacuum systems can only be carried out if a completed Declaration of Contamination (at front of manual) has been submitted. Stanford Research Systems reserves the right to refuse acceptance of vacuum equipment where the Declaration of Contamination has not been fully or correctly completed. SRS also reserves the right to deny return authorizations for any vacuum equipment that could potentially be harmful to the personnel carrying out the repair and service of the product.

Chapter 10

Testing

The performance tests described in this section are designed to verify to a high degree of confidence that the unit is performing within its published specifications.

The result of each test may be recorded on the Test Sheet included at the end of this section.

In This Chapter

Warnings

- **Read and follow all 'Safety and Preparation for Use' warnings before handling this product (see front of this manual).**
- **These tests should only be performed by qualified trained electronics technicians.**
- **Dangerous voltages, capable of causing injury or death, are present in this instrument.** Use extreme caution whenever troubleshooting any of its parts.
- Do not substitute parts or modify the instrument. Do not use the product if it has unauthorized modifications. Return the product to Stanford Research Systems for service and repair to ensure that safety features are maintained.
- Use only SRS supplied replacement/accessory parts.
- The IGC100 controller does not have any serviceable parts other than the Degas Fuse.
- Consult the 'Damage Requiring Service' section at the end of Chapter 9 for instructions on how to return the instrument for authorized service and adjustment.

Getting Ready

Necessary Equipment

The following equipment is necessary to complete the Performance Tests described in this chapter. The suggested equipment, or its equivalent, should be used.

DC Multimeter

DC Voltage Range [resolution]: 1000 V [1 mV]
Accuracy: 0.005%
DC Current Range [resolution]: 1 A [1nA]
Accuracy: 0.005%

Recommended: Hewlett-Packard HP 3458A Multimeter

DC Calibrator/Source

Voltage range: -20V to 20V
Accuracy: 0.02%
Current range: 2pA-20mA
Accuracy: 0.1% above 1 nA, 0.5% below 1 nA.

Recommended: Keithley Model 263 Calibrator/Source.

Low Noise Coaxial Cable

Used to connect the DC Calibrator to the IGC100.

Recommended: Belden 9239 Low Triboelectric Noise cable.

Sealed Ionization Gauge and Signal Cable

In order to eliminate the need for the presence of a vacuum system during performance testing, all ionization gauge related electrical specifications are tested using a sealed ionization gauge connected to the proper signal cable.

Note

The sealed ionization gauge can be replaced with any Bayard-Alpert type ionization gauge, connected to a vacuum system and exposed to base pressure (<10^{-5} Torr).

Signal Cable

Stanford Research Systems Model# O100C3, 10 foot long.

Sealed Gauge

Sealed test gauges (Fig. 10-1) are available from several third party sources:

Duniway Stockroom – Part # I-SLD-N (www.duniway.com)

Kurt J. Lesker – Part # G075S (www.lesker.com)

ETI Gauges- Part # 4336S (www.etigauges.com)

Sealed gauges can also be special ordered from Stanford Research Systems.

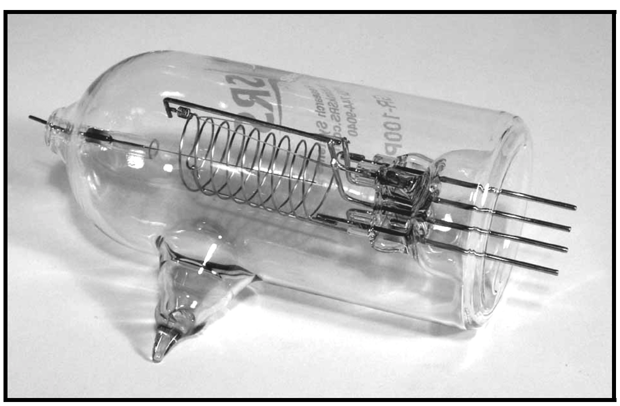


Figure 10-1. Sealed ionization gauge.

The Test Record

Make a copy of the IGC100 Performance Test Record at the end of this section. Fill in the results of the tests on this form. The Test Record will allow you to determine whether the tests pass or fail and also preserve proper test documentation.

If a Test Fails

If a test fails, you should check the settings and connections of any external equipment and, if possible, verify its operation using a DVM, scope or some other piece of test equipment.

After checking the setup, repeat the test from the beginning to make sure that the test was performed correctly.

If the test continues to fail, contact Stanford Research Systems for further instructions. Make sure that you have the units serial number and firmware revision code handy. Have the test record on hand as well.

Front Panel Overview

All IGC100 functions can be manually configured and controlled through the instrument's front panel interface. The front panel components can be divided into five categories:

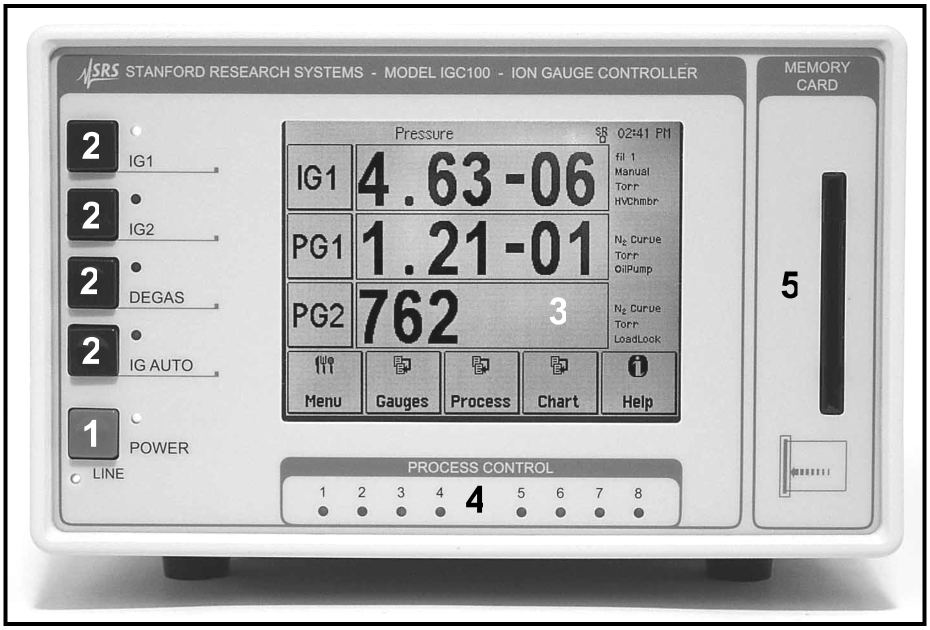


Figure 10-2. IGC100 front panel controls.

1. IGC Power - LINE LED and POWER button with LED

The LINE LED (red) lights up to indicate that the IGC100 is connected to, and getting power from, an AC outlet. Press the red POWER button to turn the IGC100 on/off.

2. Ionization Gauge Controls - IG1, IG2, DEGAS and IG AUTO buttons with LEDs.

Press the black IG1 (IG2) button to turn the IG1 (IG2) filament on/off. Press the black DEGAS to start/stop degassing of the active ionization gauge.

3. Touchscreen/LCD display

The LCD displays an intuitive menu-driven interface for instrument setup and operation. To activate an on-screen button, simply touch the LCD display over the button area. Help for any button or box is available on screen by touching the [Help] button, then touch any button or box for help about its function.

4. Process control LEDs

5. Memory Card Module

Preparation for Testing

> **Warning!**
> Before any tests are performed, make sure that the IGC100 has a sealed ionization gauge (or ionization gauge connected to a functioning vacuum system) connected to the rear panel ion gauge connector. In addition, make sure that the line power connection includes a proper ground.

Ionization Gauge Connection

> **Warning!**
> Sealed Ionization Gauges are very fragile and contain a high vacuum. Breakage of the glass envelope can result in implosion and the associated risk of flying glass.
>
> In order to eliminate the risk of electrocution, the IGC100 controller must be unpowered (i.e. LINE LED off) during the following connection procedure. Check your unit, and disconnect the IGC100 from its power source (i.e. wall outlet) at this time if necessary.

This section describes the procedure required to connect the sealed ionization gauge to the IGC100 controller with the SRS# O100C3 signal cable.

Procedure

Connect the 7-pin plug of the O100C3 cable to the ION GAUGE receptacle on the back panel of the IGC100 controller. Align the connector with the receptacle and then turn the plastic-ring clockwise to fasten the connection. Do not connect the signal cable's BNC connector to the controller since it is not required for the Performance Tests. Figure 10-3 shows the finalized connections on the back of an IGC100 box.

Figure 10-3. The 7-pin plug of the O100C3 cable is connected to the ION GAUGE receptacle on the back of the IGC100. The collector BNC is left unconnected.

The test gauge recommended for the Performance Tests is a sealed, single filament, glass-tubulated gauge easily identified by the in-line, 4-pin arrangement at the base connector of the gauge envelope. The pin assignments are detailed in Fig. 10-4.

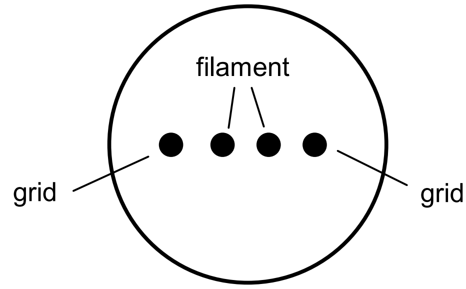


Figure 10-4 . 4 pin connector at bottom of gauge.

The O100C3 cable is compatible with ionization gauges with both single and dual filament electrode structures. The unattached end of the O100C3 cable connects to the gauge head and has six (6) individual push-on connectors housed inside a plastic connector-shield (see Fig. 10-5). Only three of the push-on connectors are used.

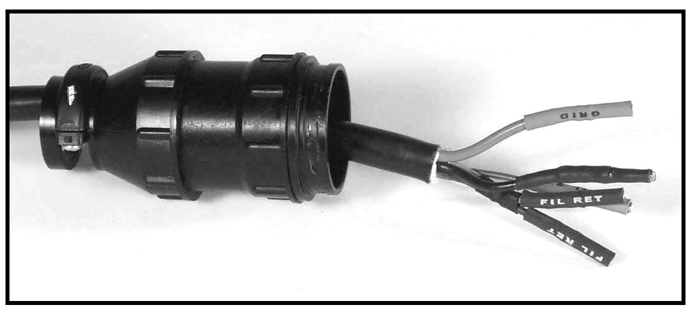


Figure 10-5. Gauge connectors of O100C3 cable.

In order to easily identify which cable connector attaches to which pin on the ion gauge, five (5) of the connectors are labeled and color coded: GRID [red], FIL 1 [yellow], FIL 2 [green], FIL RET [black], and FIL RET [black]. The sixth connector, is black, unlabelled and is not used in these tests.

Note

The plastic connector-shield, is not required for these tests either and can be pushed back or removed completely if necessary.

Connect the cable connectors to the appropriate pins on the base of the ionization gauge: (1) Connect Fil 1 and one of the FIL RET connectors to the Filament pins on the gauge, and (2) push the GRID connector onto one of the two Grid Pins on the gauge. Consult Fig. 10-6 for a completed connection.

Figure 10-6. Connection of O100C3 cable to the gauge head.

Note

Both FIL-RET cable connectors are identical and only one needs to be connected to the gauge (Fold the unconnected FIL RET cable connector back into the connector-shield with its end facing away from the gauge, and secure with electrical tape) . Only one of the grid pins on the gauge head needs to be connected (cut the unused pin or cover it with heat-shrink insulating tube to avoid the risk of high voltage electrocution while testing). Push all connectors into the pins until they seat firmly in place.

Line Power Connection

The IGC100 operates from 100V, 120V, 220V or 240V nominal AC power source having a line frequency of 50 or 60 Hz.

Procedure

Use the power entry module on the back panel of the IGC100 to power the unit from a wall outlet. Make sure that suitable power is available for the controller: 100-240 Vac, 50-60Hz, 500 W. Use the three-wire power cord, provided by Stanford Research Systems, to connect the IGC100 to a **properly grounded** wall outlet. Contact Stanford Research Systems if a power cord compatible with your outlets was not included with your unit.

The availability of LINE power to the box is clearly indicated by a lighted LINE LED (red) located under the POWER switch at the lower left corner of the front panel.

Power-On Reset

Before any tests are performed, the IGC must be powered up into a factory preset state.

Procedure

While holding down the IG AUTO Button, press the red POWER button located at the lower left corner of the front panel. The green POWER LED turns on, a brief Power-On Self Test (POST) procedure is executed and the pressure display screen is displayed on the touchscreen-LCD. Any problems detected during the Power-On Selftest procedure are prompted on the screen at this time and must be recorded in the Test Record.

IMPORTANT

Holding down the IG AUTO button during power-up reverts the controller to its factory-preset settings, a condition required by all the tests in this chapter.

Screen Contrast Adjustment

If the screen needs to be adjusted to your viewing needs after the power-on reset, adjust the contrast by touching the on-screen buttons:

[Menu]

[Screen]

[Contrast Up] or [Contrast Down]

Touch the [Pressure] button to return to the Pressure display screen at the end of the adjustment.

Serial Number

If you need to contact Stanford Research Systems, please have the serial number of your unit available. The serial number is printed on a label affixed to the rear panel. The serial number is also accessible through the touchscreen interface. To display the serial number as part of the Configuration Report, start from the Pressure Display Screen (default power-on screen) and touch the on-screen buttons:

[Menu]

[Utilities]

[Configuration]

Touch the [Pressure] button to return to the Pressure display screen at the end.

Firmware Revision

The firmware revision code, along with the update date, is briefly displayed on the LCD screen as part of the Self-Test Report when the unit is turned on. The revision code is also displayed with the serial number in the Configuration Report screen described above.

1. Self-Tests

Several Self-Test procedures are built into the IGC100 controller. These are functional tests and do not relate to the specifications. These tests should be run before any other tests.

Setup

No external setup is required for these tests. No warm-up is required for these tests.

Power-On Selftest (POST)

The IGC100 automatically performs a Power-On Selftest on its hardware every time it is powered up. Enter the results of the Power-on Selftest in the Tests Record at the end of this chapter.

System Self-Test

Starting from the Pressure Display screen (Power-on default Screen) press:

[Menu]

[Utilities]

[Selftest]

[System Selftest]

A brief Selftest procedure is performed and a Report is displayed on the LCD screen. Record any failures in the test record at the end of this section.

Button & LED Selftest

Return to the Selftest menu by pressing the [Back] button on the System Selftest Report screen and press [Button & Led Test].

All front panel LEDs light up at this time. Press the black Ion Gauge buttons (IG1, IG2 and DEGAS) to toggle their LEDs on/off.

Important

Act promptly since this test mode is abandoned after a seven seconds delay, and the display automatically reverts to the main Selftest menu. Repeat the test if you run out of time.

Enter the results of the Buttons Selftest in the test record at the end of this section. Report any defective LEDs.

Press the [Pressure] button on the lower left corner of the LCD screen to revert to the Pressure Display screen.

2. Analog I/O Tests

These tests measure the accuracy of the Analog I/O ports located on the back panel of the IGC100 (see Fig. 10-7). Each port is individually tested.

Figure 10-7. The four analog I/O ports.

Input Test

The four Analog I/O ports are factory preset to operate as inputs. Each input port is individually tested.

Warning!
Perform a Power-On reset as described above if you are uncertain about the state of your analog I/O ports at this time.

Setup

Use the DC Calibrator/Source to produce a voltage to measure with the Analog I/O input ports. Each port is tested individually.

Starting from the pressure display screen, press the [Gauges] button to access the Gauges Display. The Gauge Data Boxes labeled AN1, AN2, AN3 and AN4 display the voltage levels present at the input ports.

Procedure

1. Connect the output of the Voltage Calibrator/ Source to analog I/O port 1.
2. Set the output of the calibrator to +10.000 V, record the AN1 reading of the Gauges Display in the Test Report.

3. Repeat step 2 for source voltages +5.000, 0.000, -5.000 and –10.000 V.
4. Repeat steps 1,2 and 3 for analog I/O ports 2, 3 and 4.

Record all results in the Test Record.

Remain in the Gauges Display screen. Disconnect the calibrator from the IGC100.

Output Test

The four Analog I/O ports are factory preset to operate as inputs, so they must first be programmed to operate as outputs before the following tests are performed. Each port is individually tested.

Setup

We will use the DC Multimeter to measure the voltage sourced by the Analog I/O ports configured as outputs. Each port is individually tested. Configure the Multimeter to measure DC voltages at this time.

Procedure

Connect the DC Volt input of the multimeter to analog I/O port 1.

Touch the AN1 button on the Gauges Display screen to configure the port.

1. Touch [ADC or DAC] and choose "DAC Output".
2. Touch [DAC Source] and choose "Manual".
3. Touch [Volts When Source=Manual] and enter –10.
4. Measure the port's output voltage with the DC Multimeter.
5. Repeat steps 3 and 4 for output voltages –5.000, 0.000, +5.000 and +10.000 V.
6. Touch [Back] to return to the Gauges Display screen. Select AN2, AN3 and AN4 and repeat steps 1 through 5 connecting the multimeter to analog I/O ports 2, 3 and 4.

Record all results in the Test Record.

Remain in the Gauges Display screen.

+/- 15V AUX POWER Test

The IGC100 includes a +/-15V (100 mA max) auxiliary power output. This output will be tested with the digital multimeter.

Setup

Locate the +/- 15V AUX POWER output port in the back panel of the IGC100. Configure the DC Multimeter for voltage measurement.

Note

The +/- 15V AUX POWER includes a three (3) position Terminal Bock plug for easy connection to capacitance manometers.

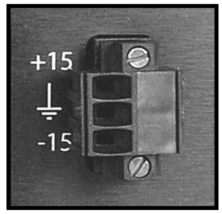


Figure 10-8. Aux Power connector.

Procedure

Measure the -15 V output. Enter test result in Test Record.

Measure the +15 V output. Enter test result in Test Record.

3. Ion Gauge Tests

IG Turn-on/Warm-up

Procedure

Press the IG1 button on the front panel of the IGC100 to activate the gauge's filament emission. The filament lights up, the gauge electrodes are biased, and a 0.1 mA filament emission current is established. Zero (nominal) is displayed in the IG1 data box of the Gauges Display, since no collector current is available (collector input is open).

1. From the main Pressure Display screen, touch [Gauges] to bring up the Gauges display.
2. Touch the IG1 Data Box in the Gauges Display to access the IG1 Setup Menu.
3. Touch the [Advanced] button to access the Advanced submenu.
4. Touch [Emission Current (mA)] and enter 10 mA.
5. Return to the Gauges Display by touching the [Back] button twice.
6. Allow the IGC100 to warm up for 1.5 hours before performing any of the following tests.

Enter any problems or failures reported by the controller in the Test Record.

Anode Grid Bias Voltage Test

This test measures the bias voltage on the anode grid electrode of the ionization gauge **while the gauge is turned on** (i.e. its filament is emitting electrons).

Warning!
Dangerous voltages capable of causing injury and even death are present during this test. Please take all necessary precautions to avoid the risk of electrocution.

Setup

Configure the DC Multimeter to measure voltages as large as +500 VDC.

Be very careful to eliminate the chances of personal injury due to electrocution during this test.

Connect the (LO) input of the multimeter to the Grounding Lug on the back of the IGC100. Use the (HI) input of the multimeter to probe the Grid pin of the ionization gauge head. **Beware that the gauge is ON and extremely hazardous high voltages are present!**

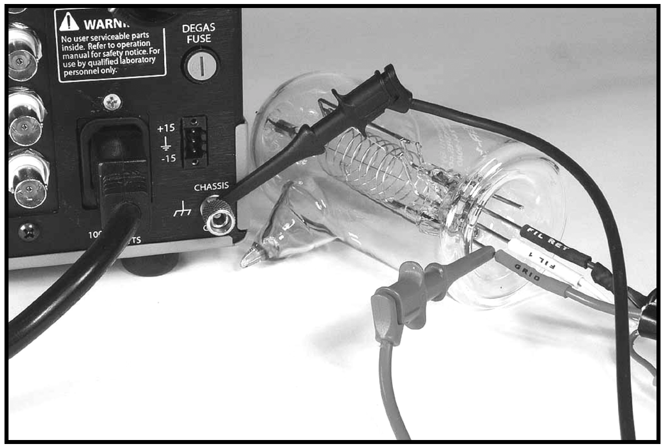


Figure 10-9. Anode Grid Bias Voltage Test. Multimeter Hi input connected to Grid pin on the gauge head and LO input connected to IGC100 Grounding Lug.

Procedure

Measure the voltage on the anode grid, under normal operating conditions. Enter the reading in the Test Record.

Press the DEGAS button and wait for degassing conditions to be established. Allow 5 minutes of warm-up and measure the voltage on the anode Grid again. Enter the reading in the Test Record.

Press the DEGAS Button to turn Degassing off. **The gauge will remain on.**

Filament Bias Voltage Test

This test measures the bias voltage on the Filament Return electrode of the ionization gauge **while the gauge is turned on** (i.e. its filament is emitting electrons).

Warning!
Dangerous voltages capable of causing injury and even death are present during this test. Please take all necessary precautions to avoid the risk of electrocution.

Setup

Configure the DC Multimeter to measure voltages as large as +50 VDC.

Be very careful to eliminate the chances of personal injury due to electrocution during this test.

Connect the (LO) input of the multimeter to the Grounding Lug on the back of the IGC100. Use the (HI) input of the multimeter to probe the Fil pin of the ionization gauge head connected to the FIL RET connector of the O100C3 cable. **Beware that the gauge is ON and extremely hazardous high voltages are present!**

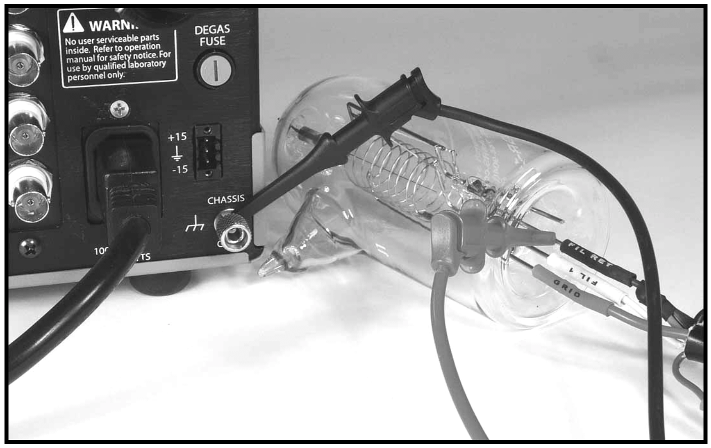


Figure 10-10. Filament Bias Voltage Test. Multimeter HI input connected to FIL RET pin on the gauge head and LO input connected to IGC100 Grounding Lug.

Procedure

Measure the voltage on the FIL RET pin, under normal operating conditions. Enter the reading in the Test Record.

Press the DEGAS button and wait for degassing conditions to be established. Allow 5 minutes of warm-up and measure the voltage on the FIL RET pin again. Enter the reading in the Test Record.

Press the DEGAS button to turn the degassing off. **The gauge will remain on.**

Filament Emission Current Test

This test measures the electron current emitted by the filament and collected at the anode Grid of the ionization gauge **while the gauge is turned on** (i.e. its filament is emitting electrons).

> **Warning!**
> Dangerous voltages capable of causing injury and death are present during this test. Please take all necessary precautions to avoid the risk of electrocution.

Setup

Configure the DC Multimeter to measure DC current.

Procedure

Press the POWER button to momentarily turn off the ionization gauge controller, **wait for 30 seconds for the electrical voltage to dissipate from the electrodes.**

Acting promptly to keep the IGC100 warmed-up, disconnect the (red) GRID push-on connector from the Grid pin of the ionization gauge and re-route the electrical connection through the current measurement inputs of the electrometer (i.e. the current flowing into the anode grid can now be measured by the DC current meter). See Fig. 10-11.

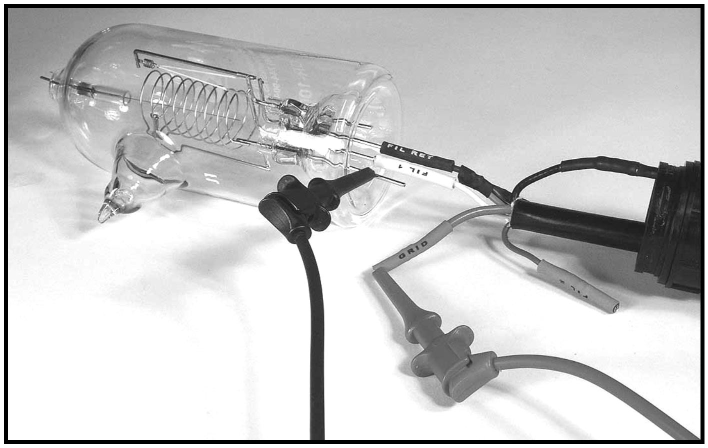


Figure 10-11. Connection for electron emission current measurement.

1. Press the POWER button to turn the controller back on.

2. Press the IG1 button to re-establish the emission current (10 mA). Allow 30 minutes of warm up time.

3. Touch the [Gauges] button to access the Gauges Display Screen.

4. Touch the [IG1 Data Box] on the Gauges Display screen to access the IG1 setup menu.

5. Touch the [Advanced] button to show the Advanced menu.

6. Touch the [Emission current (mA)] button and enter an emission current setting of 0.05 mA.

7. Wait 5 minutes for the current to stabilize.

8. Enter the emission current displayed by the multimeter into the Test Record.

9. Repeat steps 6 through 8 for emission currents: 0.5, 5 and 10 mA.

Leave the ionization gauge on, with 10 mA of emission current as a filament setting.

Remain in the Advanced Gauge Setup Menu.

Electrometer Test

This test measures the accuracy of the electrometer used to measure ion currents produced by the ionization gauge.

Setup

We will use the DC Calibrator/Source to inject a small current into the collector input 1 of the controller.

Important

Use the Low Noise Coaxial cable to complete the connection, and assure noise-free measurements below the 1 nA range.

Procedure

Connect the DC Calibrator/Source to the Collector port (BNC) labeled 1 on the back panel of the controller through the low-noise coaxial cable.

Starting from the Advanced IG1 setup submenu, touch the [Back] button to return to the main IG1 Setup Menu. Or starting from the main Pressure Display, touch [Gauges] and then [IG1].

In the IG1 Setup Menu,

Touch [N2 Sense Factor (1/Torr)] and enter 10.

Touch [Gas Correction Factor] and enter 10.

Touch the [Pressure] button to show the Pressure Display screen.

Important!

Under this setup, the magnitude of the pressure displayed on the IG1 data bar is identical to the magnitude of the collector current (in Amps) measured by the electrometer. For example, a 10^{-9} Torr IG1 reading is displayed for a 1 nA collector current.

Using the IG1 data bar as the display, measure the collector current readings for source currents: 1 nA, 10 nA, 100 nA, 1 µA, 10 µA, 100 µA and 1 mA. Enter the results in the Test Record.

This completes all the required tests.

Press IG1 to turn off the ion gauge, and the POWER button to turn off the controller.

Wait 30 seconds for electrical voltages to dissipate from the gauge before disconnecting any connectors.

IGC100 Performance Test Record

Serial #	Firmware Revision
Tested By	Firmware Updated
Date	
Equipment Used	

Self Tests

Test	Pass	Fail	Comment
Power-On Selftest			
System Seltest			
Button & Led test			

Analog I/O Tests

Input Port	Voltage	Lower limit	Reading	Upper Limit
1	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.980
	-10.000	-10.020		-9.980
2	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.980
	-10.000	-10.020		-9.980
3	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.980
	-10.000	-10.020		-9.980
4	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.980
	-10.000	-10.020		-9.980

Analog I/O Tests				
Output Port	**Voltage**	**Lower limit**	**Reading**	**Upper Limit**
1	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.98
	-10.000	-10.020		-9.980
2	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.98
	-10.000	-10.020		-9.980
3	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.98
	-10.000	-10.020		-9.980
4	10.000	9.980		10.020
	5.000	4.980		5.120
	0.000	-0.020		0.020
	-5.000	-5.020		-4.98
	-10.000	-10.020		-9.980
Aux Power Connector		**Lower Limit**	**Reading**	**Upper Limit**
-15 V Test		-17.5 V		-12.5 V
+15 V Test		+12.5 V		+17.5 V

Ion Gauge Tests			
Ion Gauge Turn-On/Warm-up			
Comments			
Anode Grid Test	**Lower Limit**	**Reading**	**Upper Limit**
Normal Operation	179.5 V		180.5 V
Degas Mode	498.5 V		501.5 V
Filament Bias Test	**Lower Limit**	**Reading**	**Upper Limit**
Normal Operation	29.91 V		30.09 V
Degas Mode	29.91 V		30.09 V

Ion Gauge Tests

Emission Current	Lower Limit	Reading	Upper Limit
0.05 mA	0.0495 mA		0.0505 mA
0.5 mA	0.495 mA		0.505 mA
5 mA	4.95 mA		5.05 mA
10 mA	9.90 mA		10.1 mA
Electrometer Current	**Lower Limit**	**Reading**	**Upper Limit**
1 nA	9.90e-10		1.01e-9
10 nA	9.90e-9		1.01e-8
100 nA	9.90e-8		1.01e-7
1 μA	9.90e-7		1.01e-6
10 μA	9.90e-6		1.01e-5
100 μA	9.90e-5		1.01e-4
1 mA	9.90e-4		1.01e-3

Tester’s Final Comments

Appendix A

Bayard-Alpert Ionization Gauges

This appendix attempts to explain the principles of operation of the Bayard-Alpert Ionization Gauge, or BAG, outline its fundamental limitations and describe the ion gauge types that have successfully surmounted some of them. A few practical tips are also provided along the way. The emphasis has been placed on gauges that are commercially available.

In This Appendix

Principle of Operation

Introduction

The Bayard-Alpert ionization gauge (BAG) was first described in 1950[1]. Modern versions of the gauge have preserved most of the basic elements of its original implementation. Standardization of the BAG design has made it possible for vacuum equipment manufacturers to produce generic ion gauge controllers, such as the IGC100, capable of controlling BAGs from many different manufacturers.

BAGs are not perfect, and the user who believes their pressure indications without a basic understanding of their operation is likely to be fooled.

This appendix attempts to explain the principles of operation of the BAG, outline its fundamental limitations and describe the ion gauge types that have successfully surmounted some of them. A few practical tips are also provided along the way. The emphasis has been placed on gauges that are commercially available.

Since it is not possible to cover this complex gauge in a short note, a comprehensive list of references is provided at the end that should allow the reader to find answers to most problems.

Gauge Principles

Figure A-1 describes a prototypical BAG design. Electrons boil from the hot filament (30Vdc) and are accelerated towards the anode grid (180Vdc). As the current (0.1-10 mA typical) of highly energetic (150eV) electrons traverse the inner volume of the grid cage, they ionize some of the gas molecules they encounter in their path. Electrons that do not encounter any obstacles in their path, exit the grid and are immediately directed back into its inner volume by the electrostatic field, resulting in a multiple-pass ionization path that ultimately ends by collision with a grid wire. The ions formed inside the anode grid are efficiently collected by the grounded (0Vdc) collector wire that is located along the axis of the cylindrical grid and connected to the controller's electrometer. If the electron emission current and the temperature of the gas are constant, then the ion current is proportional to the number density and the pressure of the gas. *The positive ion current provides an indirect measurement of the gas pressure.*

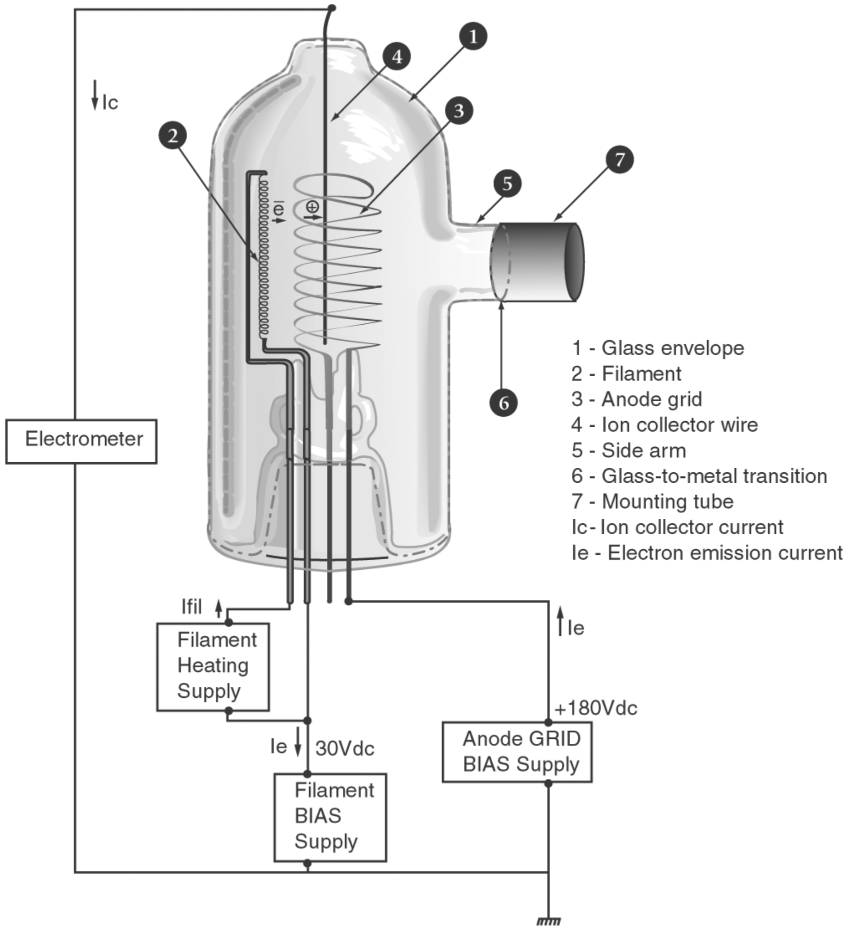


Figure A-1. Typical Bayard-Alpert configuration (glass-tubulated design)

Gauge Sensitivity

Definition

The number of ions formed inside the anode grid, and therefore the current measured by the electrometer of Figure A-1, is a function of

- the number of molecules per unit volume
- the ionization cross section for the particular gas at the specified electron energy
- the arrival rate of the electrons (i.e. emission current)
- the path length of the electrons.

A simple ionization gauge equation, based on very simple assumptions[2], that connects these quantities is derived below and used to define a sensitivity factor for the BAG.

Let σ_i be the ionization cross section for a gas molecule, L the length of the ionizing space, and A the cross-sectional area of the electron beam. The number of molecules included in this volume is $n \cdot L \cdot A$, where n is the molecular density, related to the gas pressure by $n = P/(k \cdot T)$. The collective ionization cross area of the molecules contained in this volume is $A_\sigma = (n \cdot L \cdot A) \cdot \sigma_i = \sigma_i \cdot L \cdot A \cdot P/(k \cdot T)$ and the fraction of incoming electrons that participate in ionizing collisions is $A_\sigma / A = n \cdot L \cdot \sigma_i = \sigma_i \cdot L \cdot P/(k \cdot T)$. Let N be the number of electrons entering the anode grid cage per unit time. The number of ionizing collisions per unit time is then $N \cdot \sigma_i \cdot L \cdot P/(k \cdot T)$ and, assuming all ions are effectively collected, the corresponding collector current I_c measured by the electrometer can then be expressed as:

$$I_c = \sigma_i \cdot L \cdot [P/(k \cdot T)] \cdot N \cdot e \qquad \text{(eqn.1)}$$

where e is the electron charge.

Substituting the electron emission current $I_e = N \cdot e$ into eqn. 1 leads to the expression

$$I_c = [\sigma_i \cdot L/(k \cdot T)] \cdot I_e \cdot P \qquad \text{(eqn. 2)}$$

The factor $[\sigma_i \cdot L/(k \cdot T)]$ is a function of (1) the gas type (σ_i), (2) the geometry of the gauge (L), and (3) the absolute temperature (T), and is generally defined as the *gauge sensitivity factor*, or S. Substituting this sensitivity factor into eqn. 2 leads to the standard ionization gauge equation

$$I_c = S \cdot I_e \cdot P \qquad \text{(eqn. 3)}$$

And rearranging terms leads to the well-known expression for the gauge sensitivity factor

$$\text{Sensitivity} = (\text{Ion Current}) / [(\text{Electron Current}) \cdot (\text{Pressure})] \qquad \text{(eqn. 4)}$$

This definition assumes a linear relationship between the pressure, the ion current and the electron emission current, and provides a proportionality constant independent of the electron current and dependent only on gas species, gauge geometry and operating temperature. As defined, the sensitivity factor has units of reciprocal pressure (i.e. $Torr^{-1}$).

Some gauge manufacturers prefer to use the term *gauge constant* or *gauge coefficient* for S. Then *sensitivity* can be reserved for the product $S \cdot I_e$, which is also an important parameter for the gauge.

Knowing the sensitivity factor S_g for a gas g, and assuming the electron emission current is also available, the total pressure for the pure gas can be easily calculated from the collector current using the following equation

$$P = I_c / (S_g \cdot I_e) \qquad \text{(eqn. 5)}$$

A nominal sensitivity factor for nitrogen is usually provided by the gauge manufacturer. *This value should not be relied upon for accurate work* since the precise values will vary significantly between seemingly identical gauges and even more between different gauge types, filament materials and operating potentials. Typical nitrogen sensitivity factors for commercially available BAGs fall in the range of 8 to 45 $Torr^{-1}$. Several aging mechanisms are also responsible for changes in gauge sensitivity with time, affecting the long term stability and reproducibility of BAG pressure readings.

IMPORTANT!
The only truly reliable method of determining a BAG sensitivity factor is through direct and careful calibration.

The electron emission current of many modern ion gauge controllers, including the IGC100, is fully adjustable and generally available to the user.

The sensitivity of a BAG, and the reliability of its measurements, is affected by several different variables. Some of these variables may be beyond operator control, or are controllable only with significant effort. Attempts to calculate sensitivity factors for BAGs, based on ionization efficiencies and geometrical considerations, have not proven useful because of a number of ill-defined parameters such as temperature, field distribution and ion collection efficiency. The effects of some of the variables are readily quantified, others are not, and only the magnitude of potential errors can be indicated.

The following sections cover some of the variables that can significantly affect the sensitivity of BAGs.

Pressure Dependence

A strict linear relationship between the pressure and the ion current makes the BAG the most accurate continuous indicator of total pressure in high vacuum applications.

The upper limit of BAG operation is about 10^{-3} Torr for most gauge designs, and is defined as the pressure at which the ion current vs. pressure relationship deviates from linearity. Specification claims beyond this range must be approached with caution!

The exact pressure value at which a BAG deviates from linearity differs significantly between gauge types and is a function of the electron emission current setting, I_e. In general, a reduction of the electron emission current results in an extension of the linearity range, and it is generally agreed that I_e must be kept at the lowest practical value (certainly no more than 0.1 mA) for all work at and above 10^{-3} Torr. Some commercially available ion gauge controllers are programmed to automatically reduce the electron emission current to 0.1 mA, or less, as the pressure approaches this upper limit. This approach is only adequate for moderately accurate measurements since, as described later, the sensitivity factor is dependent on the electron current[3] at these higher pressures and that effect is generally not accounted for in those controllers. A more accurate approach (available on the IGC100) that does not rely on linear behavior of the sensitivity, and has been shown to effectively extend the usable range of conventional BAGs into the 10^{-2} Torr range, involves the use of fixed low electron emission currents (0.1 mA typical) and the calculation of pressure values from a gauge calibration curve (P vs. I_c) stored in the controller's memory.

An interesting trick to extend the high-pressure operation of a conventional BAG and implemented in at least one commercially available controller, is given in a patent by Paitich and Briglia[4] describing a method of measuring pressure up to 1 Torr by modulating the anode grid voltage and using a non-linear amplifier. This method is not recommended if moderate accuracy is required at the higher pressures where capacitance manometers are a much better choice. Thoria coated filaments are the only option at these high pressures.

Non-linearity at the high end of the pressure scale is caused by several effects[5]. Increased positive ion density and multiple non-elastic collisions with neutral molecules (due to the reduced mean free path) can alter the path[6] and energy of the electron beam and also force some of the newly formed ions out of the anode grid without a chance of being captured by the collector. As the pressure increases, the secondary electrons and ions produced by ionization become a significant fraction of the electron stream. These secondary electrons do not contribute to ionization but are part of the electron emission current. These effects were thoroughly investigated by Schultz and Phelps and the reader is referred to their publications for further information[7].

Various attempts have been made to extend the range of BAGs[8], but very few have been commercial successes. One such commercial design, available under several different trade names[9], uses a narrow grid (12mm diameter x 46mm long), a thoria-coated filament, and a grounded platinum coating on the inside of the 41mm diameter glass tube. These broad-range glass tubulated gauges are designed to operate all the way up to 10^{-1} Torr (with 0.01 mA emission current above 10^{-3} Torr) while still providing a sensitivity factor of 8 $Torr^{-1}$. However, they have been shown to be susceptible to large time-dependent instabilities and non-linearities[10]. A miniaturized, all-metal ionization gauge that retains the traditional design, operating voltages, good sensitivity and low X-ray limit of the conventional BAG has recently become commercially available[11]. This tiny gauge (5% of the conventional volume) utilizes a dual collector design to increase ion collection efficiency (20 $Torr^{-1}$ typical) while at the same time providing a wider usable pressure range that extends from $3x10^{-10}$ to $5x10^{-2}$ Torr. Tiny gauges are a modern alternative to glass tubulated gauges and will likely become relatively more important in the future.

Note

The IGC100 controller is compatible with most commercially available BAG designs including: Glass-tubulated, Nude, Nude-UHV, STABIL-ION® (Granville-Phillips, Helix Corporation), and MICRO-ION® (Granville-Phillips, Helix Corporation). Default setup files are stored in the controller's memory to facilitate configuration of the instrument for operation with any of these gauges.

As the total pressure is decreased below $\approx 10^{-4}$ Torr, the gauge sensitivity factor is expected to become pressure independent. For most common gases encountered in high vacuum applications, this behavior has been confirmed experimentally for total pressures down to 10^{-9} Torr [12]. Consequently, in all cases (including the IGC100 controller), pressure measurements with a BAG in the UHV region below 10^{-7} Torr are based on linear extrapolation of gauge response determined at higher pressures.

Gas Dependence

BAG sensitivity depends upon the gas composition.

For electrons to produce ionization of gas molecules by bombardment, they must have a certain minimum kinetic energy. This minimum energy is called the *ionization potential* and is different for every type of molecule. Above the threshold energy, the ionization efficiency increases linearly with the electron energy until a maximum is reached. For most molecules, this maximum occurs between 50 and 150 eV. For electron energies above the maximum, the ionization efficiency slowly decreases with electron energy.

Plots of ionization efficiency vs. incident electron energy can be obtained from the careful data of Smith and Tate[13]. Their results show that ionization cross sections, σ_i, of common gases differ by almost a decade at the electron energies of 150 eV that are typical in BAGs. Furthermore, the relative ionization efficiencies R_σ - the ratio of the ionization efficiency for a given gas to the ionization efficiency for a standard gas (usually nitrogen) - is a function of electron energy.

Since the BAG sensitivity for a specific gas is directly related to the value of the ionization cross section of the corresponding gas molecules (eqn. 2), the sensitivity factor S_g, supplied by the gauge manufacturer, is *only valid for the gas for which it is specified* and the pressure readout of the controller provides a direct reading only for that specific gas. The standard gas, used by the entire industry for gauge specification, is *nitrogen* and, unless correction factors are applied, all readings are considered to be *nitrogen-equivalent pressures.*

The sensitivity of a generic BAG to some of the most common gases encountered in a high vacuum environment follows the order: He < Ne < D_2 < H_2 < N_2 ≈ Air < O_2 < CO < H_2O < NO < Ar < CO_2 < Kr < Xe. Nominal *relative sensitivity factors*, R_g, to convert nitrogen-equivalent readings into direct pressure readouts for gases other than nitrogen, are available from all gauge manufacturers and from the general vacuum literature[14]. For gases where little or no data are available, it has been shown that a reasonable approximation to the relative sensitivity factor R_g can be obtained from the ratio of ionization cross sections for those gases at 150 eV of electron collisional energy. Several ionization cross section tables are available in the scientific literature[15].

Once the relative sensitivity factor is known, direct pressure readings are calculated from the straightforward mathematical equation

$$P = [I_c/(S_g \cdot I_e)] \qquad \text{where } S_g = S_{N2} \cdot R_g \qquad \text{(eqn. 6)}$$

Nominal relative sensitivity factors cannot be relied upon for accurate measurements since they are known to vary significantly between seemingly identical gauges and even more for different gauge types, filament materials, and operating potentials. For general vacuum use, the discrepancy in reported measurements is not greater than 10% for the common gases rising to a little above 20% for the less common gases where less accurate information is available. Relative sensitivities are pressure dependent and become particularly unreliable above 10^{-5} Torr[16]. Where greater precision is required, gauges must be calibrated individually against the specific gases and under conditions as near as possible to the operating conditions of the vacuum system.

Note

The IGC100 controller uses a nitrogen sensitivity factor, S_{N2}, and a single relative sensitivity factor R_g (labeled 'gas correction factor') for every BAG connected to its back panel. The two parameters are automatically applied to the calculation of pressures when N2 Sense Factor is used as the pressure calibration source.

Note

The nominal gas correction factors, used by most high vacuum practitioners to correct their 'nitrogen-equivalent' pressure readings for other common gases, can be found in Appendix D, 'Gas Correction Factors for Bayard-Alpert Ionization Gauge Readings'.

Electrode Geometry Dependence

Many design parameters affect the probability of creating and collecting ions in a BAG, and thus the value of the sensitivity. This section focuses on the effects that electrode geometry have on BAG sensitivity. Important geometrical factors include

- filament to grid spacing
- collector wire location and diameter
- anode grid end closures
- grid diameter

To the extent that any of these parameters change with time of operation, or differ from gauge to gauge, the sensitivity will change or be different gauge-to-gauge.

The sensitivity of a 'conventional' BAG (available from almost any gauge supplier) with 22 mm diameter anode grid x 45 mm length, with filament to grid spacing of 6 mm and collector wire 0.25 mm diameter, is nominally 10 $Torr^{-1}$. Adding grid end closures roughly doubles this. Increasing the collector wire diameter to 1 mm adds another factor of two to the sensitivity and extends the high-pressure range.

The effect of grid-filament spacing on sensitivity has received considerable attention. Redhead[17] was the first researcher to illustrate the significance of the precise positioning and biasing of the filament. More recently, Bills[18] utilized computer simulations to demonstrate and prove that filament position displacements as small as 1 mm can significantly affect the electron trajectories within the anode volume. Any change in electron trajectories will automatically affect the sensitivity of a BAG. Sources for grid-filament spacing variations are (1) relaxed manufacturing tolerances resulting in significant gauge-to-gauge variations, (2) changes in filament position and/or shape due to rough handling (i.e. mounting accidents in nude gauges), (3) changes in filament position and/or shape due to thermal cycling.

Some investigators[19] have obtained results suggesting that gauges with tungsten filaments provide better stability than do gauges with thoria coated filaments. The current belief is it is not the filament material that causes the improvement, but rather the shape of the cathode. Tungsten cathodes are typically made as tight springs stretched between rigid posts that tend to move relatively little during long term use as compared to the hairpin shaped or relatively unsupported ribbon shaped thoria coated cathodes. BAGs with spring-tensioned filament assemblies have recently become commercially available and should be considered if long term accuracy and stability are a concern[20].

The preferred mounting orientation is with the filament and anode grid in a vertical position to minimize electrode distortion caused by gravity pull and thermal cycles. Whenever possible, choose the gauge with the strongest electrode-support posts.

Note

Spring tensioned filament assemblies are standard in all Bayard-Alpert gauges purchased directly from Stanford Research Systems.

The ion collection efficiency of an ionization gauge is affected by the diameter of the collector wire. This effect has been extensively studied and discussed in the vacuum literature[21]. The 'conventional' BAG has a 0.25 mm diameter ion collector wire. This small diameter is required to extend the low pressure operating limit of the BAG into the 10^{-10} Torr range as described later. Many ions have too much angular momentum to be collected by the small diameter wire. Ions that are not collected on their first pass at the ion collector continue to orbit until they strike a low potential surface such as the cathode or gauge envelope[22]. Thus, it is likely that a space charge cloud of orbiting ions surrounds the collector and is susceptible to small changes in geometry or local potentials. Any variation in this space charge affects electron trajectories and thus the sensitivity. This space charge effect becomes more noticeable with increases in either pressure or emission current. It is not unusual to detect drops in BAG sensitivity factors as the emission current is increased from 1 to 10 mA at pressures as low as 10^{-6} Torr[23]. In fact, in gauges with very fine (< 0.1 mm) wires, sensitivity decreases can be observed as early as 10^{-8} Torr[24].

It is generally accepted that there is no advantage to using collector wires with a diameter smaller than 0.125 mm (as typically found in nude BAGs for UHV applications). High accuracy BAGs with a 1 mm diameter ion collector have recently become commercially available[25]. The thicker wire provides increased mechanical stability, a higher overall sensitivity (as a result of the more efficient capture of high angular momentum ions) and an extended upper limit range extending to 10^{-2} Torr for 0.1 mA electron emission current. The extended upper range is due to the reduced space charge around the collector that results from the more efficient ion collection. These improvements are achieved with no significant compromise at the low pressure end, which still remains at 1.6×10^{-10} Torr for 4 mA of emission current.

Until recently, few gauge manufacturers have made an effort to produce electrode structures with sufficiently close tolerances. It is not unusual to see gauges where the center collector is curved, not coaxial with the anode grid, or is at an angle with respect to the anode's axis. In some gauges, a slight lateral force on the collector feedthru, such as might be caused by the collector wire, can visibly change the position of the collector. As demonstrated by Bills[26], a 2 mm displacement of the collector wire from the axis is enough to show changes in electron trajectories and sensitivity. High accuracy gauges manufactured to very tight mechanical tolerances are now commercially available and should be carefully considered if gauge-to-gauge reproducibility and long term stability are important. Whenever possible, mount the BAG in a vertical position, with the collector pin pointing down, to avoid electrode shape distortions by gravity pull.

Conventional BAGs traditionally include wire helix anode grid structures with open ends. A popular double-helix design allows for safe resistive heating of the electrode assembly during degas, and also provides a fairly robust structure. Nude ultrahigh vacuum gauges usually include a more delicate (i.e. very fine wire) 'squirrel-cage' anode grid design with closed ends. Nottingham[27] was the first to report the addition of grid end closures to the BAG to prevent the escape of uncaptured ions from the open ends of the cylindrical grid, thereby increasing the sensitivity of the gauge and extending the low pressure limit into the 10^{-11} Torr range. As a rule-of-thumb, adding grid end closures roughly doubles the sensitivity factor of a BAG. A typical UHV nude BAG has a specified sensitivity factor of 25 $Torr^{-1}$ for 4 mA of electron emission current. However, as demonstrated by Peacock and Peacock[28], the sensitivity of gauges with grid end closures declines sharply above 10^{-5} Torr when operating at an emission current of 1 mA. With open grids, the sensitivity remains constant up to 10^{-3} Torr under identical operating conditions. The origin of this effect is poorly understood, but it is most likely caused by the relative increase in space charge from the non-collectable ions that accumulate inside the enclosed grid volume[29].

As mentioned before, the high pressure limit of UHV BAGs with closed grids can be extended operating at an emission current of ≤0.1 mA.

Most commercially available BAGs are manufactured with 22 mm diameter x 45 mm long anode grid cages. A narrow grid design, 12 mm diameter, can be found in broad-range ionization BAGs that extend the operating limit into the 10^{-1} Torr range. The larger length-to-diameter ratio is designed to minimize axial drift of ions out of the collector region. An internal conductive coating is used in these glass tubulated gauges to control the electrostatic environment and maximize electron ionization paths. Performance characteristics for these gauges have been published in the vacuum literature, and the reader should consult the references for further information[30].

Bias Voltage and Emission Current Dependence

A survey of the specifications for all commercially available BAGs quickly reveals that they all share the same electrode potential requirements

- collector potential of 0 Vdc
- filament bias of +30 Vdc
- anode grid bias +150-180 Vdc
- shield potential 0 Vdc.

Manufacturer recommended electrode emission currents are usually 10 mA for conventional BAGs (10 $Torr^{-1}$) and 4 mA for UHV nude BAGs (25 $Torr^{-1}$).

Changes in electrode potentials cause shifts in sensitivity[31]. As may be expected, the collector current is a complex function of the electrode potentials because both the electron trajectories and ionization efficiencies depend on these voltages.

The positive (+30 Vdc) filament bias assures that all electrons emitted from the filament stay away from the relatively negative (0 Vdc) ion collector[32]. Any increase in collector voltage results in a decrease in the ion current because of the decreased electron penetration (i.e. reduced pathlength) of electrons into the anode grid space and the reduction in electron energy. Sensitivity differences up to 2% have been observed when the cathode bias was applied to the top rather than bottom of the filament.

The filament-to-anode voltage determines the collisional energy of the electrons that traverse the inner volume of the grid cage. The electron energy is simply calculated, in eV, as the difference in bias voltage between the anode grid and the filament. The electron energy for the prototypical ion gauge controller is 150 eV. If the collector current is measured for varying grid potentials, at a fixed pressure (above 10^{-7} Torr), filament bias and electron current, the curve showing I_c vs. V_g follows the expected characteristic shape of gas ionization probability vs. electron impact energy - I_c rises rapidly with V_g up to 200 V and varies slowly with grid voltages above this value[33].

As a rule of thumb, the sensitivity of an ion gauge is observed to change 0.1%/V and 1%/V for filament-to-grid and filament-to-ground voltage variations, respectively. Broad-range BAGs have been reported to exhibit the largest sensitivities to electrode bias variations of all current designs[34]. Most BAGs are so non-stable and so non-reproducible for other causes that the relatively minor effects of variations in potentials applied by traditional controllers[35] have been generally ignored. However, with the recent introduction of high-accuracy (and highly stable) BAGs, the need for accurate and reproducible electronic control of the biasing voltages has been finally established.

The sensitivity factor of a BAG is a function of the emission current[36]. Changing the emission current from 0.1 to 1 mA usually causes no significant changes in nitrogen sensitivity, but increasing it to 10 mA can decrease the sensitivity factor by more than 20% and cause marked high pressure non-linearities above 10^{-5} Torr. The extent of this effect is highly dependent on gauge geometry. In general, a reduction of the electron emission current results in an extension of the linearity range, and it is generally agreed that I_e must be kept at the lowest practical value (certainly no more than 0.1 mA) for all work at and above 10^{-3} Torr.

