Operation and Service Manual

Isolated Voltage Source

SIM928

Stanford Research Systems

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Certification

Stanford Research Systems certifies that this product met its published specifications at the time of shipment.

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.

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Stanford Research Systems, Inc.
1290–D Reamwood Avenue
Sunnyvale, CA 94089 USA
Phone: (408) 744-9040 • Fax: (408) 744-9049
www.thinkSRS.com • e-mail: info@thinkSRS.com

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Contents

General Information

The SIM928 Isolated Voltage Source, part of Stanford Research Systems' Small Instrumentation Modules family, is a low-noise programmable voltage source intended for sensor biasing and other demanding, low-power applications. Dual, auto-switching internal nickel-metal-hydride batteries provide continuous uninterrupted operation at the isolated output, which can deliver up to ±20 V bias at up to ±10 mA current load.

Safety and Preparation for Use

⚠ WARNING

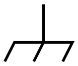
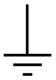
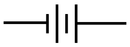
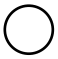
The front-panel binding post outputs (+ and −) are isolated from the Earth, the power-line-outlet ground, and the metal chassis of the module. No dangerous voltages are generated by the SIM928. However, if a dangerous voltage is externally applied to the module, it may be present on (either) binding post connector, the chassis, or the SIM interface connector, and may cause injury or death.

Do not exceed ±40 V to the Earth at either binding post terminal.

The SIM928 ships from the factory with the internal battery pack installed and ready for operation. Do not install substitute parts or perform any unauthorized modifications to this instrument.

The SIM928 is a single-wide module designed to be used inside the SIM900 Mainframe. Do not turn on the power until the module is completely inserted into the mainframe and locked in place.

Symbols you may Find on SRS Products

Symbol	Description
	Alternating current
	Caution - risk of electric shock
	Frame or chassis terminal
	Caution - refer to accompanying documents
	Earth (ground) terminal
	Battery
	Fuse
	On (supply)
	Off (supply)

Notation

The following notation will be used throughout this manual.

⚠ WARNING	A warning means that injury or death is possible if the instructions are not obeyed.
⚠ CAUTION	A caution means that damage to the instrument or other equipment is possible.

Typesetting conventions used in this manual are:

- Front-panel buttons are set as [Button];
  [Adjust ▲▼] is shorthand for "[Adjust ▲] & [Adjust ▼]".
- Front-panel indicators are set as *Overload*.
- Remote command names are set as *IDN?.
- Literal text other than command names is set as `OFF`.

Remote command examples will all be set in monospaced font. In these examples, data sent by the host computer to the SIM928 are set as `straight teletype font`, while responses received by the host computer from the SIM928 are set as *`slanted teletype font`*.

Specifications

Performance Characteristics

		Min	Typ	Max	Units
Output	Output range	−20		+20	V
	Floating output	−40		+40	V (common mode to ground)
	Noise		10		μV_{rms}, 1 kHz BW
	Settable resolution		1		mV
	Display resolution		1		mV, $\lvert V \rvert < 1.999$ V
			10		mV, $\lvert V \rvert < 19.99$ V
	Max. output current	−10		+10	mA (before dropout)
	Short circuit current		±15		mA
	Short circuit duration	indefinite			
Batteries	Number of batteries	2			1 operating, 1 charging/standby
	Chemistry	Nickel metal hydride			
	Charge time		5		h
	Discharge time		12		h (10 mA load)
	Lifetime		1000		charge cycles, 2 yr shelf life
	Battery switching	Automatic, when active battery is fully discharged			
	Switchover glitch	<1 mV for <1 ms			
	Battery charge override	Allows manual switching of batteries. Triggered when [Battery Override] is held for 5 s or more. Only armed when standby battery is in ready state			
Operating	Temperature	0		40	°C
	Power	−15, +5, +24			V DC
	Supply current		250		mA (+5 V)
			40		mA (−15, +24 V)

General Characteristics

Interface	Serial (RS-232) through SIM interface
Connectors	Banana binding posts (+, −, and chassis ground)
	DB–15 (male) SIM interface
Weight	3 lbs
Dimensions	1.5″ W × 3.6″ H × 7.0″ D

1 Getting Started

This chapter gives you the necessary information to get started quickly with the SIM928 Isolated Voltage Source.

In This Chapter

1.1 Introduction to the Instrument

The SIM928 Isolated Voltage Source is ideally suited for applications demanding flexibility and low-noise from a programmable voltage source.