Sensitivity differences of several percent have been observed at the same filament heating power, emission current and pressure when AC rather than DC power is used. Changes in the duty cycle of the AC power also cause observable changes in sensitivity[37].

The *recommended operating procedure* from the Vacuum Group of the National Institute of Standards includes

- Operate all BAGs with 1 mA, or less, emission current . The only reason to operate a modern gauge with 10 mA of emission is to increase the temperature of the gauge and speed outgassing.

- The linearity of BAG response is also improved if a noise free, direct-current filament current supply is used (such as the IGC100).

A quality ionization gauge controller designed for high accuracy measurements (such as the IGC100) must control biasing voltages to within a few volts directly at the gauge head[38] and emission currents[39] to within a few percent.

Note

In conventional controller designs, the filament bias voltage is measured and controlled inside the box. As a result, the filament bias can vary with heating current because of the resistive voltage drop across the cable. This voltage drop may be substantial when using long cables and typical heating currents (between 3 and 10 amps). This variability is of no consequence for conventional (nude or glass) BAGs because these minute instabilities are overwhelmed by much larger effects. However, controlling filament bias at the controller is inadequate for measurements with modern high-accuracy gauges. In the IGC100, the filament bias voltage is measured at the gauge head, and hence, electrode potentials are independent of cable length[40].

Gauge Envelope Dependence

Several researchers have shown that the sensitivity of a BAG assembly can be influenced significantly by the relative positioning and electrical potential of the gauge envelope[41].

In a glass tubulated gauge, the inner insulating surfaces of the glass tube can change potential abruptly due to the accumulation of electrical charge, causing sudden shifts in pressure indication unrelated to any gas density variation. The effect was first described and explained by Carter and Leck[42] as early as 1959, and analyzed by Redhead[43] and

Pittaway[44] based on the dependence of electron paths on changing electrical boundary conditions. As a conductive film builds up on these surfaces with time of use, sudden mode shifts tend to occur less frequently and eventually disappear. This gradual change in potential affects the long-term stability of glass tubulated ion gauges. Keep in mind that exposed insulators in nude gauges may cause similar effects if conductive films deposit on them.

Several glass BAGs utilize a platinum conductive thin-coating on the inner glass wall to help stabilize the wall potential. The shield potential is either electrically grounded through a separate connection pin, or internally connected to the filament return electrode. Tilford, McCulloh and Woong[45] demonstrated the effect of these coatings and observed that when the shield of one gauge, normally held at ground potential, was allowed to float up to filament potential, the collector current increased by 23%. Abbott and Looney[46] performed a detailed study of the influence of inner potential on the sensitivity of platinum-coated glass gauges and found that the shield potential depended on pressure and also on the details of the filament potential waveform provided by the gauge controller. They concluded that sensitivity non-linearities in those gauges could be minimized by holding the inner surface to a fixed direct current potential or by using a controller (such as the IGC100) that provides a noise-free filament heating DC current.

Note

These effects are not commonly considered by the users of glass ionization gauges because very often the gauge envelope is an integral part of the gauge structure (i.e. glass tubulated gauges) and the dimensions and relative spacing of the envelope and electrode assembly cannot be altered by the user. The potential of the glass wall also influences the residual current produced as a result of the reverse X-ray effect described later in this application note.

The sensitivity value of a nude gauge is dependent on the way it is mounted on the system. This is not new knowledge, but there is no widespread appreciation of the effect among current users of nude gauges. Filippelli[47] investigated the influence of envelope size and shape on the nitrogen sensitivity of conventional nude BAGs. His report shows that changes in gauge envelope can result in measurement errors as large as 50% with some BAGs. Thus, the envelope must be considered a proper part of an ionization gauge, and a specification of nude gauge sensitivity is not complete unless the geometry and potential of its envelope are also given. It is common practice to calibrate and operate nude ion gauges inside a nipple 38 mm ID x 100 mm long, with a screen at the input port.

Modern high accuracy gauges rely on heavy shielding to (1) protect the electrode structure from external or uncontrollable fields, (2) better define charged particle trajectories and (3) improve gauge-to-gauge reproducibility and long term stability. In a commercially available design[48], the entire electrode assembly, is housed inside a grounded metal envelope. This envelope completely surrounds the anode-filament-collector structure to help provide a stable electrical environment for charged particle trajectories. A grounded, perforated, high conductance shield over the port helps to electrically isolate the transducer from the remaining of the vacuum system, and grounded conducting shield between anode and the feedthrus prevents the ceramic insulators from becoming contaminated and charged.

Temperature Dependence

For most room temperature measurements the effects of ambient temperature variations on BAG readings are insignificant.

Studies of this effect have generally shown that it is not as large as would be predicted from theoretical considerations accounting for both density and thermal transpiration effects, i.e. the sensitivity varying inversely with the square root of the absolute temperature of the gas inside the gauge[49].

Determining the gas temperature is a difficult task in a tubulated BAG. It is probably accurate to say that most of the molecules equilibrate with the envelope, but the envelope temperature is not symmetric because of the asymmetric location of the filament. The envelope (glass or metal) of a BAG is usually at a temperature much higher than ambient as determined by the power (10 W) radiated by the hot filament and absorbed by the envelope's walls. For example, some metal encapsulated gauges are actually provided with vented guards to protect users against burns. The absorption of energy from the filament by the envelope increases with age as the walls get progressively darker due to contamination. Variations in filament work-function and emissivity due to aging, contamination or chemical reaction with the gas will result in changes in filament and envelope temperature that might require correction for accurate measurements. Bills, Borenstein and Arnold[50] suggested a pressure calculation procedure that includes the filament heating power as a parameter, increasing gauge-to-gauge reproducibility and long term stability.

Haefer[51] did find a correlation with the square root of the temperature of the flange of a nude BAG mounted in an enclosure. Close, Lane and Yarwood[52] found the ion current to change 0.075%/K, approximately half what one would expect from the envelope temperature of a BAG. If a BAG is not used under the same temperature conditions as those during its calibration, a correction might be required in high accuracy measurements[53].

There is always a delay between turning on a BAG and obtaining a reliable reading. It is necessary to wait for thermal equilibrium of the gauge[54] and its surroundings (not that easy under vacuum).

Magnetic Field Dependence

Magnetic fields have a strong and rather unpredictable effect on gauge sensitivity by changing the trajectories of the charged particles (especially the electrons which perform spiral trajectories). Since many vacuum experiments operate in a magnetic field environment, often of varying or unknown magnitude and direction, it is surprising how little data is available on magnetic field dependencies of BAGs. A few studies[55] are available that do not lead to summary conclusions. Investigation of the effect of the magnetic field on the accuracy of pressure measurement with BAGs has not been made yet.

The effect depends on the direction and magnitude of the field as well as gauge design and pressure. The effects are generally non-linear with both magnetic field and pressure. The common approach is to either remove the gauge from the magnetic field or to try shielding it. In both cases, it is a good idea to test the gauge readings by changing the magnitude and/or direction of the magnetic field to see if the readings are affected. In general, operation of a BAG in a magnetic field is possible with suitable orientation and altered gauge constant.

Note

Remember that cold cathode (i.e. Penning) gauges and ion pumps include magnets in their assembly.

History Dependence

A major factor affecting a gauge's stability is its history.

It is well known that all BAGs can exhibit general drifts in sensitivity, usually downward, when operated for long periods. The dependence of the sensitivity drifts on the type of gauge and its operating conditions has made it impossible to develop a unified model or theory that completely and systematically explains all experimental observations. Most knowledge is phenomenological and based on the experience accumulated over several decades of pressure measurements with commercial BAGs.

Many instabilities in commercial ionization gauges can be traced back to changes in the path of the electron beam[56] caused by several different aging effects. Most ion gauge controllers do an adequate job at maintaining the electron emission current and bias voltages at a constant value; however, they have no influence over the trajectories of the electrons once they leave the hot filament surface.

Changes in the emission characteristics of the filament are of high concern since they directly affect the electron trajectories and can result in changes in both the potential distribution and the charged particle trajectories inside the anode grid[57]. Large variations in the emission characteristics of the filament can be caused by the following effects.

- Changes in geometry of the electrode structure, due to repeated thermal cycling and/or mechanical shock.

  This effect is most prevalent in BAGs with poorly-supported hairpin shaped filaments and open-ended, helix-shaped grids. To avoid filament sag and accumulation of 'rubbish', BAGs should be mounted vertically with their electrical connections uppermost. High accuracy BAGs with spring-tensioned filaments and improved electrode supports have recently become commercially available and should be considered if accuracy and long term stability are a concern. Filament sag is eliminated allowing the user to mount the gauge in any position.

- Local temperature variations in the filament wire.

  Changes in filament temperature are usually associated to changes in temperature distribution along the filament and changes in the distribution of emission along the cathode. In general, a temperature increase results in a longer segment of the cathode being heated and emission from a relatively larger area of its surface. The temperature of operation of a filament is affected by the gauge history as described next.

- Changes in cathode dimensions (i.e. diameter).

Refractory metal filaments (i.e. tungsten, rhenium, tantalum, etc) do not last forever, and are the subject of continuous metal evaporation during emission[58]. Certain gases can accelerate the thinning of the filament through catalytic cycles that transfer material from the filament surface to the inner walls of the gauge tubulation. As the filament becomes thinner, the ion gauge controller automatically maintains the levels of emission current by increasing the filament temperature to compensate for the reduced surface area[59]. The increased temperature, combined with the change in filament shape (i.e. preferential depletion of the central portion) and temperature distribution, causes the distribution of emitted electrons to change.

- Changes in the electrode potentials due to power supply inaccuracies, grid wire contamination and space charge effects.

  At the higher emission currents, the efficiency of electron emission is affected by the extraction potential responsible for removing the electrons from the filament boundaries.

- Surface contamination.

  Impurity diffusion can change both the work function and emissivity of the cathode surface. For example, W can react with hydrocarbon molecules and form a layer of WC that can slowly diffuse into the bulk of the metal.

- Chemical reaction with an active gas.

  Cathode poisoning by gases, such as Oxygen, water, CO and CO_2 increases the work function of the filament, which in term affects its temperature of operation.

  Several reducing gases (such as SiH_4 and diborane) used routinely in the semiconductor industry are incompatible with the rare earth oxides used in filament coatings (W is recommended instead).

- Detachment and/or aging of the filament coating (i.e. Thoria detachment)

  Several different methods are used to deposit low-work-function oxide layers on refractory metal wires. Some methods are better than others. Evaporation and ion bombardment may also deplete the central portion of the coating, causing the emission distribution to gradually shift towards the ends of the wire.

- Changes in envelope bias and appearance can also affect the charged particle trajectories in a BAG.

  The electrons emitted by the filament spend time outside the anode grid and are affected by the gauge's boundary conditions. Changes in the potential distribution around the gauge caused by contamination will affect its sensitivity. The progressive darkening of the bulb in glass gauges results in higher envelope temperatures due to increased absorption of filament radiated power.

Limiting Factors for Low Pressure Operation

Based on eqn. 3, it appears that the lower limit to the pressure range of a BAG, is entirely determined by the current detection capabilities of the electrometer used to measure the collector current. However, it is well known, from experiments, that the total collector current of a BAG is better represented by the more general equation

$$I_c = S \cdot I_e \cdot P + I_r \quad \text{(eqn. 7)}$$

where the *residual current*, I_r, is a *pressure-independent* term. Residual currents are often defined as those which would exist at the collector electrode if the molecular density within the gauge head were zero, and result in erroneously high readings at low pressures that must be accounted for in accurate measurements.

The main known contributors to I_r are

- X-ray induced photo-emission of electrons from the ion collector and gauge envelope
- ion currents caused by electron stimulated desorption (ESD)
- leakage currents at the electrodes
- electrometer offset errors.

Any BAG, depending on its past history of operation and the precise atmosphere in the vacuum system, can act as either a source (outgassing) or sink (pumping) of gas[60]. Its operation can cause significant changes to the gas composition in the system. The relative importance of these effects depends upon the overall vacuum system characteristics and operating conditions. For example, changes in pressure and gas composition due to pumping or outgassing will be relatively more significant in a small UHV system with low pumping speed, than in a large industrial vacuum chamber with large diffusion pumps. Similarly, any pressure gradient between the gauge and the main chamber will depend upon the conductance of the tube connecting the two, and will be zero when the gauge is inserted directly into the chamber (i.e. nude gauge).

Reactions of the gas molecules with the hot filament can seriously affect the composition of the gas, and the reliability of the pressure measurements, in a BAG. This effect must also be accounted for in high accuracy measurements at low pressures.

Gas permeation through the envelope, particularly of He and other light gases, must be considered in UHV systems at base pressure, and provides another good reason to use nude all-metal gauges in those applications.

X-ray Limit

X-rays are produced when the energetic electrons emitted by the filament impact the grid and support posts[61]. Some of these X-rays strike the collector wire and cause electrons to be photo-electrically ejected. The resulting 'X-ray induced' electron current, I_x, cannot be electrically distinguished from the pressure dependent ion current at the collector, and results in erroneously high readings at low pressures. The 'X-ray induced' contribution to the pressure indication, in terms of pressure, is calculated as

$$P_x = I_x / (S \cdot I_e) \quad \text{(eqn. 8)}$$

This pressure equivalent value is often called the *X-ray limit*, and is part of the manufacturer specifications for a BAG. As expressed by eqn. 8, the X-ray limit is simply defined as the lowest pressure indication which may be obtained in a BAG when all the output current is due to X-ray induced photoemission and there is an absence of gas.

The X-ray limit varies with different gauge designs. The nominal over-reading typically amounts to 1-3x10^{-10} Torr for BAGs of the most popular type (i.e. continuous helical anode grid and a 0.25 mm diameter collector). Special design features, such as closed grid ends and reduced collector diameter (0.125 mm) reduce these levels to 2x10^{-11} Torr, as is typically specified for UHV nude BAGs. The X-ray contribution dominates the residual current, I_r, of eqn. 8 in reasonably clean BAGs. For accurate HV and UHV measurements with BAGs, it is necessary to correct the gauge indication for X-ray contributions. Variations in the X-ray limit for a given gauge as well as variations between supposedly identical gauges, make it difficult to use a nominal X-ray limit for correction. Instead, the X-ray limit should be determined for each gauge and rechecked periodically. A useful collection of X-ray limit measurement techniques can be found in the vacuum literature[62].

Earlier ionization gauges (i.e. triode gauges), which had a solid cylindrical collector outside an anode grid, and a fine filament inside, experienced a much larger X-ray limit of about 10^{-8} Torr as expected from the larger exposed surface area of the collector. Bayard and Alpert were the first ones to systematically test the validity of the X-ray induced current theory[63] around 1950. The direct result of their studies was the invention of the inverted-triode ionization gauge design that bears their names[64]. By replacing the large surface area external collector with a thin internal wire, and placing the filament outside the grid cage, they were able to realize two to three order of magnitude reductions in residual currents, extending the lower operating limit into the 10^{-11} Torr range. A commercial version of the BAG soon followed their initial report[65]. A period of rapid exploration after their early implementation, proved it difficult to improve upon the original. The BAG provided an ingenious solution to the X-ray current limit problem while at the same time preserving the high levels of sensitivity of previous designs. The thinner collector wire intercepts only a small fraction of the X-rays produced at the grid. The positive potential of the grid forms a potential well for the ions created inside the ionization volume so that many of them are collected at the center wire.

The X-ray limit of a BAG is affected by several different variables. A few are discussed below.

Gauge design

As mentioned above, the value of the X-ray limit is strongly dependent on gauge design. All UHV gauges, designed to operate into the 10^{-11} Torr range, have closed-end grids (i.e. squirrel-cage design) and use very fine wires in their electrode structure. The fine anode grid wires provide an enhanced open area, increasing the pathlength of the electrons before colliding with the grid. This effect, along with the closed ends, increases the sensitivity of the gauge by about a factor of two, relative to conventional BAG designs with open grids. The thin collector wire reduces the X-ray induced residual current by minimizing the collisional cross section with the X-rays emitted from the grid. The combination of enhanced sensitivity and reduced X-ray induced residual current is responsible for the extended X-ray limit.

Further reducing the surface area (and/or length) of the collector wire of the BAG will, of course, reduce the X-ray current. For example, Hseuh and Lanni[66], were able to extend the X-ray limit of BAGs into the 10^{-12} Torr range by reducing the collector diameter of mass produced gauges to 0.05 mm. However, there are two problems associated with this approach: (1) the reduction in mechanical strength of the wire and (2) a drop in sensitivity and linearity due to the difficulty in collecting ions with a high tangential velocity about the collector. In practice, there is a critical size of the wire below which the probability of collecting ions goes down as rapidly as (or faster than) the X-ray effect. It is generally accepted that there is no advantage to use collector wires with a diameter smaller than 0.1 mm in a BAG[67].

Recently, high accuracy BAGs with 1 mm diameter collectors have become commercially available. As demonstrated by Bills and collaborators, the thick wire provides mechanical stability, higher sensitivity (50 $Torr^{-1}$) while at the same time preserving a typical 1.6×10^{-10} Torr X-ray limit at 4 mA of emission current. The only disadvantage of the thicker wire is a higher sensitivity to the energetic ions formed by ESD, but this problem is generally avoided by careful bakeout and/or degas.

Electrode Surface conditions

The X-ray limit is affected by the conditions of the electrode surfaces.

For example, the X-ray limit is increased as a result of hydrocarbon contamination of the electrodes, since the contaminated surface releases relatively more electrons under identical X-ray bombardment conditions.

In a similar fashion, the efficiency of emission of X-rays from the grid wires is also affected by contamination.

Emission Current

The X-ray limit has been experimentally shown to be dependent on the emission current value. A 25% (typical) reduction on the X-ray limit of commercial BAGs was reported by Peacock when the emission current was increased from 1 mA to 10 mA[68].

Envelope Bias (Forward vs. Reverse X-ray Effect)

X-ray induced photoemission of electrons from the ion collector is known as the *forward X-ray effect*. Less well known is the *reverse X-ray effect* leading to a superimposed, but usually smaller error signal in the opposite direction. The reverse X-ray effect is caused by X-ray induced photoelectrons from the gauge envelope. The effect is particularly noticeable if the gauge envelope is at or below the collector potential. Several different situations can be envisioned. (1) If the potential of the envelope is near that of the cathode, as is usually the case in glass envelope gauges, photoelectrons emitted from the envelope do not have enough energy to reach the ion collector and do not contribute to I_r. (2) If the gauge envelope is at ground potential, like in a nude BAG, the reverse X-ray effect may be large enough to significantly reduce the net X-ray induced residual current. (3) If the gauge envelope is at a suitable negative potential relative to the collector, the two effects might be adjusted to temporarily cancel[69]. B. R. F. Kendall and E. Drubetsky[70] were able to successfully stabilize this cancellation process by the use of identical materials (i.e. gold or Rhodium) in the two photoemission surfaces. The result was a shielded BAG of conventional internal geometry, with a net X-ray error reduced by well over one order of magnitude over a period exceeding one year. Short-term improvements, by a factor of 100, were also achieved by the same authors. Metal and glass encapsulated gauges using the X-ray cancellation technique are now commercially available[71] and are fully compatible with the IGC100.

Electron-Stimulated Desorption (ESD)

In the context of BAGs, ESD[72] implies desorption of atoms, molecules, ions and fragments from the *anode* grid surface *as the direct result of electron impact excitation*. The pressure-independent ions generated by this process reach the ion collector and are registered as falsely-high pressure readings. The mechanism is initiated by the electron excitation or dissociation of the molecules previously adsorbed on the surface of the grid wires. The most common species desorbed are CO, CO_2, H_2, O_2, H_2O, halogens and hydrocarbons. The number of neutrals desorbed is usually large compared with that of ions.

ESD can make a significant contribution to the residual current[73] of eqn. 7; however, the resulting errors are unusual in that they are completely unpredictable. They seem to come and go for no apparent reason, they might affect one batch of gauges and not another and can be mysteriously affected by gauge history. The effect has been the subject of extensive work and several review articles[74]. Readers are referred to the vacuum literature for details beyond what is covered in this appendix.

The gas used in a gauge can cause permanent or semi-permanent changes in its pressure reading as a result of electron-stimulated and thermal-induced desorption of the gas molecules (ions and neutrals) that remain adsorbed on the electrode surfaces. Some gases are worse than others, with hydrocarbons, oxygen and reactive or corrosive gases yielding some of the biggest effects. For example, if a burst of oxygen gas is introduced into a clean HV system increasing the pressure from 10^{-9} to 10^{-6} Torr for only one minute, then the reading of the BAG will be spurious for many hours or even days. The pressure indication continues to drop back to the original base pressure reading with a time constant between one hour and one week depending on the operation of the gauge.

A typical procedure used to minimize the residual current due to ESD is to operate the BAG at 10 mA of emission current to keep the anode grid clean. Electron bombardment degassing of the grid is recommended for fast recovery from exposure to gases known to cause significant ESD (i.e. oxygen, oxygen containing molecules such as water, CO and hydrogen). ESD can be minimized by a correct choice of material for the anode grid, for example, platinum clad molybdenum or gold.

The ions generated by the ESD process are more energetic (i.e. several eV) than the ions formed by electron ionization of the bulk gas[75], and are not very effectively collected by the thin collector wires (0.125mm diameter) used in UHV nude gauges. Another reason to use nude UHV gauges for low pressure measurements in UHV applications!

Leakage Currents

The output of a BAG is a very small current and even relatively small leakage currents can add significant errors to the measurements at low pressures. Some useful tips to reduce leakage currents include

- The area around the collector pin on the gauge must be kept clean at all times on both the air and vacuum sides of the feedthrough connectors.
- A collector insulator shield is present in most BAG designs to avoid the development of leakage currents due to contamination of the ceramic or glass insulators with conductive layers of impurities. Internal leakage usually results from the evaporation of tungsten or thoria molecules from the filament. Do not use nude gauges that do not include such shields.
- The collector terminal of glass tubulated gauges is purposely located at the opposite end of the envelope from the grid and filament conductors, and usually has a built in glass skirt that acts as a shield against contamination deposits.
- It is important to use good quality leads to make connections to the controller. Gold plated connector pins are often used, and assure that the gauge tube can be easily removed from the connector after extended use.
- Changes in the glass conductivity can occur at the elevated temperatures used to make some pressure measurements. For such situations, envelopes of metal and alumina are recommended.

Outgassing

Outgassing of BAGs occurs when heating by the filament and electron bombardment of the grid raises the temperature of the electrodes and surrounding surfaces considerably above ambient temperature, resulting in an increased thermal desorption rate of gas molecules from those surfaces. The outgassing of hot cathode gauges is a potentially large source of error when such gauges are used at base pressure levels in high vacuum systems. Outgassing levels are particularly high when a gauge is turned on for the first time after exposure to ambient or high gas pressures.

It is well known by ultra high vacuum practitioners that the gas composition and pressure in even a rather large vacuum system may be dominated by gases released from a single BAG and its surroundings. This is particularly true when nude and metal-coated glass gauges are used, because the high infrared absorption of the metal envelope results in increased heating of metal components in and adjacent to the gauge.

The easiest way to detect outgassing levels from a test gauge is to use a second gauge to monitor the change of pressure in the vacuum chamber as the test gauge filament is turned on and off. Residual gas analyzers (such as the SRS RGA100[76]) are routinely used in a similar fashion to selectively detect the particular species outgassed into the vacuum system by a test BAG. It is generally accepted that BAGs outgas at rates about 10-100 times faster than cold cathode gauges under identical conditions.

Outgassing is a pervasive effect that is observed in even the most carefully handled gauges. An aggressive and prolonged degassing and/or bakeout can dramatically reduce gauge outgassing but it will rarely completely eliminate it![77]

As expected, outgassing rates are a function of ambient temperature. When a glass BAG operated at a pressures of 10^{-8} Torr, with a typical envelope temperature of 50°C, is cooled down with an air blast jet, the pressure in the measuring system can change by as much as a factor of two and the composition of the gas is seen to change radically. The effect is a direct consequence of changes in the desorption and permeation rates of the envelope as a function of temperature[78].

The most effective way to reduce the contribution of gauge outgassing to system pressure is to bake out the gauge, along with as much of the rest of the vacuum system as possible, for an extended period of time (i.e. overnight typical).

Frequently, a BAG is automatically degassed and/or the system baked after the gauge is exposed to ambient, or after surface contamination is suspected. BAGs will be unstable for several hours following degassing until the chemical composition and adsorbed layers on the newly cleaned surfaces reach equilibrium. This effect must be carefully considered for high accuracy determinations. The recommendation from the NIST High Vacuum Group is to eliminate degassing by high temperature heating of the grid (whether resistive or electron bombardment). For baked systems, their observation is that gauges can be effectively outgassed by simply operating them at normal emission currents while the BAG and vacuum system are baked. For unbaked systems, the gauge can be baked and outgassed by thermally insulating it with fiberglass. Degassing by electron bombardment is only recommended if (1) the gauge is heavily contaminated or (2) after exposure to surface active gases such as O_2[79]. Whenever possible minimize the emission current during degas and extend the degas time to compensate.

Note

The IGC100 offers fully adjustable Degas power and Degas time as part of its Gauge Setup Parameters.

Gauge Pumping

It is well known that all BAGs have gas-sinking capacity at pressures below 10^{-3} Torr. For the purpose of calculation, the gas pumping action of a BAG is represented by a vacuum pump with a constant speed, S, normally expressed in units of $L{\cdot}s^{-1}$.

The effect is gas dependent and constitutes another mechanism by which a BAG can affect the pressure and composition of the gas in an ultra high vacuum system.

The pumping speed is also a strong function of the history of the gauge.

The pumping is generally considered to be the sum of several contributions:

Ionic Pumping

Ions formed by electron impact ionization inside and outside the anode grid, are transported to the electrodes and surrounding walls and driven to the interior of their surfaces where they are neutralized. This is the mechanism by which inert gases are removed in ionization gauge heads. The number of ions that goes to the walls depends on the region in which they are formed, the design of the electrodes, the geometry of the gauge head, and the electrode biasing voltages[80]. Ionic pumping usually stabilizes after three months of operation at 10^{-9} Torr.

Chemical pumping

Thermally activated gas molecules are chemisorbed by the clean surfaces of the surrounding walls (i.e. glass envelope) of a gauge operated for the first time. The bonding is much stronger than that produced by van der Waals forces and effectively removes the molecules from the vacuum. Chemical pumping continues even after switching off the emission current and may greatly exceed the ionic pumping under certain conditions. The gettering effect is perpetuated when tungsten is used as the filament material, by a surface regeneration effect based on the constant deposition of fresh layers of tungsten molecules on all exposed internal surfaces. The effect is simply driven by the affinity of gases for very clean surfaces. As the surface becomes saturated the pumping speed diminishes to near zero and stabilizes. The duration of this stabilization process is of the order of four hours for a freshly baked gauge operated at 10^{-9} Torr.

Filament pumping

When chemically active gases such as hydrocarbons are present within a BAG head, their removal may occur via chemical reaction with the filament. This process usually also affects the overall sensitivity of the gauge, and is most marked for oxygen, nitrogen, water and hydrogen.

Several studies and reviews are available in the literature that show that for an electron emission current of 1 mA, the initial effective pumping speed in a glass tubulated gauge varies from about 0.001 Ls^{-1} for inert gases to 10 Ls^{-1} for nitrogen[81].

The pumping effect is particularly significant in the measurement of the background or residual pressures in any vacuum environment where there is a large contribution of heavy hydrocarbon vapor. Blears[82] demonstrated that glass tubulated gauges are very effective at pumping oils, and the pumping speed is maintained intact almost indefinitely. Large errors (up to a factor of 10) can be expected at base pressures when using glass tubulated gauges under these conditions. The process is also responsible for the typical dark coatings that develop on the internal walls and side tubes of tubulated gauges operated in the presence of hydrocarbons.

The most common remedy for pumping effects is to provide a large conductance connection between the gauge and the vacuum system.

- Nude gauges are the best solution to severe gauge pumping problems, since no tubulation is necessary, and the electrodes can be positioned directly into the chamber.
- In a glass tubulated BAG a gauge tubulation conductance greater than 10 Ls^{-1} is recommended to avoid pressure errors due to pumping effects at low pressures. A glass envelope gauge with a 0.75" side-arm tubulation has adequate conductance for use down to 10^{-8} Torr. Operation into the 10^{-10} Torr range requires minimum 1" diameter connection.

Filament reactions and outgassing

Chemical reactions involving the hot filament surface and the gas molecules can significantly affect the chemical composition and the total pressure of the gas environment in a high vacuum system[83]. There is a large dependence of these reactions on the material chosen for the cathode and the type of gas in the environment. Some of the processes triggered by these reactions include

- active pumping of selected gas components
- outgassing of impurities into the vacuum environment
- thinning of the filament
- poisoning of the filament surface (change in work function and emissivity).

The high temperature of the filament and its specific chemical composition contribute to the emission of neutrals and charged particles from the cathode that affect the gas composition at the gauge head, and the rest of the vacuum environment.

A detailed analysis of filament materials, filament-gas reactions, and filament outgassing is provided in the 'Filament Considerations' section of this appendix and will not be repeated here.

Gas Permeation

Pressure measurement in UHV chambers at base pressure may be impaired by the presence of He diffused through the glass envelope of the BAG. Permeation rates, involving sequential diffusion and desorption steps, depend on the material and temperature of the gauge head.

The simplest way to eliminate this problem in UHV systems is to use metal envelopes and all-metal BAGs.

Note

Remember this effect while leak testing your vacuum system! If helium leak testing with the ion gauge is common practice in your facility, consider an all metal gauge instead.

Mechanical Construction

Two basic mechanical variants of the BAG are commonly encountered in high vacuum systems: (1) nude gauges and (2) glass tubulated gauges. More recently, all-metal encapsulated BAGs have become commercially available with special specifications such as (3) miniaturized design (tiny gauges) and (4) enhanced accuracy and stability (high-accuracy gauges).

All commercially available gauges use the same basic electrode configuration, (virtually identical to the original) and, with few exceptions, the same electrode dimensions, materials, and biasing voltages.

Most BAG designs are offered with at least two different choices of filament material: (1) tungsten (W) and (2) Thoriated Iridium (ThO_2Ir). Some gauges include a dual-filament assembly to avoid having to break vacuum in cause of filament failure. For details on filament choices consult the 'Filament Options' section of this appendix.

Cross-reference tables for all current, and even obsolete, BAGs are available from many gauge manufacturers (including Stanford Research Systems). This makes it easy to buy and compare gauges from several different vendors without having to worry about gauge incompatibilities.

The most important and interesting features of commercially available BAGs are discussed next[84]. For information on the accuracy and stability of the different designs consult the 'Accuracy and Stability' section of this appendix.

Glass tubulated gauges

The glass tubulated BAG is, by far, the most commonly used gauge design in the world.

Glass tubulated gauges are the most inexpensive BAGs available.

When connected to a suitable controller, they provide pressure readings between 10^{-3} and $\approx 5.10^{-10}$ Torr (typical X-ray limit). Specification claims beyond this range must be approached with caution!

The glass tubulated gauge (Figure A-2) has its electrodes surrounded by a glass envelope (57 mm diameter typical) with a side tube that attaches to the vacuum system. The most common construction materials for the glass envelope are Nonex (an inexpensive glass used in old vacuum tubes), Pyrex and 7052 (another soft glass similar to Nonex).

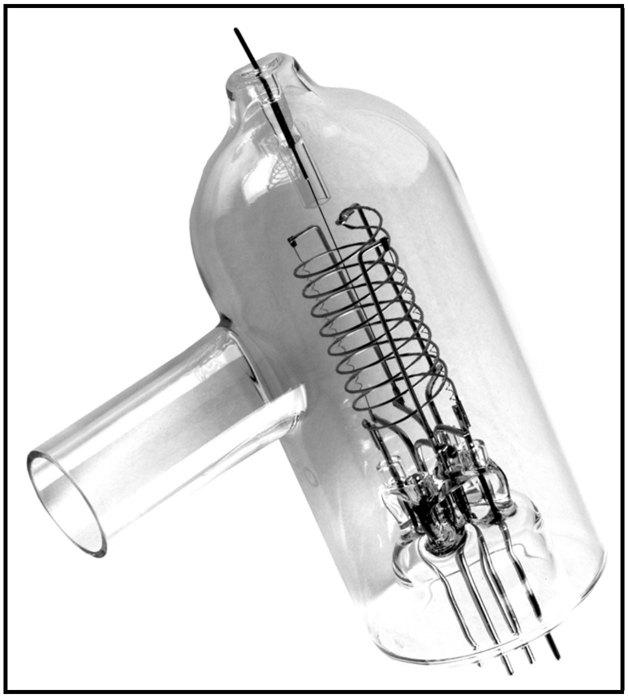


Figure A-2. Glass-tubulated Bayard-Alpert gauge with glass side tube connection.

Most tubulated BAGs are connected to the vacuum system through an O-ring compression fitting. Pyrex is the material selected when the side tube must be directly glass-blown on to the vacuum system. Kovar alloy is the material of choice when metallic tubulation is required for the side port[85]. Kovar tubulation is sometimes combined with compression fittings, but most often it is welded to Quick-Connect or ConFlat® flanges for compatibility with standard vacuum ports. While slightly more expensive, flanged tubulated BAGs offer better vacuum integrity and higher bakeout temperatures than compression fitting options.

Side tube diameters are set by standard compression fitting diameters to ½", ¾" and 1" OD. Whenever possible, choose the widest possible bore to assure structural integrity and maximum gas conductance between the vacuum chamber and the BAG ionization region.

All glass tubulated gauges use the same bias voltages and emission currents, making them compatible with generic ion-gauge controllers (such as the IGC100**)**. The anode grid structure is always a wire helix with open ends. A popular double-helix design allows for resistive, as well as electron bombardment, heating of the electrode assembly during degas, and also provides a fairly robust structure. Typical sensitivities fall in the range of 8-10 $Torr^{-1}$. A typical outgassing procedure includes heating the envelope to 250-400°C for 1 hour followed by a 15 minute degas step.

Several gauge manufacturers offer internal precious metal coatings (Pt) in their BAG tubes. The coating is electrically connected to the filament to reduce electrostatic charge on the glass surface and improve repeatability providing a slight advantage over uncoated gauges. With uncoated glass it impossible to control the potential of the internal surfaces, which results in uncontrolled electron and ion trajectories within the gauge and reduced measurement accuracy and repeatability.

Long term stability is affected by changes in the electrode structure particularly after repeated thermal cycling. High stability tubulated gauges with spring tensioned (sag-free) filaments and reinforced supports that provide improved measurement stability and accuracy without adding any significant cost are available from at least one manufacturer and are worth considering.

Broad-range glass tubulated BAGs are available from many different manufacturers, and under several different trade names. These gauges are designed to operate all the way up to 10^{-1} Torr (with 0.01 mA emission current above 10^{-3} Torr) while still providing a sensitivity factor of 8 $Torr^{-1}$. They are easily identified because of the narrow grid design (12 mm diameter x 46 mm long), a thoria-coated filament, and a grounded platinum coating on the inside of a reduced diameter (41 mm vs. the traditional 57 mm) glass tube. However, they have been shown to be susceptible to large time-dependent instabilities and non-linearities[86] that must be carefully considered during measurements.

Glass-tubulated BAGs are fragile and present a safety hazard due to implosion if not adequately shielded. Whenever possible, place them where they cannot be bumped, and be particularly careful during installation. A common problem is crushed side tubes due to excessive tightening of compression fittings. If possible, install the gauge so that the filament is visible during operation. A quick visual check might save a tungsten filament from burnout during a venting or gas loading operation. The preferred mounting orientation is with the filament and anode grid in a vertical position, with the connectors on top. This position minimizes the electrode distortion caused by gravity pull and thermal cycles.

Tubulated gauges with single and dual filament designs are available. Both tungsten and thoriated-iridium filament options are offered. Filaments are not replaceable, making the single filament gauges disposable after a burnout (A maintenance cost that must be considered!). The amount of power required to operate the filament can vary significantly from one gauge to another, depending on filament dimensions and material.

Glass tubulated gauges may be significant sinks of gas molecules and exhibit a certain pumping capacity that is usually time-dependent. This pumping is due to both chemical and electrical effects. The effect usually saturates after approximately three months of operation. The best way to handle this, is to provide a large conductance connection between the gauge and the vacuum system. A glass envelope gauge with 1" tubulation is recommended for applications requiring pressure measurements down to the 10^{-10} scale, ¾" tubulation is adequate for routine pressure measurements above 10^{-8} Torr.

Glass when heated permits permeation of helium from the atmosphere. Remember this effect while leak testing your vacuum system! If helium leak testing with the ion gauge is common practice in your facility consider an all metal gauge instead.

BAGs require few electrical connections; however, there is no standard mating socket that will work with all gauge designs. It is usually the user’s responsibility to assure that the correct electrical connections are made at the gauge pins. The correct pinouts for a gauge can be obtained from the original manufacturer. Experienced users can usually identify the different pins by visual inspection. Wrong connections can cause damage to equipment and may be dangerous for the vacuum system operator.

Note
Stanford Research Systems offers a line of BAG connection cables (O100C1, O100C2 and O100C3) that make it easy and safe to connect almost any commercially available gauge to the IGC100 controller without having to be a gauge expert!

Tubulated gauges owe their popularity to their low cost, convenient measurement range, and ease of mounting. Their accuracy is more than adequate for most vacuum applications since very often a 'rough' pressure indication is all that is required by the vacuum operator to define the status of a vacuum system.

Nude gauges

In nude BAGs (see Figures A-3 and A-4) the electrode structures are welded onto insulating feedthroughs mounted on a vacuum compatible flange (typically a 2.75" ConFlat®), and inserted directly into the vacuum chamber environment. The gas molecules of the vacuum chamber can flow freely into the ionization volume of the gauge thereby eliminating the pressure differential normally associated with tubulated gauges.

The basic electrode arrangement is same as in glass-tubulated BAGs so that many (but not all) modern ion gauge controllers can operate both gauge designs without any modifications. The biasing voltages and emission currents are generally identical or very similar. A connection cable replacement is usually all that is required to switch from one gauge design to the other.

Figure A-3. Nude Bayard-Alpert ionization gauge with standard (i.e. bi-filar helix anode grid) electrode design.

Nude BAGs are always more expensive than glass-tubulated designs. When connected to a suitable controller, they provide pressure readings between 10^{-3} and $4x10^{-10}$ Torr (typical X-ray limit), with extended UHV versions reaching a $2x10^{-11}$ Torr low limit. Typical sensitivities fall in the range of 8-10 $Torr^{-1}$ for standard gauges and 25 $Torr^{-1}$ for the extended UHV versions. Extended UHV versions are easily identified by the fragile closed end design (squirrel cage) of their anode grid and the thinner collector wire.

Since the elements are exposed, and easily accessible, most nude ion gauges are designed with replacement filament assemblies. This allows filaments to be replaced after a burnout without having to dispose of the gauge (an important cost saving feature!). Unless a viewport is available, it is generally not possible to see the filament once the gauge is mounted on a port, making the filament more susceptible to accidental and catastrophic overpressures.

With the exception of UHV versions (EB only), conventional nude BAGs include a double-helix anode grid design that allows for resistive, as well as electron bombardment, heating of the electrode assembly during degas.

The sensitivity of nude ion gauges is affected by the way it is mounted on the system[87]. This effect was recently demonstrated by a careful study, which showed that when the dimensions or shape of the gauge's metal envelope are changed there can be a dramatic effect (up to 2X) on the absolute magnitude of the gauge's sensitivity. There may also be a change in the relative dependence of its sensitivity on pressure. If these effects are not taken into account, the accuracy and consistency of the measurements performed with the gauge will be compromised. The envelope must be considered an integral part of the ionization gauge when specifying sensitivity. The practical consequence of these findings is that nude ion gauges must be calibrated in situ, or in an environment that exactly matches the one experienced by the gauge during its measurements. It is common practice to calibrate and operate nude ion gauges inside a nipple 38 mm ID x 100 mm long, with a screen at the input port. The input screen is necessary to eliminate the collection of ions produced somewhere else in the vacuum system, and attracted by the exposed electrodes of the ion gauge.

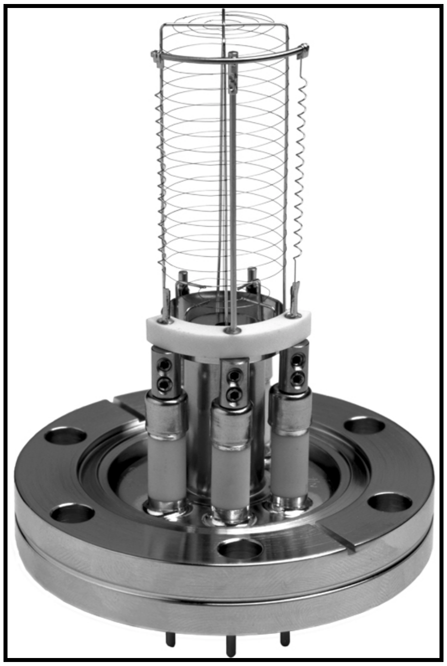


Figure A-4. Nude Bayard-Alpert ionization- UHV extended. Notice closed ends (squirrel-cage design) and fine wire design of anode grid.

Nude ions gauges are the choice of many UHV practitioners who appreciate the enhanced vacuum integrity provided by its mounting flange, the unrestricted conductance to the vacuum chamber, the reduced outgassing provided by the minimal surface area of its surroundings, and the higher bakeout temperatures that it can handle. Typical nude gauges can be baked to 450°C without any effect on performance. Nude ion gauges are the definitive solution to the gauge pumping problems experienced in tubulated gauges. The unrestricted conductance to the vacuum system also provides faster response to pressure changes in the chamber.

Extended UHV gauges provide the most cost-effective alternative for pressure measurements in the low 10^{-10} ranges typically accessed in surface science and extreme high vacuum experiments. The fine anode grid wires provide an enhanced open area, increasing the pathlength of the electrons before colliding with the grid. This effect, along with the closed ends, increases the sensitivity of the gauge by about a factor of two, relative to conventional BAG designs with open grids. The thin collector wire reduces the X-ray induced residual current by minimizing the collisional cross section with the X-rays emitted from the grid. The combination of enhanced sensitivity and reduced X-ray induced residual current is responsible for the extended X-ray limit. The effect of ESD is also relatively smaller in these gauges, since the thinner collector wire (0.125 mm vs. 0.25 mm) is very ineffective at collecting the energetic ions produced by electron stimulated desorption from the grid. The main limitation of the UHV design is the reduced linearity of the pressure gauge readings at upper pressures, starting sometimes as early as 10^{-5} Torr[88].

High-accuracy gauges

One of the most significant developments in BAG design in recent years has been the introduction of the 'high-accuracy gauge' design[89]. High-accuracy gauges operate based on the same ionization principles as nude and tubulated gauges; however, they provide highly accurate, reproducible and stable pressure readings by systematically avoiding the known problems associated with traditional gauge designs.

The long-term stability, accuracy and gauge-to-gauge reproducibility of pressure measurements in high-accuracy gauges are assured by the unique design and precise manufacturing applied to their construction.

In a commercially available design[90], dual, independent, thoria coated, ribbon filaments are carefully positioned relative to the anode axis and maintained in tension by refractory metal springs. Consequently, the filaments exhibit negligible bow, sag or twist with use, assuring stable and reproducible electron trajectories over time. Partial end-caps are employed to extend the radial electric field over a much larger area of the anode grid while at the same time short filaments are used to introduce electrons away from the end regions of the anode, assuring stable ion production conditions within the ionizer. The end-capped anode is precision assembled and stress-relieved so that it maintains its exact shape and position even after high temperature degassing. Electrode positions relative to wall are identical from gauge to gauge to assure reproducibility of measurements. A grounded conductive shield completely surrounds the anode-cathode structure to help provide a stable electrical environment for charged particle trajectories. The entire shield is designed to remain dimensionally stable over time and to have the same dimension from gauge to gauge within close tolerances. A grounded perforated high conductance shield over the port electrically isolates the electrode structures from the rest of the vacuum system.

Two different collector wire diameters of 0.005" and 0.040" are used. The thicker collector wire, precisely located at the anode axis, is so effective at collecting ions (50 $Torr^{-1}$ sensitivity) that it helps extend the upper pressure limit to 10^{-2} Torr while keeping the X-ray limit at 10^{-10} Torr. The thinner collector wire, while providing a lower sensitivity, extends the X-ray limit into the low 10^{-11} Torr range for performance compatible with ultra- and extreme-high vacuum applications.

The premise is simple, high accuracy gauges provide long-term, stable, accurate, gauge-to-gauge reproducible measurements in a way that is unmatched by any other BAG design. Current state-of-the art midrange accuracy specifications for uncalibrated high-accuracy gauges are 6%, and they get better for individually calibrated gauges.

Note

It is important to mention at this early point that no independent studies on the long term behavior of high accuracy gauges have yet been reported in the vacuum literature. All long term stability claims are based on experiments performed, and data published, by the gauge manufacturer itself. No certified independent vacuum calibration laboratory has looked at these gauges over a long period of time and compared their long term behavior to that of traditional designs.

Full enjoyment of the enhanced accuracy and stability capabilities of high-accuracy gauges requires the use of high-quality controllers such as the IGC100. Traditional (older design) controllers can contribute up to 15% uncertainty to a BAG readout[91].

High accuracy gauges are stable and reproducible enough, that it makes sense to calibrate them. Using the IGC100, it is possible to perform NIST traceable calibrations on individual gauges and store calibration information on Memory Cards that can be loaded into the controller's memory when needed. Stored values of gauge sensitivity track the actual gauge sensitivity across the entire pressure range, providing real time correction for the non-linearities that lead to errors in traditional gauge systems. Individually calibrated high accuracy gauges offer midrange reading accuracies better than 3% (close to spinning rotor gauge performance)[92].

High accuracy gauges are usually expensive, costing up to 10 times as much as a glass tubulated gauge, but they make a lot of sense in strictly controlled vacuum process environments where pressure reading inaccuracies can lead to reduced yields and increased production costs. When properly selected they can pay for themselves very quickly! The gauge-to-gauge reproducibility is a welcome feature when forced to switch to a new gauge right before trying to reproduce a production run. Calibrated high accuracy gauges are also cost-effective NIST traceable transfer standards, providing accuracies comparable to spinning rotor gauges over a larger pressure range. It is common practice for pressure calibration laboratories to use high-accuracy gauges as transfer, check and working standards. Keep in mind that whereas the gauge-to-gauge reproducibility claims for high accuracy ion gauges are generally well accepted by vacuum users, the longer term stability of these gauges has not yet been verified by any independent vacuum calibration lab.

Note

Consult Appendix C for details on the connection of high accuracy gauges to the IGC100.

Tiny Gauges

Miniaturization has not escaped BAG designs. Almost every vacuum gauge manufacturer now offers a version of 'tiny' ionization gauge[93].

Tiny gauges are a modern alternative to glass tubulated gauges and are likely to become relatively more important in the future. They eliminate glass gauge accidents by relying in all-metal construction. They offer an operational range that overlaps or sometimes exceeds that of traditional tubulated designs. The reduced size also minimizes the power requirements of the filament resulting in less heat being dissipated into the vacuum chamber and reduced outgassing.

A miniaturized, all-metal ionization gauge that retains the traditional inverted-triode design, operating voltages, good sensitivity and low X-ray limit of the conventional glass tubulated BAG has recently become commercially available[94]. This tiny gauge (5% of the conventional volume) utilizes a dual collector design to increase ion collection efficiency (20 $Torr^{-1}$ typical) while at the same time providing a wider usable pressure range that extends from $3x10^{-10}$ (X-ray limit) to $5x10^{-2}$ Torr.

Note

The IGC100 controller is compatible with most commercially available tiny-BAGs and a connector adapter is all that is required to operate them. Consult Appendix M for details.

Tiny gauges are more expensive than tubulated designs (up to 4 times) and are usually only available with dual thoriated (burn-out resistant) filaments. Filaments are not replaceable, making the gauges disposable after filament failure. Both flanged and tubular mounting options are available.

No reports on the repeatability, short- and long-term stability, and gauge-to-gauge reproducibility of tiny gauges are currently available since the gauges have only been recently introduced into the market. However, It is probably fair to assume that their accuracy specifications will be comparable to those of glass tubulated ion gauges.

Filament Considerations

Careful consideration must be dedicated to the choice of filament material.

Filaments are based on thermionic phenomena[95]- the emission of charged particles from the surface of a conductive material or compound at high temperature. The emission of charged particles depends on the *work function*[96] of the material, defined as the energy, measured in eV, required to move an electron from Fermi level outside the surface.

Filaments, in both wire and ribbon shapes, are required to

- supply a stable electron emission current with reasonable energy input and filament temperature
- have reduced chemical reactivity with the rarefied environment being measured
- have a reduced evaporation rate at the operating temperature (i.e. long life)
- have a vapor pressure at least one tenth of the lowest pressure that has to be measured
- have low levels of ionic and neutral molecule outgassing compatible with the lowest pressure measurements.

It is commonly believed that the filament in a BAG presents a reliability problem (especially when compared to Cold Cathode Gauges) and it is often true that the operating life of hot cathode ionization gauges is determined by filament lifetime. However, unless damaged by ion bombardment, high pressure operation, chemical reactions or severe contamination, filament lifetimes are usually in the thousands of hours (usually years).

The optimum choice of filament material is very application dependent, and interactions of the gas with the cathode material must be considered during filament selection.

Several attempts have been made to replace hot filaments with cold electron emitters in BAGs[97]; however, no commercially available gauges have resulted from those efforts yet.

Filament Materials

The filament materials used in BAGs can be grouped into two classes: (1) pure metals and (2) oxide-coated cathodes. This section only concentrates on the materials commonly encountered in commercially available gauges. For information on less common materials, consult the excellent primer by Gear[98] and the work by W. Kohl[99].

Among pure metals, tungsten (W) is used on a large scale in ionization gauge heads operated in medium and high vacuum environments. The operating temperature of tungsten cathodes is between 1900°C and 2200°C. At this high operating temperatures, contaminating electronegative gases, which would increase the work function and reduce emission levels, are rapidly evaporated from the filament surface. As a result, tungsten filaments provide more stable gauge operation compared to metal oxide cathodes. However, this advantage is usually at the expense of (1) large outgassing levels as a result of the elevated temperatures in the surrounding walls and (2) an increased reactivity with chemically active gases that react at the filament to produce other gases. Chemical reactions as well as a high vapor pressure (10^{-8} Torr at 2200K) make W a bad choice for

UHV measurements. Glass tubulated BAG tubes with dual W filaments are often the best choice for ion implantation applications.

The lifetime of W filaments, as determined by typical evaporation rates, is typically 10-20 hours at 10^{-3}-10^{-2} Torr, and about 1000 hours at 10^{-6} Torr (gas dependent). However, accidental exposure to air and/or mechanical mishandling will damage tungsten filaments irreversibly. Tungsten is not seriously affected by hydrocarbons and halogens during operation.

Thoria-coated iridium (ThO_2Ir) filaments are the oxide-coated cathodes most commonly encountered in BAG heads manufactured in the US[100]. These cathodes are prepared by depositing a layer of thoria (i.e. thorium oxide) on a base metal of iridium by cataphoresis. The coating is then preconditioned[101] by operation in a vacuum at about 1800°C. Iridium is the preferred substrate because it is very resistant to oxidation and does not burn out if exposed to high air pressures while hot. ThO_2Ir filaments are very resistant to poisoning and do not burn out if exposed for a short time during operation to a sudden inrush of air. In fact, BAGs with ThO_2Ir filaments are known to survive several brief exposures to atmospheric air, without any performance deterioration.

ThO_2Ir filaments operate at a 'relatively cool' temperature of ≈1400°C, resulting in reduced outgassing and chemical reactivity with active gases when compared to W filaments. These two advantages, make ThO_2Ir filaments the preferred filament choice for measurements in the ultrahigh vacuum region. Most thoriated filaments are ribbon shaped to minimize heat flow to the ends which results in reduced outgassing.

Thoria coatings are very sensitive to electron and ionic bombardment. As a consequence, electron bombardment degassing must be minimized in gauge heads with ThO_2Ir filaments. A thorough bakeout is a better alternative in this case.

The material choice is dictated by the application. Tungsten filaments are by far the least expensive and the most popular. The use of ThO_2Ir filaments is recommended for systems that are frequently brought to atmosphere (voluntarily or not!). ThO_2Ir is the only practical alternative for operation above 10^{-3} Torr. Some investigators[102] have obtained results suggesting that gauges with tungsten filaments provide better stability than do gauges with thoria coated versions. The current belief is that it is not the filament material that causes the improvement, but rather the shape of the cathode. Tungsten cathodes are typically made as tight springs stretched between rigid posts that tend to move relatively little during long term use compared to the hairpin shaped or relatively unsupported ribbon shaped thoria-coated cathodes. Whenever possible opt for spring tensioned filaments in your BAG heads, particularly those with hair pin designs.

Dual filament assemblies provide security against filament burnout if the system cannot be brought to atmosphere to change the gauge. They are the most cost-effective alternative for tubulated gauges where filament replacement is not an option. Do not expect both filaments to give identical readings in a dual filament gauge unless a high accuracy gauge is being used. Simple methods for in-house replacement of tungsten filaments in nude gauges have been described in the vacuum literature as a cost-effective alternative if high accuracy and reproducibility is not a requirement in the pressure measurements performed by the repaired gauge[103].

Filament Reactions

Chemical reactions at the hot filament can occur and usually belong to one of two groups: (1) thermal dissociation of gas or vapor at the hot cathode and further recombination of the resulting fragments with impurities in the gas or on the walls or (2) combination of gas with the filament material.

Chemical reactions involving the hot filament surface and the gas molecules can significantly affect the chemical composition and the total pressure of the gas environment in a high vacuum system[104]. There is a large dependence of these reactions on the material chosen for the cathode and the type of gas in the environment. Some of the processes triggered by these reactions include: (1) active pumping of selected gas components, (2) outgassing of impurities into the vacuum environment, (3) thinning of the filament, and (4) poisoning of the filament surface (change in work function and emissivity).

Gases and vapor usually found in measuring systems are oxygen, hydrogen and water vapor.

Oxygen

Oxygen molecules react with the hot tungsten cathode and dissociate into atomic oxygen. The atomic oxygen then reacts with the carbon impurities at the surface to yield CO and CO_2. Since carbon constantly diffuses to the surface from the bulk, CO is continuously generated by this process. Even after the carbon is consumed, atomic oxygen still combines with carbon containing impurities present on the gauge walls, yielding CO.

Oxygen atoms interact with tungsten and produce oxides (WO_2, WO_3) as surface species. These species affect the work function of the material and also make the wire very brittle. These chemical processes result in the removal of oxygen from the system, therefore an ion gauge with W filament acts as a pump for oxygen.

Hydrogen

Hydrogen molecules dissociate to atomic hydrogen in the presence of a tungsten cathode at temperatures > 800°C. The atomic hydrogen reacts with glass or metal surfaces to yield CO, H_2O, and CH_4. This fast removal of hydrogen from the gas results in anomalously high pumping speeds for hydrogen in BAG heads with W filaments.

After adsorbing a monolayer of hydrogen, the work function of a tungsten filament is significantly increased (+0.35 eV typical) and the filament must run hotter to achieve the same emission current.

Water

Water vapor reacts with hot tungsten cathodes initiating an efficient transport of tungsten molecules to the gauge walls. This process, known as the *water vapor cycle*, includes several steps: (1) water dissociates at the filament into atomic oxygen and hydrogen, (2) the atomic oxygen reacts with W to form a volatile oxide that deposits on the glass walls of the gauge head as a film, (3) atomic hydrogen reduces the film back to W thus setting free water vapor, which repeats the cycle. The cathode lifetime is severely compromised by this process. CH_4, CO and CO_2 are also formed at the filament as a result of chemical reaction with water.

Hydrocarbons

Hydrocarbons, such as methane and pump oils, backstreaming from vacuum pumps can dissociate on hot filaments to produce CO.

Emission of ions and neutrals

The emission of positive ions and neutrals from heated surfaces is a common occurrence that can affect the performance of BAGs in the UHV range.

Although the positive ions cannot normally reach the collector because of the grid potential, the emission of positive ions is accompanied by a larger flux of neutrals. These neutrals can then be ionized and reach the collector giving a pressure independent current which ultimately limits the lowest measurable pressure. The evaporation of neutrals and ions can be minimized by heating the pure metal cathodes at high temperature for prolonged periods of time while pumping the gauge head.

Accuracy and Stability

The two main variables that affect the accuracy and reproducibility of pressure measurements are (1) gauge-to-gauge reproducibility and (2) long-term stability.

Reproducibility

Gauge-to-gauge reproducibility has been examined by the High Vacuum Group at NIST (National Institute of Standards and Technology, Gaithersburg, MD). The sensitivities of a large collection of commercially available BAGs were carefully calibrated and surprisingly large sensitivity factor variations were observed even amongst seemingly identical gauge heads. The reported ranges[105] in gauge constants are summarized next:

- Glass tubulated with opposed W filaments: +20 to –10%
- Glass tubulated, with side-by-side W filaments: +25 to –5%.
- Glass tubulated, with thoria filament: +13 to –38%
- Nude UHV version, with thoria filaments: +22 to –65%

The gauge-to-gauge reproducibility and long-term stability of broad-range glass tubulated gauges was also studied at NIST[106]. A check of the sensitivity factors for the seven gauges tested found the nitrogen sensitivities to vary between 52 and 67% of their specified values. Significant non-linearities as a function of pressure were also evident. Instabilities were in the order of 10%. Some of the gauges were inoperable in hydrogen environments.

The scatter of sensitivities is easily corrected by calibration. However, many users simply accept the catalog values for sensitivity factors without correction. This practice is only acceptable for applications where a rough determination of pressure is necessary.

As a rule-of-thumb:

- gauge-to-gauge variations can be considered to be an average ±15%.
- For any one uncalibrated gauge, an accuracy of ±25% at midrange should be considered good.
- Measurement accuracies better than 1% are not achievable with BAGs.
- Calibration of the gauge is recommended whenever an accuracy better than 50% is required.

Stability

Long-term stability of measurements over long operating times is also very important for accurate measurements. Filippelli and Abbott[107] compared repeated calibrations of 20 gauges used as transfer standards in industrial applications (returned to NIST for recalibration every one to two years several times) and concluded that for tubulated gauges with W filaments the standard deviation of the maximum difference between successive calibrations was 3% (maximum 12%) while for gauges with thoria cathodes it was 6% (maximum 18%). In most cases, the sensitivity of the gauges tended to decrease. The change in gauge sensitivity did not occur in a uniform manner with time of use.

P. C. Arnold and S. C. Borichevski[108] studied the stability and gauge-to-gauge reproducibility of eleven 'conventional' BAGs with various different mechanical constructions and thoriated filaments and reported much larger sensitivity variations ranging from –57 to +72% over the first 4000 hours of operation. Gauge-to-gauge variations between –20 and +32% were observed for five virtually identical glass tubulated gauges after 48 hours of operation. The gauges were operated at 10 mA of emission current (compare to 1 mA for NIST), and were degassed daily for 20 minutes (not recommended by NIST) which might explain the poor performance of the tested gauges.

The long term stability of a BAG is highly affected by its history (see 'History Dependence' in this appendix). Gauge sensitivity factors are seen to change with time even under the carefully controlled conditions of a standards laboratory. Industrial systems with gases that contaminate the electrodes are much worse. Unfortunately, there is very little written on the effects of contamination, for, as might be expected , there are wide variations in performance, depending upon both the type of gauge and its treatment in the vacuum system. Two very useful papers[109] that deal with the causes of non-stability in BAGs are found in the references, and should be consulted for details. An excellent set of 'Recommended Operating Procedures' for better BAG stability was compiled by Tilford[110] and is highly recommended.

Partial restoration procedures for heavily contaminated glass-tubulated BAGs have been reported in the vacuum literature[111]. These procedures are only recommended for inoperable gauges, and in general only restore the sensitivity of the gauge within a factor of two of a new gauge.

Systematic differences in sensitivity are observed between the two filament positions in BAGs with dual filament assemblies and conventional design. An individual calibration for each filament is necessary for accurate measurements.

Confidence in gauge stability can be increased by periodically checking the gauge against a check gauge (work standard). This will be most effective if the check gauge is of proven stability and/or is protected from abuse or unnecessary use.

Even with inactive gases, time must be allowed for gauge equilibrium to be reached following pressure changes. Limited experimental data is available in this area. Some general rules of thumb, applicable to transient measurements, can be obtained from Tilford's work[112]:

- Tungsten (W) filament gauges accommodate to increasing nitrogen pressure faster than thoria-coated filament gauges.
- W filament gauges respond to a three fold increase in pressure to within 0.1% within a few minutes.
- The response is slower in a dirty system or with active gases.
- The response to decreasing pressure is slower by several orders of magnitude.

These effects are compounded by conductance limitations of the gauge tubulation and the time constant of the electrometer.

One of the most significant developments in BAG design in recent years has been the introduction of the 'high-accuracy gauge' design[113]. High-accuracy gauges operate based on the same ionization principles as nude and tubulated gauges; however, they provide highly accurate, reproducible and stable pressure readings by systematically avoiding the known problems associated with traditional gauge designs. The long-term stability, accuracy and gauge-to-gauge reproducibility of pressure measurements in high-accuracy gauges are assured by the unique design and precise manufacturing applied to their construction (see 'Mechanical Construction' in this appendix for details).

High accuracy gauges are stable and reproducible enough, that it makes sense to fully calibrate them. Using the IGC100 it is possible to perform NIST traceable calibrations on individual gauges and store calibration information in special Memory Cards that can be downloaded into the controller's memory when needed. Stored values of gauge sensitivity track the actual gauge sensitivity across the entire pressure range, providing real time correction for the non-linearities that lead to errors in traditional gauge systems. Individually calibrated high accuracy gauges offer midrange reading accuracies better than 3% (close to spinning rotor gauge performance) [114].

Full enjoyment of the enhanced accuracy and stability capabilities of high-accuracy gauges requires the use of high-quality controllers, with properly specified electronics, such as the IGC100. Traditional (older design) controllers can contribute up to 15% uncertainty to a BAG readout[115].

Degassing

The cleanliness of an ionization gauge has a considerable effect on its performance.

The filament is rapidly outgassed when first turned on. The radiant heat from the hot wire then causes outgassing from nearby surfaces including electrode supports and envelope walls. These effects are readily seen following the pressure indication of the BAG immediately after the filament is switched on.

The heat generated by the filament during normal operation is not enough to effectively clean the grid and collector surfaces, and effective outgassing of the envelope requires bakeout (400°C for 1 hour is typical for glass tubulated gauges).

To reduce the outgassing in a gauge to a negligible level, and minimize the effects of ESD on low pressure measurements, the outgassing technique known as *Degassing* is often employed to drive off the gas molecules adsorbed on the anode grid structure. During degas the electrodes are degassed by heating to a temperature of 900°C (nominal) for 10-20 minutes. The electrode heating is accomplished by either electron bombardment (EB Degas) or by passing a high current through the grid ($\mathbf{I}^2$R Degas) .

In conventional gauges, particularly those manufactured in the US, the anode grid is in the form of a single or double helix designed to allow a current to be passed through to provide ohmic heating. Distortion and sagging can occur here if the temperature attained during degassing is too high. Modern gauge heads use molybdenum or tungsten grids to avoid or minimize this problem. Typical powers used during resistive heating degassing are about 70 Watts (7 Vdc @ 10 A). All helix gauges can also be degassed by EB as well.

Gauges made with squirrel-cage grids (UHV nude BAGs) can accept only EB degas. During EB degas, the grid (and sometimes the collector as well) are biased at around 500 Vdc and bombarded with electrons from the filament (biased at 30 Vdc). An emission current of a few tens of milliamps is sufficient to heat the electrodes (usually molybdenum) to a dull red. The combination of heating with the electron bombardment of the electrodes provides a very effective cleaning procedure.

Degassing is best carried out, while the rest of the vacuum system is also being baked to avoid degassing products from adsorbing onto the walls of the chamber.

It is common practice for many HV users to automatically degas the gauge and/or bake the vacuum system after the gauge is exposed to ambient, or after surface contamination is suspected. BAGs will be unstable for several hours following degassing until the chemical composition and adsorbed layers on the newly cleaned surfaces reach equilibrium. This effect must be carefully considered for high accuracy determinations.

All commercially available BAGs can be degassed by electron bombardment. However, thoriated filaments can be rapidly damaged by the intense ionic bombardment that they experience when EB degassing takes place at pressures above 10^{-5} Torr. To extend filament lifetime, minimize the emission current during degas and extend the degas time to compensate. Keep the EB degas power under 40 W for all thoriated filament gauges.

Some vacuum researchers suggest bombarding the collector wire along with the anode grid during EB degassing. This approach leads to clean electrodes, but it is intrinsically dangerous in practice. Instead, it is recommended to keep the collector connected to the electrometer to get a rough estimate of the pressure during degas. EB degassing at pressures >5x10^{-5} Torr can damage the gauge, and injure the user if the system is not properly grounded (see the **Safety and Health Considerations** section for details)

The recommendation from the NIST High Vacuum Group is to eliminate degassing by high temperature heating of the grid (whether resistive or electron bombardment). For baked systems, their observation is that gauges can be effectively outgassed by simply operating them at normal emission currents while the BAG and vacuum system are baked. For unbaked systems, the gauge can be baked and outgassed by thermally insulating it with fiberglass. Degassing by electron bombardment is only recommended if (1) the gauge is heavily contaminated or (2) after exposure to surface active gases such as O_2[116]. Whenever possible minimize the emission current during degas and extend the degas time to compensate.

Note
The IGC100 offers EB degas with fully adjustable Degas power and Degas time.

Safety and Health Considerations

Electric Shock

DANGER!
The most serious hazard with BAGs and their controllers is electrical shock[117].

During normal operation the anode grid of a BAG is biased at about 180 Vdc and connected to a power supply capable of supplying 10 mA. This is enough to cause defibrillation and even death. During EB degas, the anode grid is biased to 500 Vdc at currents of up to 160 mA! Contact with this supply, with a direct current path through the body, would very likely be fatal to anybody.

A more subtle way of contacting the high voltage during EB degas was described by Morrison[118]. If EB degas is allowed at pressures above 10^{-4} Torr, a plasma might develop inside the gauge capable of providing a current path to metal portions of the system. If the system is not properly grounded, touching the charged metal section may cause a lethal shock. The effect might remain even after the filament is shut down (depending on the amount of energy stored)!

A well designed gauge system should include suitable cables, connectors and grounds. A user should never touch any connector or the gauge when the power is on. Both the controller and the vacuum system must be earth grounded with heavy gauge (12 AWG) wire.

Thoria Alpha Emission

In gauges with thoriated filaments, exposure to the alpha particles emitted by thorium is of concern to some users. The use of yttria coated iridium filaments is recommended in those cases as an alternative. Most gauge manufacturers offer this filament material as an option.

Glass breakage

With glass tubulated gauges, breakage of the glass envelope can result in implosion and the associated danger of flying glass. Whenever possible protect the gauge with a shield and provide stress relief for the cables. Do not overtighten the O-rings of the compression fittings traditionally used to connect glass tubulated gauges to vacuum systems. All-metal nude gauges should also be considered if the risk of breakage is high.

Burns

Gauge envelopes can get hot, and cause burns if touched during operation.

X-rays

The X-rays produced at the anode grid, and responsible for the X-ray limit, are not a risk since they do not have enough energy to penetrate through the gauge envelope. This is also true for the X-rays generated during EB Degas.

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[114] Midrange accuracy is better than 2% when the calibration is performed by a primary standards lab such as NIST.

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Appendix B

Manufacturer Cross-Reference for Bayard-Alpert Gauges

In This Appendix

Manufacturer Cross Reference Table

Glass Tubulated									
Connection Type	**Diameter**	**Filament Material (count)**	**Pin Config**	**SRS (Stock#)**	**Granville-Phillips**	**ETI**	**Duniway Stockroom**	**Kurt J. Lesker**	**Varian**
Glass Tube (Pyrex)	0.75 in.	ThO_2/Ir (single)	Fig. B-1	GR-075P (6-552)	274002	4336P	I-075-P	G075P	K2471304
		Tungsten (dual)	Fig. B-2	GW-075P (6-548)	274012	4336TP	T-075-P	G075TP	K7360303
	1 in.	ThO_2/Ir (single)	Fig. B-1	GR-100P (6-554)	274005	4336P/1	I-100-P	G100P	K2471301
		Tungsten (dual)	Fig. B-2	GW-100P (6-551)	274015	4336TP/1	T-100-P	G100TP	K7360301
Metal Tube (Kovar)	0.75 in	ThO_2/Ir (single)	Fig. B-1	GR-075K (6-547)	274003	4336K	I-075-K	G075K	K2471305
		Tungsten (dual)	Fig. B-2	GW-075K (6-550)	274013	4336TK	T-075-K	G075TK	K7360304
	1 in.	ThO_2/Ir (single)	Fig. B-1	GR-100K (6-549)	274006	4336K/1	I-100-K	G100K	K2471302
		Tungsten (dual)	Fig. B-2	GW-100K (6-553)	274016	4336TK/1	T-100-K	G100TK	K7360302
2.75" Conflat® Flange	1 in. side tube	ThO_2/Ir (single)	Fig. B-1	GR-100F (6-556)	274008	4336F/1	I-CFF-275	G100F	K2471303
		Tungsten (dual)	Fig. B-2	GW-100F (6-555)	274018	4336TF/1	T-CFF-275	G100TF	K7360307
Nude (2.75" CF flange)									
Range	**Anode Grid**	**Filament Material (count)**	**Pin Config**	**SRS (Stock#)**	**Granville-Phillips**	**ETI**	**Duniway Stockroom**	**Kurt J. Lesker**	**Varian**
Std.	Bi-filar Helix	ThO_2/Ir (single)	Fig. B-3	NR-F (6-559)	274028	8140	I-NUDE-BAC	G8140	L5150-302
UHV	closed end cage	ThO_2/Ir (dual)	Fig. B-4	NR-F-UHV (6-557)	274023	8130	I-NUDE-F	G8130	971-5007
UHV	closed end cage	Tungsten (dual)	Fig. B-4	NW-F-UHV (6-558)	274022	8130T	T-NUDE-F	G8130T	971-5008

Note

The IGC100 is also compatible with STABIL-ION® and MICRO-ION® gauges manufactured by Granville-Phillips (Helix Corp., Longmont, CO, USA). Consult Appendices C and M for more information on using these third party gauges.

Replacement Filament Assemblies for Nude Gauges		
SRS Model #	**SRS Part #**	**Description**
O100RFA-DR	6-581	Dual ThO_2/Ir Replacement Filament Assembly for NR-F-UHV Gauge
O100RFA-DW	6-582	Dual Tungsten Replacement Filament Assembly for NW-F-UHV Gauge
O100RFA-SR	6-583	Dual ThO_2/Ir Replacement Filament Assembly for NR-F Gauge

Bayard Alpert Gauge- Pin Connector Configuration-Cable Selector

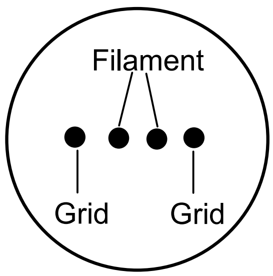


Figure B-1
Glass Tubulated Gauge
Single ThO_2/Ir filament
IGC100 Cable: **O100C1**
Default Setup: **GLASS**

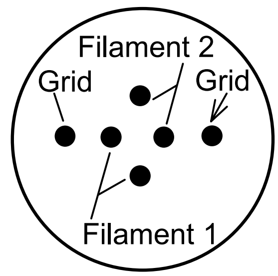


Figure B-2
Glass Tubulated Gauge
Dual Tungsten filaments
IGC100 Cable: **O100C2**
Default Setup: **GLASS**

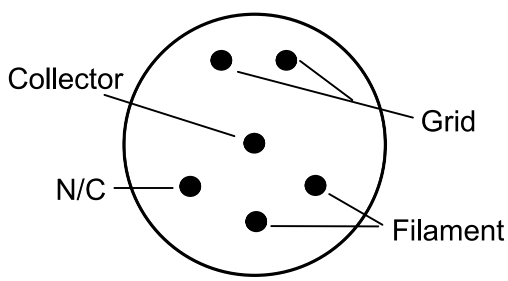


Figure B-3
Nude Gauge
Single ThO_2/Ir filament
Bi-filar helical anode grid
IGC100 Cable: **O100C3**
Default Setup: **NUDE**

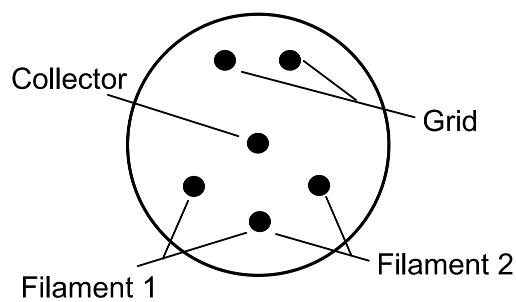
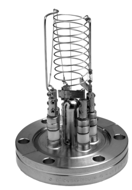
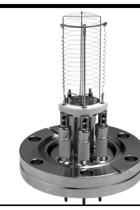


Figure B-4
Nude Gauge-UHV
Dual ThO_2/Ir or W filaments
Closed end anode grid cage
IGC100 Cable: **O100C3**
Default Setup**: NUDE-UHV**

Specifications of SRS Bayard-Alpert Ionization Gauges

	Glass Tubulated	Nude	Nude –UHV
Physical Data			
Appearance			
Connection	Side Tube or 2.75 in. Conflat® Flange	2.75 in. CF Flange	2.75 in. CF Flange
Side Tube diameter	0.75 in. (19.1 mm) or 1 in. (25.4 mm)	N.A.	N.A
Side tube material	Pyrex or Kovar[1]	N.A.	N.A.
Envelope	Nonex 7720 Glass, 2.25 in. dia. (57 mm) x 5.25 in. (133 mm) long	Nude	Nude
Mounting Position	Any, vertical preferred[2]	Any	
Collector	Tungsten, 0.005 in. diameter		
Filament	Single[6] ThO_2/Ir or dual tungsten	Single[6] ThO_2/Ir Replaceable.	Dual ThO_2/Ir or dual tungsten. Replaceable
Grid	Tungsten, bi-filar helix configuration	Tungsten, bi-filar helix configuration	Tantalum and Pt/Moly support, closed end (“squirrel cage”).
Overall Length, max	6.0 in. (152 mm)	4.13 in. (105 mm)	
Insertion Length, max.	N.A.	3.30 in. (84 mm)	3.00 in. (76 mm)
Operating Data			
Operating Pressure	2×10^{-10} to 10^{-3}Torr	4×10^{-10} to 10^{-3}Torr	2×10^{-11} to 10^{-3}Torr
Sensitivity for N2, nominal	10/Torr	10/Torr	25/Torr
X-ray limit	2×10^{-10}Torr	4×10^{-10}Torr	2×10^{-11}Torr
Electron Bombardment Degas, Power @500V	70 Watts, nominal 100 Watts, max	70 Watts, nominal 100 Watts, max	40 Watts, max
Resistance Heated Degas	6.3 to 7.5 volts @ 10 amps	6.3 to 7.5 volts @ 10 amps	N.A.
Bakeout Temperature	250º C	450º C	450º C
Electrical Operating Parameters[3]			
Anode Grid Bias Voltage	180 V dc		
Collector Bias Voltage	0 V dc		
Filament Bias Voltage	30 V dc		
Emission Current (nom)	10 mA	10 mA	4 mA
Filament Supply Current	4 to 6 amps		
Filament supply Voltage	3 to 5 Volts		
SRS Cable # [4]	O100C1 – one filament O100C2-dual filament	O100C3	O100C3
Default Setup File[5]	GLASS	NUDE	NUDE-UHV

Notes

[1] Glass-to-metal transition.

[2] Vertical orientation provides strain relief for electrode structures increasing long term stability performance.

[3] Direct current (dc) bias and supply voltages are recommended for all electrical connections.

[4] O100C3 cable is compatible with all Bayard Alpert Gauges in this table.

[5] Default Setup files are factory pre-loaded in the IGC100 controller and facilitate controller setup.

[6] Single filaments are hair pin shaped and spring loaded to eliminate sagging.

Appendix C

Using the IGC100 with STABIL-ION® Gauges

The IGC100 controller is compatible with STABIL-ION® gauges - model numbers 360120, 370120 and 370121- manufactured by Granville-Phillips, Helix Technology Corp (Longmont, CO, www.granville.com).

This short note discusses the wiring details, parts and gauge setup parameters required to connect and operate a STABIL-ION® gauge with an IGC100 controller.

The data included in this note is based on information available directly from Granville-Phillips[1], as well as SRS's own experience with STABIL-ION® gauges. For further information, please contact our application engineers at (408) 744-9040 or e-mail to info@thinkSRS.com.

In This Appendix

Compatibility

The ION GAUGE connector (female), located on the back panel of the IGC100, is pin-compatible with the connector (male) found on all STABIL-ION® Gauge cables manufactured by Granville-Phillips – model numbers 360112 through 360117.

1. Purchase the STABIL-ION® cable directly from Granville-Phillips[2]. For the best fit[3], choose from cable part numbers 360112 (3 m), 360114 (8m) or 360116 (user selectable length).
2. Connect the cable to the gauge and to the controller following the standard gauge connection procedure.
3. Adjust the gauge setup parameters according to the directions below.

See 'Getting Started' Chapter 1 for more complete details about connecting and configuring ionization gauges.

Gauge Setup Parameters

The IGC100 gauge setup parameters must be properly adjusted to obtain accurate pressure readings with STABIL-ION® gauges.

Select N_2 Sense Factor as the IG Cal Source for all STABIL-ION® models. The rest of the parameters are model dependent.

Tip

Default setup files are available and are based on the gauge manufacturer's recommendations.

Select 'Normal' for the Gauge Protection mode for all STABIL-ION® models.

The adjustments required for pressure measurement accuracy are:

1. IG Calibration Source.
   Select N_2 Sense Factor for all STABIL-ION® models. The rest of the parameters are model dependent.
2. N_2 Sensitivity Factor
3. Emission Current
4. Degas Power
5. Degas Time
6. Overpressure threshold.

STABIL-ION® models 360120 and 370120

These two gauge models are identical and share the same parameters.

Degas Power: 40 W
Degas Time: 10 minutes
Gauge Protection: Normal

Adjust the remaining settings depending on the vacuum system pressure range:

Pressure Range	Emission Current	N2 Sensitivity Factor	Overpressure Threshold	Default Setup File
($5x10^{-8}$ – $5x10^{-3}$ Torr) Use for P >10^{-4} Torr	0.1 mA	46/Torr	$2x10^{-2}$ Torr	Stabil-H
($2x10^{-10}$ – $5x10^{-4}$ Torr) Use for P < 10^{-7} Torr	4 mA	42/Torr	$1x10^{-3}$ Torr	Stabil-L

Use either setup for pressures between 10^{-7} and 10^{-4} Torr.

STABIL-ION® model 370121 (UHV-version)

Degas Power: 25 W
Degas Time: 10 minutes
Gauge Protection: Normal

Pressure Range	Emission Current	N2 Sensitivity Factor	Overpressure Threshold	Default Setup File
$5x10^{-11}$ to $2x10^{-5}$ Torr	4 mA	21/Torr	10^{-4} Torr	Stabil-UHV

Note

In the UHV version, the 0.040" diameter collector of the standard STABIL-ION® gauge is replaced with a 0.005" diameter ion collector. As a result, gauge sensitivity is lower, linearity range is reduced, and long term reproducibility is not as good[4].

DEGAS

The degas power may be set at a maximum of 40 Watts for models 360120 and 370120 and 25W for 370121 (UHV-version). Recommended degas times are 10 to 20 minutes. Degas powers higher than the recommended maximum can cause damaging pressure bursts in the vacuum system, and compromise filament lifetime. They can also have an effect on the long-term stability of the gauges.

Note

The IGC100 will not begin a degas process if the pressure at the gauge is above $5x10^{-5}$ Torr. A rough pressure indication is displayed during the degas process. The degas power is controlled during the entire process to minimize pressure bursts above $5x10^{-5}$ Torr.

Final Comments

Until the recent introduction of the IGC100, operation of STABIL-ION® gauges required the use of dedicated Granville-Phillips controllers (models 360 and 370) to fully enjoy accurate pressure readings. The IGC100 is a high quality instrument, built with all the electrical specifications required to control high accuracy Bayard-Alpert gauges, while at the same time providing powerful new features and significant cost savings. STABIL-ION® users looking for a gauge controller upgrade should seriously consider the IGC100 as a cost-effective and more powerful alternative to the previously available instruments.

Important!

No independent studies confirming the high accuracy and long-term stability specifications claimed by Granville-Phillips for their STABIL-ION® gauges[5] have been reported to date. Stanford Research Systems has used STABIL-ION® gauges in several applications, but no systematic study of their accuracy and long-term performance has been conducted. STABIL-ION® users should contact Granville-Phillips directly for gauge accuracy information. Long term studies and systematic comparisons against standard Bayard-Alpert designs[6] will be required to confirm the utility of these new gauges and justify their premium cost.

References

[1] Application Bulletin #360173, Granville-Phillips, Helix Technology Corporation, www.granville.com, 1996.

[2] Contact Granville-Phillips at: www.granville.com.

[3] Cables with part numbers 360113, 360115 and 360117 are also compatible with the IGC100 box but have an unnecessarily long collector current cable.

[4] P. C. Arnold, et. al. , "Stable and reproducible Bayard-Alpert ionization gauge", J. Vac. Sci. Technol. A 12 (2) (1994) 580. See Test Results section in p. 583 for details on the UHV version STABIL-ION® gauge.

[5] P. C. Arnold and S.C. Borichevsky, "Nonstable behavior of widely used ionization gauges", J. Vac. Sci. Technol. A 12(2) (1994) 568; D. G. Bills, "Causes of nonstability and nonreproducibility in widely used Bayard-Alpert ionization gauges", J. Vac. Sci. Technol. A 12 (1994) 574.

[6] C. R. Tilford, A. R. Filippelli and P. J. Abbott, "Comments on the stability of Bayard-Alpert ionization gauges", J. Vac. Sci. Technol. A 13 (2) (1995) 485.

Appendix D

Gas Correction Factors for Bayard-Alpert Ionization Gauges

The sensitivity factor, S_g, supplied by gauge manufacturers (usually in $Torr^{-1}$), *is valid only for the gas for which it is specified* and the readout of the controller provides a direct pressure reading only for that specific gas. The standard gas, used by the entire industry for gauge specification, is *nitrogen* and, unless gas correction factors are applied, all readings are considered to be 'nitrogen-equivalent pressures'.

In This Appendix

Gas Correction Factors

The sensitivity factor, S_g, supplied by gauge manufacturers (usually in $Torr^{-1}$), is only valid for the gas for which it is specified and the pressure readout of a BAG controller provides a direct reading only for that specific gas. The standard gas, used by the entire industry for gauge specification, is *nitrogen* and, unless gas correction factors are applied, all readings are considered to be 'nitrogen-equivalent pressures'.

Nominal *relative sensitivity factors*, R_g, to convert nitrogen-equivalent readings into direct pressure readouts for gases other than nitrogen, are available from most gauge manufacturers and from the public vacuum literature. A summary table and reference list, is included in this appendix. For gases where little or no data are available, it has been shown that a reasonable approximation to the relative sensitivity factor, R_g, can be obtained from the ratio of ionization cross sections at 150 eV of electron energy. Several ionization cross section tables are also available in the scientific literature.

Once the relative sensitivity factor is known, direct pressure readings are calculated from the straightforward mathematical equation:

$$P = [\, I_c / (S_g \cdot I_e)] \qquad \text{(eqn.1)}$$

where

$S_g = S_{N2} \cdot R_g$

S_g, sensitivity factor for gas 'g' [$Torr^{-1}$]

S_{N2}, sensitivity factor for nitrogen [$Torr^{-1}$]

R_g, gas correction or relative sensitivity factor

I_c , ion collector current [amps]

I_e, electron emission current [amps]

See Appendix A 'Bayard-Alpert Ionization Gauges' for a detailed explanation of gauge sensitivity.

Note

The IGC100 controller stores a nitrogen sensitivity factor, S_{N2} (N2 Sense Factor), and a single relative sensitivity factor, R_g (Gas Correction Factor), for every BAG connected to its back panel. The two parameters are automatically applied to the calculation of pressures according to eqn. 1 when the N_2 Sensitivity Factor is selected as Calibration Source from the Gauge Setup menu.

The Gas Correction Factor is fixed at 1.0 when 'Cal Curve' is selected as the IG Calibration Source.

Nominal Gas Correction Factors for Common Gases

(relative to $N_2 = 1.00$)

Gas	R_g
He	.18
Ne	.30
D_2	.35
H_2	.46
N_2	**1.00**
Air	1.0
O_2	1.01
CO	1.05
H_2O	1.12
NO	1.15
NH_3	1.23
Ar	1.29
CO_2	1.42
CH_4 (methane)	1.4
Kr	1.94
SF_6	2.2
C_2H_6 (ethane)	2.6
Xe	2.87
Hg	3.64
C_3H_8 (Propane)	4.2

IMPORTANT!

Nominal relative sensitivity factors cannot be relied upon for accurate measurements since they are known to vary significantly between seemingly identical gauges and even more for different gauge types, filament materials, and operating potentials. For general vacuum use, the discrepancy in reported measurements is not greater than 10% for the common gases, rising to a little above 20% for the less common gases, where less accurate information is available. Relative sensitivities are pressure dependent and become particularly unreliable above 10^{-5} Torr. Where greater precision is required, gauges must be calibrated individually against the specific gases and under conditions as close as possible to the operating conditions of the vacuum system.

References

Gas Correction factors

R. L. Summers, "Empirical Observations on the sensitivity of hot cathode ionization type vacuum gauges", NASA Technical Report, NASA-TN-D-5285, published 1969. *Comment: This publication is the industry standard used by BAG manufacturers to specify gas correction factors for their gauges. It includes a fairly complete compilation and review of prior literature numbers.*

R. Holanda, "Sensitivity of hot-cathode ionization vacuum gauges in several gases", NASA Technical Report, NASA-TN-D-6815 E-6759, published 1972. *Comment: Includes calibration data for 12 different gases and 4 different gauges.*

R. Holanda, "Investigation of the Sensitivity of Ionization-Type Vacuum Gauges", J. Vac. Sci. Technol. 10(6) (1973) 1133. *Comment: Demonstrates the good correlation between gas correction factor and ionization cross sections.*

F. Nakao, "Determination of the ionization gauge sensitivity using the relative ionization cross section", Vacuum 25 (1975) 431. *Comment: Includes numbers, compiled from the literature, for 44 different gases including inorganic and hydrocarbon (up to C_{10}) compounds.*

J. E. Bartmess and R.M. Georgiadis, "Empirical methods for determination of ionization gauge relative sensitivities for different gases", Vacuum 33(3) (1983) 149. *Comment: Includes data for 74 different gases including various organic compounds. All hydrocarbon numbers of Table I. were extracted from this report.*

C. R. Tilford, "Reliability of high vacuum measurements", J. Vac. Sci. Technol. A 1(2) (1983) 152. *Comment: A must-read paper on BAG readings and the different variables that affect them. Includes correction factors for several gases plotted as a function of pressure and a very useful discussion on the subject.*

T. A. Flaim and P. D. Ownby, "Observations on Bayard-Alpert Ion Gauge Sensitivities to Various Gases", J. Vac. Sci. Technol. 8(5) (1971) 661

M. Schulte, B. Schlosser, and W. Seidel, "Ionization gauge sensitivities of N_2, N_2O, NO, NO_2, NH_3, $CClF_3$ and CH_3OH", Fresenius Journal of Analytical Chemistry, 348(11) (1994) 778

Ionization cross sections

L. J. Kieffer and Gordon H. Dunn, "Electron Impact Ionization Cross section. Data for Atoms, Atomic Ions, and Diatomic Molecules: I. Experimental Data", Reviews of Modern Physics, 38 (1966) 1

Appendix E

Selecting a Bayard-Alpert Ionization Gauge

An immense amount of research and development work, by many talented scientists and engineers, has led to a variety of new Bayard-Alpert Gauge (BAG) designs. In fact, a high vacuum user looking for a new BAG might be surprised, and possibly overwhelmed, by the large number of new commercial options that have become available. Standardization of the BAG design has made it possible for generic ion gauge controllers, such as the IGC100, to control gauges from many different manufacturers.

This appendix provides an overview of the current state of BAG technology to help high vacuum users choose the best hot-cathode ion gauge for their application.

In This Appendix

BAG Designs

This appendix provides an overview of the current state of the BAG technology to help choose the best hot-cathode ion gauge for any application. For detailed information on the principle of operation of BAGs see Appendix A, 'Bayard-Alpert Ionization Gauges'.

Glass Tubulated Gauges

The glass tubulated BAG is the most commonly used gauge design in the world. Glass tubulated gauges are also the most inexpensive BAGs available.

The tubulated gauge has its electrodes surrounded by a glass envelope with a side tube that attaches to the vacuum system. The most common construction materials for the glass envelope are Nonex (an inexpensive glass used in old vacuum tubes) and Pyrex. Most tubulated BAGs are connected to the vacuum system through an O-ring compression fitting. Pyrex is the material selected when the side tube must be glass-blown directly on to the vacuum system. Kovar alloy is the material of choice when metallic tubulation is required for the side port. The thermal expansion coefficient of Kovar matches that of Pyrex producing strong glass-to-metal transitions. Kovar tubulation is sometimes combined with compression fittings, but most often it is welded to Klein or ConFlat® flanges for compatibility with standard vacuum ports. While slightly more expensive, flanged tubulated BAGs offer better vacuum integrity and higher bakeout temperatures than compression fitting options. Side tube diameters are set by standard compression fitting diameters to ½", ¾" and 1" OD. Whenever possible, choose the widest possible bore to assure structural integrity and maximum gas conductance between the vacuum chamber and the BAG ionization region.

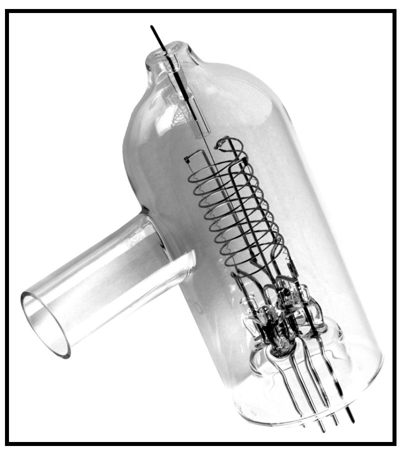


Figure E-1. Glass tubulated Bayard-Alpert ionization gauge, with glass side tube.

All glass tubulated gauges use the same bias voltages and similar emission currents, compatible with IGC100 electrical specifications, and provide pressure readings between 10^{-3} and $\approx 5 \times 10^{-10}$ Torr (typical X-ray limit). Specification claims beyond this range must be approached with caution!

Typical sensitivity factors fall in the range of 8-10 $Torr^{-1}$. Both I^2R and EB degas are supported by most of these gauges. A typical outgassing procedure includes heating the envelope to 250-400°C for 1 hour followed by a 15 minute degas step.

The repeatability, short and long term stability, and gauge-to-gauge reproducibility of glass tubulated gauges have been the subject of many studies. Several reports show that tubulated BAG users must be careful not to rely blindly on the accuracy of their gauge pressure readings. Gauge-to-gauge sensitivity variations are not unusual for seemingly identical gauges and 25% accuracy at midrange should be considered good for any one gauge, even with new, unused tubes. Long term stability is highly dependent on gauge construction, filament material, operation conditions and environment. Sensitivity changes are usually in the direction of decreased sensitivity. Repeatability in glass tubulated gauges is affected by accumulated electrostatic charge (electrons from the filament) on the glass walls. Several gauge manufacturers offer internal precious metal coatings (Pt) in their BAG tubes. The coating is electrically connected to the filament to reduce electrostatic charge on the glass surface and improve repeatability providing a slight advantage over standard gauges. With uncoated glass, it impossible to control the potential of the internal surfaces, which results in uncontrolled electron and ion trajectories within the gauge and reduced measurement accuracy and repeatability. Long-term stability is affected by changes in the electrode structure, particularly after repeated thermal cycling.

High stability tubulated gauges with spring tensioned (sag-free) filaments and reinforced supports that provide improved measurement stability and accuracy without adding any significant cost are available from Stanford Research .

Glass-tubulated BAGs are fragile and present a safety hazard due to implosion if not adequately shielded. Whenever possible, place them where they cannot be bumped, and be particularly careful during installation. A common problem is crushed side tubes due to excessive tightening of compression fittings. If possible, install the gauge so that the filament is visible during operation. A quick visual check might save a tungsten filament from burnout during a venting or gas loading operation. The preferred mounting orientation is with the filament and anode grid in a vertical position, with the connection pins pointing up, to minimize the electrode distortion caused by gravity pull and thermal cycles.

Tubulated gauges with single and dual filament designs are available. Both tungsten and thoriated-iridium filament materials are offered. Gauges with opposed tungsten filaments have shown better long-term stability (about a factor of two) than gauges with thoriated cathodes. Filaments are not replaceable, making single filament gauges disposable after a burnout (an added cost that must be considered!).

Glass tubulated gauges may be significant sinks of gas molecules and exhibit a certain pumping capacity that is usually time-dependent. This pumping is due to both chemical and electrical effects. The effect usually saturates after approximately three months of operation. The best way to handle gauge pumping is to provide a large conductance connection between the gauge and the vacuum system. A glass envelope gauge with 1" tubulation is recommended for applications requiring pressure measurements down to the 10^{-10} Torr scale, ¾" tubulation is adequate for routine pressure measurements above 10^{-8} Torr.

Glass, when heated, permits permeation of helium from the atmosphere. Remember this effect while leak testing your vacuum system! If helium leak testing with the ion gauge is common practice in your facility, consider an all-metal gauge instead.

BAGs require few electrical connections; however, there is no standard mating socket that will work with all gauge designs. It is the user's responsibility to assure that the correct electrical connections are made at the gauge pins. Wrong connections can cause damage to equipment and may be dangerous for the vacuum system operator. Experienced users can usually identify the different pins by visual inspection; however, the use of pre-wired cables available directly from Stanford Research Systems is recommended to connect BAGs to the IGC100 controller.

Tubulated gauges owe their popularity to their low cost, convenient measurement range, and ease of mounting. Their limited accuracy is more than adequate for most vacuum applications since very often a 'rough' pressure indication (i.e. ±50%) is all that is required by the vacuum operator to characterize the status of a vacuum system.

Broad-Range Glass Tubulated Gauges

Broad-range glass tubulated BAGs are available from many different manufacturers, and under several different trade names. These gauges are designed to operate all the way up to 10^{-1} Torr (with 0.01 mA emission current above 10^{-3} Torr) while still providing a sensitivity factor of 8 $Torr^{-1}$. They are easily identified because of the narrow grid design (12 mm diameter x 46 mm long), a thoria-coated filament, and a grounded platinum coating on the inside of a reduced diameter (41 mm vs the traditional 57 mm) glass tube. However, they have been shown to be susceptible to large time-dependent instabilities and non-linearities that must be carefully considered during measurements.

In several independent studies, broad-range tubulated gauges have shown large gauge-to-gauge sensitivity variations and non-linearities that make reliable measurements impossible in the absence of individual calibration over the entire pressure range.

Nude Gauges

In nude BAGs the electrodes are not enclosed in a glass envelope. Instead, the electrode structures are welded onto insulating feedthroughs mounted on a vacuum compatible flange (typically a 2.75" ConFlat®), and inserted directly into the vacuum chamber environment. The gas molecules of the vacuum chamber can flow freely into the ionization volume of the gauge thereby eliminating the pressure differential normally associated with tubulated gauges.

The electrode arrangement, biasing voltages and emission current are similar (or identical) to the glass-tubulated BAG and the IGC100 controller can operate both gauge designs without any problems. A cable replacement is usually all that is required to switch from one gauge design to another.

Figure E-2. Nude Bayard-Alpert gauge, with standard electrode design.

Nude BAGs are more expensive than glass-tubulated designs. When connected to a suitable controller, they provide pressure readings between 10^{-3} and $4x10^{-10}$ Torr (typical X-ray limit), with extended UHV versions reaching a $2x10^{-11}$ Torr low limit. Typical sensitivities fall in the range of 8-10 $Torr^{-1}$ for standard gauges and 25 $Torr^{-1}$ for the extended UHV versions. Extended UHV versions are easily identified by the fragile 'squirrel-cage' design (i.e. closed ends) of their anode grid.

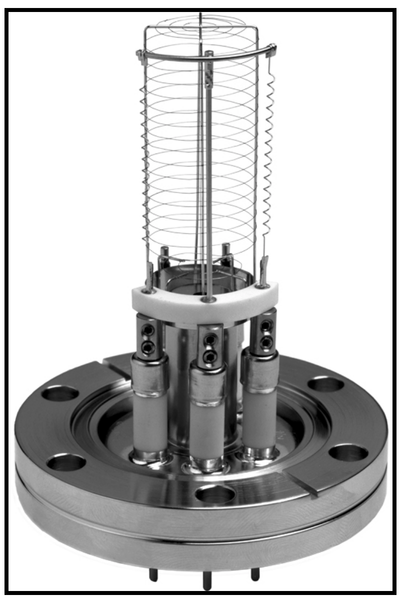


Figure E-3. Nude Bayard-Alpert Gauge, with UHV-extended design.

Gauge-to-gauge reproducibility has been shown to be worse than in tubulated gauges, particularly in UHV versions. Long term stability is comparable to that of tubulated gauges. Overall accuracies better than 30% should not be expected in general. Repeatability is improved in the absence of the insulating glass envelope.

Nude ion gauges are the definitive solution to the gauge pumping problems experienced in tubulated gauges. The unrestricted conductance to the vacuum system also provides faster response to pressure changes in the chamber.

Since the elements are exposed, and easily accessible, most nude ion gauges are designed with replacement filament assemblies. This allows filaments to be replaced after a burnout without having to dispose of the gauge (an important cost saving feature!). Unless a viewport is available, it is generally not possible to see the filament once the gauge is mounted on a port, making the filament more susceptible to accidental and catastrophic overpressures.

With the exception of extended range UHV gauges (EB only), all nude ion gauges provide both EB and I^2R degas options.

The sensitivity of nude ion gauges is affected by the way it is mounted on the system. This effect was recently demonstrated by a careful study, which showed that when the dimensions or shape of the gauge's metal envelope are changed there can be a dramatic effect (up to 2X) on the absolute magnitude of the gauge's sensitivity. There may also be a change in the relative dependence of its sensitivity on pressure. If these effects are not taken into account, the accuracy and consistency of the measurements performed with the gauge will be compromised. The envelope must be considered an integral part of the ionization gauge when specifying sensitivity. The practical consequence of these findings is that nude ion gauges must be calibrated in situ, or in an environment that exactly matches the one experienced by the gauge during its measurements.

Nude ions gauges are the choice of many UHV practitioners who appreciate the enhanced vacuum integrity provided by its mounting flange, the unrestricted conductance to the vacuum chamber, the reduced outgassing provided by its minimal surface area, and the higher bakeout temperatures that it can handle. Typical nude gauges can be baked to 450°C without any effect on performance.

Extended UHV gauges provide the most cost-effective alternative for pressure measurements in the low 10^{-10} Torr ranges typically seen in surface science and extreme high vacuum experiments. ThO_2Ir must be the filament material of choice for these applications.

High-Accuracy Gauges

One of the most significant developments in BAG design in recent years has been the introduction of the 'high-accuracy gauge' design. High-accuracy gauges operate based on the same ionization principles as nude and tubulated gauges; however, they provide highly accurate, reproducible and stable pressure readings by systematically avoiding the known problems associated with those gauge designs.

At the time of this writing, high-accuracy gauges are only available from one commercial source and the IGC100 controller is compatible with all available models (consult Appendix C). It is very likely that as a market is established, and the utility of the new design is demonstrated, other vacuum gauge manufacturers will follow with similar offers.

The long-term stability, accuracy and gauge-to-gauge reproducibility of pressure measurements in high-accuracy gauges are assured by the unique design and precise manufacturing applied to their construction.

In the commercially available design, dual, independent, thoria-coated, ribbon filaments are carefully positioned relative to the anode axis and maintained in tension by refractory metal springs. Consequently, the filaments exhibit negligible bow, sag or twist with use, assuring stable and reproducible electron trajectories over time. Partial end-caps are employed to extend the radial electric field over a much larger area of the anode grid, while at the same time, short filaments are used to introduce electrons away from the end regions of the anode, assuring stable ion production conditions within the ionizer. The end-capped anode is precision assembled and stress-relieved so that it maintains its exact shape and position even after high temperature degassing. Electrode positions relative to the walls are identical from gauge to gauge to ensure reproducibility of measurements. A grounded conductive shield completely surrounds the anode-cathode structure to provide a stable electrical environment for charged particle trajectories. The entire shield is designed to remain dimensionally stable over time and to have the same dimension from gauge to gauge within close tolerances. A grounded perforated high conductance shield over the port electrically isolates the electrode structures from the rest of the vacuum system.

Note

It must be noted at this point that the gauge-to-gauge reproducibility and long-term stability claims associated with high accuracy gauges have not been verified by any independent vacuum calibration laboratory. The only experiments performed and data published on these gauges come directly from the manufacturer. SRS has not directly verified any of their claims.

Two different collector wire diameters, 0.005" and 0.040", are used. The thicker collector wire, precisely located at the anode axis, is so effective at collecting ions (≈50 $Torr^{-1}$ nominal sensitivity) that it extends the upper pressure limit to 10^{-2} Torr while keeping the X-ray limit at mid-10^{-10} Torr. The thinner collector wire, while providing a lower sensitivity (≈ 25 $Torr^{-1}$), extends the X-ray limit into the low 10^{-11} Torr range for performance compatible with ultra- and extreme-high vacuum applications.

The premise is simple - high-accuracy gauges provide long-term, stable, accurate, gauge-to-gauge reproducible measurements in a way that is unmatched by any other BAG design. Current state-of-the art midrange accuracy specifications for uncalibrated gauges are ≈6%, and they get better for individually calibrated gauges. However, this increased performance comes at a price! High-accuracy gauges are expensive, costing up to 10 times as much as a glass tubulated gauge.

High-accuracy gauges are stable and reproducible enough, that it makes sense for their controllers to store gauge specific sensitivity data. In fact, it is possible to perform NIST traceable calibrations on individual gauges and store their calibration information in the IGC100 controller memory. Stored values of gauge sensitivity track the actual gauge sensitivity across the entire pressure range, providing real time correction for the non-linearities that lead to errors in traditional gauge systems. Individually calibrated high-accuracy gauges offer midrange reading accuracies better than 3% (close to spinning rotor gauge performance).

High-accuracy gauges make a lot of sense in strictly controlled vacuum process environments where pressure reading inaccuracies can lead to reduced yields and increased production costs. The gauge-to-gauge reproducibility is a welcome feature when forced to switch to a new gauge before trying to reproduce a production run. Calibrated high-accuracy gauges are also cost-effective NIST traceable transfer standards, providing accuracies comparable to spinning rotor gauges over a larger pressure range. It is common practice for pressure calibration laboratories to use high-accuracy gauges as transfer, check and working standards.

Tiny Gauges

Miniaturization has not escaped BAG designs. Almost every vacuum gauge manufacturer now offers a version of 'tiny' ionization gauge. The principle of operation remains the same, the advantages and disadvantages must be considered carefully.

Their goal is clear - replace the unreliable and fragile glass envelope gauges with much smaller and rugged designs without any compromises in performance and specifications.

The new tiny gauges accomplish most of that. They are small, occupying as little as 5% of the volume of a traditional glass envelope gauge. They eliminate glass gauge accidents by relying in all-metal construction. They offer an operational range that overlaps or sometimes exceeds that of traditional tubulated designs. The reduced size also minimizes the power requirements of the filament resulting in less heat being dissipated into the vacuum chamber.

No independent reports on the repeatability, short and long term stability, and gauge-to-gauge reproducibility of tiny gauges are currently available since the gauges have only been recently introduced into the market. However, it is probably fair to estimate that their accuracy specifications will be comparable to those of tubulated ion gauges.

Tiny gauges are more expensive than tubulated designs (up to 4 times). Tiny gauges are usually only available with thoria (burn-out resistant) filaments. Filaments are not replaceable, making the gauges disposable after filament failure. Both flanged and tubular mounting options are available.

Tiny gauges are a perfect match for applications requiring a small rugged gauge, with low power dissipation. They are often found as hidden components of portable systems including mass spectrometers, leak detectors, small sputtering systems, etc. It is possible that all-metal tiny gauges will some day become preferred over traditional glass tubulated gauges. However, in the meantime, traditional designs still offer a significant price advantage that cannot be easily overlooked. An advantage of glass envelope gauges, rarely mentioned by tiny gauge marketers, is that their use is so widespread that it is possible that your facility, or your next door neighbor, will have a spare on a shelf when you desperately need one in the middle of an experiment.

Appendix G

Hot vs. Cold Ionization Gauges

Every modern high vacuum and ultrahigh vacuum system relies on some form of ionization gauge for pressure measurements under 10^{-3} Torr. There are currently two competing ionization gauge technologies to choose from - the hot cathode gauge (HCG) and the cold cathode gauge (CCG). This appendix is designed to help vacuum users choose between the two competing ionization technologies. Each gauge type has its own advantages and disadvantages. The best choice requires careful consideration of the operating characteristics of both gauges and is dependent on the application.

In This Appendix

Introduction

Every modern high vacuum and ultrahigh vacuum system relies on some form of ionization gauge for pressure measurements under 10^{-3} Torr. There are currently two competing ionization gauge technologies to choose from which are viable means for pressure measurements between 10^{-2} and 10^{-10} Torr:

1. In the hot cathode gauge (HCG) ionizing electrons from a thermionic cathode are accelerated by suitable electrodes into an ionizing space.

2. In the cold cathode gauge (CCG) ionization is caused by a circulating electron plasma trapped in crossed electric and magnetic fields.

In both cases, the electrical current resulting from the collection of the positive ions created inside the gauge is used as an indirect measure of gas density and pressure.

This appendix is designed to help vacuum users choose between the two competing ionization technologies. Each gauge type has its own advantages and disadvantages. The best choice requires careful consideration of the operating characteristics of both gauges and is dependent on the application.

For more detailed information on this subject consult the following publications:

1. J. M. Lafferty, Ed., "Foundations of Vacuum Science and Technology", p. 414, section 6.9., John Wiley and Sons, NY, 1998. Note: This is an excellent book recommended for any high vacuum question.

2. R. N. Peacock, N. T. Preacock, and D. S. Hauschulz, "Comparison of hot cathode and cold cathode ionization gauges", J. Vac. Sci. Technol. A 9(3) (1991) 1977.

3. R. F. Kendall, "Cold cathode gauges for ultrahigh vacuum measurements", J. Vac. Sci. Technol. A 15(3) (1997) 740.

4. R. F. Kendall, "Ionization Gauge Errors at Low Pressures", J. Vac. Sci. Technol. A 17(4) (1999) 2041. Note: Great paper that compares the performance of both gauges, particularly at low pressures.

5. Vic. Comello, "Should your next ion gauge run hot or cold?", R&D Magazine, p. 65, Nov. 1997.

6. Eric Bopp, "Pressure measurement in ion implanters", Solid State Technology, February 2000, p. 51. Note: The special gauging requirements of ion implant applications are nicely discussed in this article.

7. J. H. Singleton, "Practical Guide to the use of Bayard-Alpert Ionization Gauges", J. Vac. Sci. Technol. A 19(4) (2001) 1712.

Hot-Cathode Gauges (HCG)

The majority of commercially available HCGs are of the Bayard-Alpert design and are compatible with the IGC100 controller.

A Bayard-Alpert gauge (BAG) boils electrons from a hot filament and accelerates them toward a cylindrical grid cage. As the electrons traverse the space enclosed by the grid, which is fully open to the vacuum chamber, they collide with gas molecules ionizing some of them. A fine wire located at the center of the ionization volume collects the resulting cations producing a current proportional to the gas density at the gauge. At constant temperature, the collector current is linearly related to the gas pressure.

The useful operating range of a conventional BAG extends between 10^{-3} and 10^{-10} Torr, corresponding to an impressive seven decades of dynamic range. Special gauge designs are available to extend the lower limit to 10^{-11} Torr for UHV applications, or the upper end to 10^{-1} Torr for process applications.

The strict linear dependence of collector current on pressure is one of the most important advantages of HCGs over the competing ionization technology. It is generally possible to approximate the 'collector current vs. pressure' response of a BAG to a straight line and calculate pressures from a single linear proportionality factor (i.e. sensitivity factor) stored in the gauge controller. A sensitivity factor calibrated at mid-range, can be used for accurate and reproducible pressure measurements between 10^{-9} and 10^{-4} Torr. Deviations from linearity typically amount to less than ±25% over the entire useful dynamic range of the gauge, with the biggest deviations taking place at the operating limits.