1.1.1 Overview

The basic function of the SIM928 is to generate a user-specified voltage, between −20 V and +20 V, between the + and − front-panel terminals. The architecture of the SIM928 uses an internal battery to power the output stage. This provides an ideal voltage source, free of power-supply ripple. Two independent batteries are used; while one is powering the output circuitry, the second is either being recharged or held in standby. When the output battery nears its fully-discharged state, the standby battery is seamlessly switched into the output circuit, and the depleted battery switched to the internal charger. With this arrangement, essentially continuous isolated bias voltage is available to the user.

Note that, although the output stage is energized by internal storage batteries, the control circuitry is powered externally (typically, by the SIM900 Mainframe). Absent any external power, the SIM928 will be off.

1.1.2 Power-on State

The SIM928 stores its operation state (programmed voltage and on/off configuration) in non-volatile memory. At power-on, the SIM928 will return to its previous configuration after a brief system check and initialization.

first use after extended storage

The power-on system check includes a brief test of both internal batteries. If either battery appears fully discharged, it will be switched onto the internal charger circuit; if both batteries appear discharged (as can occur after an extended storage period), the SIM928 will not be able to turn on the output stage. In this case, you should allow about 5–6 hours of powered operation to bring the first battery up to full charge, at which time it will switch to the *On* state and begin charging the second battery. This period can be shortened by power-cycling the SIM900 Mainframe, which will cause the SIM928 to re-initiate it’s power-on checks. Note that at least 1–2 hours should be allowed to provide a sufficient partial charge for reasonable operation.

1.2 Front-Panel Operation

The front panel of the SIM928(see Figure 1.1) provides a simple operator interface.

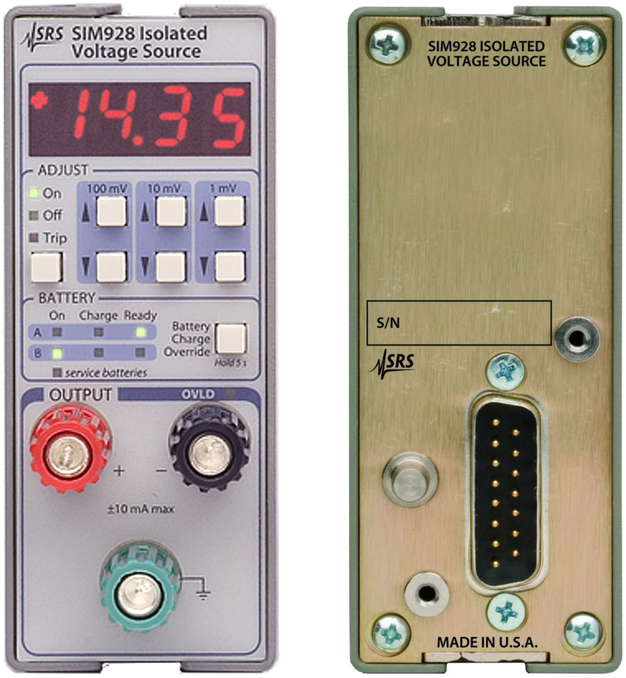


Figure 1.1: The SIM928 front and rear panels.

1.2.1 Adjust

Routine operation of the SIM928 is through the front panel "ADJUST" block.

1.2.1.1 On/Off toggle

The output circuit of the SIM928 is toggled between enabled and disabled with [On/Off]. In the event of an overvoltage Trip (see section 1.2.3.2), press [On/Off] to clear the *Trip* indicator.

1.2.1.2 Changing the programmed voltage

The remaining 6 adjust keys allow changing the programmed voltage from the front panel. Brief taps on [100 mV ▲▼] increment or decrement the setting by 100 mV; similarly, the [10 mV ▲▼] and [1 mV ▲▼] step the setting by 10 mV and 1 mV, respectively. Holding any of these keys for 1 second begins an (accelerating) auto-repeat for faster voltage changes. Note that the auto-repeat function will *not* scroll across 0 V; when decreasing a positive setting, or increasing a negative setting, the auto-repeat will stop at 0 V. To reverse the polarity, the key must be released and then re-pressed to resume auto-repeat.

Note that the programmed voltage can be modified independent of the on/off state of the SIM928. Adjusting the voltage while in the *On* state causes the output voltage to change in real time.