BAGs are generally considered to be more accurate, stable and reproducible than CCGs. Under controlled vacuum conditions, the reproducibility of a BAG calibration can be as good as 2% through a year of uninterrupted operation. Repeatability is 1-2%, limited by uncontrollable random sensitivity variations. However, not all BAGs are created equal and gauge-to-gauge and long-term stability variations are to be expected from commercial devices used in 'real' systems. Measurement accuracies better than ±50% require calibration of the individual gauge response. High accuracy gauge designs have recently become available that guarantee better than 3% measurement accuracy following calibration against NIST standards. Calibrated, high-accuracy BAGs combined with high quality controllers, such as the IGC100, are commonly used as transfer standards in high vacuum gauge calibration laboratories.

BAG readings are gas dependent due to varying ionization efficiencies, and are usually calibrated for nitrogen gas (argon is also a popular choice in semiconductor processing). Gas correction factors, readily available from the vacuum literature, can be used to correct the gauge readings for other gases.

Any BAG, depending on its past history of operation and the precise atmosphere in the vacuum system, can act as either a source (outgassing) or sink (pumping) of gas. Its operation can cause significant changes to the gas composition in the system. The relative importance of these effects depends upon the overall vacuum system characteristics and operating conditions. For example, changes in pressure and gas composition due to pumping or outgassing will be relatively more significant in a small UHV system with low pumping speed, than in a large industrial vacuum chamber with large diffusion pumps. Similarly, any pressure gradient between the gauge and the main chamber will depend upon the conductance of the tube connecting the two, and will be zero when the gauge is inserted directly into the chamber (i.e. nude BAG).

The power requirement of a typical filament for 1 mA emission is between 10 and 15 W. This is enough to cause thermal degassing from the gauge elements and surroundings that affect the reliability of low pressure measurements. It is possible for gas composition and pressure in even a large vacuum system to be dominated by gases released from a single HCG and its immediate surroundings when such a gauge is not properly degassed.

HCGs encounter most of their problems at $\approx 10^{-10}$ Torr where the X-ray limit, electron stimulated desorption (ESD) and outgassing set a limit on the usefulness of the gauge. Degassing and bakeout of the gauge can minimize the effects of ESD and outgassing. The ultimate accuracy of a BAG may be seriously compromised in the absence of a bakeout and/or degassing. The X-ray limit provides a residual collector current comparable to the ion signal from 10^{-10} Torr of gas in conventional gauges. Special nude gauge designs, with reduced collector and grid wire diameters and closed-end grids, are required to reduce the magnitude of that residual current into the 10^{-11} Torr level.

Reactions of the gas molecules with the hot filament can seriously affect the composition of the gas, and the reliability of the pressure measurements, in a BAG. This effect must also be accounted for in high accuracy measurements at low pressures.

Gas permeation through the glass envelope, particularly of He and other light gases, must be considered in UHV systems at base pressure, and provides another good reason to use all-metal gauges in those applications.

The operating life of a HCG is frequently determined by the filament lifetime. This is, by far, the main reason why high vacuum users choose 'filament-free' Cold-Cathode Gauges (CCGs) over BAGs. However, unless damaged by ion bombardment, high pressure operation or chemical effects, filament lifetimes can be many thousands of hours, thus filament life is not an important consideration in most cases. This is especially true with ThO_2Ir filaments and when smart controllers, such as the IGC100, which protect the gauge from overpressures.

There is always a delay between turning on a HCG and obtaining a meaningful reading. It is necessary to wait for thermal equilibrium of the gauge and its surroundings. Depending on the pressure to be measured, and the history of the gauge, stabilization can last from minutes to weeks, and might require bakeout and/or degassing to reach completion.

A good quality controller, such as the IGC100, must always be part of a BAG measuring system. Controllers have been known to add as much as ±15% inaccuracies to BAG readings. The electronics required to run a BAG are generally (1) more complicated, (2) require more power, and (3) are bigger in size than those required to operate CCGs.

BAGs have safety hazards associated to them that must be considered during gauge selection and operation. Glass envelope gauges can break and/or implode violently resulting in the danger of flying glass. Gauge walls can get hot and cause burns. The risk of electrical shock is always present and can be deadly in some cases. All these risks are easily eliminated by proper system design, including glass shields, suitable connector cables and good grounds.

Cold-Cathode Gauges (CCG)

Several varieties of CCGs are used for vacuum measurements including the Penning, the magnetron, the inverted magnetron and the double inverted magnetron.

All CCGs utilize crossed electric and magnetic fields to trap electrons. The high voltage ranges from 2-6 kV and the magnetic field 1-2 kG. The electron plasma, responsible for ionization, originates from the random release of an electron at the cathode caused directly, or indirectly, by a cosmic ray, field emission, a photon, radioactivity or some other event. A discharge slowly builds inside the ionization volume to the point where the entry of new electrons into the plasma is limited by space charge repulsion. At pressures below 10^{-4} Torr, the discharge is practically a pure-electron plasma. The electrons move in cycloidal jumps, circling about the anode, and during part of each jump they have sufficient energy to ionize gas molecules through electron impact ionization. The probability of collision is proportional to the gas density. The slow ions generated, are quickly captured by the cathode. The current generated by this ion collection process is measured and used as an indirect indication of gas density and pressure.

The typical operating range of a CCG is between 10^{-2} and 10^{-9} Torr. With very special precautions, the lower end has been extended into the 10^{-11} Torr for some special gauges, but only with marginal accuracy. Claims that commercially available CCGs will measure total pressures below 10^{-9} Torr should be treated with extreme caution!

The upper pressure limit of the CCG is reached when the current becomes so large that heating and sputtering from the electrodes becomes a problem. This sets a usual limit of 10^{-4} Torr. However, several tricks are commonly implemented to extend the useful upper pressure into the 10^{-2} Torr range. At the other end of the pressure range, CCGs have been used down to 10^{-11} Torr but only under very carefully optimized conditions and with very limited accuracy.

The ion-induced current is not linearly related to the pressure in the chamber. Rather, the relationship is exponential and complicated by the presence of spurious discontinuities in the current vs. pressure characteristic. The number and size of discontinuities depends on gauge design, with the inverted magnetron being the least susceptible to this problem. Gauge-to-gauge variations among seemingly identical gauges are often observed and it is not unusual to observe discontinuities disappear between successive calibrations. Elimination of discontinuities has been a major challenge to designers of CCGs since their conception. The non-linear relationship between current and pressure is a disadvantage that complicates the reliability of pressure measurements, particularly below 10^{-9} Torr. Between 10^{-4} and 10^{-9} Torr the exponent is usually fairly constant, close to 1.0 and hidden from the user by a logarithmic detector or look-up table. Somewhere between 10^{-9} and10^{-10} Torr the exponent often shifts suddenly to higher values (1.25 or higher). This sudden *and spurious* change in exponent requires special precautions to account for the more pronounced logarithmic response, and only marginal accuracy is generally possible below 10^{-9} Torr. No standard method for dealing with currents below the magnetron knee is available as of this writing.

CCG readings are gas dependent and the gas correction factors are *not* the same as for HCGs.

There are few results in the vacuum literature on the accuracy, stability and repeatability of CCGs. In general, CCGs are considered to be less accurate than HCGs and are not recommended as high vacuum transfer standards. Repeatability is about ±5%, and sensor-to-sensor matching is within 20-25% for inverted magnetrons. Manufacturers often specify accuracies within a factor of two for new (and clean) gauges. Whenever higher accuracy is required, the specific tube/controller combination must be calibrated against a transfer standard such as a spinning rotor gauge or high-accuracy BAG. Calibration is more complicated than in HCGs because of the non-linear 'current vs. pressure' response and the presence of discontinuities in the calibration curve. Stable operation appears to be possible over periods of several years under clean, low pressure vacuum conditions. However, contamination can cause failure of a CCG just as a HCG. Pump oil is polymerized by the discharge and forms insulating films on the electrodes. Metal vapors, caused by sputtering, can cause insulator leakage. Most CCGs can be disassembled and serviced by the user in the field to restore them to normal operation when they become contaminated.

CCGs respond very quickly to pumpdowns. In general, they arrive at stable readings faster than HCGs during pressure cyclings between 10^{-3} and 10^{-7} Torr. There is also no filament to burn out. The absence of a hot filament also makes outgassing much less of a problem.

Outgassing rates are typically very much lower and more predictable than for HCGs. Degassing is not necessary since the input power is very low and there is no internal heating to cause localized outgassing. Measured pumping speeds are also low (comparable to those of HCGs) so that pressure measurement errors are generally insignificant, provided adequate tubulation to the vacuum system is provided. Residual currents are not a problem at UHV levels in CCGs which are essentially free of X-ray and ESD effects. In applications requiring frequent pumpdowns to low pressures with little or no opportunity for degassing, the readings of a CCG may be significantly closer to true chamber pressures than HCG readings. CCGs are often preferred over HCGs for critical applications such as material outgassing studies.

Sensitivity to externally produced magnetic fields is typically far lower than for unshielded HCGs and usually not a problem under normal laboratory conditions.

Concerns about stray magnetic fields from modern CCGs are mostly unfounded. Inverted and double inverted magnetron gauges reduce stray field to only a few Gauss. Addition of shielding sleeves further reduces stray fields to levels comparable with background effects in a typical laboratory. Special applications, such as electron microscopes, might still require careful experimentation with the exact location and orientation of the gauge even after shielding is in place.

On the downside, CCGs can be hard to start. The discharge in a CCG does not start (i.e. strike) the moment the high voltage is applied. The 'striking' time varies from gauge to gauge. This delay ranges from seconds at 10^{-6} Torr to hours at 10^{-10} Torr. Auxiliary 'strikers' consisting of (1) edge emitters, (2) radioactive sources or (3) UV lamps are often included in modern gauge designs to reduce this problem greatly. Striking is not a problem if the CCG can be turned on during pumpdown before the pressure reaches 10^{-5} or 10^{-6} Torr. A gauge also starts quickly if charges from any other source of ionization can reach the gauge. Once a CCG strikes, the readings are meaningful within a few seconds, faster than the time it takes a HCG to stabilize after a filament emission is established.

The circulating electron current and energy are determined by the gauge construction and its fixed operating parameters - they cannot be controlled by the user! This is a big difference from the HCG operation where most parameters can, and usually are, accessible to the user from the controller.

The electronics required to operate a CCG are usually much simpler and less expensive than those for HCGs. The CCG controller supplies only the high voltage required, and it measures the current in the same loop. Small permanent magnets are used to set the magnetic field. The amount of current in the high voltage power supply is usually limited to 0.1 mA so that danger of serious electric shock is reduced. It is generally possible to enclose the gauge assembly and low-power (i.e. <1 W) electronics into a package not much bigger in size than a tubulated BAG.

CCGs are usually of all-metal construction, and are not hot to the touch.

Conclusions

HCGs and CCGs are both capable of measuring pressures between 10^{-2} and 10^{-10} Torr. They both produce gas dependent readings. Their pumping effects are of similar magnitude and negligible in the presence of adequate (i.e. >10 Ls^{-1}) tubulation to the vacuum system.

The ultimate accuracy of the BAG is better than the CCG. However, due to increased outgassing, a bakeout and/or degassing are often required to achieve the full advantage with the HCG. In most cases, a longer delay is also required to obtain a stable reading from a HCG. For applications involving continuous pumpdowns to low pressures, without an opportunity to degas or bakeout, a CCG might be the best choice to follow chamber pressure in real time.

HCGs are more easily calibrated than CCGs because of their linear response to pressure. Spurious discontinuities in the calibration curve can also affect readings of CCGs; however, this is rarely a serious problem in modern inverted magnetrons.

The filament life often limits the useful lifespan of a HCG; however, in most applications, filament lifetime is several years of continuous operation.

Starting the CCG can be delayed, particularly at low pressures; however, this is not a serious problem if strikers are built into the gauge to shorten the delay. CCGs can also be turned on at higher pressures during a pumpdown.

Careful consideration of the effects described in this note should help you choose between the two competing ionization gauge technologies.

Appendix H

PG105 Convection Enhanced Pirani Gauge

The SRS PG105 is a convection-enhanced Pirani gauge (CEPG) manufactured by Stanford Research Systems. When used with an IGC100 controller the PG105 provides a convenient, reliable and low-cost measurement of vacuum over an wide pressure range extending from atmosphere to 10^{-4} Torr.

This appendix provides a detailed description of the principle of operation, construction, gas dependence, calibration and fundamental strengths and weaknesses of the PG105 gauge head. Application examples and a few practical tips are provided along the way. Basic maintenance and troubleshooting information are also included.

Since it is not possible to cover this complex gauge in such a short note, a comprehensive list of references is provided at the end.

In This Appendix

Principle of Operation

The PG105 Convection Enhanced Pirani Gauge (CEPG) is a variation of the traditional Pirani vacuum gauge design[1]. Pressure measurement is based on the transfer of heat from a fine wire in the sensor to the surrounding gas [2].

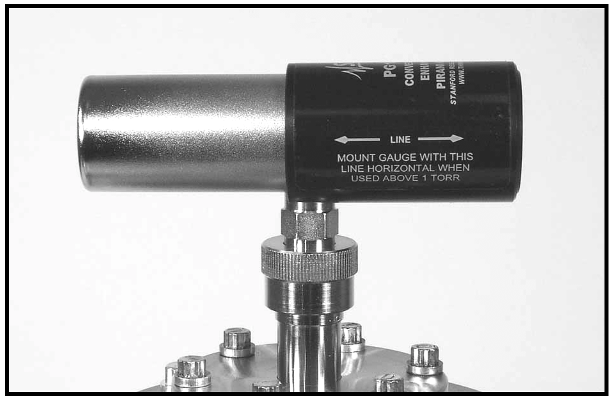


Figure H-1. PG105 Convection-Enhanced Pirani Gauge

A schematic representation of the basic gauge design is depicted in Fig. H-2. The hot wire sensor is located inside the vacuum and is one leg, R_{sense}, of a Wheatstone resistor bridge. The entire bridge circuit is an integral part of the gauge head. An external feedback amplifier[3] is connected to this circuit, and balances the bridge, $V_{NULL} = 0$, during normal operation. If there are no changes in ambient temperature, the value of R_{sense} at bridge 'null' is a constant, independent of pressure, and given by the product: $R_{sense} = R_{comp} \cdot R_3 / R_4$. The components R_3, R_4 and R_{comp} are located outside the vacuum and their values determine the temperature of the wire (≈120°C) during operation.

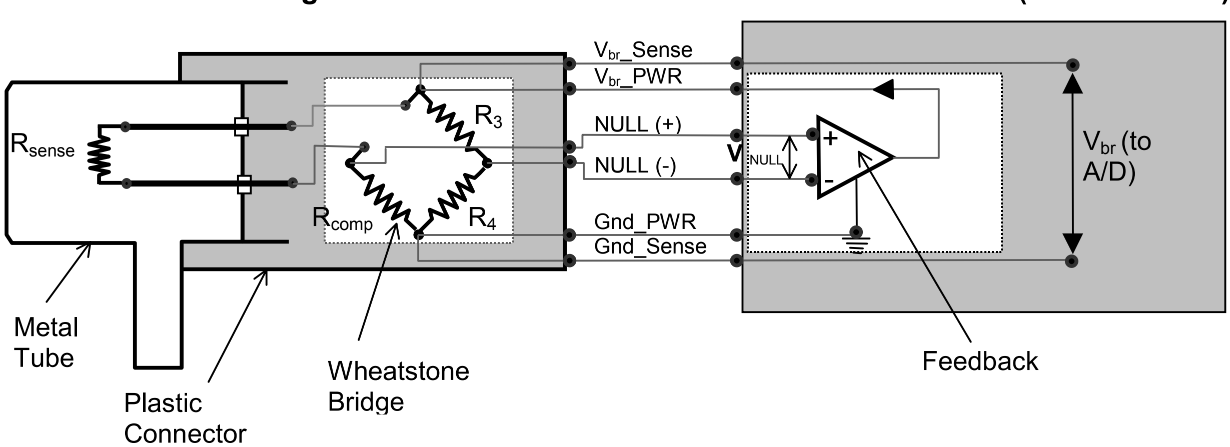


Figure H-2. Schematic representation of gauge, bridge and feedback amplifier.

In a gaseous environment the hot wire loses heat in four ways[4]: (1) radiation, (2) conduction along the wire to the end supports (3) heat conduction by the gas molecules and (4) gas convection. The energy transfer by the gas is pressure-dependent and driven by the temperature difference between the wire and the outer walls. As the vacuum system pressure is decreased, there are fewer molecules in the system to conduct heat away from the wire causing the temperature and R_{sense} to increase. The increased resistance of R_{sense} unbalances the bridge causing a voltage differential between the NULL terminals, $V_{NULL} \neq 0$. The bridge control circuit senses the NULL voltage change and decreases the voltage across the bridge, V_{br}, until V_{NULL} is again zero. Once the bridge voltage is decreased, the power dissipated by the sensor wire is decreased bringing the resistance of R_{sense} back to its original value. Obviously, the opposite set of events occurs when the pressure is increased. *The bridge voltage,* V_{br}*, is read by the controller and used as a non-linear measure of pressure*. As with all Pirani gauges, the voltage output depends on pressure as well as the thermal conductivity of the surrounding gases (i.e. indirect pressure measurement) - the gas composition must be known in order to indicate pressures correctly.

IMPORTANT

With a Pirani gauge, you need to know the gases you are pumping and calibrate the gauge for those gases before you can measure true vacuum levels.

The nominal 'V_{br} vs. P' curve for the PG105 operated in air is shown in Fig. H-3.

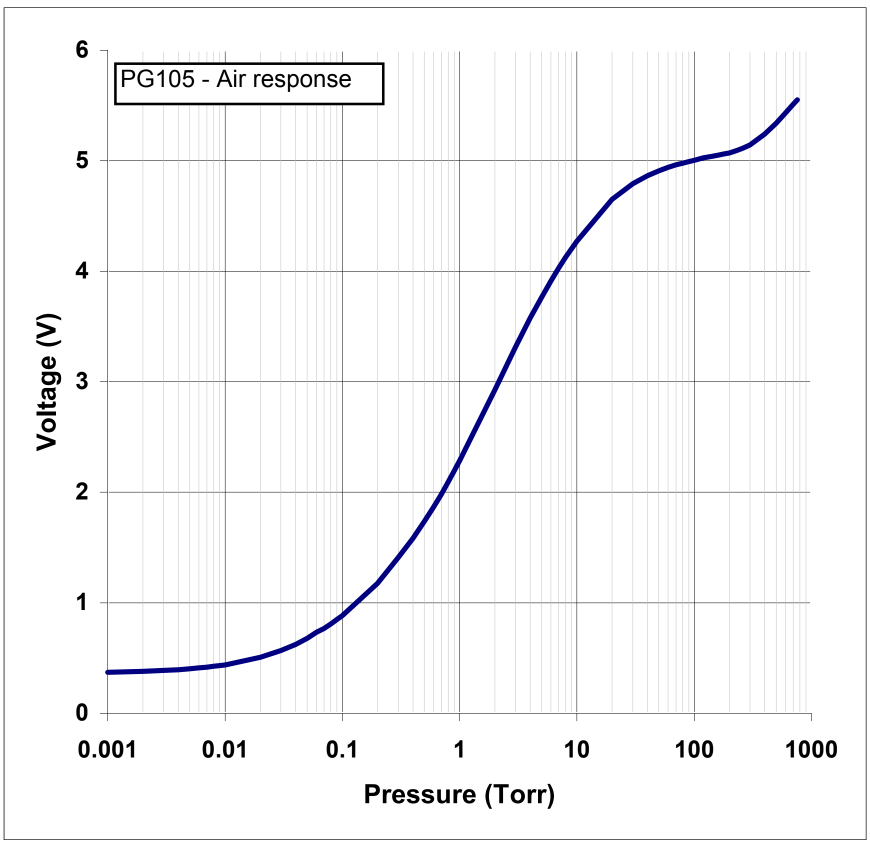


Figure H-3. PG105 Air response (gauge in horizontal orientation).

Several different heat dissipation effects contribute to the complicated shape of this curve. Below 10 Torr, the heat losses are primarily due to gas thermal conduction, and radiation. At pressures above 10 Torr, and as the mean free paths become shorter, energetic molecules departing from the wire collide with others before getting far away from its surface - a thermal insulating sheath of hot gas molecules develops around the wire as the pressure increases. This effect reduces the heat transfer efficiency of the gas as evidenced by the gradual flattening of the voltage response that takes place as the pressure increases. Above 10 Torr, convection currents also start to circulate around the wire. As the pressure increases further, they become more significant and start to slowly dominate the heat transfer. Convection currents are fully responsible for the sudden increase in gauge response that takes place above 100 Torr.

Convection-enhanced Pirani gauges, are specifically designed to optimize and take advantage of the thermal convection currents that develop around the hot wire at pressures above 10 Torr[5]. The distance from the hot wire to the tube walls in the PG105 has been carefully optimized so that convection can be quantified and reproduced well enough to give valid pressure readings up to 1000 Torr. As convection depends upon gravity, the magnitude of its effect depends upon the orientation of the wire. *The gauge tube axis must be mounted horizontally during operation to achieve efficient and reproducible natural convection above 1 Torr*. The gauge calibration above 1 Torr changes when the gauge moves from the horizontal to a vertical position, this change is most noticeable above 100 Torr.

IMPORTANT

It is important to consider the orientation of the gauge tube if accurate readings above 1 Torr are required! See 'Mounting Orientation' below for more details.

As the pressure decreases, the gas contribution to heat dissipation from the hot wire becomes smaller. The lower pressure limit of the PG105 gauge is reached when the contributions due to radiation and conduction to the mounting posts greatly exceed the thermal transfer by gas molecules. Below that limit, typically around 10^{-3} Torr, the output becomes virtually constant and the drift of the radiation component and of the ambient temperature makes long term accuracy questionable at best. The gas dependent component of the gauge response can still be followed below 10^{-3} Torr, but only under carefully monitored, short term, conditions.

IMPORTANT

Operation of the PG105 convection gauge between 10^{-4} and 10^{-3} Torr is still possible, but it requires periodic 'zero' readjustments of the controller readings to compensate against sensor drift. Only rough pressure measurement accuracy should be expected in this range! See 'Operation Below 10^{-3} Torr' below for details.

Energy transfer by the heat dissipation processes described above, is strongly dependent on the temperature of the outer walls. The power dissipated by gas molecules diminishes as the ambient temperature increases. Without proper compensation, a gauge controller cannot differentiate if a reduction in V_{br} was caused by a decrease in pressure or an increase in room temperature. The PG105 convection gauge has built-in temperature compensation that makes it possible to obtain temperature corrected pressure readings between 10°C and 40°C. A very simple but effective scheme, first described in 1965[6], is used to provide ambient temperature compensation: The R_{comp} component of the Wheatstone bridge is not a simple resistor as sketched in Fig. H-2, but rather a composite, temperature-sensitive, resistor network made up to have a temperature coefficient (R_4/R_3) times that of R_{sense}. A thin metal wire, with a high temperature coefficient of resistance, tightly wound around the outer diameter of the gauge tube, provides the temperature sensitive component of the network. The other components of the resistor network have relatively insignificant temperature coefficients and are carefully selected at the factory to trim the effective temperature coefficient of R_{comp} to the required value. Under this simple bridge configuration, a constant temperature difference is maintained between the wire and the walls at all times, and bridge voltages are relatively unaffected by ambient temperature changes. In addition to compensating for ambient temperature variations, this compensation scheme also corrects for heating of the gauge envelope due to filament dissipation at high pressures. At atmospheric pressure, the dissipation of ≈1/8 Watt from the hot filament can cause a slow temperature rise of a few degrees Celsius at the tube's outer wall. *Temperature compensation is vital if the gauge output is to have any real meaning above 100 Torr*. It also effectively reduces the time required to obtain accurate and stable pressure readings after a rapid pressure change.

Construction

The PG105 gauge head has been designed for the most demanding applications. A schematic representation of the gauge head is shown in Fig. H-4.

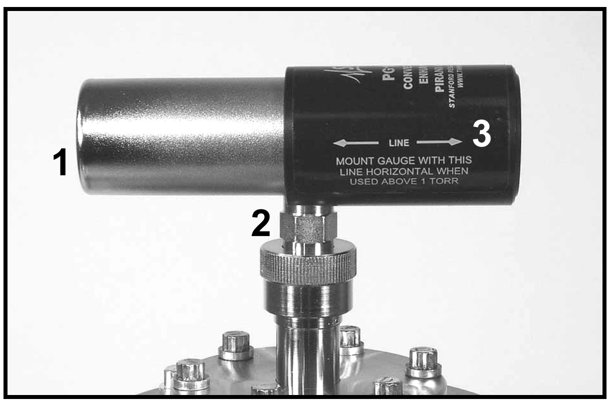


Figure H-4. PG105 Gauge components.
1. Cylindrical metal tube, 2. Side port, 3. Detachable plastic connector.

The gauge assembly is divided into three main components:

1. Cylindrical metal tube.
2. Side port (with optional vacuum fittings.)
3. Detachable plastic connector.

The cylindrical metal section consists of an inner sensor tube surrounded by an outer metal case. The vacuum-sealed inner metal tube houses the hot wire sensor, and connects to the vacuum system through the side port. The sensor wire material is gold plated tungsten, selected for the stability of its surface properties, reproducible electrical characteristics and mechanical strength. The back end of the tube, facing the plastic connector, consists of a gasket-sealed, 4-pin, electrical feedthru flange with 1/16" diameter Ni alloy conductors and glass-ceramic insulators. Two of the electrical connectors are integral parts of the filament mounting posts. The other two pins provide electrical connection points for the ends of the temperature compensation wire that is tightly wound around the waist of the inner tube. The outer shell effectively protects the sensor tube, feedthru pins and temperature compensating element from mechanical damage.

The standard PG105 convection gauge uses a high-quality Viton O-ring to seal the feedthru flange end of the tube, allowing maximum bakeout temperatures of 110°C (with the plastic connector detached). Metal gasket sealed gauge heads are also available, option PG105-UHV, that can be baked up to 250°C for more complete UHV compatibility. The metal gaskets used in all UHV enhanced gauge versions, are made out of OFHC Cu and belong to the Helicoflex Delta® family of high-performance compression metal seals, widely used for ultrahigh vacuum and ultrahigh purity applications.

IMPORTANT

Metal sealed gauge tubes, option PG105-UHV, are recommended for all ultrahigh vacuum and ultrahigh purity applications incompatible with the standard compression O-ring seal.

The stainless steel side tube provides the only connection to the vacuum system. The standard gauge head is fitted with a ½" diameter side tube terminated in a male 1/8"-NPT fitting. This allows direct attachment to a ½" ID compression fitting or into a standard 1/8" - NPR female pipe fitting. To accommodate most applications, the side tube is available with a variety of end-fittings. Some examples of available fittings include: NW16KF, NW25KF, 1.33" and 2.75" ConFlat®, Cajon® SS-4-VCR and SS-6-VCO, etc. Consult Stanford Research Systems for additional details on available fittings.

The detachable plastic connector mounts, and locks, onto the back of the metal tube and houses (1) the rest of the Wheatstone bridge components and (2) an 8-pin, RJ45 compatible socket connector (used to connect the gauge to the O105C4 connector cable). Self alignment, and a symmetric pin arrangement, prevents improper hook-up and protects the electrical pins from breakage.

As indicated before, the entire resistor bridge circuit is located inside the PG105 Pirani head. The IGC100 measures pressure-dependent bridge voltages right at the PG105 head using a four-wire (i.e. Kelvin probe) arrangement. Two wires supply electrical power to the bridge while a separate pair senses the bridge voltage right at the gauge head without drawing any additional current out of the circuit. This configuration makes the gauge calibration independent of cable length.

Strong, thick components contribute to a rugged head design that stands up to process environments and provides long-lasting reliability. Internal construction materials have been chosen to ensure compatibility with many process gases as well as UHV systems. Stainless steel construction (SS316) provides good resistance against corrosive gases. Glass-ceramic (SiOx) electrical feedthrus provide compatibility with high temperature bakeouts and UHV applications. TIG welding and assembly under cleanroom conditions, ensure compatibility with particle sensitive process applications. The inner measurement chamber offers effective RF shielding and protects the sensor wire. The temperature compensation element is located outside the vacuum to reduce outgassing and preserve UHV compatibility. Gold plated tungsten sensor construction helps minimize calibration drift (see 'Contamination' section below). A very thin and long sensor wire is used to minimize heat loss to the end supports and minimize temperature gradients along its length. This is very important for operating below 10^{-3} Torr.

The following materials are exposed to the vacuum:

1. Type 316 stainless steel
2. Carpenter glass sealing "52" alloy™ (50.5% Ni/Fe alloy)
3. Gold plated tungsten
4. Glass ceramic (SiOx ceramic)
5. Viton (standard, O-ring sealed, heads only)
6. OFHC Copper (PG105-UHV heads only)

Note

There is no brazing material in the ceramic feedthrus- the glass ceramic wets right on to the stainless steel. No solder or solder flux material is used inside the gauge tube.

Calibration

Following factory assembly, each PG105 gauge tube is *individually* calibrated for nitrogen, and temperature compensated between 10° and 40°C. After calibration, each gauge tube is then individually tested to determine if selected pressure readouts fall within narrow limits before the unit is ready for shipment. Individual factory calibration of the gauge response provides true 'plug-and-play' convenience and eliminates the need to rezero the controller each time a new gauge tube is connected[7]. PG105 gauges and IGC100 controllers are completely interchangeable without any need for instrument adjustments! In order to assure that calibration does not change with use, all gauge tubes are baked at high temperature for an extended period of time before final calibration takes place.

It is important to understand that the pressure indicated by a PG105 convection gauge depends on (1) the type of gas, (2) the orientation of the gauge axis and (3) the gas density inside the gauge tube. As mentioned before, the PG105 gauge is factory calibrated and temperature compensated for nitrogen gas. However the response of the gauge for gases other than nitrogen is very well characterized and, with the proper calibration data (i.e. V_{br} vs. P curve for the specific gas type), it is possible to obtain accurate pressure measurements for other gases.

IGC100 controllers are factory loaded with nitrogen and argon specific calibration curves compatible with all PG105 convection gauges[8]. The non-linear dependence of the bridge voltage on pressure is evident from Fig. H-3, and shows the need for detailed lookup tables to obtain accurate readings over the entire pressure range.

Note

Gas correction curves and correction factors, used to convert 'nitrogen equivalent pressure' readings into true pressure readings for some common gases, can be found in the Appendix I, 'Gas Correction Curves for PG105 Readings'. The conversion curves only apply when the pressure readings displayed by the controller are based on the nitrogen calibration curve and the gauge tube is mounted with its axis horizontal. Use the curves or correction factors (where applicable) to convert indicated (i.e. nitrogen equivalent) pressure readings into true pressures for all the gases included in the appendix.

Users should generate their own conversion curves for gases, or mixtures of gases, not listed in the appendix. A calibrated, gas-independent, capacitance manometer is recommended as a transfer standard.

WARNING!
A serious danger of explosion can arise if the calibration data for one gas is applied without correction to measure pressures for a different gas (or gases) at or above atmospheric pressure. Please consult the 'Safety Considerations' section below for information on overpressure risks.

The calibration data loaded into all IGC100 controllers is based on the response of a new gauge free of contaminants. If a tube becomes contaminated or does not seem to read correctly, the front panel readings can often be readjusted using the ZERO and ATM adjustments in the Pirani Gauge calibration menu. Consult the IGC100 instructions for details on these two adjustment procedures.

Note
The ZERO and ATM adjustments built into the IGC100 controller make it possible to accommodate considerable changes in PG105 calibration while retaining acceptable measurement accuracy.

Accuracy and Stability

Very limited information exists in the vacuum literature on the accuracy, repeatability and long term stability of measurements made with thermal conductivity vacuum gauges. This is probably because most of the users that rely on these gauges for their applications do not require high accuracy pressure reports!

The measurement accuracy of all convection gauges (including the PG105) is pressure dependent and generally between 5% to 20% of the indicated pressure[9]. Accuracies not better than 25% should be expected from convection gauges used at atmospheric pressures[10]. Highest accuracies are usually observed between 1 and 10^{-2} Torr.

Because the pressure range where gas conduction cooling is predominant does not neatly overlap the pressure range where convection cooling occurs (see Fig. H-3), all convection enhanced Pirani gauges have limited sensitivity between 20 and 200 Torr[11].

Only one relevant study on the long term performance of constant temperature Pirani gauges has appeared in the vacuum literature[12]. Over the six months of the study, the gauges tested showed reproducibilities within ±6% over the pressure range extending from 10^{-2} to 10 Torr. Similar stability should probably be expected from PG105 gauges used under controlled conditions. However, always remember that the operating environment conditions ultimately limit the long term performance of a vacuum gauge! Also remember that the ZERO and ATM adjustments built into the IGC100 controller often make it possible to accommodate slight changes in tube characteristics while still retaining acceptable reading accuracy.

Periodic comparison at several pressures against a reliable check standard is recommended to determine if gross changes in response have occurred, and to determine if readjustment, bakeout , cleaning or full replacement is necessary.

Operation Below 10^{-3} Torr

Variations in ambient temperature and wire contamination are the two major sources of instability for readings below 10^{-3} Torr, where radiation and conduction to the mounting posts dominate the heat transfer process. The emissivity of a wire might vary from 0.05 for a clean wire to unity when contaminated. Power dissipation due to radiation is a function of the fourth power of the filament temperature. As a result, operation of the PG105 convection gauge below 10^{-3} Torr (where molecular conduction contributes as little as 1% of the total heat dissipation) is still possible, but it requires periodic ZERO readjustments of the controller readings to compensate against background drift.

Only rough pressure measurement accuracy should be expected below 10^{-3} Torr!

During fast pumpdown, thermal effects will prevent the PG105 gauge from providing immediate accurate pressure readings below 10^{-3} Torr. Readings in the 10^{-4} Torr range are valid only after a 15-20 minute period of thermal stabilization. ZERO adjustments of the controller readings should not be performed until full thermal stabilization has been accomplished.

IMPORTANT

For accurate results in the 10^{-4} Torr range, ZERO readjustments of the controller readings should be performed periodically.

The peak-to-peak random noise for pressure measurements below 10^{-3} Torr is $\pm 1.5 \times 10^{-4}$ Torr (nom) for all IGC100 controllers.

Mounting Orientation

Below 1 Torr

The PG105 convection gauge will operate and report accurate pressures in any orientation.

Above 1 Torr

The PG105 convection gauge will accurately read pressures only while mounted with its axis horizontal.

In both cases, it is recommended that the gauge be installed with the port oriented vertically downward to ensure that no system condensates or other liquids collect inside the gauge tube.

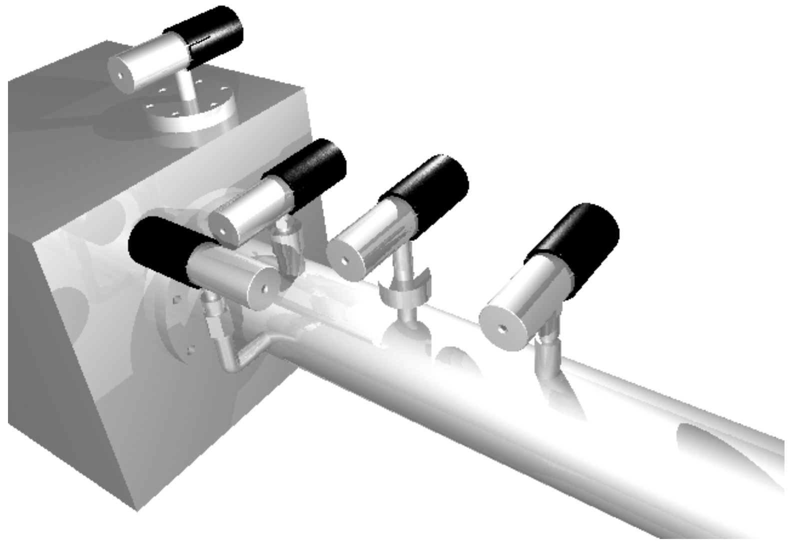


Figure H-5. PG105 Gauge mounting examples

It has been shown that for convection gauges such as the PG105, deviations as small as 5° from the horizontal can be significant above 100 Torr[13]. Erroneous readings can result in over or underpressure conditions which may damage equipment and/or injure personnel.

Mounting Recommendations

Handling

- Always use proper vacuum handling while installing the gauge.
- Keep the gauge clean- away from contamination sources!
- Use clean tools.
- Do not talk or breathe into any exposed/open vacuum ports.
- Use good quality seals and verify their integrity.
- Keep the port cover on until moments before installation.
- Do not drop or mishandle the gauge during installation causing permanent damage to the delicate sensor wire.

Location

The physical location of the gauge is critical to obtaining reliable pressure measurements. If placed near a pump, the pressure in the gauge may be considerably lower than in the rest of the system. If placed near a gas inlet or source of contamination, the pressure in the gauge may be much higher. Long tubulation or other constrictions between the gauge and the rest of the vacuum system can cause large errors in the pressure readings.

Temperature

Minimize temperature effects - locate the gauge away from internal and external heat sources. Whenever possible, choose an area where the ambient temperature is reasonably constant.

Vibration

Mount PG105 gauges where they will not experience excessive vibrations. Vibration causes convection cooling of the sensor and results in high readings at the high pressure end. Damage to the filament is also possible.

Grounding

Verify the proper electrical grounding of the vacuum port before connecting the PG105 gauge head to the vacuum system. The gauge envelope must be properly grounded during operation. If necessary, use a ground lug on a flange bolt to establish a dedicated connection to a facility ground. Alternatively, the gauge envelope may be grounded by using a metal hose clamp on the gauge connected to the system's safety ground by a #12 AWG copper wire.

Compression fittings

The standard PG105 gauge port is designed to fit any standard ½" compression fitting such as an Ultra-Torr® fitting. Do not use compression fittings for positive pressure applications!

1/8 NPT Fittings

The threads on the standard PG105 side port will fit a standard 1/8" NPT female fitting. Wrap the gauge threads with Teflon tape and screw the gauge into the female fitting. Twist the gauge body by hand until the first sign of resistance is felt. *Do not use the body of the gauge as its own wrench past this point*. Instead, finish tightening with a ½" wrench applied to the nut built into the side tube until a proper seal is achieved. Do not overtighten as that might stress the tube port!

Other Fittings

In addition to the standard tube, which provides a ½" compression port and a 1/8" NPT male thread, a variety of other mounting options are available. They include: NW16KF, NW25KF, 1.33" and 2.75" ConFlat®, Cajon® SS-4-VCR and SS-6-VCO, etc. Consult Stanford Research Systems for additional information on available fittings.

Contamination

Contamination of the sensor wire with pump oil or other films is the main source of calibration drifts in Pirani gauges.

Wire material and temperature[14] play the most important role in the long-term performance of the PG105 convection gauge.

A gold-plated tungsten wire is used in all PG105 gauge tubes. This material was selected for the stability of its surface properties, reproducible electrical characteristics and mechanical strength. Gold plating minimizes wire contamination as caused by oxidation, corrosion and surface induced decomposition reactions. A shiny gold surface offers the low emissivity levels required to extend the low limit of the gauge into the sub-mTorr pressure range.

The temperature of the wire inside the PG105 gauge tube is approximately 120°C during operation. This temperature delivers optimal gauge response[15] while, at the same time, it remains low enough to minimize contamination by surface induced decomposition of foreign materials, such as pump-oil vapors.

Care must be taken not to mount the PG105 tube in a way such that deposition of process vapor impurities may occur through direct line-of-sight access from the vacuum chamber to the interior of the gauge.

It is also recommended that the PG105 tube be installed with the side port oriented vertically downward to ensure that no system condensates or other liquids collect inside the gauge tube.

IMPORTANT

PG105 gauges should not be used in the presence of fluorine or mercury vapors. Both gases can react with the gold plated sensor and change its emissivity and/or overall diameter irreversibly.

Surface contamination strongly affects both the emissivity and accommodation coefficient[16] of the hot wire. Changes in emissivity affect the stability of the background, and effectively set the lower operating limit of a Pirani gauge during actual use. Periodic ZERO readjustments of the controller readings, to compensate against background drift, are required for operation in the millitorr and especially in the sub-millitorr range. Changes in surface properties result in changes in the efficiency of heat conduction by the gas molecules and cause calibration drifts. If, and when, contamination causes the PG105 calibration to change, the user can correct the pressure readings displayed by the IGC100 controller performing a quick ATM readjustment of the controller readings at atmospheric pressure.

The ZERO and ATM(mosphere) adjustments built into the IGC100 controller make it possible to accommodate considerable changes in tube characteristics while retaining acceptable measurement accuracy.

Periodic gauge bakeouts provide an effective way to avoid serious contamination buildup problems. Maximum bakeout temperatures are 110°C for standard (i.e. O-ring sealed) heads, and 250°C for metal-gasket sealed tubes (option PG105-UHV). The plastic connector must be disconnected from the head during bakeouts. An overnight bakeout, at ≈200°C, is the only recommended cleaning procedure for PG105-UHV gauges in direct contact with ultra high vacuum environments.

The calibration of grossly contaminated convection gauges can sometimes be partially restored using the solvent-based cleaning procedure described in the next section. This cleaning procedure is mostly recommended for gauges heavily contaminated by hydrocarbon impurities originated from vacuum pumps.

Cleaning

WARNING!

- This cleaning procedure should only be used on severely contaminated gauges, when the ZERO and ATM controller adjustments can no longer correct for drifts in the calibration.
- Stanford Research Systems does not guarantee that this procedure will remove contamination from a PG105 convection gauge.
- Use this cleaning method as a last resort only!

WARNING!
The fumes from acetone and isopropyl alcohol can be dangerous to health if inhaled and are highly flammable. Work in well ventilated areas and away from ignition sources!

Materials

1. Isopropyl alcohol or acetone, electronic grade or better.
2. Wash bottle with long thin neck.

Cleaning Procedure

Disconnect the gauge from the electrical cable and from the vacuum system port. Physically disconnect the detachable plastic connector from the back of the gauge tube and store it in a safe and clean place.

Hold the metal gauge tube in a horizontal position with the side port pointing upwards at a 45° angle. Slowly fill the volume of the gauge with solvent using the wash bottle to squirt the liquid into the side tube. Let the solvent stand inside the gauge for at least 10 minutes. Do not shake the gauge, since that might cause damage to the sensor wire. To drain the gauge, position it horizontally with the side port facing downward. Slightly warming the gauge will help dry the gauge. Allow the gauge tube to dry overnight with the port facing downward. Before reinstalling the gauge in the system, be certain no solvent odor remains.

Viton O-rings soaked in organic liquids can outgas solvent molecules for extended periods of time. Solvent outgassing rates can be significantly diminished: (a) baking the gauge tube overnight in a vacuum oven between 100-110°C before gauge installation or (b) baking out the gauge while attached to the vacuum system and before reconnecting its plastic connector.

Bakeout

> **WARNING!**
> The detachable plastic connector must be physically disconnected from the PG105 gauge head during bakeout.

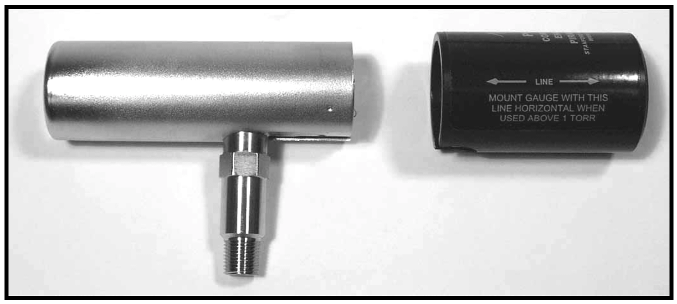


Figure H-6. Side view of the PG105 gauge tube with the detachable plastic connector disconnected.

Periodic, overnight, gauge bakeouts provide an effective way to minimize contamination buildup problems. Maximum bakeout temperatures are 110°C for standard (i.e. Viton O-ring sealed) heads, and 250°C for metal-gasket sealed tubes (option PG105-UHV) used in UHV or low contamination applications.

An overnight bakeout, at 200-250°C, is the only recommended cleaning procedure for PG105-UHV gauges in direct contact with ultra high vacuum environments.

Application Examples and Tips

Convection gauges, such as the PG105, are an accurate, fast and inexpensive means of measuring foreline and roughing line pressures, or moderate backfill pressures!

The PG105 convection enhanced Pirani gauge is the best choice for vacuum applications where conventional thermocouple and Pirani gauges are not suitable because of (1) limited range, (2) drift and (3) slow response. It is often selected as a cost effective alternative to a capacitance manometer[17].

The exceptionally wide measurement range of the PG105 makes it possible to continuously monitor the pumpdown of a vacuum system from atmospheric to the base pressure of most mechanical pumps without any blind spots. Convection gauges are found in virtually every modern semiconductor and thin film process system, for monitoring pumping system performance.

Convection gauges are the type of vacuum gauge most commonly encountered on loadlocks[18] and are often used to tell when a chamber may be safe to open to atmosphere. Yet, a convection gauge alone may not be accurate enough to tell you when there is enough internal positive pressure to ensure a gentle flow of gas out of the chamber once you open the door. For this reason, many users combine their convection gauges with differential pressure devices called atmospheric pressure switches.

A response time of a few milliseconds makes the PG105 convection gauge ideally suited for protective functions, such as determining when BAG emission should be de-activated or turned off. They are also well suited to control valves, heaters, bakeout ovens and safety interlocks.

Gas dependence makes the PG105 useful as an inexpensive leak detector. By using a tracer gas whose thermal conductivity is very different from the gases in the vacuum system, leaks as small as 10^{-4} atm cc/sec can be sensed and located. Typical gases used for leak testing include hydrogen, helium, argon and freon. This can eliminate the need for a very expensive leak detector. Several applications of Pirani gauges to leak detection have been reported in the vacuum literature[19].

The PG105 convection gauge is ideal for applications that operate between atmosphere and a few microns, and where gas composition is well known and repeatable! Convection gauges are usually found in pharmaceutical, food processing and lamp tube manufacturing process environments.

The all-metal interior construction of the PG105-UHV gauge makes it the best choice for applications requiring ultrahigh vacuum and/or ultrahigh purity compatibility. PG105-UHV gauges are often connected directly to high and ultrahigh vacuum chambers and used as cross-over gauges to protect the filaments of much more expensive ionization gauges.

PG105 gauges are not recommended for backfilling operations because of their gas dependence and risk of overpressure. For critical applications where repeatability and precision are required, a capacitance manometer gauge should be used to monitor and control the process pressure! This is particularly true if complex or changing gas mixtures are involved.

PG105 gauges are not recommended in contaminating environments because of their sensitivity to surface conditions.

Safety Considerations

Experience has proven all vacuum gauges remarkably safe. However, *incorrect use of any pressure gauge can cause accidents*. This section describes some very important safety considerations that must be taken into account during the selection, installation and operation of convection gauges[20]. The safety hazards related in this section apply to all commercially available convection enhanced Pirani gauges, and are not peculiar to the SRS PG105 convection gauge!

Consult Stanford Research Systems directly for any safety concerns related to PG105 convection gauges not addressed in this section.

Explosive Gases

WARNING!
Do not use the PG105 convection gauge to measure the pressure of combustible or flammable gases.

Thermal conductivity gauges are dangerous in applications where explosive gas mixtures may be present. This situation could exist, for example, during the fill or vent cycle of a metallurgical hydrogen furnace, or during the regeneration process of a cryopump which had frozen a quantity of organic material and oxygen. The filament temperature must remain below the ignition point of the gas mixture being measured at all times. The hot wire inside the gauge tube normally operates at a low temperature (≈120°C); however, it is possible to experience brief thermal transients during turn on or circuit failure that could raise the temperature above the safe limit. The risk of explosion, resulting in expensive equipment damage and serious personnel injuries must be carefully considered during the gauge selection process. A capacitance manometer is always a safer alternative in the presence of combustible, flammable or explosive gases.

IGC100 users can turn their PG105 convection gauges off directly from the front panel, without the need to physically disconnect the gauge tube from the controller. The filament cools down very rapidly to ambient temperature as soon as the electrical power is removed from the bridge circuit.

Compression Mounts

WARNING!
Do not use a compression fitting to attach a PG105 gauge tube to a vacuum system if positive (i.e. greater than ambient) pressures at the gauge head are possible during operation.

Positive pressures can forcefully eject the gauge head out of the fitting resulting in damaged equipment and/or injured personnel. A pressure relief valve or rupture disk should be installed in the system if the possibility of exceeding ambient pressure exists.

In general, the pressure inside the PG105 convection gauge should never exceed 1000 Torr. No reliable measurements are obtained above that limit.

Overpressure Risks

WARNING!
Using a PG105 convection gauge to backfill to atmospheric pressure should be avoided unless the gas-specific calibration curve for the backfilled gas is used to calculate and display pressures.

A serious danger can arise if the calibration data for one gas is applied without correction to measure pressures for a different gas (or gases) at or above atmospheric pressure. Argon provides an excellent example of how things can go very wrong. Applying the nitrogen calibration data to measure argon pressures provides a 'nitrogen equivalent' reading of only ≈25 Torr when the gauge is exposed to an atmosphere of Argon gas. The chamber could be seriously pressurized while the gauge controller continues to display <100Torr of 'nitrogen equivalent' pressure. An oblivious operator, looking for a 760 Torr pressure reading, might continue to increase the gas pressure leading to the possibility of a dangerous explosion. Reports of accidents caused by this effect have appeared in the vacuum literature[21]. Accidents such as these can occur only if a thermal conductivity gauge is used to measure pressures at the upper end of the range where the calibrations for different gases diverge widely. This is the one reason why many vacuum practitioners reserve their convection gauges for measuring foreline and roughing line pressures, or *moderate* backfill pressures only!

At pressures below a few Torr the danger of using the nitrogen (or argon) calibration to measure the pressures of an uncalibrated gas (or gases) disappears. The only problem left is the inaccuracy of the readings. However, it is generally possible to correct pressure readings for uncalibrated gases using lookup tables or even simple correction factors.

With systems that could be potentially backfilled to excessive pressures by failure of gauges or regulator valves the inclusion of a pressure relief valve or burst disk is the safest way to avoid over pressurization!

Grounding

WARNING!
Verify the proper electrical grounding of the vacuum port before connecting the PG105 gauge head to the vacuum system.

The gauge envelope must be properly grounded during operation. If necessary, use a ground lug on a flange bolt to establish a dedicated connection to a facility ground. Alternatively, the gauge envelope may be grounded by using a metal hose clamp on the gauge connected by a #12 AWG copper wire to the system’s safety ground.

Electrical Connection

A single 8-pin, RJ45 compatible, connection socket, located on the back wall of the detachable plastic connector, provides the only electrical connection required between the PG105 gauge head and its controller cable. Fig. H-7 shows a picture of the electrical connector and lists the pin assignments in Table 1.

Pin#	Description
1	V_{br}_Sense
2	V_{br}_PWR
3	NULL(+)
4	NULL (-)
5	Not used
6	Not used
7	Ground
8	Ground

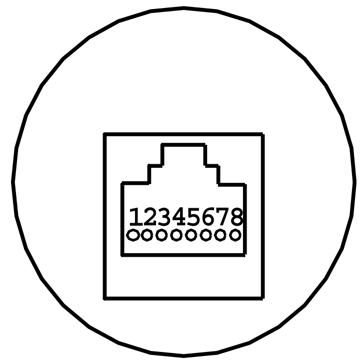


Figure H-7. PG105/RJ45 connector pin assignments.

As mentioned previously, the resistor bridge is an integral component of the PG105 gauge head (see Fig. H-2). Since pressure-dependent bridge voltages are measured right at the PG105 head using a four-wire arrangement, a total of six wires is required to establish a connection between an individual PG105 gauge head and a Pirani port of the IGC100 controller: Two wires supply the electrical power to the bridge while an independent pair senses the bridge voltage right at the gauge head without drawing any additional current out of the circuit. The last two wires connect the NULL(+) and NULL(-) voltages of the bridge to the differential input of the controller's feedback amplifier. This configuration makes the gauge calibration independent of cable length.

PG105 Gauge Test Procedure

Breakage of the small diameter sensor wire located inside the tube is a common failure mechanism for all Pirani gauges. Fortunately it is very easy to test the PG105 gauges for electrical continuity, to determine the integrity of both the sensor and temperature compensation wires.

WARNING!
Use an ohmmeter that cannot apply more than 0.1 V when the gauge is at vacuum or 2 V when at atmospheric pressure.

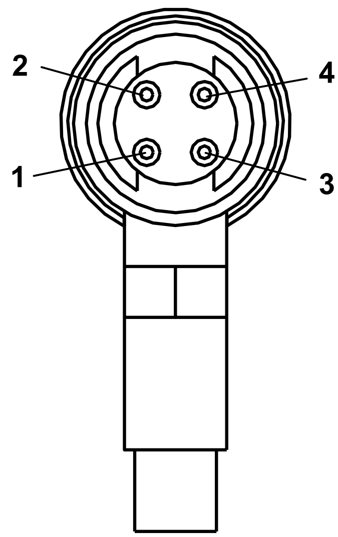


Figure H-8. Back view of the PG105 tube, with the plastic connector removed.

1. Disconnect the Detachable Plastic Connector from the PG105 gauge head. Four feedthru connector pins are now easily accessible from the back of the gauge tube as schematically represented in Fig. H-8.

2. Following the pin assignments of Fig. H-8, measure the resistance between pins 1 and 4 and between pins 2 and 3. The nominal wire resistances are:

Pins	Wire	Expected value (Ohms)
1 to 4	Sensor	20 – 22
2 to 3	Compensate	35 - 40

3. Gauge wires are not replaceable! Replace the gauge head if the wire resistance values do not fall within the ranges specified above.

References

[1] Pirani, M., Deutsche Phys. Ges. 8 (1906) 686. The first report of the Pirani gauge by its inventor.

[2] For one of the most complete discussions of Pirani Gauges consult: J.H. Leck, "Total and partial pressure measurement in vacuum systems", Chapter 2, titled "Thermal conductivity gauges", starting at page 39. Blackie & Son Ltd., Glasgow, England, 1989.

[3] Two amplifier circuits are built into every IGC100 controller, to control up to two PG105 gauges simultaneously.

[4] For theoretical derivations consult: J. M. Lafferty, "Foundations of vacuum science and technology", Wiley Interscience, 1998, NY, p. 404, section 6.8.1.

[5] L. Heijne and A. T. Vink, "A Pirani gauge for pressures up to 1000 Torr and higher", Philips Technical Rev. 30 (1969) 166; see also: J. B. Johnson, "Convection Type Manometer", The Review of Scientific Instruments, 27(5) (1956) 303; and J. A. McMillan, et. al. "Wide Range Thermal Convection Manometer", The review of Scientific Instruments , 28(11) (1957) 881.

[6] J. English, B. Fletcher and W. Steckelmacher, "A wide range constant-resistance Pirani gauge with ambient temperature compensation", J. Sci. Instrum. 42 (1965) 77; W. Steckelmacher and B. Fletcher, "Extension of range of thermal conductivity vacuum gauge to atmospheric pressure by natural convection", J. Phys. E, Sci. Instrum. 5 (1972) 405; W. Steckelmacher, "The high pressure sensitivity extension of thermal conductivity gauges", Vacuum 23 (9) (1973) 307.

[7] Zero adjustment of the gauge should not be necessary unless readout accuracy is required below 1 mTorr or the gauge has been contaminated.

[8] Consult R. E. Ellefson and A.P. Miller, "Recommended practice for calibrating vacuum gauges of the thermal conductivity type", J. Vac. Sci. Technol. A 18(5) (2000) 2568, for information on thermal gauge calibration and accuracy.

[9] R.E. Ellefson, and A. P. Miller, "Recommended Practice for Calibrating Vacuum Gauges of the Thermal Conductivity Type", J. Vac. Sci. Technol. To be published sometime during the spring of the year 2000.

[10] Vic Comello, "Simplify Rough Pumping With a Wide-Range Gauge", R&D Magazine, May 1999, p. 57.

[11] See also U.S. patent #6,227,056 for more details.

[12] K. F. Poulter, Mary-Jo Rodgers and K. W. Ascroft, "Reproducibility of the performance of Pirani Gauges", J. Vac. Sci. Technol. 17(2) (1980) 638.

[13] McMillan, J. A. and Buch, T., Rev. Sci. Instr. 28 (1957) 881.

[14] J. H. Leck, "The high temperature Pirani Gauge", J. Sci. Instr. 29 (1952) 258.

[15] Consult the book by J. H. Leck mentioned above, p. 45, section 2.3.

[16] The accommodation coefficient provides a measure of the efficiency of energy transfer from the hot wire to the gas molecules that collide with its surface. Its magnitude depends on (1) the gas, (2) the metal surface material, (3) contamination buildup on the wire surface, and (4) the temperatures involved. For more details consult: J.H. Leck, "Total and partial pressure measurement in vacuum systems", Chapter 2, titled "Thermal conductivity gauges", section 2.5., page 46. Blackie & Son Ltd., Glasgow, England.(1989).

[17] Vic. Comello, "Using Thermal Conductivity Gauges", R&D Magazine, Vol. 38, Number 8, July 1997, p. 57. Useful article with application examples, and some tips.

[18] Stephen Hansen, "Pressure measurement and control in loadlocks", Solid State Technology, October 1997, p. 151.

[19] J. Blears and J. H. Leck, J. Sci. Instrum. 28, Suppl. 1, 20 (1951); W. Steckelmacher and D. M. Tinsley, Vacuum 12 (1962) 153; J. K. N. Sharma and A. C. Gupta, Vacuum 36 (1986) 279; C. C. Minter, Rev. Sci. Instrum. 29 (1958) 793.

[20] R. N. Peacock, "Safety and health considerations related to vacuum gauging", J. Vac. Sci. Technol. A 11(4) (1993) 1627.

[21] R. Chapman and J. P. Hobson, J. Vac. Sci. Technol. 16 (1979) 965, D. G. Bills, J. Vac. Sci. Technol. 16 (1979) 2109.

Appendix I

Gas Correction Curves for PG105 Gauges

It is important to understand that the pressure indicated by a PG105 convection-enhanced Pirani gauge depends on the type of gas. All PG105 convection-enhanced Pirani gauges are factory-calibrated and temperature-compensated for nitrogen (air). However the response of the gauge to other gases is very well characterized and, with the proper calibration data, it is possible to obtain accurate pressure measurements for other gases as well.

IGC100 controllers are factory-loaded with Nitrogen and Argon specific calibration curves compatible with all PG105 gauges, and direct pressure measurements are possible for both gases.

If you must measure the pressure of gases other than Nitrogen or Argon, use Gas Correction Curves, like figures I-1 and I-2 included in this appendix, to convert “nitrogen equivalent pressure” readings into “actual pressure” readings for those gases.

Gas Correction Factors (relative to nitrogen equivalent readings) can also be used for pressure measurements below 1 Torr (See Table I-1)

PG105 users should generate their own conversion curves for gases, or mixtures of gases, not included in this appendix. A calibrated, gas-independent, capacitance manometer is recommended as a transfer standard[1].

In This Appendix

Gas Correction Curves and Factors

Important
The conversion curves and factors listed in this appendix only apply

1. when the pressure readings displayed by the controller are based on the nitrogen calibration curve (i.e. PG Cal Curve = N2 Curve)

2. the gauge tube is mounted with its axis horizontal.

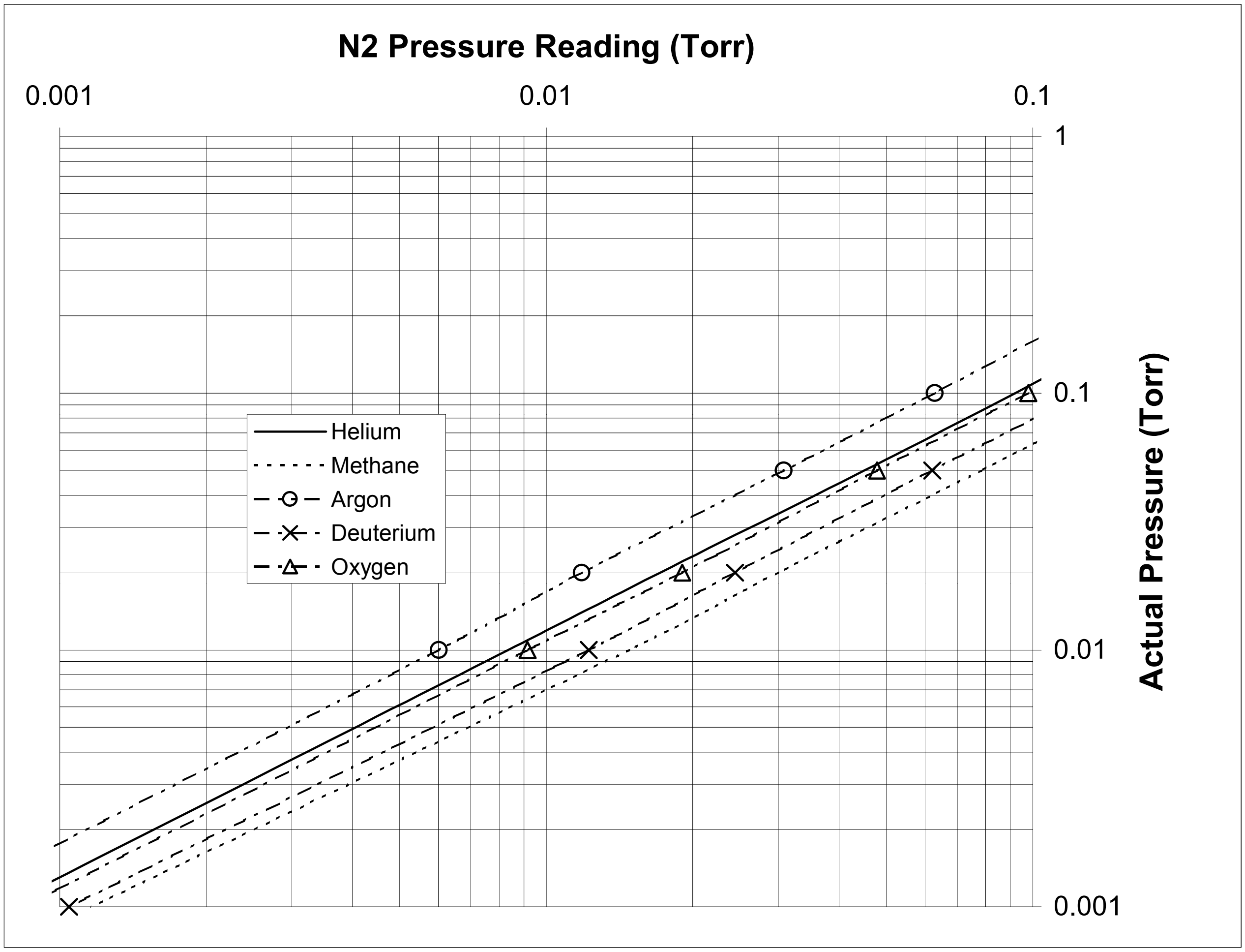


Figure I-1. PG105 Gauge Indicated Pressure (N_2 equivalent) vs. Actual Pressure Curve: 10^{-3} to 10^{-1} Torr.

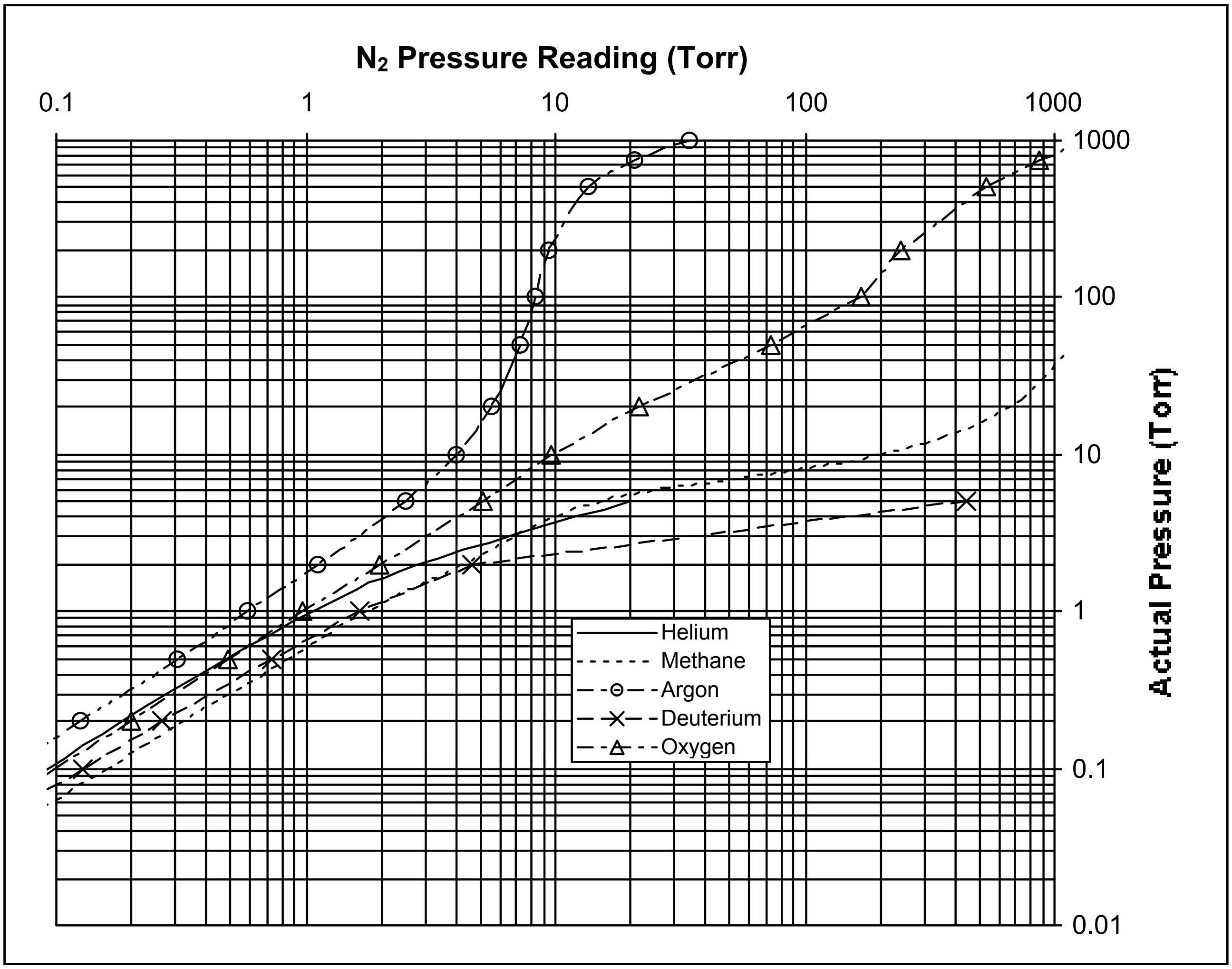


Figure I-2. PG105 Gauge Indicated Pressure (N2 equivalent) vs. Actual Pressure Curve: 10^{-1} to 1000 Torr. Use only when gauge axis is horizontal.

Nominal Gas Correction Factors for Figures I-1 and I-2.

Actual pressure = N_2 equivalent reading x K_g

(Use for pressures below 1 Torr only!)

Gas	**K_g**
Ar	1.59
He	1.10
Oxygen	1.03
Nitrogen	1.00
Deuterium	0.79
Methane	0.63

Overpressure risks

DANGER!

Using a PG105 convection gauge to backfill to atmospheric pressure should be avoided unless the gas-specific calibration curve for the backfilled gas is used to calculate and display pressures.

A serious danger can arise if the calibration data for one gas is applied without correction to measure pressures for a different gas (or gases) at or above atmospheric pressure. Argon provides an excellent example of how things can go very wrong. Applying the nitrogen calibration data to measure argon pressures provides a “nitrogen equivalent” reading of only ≈22 Torr when the gauge is exposed to an atmosphere of Argon gas (see Figure I-2). The chamber could be seriously pressurized while the gauge controller continues to display <100 Torr of nitrogen equivalent pressure. An oblivious operator, looking for a 760 Torr pressure reading, might continue to increase the gas pressure leading to the possibility of a dangerous explosion. Reports of accidents caused by this effect have appeared in the vacuum literature[2]. Accidents such as these can occur only if a thermal conductivity gauge is used to measure pressures at the upper end of the range where the calibrations for different gases diverge widely. This is the one reason why many vacuum practitioners reserve their convection gauges for measuring foreline and roughing line pressures, or *moderate* backfill pressures only!

At pressures below a few Torr the danger of using the nitrogen (or argon) calibration to measure the pressures of an uncalibrated gas (or gases) disappears. The only problem left is the inaccuracy of the readings. However, it is generally possible to correct pressure readings for uncalibrated gases using lookup tables, conversion curves and even simple correction factors .

TIP

With systems that could be potentially backfilled to excessive pressures by failure of gauges or regulator valves the inclusion of a pressure relief valve or burst disk is the safest way to avoid over pressurization!

References

[1] Consult R. E. Ellefson and A.P. Miller, "Recommended practice for calibrating vacuum gauges of the thermal conductivity type", J. Vac. Sci. Technol. A 18(5) (2000) 2568, for information on thermal gauge calibration and accuracy.

[2] R. Chapman and J. P. Hobson, J. Vac. Sci. Technol. 16 (1979) 965, D. G. Bills, J. Vac. Sci. Technol. 16 (1979) 2109.

Appendix J

PG105 vs. Thermocouple Gauges

The two most common thermal conductivity gauge technologies used in modern vacuum applications are Pirani gauges and thermocouple gauges.

This appendix is designed to help vacuum users choose between the two competing gauge technologies and decide when a pressure measurement setup based on TC gauges should be upgraded to PG105 convection gauges.

In This Appendix

Introduction

Pressure measurement in a thermal conductivity gauge is based on the transfer of heat from a hot wire, located inside the sensor, to the surrounding gases. Since gauge output depends on the thermal conductivity of the gases as well as their pressure, all thermal conductivity gauges provide indirect, gas-dependent, pressure readings.

The two most common thermal conductivity gauge technologies used in modern vacuum applications are:

Pirani Gauges

In the Pirani gauge (PG) the voltage required to maintain the hot wire at a constant temperature is *used as a non-linear, gas-dependent, function of pressure*. Traditional Pirani gauges provide useful pressure readings between 10^{-3} and 10 Torr. In convection-enhanced Pirani gauges, the upper range is extended upward to 1000 Torr by taking advantage of thermal convection currents created at the higher pressures.

Thermocouple Gauges

In the thermocouple gauge (TC) the pressure is indicated by measuring the small voltage of a thermocouple spot welded directly onto the hot wire. The wire is fed with a constant current and its temperature depends on the thermal conductivity and pressure of the gases present. TC gauges display useful pressures between 10^{-3} and 1 Torr.

TC gauges have long been regarded a cost-effective means to (1) monitor the foreline pressures of pumping stations and (2) as crossover gauges for vacuum systems in general. However, they are being systematically replaced in all modern vacuum systems by more accurate and reliable Pirani gauges, such as the PG105 convection-enhanced Pirani gauge manufactured by Stanford Research Systems.

This appendix is designed to (1) help vacuum users choose between the two competing gauge technologies and (2) decide when a pressure measurement setup based on TC gauges should be upgraded to PG105 convection gauges.

For additional information on this subject consult the following references:

1. J. M. Lafferty, "Foundations of Vacuum Science and Technology", section 6.8. "Thermal Conductivity Gauges", p. 403-414, Wiley-Interscience, 1998. A great book with lots of great information on almost every imaginable vacuum subject.

2. J. H. Leck, "Total and Partial Pressure Measurement in Vacuum Systems", Chapter 2., "Thermal Conductivity Gauges", p. 39, Blackie and Sons, Glasgow, 1989.

3. Stephen P. Hansen , "Pressure measurement and control in loadlocks", Solid State Technology, Oct. 1997, p. 151.

4. Simplify Rough Pumping with a Wide-Range Gauge", R&D Magazine, May 1999, p. 57.

5. J. Zettler and R. Sud, "Extension of thermocouple gauge sensitivity to atmospheric pressure", J. Vac. Sci. Technol. A6(3) (1988) 1153. Note: this is what it takes to make a TC tube extend into atmospheric pressures!

6. Vic Comello, "Using Thermal Conductivity Gauges", Back to Basics, R&D Magazine, Vol 39, Number 8, July 1997, p. 57 .

7. Vic Comello, "When to Choose a Thermocouple Gauge", Back to Basics, R&D Magazine, May 2000, p. 75.

Pressure Range Considerations

TC gauges deliver useful pressure readings between 10^{-3} and 10 Torr. Pressure readings above the upper limit are virtually useless, making it impossible, for example, to tell the difference between an overpressure condition caused by (1) a malfunctioning pump or (2) an accidental venting to ambient air by improper use of the foreline valves. While pumping down a system, a TC gauge cannot indicate if the pumps are working until pressures in the 1-10 Torr range are achieved and valid readings start to be displayed. This forces the operator to wait in front of the vacuum system until a reading of vacuum is obtained before being able to move on to something new!

PG105 convection gauges deliver useful pressure readings between 10^{-3} and 10^{3} Torr. This extended pressure range makes the PG105 convection gauge ideal for monitoring the pumpdown of vacuum systems from atmosphere to the base pressure of most mechanical pumps, without any blind pressure spots. Convection gauges are found in virtually every modern semiconductor and thin film process system, for monitoring pumping system performance. The vacuum operator gets an immediate indication of pumping action as soon as the pumpdown begins! Atmospheric pressure response is what makes convection gauges one of the most popular sensors found in loadlock systems. Most loadlocks must be open to atmosphere under a positive internal pressure of dry nitrogen or air to ensure a gentle flow of gas out of the chamber once the door is open. A convection gauge is often used to decide whether it is safe to open the gate and expose the loadlock chamber to air! Many users even combine their convection gauges with differential pressure devices called atmospheric pressure switches for added reliability. *Thermocouple gauges should definitely not be used to monitor the backfilling of loadlocks!*

WARNING!
Claims of TC Gauge readings extending to atmospheric pressures must be treated with extreme caution!

Modern oil-free high vacuum systems increasingly rely on hybrid turbo pumps backed by oil-free mechanical pumps. As the compression ratios of turbo pumps continue to increase so do the foreline pressures those systems require. Convection gauges are better suited to monitor pressures in modern turbo pumped systems. It is not uncommon to cold start a turbo pumped station from atmosphere and use a convection gauge to follow the pressure in the foreline from atmosphere to the base pressure of a diaphragm or scroll pump. The ultimate pressure of the mechanical (diaphragm) pump is one of the numbers that can be used to define if the system is properly pumped down.

With proper precautions, the PG105 lower range can also be extended further down into the 10^{-4} Torr decade, providing an amazing seven orders of magnitude of dynamic range from one gauge!

Response Times

Operation at constant wire temperature provides the PG105 convection gauge the advantage of a faster response to pressure transients. The response time is very fast (milliseconds in most cases) because components do not have to change temperature as pressure changes. Response time to a pressure step-function is pressure dependent, but it is roughly about an order of magnitude faster than in TC gauges.

Fast response time makes the PG105 convection gauge ideally suited for protective functions, as in determining when ionization gauge emission current should be deactivated or turned off. They are also well suited to control valves, heaters, bakeout ovens and safety interlocks.

Ion Gauge Auto Start

The IGC100 has a built in Auto-Start mode that makes it possible to automatically link the emission status of an ionization gauge to the pressure readings of a PG105 gauge exposed to the same vacuum environment. The ion gauge emission is immediately turned off as soon as the pressure goes above a user specified threshold value. This protects the filament from accidental burnouts. The emission is automatically reestablished as soon as the PG105 pressure readings goes below the threshold value, making it possible to automate pressure measurements from atmosphere down to UHV during pumpdown.

Remote Sensing

Compatibility with long cabling and immunity to electrical noise are important specifications for thermal conductivity gauges used in vacuum setups where the sensor must be placed far away from the controller.

The bridge circuit used to set the wire temperature is built right into the PG105 head, and the voltages are read using a Kelvin probe (4 wire) arrangement making them independent of cable length. Up to 150 m long cables can be used with PG105 gauges.

The output of the PG105 convection gauge is between 0.3 and 6 V as opposed to the much smaller, and noise sensitive, 1 – 15 mV levels that are delivered by thermocouple gauges.

Controller/Gauge Interchangeability

Thermocouple gauge tubes are made in about seven types that cannot be used interchangeably. A TC gauge controller must be matched to the gauge tubes for which it was built to assure accurate pressure measurements. Many manufacturers make tubes with compatible specifications.

TC Gauges are often differentiated by the filament current they require for their operation, and it is not unusual to need to fine tune the current delivered by the controller to the gauge to obtain accurate readings. Some TC tubes include a label with the recommended heater current required to obtain accurate pressure readings. Re-zeroing of the controller is recommended every time a new TC gauge tube is connected.

Following factory assembly, each PG105 gauge tube is individually calibrated for nitrogen, and temperature compensated between 10 and 40°C. After calibration each gauge tube is then individually tested to determine if selected pressure readouts fall within narrow limits before the unit is ready for shipment. Individual factory calibration of the gauge response provides true 'plug-and-play' convenience and eliminates the need to rezero the controller each time a new gauge tube is connected. PG105 gauges and IGC100 controllers are completely interchangeable without any need for instrument adjustments! In order to assure that calibration does not change with use, all gauge tubes are baked at high temperature for an extended period of time before final calibration takes place.

Contamination Resistance

Some widely used TC gauges utilize sensor wire temperatures of 250°C or higher at vacuum. Such high temperatures can cause pump oil to crack and leave carbon residues on the sensor which can then cause calibration shifts.

The temperature of the wire inside the PG105 gauge tube is approximately 120°C during operation. This temperature delivers optimal gauge response while, at the same time, remains low enough to minimize contamination by surface induced decomposition of foreign materials, such as pump-oil vapors. Contamination resistance provides enhanced accuracy, repeatability and long term stability compared to TC gauges.

UHV Compatibility

TC gauges are not compatible with UHV environments. Most of them include plastic feedthru headers and cannot be baked out.

The standard PG105 convection gauge uses a high-quality Viton® O-ring to seal the feedthru flange end of the tube, allowing maximum bakeout temperatures of 110°C (with the plastic connector detached). Metal gasket sealed gauge heads are also available, option PG105-UHV, that can be baked up to 250°C for more complete UHV compatibility. The metal gaskets used in all UHV enhanced gauge versions, are made out of OFHC Cu and belong to the Helicoflex Delta® family of high-performance compression metal seals, widely used for ultrahigh vacuum and ultrahigh purity applications. (Note: Helicoflex Delta® Seal is a registered trademark of Garlock Helicoflex, Columbia, SC)

Metal sealed gauge tubes, option PG105-UHV, are recommended for all ultrahigh vacuum and ultrahigh purity applications incompatible with the standard compression O-ring seal.

The all-metal interior construction of the PG105-UHV gauge makes it the best choice for applications requiring ultrahigh vacuum and/or ultrahigh purity compatibility. PG105-UHV gauges are often connected directly to high and ultrahigh vacuum chambers and used as cross-over gauges to protect the filaments of much more expensive ionization gauges.

Price/Performance Ratio

In relative terms, convection gauges are more expensive than most thermocouple gauges (about twice the price). However, in absolute numbers, the difference amounts to a very small extra cost that is usually insignificant relative to other recurring costs associated to the design and operation of a standard vacuum system.

Cost only plays a role in heavily contaminated systems, which require constant gauge replacements and do not rely on high accuracy pressure reports. A TC gauge might be the way to go in those applications. TC gauges are often preferred for dirty or corrosive processes because they are inexpensive enough to be thrown away when they become contaminated.

Freeze-Drying Processes

TCs are the gauge of choice in freeze drying operations because of the high water contents present during the drying processes. Pirani gauges do not fare as well in high humidity environments.

Leak Testing

Gas dependence makes the PG105 useful as an inexpensive leak detector. By using a tracer gas whose thermal conductivity is very different from the gases in the vacuum system, leaks as small as 10^{-4} atm cc/sec can be sensed and located. Typical gases used for leak testing include hydrogen, helium, argon and freon. This can eliminate the need for a very expensive leak detector. Several applications of Pirani gauges to leak detection have been reported in the vacuum literature.

Appendix K

Conversion Factors for Pressure Units

	Pascal	bar	mbar	μbar	Torr (mm Hg)	micron (mTorr)	atm	psi
Pascal	1	10^{-5}	10^{-2}	10	$7.5006 \cdot 10^{-3}$	7.5006	$9.8692 \cdot 10^{-6}$	$1.4504 \cdot 10^{-4}$
bar	10^{5}	1	10^{3}	10^{6}	750.06	$7.5006 \cdot 10^{5}$	0.98692	14.504
mbar	10^{2}	10^{-3}	1	1000	0.75006	750.06	$9.8692 \cdot 10^{-4}$	$1.4504 \cdot 10^{-2}$
μbar	10^{-1}	10^{-6}	10^{-3}	1	$7.5006 \cdot 10^{-4}$	0.75006	$9.8692 \cdot 10^{-7}$	$1.4504 \cdot 10^{-5}$
Torr (mm Hg)	$1.3332 \cdot 10^{2}$	$1.3332 \cdot 10^{-3}$	1.3332	1333.2	1	10^{3}	$1.3158 \cdot 10^{-3}$	$1.9337 \cdot 10^{-2}$
micron (mTorr)	0.13332	$1.3332 \cdot 10^{-6}$	$1.3332 \cdot 10^{-3}$	1.3332	10^{-3}	1	$1.3158 \cdot 10^{-6}$	$1.9337 \cdot 10^{-5}$
atm	$1.0133 \cdot 10^{5}$	1.0133	1013.3	$1.0133 \cdot 10^{6}$	760	$7.6 \cdot 10^{5}$	1	14.696
psi	$6.8948 \cdot 10^{3}$	$6.8948 \cdot 10^{-2}$	68.948	$6.8948 \cdot 10^{4}$	51.715	$5.1715 \cdot 10^{4}$	$6.8046 \cdot 10^{-2}$	1

How do you use this conversion table?

Example

Convert a pressure reading of 2.1 Torr into mbar units.

Start on the left side of the table and move down vertically until you reach the row labeled **Torr**. Move horizontally to the right along that row until you reach the 'Torr-to-mbar' conversion factor at the intersection with the **mbar** column. The conversion factor is 1.3332 (mbar/Torr). Multiply the pressure value expressed in Torr by this conversion factor to obtain the corresponding pressure value in mbar units –
2.1 Torr x 1.3332 mbar/Torr = 2.7997 mbar.

Appendix L

Dual Ionization Gauge Connector Box Option O100IG

The standard IGC100 controller can connect to, and display pressures from, only one ionization gauge. The Dual Ionization Gauge Connector Box (SRS Model # O100IG) is an optional component that, when attached to an IGC100, makes it possible to simultaneously connect two ionization gauges to the IGC100. An IGC100 properly fitted with the O100IG optional box can switch operation between two independent ionization gauges (i.e. sequential operation) from the front panel, and measure pressure at a first or second location (IG1 or IG2) at a small fraction of the cost of a second instrument.

The O100IG option is easily installed in the field making it easy to extend the capabilities of the IGC100 controller as needed.

In This Appendix

What does the Kit include?

The O100IG Option Kit includes all the components required to add a second ionization gauge connection port to your IGC100 controller. The basic package includes…

1. Dual Gauge Connector Box.
2. Connection Cable (connects O100IG box to IGC100 controller)
3. Mounting pins (for side mounting)
4. Fastening screw (for side mounting).
5. Instructions sheet.

Installation

IMPORTANT

For the most compact design and safest operation, SRS recommends you mount the O100IG box on the left side of the IGC100 controller as shown below in Fig. L-1. However, side mounting is not a requisite for the proper operation of the O100IG option (i.e. steps 1 –4 of the following installation procedure are optional).

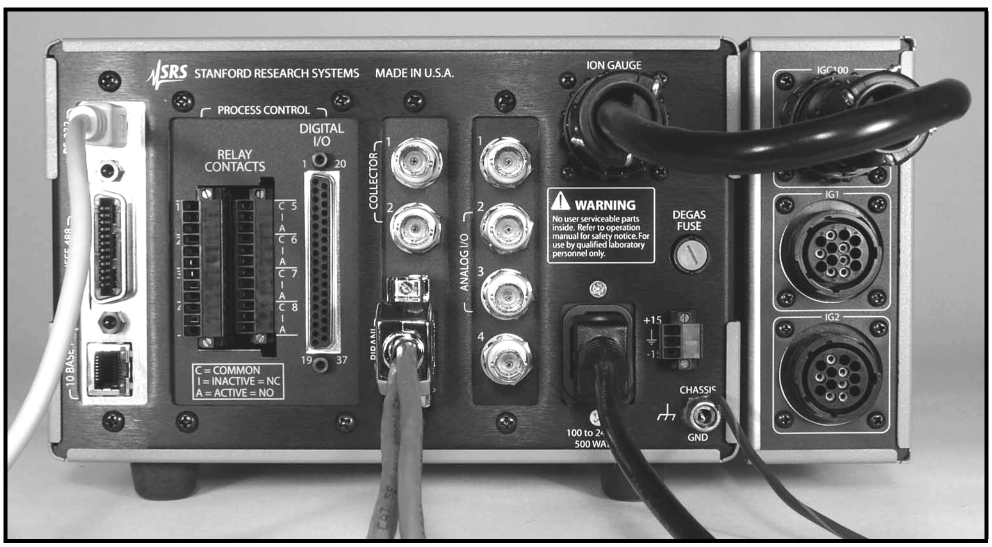


Figure L-1. Side Mounting configuration.

A few steps are required to complete a side mount installation…

Step 1

Working on the back end of the left side of the controller box, remove the top and bottom cover screws as shown in Fig. L-2. A #2 Phillips screwdriver is required.

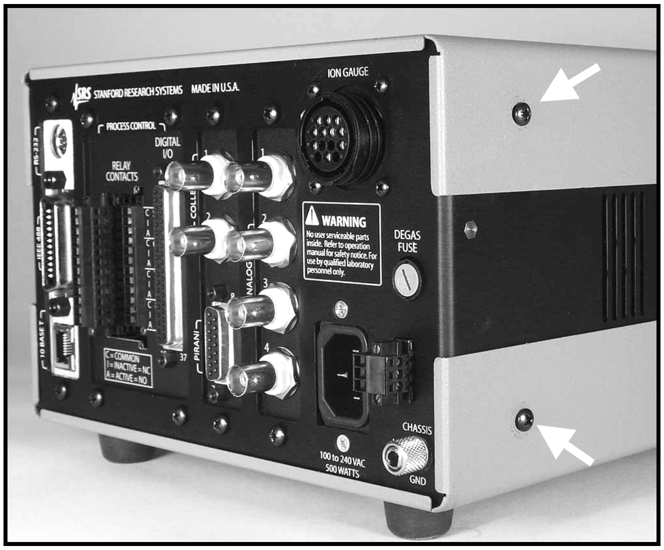


Figure L-2. Remove of the top and bottom cover screws from the back end of the left side of the IGC100.

Step 2

Replace the screws with the Mounting Pins included in the O100IGC Kit.

Figure L-3. Mounting pins in place.

Step 3

Mount the O100IG box on the left side of the IGC100. Insert the side pins into the round holes of the keyhole shaped slots located at the bottom of the O100IG box, and pull the box forward, towards the front of the controller, so that the box locks in place (i.e. the pins slide into the keyhole slots).

Step 4

Fasten the O100IG box to the side of the IGC100 controller using the Phillips screw included in the kit, as shown in Figure L-4.

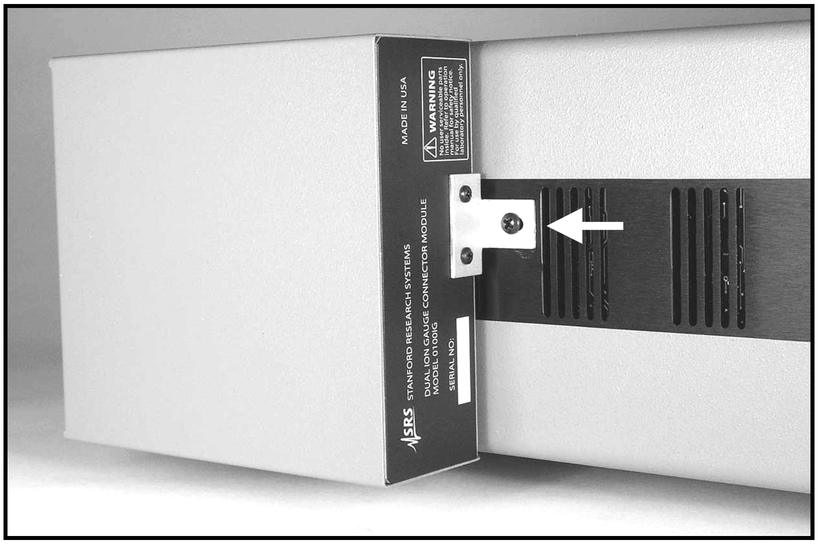


Figure L-4. O100IG box must be fastened to the side of the IGC100 controller.

Step 5

Electrically connect the O100IG box to the IGC100 using the Connection Cable included in the kit. The male cable connector end attaches to the ION GAUGE port on the back of the IGC100, while the female cable connector end attaches to the IGC100 port on the O100IG Box. Figure L-5 shows a completed connection.

Figure L-5. Connect the IGC100 Ionization Gauge port to the O100IG Box.

Step 6

Connect the ionization gauges to the IG1 and IG2 ports of the O100IG box, using signal cables purchased directly from Stanford Research Systems. Connect the collector cable BNC connectors to the Collector ports labeled 1 (for IG1) and 2 (for IG2) on the back of the IGC100.The system is now fully configured for dual gauge operation and ready to go.

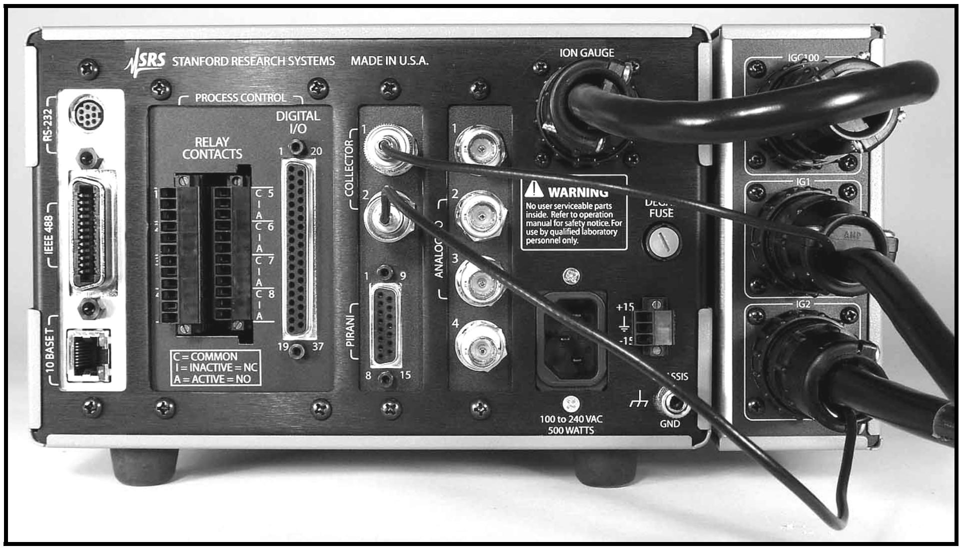


Figure L-6. An IGC100 with an O100IG option installed and two Ion gauges connected to its back panel. Decide up front which gauge you want to connect to the IG1 port and which one to the IG2 port.

Appendix M

Using MICRO-ION® Gauges

The IGC100 controller is compatible with Series 355 MICRO-ION® gauges manufactured exclusively by Granville-Phillips, Helix Technology Corp (Longmont, CO, USA, www.granville.com).

This appendix discusses the wiring details, parts and gauge setup parameters required to connect and operate a MICRO-ION® gauge (G-P Catalog 355001) with an IGC100 controller.

The data included here is based on information available directly from Granville-Phillips[1], as well as SRS's own experience with MICRO-ION® gauges. For further information, please contact Stanford Research Systems.

In This Appendix

Wiring Requirements

IMPORTANT

The ION GAUGE connector (female), located on the back of the IGC100, is **NOT** pin-compatible with the connector (male) found in all MICRO-ION® Gauge cables manufactured by Granville-Phillips. A cable adapter, SRS# O100CA1, is required to complete the connection.

1. Purchase the MICRO-ION® gauge (G-P Catalog 355001) and signal cable (G-P Catalog 358008, 358009 or 358010) directly from Granville-Phillips[2].
2. Purchase a MICRO-ION® cable adapter, SRS# O100CA1, directly from Stanford Research Systems.
3. Mount the MICRO-ION® gauge on your vacuum system following the manufacturer's recommendations.
4. Connect the O100CA1 cable adapter to the ION GAUGE connector[3] on the back plane of the IGC100 controller.
5. Connect the O100CA1 cable adapter to the MICRO-ION® signal cable.
6. Connect the collector cable BNC connector of the signal cable to the proper collector port (1 for IG1, and 2 for IG2) on the back of the IGC100.
7. Connect the gauge end of the MICRO-ION® signal cable to the gauge head.
8. Adjust the gauge setup parameters according to the directions of the next section.

Gauge Setup Parameters

The IGC100 Gauge Setup parameters must be properly adjusted to obtain accurate pressure readings with MICRO-ION® gauges.

The adjustments required for pressure measurement accuracy are

1. IG Calibration Source
2. N_2 Sensitivity Factor
3. Emission Current
4. Degas Power
5. Degas Time
6. Overpressure Threshold
7. Gauge Protection

The following settings are strictly based on manufacturer's recommendations[4] :

IG Calibration Source	N2 Sense Factor(1/Torr)
N2 Sense Factor	20/Torr (nominal)
Degas Power	3 Watts (max)
Degas Time	2 minutes (max)
Gauge Protection	Micro-Ion

Adjust the emission current and overpressure threshold settings taking into account the vacuum system pressure range:

Pressure Range	Emission Current	Overpressure Threshold	Default Setup File
1E-9 to 2E-4 Torr (1)	4 mA	2E-4 Torr	N.A.
1E-7 to 8E-4 Torr	1 mA	8E-4 Torr	N.A.
1E-6 to 5E-2 Torr	.02 mA	5E-2	MICRO

(1) X-ray limit is specified at 3×10^{-10} Torr.

Degas

Recommendation

Granville-Phillips recommends the use of both filaments during degas. The "Both" filament selection setting cleans up the tube more satisfactorily allowing for a lower ultimate pressure reading.

Warning

Do not touch the MICRO-ION® Gauge during degas operation. Burns can occur.

The IGC100 controller will not allow a degas process to start if the pressure at the gauge head is above 2×10^{-5} Torr. A rough pressure indication is displayed during the degas process. Degas power is carefully regulated during the entire process to minimize pressure bursts. Degas is completely shutdown if a pressure burst exceeding $5x10^{-5}$ Torr is detected at any time during the process.

The following recommendations should be observed while degassing MICRO-ION® gauges:

P > 10^{-5} Torr

If the pressure in the chamber (as measured at the MICRO-ION® gauge head) is above 10^{-5} Torr, perform a gauge and vacuum system bakeout instead of attempting an electron-bombardment degassing procedure. Degassing above 10^{-5} Torr is of little value and may (1) damage the filament and (2) cause pressure bursts that can cause an electrical discharge which can couple high voltage to the vacuum system hardware.

$5x10^{-7}$Torr < P < 10^{-5} Torr

Do not use the controller's Degas function while in this pressure range. Instead, outgas the MICRO-ION® gauge by operating the gauge in its normal operating mode with 4 mA of emission current for 2 minutes. Repeat this procedure as required until the desired base pressure is achieved. Degassing the gauge in this manner avoids the high electrode voltages used during a standard EB Degas. Due to its reduced size, the MICRO-ION gauge is very susceptible to high voltage electrical discharges during pressure bursts.

The normal operation of MICRO-ION® gauges with emission currents >4 mA is discouraged by its manufacturer[5].

P < $5x10^{-7}$Torr

Degas the MICRO-ION® gauge using the controller's built-in Degas function with a maximum of 3 W Degas Power and 2 minutes Degas Time settings. Do not exceed the recommended settings, since that may damage your gauge.

Bakeout

It is recommended to bake the gauge (and entire vacuum system if possible) in order to achieve an ultra-clean state. Recommended bakeout temperatures between 150ºC and 200ºC are usually adequate.

IMPORTANT

The gauge must not be baked above 200ºC. Remove the MICRO-ION® gauge cable from the gauge head when baking over 150ºC.

Gauge Protection

MICRO-ION® gauges are very compact, but still manage to include a dual filament assembly in their electrode structure. The dual ThO_2/Ir filament wires used for electron emission are very thin and require significantly less electrical power during operation (2V/2A normal, 2.3V/3A max) than standard ionization gauge filaments. As a result, the risk of overpowering is always present when MICRO-ION® gauges are connected to an ion gauge controller designed to operate standard ionization gauges.[6] Electrical overpowering will, in most cases, cause permanent damage to the filament wire.

The IGC100 controller includes a Gauge Protection function in its design which allows the user to limit the amount of power that can be safely delivered to a filament during operation. This Gauge Protection feature is gauge specific and intended to reduce the chances of filament burnouts when using gauges with delicate filaments, such as MICRO-ION® gauges.

To activate this protection for MICRO-ION® gauges, set the Gauge Protection (in the Advanced Gauge Setup menu) to Micro-Ion before operating a MICRO-ION® gauge. The MICRO-ION® protection is also set when the MICRO-ION® Default Setup is loaded.

IMPORTANT
Set the Gauge Protection to Micro-Ion when operating MICRO-ION® gauges with the IGC100 controller.

Accuracy

No independent studies on the accuracy and long-term stability specifications of MICRO-ION® gauges have been reported to date. Stanford Research Systems has used MICRO-ION® gauges in several applications, but no systematic study of their accuracy, gauge-to-gauge reproducibility and long-term performance has been conducted. MICRO-ION® users should contact Granville-Phillips directly for gauge accuracy information. Long term studies and systematic comparisons against standard Bayard-Alpert designs will be required to confirm the utility of these new gauges.

References

[1] Technical Notes #013606 and 355004, and Series 358 Vacuum Gauge Controller Instruction Manual (G-P Catalog#358013), Granville-Phillips, Helix Technology Corporation, Longmont, CO, USA, 1998, U.S. patent 6,198,105.

[2] Contact Granville-Phillips at: www.granville.com.

[3] Connect the cable adapter to the IG1 or IG2 port of the Dual Ion Gauge Connector Box, when connecting to an IGC100 with an O100IG option.

[4] Stanford Research Systems is not responsible for changes in design or specifications of third-party products that might render them incompatible with these recommendations and/or the IGC100 controller.

[5] Private communication from Granville-Phillips, Helix Technology Corporation, Longmont, CO, USA.

[6] For example, the gauge manufacturer (Helix Corporation, Longmont, CO) offers a cable adapter module (G-P part# 355002) to connect MICRO-ION® gauges to its standard ionization gauge controllers that limits the filament current to 3A.

Appendix N

Circuitry and Parts Lists

In This Chapter

Warnings

- **Read and follow all 'Safety and Preparation for Use' warnings before handling this product (see front of this manual).**
- Dangerous voltages, capable of causing injury or death, are present in this instrument. Use extreme caution whenever troubleshooting any of its parts.
- Do not substitute parts or modify the instrument. Do not use the product if it has unauthorized modifications. Return the product to Stanford Research Systems for service and repair to ensure that safety features are maintained.
- Use only SRS supplied replacement/accessory parts.
- The IGC100 controller does not have any serviceable parts other than the Degas Fuse.
- Consult the 'Damage Requiring Service' section at the end of this chapter for instructions on how to return the instrument for authorized service and adjustment.

Circuit Board Locations

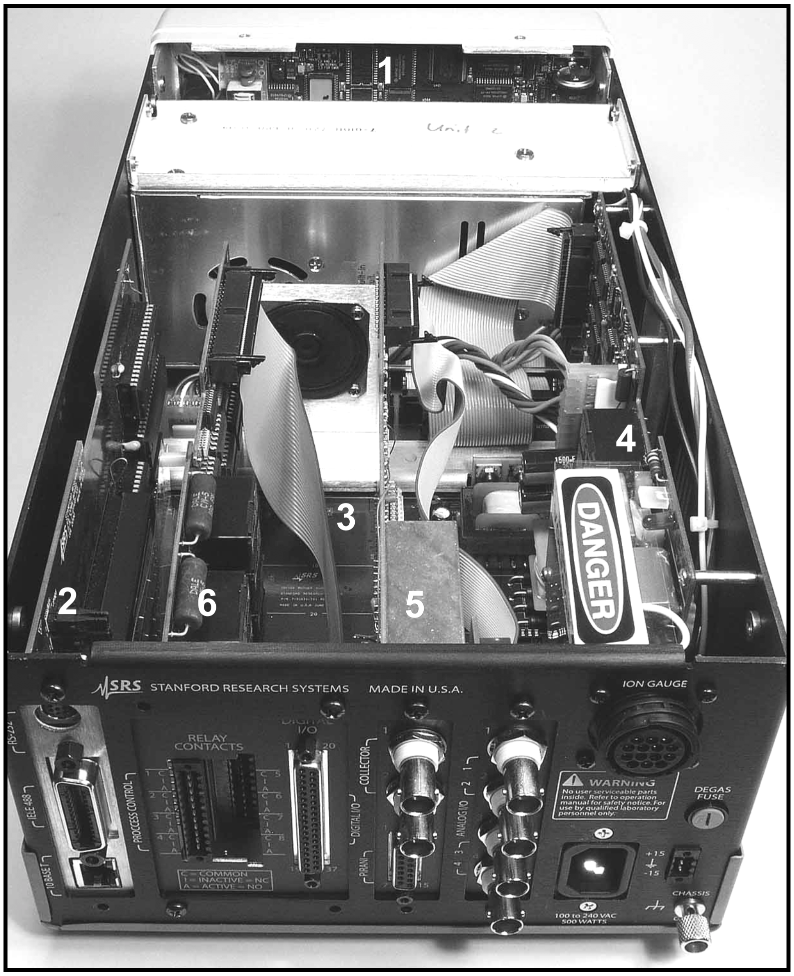


Figure N-1. Circuit board locations inside the IGC100 (rear view).

Circuit Boards

The IGC100 has six main printed circuit boards shown above.

1. CPU board
2. Communications board
3. Motherboard
4. High Voltage Power Supply board
5. Gauge Board
6. Process Control board (optional)

Circuit Descriptions

CPU Board

Overview

The CPU board contains the main microprocessor system. CPU memory, front panel and serial interfaces are on this board. An off-board data bus is driven from this board via connectors J601 and J602. This bus connects to the Motherboard via ribbon cables. These cables also bring Vcc power to the CPU board.

Microprocessor System

The microprocessor, U101, is an 80C186XL (or 80C186EA) microcontroller which integrates a fast 16-bit processor, counter-timers, interrupt controller, DMA controller and I/O decoding into a single component.

The 80C186 is clocked at 40.00 MHz by crystal oscillator U102. The external clock period is 2 oscillator cycles or 20.0 MHz. The data and lower 16 bits of address are multiplexed on processor lines AD0-AD15. U201, U202, U203 latch the address A0-A19 at the beginning of each memory or I/O cycle. U204 and U205 are bi-directional data bus drivers which are active during the data read/write portion of each memory or I/O cycle. U201-U205 provide the on-board System bus.

Memory Map

The 80C186 can address 1 Mbyte of memory and 64k of I/O space. U301 is a 512 kbyte flash EPROM mapped from 80000H to FFFFFH. U302-U303 are 128 kbyte CMOS static RAMs mapped from 00000H to 3FFFFH (256 kbytes). Locations U305 and U306 are not used.

I/O Map

U206, U207 and U213 are the bus drivers for the off-board I/O bus. U208 enables the correct bus drivers depending upon the I/O address space being accessed. All memory accesses and on-board I/O use the System bus.

The 80C186 generates 7 peripheral chip select strobes, each covering 128 byte I/O addresses. -PCS0 enables the LCD controller U401. -PCS1 enables the UART U501. -PCS2 through –PCS6 enable individual boards plugged into the Motherboard.

U208 and U212 decode on-board I/O and memory.

Interrupts generated by the UART and the Communications board are routed directly to the microprocessor.

U507 is the clock/calendar.

Front Panel

U401 is the LCD controller. U401 generates the timing signals for the front panel LCD. U402 and U403 are 32 kbyte static RAMs which contain the screen information. This memory is mapped to processor memory starting at location 40000H.

U405 is a switching power supply to generate the LCD bias voltage. U406 is an inverter to power the LCD backlight.

U404 is the touchscreen controller. U404 senses the location of a touch and reports the X and Y location to the microprocessor.

Latches U503-U508 are used to read the front panel buttons, turn on the front panel LEDs and control various on-board peripherals.

Communications Board

Serial Port

The Communications board passes the connections from the UART on the CPU board to the serial DIN connector (JP103) on the back panel.

GPIB Port

If the GPIB option is installed, a NAT9914 (U101) provides the GPIB interface.

Web Server

If the Web Server option is installed, a web controller module (U109) provides the ethernet interface as well as the web server. U109 communicates with the IGC100 via 2 serial ports provided by dual UART U105.

Jumpers identify which options are available in the unit.

Mother Board

The Motherboard provides the necessary CPU power, regulated 5 V (Vcc) and unregulated ±20 V, for the entire IGC100 while accommodating the Gauge Board, Process Control Board and the Communication Board.

In the power generation section, the primary of transformer T22 is operated from the +24 Vdc supply and is driven differentially by a pair of IRF530 MOSFETs (Q211 and Q212). An SG3525 switching controller, U21, is used to drive the FET gates. Since a reference voltage of 5.1 V (from pin 16) is supplied to the COMP pin (pin 9) the controller is set to run freely at a switching frequency of 120 kHz. The voltage developed at the sense resistor R214 is fed to the shutdown pin (pin 10) on U21 as a hardware safety precaution. When the voltage on this pin goes higher than 1 V U21 is shut off on by pulse-by-pulse basis. A snubber circuit (R221 and C222) is used to damp the transient, which occurs when a FET is turned off.

On the secondary side of the transformer there are two secondary windings to generate Vcc (5 V) and ±20 V. Two full wave bridge rectifiers (with Schottky diodes D221 through D228) are used to generate final 5 Vdc and ±20 Vdc. U23 is used to generate the regulated 5 Vdc as the Vcc supply for the entire gauge controller.

High Voltage Power Supply Board

Overview

The High Voltage Power Supply (HVPS) board provides the high voltages and high currents necessary to operate ion gauges. In the normal mode of operation, ion gauges require steady grid voltages and filament heater power. In addition, the IGC100 is capable of supplying 1.5 W to power capacitance manometers (AUX Power). The HVPS board contains the circuitry for the filament heater power, grid voltage, emission current control, analog power for the board, and a digital interface.

Filament Power Supply

Stable filament power is one of the key factors required to operate an ion gauge reliably. The filament emission current is controlled by regulating the filament temperature via the filament heater current's duty cycle. A 120 kHz switching power supply is used to power the filament heater. The transformer T12, driven by PWM U11, produces 8 Vmax output stepping down from 24 V. This transformer is capable of supplying 64 W (max) power to the filament heater depending upon the emission current setting. The output of the transformer is rectified by two Schottky diodes D121.

The primary of the transformer is operated from the +24 Vdc supply and is driven differentially by the pair of IRF530 MOSFETs (Q111 and Q112). An SG3525 switching controller, U11, is used to drive the FET gates. The duty cycle of the gate drive depends on the voltage at the COMP pin (pin 9). A voltage of about 0.9 V or below will set the duty cycle to zero. A snubber circuit (R122 and C122) is used to damp the transient, which occurs when a FET is turned off.

The voltage at the (COMP pin 9) on U11 is controlled according to the required emission current via opamp U14. The values of the closed loop compensating network components C131, R132 and C132 have been set to establish the best loop stabilization during both normal and degas operations. The analog switch U15A is used as an On/Off switch to turn on and off the ion gauge. Closing the switch (5 V at pin 1 of U15) is equivalent to switching off the gauge since the output of U14 drops to zero volts.

The primary side current is passed through a 0.01Ω sense resistor (R126). The voltage (with reference to 24 Vdc return) across this resistor is amplified by a differential amplifier, U13A, and read by the CPU via mux U51 and the 8-bit analog to digital converter, U52. The duty cycle of the gate drivers are measured at C127 in terms of voltage and is read by the CPU via U51 and U52. By reading the duty cycle and the primary current, the CPU can detect if there is any malfunction in the ion gauge filament.

On the secondary side of transformer T12 there is a snubber circuit (R121 and C123) to suppress the transient, which occurs when a FET is turned off. The components L122, C124, and C125 act as a LC filter for the DC output which drives the filament heater.