When the programmed voltage $|V| < 1.999$ V, the display shows the full settable resolution of the SIM928. At greater voltages ($|V| >$ 1.999 V) the least significant digit shown corresponds to 10 mV. It is still possible to make discrete 1 mV steps using [1 mV ▲▼]; by counting key taps, the user can determine the sub-display voltage setting. When $|V| \geq 2.00$ V, the display always corresponds to the *truncated* value of the programmed voltage. For instance, if $V = +2.120$ V through +2.129 V, the display will show +2.12; similarly, if $V =$ −12.730 V through −12.739 V, the display will show -12.73.

1.2.2 Battery

The "BATTERY" block of the front panel shows the present state of the SIM928's internal battery system. The two batteries, labeled "A" and "B", correspond to the two shaded rows, while the available battery states *On*, *Charge*, and *Ready* correspond to the three columns. A battery is *On* when it is switched to power the output stage; *Ready* corresponds to a battery in the (nominally) fully-charged state that is ready for operation when the *On* battery is depleted. The *Charge* state indicates that the battery is connected to the charger circuit.

1.2.2.1 Battery cycle

Under typical operation, a fully charged battery should run for 12–18 hours before being depleted. When the *On* battery is nearly discharged, an internal threshold circuit signals the SIM928 controller to begin a battery switch-over. The stand-by battery (which at this point is typically in the *Ready* state) is switched onto the output circuit, after which the discharged battery is switched to the charger circuit. A "diode-or" circuit effectively prevents the discharged battery from loading down the fresh battery, and the output driver operates without interuption.[1].

When the discharged battery is first connected to the charger circuit, a resistive load is briefly applied to complete the discharge of the cell to a known starting voltage. From that point, the charger applies a fixed charging current for ~ 5 hours to completely charge the battery.

If power is interrupted while the battery is charging, the charge cycle will *not* resume; rather, the power-on system check will select the most depleted battery for initial operation and place the other battery in the *Ready* state (assuming neither battery appears fully discharged). This algorithm ensures that a battery cannot be overcharged by an unfortunate series of power-cycles.

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[1] A small glitch may appear at the output when the fresh battery switches in

1.2.2.2 Battery charge override

For some applications, it may be important to insure that the SIM928 will not begin a battery switch-over during a particularly sensitive experiment. The [Battery Override] can be used to force the *Ready* battery to be switched to *On* immediately, ensuring a 12+ hour period of un-switched operation.

The [Battery Override] is only armed when one of the batteries is in the *Ready* state; while a battery is in the *Charge* state, this key is temporarily disabled. To initiate a forced swich-over, press and hold [Battery Override] for at least 5 seconds. Over the next few seconds, the standby battery will be switched in, and the previously *On* battery will be switched to the standby (*Ready*) state—not to the charger—where it will remain.

1.2.2.3 Service batteries

The nickel-metal-hydride battery packs used in the SIM928 have a finite lifetime. After around 1000 charge/discharge cycles, the remaining battery capacity is significantly reduced; to restore the instrument to full performance, the battery pack must be replaced. The yellow *service batteries* indicator turns on when the battery pack has reached this limit. The SIM928 will continue to operate properly with reduced-capacity batteries; the only effect will be the battery switch-over will occur more frequently.

It is also possible, if a SIM928 is left in storage for several years without operation, that the batteries will have lost a significant fraction of their capacity due to aging. In this case, the yellow *service batteries* indicator will *not* turn on, but the user may notice a shorter period between battery charge cycles. The manufacture date of the battery pack can be determined with the remote BIDN? query.

Replacement battery packs can be ordered from Stanford Research Systems.

1.2.3 Output

The SIM928 output voltage is available at the front-panel between the red + and black − banana jack/binding posts. These connectors accept standard 0.175″ in Banana plugs. The binding post accomodates wire leads up to #12 AWG, as well as open spade lugs for #8 studs (0.165″ minimum opening).

The lower, green terminal is tied to the SIM928 chassis, and is available for user grounding. Either output terminal may be tied to chassis ground, if desired.

1.2.3.1 Output Overload

The SIM928 is specified to maintain its programmed voltage difference between the output terminals for load currents smaller than ±10 mA. If an low-impedance load causes the output current to reach around ±15 mA, the output will go into current-limit mode, and the red *OVLD* indicator will turn on. The SIM928 can remain in overload indefinitely, and will return to its programmed output voltage as soon as the load current is reduced.

1.2.3.2 Overvoltage / TRIP

In addition to its current-limiting circuitry, the SIM928 has an overvoltage sensing circuit that detects excessive voltage across the output terminals. If the voltage across the outputs exceeds ∼ ±30 V, this protection circuitry disconnects the output driver from the output terminals, and the red *Trip* indicator will turn on. Typically, an overvoltage TRIP is generated by some external voltage applied to the SIM928 across its output terminals.

To clear an overvoltage TRIP, press [On/Off]. This will return the SIM928 to the *Off* state; a second press of [On/Off] will attempt to switch the instrument back on. If the overvoltage condition still exists, the output will again trip off.

1.3 SIM Interface

The primary connection to the SIM928 Isolated Voltage Source is the rear-panel DB–15 SIM interface connector. Typically, the SIM928 is mated to a SIM900 Mainframe via this connection, either through one of the internal Mainframe slots, or the remote cable interface.

It is also possible to operate the SIM928 directly, without using the SIM900 Mainframe. This section provides details on the interface.

⚠ CAUTION

The SIM928 has no internal protection against reverse polarity, missing supply, or overvoltage on the power supply pins. Misapplication of power may cause circuit damage. SRS recommends using the SIM928 together with the SIM900 Mainframe for most applications.

1.3.1 SIM interface connector

The DB–15 SIM interface connector carries all the power and communications lines to the instrument. The connector signals are specified in Table 1.1

Pin	Signal	Direction Src ⇒ Dest	Description
1	SIGNAL_GND	MF ⇒ SIM	Ground reference for signal
2	−STATUS	SIM ⇒ MF	Status/service request (GND = asserted, +5 V= idle)
3	RTS	MF ⇒ SIM	HW handshake (+5 V= talk; GND = stop)
4	CTS	SIM ⇒ MF	HW handshake (+5 V= talk; GND = stop)
5	−REF_10MHZ	MF ⇒ SIM	10 MHz reference (optional connection)
6	−5 V	MF ⇒ SIM	Power supply (no connection in SIM928)
7	−15 V	MF ⇒ SIM	Power supply (battery charger)
8	PS_RTN	MF ⇒ SIM	Power supply return
9	CHASSIS_GND		Chassis ground
10	TXD	MF ⇒ SIM	Async data (start bit = "0"= +5 V; "1" = GND)
11	RXD	SIM ⇒ MF	Async data (start bit = "0"= +5 V; "1" = GND)
12	+REF_10MHz	MF ⇒ SIM	10 MHz reference (optional connection)
13	+5 V	MF ⇒ SIM	Power supply (digital circuitry)
14	+15 V	MF ⇒ SIM	Power supply (no connection in SIM928)
15	+24 V	MF ⇒ SIM	Power supply (battery charger)

Table 1.1: SIM Interface Connector Pin Assignments, DB-15

1.3.2 Direct interfacing

The SIM928 is intended for operation in the SIM900 Mainframe, but users may wish to directly interface the module to their own systems without the use of additional hardware.

The mating connector needed is a standard DB–15 receptacle, such as Amp part # 747909-2 (or equivalent). Clean, well-regulated supply voltages of −15,+5,+24 VDC must be provided, following the pin-out specified in Table 1.1. Ground must be provided on pins 1 and 8, with chassis ground on pin 9. The −STATUS signal may be monitored on pin 2 for a low-going TTL-compatible output indicating a status message.

1.3.2.1 Direct interface cabling

If the user intends to directly wire the SIM928 independent of the SIM900 Mainframe, communication is usually possible by directly connecting the appropriate interface lines from the SIM928 DB–15 plug to the RS-232 serial port of a personal computer.[2] Connect RXD from the SIM928 directly to RD on the PC, TXD directly to TD, and similarly RTS→RTS and CTS→CTS. In other words, a null-modem style cable is *not* needed.

---

[2] Although the serial interface lines on the DB-15 do not satisfy the minimum voltage levels of the RS-232 standard, they are typically compatible with desktop personal computers

To interface directly to the DB–9 male (DTE) RS-232 port typically found on contemporary personal computers, a cable must be made with a female DB–15 socket to mate with the SIM928, and a female DB–9 socket to mate with the PC's serial port. Separate leads from the DB–15 need to go to the power supply, making what is sometimes know as a "hydra" cable. The pin-connections are given in Table 1.2.