Grid Power Supply

The grid power operates very similarly to the heater power supply with the major difference being the generation of high voltages instead of high currents. During degas, ion gauges require 500 Vdc to be applied to the grid. During normal operation, the grid should have a steady 180 Vdc. In addition, the grid power supply should be able to supply sufficient current as the emission current in various settings. The highest emission current that the IGC100 can deliver is approximately 160 mA during degas. Therefore the grid power supply should be able handle up to 80 W of power.

The primary of the transformer, T24, is operated from the +24 Vdc supply and is driven differentially by a pair of IRF530 MOSFETs (Q231 and Q232). An SG3525 switching controller (U23), running at 120 kHz, is used to drive the FET gates. The duty cycle of the gate drive depends on the voltage at the COMP pin (pin 9). A voltage of about 0.9 V or below will set the duty cycle to zero.

The voltage at the (COMP pin 9) on U23 is controlled according to the required grid voltage. During normal operations the grid voltage is 180 V and during degas it is 500 V. The voltage divider resistors R242 and R244 generate the feedback voltage and is fed to the input of the opamp U22B via R227. In addition, the feedback voltage is read by the CPU via U51 and U52 periodically to make sure the grid the voltage has the expected value. The output of opamp U22B is switched between two values during normal and degas conditions depending on voltages set by GRID_SET_1, GRID_SET_2 and the output of the opamp U22A. The analog switch U15B is used to switch the output of the opamp U22A between –2.5 V and –6.94 V (normal and degas settings). The values of the closed loop compensating network components C221, R225 and C222 have been set to establish the best loop stabilization during both normal and degas operations.

The grid power supply circuit has two on/off switches, U25A and U27A. Similar to filament heater power supply, U15B is an analog switch, which will be in the closed position (HIGH on pin 6) to ensure that the output of opamp 22B (and COMP pin on U23) is at zero volts. The second switch, U27, is a D-flip flop which will pull pin 5 up (HIGH) or down (LOW) depending on PR signal on pin 4 and CL signal on pin 1. Pin 5 (D) on U27 is connected to the shutdown pin (pin 10) on the switching controller U23. When the voltage on this pin goes higher than 1 V U23 is shut off on a pulse-by-pulse basis. As long as this pin is pulled high (by pin 5 on U27) the grid power supply is switched off. LED D271 shows the status of shutoff pin on U23.

The primary current is passed through the 0.01Ω sense resistor R245. The voltage (with reference to 24 Vdc return) across this resistor is compared (using U26) with a preset value at the voltage divider (R262 and R263) and generates a clock signal at the output of the comparator. If the primary current exceeds a predetermined value defined by the voltage divider, a high clock signal is generated and the grid power supply will be switched off.

On the secondary side of transformer T24 there is a full wave bridge rectifier with four Schottky diodes (D214, 242, 243 and 244). R241 and C242 act as an output filter for the grid supply voltage. LED D245 shows the status of the grid voltage even if the fuse F241 is blown out.

Emission Control Circuit

One of the most sensitive circuits in the HVPS board is the emission control circuit. The IGC100 emission current has a tolerance of ±0.03% or better. The emission control circuit has two sections.

In the first section the 30 V bias voltage (to bias the filament) is generated by regulating down from 180 V/500 V. A MOSFET IRF530 (Q311), opamp U31, voltage divider R312 and R316 are used to generate the bias voltage. The grid voltage is sensed at the voltage divider and compared with a preset value at the inputs of U31. The FET Q311 and its feedback network maintain the bias voltage at 30 V within the required tolerance. The filament is kept at this bias voltage by connecting the filament return to the drain of the FET Q311.

In the second section, the emission current which is generated at the grid and coming to the HVPS board via the filament return, is fed into the emission current control circuit via Q311. Under normal operation the switch U32 is off and the incoming emission current goes through an I-V converter (U31, R336, R318 and R341). The resulting voltage is compared with a preset value generated by a 20-bit DAC U35 and is fedback to the filament heater control circuit at the output of opamp U34 to supply heater power.

The emission control circuit has three different gain settings. The three resistors in the I to V converter (R336, R314 and R318) and analog switches are used to select the required gain setting. The opamp U13D, resistors R1393, R1395, R1392, R1394 and D132 give a diagnostic voltage output for the emission current. This voltage may be read by the CPU for further processing.

Power Supplies

The HVPS board is operated from ±20 V and Vcc (+5 V) supplied from the motherboard through J72. The on board ± 15 V regulators (U76 and U66) generate most of the power used on this board. In addition, other miscellaneous power such as ±15 V (AUX) and ±2.5 V reference are generated from U74, U75, and U78. Required Vcc is directly supplied from the motherboard via the J72 connector.

Digital Interface

In the digital interface circuitry there are two CMOS decoders (U61 and U62), one octal latch with 3-state output (U63) and three octal 3-state non-inverting D flip-flops (U64, U65, U66). U61 and U62 are mainly used to generate Out Enable signals for the octal latch and the D-flip flops. The board ID is generated on U63 and latched out to the CPU when it is requested. Similarly all the other data are latched into the HVPS board from the CPU board via octal 3-state non-inverting D flip-flops (U64, U65 and U66).

Gauge Board

Overview

The Gauge Board is the most important circuit board when it comes to measuring pressures. The pressure measurement is done by two different circuits depending on the type of gauge used. The Gauge Board consists of five different sections, namely the I to V converter, Pirani Gauge electronics, Analog to Digital I/O circuitry, Digital Interface Circuitry, and Board Power Supplies.

When measuring pressure using an ion gauge, a minute ion current, which is a function of pressure, is generated by the ion gauge and fed into the gauge board. The first section of the Gauge Board is a very sensitive electrometer that measures the incoming ion current through an I to V converter. The I to V converter has three different gain stages to handle pressures ranging from 10^{-2} to 10^{-11} Torr. The resulting voltage is then converted to a digital signal by a 24-bit analog to digital converter. The digitized signal is sent to the CPU board for further processing and displayed as pressure on the LCD Display.

In the Pirani gauge circuit, the gauge bridge voltage, which is a function of pressure in the range of 1000 to 10^{-4} Torr, is measured and converted to a digital signal by a 14-bit analog to digital converter. The digitized signal is sent to the CPU board for processing and displaying on the LCD screen.

In addition to measuring pressure, the gauge board has circuitry for four analog I/O channels. The low voltage power required for the Gauge Board is produced by on board power circuitry.

Ion Current

The front end of the Gauge Board has two separate input BNCs to convert ion current from two different ion gauges (sequentially) to a voltage signal. Both these inputs share one electrometer unit. The most sensitive part of the entire instrument is the I to V converter of the electrometer unit. The electrometer has circuitry for four different gain stages including an Ultra-Low Input Current op amp LMC6001. Depending on the ion current, each stage is selected by applying a HIGH signal from the CPU to three different solid-state relays U17, U13, and U14. The relays U11 and U12 act as on and off switches to select ion current between two gauges sequentially. Switches U111 and U121 are used to ground the input signal during auto zero cycles. The resulting positive voltage at the output of U16 (high precision op amp) is converted to a digital signal by a 24-bit A to D (U31) and is sent to the CPU board via U54. The hex inverter U18 is used as to buffer the SCK and F0 inputs of the LTC 2400 24-bit A to D converter. JP181 selects the filtering of the 50/60 Hz line frequency. The LTC 2400 internal oscillator provides better than 110 dB normal mode rejection at the line frequency and all its harmonics for 50 and 60 Hz (within 2%). For 60 Hz rejection pin 8 should be at ground and for 50 Hz rejection pin 8 should be at +5 V.

Pirani Bridge Voltage

The Pirani gauge section consists of two identical circuits to drive two gauges simultaneously. The bridge circuit inside the gauge is connected to the pin 3,4,7 and 8 of

DB15 connector (P21). The bridge is balanced and driven by U21A and the gauge power can be switched off or on by U23. The bridge voltage is measured by U21B via a 4-wire connection through pin 3 and 8 of P21 connector. The resistor R244 measures the bridge current and the resulting voltage is digitized via mux U34. Once the power is gently applied through R217 to the gauge the U21A opamp will begin to control the power through Q232 properly. The output of U21B, the bridge voltage which represents the pressure, is sent to U32 (14 bit A to D) via mux U34.

Analog I/O

The Gauge Board also has four Analog Inputs/Output BNCs. The analog outputs are generated by a four channel 12 bit DAC (U42). The DAC output from each channel is amplified with a gain of 5.2 to produce the required analog output up to 12 V. Similarly, the analog input is attenuated by U43 and is fed into a 14-bit analog to digital converter (U32) via MUX U34. The analog inputs and outputs are able to share the same BNCs by using a CMOS analog switch U44.

Digital Interface

In the digital interface circuitry there are two CMOS decoders (U51 and U52), one octal latch with 3-state output (U54) and three Octal 3-state non-inverting D flip flops (U53, U55, U56). U51 and U52 are used mainly to generate Out Enable signals for U53, U54, U55 and U56. The board ID generated on U54 is latched out the CPU when it is requested. Similarly all the other data are latched into the gauge board from the CPU board via Octal 3-state non-inverting D flip flops (U53, U55 and U56).

Power Supplies

The gauge board is operated from ±20 V and Vcc (+5 V) supplied from the motherboard through the J51 Euro card 96 pin connector. The on board ± 15 V regulators (U61 and U62) generate most of the power used on this board. In addition, other miscellaneous power such ±7.5 V and ±5 V are regulated from U63, U64, U65 and U66. Required Vcc is supplied directly from the motherboard via J51 connector.

Process Controller Board

The Process Control Board has electronics for 12 remote TTL inputs, 8 process control inputs, 8 TTL outputs and 8 relay outputs. All TTL inputs and outputs are optically isolated with a photo coupler LTV847S.

The status of each TTL input is latched out to the CPU via with 3-state output (U53, U54 and U55). Each TTL output is buffered with an inverting octal buffer U33. In the relay output section, the status byte of the each relay is generated at the DPDT relay (using the 2nd pole). The status of the relay is latched out to the CPU via U56 and U57. The activation signal (from the CPU) for each relay is latched into the process controller board via octal 3-state non-inverting D flip-flop U58. The board ID generated on U54 and latched out to the CPU when requested.

Parts Lists

Parts lists for all of the circuit boards are listed in the following sections. Schematic diagrams follow the parts lists.

CPU Board

CPU Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
BT201	6-00534-612	CR2032/1GV	Battery
C 101	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 102	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 103	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 104	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 401	5-00369-552	33P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 402	5-00369-552	33P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 410	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 411	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 412	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 413	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 430	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 431	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 432	5-00518-569	15U/T35	Cap, Tantalum, SMT (all case sizes)
C 433	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 434	5-00520-569	4.7U/T35	Cap, Tantalum, SMT (all case sizes)
C 435	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 450	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 501	5-00368-552	27P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 502	5-00368-552	27P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 510	5-00543-568	.33UF 25V	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 511	5-00407-552	.047U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 512	5-00543-568	.33UF 25V	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 513	5-00543-568	.33UF 25V	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 514	5-00543-568	.33UF 25V	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 650	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 651	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 652	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 653	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 654	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 655	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 656	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 657	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 658	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 659	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 661	5-00393-552	3300P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 662	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 664	5-00522-569	47U/T10	Cap, Tantalum, SMT (all case sizes)
C 670	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 671	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 672	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 673	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 690	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
D 201	3-00806-360	BAV170LT1	Integrated Circuit (Surface Mount Pkg)
D 430	3-00926-360	MBR0540T1	Integrated Circuit (Surface Mount Pkg)
D 501	3-00010-303	GREEN	LED, T1 Package
D 502	3-00010-303	GREEN	LED, T1 Package
D 503	3-00010-303	GREEN	LED, T1 Package
D 504	3-00010-303	GREEN	LED, T1 Package

CPU Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
D 505	3-00010-303	GREEN	LED, T1 Package
D 506	3-00010-303	GREEN	LED, T1 Package
D 507	3-00010-303	GREEN	LED, T1 Package
D 508	3-00010-303	GREEN	LED, T1 Package
D 509	3-00009-303	YELLOW	LED, T1 Package
D 510	3-00010-303	GREEN	LED, T1 Package
D 511	3-00011-303	RED	LED, T1 Package
D 513	3-00010-303	GREEN	LED, T1 Package
D 514	3-00010-303	GREEN	LED, T1 Package
D 515	3-00011-303	RED	LED, T1 Package
D 520	3-00806-360	BAV170LT1	DUAL DIODE COMMON CATHODE
J 401	1-00078-130	4 PIN SI	Connector, Male
J 402	1-00522-179	FFC 12CKT	Connector Housing, Receptacle
J 403	1-00515-130	2 PIN HEADER	Connector, Male
J 502	1-00531-100	MICRO-MATK RECP	Connector, Misc.
J 601	1-00529-130	50 PIN ELH VERT	Connector, Male
J 602	1-00530-130	40 PIN ELH VERT	Connector, Male
L 430	6-00519-609	22UH - SMT	Inductor, Fixed, SMT
N 101	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
N 102	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
N 201	4-01617-463	82X8D	Resistor network, SMT, Leadless
N 202	4-01617-463	82X8D	Resistor network, SMT, Leadless
N 203	4-01617-463	82X8D	Resistor network, SMT, Leadless
N 205	4-01617-463	82X8D	Resistor network, SMT, Leadless
N 501	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
N 503	4-01618-463	330X8D	Resistor network, SMT, Leadless
PC1	7-00858-701	IGC CPU	Printed Circuit Board
Q 201	3-00580-360	MMBT3906LT1	Integrated Circuit (Surface Mount Pkg)
Q 401	3-00580-360	MMBT3906LT1	Integrated Circuit (Surface Mount Pkg)
Q 402	3-00966-360	IRF7103	Integrated Circuit (Surface Mount Pkg)
R 201	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 202	4-01453-461	82	Thick Film, 5%, 200 ppm, Chip Resistor
R 203	4-01453-461	82	Thick Film, 5%, 200 ppm, Chip Resistor
R 301	4-01491-461	3.3K	Thick Film, 5%, 200 ppm, Chip Resistor
R 401	4-01551-461	1.0M	Thick Film, 5%, 200 ppm, Chip Resistor
R 410	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 411	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 412	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 413	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 414	4-01527-461	100K	Thick Film, 5%, 200 ppm, Chip Resistor
R 420	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 421	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 431	4-01527-461	100K	Thick Film, 5%, 200 ppm, Chip Resistor
R 432	4-01527-461	100K	Thick Film, 5%, 200 ppm, Chip Resistor
R 433	4-01521-461	56K	Thick Film, 5%, 200 ppm, Chip Resistor
R 434	4-01521-461	56K	Thick Film, 5%, 200 ppm, Chip Resistor
R 435	4-01551-461	1.0M	Thick Film, 5%, 200 ppm, Chip Resistor
R 436	4-01524-461	75K	Thick Film, 5%, 200 ppm, Chip Resistor
R 437	4-01355-462	301K	Thin Film, 1%, 50 ppm, MELF Resistor
R 450	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 501	4-01551-461	1.0M	Thick Film, 5%, 200 ppm, Chip Resistor
R 511	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 512	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 520	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 521	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 522	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 523	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 524	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 530	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor

CPU Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
R 531	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor
R 532	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor
R 533	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor
R 534	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor
R 535	4-01467-461	330	Thick Film, 5%, 200 ppm, Chip Resistor
R 601	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 602	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 610	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 611	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
SO101	1-00108-150	PLCC 68 TH	Socket, THRU-HOLE
SW500	2-00050-201	E-SWITCH BLCK	Switch, Momentary Push Button
SW501	2-00050-201	E-SWITCH BLCK	Switch, Momentary Push Button
SW502	2-00050-201	E-SWITCH BLCK	Switch, Momentary Push Button
SW503	2-00050-201	E-SWITCH BLCK	Switch, Momentary Push Button
SW504	2-00051-201	E-SWITCH RED	Switch, Momentary Push Button
U 101	3-01439-360	80C186XL-25	Integrated Circuit (Surface Mount Pkg)
U 102	6-00586-626	50.0MHZ 100PPM	Crystal, SMT
U 201	3-00790-360	74ACT573	Integrated Circuit (Surface Mount Pkg)
U 202	3-00790-360	74ACT573	Integrated Circuit (Surface Mount Pkg)
U 203	3-00790-360	74ACT573	Integrated Circuit (Surface Mount Pkg)
U 204	3-00928-360	74ACT245	Integrated Circuit (Surface Mount Pkg)
U 205	3-00928-360	74ACT245	Integrated Circuit (Surface Mount Pkg)
U 206	3-00928-360	74ACT245	Integrated Circuit (Surface Mount Pkg)
U 207	3-00790-360	74ACT573	Integrated Circuit (Surface Mount Pkg)
U 208	3-00460-343	22V10-25	GAL/PAL, I.C.
U 209	3-00930-360	MAX693ACSE	Integrated Circuit (Surface Mount Pkg)
U 210	3-00929-360	74ACT32	Integrated Circuit (Surface Mount Pkg)
U 211	3-00790-360	74ACT573	Integrated Circuit (Surface Mount Pkg)
U 212	3-00405-343	16V8-15	GAL/PAL, I.C.
U 213	3-00928-360	74ACT245	Integrated Circuit (Surface Mount Pkg)
U 301	3-00931-360	29F400B	Integrated Circuit (Surface Mount Pkg)
U 302	3-00932-360	128KX8	Integrated Circuit (Surface Mount Pkg)
U 303	3-00932-360	128KX8	Integrated Circuit (Surface Mount Pkg)
U 401	3-00933-360	SED1352FOB	Integrated Circuit (Surface Mount Pkg)
U 402	3-00934-360	32KX8	Integrated Circuit (Surface Mount Pkg)
U 403	3-00934-360	32KX8	Integrated Circuit (Surface Mount Pkg)
U 404	3-00958-360	ADS7843E	Integrated Circuit (Surface Mount Pkg)
U 405	3-00959-360	MAX686EEE	Integrated Circuit (Surface Mount Pkg)
U 406	8-00069-800	INVERTER	Miscellaneous
U 501	3-00935-360	ST16C550CQ48	Integrated Circuit (Surface Mount Pkg)
U 502	3-00936-360	MAX3232CSE	Integrated Circuit (Surface Mount Pkg)
U 503	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 504	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 505	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 506	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 507	3-00937-360	DS1307Z	Integrated Circuit (Surface Mount Pkg)
U 508	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 601	3-00938-360	AD7528JR	Integrated Circuit (Surface Mount Pkg)
U 602	3-00581-360	AD822	Integrated Circuit (Surface Mount Pkg)
U 603	3-00939-360	LM4882M	Integrated Circuit (Surface Mount Pkg)
W 601	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 602	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 603	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 604	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 605	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 606	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 607	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 608	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 609	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R

CPU Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
W 610	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 611	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 612	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 613	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 614	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 615	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 616	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 617	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 618	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 619	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 620	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 621	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 622	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 623	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 624	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 625	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 626	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
W 627	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
X 401	6-00514-626	6 MHZ 32PF SMD	Crystal, SMT
X 501	6-00515-626	3.68MHZ 20PF	Crystal, SMT
X 502	6-00516-626	32.768KHZ SMD	Crystal, SMT

Communications Board

Communications Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 101	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 102	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 103	5-00100-517	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 104	5-00225-548	.1U AXIAL	Capacitor, Ceramic, 50V,+80/-20% Z5U AX
C 105	5-00225-548	.1U AXIAL	Capacitor, Ceramic, 50V,+80/-20% Z5U AX
C 106	5-00225-548	.1U AXIAL	Capacitor, Ceramic, 50V,+80/-20% Z5U AX
C 107	5-00225-548	.1U AXIAL	Capacitor, Ceramic, 50V,+80/-20% Z5U AX
C 108	5-00225-548	.1U AXIAL	Capacitor, Ceramic, 50V,+80/-20% Z5U AX
C 110	5-00011-501	27P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 111	5-00011-501	27P	Capacitor, Ceramic Disc, 50V, 10%, SL
J 200	1-00234-109	96 PIN RT ANGLE	DIN Connector, Male
JP102	1-00238-161	GPIB SHIELDED	Connector, IEEE488, Reverse, R/A, Female
JP103	1-00580-136	8 MINI-DIN RTA	Connector, Other
JP112	0-00985-000	ENETLED (G/Y)	Hardware, Misc.
JP114	1-00285-130	4 PIN DI MTLW	Connector, Male
PC1	7-01108-701	IGC COMM BD	Printed Circuit Board
R 100	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 101	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 102	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 103	4-00031-401	100	Resistor, Carbon Film, 1/4W, 5%
R 104	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 105	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 106	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 107	4-00065-401	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 110	4-00022-401	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 120	4-00072-401	330	Resistor, Carbon Film, 1/4W, 5%
R 121	4-00072-401	330	Resistor, Carbon Film, 1/4W, 5%
S0104	1-00024-150	20 PIN 300 MIL	Socket, THRU-HOLE
U 101	3-00645-340	NAT9914BPD	Integrated Circuit (Thru-hole Pkg)
U 103	3-00440-340	74HC573	Integrated Circuit (Thru-hole Pkg)
U 104	3-00405-343	16V8-15	GAL/PAL, I.C.
U 105	3-00960-340	ST16C2550CP40	Integrated Circuit (Thru-hole Pkg)
U 106	3-00078-340	DS75160A	Integrated Circuit (Thru-hole Pkg)
U 107	3-00079-340	DS75161A	Integrated Circuit (Thru-hole Pkg)
U 108	3-00155-340	74HC04	Integrated Circuit (Thru-hole Pkg)
U 109	3-01059-340	XEAWC86	Integrated Circuit (Thru-hole Pkg)
X 101	6-00037-620	3.6864 MHZ	Crystal
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00209-021	4-40X3/8PP	Screw, Panhead Phillips
Z 0	0-00500-000	554808-1	Hardware, Misc.
Z 0	7-01008-720	I/O PCB BRK	Fabricated Part
Z 0	7-01297-715	BRKT	Bracket
Z 0	7-01298-715	BRKT	Bracket
Z 0	7-01299-715	BRKT	Bracket
Z 0	7-01300-715	BRKT	Bracket

Motherboard

Motherboard			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 211	5-00395-552	4700P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 212	5-00472-569	4.7U/T35	Cap, Tantalum, SMT (all case sizes)
C 221	5-00329-526	120U	Capacitor, Electrolytic, 35V, 20%, Rad
C 222	5-00384-552	560P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 2110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2210	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 2220	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 2310	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 2320	5-00522-569	47U/T10	Cap, Tantalum, SMT (all case sizes)
C 2330	5-00522-569	47U/T10	Cap, Tantalum, SMT (all case sizes)
C 2340	5-00522-569	47U/T10	Cap, Tantalum, SMT (all case sizes)
C 2510	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
D 211	3-00380-301	1N5248	Diode
D 221	3-00479-301	MUR410	Diode
D 222	3-00479-301	MUR410	Diode
D 223	3-00479-301	MUR410	Diode
D 224	3-00479-301	MUR410	Diode
D 225	3-00479-301	MUR410	Diode
D 226	3-00479-301	MUR410	Diode
D 227	3-00479-301	MUR410	Diode
D 228	3-00479-301	MUR410	Diode
J 11	1-00235-108	96 PIN VERTICAL	DIN Connector, Female
J 12	1-00235-108	96 PIN VERTICAL	DIN Connector, Female
J 13	1-00235-108	96 PIN VERTICAL	DIN Connector, Female
J 18	1-00533-110	34 PIN CNCTR	Pins & Connectors, AMP
J 26	1-00036-116	7 PIN, WHITE	Header, Amp, MTA-156
J 151	1-00529-130	50 PIN ELH VERT	Connector, Male
J 152	1-00530-130	40 PIN ELH VERT	Connector, Male
L 221	6-00055-630	FB43-1801	Ferrite Beads
PC1	7-01031-701	IGC MOTHER BD	Printed Circuit Board
Q 211	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
Q 212	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
R 211	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 212	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 213	4-01158-462	2.67K	Thin Film, 1%, 50 ppm, MELF Resistor
R 214	4-00436-409	.1	Resistor, Wire Wound
R 221	4-01001-462	61.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 251	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 254	4-01013-462	82.5	Thin Film, 1%, 50 ppm, MELF Resistor
R 255	4-01013-462	82.5	Thin Film, 1%, 50 ppm, MELF Resistor
R 256	4-01013-462	82.5	Thin Film, 1%, 50 ppm, MELF Resistor
R 261	4-01588-453	10.0 - 2W	Resistor, 2W, 1%
R 262	4-01588-453	10.0 - 2W	Resistor, 2W, 1%
R 2110	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 2120	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
T 22	6-00535-610	Q8283C-04	Transformer
U 21	3-00919-360	3525A	Integrated Circuit (Surface Mount Pkg)
U 23	3-00549-329	LT1085CT-5	Voltage Reg., TO-220 (TAB) Package
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00048-011	6-32 KEP	Nut, Kep
Z 0	0-00128-053	4" #24	Wire #24 UL1007 Strip 1/4x1/4 Tin
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00209-021	4-40X3/8PP	Screw, Panhead Phillips
Z 0	0-00222-021	6-32X1/4PP	Screw, Panhead Phillips
Z 0	0-00231-043	#4 SHOULDER	Washer, nylon

Motherboard			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
Z 0	0-00316-003	PLTFM-28	Insulators
Z 0	0-00390-024	1-72X1/4	Screw, Slotted
Z 0	0-00391-010	1-72X5/32X3/64	Nut, Hex
Z 0	0-00772-000	1.5" WIRE	Hardware, Misc.
Z 0	6-00076-600	2" SPKR	Misc. Components
Z 0	7-01171-720	BCKT, MOTHER BD	Fabricated Part

High Voltage Power Supply Board

High Voltage Power Supply Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 111	5-00363-552	10P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 112	5-00395-552	4700P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 121	5-00329-526	120U	Capacitor, Electrolytic, 35V, 20%, Rad
C 122	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 123	5-00375-552	100P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 124	5-00515-526	1500U HIGH RIPL	Capacitor, Electrolytic, 35V, 20%, Rad
C 125	5-00515-526	1500U HIGH RIPL	Capacitor, Electrolytic, 35V, 20%, Rad
C 126	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 127	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 128	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 131	5-00527-568	.47U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 132	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 133	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 221	5-00403-552	.022U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 222	5-00526-569	22U-T16	Cap, Tantalum, SMT (all case sizes)
C 223	5-00403-552	.022U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 224	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 231	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 232	5-00395-552	4700P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 241	5-00329-526	120U	Capacitor, Electrolytic, 35V, 20%, Rad
C 242	5-00529-500	0.022UF/630V	Capacitor, Misc.
C 243	5-00530-500	0.47UF/630V	Capacitor, Misc.
C 262	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 271	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 272	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 311	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 312	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 313	5-00387-552	1000P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 314	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 315	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 351	5-00393-552	3300P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 352	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 461	5-00387-552	1000P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 462	5-00387-552	1000P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 463	5-00387-552	1000P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 511	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
C 521	5-00387-552	1000P	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 611	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 641	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1310	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1320	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1410	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1420	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1510	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1520	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1530	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2210	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2220	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2310	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2320	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2510	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2520	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2610	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2710	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R

High Voltage Power Supply Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 3110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3410	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3420	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3510	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3520	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 3530	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3540	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 5110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5210	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5310	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6110	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6210	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 6310	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 6410	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 6510	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6610	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 7110	5-00329-526	120U	Capacitor, Electrolytic, 35V, 20%, Rad
C 7120	5-00329-526	120U	Capacitor, Electrolytic, 35V, 20%, Rad
C 7410	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7420	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7430	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 7510	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7520	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7530	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 7610	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7620	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7630	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 7710	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7720	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7730	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 7810	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 7820	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
D 121	3-00625-302	MBR1535CT	Diode, Dual Schottky
D 241	3-00626-301	MUR1100E	Diode
D 242	3-00626-301	MUR1100E	Diode
D 243	3-00626-301	MUR1100E	Diode
D 244	3-00626-301	MUR1100E	Diode
D 245	3-00957-303	RED HLMP-D150	LED, T1 Package
D 251	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 252	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 271	3-00885-306	YELLOW	LED, Rectangular
D 311	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 411	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 441	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 611	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 641	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
F 241	0-00957-000	FUSE HOLDER	Hardware, Misc.
G 311	6-00088-613	NE-2H	Lamp
J 43	1-00541-110	206043-1	Pins & Connectors, AMP
J 61	1-00533-110	34 PIN CNCTR	Pins & Connectors, AMP
J 71	1-00260-116	4 PIN, WHITE	Header, Amp, MTA-156
J 72	1-00036-116	7 PIN, WHITE	Header, Amp, MTA-156
J 73	1-00528-130	3 PIN 3.5MM RT	Connector, Male
K 41	3-00964-335	845HN1CS24	Relay
K 42	3-00964-335	845HN1CS24	Relay
L 121	6-00055-630	FB43-1801	Ferrite Beads
L 122	6-00509-601	47.7UH	Inductor
L 241	6-00055-630	FB43-1801	Ferrite Beads

High Voltage Power Supply Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
L 711	6-00055-630	FB43-1801	Ferrite Beads
PC1	7-01030-701	IGC HV BOARD	Printed Circuit Board
Q 111	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
Q 112	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
Q 231	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
Q 232	3-00283-340	IRF530/IRF532	Integrated Circuit (Thru-hole Pkg)
Q 311	3-01441-340	IRF820	Integrated Circuit (Thru-hole Pkg)
R 111	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 112	4-01479-461	1.0K	Thick Film, 5%, 200 ppm, Chip Resistor
R 113	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 114	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 116	4-01158-462	2.67K	Thin Film, 1%, 50 ppm, MELF Resistor
R 117	4-01519-461	47K	Thick Film, 5%, 200 ppm, Chip Resistor
R 121	4-01443-461	33	Thick Film, 5%, 200 ppm, Chip Resistor
R 122	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 123	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 124	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 125	4-01173-462	3.83K	Thin Film, 1%, 50 ppm, MELF Resistor
R 126	4-01613-400	.01 CURRENT SNS	Resistor, Misc.
R 127	4-00111-402	390	Resistor, Carbon Comp, 1/2W, 5%
R 128	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 131	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 132	4-01309-462	100K	Thin Film, 1%, 50 ppm, MELF Resistor
R 133	4-01271-462	40.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 134	4-01203-462	7.87K	Thin Film, 1%, 50 ppm, MELF Resistor
R 135	4-01300-462	80.6K	Thin Film, 1%, 50 ppm, MELF Resistor
R 136	4-01203-462	7.87K	Thin Film, 1%, 50 ppm, MELF Resistor
R 137	4-01300-462	80.6K	Thin Film, 1%, 50 ppm, MELF Resistor
R 138	4-01251-462	24.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 139	4-01251-462	24.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 151	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 221	4-01197-462	6.81K	Thin Film, 1%, 50 ppm, MELF Resistor
R 222	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 223	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 224	4-01261-462	31.6K	Thin Film, 1%, 50 ppm, MELF Resistor
R 225	4-01070-462	324	Thin Film, 1%, 50 ppm, MELF Resistor
R 226	4-01309-462	100K	Thin Film, 1%, 50 ppm, MELF Resistor
R 227	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 228	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 229	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 231	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 232	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 233	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 234	4-01158-462	2.67K	Thin Film, 1%, 50 ppm, MELF Resistor
R 235	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 236	4-01519-461	47K	Thick Film, 5%, 200 ppm, Chip Resistor
R 241	4-01626-409	40	Resistor, Wire Wound
R 242	4-01627-453	350K	Resistor, 2W, 1%
R 243	4-01627-453	350K	Resistor, 2W, 1%
R 244	4-01133-462	1.47K	Thin Film, 1%, 50 ppm, MELF Resistor
R 245	4-01628-400	0.01/0.5W	Resistor, Misc.
R 251	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 261	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 262	4-01242-462	20.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 263	4-01105-462	750	Thin Film, 1%, 50 ppm, MELF Resistor
R 271	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 272	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 273	4-01456-461	110	Thick Film, 5%, 200 ppm, Chip Resistor
R 311	4-01623-448	10M	Resistor, Metal Film, 1W, 1%,

High Voltage Power Supply Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
R 312	4-01309-462	100K	Thin Film, 1%, 50 ppm, MELF Resistor
R 313	4-01273-462	42.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 314	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 315	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 316	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 318	4-01280-462	49.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 319	4-01280-462	49.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 333	4-01630-409	50.0 1W	Resistor, Wire Wound
R 334	4-01088-462	499	Thin Film, 1%, 50 ppm, MELF Resistor
R 336	4-01088-462	499	Thin Film, 1%, 50 ppm, MELF Resistor
R 341	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 342	4-01242-462	20.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 343	4-01242-462	20.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 345	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 411	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 421	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 431	4-01050-462	200	Thin Film, 1%, 50 ppm, MELF Resistor
R 432	4-01146-462	2.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 441	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 442	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 451	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 452	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 512	4-01503-461	10K	Thick Film, 5%, 200 ppm, Chip Resistor
R 513	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 521	4-01491-461	3.3K	Thick Film, 5%, 200 ppm, Chip Resistor
R 522	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 611	4-01448-461	51	Thick Film, 5%, 200 ppm, Chip Resistor
R 641	4-01515-461	33K	Thick Film, 5%, 200 ppm, Chip Resistor
R 661	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 741	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 742	4-01327-462	154K	Thin Film, 1%, 50 ppm, MELF Resistor
R 751	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 752	4-01301-462	82.5K	Thin Film, 1%, 50 ppm, MELF Resistor
R 1110	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 1120	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 1310	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1320	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1391	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 1394	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 1395	4-01105-462	750	Thin Film, 1%, 50 ppm, MELF Resistor
R 1410	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1420	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1510	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1520	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1530	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2210	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2220	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2310	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 2320	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 2610	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3110	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3112	4-01660-462	2.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 3120	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3410	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3420	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3510	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 3520	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 5110	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
T 12	6-00532-610	Q8283D-01	Transformer

High Voltage Power Supply Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
T 24	6-00533-610	Q8283A-04	Transformer
U 11	3-00919-360	3525A	Integrated Circuit (Surface Mount Pkg)
U 13	3-00723-360	LF347	Integrated Circuit (Surface Mount Pkg)
U 14	3-00967-360	OPA177GS	Integrated Circuit (Surface Mount Pkg)
U 15	3-00956-360	MAX4602CWE	Integrated Circuit (Surface Mount Pkg)
U 22	3-00952-360	OPA2277UA	Integrated Circuit (Surface Mount Pkg)
U 23	3-00919-360	3525A	Integrated Circuit (Surface Mount Pkg)
U 25	3-01371-360	DG417DY	Integrated Circuit (Surface Mount Pkg)
U 26	3-00965-360	LM2903M	Integrated Circuit (Surface Mount Pkg)
U 27	3-00742-360	74HC74	Integrated Circuit (Surface Mount Pkg)
U 31	3-00581-360	AD822	Integrated Circuit (Surface Mount Pkg)
U 32	3-00966-360	IRF7103	Integrated Circuit (Surface Mount Pkg)
U 34	3-00967-360	OPA177GS	Integrated Circuit (Surface Mount Pkg)
U 35	3-00969-360	DAC1220E	Integrated Circuit (Surface Mount Pkg)
U 44	3-00540-360	MMBT5087	Integrated Circuit (Surface Mount Pkg)
U 45	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
U 51	3-00661-360	74HC4051	Integrated Circuit (Surface Mount Pkg)
U 52	3-01442-340	LTC1096	Integrated Circuit (Thru-hole Pkg)
U 53	3-00655-360	TLC5628	Integrated Circuit (Surface Mount Pkg)
U 61	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 62	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 63	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 64	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 65	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 66	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 74	3-00118-325	78L15	Transistor, TO-92 Package
U 75	3-00124-325	79L15	Transistor, TO-92 Package
U 76	3-00118-325	78L15	Transistor, TO-92 Package
U 77	3-00124-325	79L15	Transistor, TO-92 Package
U 78	3-00970-360	MAX6225BCSA	Integrated Circuit (Surface Mount Pkg)
U 411	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
U 421	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Z 0	0-00039-006	66101-4	NIM (Nuclear Instrumentation Module)
Z 0	0-00096-041	#4 SPLIT	Washer, Split
Z 0	0-00130-050	5-5/8" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00209-021	4-40X3/8PP	Screw, Panhead Phillips
Z 0	0-00231-043	#4 SHOULDER	Washer, nylon
Z 0	0-00243-003	TO-220	Insulators
Z 0	0-00330-050	5-1/2" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00594-050	4-1/2" #18 BLUE	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00595-050	4-1/2" #18 ORAN	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00617-031	4-40X1-3/16 F/F	Standoff
Z 0	0-00772-000	1.5" WIRE	Hardware, Misc.
Z 0	0-00810-020	4-40X1/2PF SS	Screw, Flathead Phillips
Z 0	0-00988-050	5" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00989-050	5" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00990-050	5" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-00991-050	4" #18	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01000-048	4" #18 UL1015	Wire, #18 UL1015 Strip 3/8 x 3/8 No Tin
Z 0	0-01022-019	4-40	Lock Nut
Z 0	1-00542-110	66181-1	Pins & Connectors, AMP
Z 0	1-00612-176	1238	Terminal, Male
Z 0	6-00042-611	1.25A 3AG	Fuse
Z 0	7-01009-721	2-POS FET BRKT	Machined Part
Z 0	7-01010-721	6 POS FET BRKT	Machined Part

Gauge Board

Gauge Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 1	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 2	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 3	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 4	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 5	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 6	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 7	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 8	5-00023-529	.1U	Cap, Monolythic Ceramic, 50V, 20%, Z5U
C 121	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 151	5-00078-516	10P	Capacitor, Silver Mica, 500V, 5%,
C 152	5-00139-516	910P	Capacitor, Silver Mica, 500V, 5%,
C 153	5-00460-572	.033U	SMT Film Capacitors, 50V, 5%, All Sizes
C 154	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 155	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 211	5-00472-569	4.7U/T35	Cap, Tantalum, SMT (all case sizes)
C 212	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 213	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 214	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 215	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 216	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 217	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 218	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 221	5-00472-569	4.7U/T35	Cap, Tantalum, SMT (all case sizes)
C 222	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 223	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 224	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 225	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 226	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 227	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 228	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 421	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 422	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 423	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 424	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 431	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 432	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 433	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 434	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 435	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 436	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 437	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 438	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 531	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1510	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1520	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1610	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 1620	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2210	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2220	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2310	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2320	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 2330	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3110	5-00525-578	1U	SMT Ceramic Cap, all sizes
C 3120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R

Gauge Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 3210	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 3220	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3230	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3240	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 3250	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3260	5-00526-569	22U-T16	Cap, Tantalum, SMT (all case sizes)
C 3270	5-00470-569	2.2U/T16	Cap, Tantalum, SMT (all case sizes)
C 3410	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3420	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3610	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 3620	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4110	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4120	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4210	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4220	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4310	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4320	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4410	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4420	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 4430	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5110	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 5210	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5310	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5410	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5510	5-00299-568	.1U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5610	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6110	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6120	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6130	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 6210	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6220	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6230	5-00471-569	10U/T16	Cap, Tantalum, SMT (all case sizes)
C 6310	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6320	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6410	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6420	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6510	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6520	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6610	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 6620	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
D 45	3-00896-301	BAV99	Diode
D 46	3-00896-301	BAV99	Diode
D 47	3-00896-301	BAV99	Diode
D 48	3-00896-301	BAV99	Diode
D 231	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 241	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
D 531	3-00544-360	BAV70LT1	Integrated Circuit (Surface Mount Pkg)
G 111	6-00531-613	CG90L	Lamp
G 121	6-00531-613	CG90L	Lamp
J 1	1-00233-120	RT ANGLE	Connector, BNC
J 2	1-00233-120	RT ANGLE	Connector, BNC
J 3	1-00233-120	RT ANGLE	Connector, BNC
J 4	1-00233-120	RT ANGLE	Connector, BNC
J 5	1-00336-130	26 PIN ELH VERT	Connector, Male
J 51	1-00234-109	96 PIN RT ANGLE	DIN Connector, Male
J 111	1-00233-120	RT ANGLE	Connector, BNC
J 121	1-00233-120	RT ANGLE	Connector, BNC
JP52	1-00336-130	26 PIN ELH VERT	Connector, Male
P 21	1-00370-160	15 PIN D	Connector, D-Sub, Right Angle PC, Female

Gauge Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
PC1	7-01029-701	IGC GAUGE BOARD	Printed Circuit Board
Q 231	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 232	3-00378-329	TIP102	Voltage Reg., TO-220 (TAB) Package
Q 241	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 242	3-00378-329	TIP102	Voltage Reg., TO-220 (TAB) Package
R 111	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 112	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 121	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 122	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 131	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 141	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 151	4-00398-407	499K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 152	4-00864-458	500M 3/4-WATT	Resistor, Metal Oxide
R 153	4-00139-407	10.0M	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 154	4-00170-407	249K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 155	4-00161-407	2.49K	Resistor, Metal Film, 1/8W, 1%, 50PPM
R 156	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 163	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 164	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 165	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 166	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 171	4-01471-461	470	Thick Film, 5%, 200 ppm, Chip Resistor
R 182	4-01146-462	2.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 211	4-01230-462	15.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 212	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 213	4-01230-462	15.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 214	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 215	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 216	4-01280-462	49.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 217	4-01167-462	3.32K	Thin Film, 1%, 50 ppm, MELF Resistor
R 218	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 219	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 221	4-01230-462	15.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 222	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 223	4-01230-462	15.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 224	4-01184-462	4.99K	Thin Film, 1%, 50 ppm, MELF Resistor
R 225	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 226	4-01280-462	49.9K	Thin Film, 1%, 50 ppm, MELF Resistor
R 227	4-01167-462	3.32K	Thin Film, 1%, 50 ppm, MELF Resistor
R 228	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 229	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 231	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 232	4-01146-462	2.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 233	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 234	4-01632-462	10.0 1/4W	Thin Film, 1%, 50 ppm, MELF Resistor
R 235	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 241	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 242	4-01146-462	2.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 243	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 244	4-01632-462	10.0 1/4W	Thin Film, 1%, 50 ppm, MELF Resistor
R 245	4-01575-461	10M	Thick Film, 5%, 200 ppm, Chip Resistor
R 311	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 341	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 342	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 343	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 344	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 345	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 346	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor
R 347	4-01117-462	1.00K	Thin Film, 1%, 50 ppm, MELF Resistor

Gauge Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
R 361	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 362	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 411	4-01273-462	42.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 412	4-01273-462	42.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 413	4-01273-462	42.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 414	4-01273-462	42.2K	Thin Film, 1%, 50 ppm, MELF Resistor
R 415	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 416	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 417	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 418	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 423	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 424	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 425	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 426	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 431	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 432	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 433	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 434	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 435	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 436	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 437	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 438	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 451	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 452	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 461	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 462	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 471	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 472	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 481	4-01021-462	100	Thin Film, 1%, 50 ppm, MELF Resistor
R 482	4-00925-462	10.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 491	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 492	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 493	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 494	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 495	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 496	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 497	4-01405-462	1.00M	Thin Film, 1%, 50 ppm, MELF Resistor
R 498	4-01335-462	187K	Thin Film, 1%, 50 ppm, MELF Resistor
R 531	4-01515-461	33K	Thick Film, 5%, 200 ppm, Chip Resistor
R 541	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 542	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 543	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 544	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 551	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 1510	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1520	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1610	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1620	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 1810	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2110	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2120	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2210	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2220	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2310	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 2320	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2330	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 2331	4-00954-462	20.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 2431	4-00954-462	20.0	Thin Film, 1%, 50 ppm, MELF Resistor
R 3110	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor

Gauge Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
R 3410	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 3420	4-01455-461	100	Thick Film, 5%, 200 ppm, Chip Resistor
R 3610	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 3620	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4110	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4120	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4310	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4320	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4410	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4420	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 4430	4-01431-461	10	Thick Film, 5%, 200 ppm, Chip Resistor
R 6310	4-01058-462	243	Thin Film, 1%, 50 ppm, MELF Resistor
R 6320	4-01125-462	1.21K	Thin Film, 1%, 50 ppm, MELF Resistor
R 6410	4-01058-462	243	Thin Film, 1%, 50 ppm, MELF Resistor
R 6420	4-01125-462	1.21K	Thin Film, 1%, 50 ppm, MELF Resistor
U 11	3-00950-335	LH1541AT1	Relay
U 12	3-00950-335	LH1541AT1	Relay
U 13	3-00950-335	LH1541AT1	Relay
U 14	3-00950-335	LH1541AT1	Relay
U 15	3-00951-340	LMC6001CIN	Integrated Circuit (Thru-hole Pkg)
U 16	3-01370-360	OPA277UA	Integrated Circuit (Surface Mount Pkg)
U 17	3-00950-335	LH1541AT1	Relay
U 18	3-00662-360	74HC14	Integrated Circuit (Surface Mount Pkg)
U 21	3-00952-360	OPA2277UA	Integrated Circuit (Surface Mount Pkg)
U 22	3-00952-360	OPA2277UA	Integrated Circuit (Surface Mount Pkg)
U 23	3-00643-360	DG211BDY	Integrated Circuit (Surface Mount Pkg)
U 31	3-00953-360	LTC2400CS8	Integrated Circuit (Surface Mount Pkg)
U 32	3-00954-360	LTC1416IG	Integrated Circuit (Surface Mount Pkg)
U 34	3-00661-360	74HC4051	Integrated Circuit (Surface Mount Pkg)
U 36	3-00952-360	OPA2277UA	Integrated Circuit (Surface Mount Pkg)
U 41	3-01364-360	OPA4277UA	Integrated Circuit (Surface Mount Pkg)
U 42	3-00955-360	DAC7624U	Integrated Circuit (Surface Mount Pkg)
U 43	3-01364-360	OPA4277UA	Integrated Circuit (Surface Mount Pkg)
U 44	3-00956-360	MAX4602CWE	Integrated Circuit (Surface Mount Pkg)
U 51	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 52	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 53	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 54	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 55	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 56	3-00751-360	74HC574	Integrated Circuit (Surface Mount Pkg)
U 61	3-00114-329	7815	Voltage Reg., TO-220 (TAB) Package
U 62	3-00120-329	7915	Voltage Reg., TO-220 (TAB) Package
U 63	3-00971-360	LM317LM	Integrated Circuit (Surface Mount Pkg)
U 64	3-00972-360	LM337L/SO	Integrated Circuit (Surface Mount Pkg)
U 65	3-00122-325	79L05	Transistor, TO-92 Package
U 66	3-00709-360	78L05	Integrated Circuit (Surface Mount Pkg)
U 111	3-00950-335	LH1541AT1	Relay
U 121	3-00950-335	LH1541AT1	Relay
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00079-031	4-40X3/16 M/F	Standoff
Z 0	0-00187-021	4-40X1/4PP	Screw, Panhead Phillips
Z 0	0-00472-018	1-329631-2	Jam Nut
Z 0	0-00501-042	1-329632-2	Washer, lock
Z 0	0-01030-007	592502B03400	Heat Sinks
Z 0	1-00611-171	26 PIN, 8.5"	Cable Assembly, Ribbon
Z 0	7-01006-720	A/D PCB BRACKET	Fabricated Part
Z 0	7-01007-720	BCKT, GAUGE PWB	Fabricated Part
Z 0	7-01292-709	IGC	Lexan Overlay
Z 0	7-01305-720	IGC	Fabricated Part

Process Control Board

Process Control Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
C 581	5-00298-568	.01U	Cap, Ceramic 50V SMT (1206) +/-10% X7R
C 5110	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 5210	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 5310	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 5410	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
C 5510	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 5610	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 5710	5-00399-552	.01U	Capacitor, Chip (SMT1206), 50V, 5%, NPO
C 5810	5-00318-569	2.2U/T35	Cap, Tantalum, SMT (all case sizes)
D 411	3-00806-360	BAV170LT1	Integrated Circuit (Surface Mount Pkg)
D 431	3-00806-360	BAV170LT1	Integrated Circuit (Surface Mount Pkg)
D 451	3-00806-360	BAV170LT1	Integrated Circuit (Surface Mount Pkg)
D 471	3-00806-360	BAV170LT1	Integrated Circuit (Surface Mount Pkg)
J 51	1-00234-109	96 PIN RT ANGLE	DIN Connector, Male
J 61	1-00530-130	40 PIN ELH VERT	Connector, Male
J 62	1-00577-130	24 PIN RT.ANGLE	Connector, Male
K 41	3-01056-335	24VDC DPDT	Relay
K 42	3-01056-335	24VDC DPDT	Relay
K 43	3-01056-335	24VDC DPDT	Relay
K 44	3-01056-335	24VDC DPDT	Relay
K 45	3-01056-335	24VDC DPDT	Relay
K 46	3-01056-335	24VDC DPDT	Relay
K 47	3-01056-335	24VDC DPDT	Relay
K 48	3-01056-335	24VDC DPDT	Relay
PC1	7-01084-701	IGC PROCESS CNT	Printed Circuit Board
Q 411	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 421	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 431	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 441	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 451	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 461	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 471	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
Q 481	3-00601-360	MMBT3904LT1	Integrated Circuit (Surface Mount Pkg)
R 11	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
R 12	4-01659-463	100KX8D	Resistor network, SMT, Leadless
R 13	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
R 14	4-01659-463	100KX8D	Resistor network, SMT, Leadless
R 21	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
R 22	4-01659-463	100KX8D	Resistor network, SMT, Leadless
R 31	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
R 32	4-01659-463	100KX8D	Resistor network, SMT, Leadless
R 41	4-01644-463	10KX8D	Resistor network, SMT, Leadless
R 42	4-01644-463	10KX8D	Resistor network, SMT, Leadless
R 43	4-01616-463	3.3KX8D	Resistor network, SMT, Leadless
R 61	4-00320-409	18	Resistor, Wire Wound
R 62	4-00320-409	18	Resistor, Wire Wound
R 331	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 332	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 333	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 334	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 335	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 336	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 337	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 338	4-00992-462	49.9	Thin Film, 1%, 50 ppm, MELF Resistor
R 541	4-01213-462	10.0K	Thin Film, 1%, 50 ppm, MELF Resistor
R 581	4-01125-462	1.21K	Thin Film, 1%, 50 ppm, MELF Resistor

Process Control Board			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
U 11	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 12	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 13	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 21	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 22	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 31	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 32	3-01057-360	LTV847S	Integrated Circuit (Surface Mount Pkg)
U 33	3-01465-360	74C240	Integrated Circuit (Surface Mount Pkg)
U 51	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 52	3-00743-360	SN74HC138D	Integrated Circuit (Surface Mount Pkg)
U 53	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 54	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 55	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 56	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 57	3-00750-360	74HC573	Integrated Circuit (Surface Mount Pkg)
U 58	3-00747-360	74HC273	Integrated Circuit (Surface Mount Pkg)
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00048-011	6-32 KEP	Nut, Kep
Z 0	0-00079-031	4-40X3/16 M/F	Standoff
Z 0	0-00222-021	6-32X1/4PP	Screw, Panhead Phillips
Z 0	0-00577-024	2-56X1/8 PAN	Screw, Slotted
Z 0	0-00796-024	2-56X3/16SP	Screw, Slotted
Z 0	0-00998-032	2-56 X 3/16 F/F	Termination
Z 0	1-00586-131	24 PIN	Connector, Female
Z 0	1-00592-169	9" 40 PIN DB37	Cable Assembly, Custom
Z 0	7-01157-720	PLATE, PROC CNT	Fabricated Part
Z 0	7-01158-720	BCKT, PROC CNT	Fabricated Part
Z 0	7-01290-709	IGC	Lexan Overlay
Z 0	7-01303-709	IGC	Lexan Overlay

Dual Ion Gauge Box

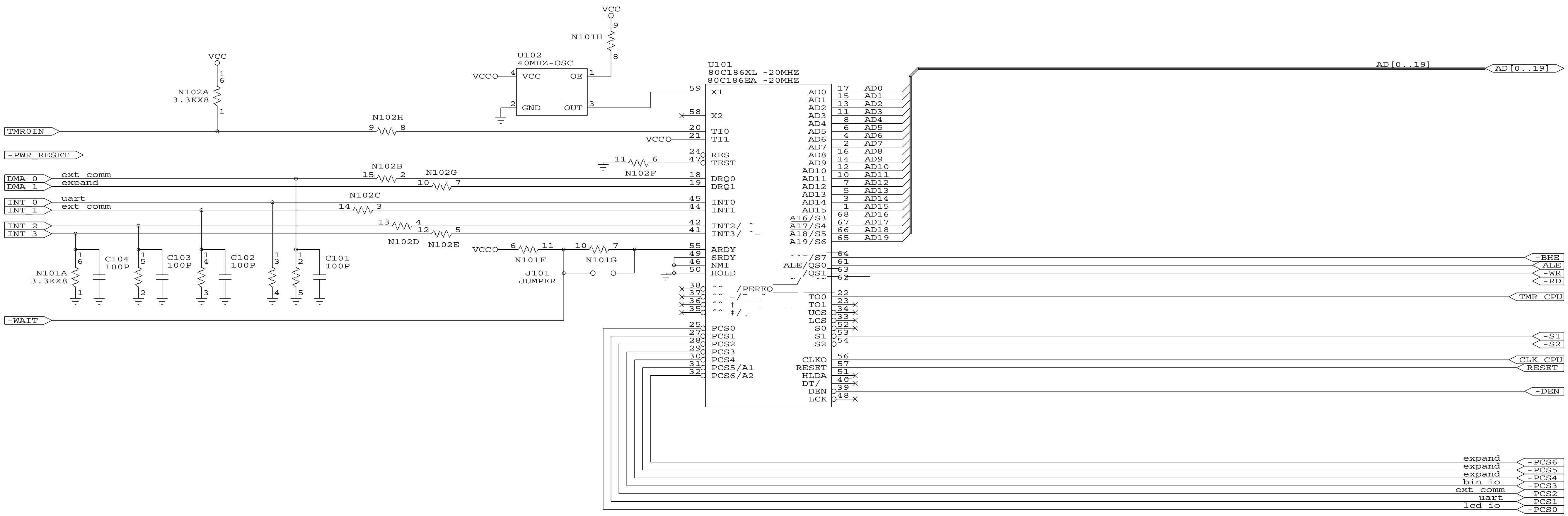
Dual Ion Gauge Box			
Ref No.	**SRS Part No.**	**Value**	**Component Description**
K 1	3-01395-335	SCL-1-DPDT-24V	Relay
K 2	3-01395-335	SCL-1-DPDT-24V	Relay
K 3	3-01394-335	241CX*1K2CAB	Relay
PC1	7-01265-701	IGC RELAY BOX	Printed Circuit Board
Z 0	0-00038-006	66099-4	NIM (Nuclear Instrumentation Module)
Z 0	0-00039-006	66101-4	NIM (Nuclear Instrumentation Module)
Z 0	0-00043-011	4-40 KEP	Nut, Kep
Z 0	0-00089-033	4"	Tie
Z 0	0-00209-021	4-40X3/8PP	Screw, Panhead Phillips
Z 0	0-00306-026	4-40X3/16PP	Screw, Black, All Types
Z 0	0-00894-026	4-40X1/2PP	Screw, Black, All Types
Z 0	0-01001-048	6" #18 UL1015	Wire, #18 UL1015 Strip 3/8 x 3/8 No Tin
Z 0	0-01002-050	6" BROWN	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01003-050	6" BLUE	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01004-050	6" ORANGE	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01005-050	6" BLACK	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01006-050	6" VIOLET	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01007-050	6" GREY	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01008-050	6" WHITE	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01009-050	6" GREEN	Wire #18 UL1007 Stripped 3/8x3/8 No Tin
Z 0	0-01010-000	RUBBER GROMMET	Hardware, Misc.
Z 0	1-00541-110	206043-1	Pins & Connectors, AMP
Z 0	1-00612-176	1238	Terminal, Male
Z 0	1-00615-169	DUAL IG BOX	Cable Assembly, Custom
Z 0	7-00581-721	SR625-6	Machined Part
Z 0	7-01281-720	IGC	Fabricated Part
Z 0	7-01282-720	IGC	Fabricated Part
Z 0	7-01283-720	IGC	Fabricated Part
Z 0	7-01291-709	IGC	Lexan Overlay

VCPU.E

RevD:

Buffer SYSCLK and TMR0OUT with U211
Move N102H from TI1 to TI0
Change R511 to 3.3k

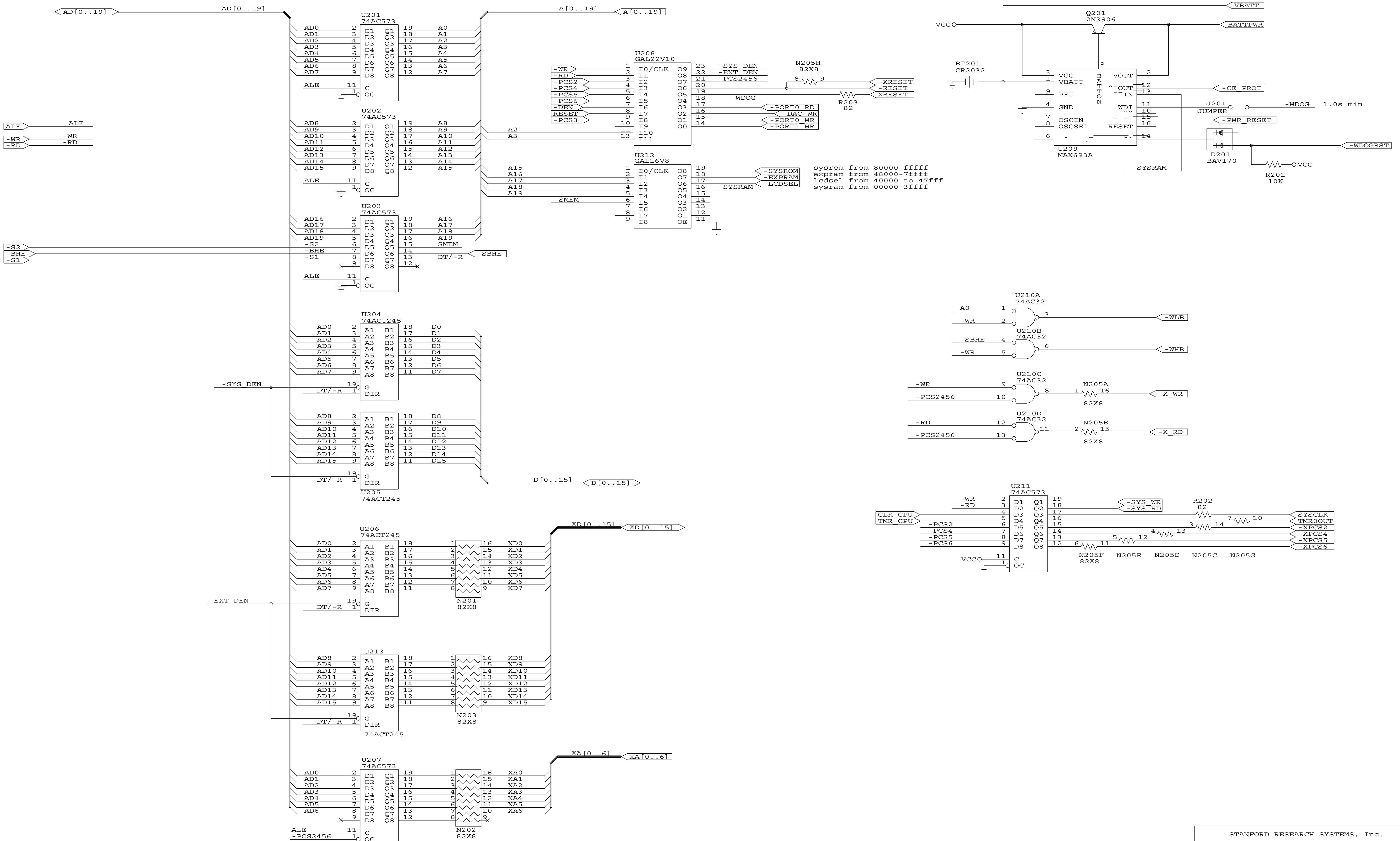
RevE:
Change Flash to 48pin TSOP
Add D520
Add grounding caps C69X



LINK
VCPU2.
VCPU3.
VCPU4.
VCPU5.
VCPU6.