DB–15/F to SIM928			Name
		DB–9/F	
3	⟷	7	RTS
4	⟷	8	CTS
10	⟷	3	TxD
11	⟷	2	RxD
		5	Computer Ground
		to P/S	
7	⟷	−15 VDC	
13	⟷	+5 VDC	
15	⟷	+24 VDC	
8,9	⟷	Ground (P/S return current)	
1	⟷	Signal Ground (separate wire to Ground)	

Table 1.2: SIM928 Direct Interface Cable Pin Assignments

1.3.2.2 Serial settings

The initial serial port settings at power-on are: 9600 Baud, 8–bits, no parity, 1 stop bit, and RTS/CTS flow control. These may be changed with the BAUD, FLOW, or PARI commands.

The maximum *standard* baud rate that the SIM928 supports is 38400. The minimum baud rate is 110. Above 38400, the SIM928 can be set to the following (non-RS-232-standard) baud rates: 62500, 78125, 104167, 156250. Note that these rates are typically not accessible on a standard PC RS-232 port, but can be used between the SIM928 and the SIM900 Mainframe.

2 Remote Operation

This chapter describes operating the SIM928 over the serial interface.

In This Chapter

2.1 Index of Common Commands

symbol	definition
i,j	Integers
f	Floating-point values
z	Literal token
(?)	Required for queries; illegal for set commands
var	Parameter always required
{*var*}	Required parameter for set commands; illegal for queries
[*var*]	Optional parameter for both set and query forms

Output		
VOLT(?) {*f*}	2 – 9	Voltage
OPON	2 – 9	Output On
OPOF	2 – 9	Output Off
EXON(?) {*z*}	2 – 9	Excitation On/Off
Battery		
BCOR	2 – 9	Battery charger override
BATS?	2 – 10	Battery State
BIDN? z	2 – 10	Battery Identification
Serial Communications		
BAUD(?) {*i*}	2 – 11	Baud Rate
FLOW(?) {*z*}	2 – 11	Flow Control
PARI(?) {*z*}	2 – 11	Parity
Status		
*CLS	2 – 11	Clear Status
*STB? [*i*]	2 – 12	Status Byte
*SRE(?) [*i*,] {*j*}	2 – 12	Service Request Enable
*ESR? [*i*]	2 – 12	Standard Event Status
*ESE(?) [*i*,] {*j*}	2 – 12	Standard Event Status Enable
CESR? [*i*]	2 – 12	Communication Error Status
CESE(?) [*i*,]{*j*}	2 – 12	Communication Error Status Enable
OVCR? [*i*]	2 – 13	Overload Condition
OVSR? [*i*]	2 – 13	Overload Status
OVSE(?) [*i*,]{*j*}	2 – 13	Overload Status Enable
PSTA(?) {*z*}	2 – 13	Pulse −STATUS Mode
Interface		
*RST	2 – 13	Reset
CONS(?) {*z*}	2 – 14	Console Mode
*IDN?	2 – 14	Identify

2.2 Alphabetic List of Commands

★

*CLS	2 – 11	Clear Status
*ESE(?) [*i*,] {*j*}	2 – 12	Standard Event Status Enable
*ESR? [*i*]	2 – 12	Standard Event Status
*IDN?	2 – 14	Identify
*OPC(?)	2 – 14	Operation Complete
*RST	2 – 13	Reset
*SRE(?) [*i*,] {*j*}	2 – 12	Service Request Enable
*STB? [*i*]	2 – 12	Status Byte

B

BATS?	2 – 10	Battery State
BAUD(?) {*i*}	2 – 11	Baud Rate
BCOR	2 – 9	Battery charger override
BIDN? z	2 – 10	Battery Identification

C

CESE(?) [*i*,]{*j*}	2 – 12	Communication Error Status Enable
CESR? [*i*]	2 – 12	Communication Error Status
CONS(?) {*z*}	2 – 14	Console Mode

E

EXON(?) {*z*}	2 – 9	Excitation On/Off

F

FLOW(?) {*z*}	2 – 11	Flow Control

L

LBTN?	2 – 15	Button
LCME?	2 – 15	Device Error
LEXE?	2 – 14	Execution Error

O

OPOF	2 – 9	Output Off
OPON	2 – 9	Output On
OVCR? [*i*]	2 – 13	Overload Condition
OVSE(?) [*i*,]{*j*}	2 – 13	Overload Status Enable
OVSR? [*i*]	2 – 13	Overload Status

P

PARI(?) {*z*}	2 – 11	Parity

PSTA(?) {*z*}	2 – 13	Pulse −STATUS Mode

T

TERM(?) {*z*}	2 – 16	Response Termination
TOKN(?) {*z*}	2 – 16	Token Mode

V

VOLT(?) {*f*}	2 – 9	Voltage

2.3 Introduction

Remote operation of the SIM928 is through a simple command language documented in this chapter. Both set and query forms of most commands are supported, allowing the user complete control of the voltage source from a remote computer, either through the SIM900 Mainframe or directly via RS-232 (see Section 1.3.2.1).