STANFORD RESEARCH SYSTEMS, Inc.
1290-D Reamwood Avenue
Sunnyvale, CA 94089
(408) 744-9040

Title		
	CPU	
Size	Document Number	REV
C	VCPU-1	E
Date: April 22, 2002	Sheet 1 of 6	



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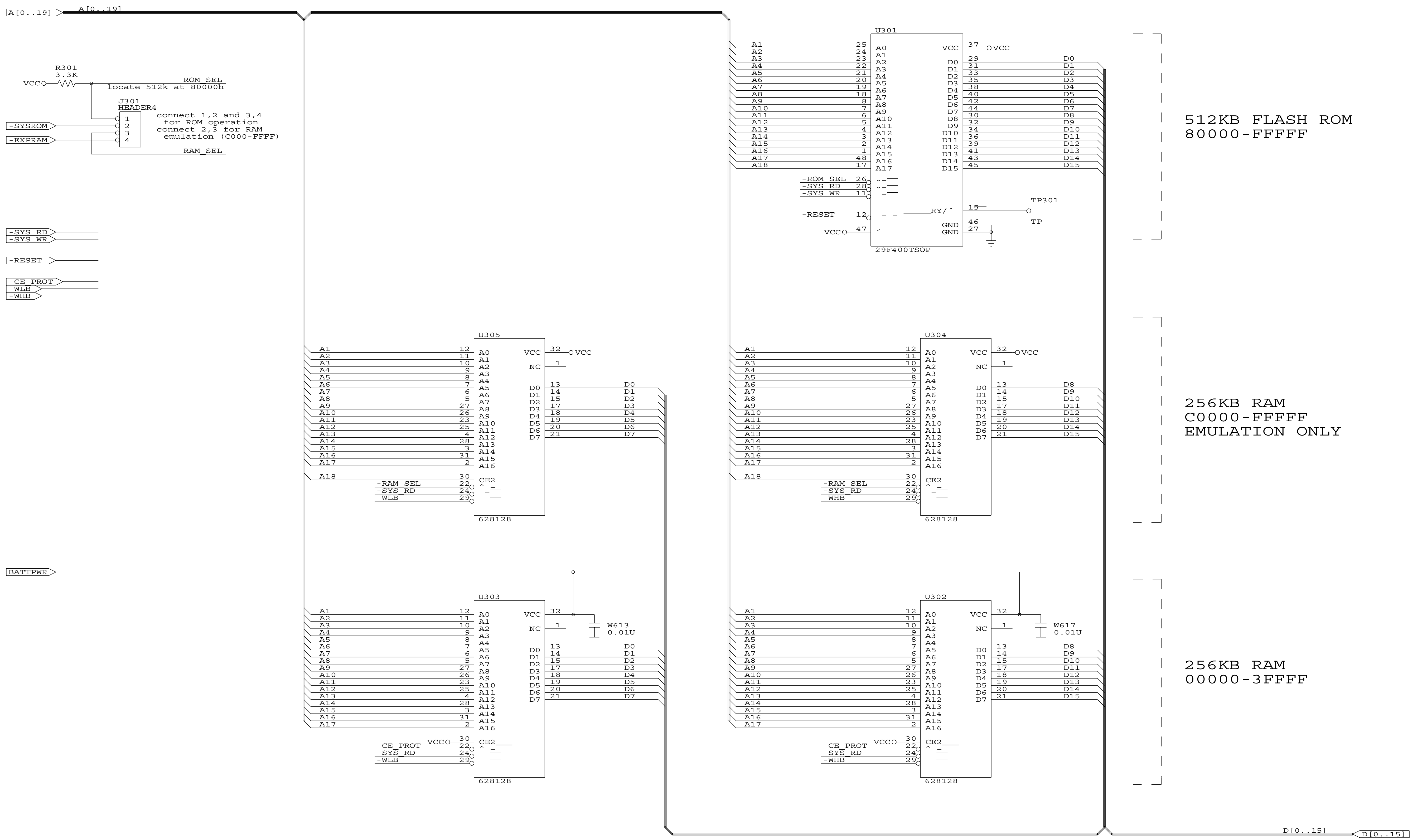
Title: ADDRESS AND DATA BUFFERS		
Size: C	Document Number: VCPU-2	REV: E
Date: December 5, 2001	Sheet 2 of 6	



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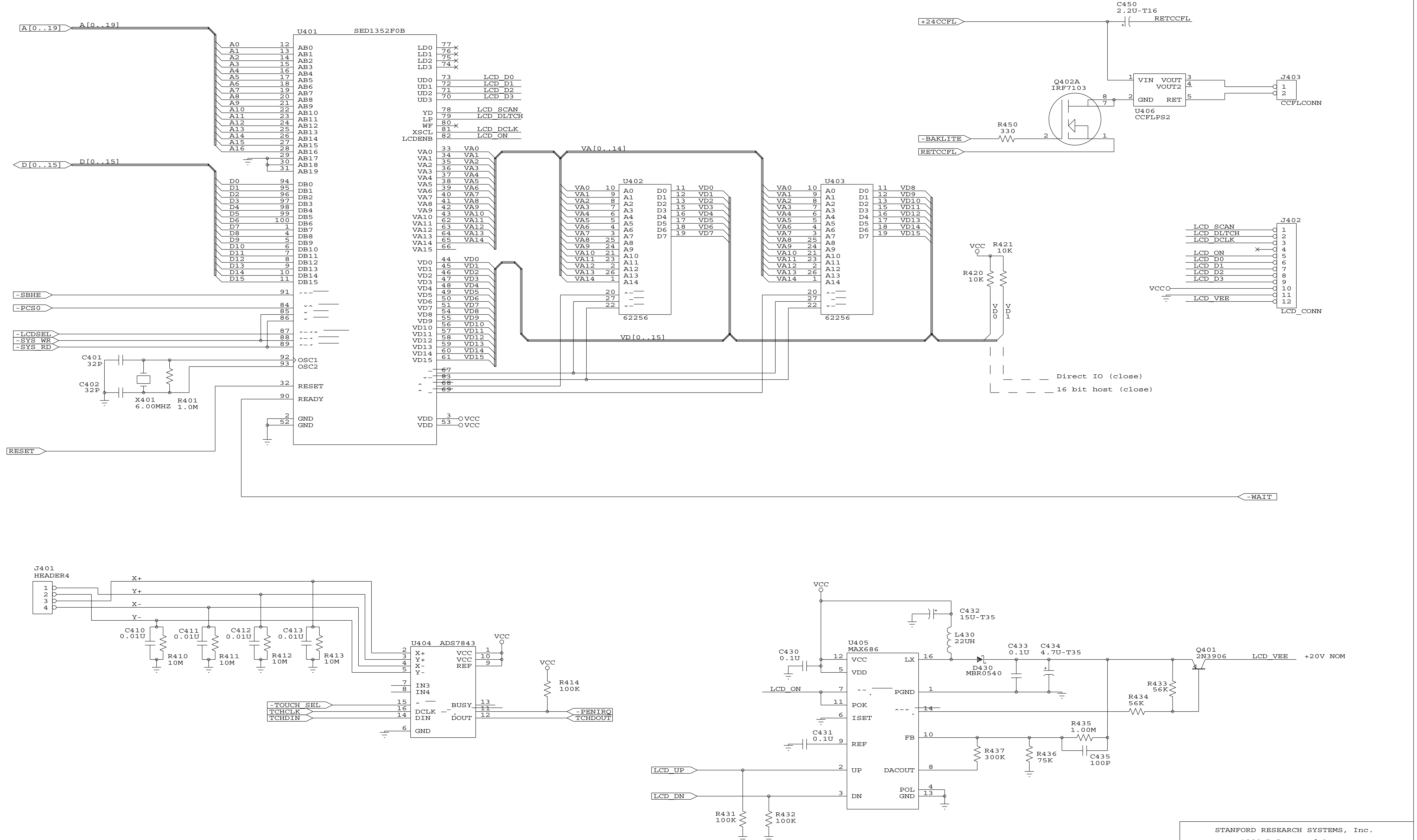
Title		
SYSTEM MEMORY		
Size	Document Number	REV
C	VCPU-3	E
Date: December 5, 2001	Sheet 3 of 6	



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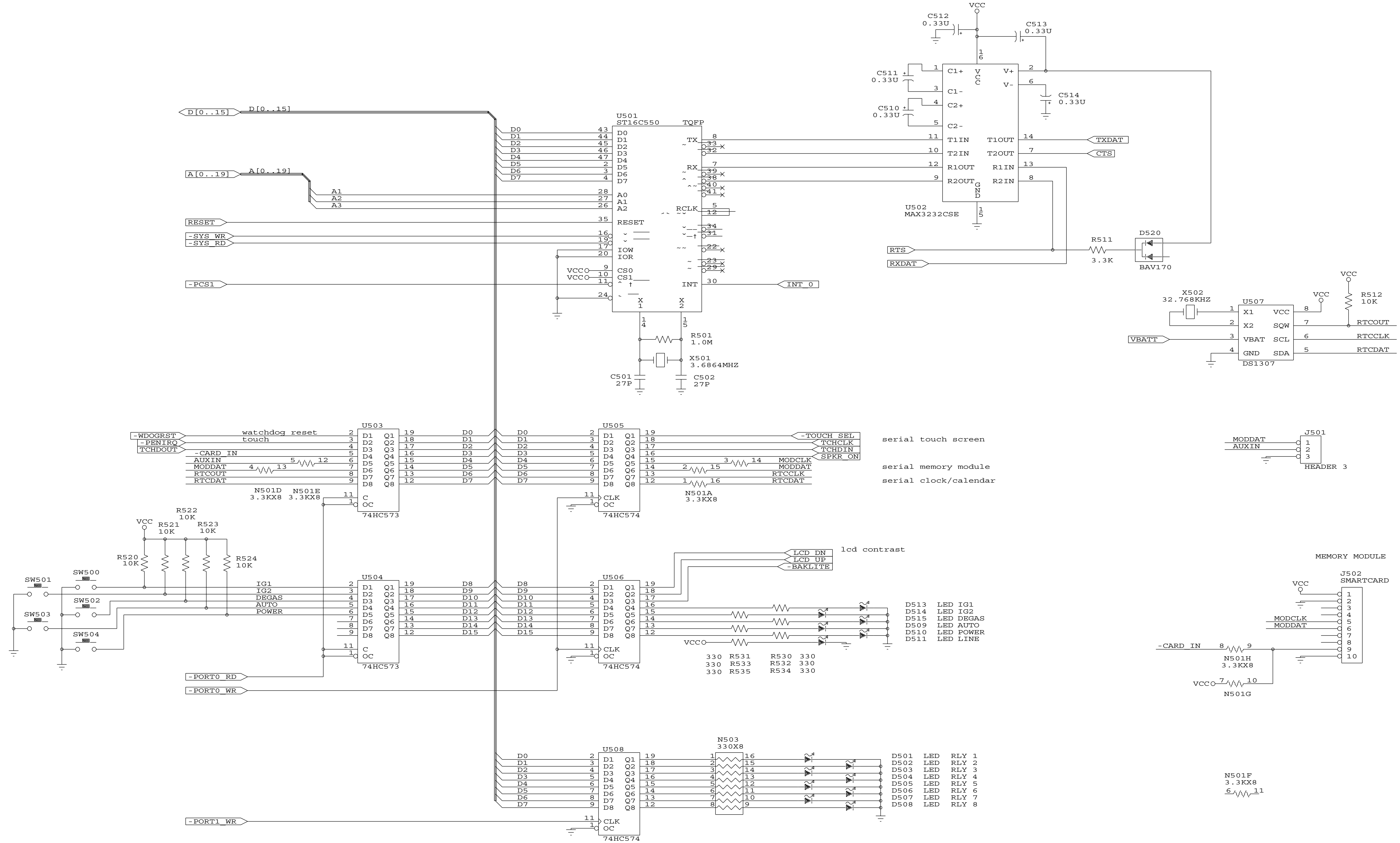
Title		
LCD CONTROLLER		
Size	Document Number	REV
C	VCPU-4	E
Date: December 5, 2001	Sheet 4 of 6	



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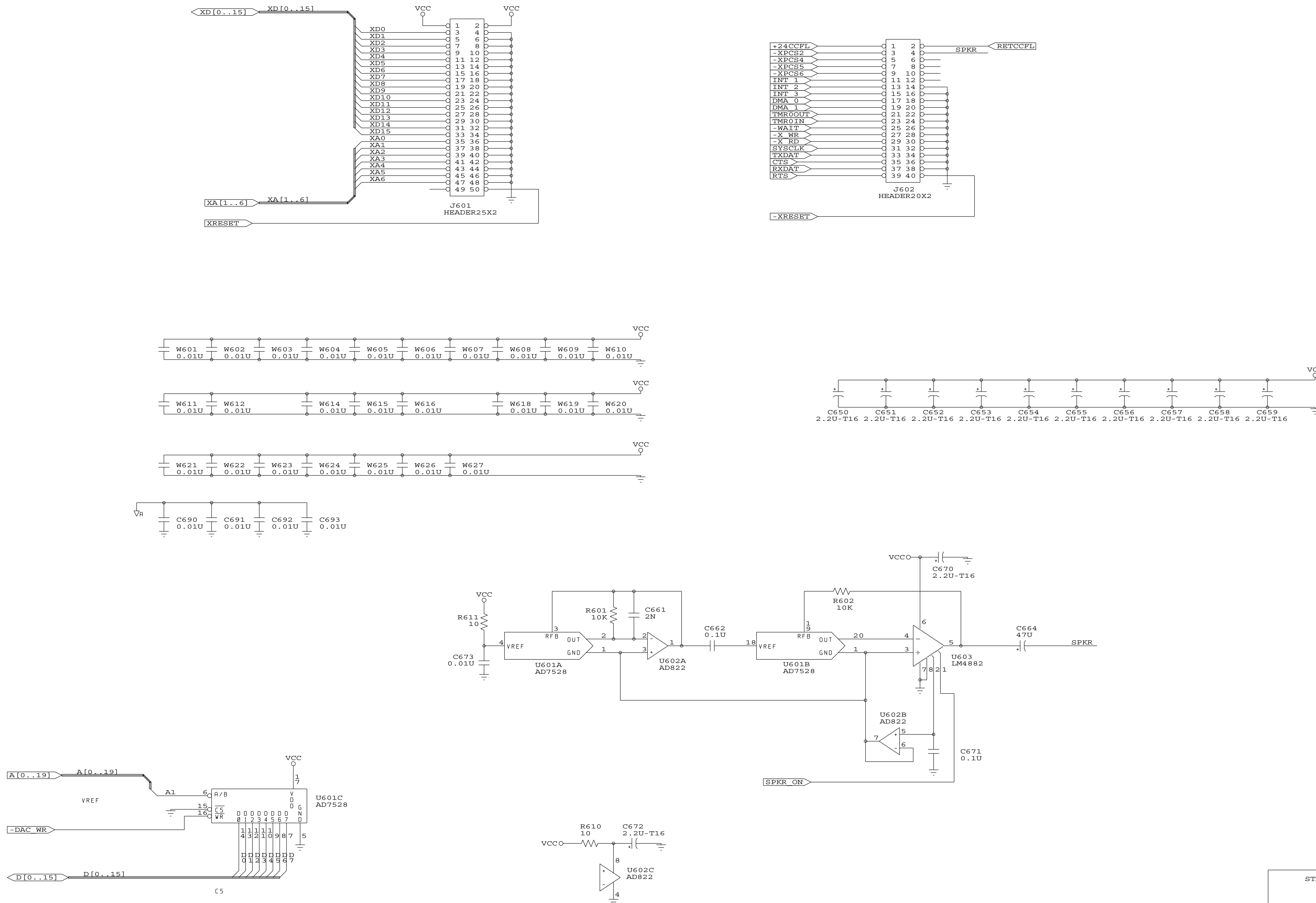
Title		
SERIAL/CLOCK/TOUCH		
Size	Document Number	REV
C	VCPU-5	E
Date: December 5, 2001	Sheet 5 of 6	



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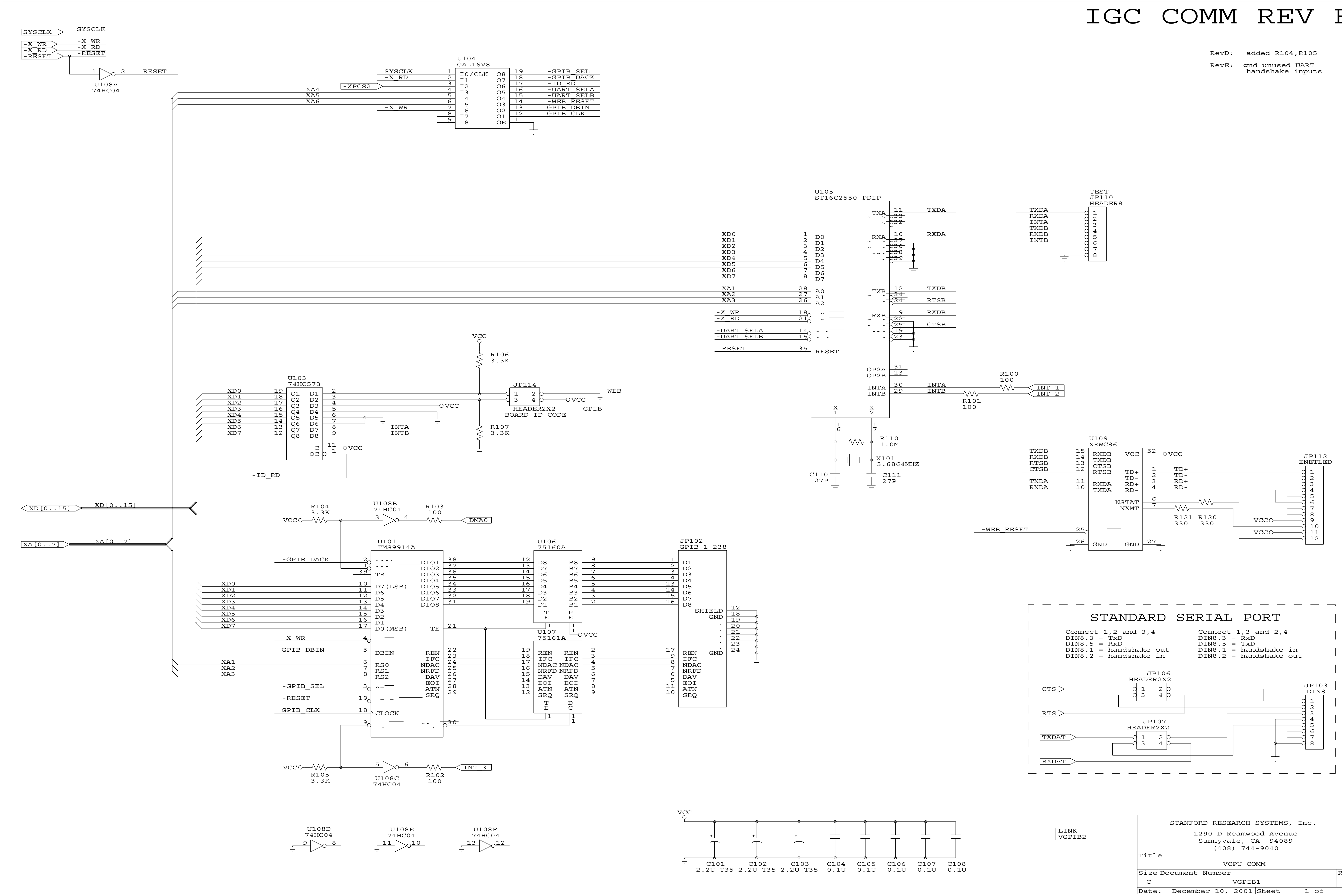
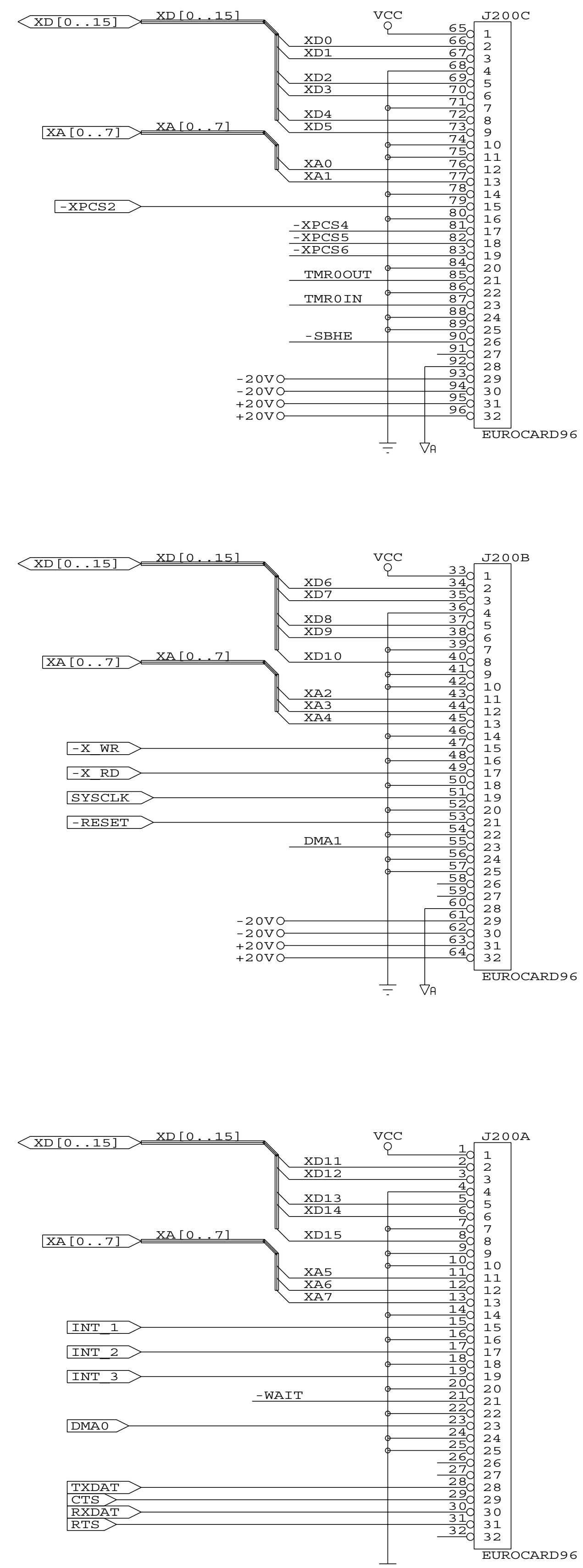
Sunnyvale, CA 94089
(408) 744-9040

Title: INTERCONNECT		
Size: C	Document Number: VCPU-6	REV: E
Date: April 22, 2002	Sheet 6 of 6	


IGC COMM REV E
RevD: added R104,R105
RevE: gnd unused UART handshake inputs
SYSCLK
-X_WR
-X_RD
-RESET
U108A 74HC04
U104 GAL16V8
-XPCS2
-GPIB_SEL
-GPIB_DACK
-ID_RD
-UART_SELA
-UART_SELB
-WEB_RESET
GPIB_DBIN
GPIB_CLK
U105 ST16C2550-PDIP
TXDA
RXDA
TXDB
RTSB
RXDB
CTSB
INTA
INTB
TEST JP110 HEADER8
R100 100
R101 100
INT_1
INT_2
R110 1.0M
X101 3.6864MHZ
C110 27P
C111 27P
U109 XEWC86
JP112 ENETLED
R121 330
R120 330
U103 74HC573
R106 3.3K
R107 3.3K
JP114 HEADER2X2 BOARD ID CODE
WEB
GPIB
XD[0..15]
XA[0..7]
R104 3.3K
U108B 74HC04
R103 100
DMA0
U101 TMS9914A
U106 75160A
U107 75161A
JP102 GPIB-1-238
R105 3.3K
U108C 74HC04
R102 100
INT_3
U108D 74HC04
U108E 74HC04
U108F 74HC04
STANDARD SERIAL PORT
Connect 1,2 and 3,4
DIN8.3 = TxD
DIN8.5 = RxD
DIN8.1 = handshake out
DIN8.2 = handshake in
Connect 1,3 and 2,4
DIN8.3 = RxD
DIN8.5 = TxD
DIN8.1 = handshake in
DIN8.2 = handshake out
JP106 HEADER2X2
JP107 HEADER2X2
JP103 DIN8
CTS
RTS
TXDAT
RXDAT
C101 2.2U-T35
C102 2.2U-T35
C103 2.2U-T35
C104 0.1U
C105 0.1U
C106 0.1U
C107 0.1U
C108 0.1U
LINK VGPIB2
STANFORD RESEARCH SYSTEMS, Inc.
1290-D Reamwood Avenue
Sunnyvale, CA 94089
(408) 744-9040
Title
VCPU-COMM
Size C
Document Number VGPIB1
REV E
Date: December 10, 2001
Sheet 1 of 2



Stanford Research Systems
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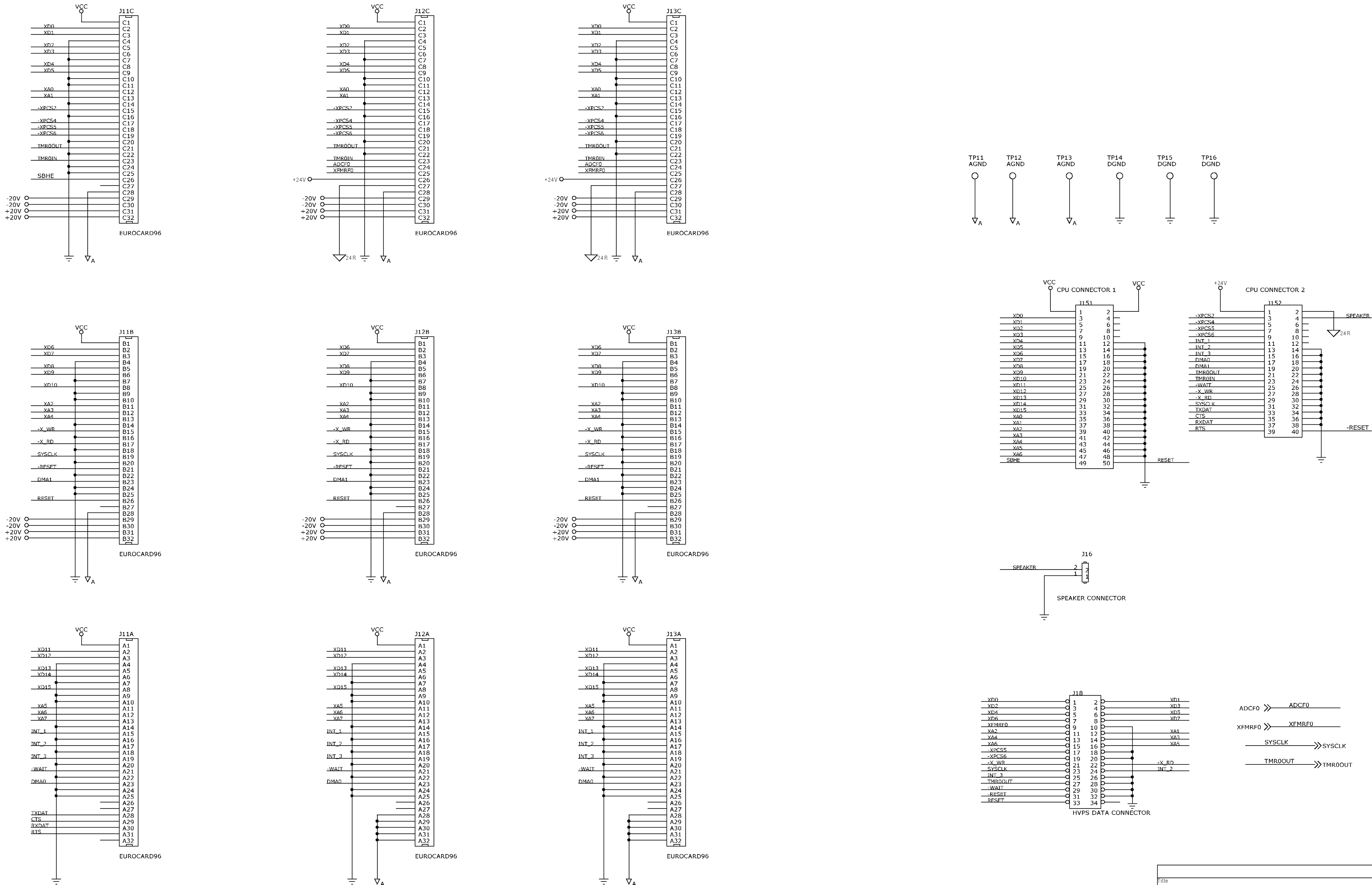
Sunnyvale, CA 94089
(408) 744-9047

Title	VCPU-GPIB CARD	
Size C	Document Number VGPIB2	REV E
Date: December 10, 2001	Sheet 2 of 2	



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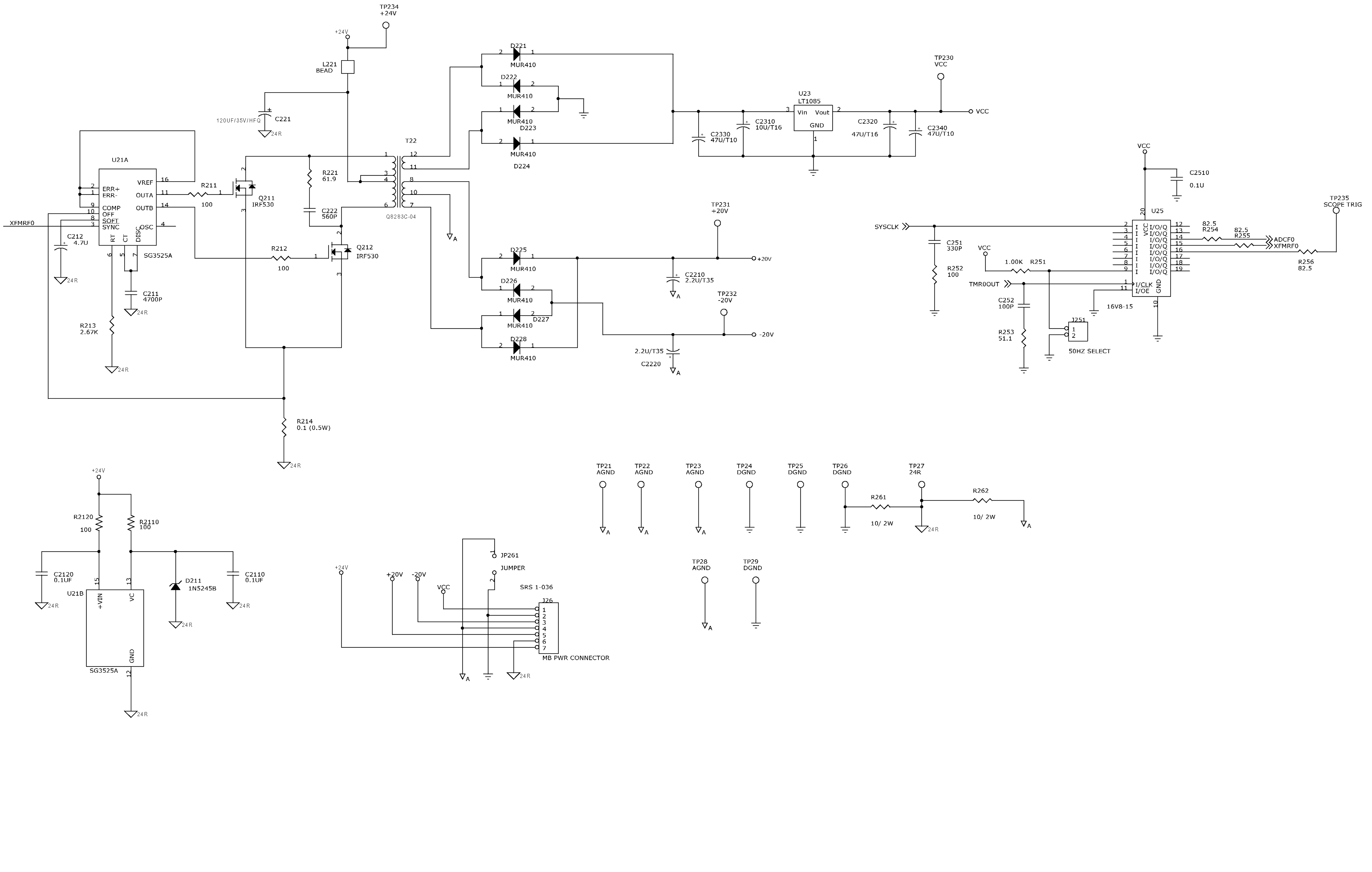
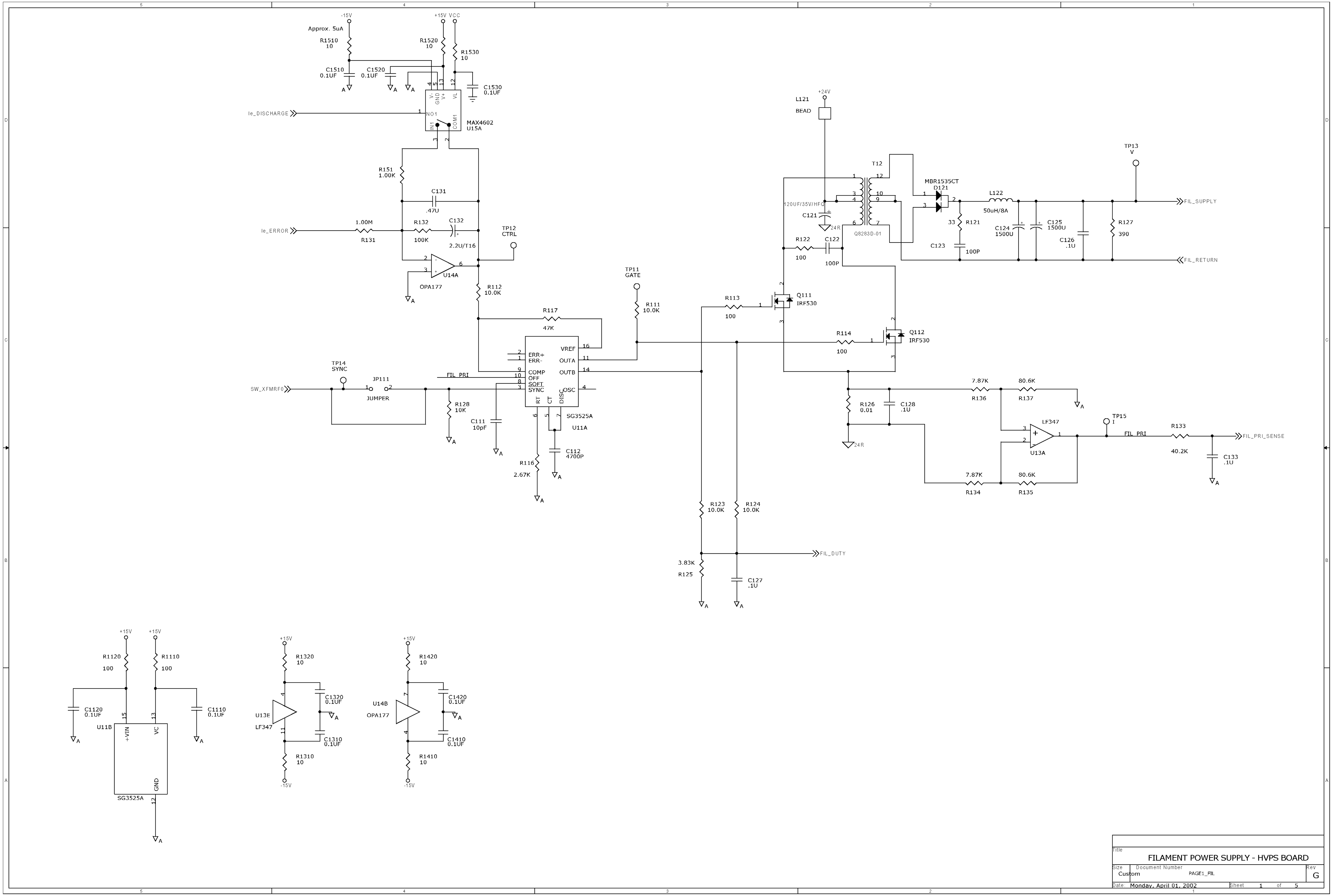
Size	Custom
Document Number	MOTHER BOARD INTERCONNECT
Rev	E
Date	Wednesday, September 19, 2001
Sheet	1 of 2



Title	MOTHER BOARD - IGC100
Size: Custom	Document Number: ANALOG AND DIGITAL POWER SUPPLY	Rev: E
Date: Wednesday, September 19, 2001	Sheet 2 of 2



-15V
+15V VCC
Approx. 5uA
R1510 10
R1520 10
R1530 10
C1510 0.1UF
C1520 0.1UF
C1530 0.1UF
MAX4602 U15A
Ie_DISCHARGE
Ie_ERROR
R151 1.00K
C131 .47U
1.00M R131
R132 100K
C132 2.2U/T16
TP12 CTRL
U14A OPA177
R112 10.0K
R117 47K
TP11 GATE
R111 10.0K
VREF OUTA OUTB COMP OFF SOFT SYNC ERR+ ERR- RT CT DISC OSC
SG3525A U11A
FIL_PRI
TP14 SYNC
SW_XFMRF0
JP111 JUMPER
R128 10K
C111 10pF
R116 2.67K
C112 4700P
R113 100
R114 100
Q111 IRF530
Q112 IRF530
L121 BEAD
+24V
T12 Q8283D-01
120UF/35V/HFQ
C121
24R
R122 100
C122 100P
MBR1535CT D121
L122 50uH/8A
33 R121
C123 100P
C124 1500U
C125 1500U
C126 .1U
R127 390
TP13 V
FIL_SUPPLY
FIL_RETURN
R126 0.01
C128 .1U
7.87K R136
80.6K R137
LF347 U13A
TP15 I
FIL_PRI
R133 40.2K
C133 .1U
FIL_PRI_SENSE
7.87K R134
80.6K R135
R123 10.0K
R124 10.0K
FIL_DUTY
3.83K R125
C127 .1U
R1120 100
R1110 100
C1120 0.1UF
C1110 0.1UF
U11B +VIN VC GND SG3525A
R1320 10
C1320 0.1UF
U13E LF347
C1310 0.1UF
R1310 10
U14B OPA177
R1420 10
C1420 0.1UF
C1410 0.1UF
R1410 10
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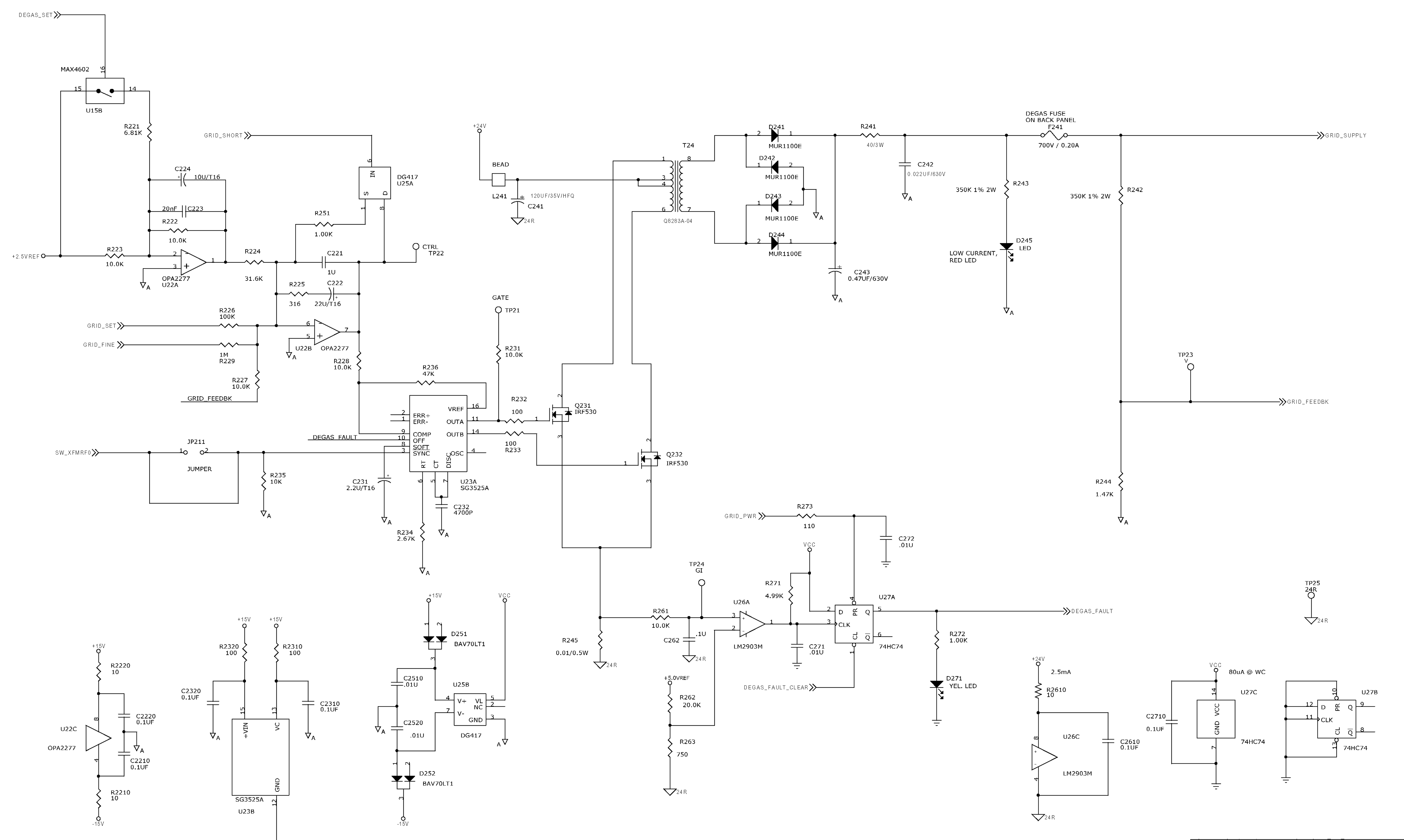
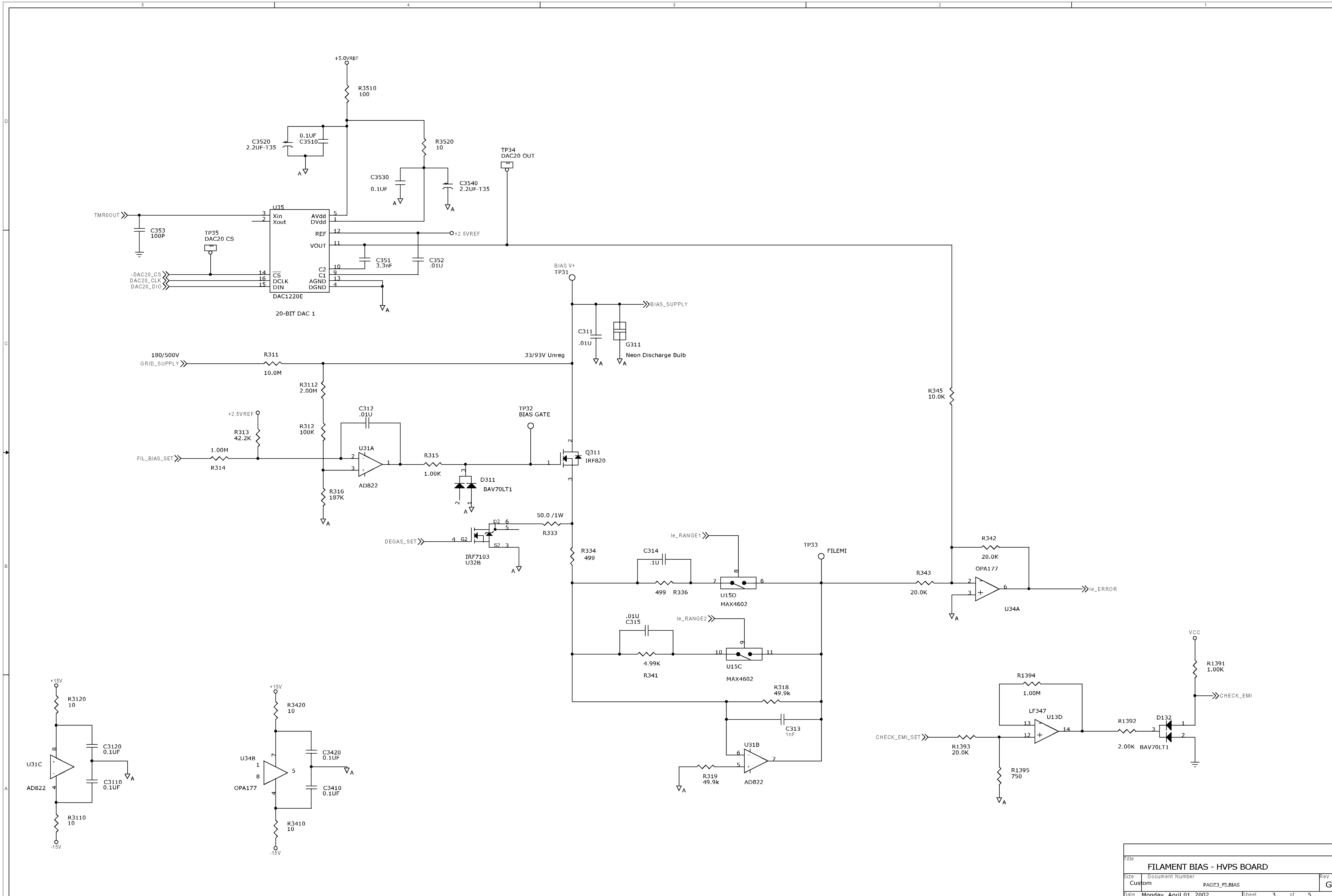
FILAMENT POWER SUPPLY - HVPS BOARD
Size Custom
Document Number PAGE1_FIL
Rev G
Date: Monday, April 01, 2002
Sheet 1 of 5



Title		
GRID POWER SUPPLY - HVPS BOARD		
Size: Custom	Document Number: PAGE2_GRID1BIAS	Rev: G
Date: Monday, April 01, 2002	Sheet 2 of 5	


+5.0VREF
R3510
100
C3520
2.2UF-T35
0.1UF
C3510
R3520
10
C3530
0.1UF
C3540
2.2UF-T35
TP34
DAC20 OUT
TMR0OUT
C353
100P
TP35
DAC20 CS
U35
Xin
Xout
AVdd
DVdd
REF
VOUT
CS
DCLK
DIN
C2
C1
AGND
DGND
DAC1220E
20-BIT DAC 1
+2.5VREF
C351
3.3nF
C352
.01U
-DAC20_CS
DAC20_CLK
DAC20_DIO
BIAS V+
TP31
BIAS_SUPPLY
C311
.01U
G311
Neon Discharge Bulb
180/500V
GRID_SUPPLY
R311
10.0M
33/93V Unreg
R3112
2.00M
R312
100K
+2.5VREF
R313
42.2K
C312
.01U
U31A
AD822
TP32
BIAS GATE
FIL_BIAS_SET
1.00M
R314
R315
1.00K
Q311
IRF820
D311
BAV70LT1
R316
187K
R345
10.0K
50.0 /1W
R333
DEGAS_SET
IRF7103
U32B
R334
499
C314
.1U
499
R336
Ie_RANGE1
U15D
MAX4602
TP33
FILEMI
R342
20.0K
OPA177
R343
20.0K
Ie_ERROR
U34A
.01U
C315
Ie_RANGE2
4.99K
R341
U15C
MAX4602
R318
49.9k
C313
1nF
U31B
AD822
R319
49.9k
VCC
R1391
1.00K
CHECK_EMI
R1394
1.00M
LF347
U13D
R1392
2.00K
D132
BAV70LT1
CHECK_EMI_SET
R1393
20.0K
R1395
750
+15V
R3120
10
C3120
0.1UF
U31C
AD822
C3110
0.1UF
R3110
10
-15V
+15V
R3420
10
U34B
OPA177
C3420
0.1UF
C3410
0.1UF
R3410
10
-15V
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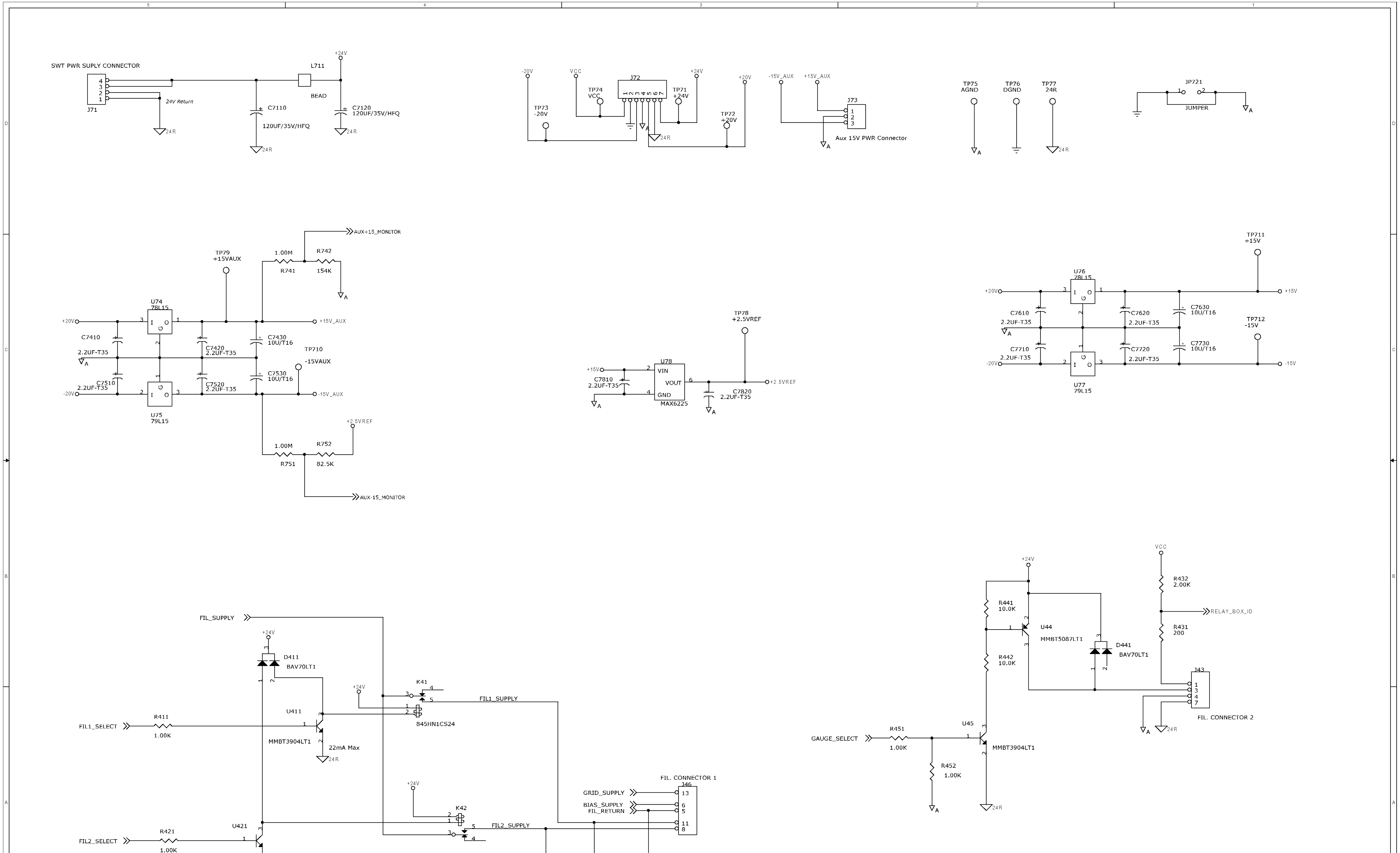
FILAMENT BIAS - HVPS BOARD
Size
Custom
Document Number
PAGE3_FILBIAS
Rev
G
Date: Monday, April 01, 2002
Sheet 3 of 5



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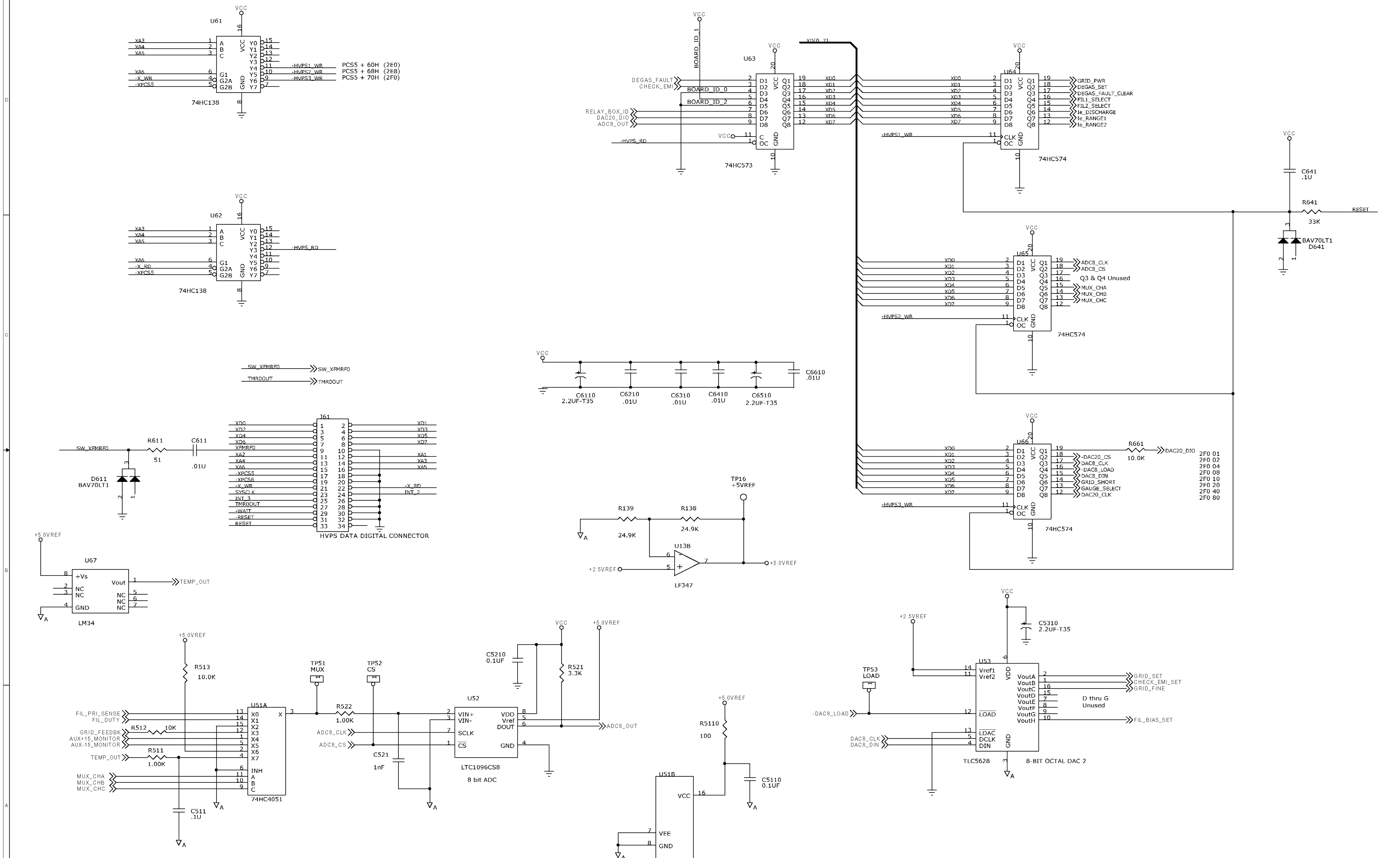
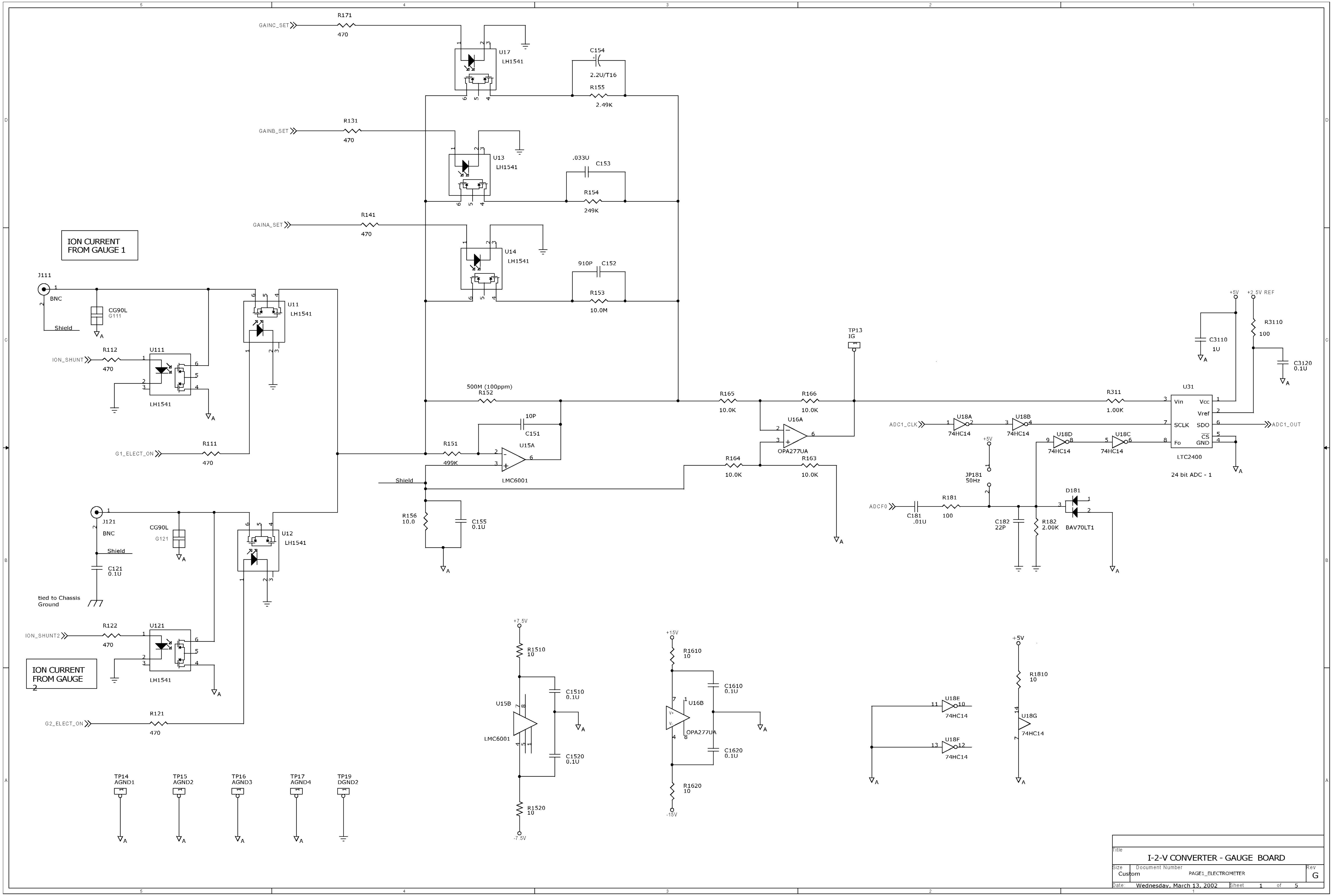
Size: Custom	Document Number: PAGE4_ANALOGPS & RELAYS	Rev: G
Date: Monday, April 01, 2002	Sheet 4 of 5	



Title: INTERFACE & ADC/DAC - HVPS BOARD

Size	Document Number	Rev
Custom	PAGE5_INTERFACE	G

Date: Monday, April 01, 2002 — Sheet 5 of 5



GAINC_SET
R171
470
U17
LH1541
C154
2.2U/T16
R155
2.49K
GAINB_SET
R131
470
U13
LH1541
.033U
C153
R154
249K
GAINA_SET
R141
470
U14
LH1541
910P
C152
R153
10.0M
ION CURRENT
FROM GAUGE 1
J111
BNC
CG90L
G111
Shield
U11
LH1541
ION_SHUNT
R112
470
U111
LH1541
G1_ELECT_ON
R111
470
500M (100ppm)
R152
10P
C151
R151
499K
U15A
LMC6001
Shield
R156
10.0
C155
0.1U
TP13
IG
R165
10.0K
R166
10.0K
U16A
OPA277UA
R164
10.0K
R163
10.0K
J121
BNC
CG90L
G121
Shield
C121
0.1U
tied to Chassis
Ground
U12
LH1541
ION_SHUNT2
R122
470
U121
LH1541
ION CURRENT
FROM GAUGE
2
G2_ELECT_ON
R121
470
+5V
+2.5V REF
R3110
100
C3110
1U
C3120
0.1U
R311
1.00K
U31
Vin
Vcc
Vref
SCLK
SDO
CS
Fo
GND
LTC2400
24 bit ADC - 1
ADC1_CLK
U18A
74HC14
U18B
74HC14
ADC1_OUT
U18D
74HC14
U18C
74HC14
JP181
50Hz
D181
BAV70LT1
ADCF0
C181
.01U
R181
100
C182
22P
R182
2.00K
+7.5V
R1510
10
C1510
0.1U
U15B
LMC6001
C1520
0.1U
R1520
10
-7.5V
+15V
R1610
10
C1610
0.1U
U16B
OPA277UA
C1620
0.1U
R1620
10
-15V
U18E
74HC14
U18F
74HC14
+5V
R1810
10
U18G
74HC14
TP14
AGND1
TP15
AGND2
TP16
AGND3
TP17
AGND4
TP19
DGND2
Title
I-2-V CONVERTER - GAUGE BOARD
Size
Custom
Document Number
PAGE1_ELECTROMETER
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Date
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1
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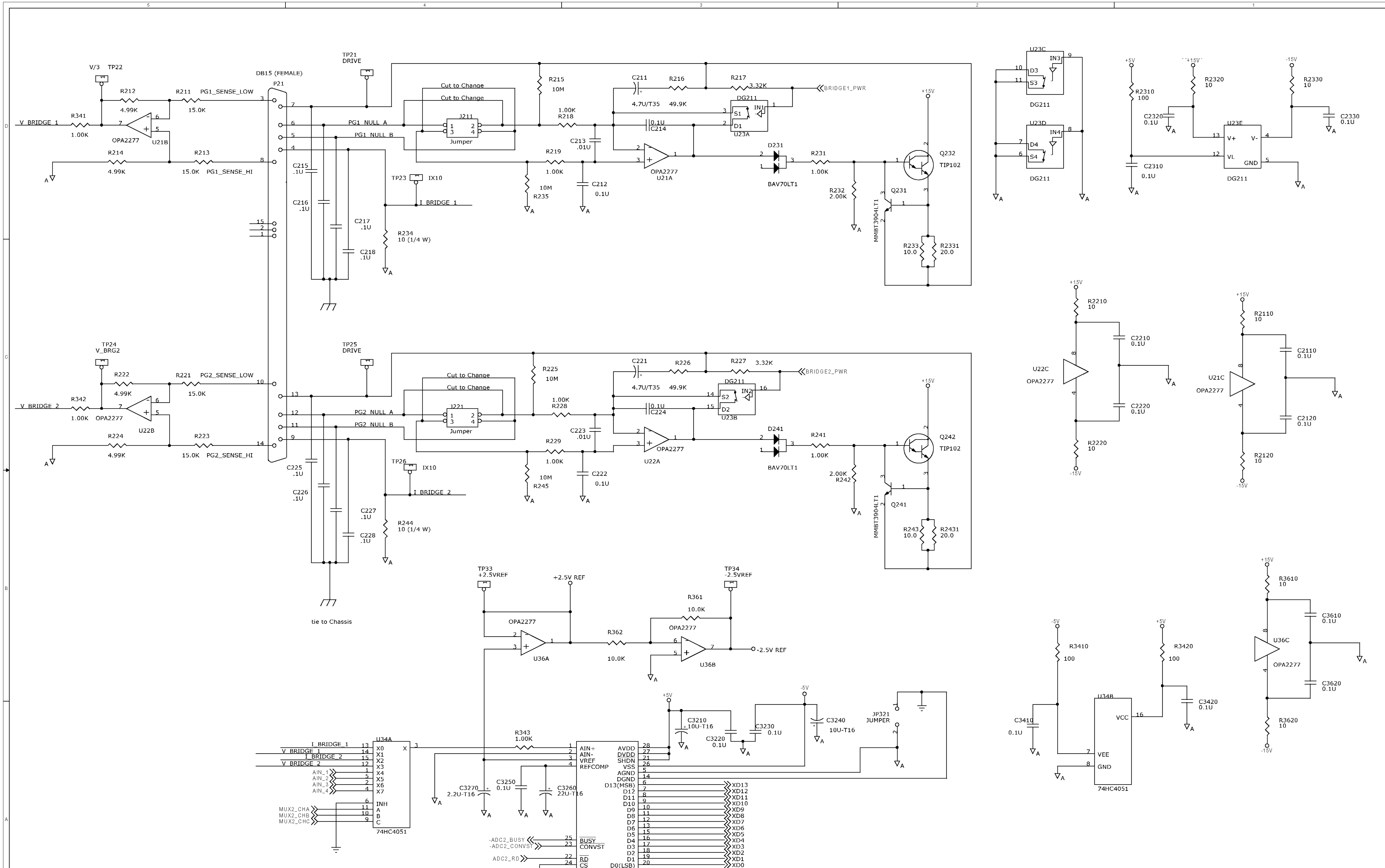
5



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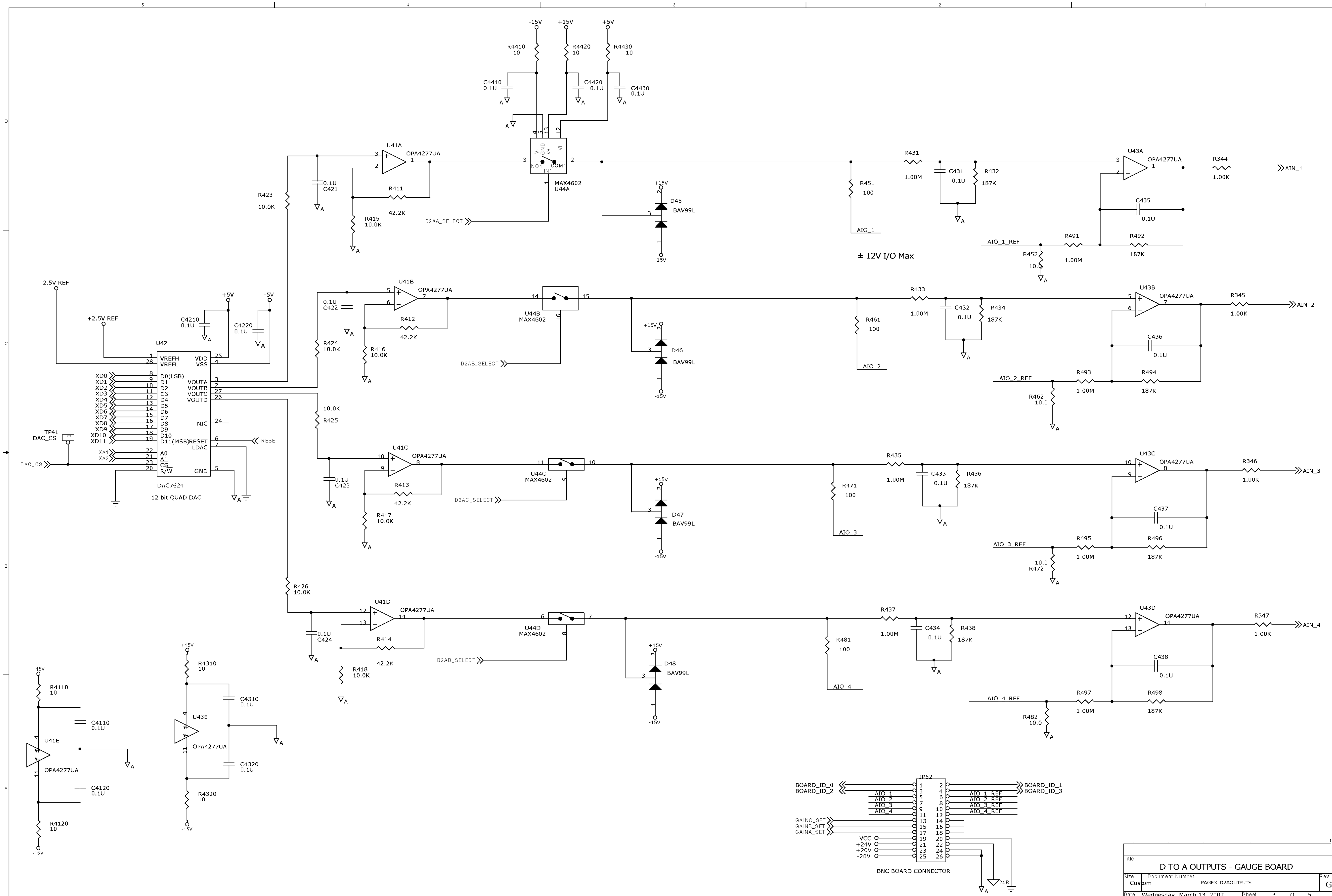
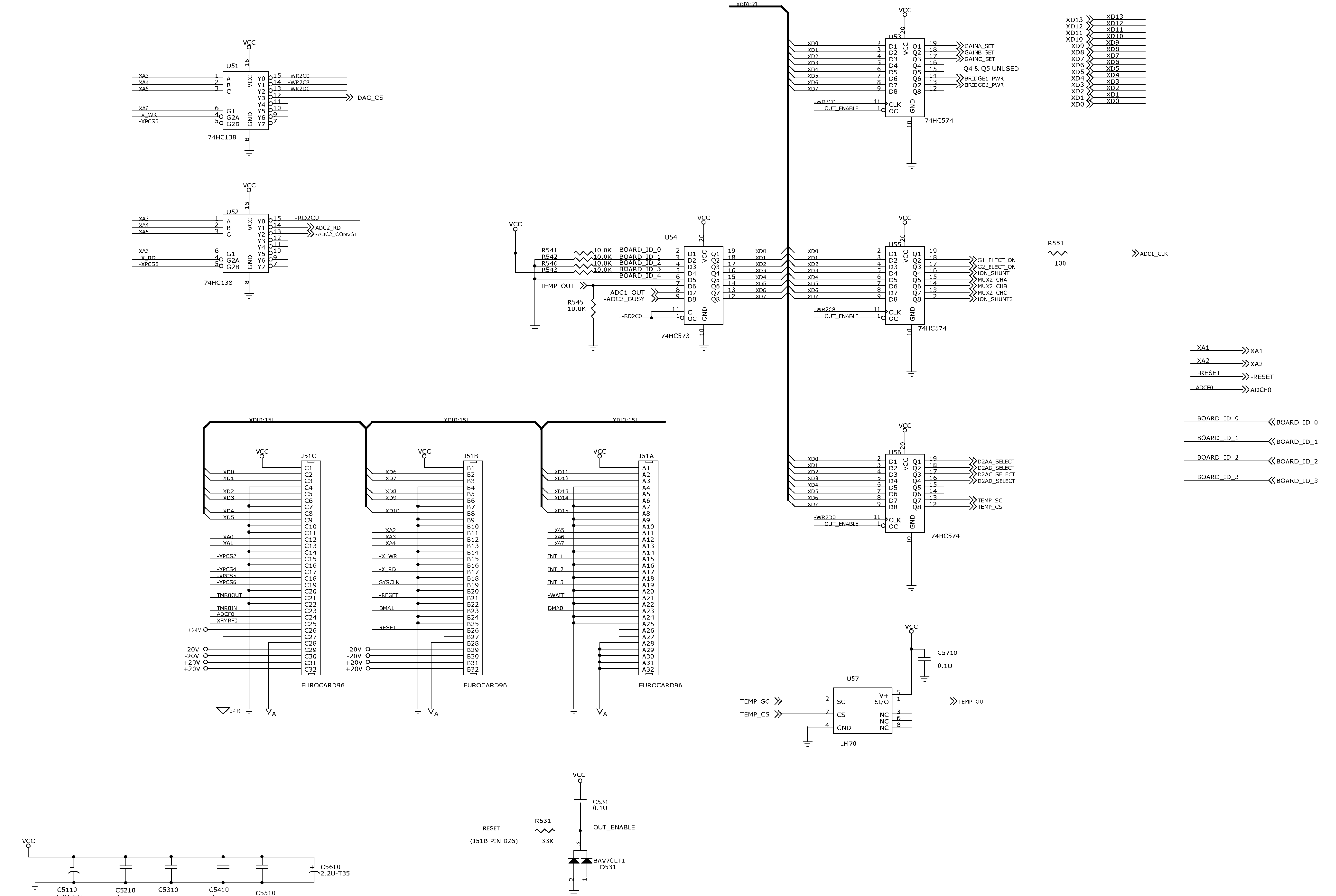
Size: Custom	Document Number: PAGE2_PIRANI		Rev: G
Date: Friday, March 29, 2002	Sheet 2 of 5		



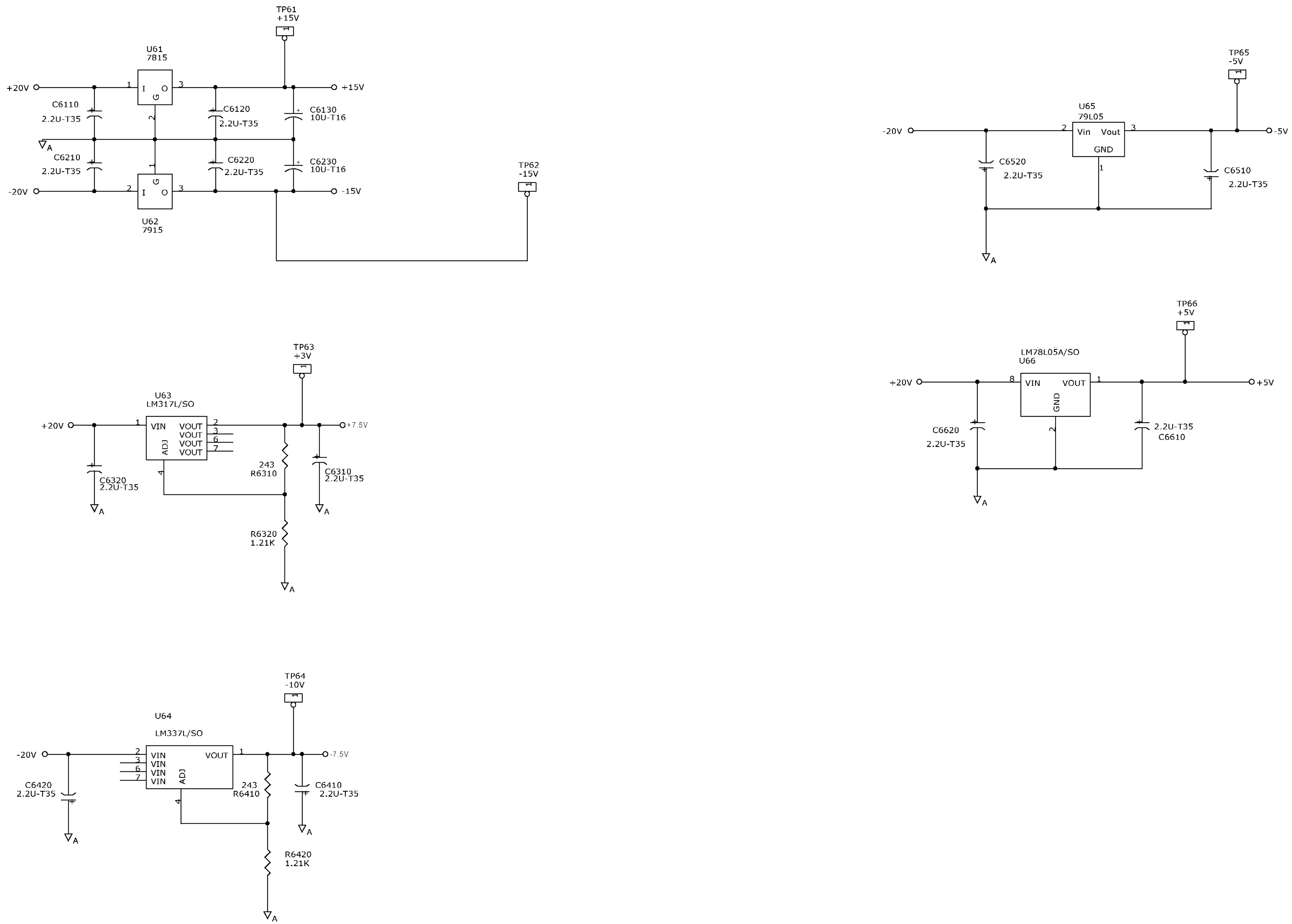
Title	D TO A OUTPUTS - GAUGE BOARD
Size: Custom	Document Number: PAGE3_D2AOUTPUTS
Rev	G
Date: Wednesday, March 13, 2002	Sheet 3 of 5



Title: INTERFACE- GAUGE BOARD

Size	Document Number	Rev
Custom	PAGE4_INTERFACE	G

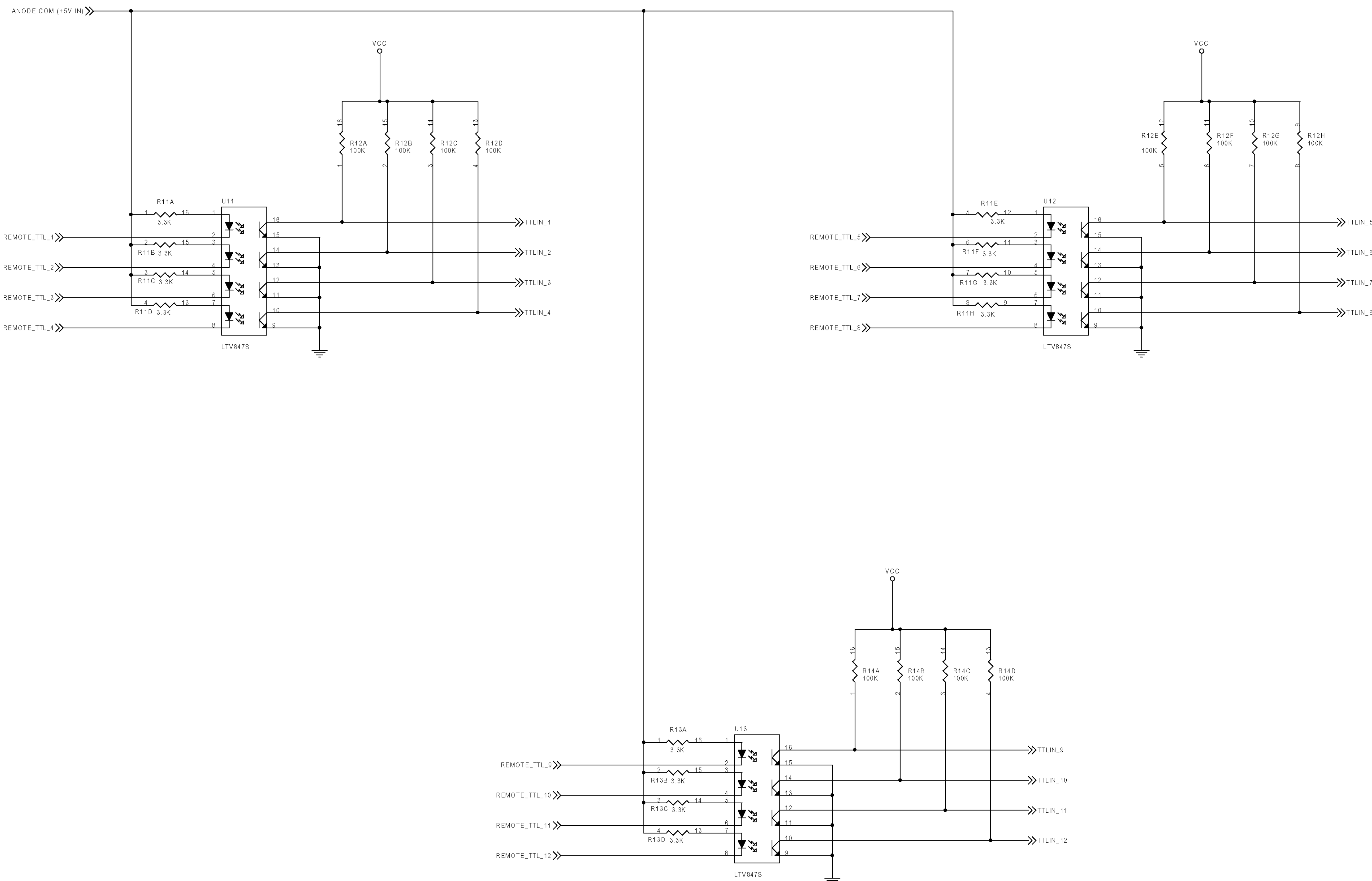
Date: Friday, March 29, 2002 Sheet 4 of 5



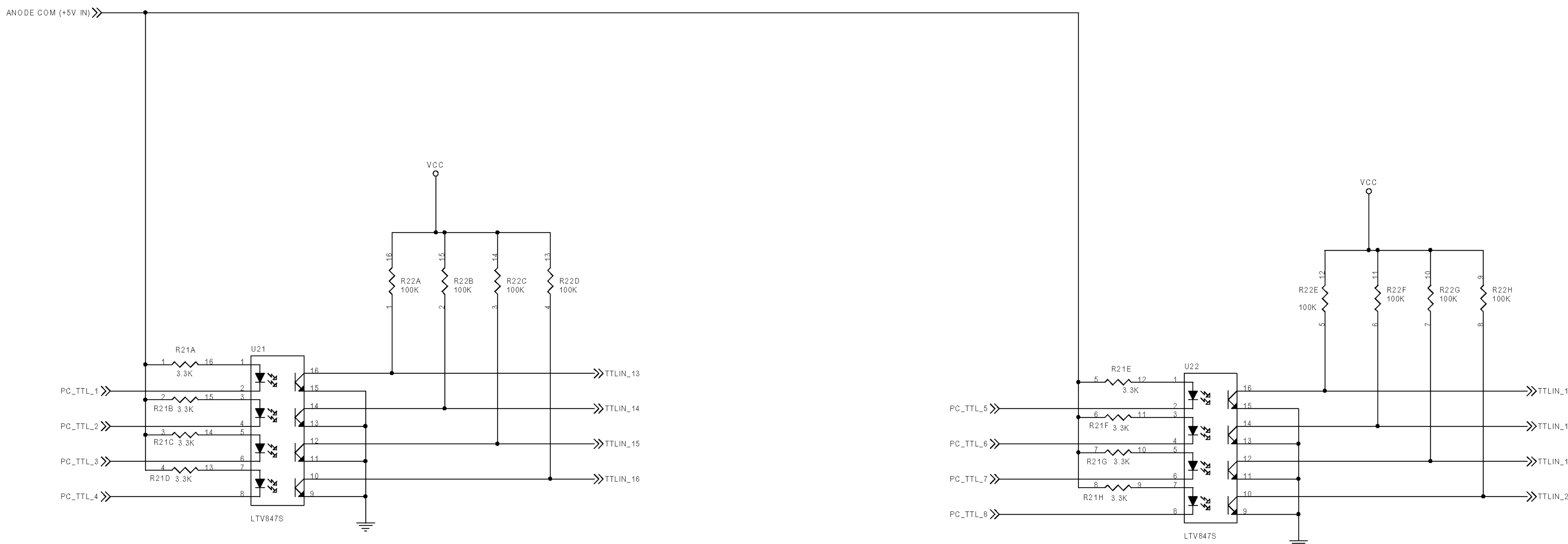
Title
CIRCUIT POWER - GAUGE BOARD

Size	Document Number	Rev
Custom	PAGE5_POWER	G

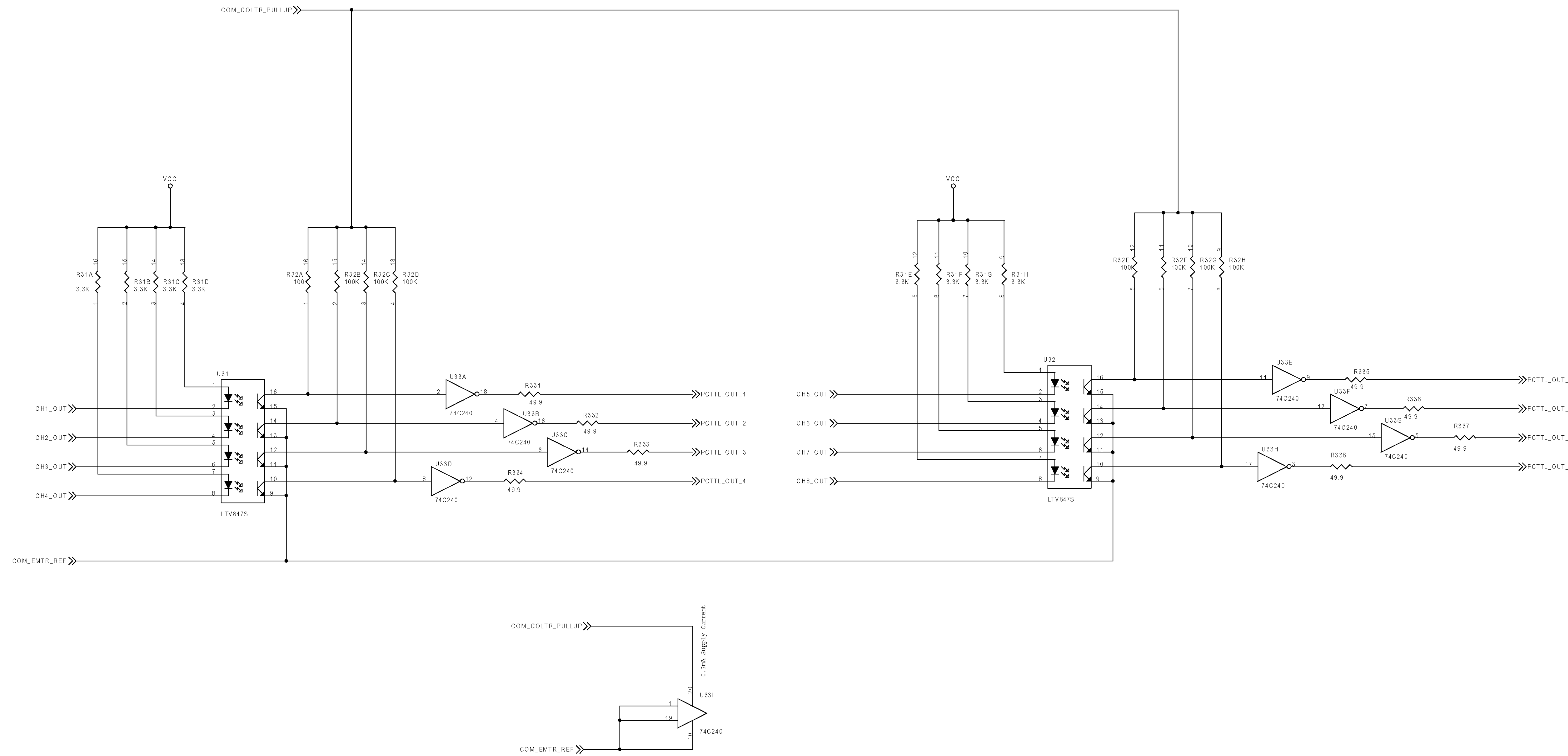
Date: Wednesday, March 13, 2002 Sheet 5 of 5



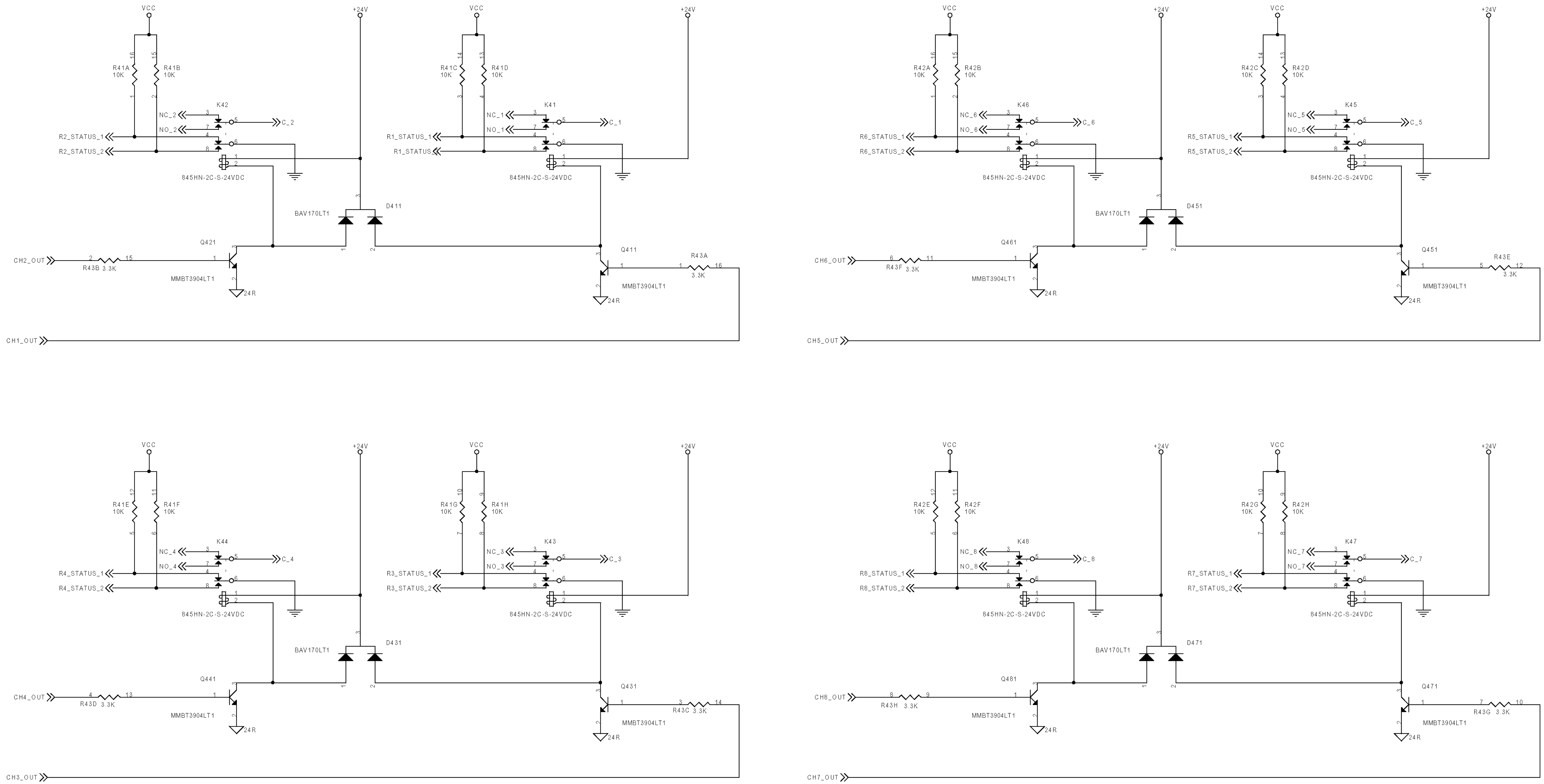
Title	Process Controller for IGC100		
Size: Custom	Document Number: REMOTE_TTL_INPUT		Rev: C
Date: Friday, March 22, 2002	Sheet 1 of 6		



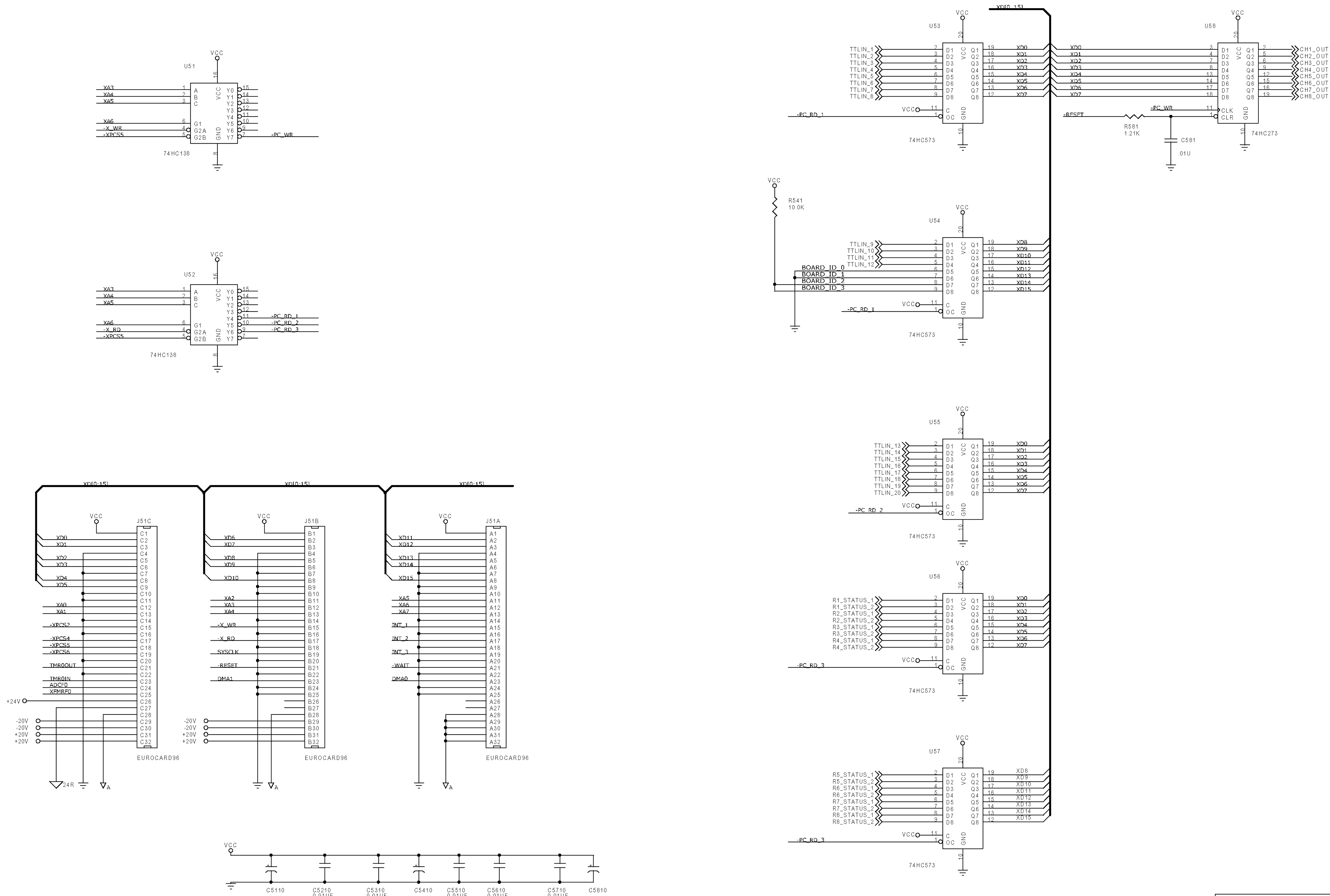
Title		
Process Controller for IGC100		
Size: Custom	Document Number: PC_TTL_INPUT	Rev: C
Date: Friday, March 22, 2002	Sheet 2 of 6	



Title	Process Controller for IGC100
Size: Custom	Document Number: TTL_OUTPUT
Rev	C
Date	Friday, March 22, 2002
Sheet	3 of 6



Title	Process Controller for IGC100	
Size Custom	Document Number RELAY_OUTPUT	Rev C
Date Friday, March 22, 2002	Sheet 4 of 6	

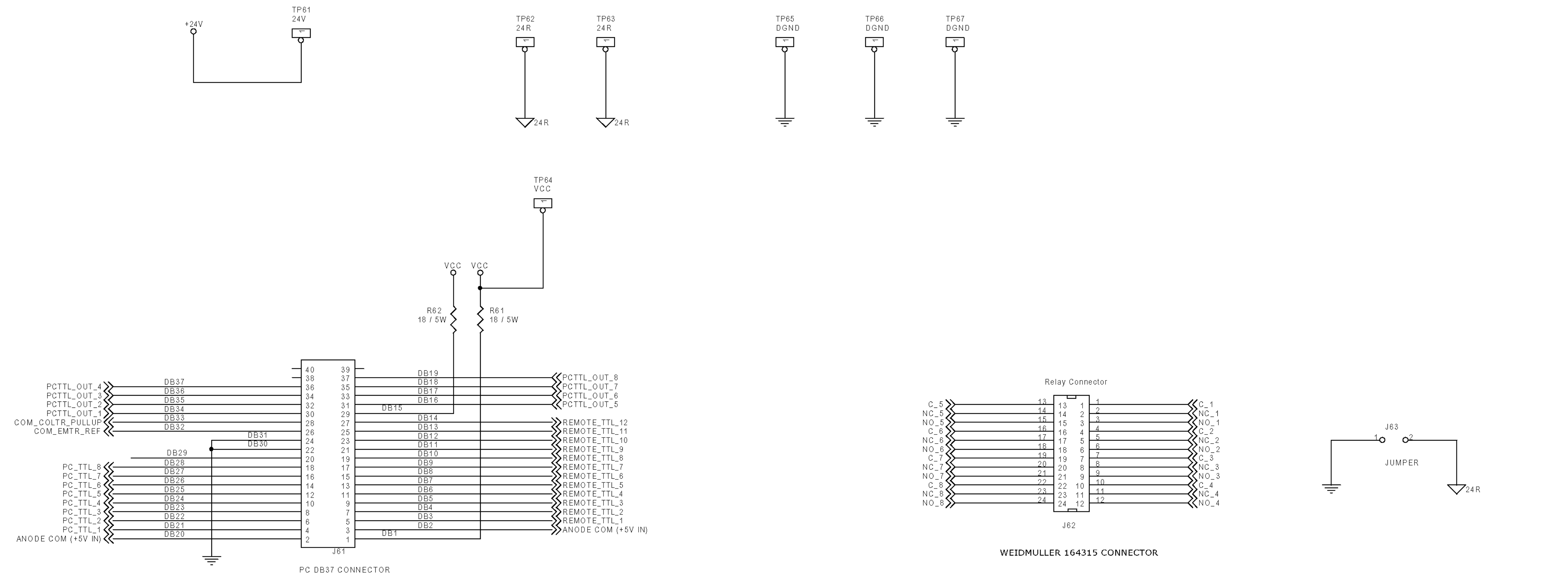


Title

Process Controller for IGC100

Size	Document Number	Rev
Custom	INTERFACE	C

Date: Friday, March 22, 2002 Sheet 5 of 6



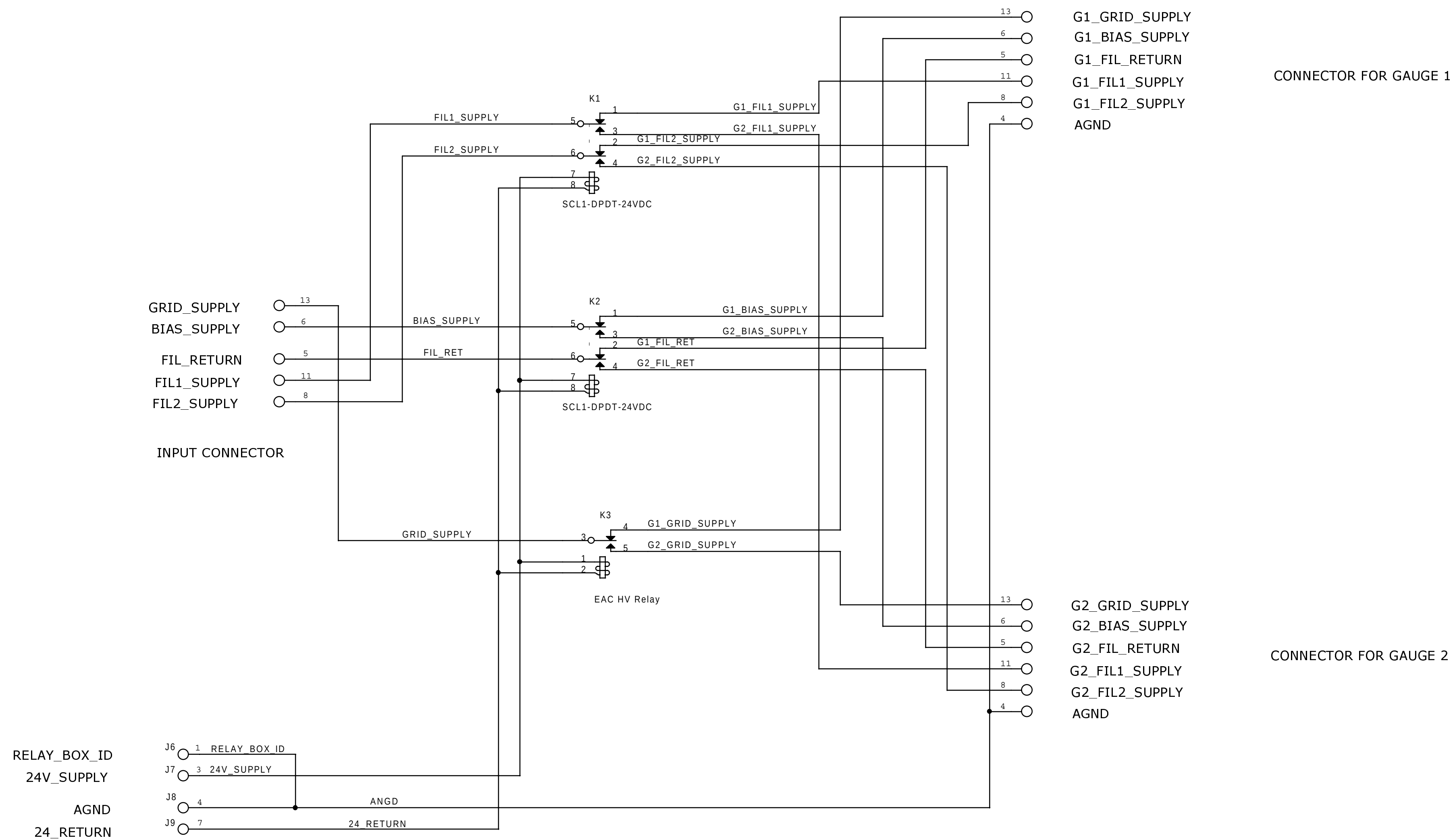
REMOTE TTL INPUTS:

1 = IG1_ON
2 = IG2_ON
3 = IG_DEGAS
4 = IG_TTL_LOCKOUT
5 = IG_KEY_DIABLE
6 = IG1_OFF
7 = IG2_OFF
8 = PRESSURE_LOG_RESET
9 = IG_REMOTE_SETUP_ENABLE
10 = IG_REMOTE_SELECT_FIL2
11 = IG_REMOTE_SELECT_FIL_BOTH
12 = TOUCH_SCREEN_DISABLE

Title: Process Controller for IGC100

Size: Custom | Document Number: CONNECTORS | Rev: C

Date: Friday, March 22, 2002 | Sheet 6 of 6



Title	RELAY BOX - IGC100
Size	Custom
Document Number	PAGE 1
Rev	A
Date:	Thursday, October 11, 2001
Sheet	1 of 1