See Table 1.1 for specification of the DB–15 SIM interface connector.

2.3.1 Power-on configuration

The settings for the remote interface are 9600 baud with no parity and hardware flow control, and local echo disabled (CONS `OFF`).

Most of the SIM928 instrument settings are stored in non-volatile memory, and at power-on the instrument returns to the state it was last in when power was removed. Exceptions are noted in the command descriptions.

Reset values of parameters are shown in **`boldface`**.

2.3.2 Buffers

Incoming data from the host interface is stored in a 32-byte input buffer. Characters accumulate in the input buffer until a command terminator (either ⟨CR⟩ or ⟨LF⟩) is received, at which point the message is parsed and executed. Query responses from the SIM928 are buffered in a 128-byte output queue.

If the input buffer overflows, then all data in *both* the input buffer and the output queue are discarded, and an error is recorded in the CESR and ESR status registers.

2.3.3 Device Clear

The SIM928 host interface can be asynchronously reset to its power-on configuration by sending an RS-232-style ⟨break⟩ signal. From the SIM900 Mainframe, this is accomplished with the SRST command; if directly interfacing via RS-232, then use a serial break signal. After receiving the Device Clear, the interface is reset to 9600 baud and CONS mode is turned `OFF`. Note that this *only* resets the communication interface; the basic function of the SIM928 is left unchanged; to reset the instrument, see *RST.

2.4 Commands

This section provides syntax and operational descriptions for remote commands.

2.4.1 Command syntax

The four letter mnemonic (shown in CAPS) in each command sequence specifies the command. The rest of the sequence consists of parameters.

Commands may take either *set* or *query* form, depending on whether the "?" character follows the mnemonic. *Set only* commands are listed without the "?", *query only* commands show the "?" after the mnemonic, and *optionally query* commands are marked with a "(?)".

Parameters shown in { } and [ ] are not always required. Parameters in { } are required to set a value, and are omitted for queries. Parameters in [ ] are optional in both set and query commands. Parameters listed without any surrounding characters are always required.

Do *not* send ( ) or { } or [ ] as part of the command.

Multiple parameters are separated by commas. Multiple commands may be sent on one command line by separating them with semicolons (;) so long as the input buffer does not overflow. Commands are terminated by either ⟨CR⟩ or ⟨LF⟩ characters. Null commands and whitespace are ignored. Execution of command(s) does not begin until the command terminator is received.

tokens Token parameters (generically shown as *z* in the command descriptions) can be specified either as a keyword or integer value. Command descriptions list the valid keyword options, with each keyword followed by its corresponding integer value. For example, to set the response termination sequence to ⟨CR⟩+⟨LF⟩, the following two commands are equivalent:

TERM CRLF —or— TERM 3

For queries that return token values, the return format (keyword or integer) is specified with the TOKN command.

2.4.2 Notation

The following table summarizes the notation used in the command descriptions:

symbol	definition
i,j	Integers
f	Floating-point values
z	Literal token
(*?*)	Required for queries; illegal for set commands
var	Parameter always required
{*var*}	Required parameter for set commands; illegal for queries
[*var*]	Optional parameter for both set and query forms

2.4.3 Examples

Each command is provided with a simple example illustrating its usage. In these examples, all data sent by the host computer to the SIM928 are set as `straight teletype font`, while responses received the host computer from the SIM928 are set as *`slanted teletype font`*.

The usage examples vary with respect to set/query, optional parameters, and token formats. These examples are not exhaustive, but are intended to provide a convenient starting point for user programming.

2.4.4 Output commands

These commands directly query and control the output state of the SIM928.

VOLT(?) {*f*}

Voltage

Set (query) the programmed voltage {to *f*}.

Example:
```
VOLT -1.012e+1; VOLT?
-10.120
```

OPON

Output On

Turn the output on. The output state can be queried with the EXON(?) command, below.

Example:
```
OPON
```

OPOF

Output Off

Turn the output off. The output state can be queried with the EXON(?) command, below.

Example:
```
OPOF
```

EXON(?) {*z*}

Excitation On/Off

Set (query) the output {to *z*=(`OFF 0`, **`ON 1`**)}. The output can also be turned on with the OPON command, and turned off with the OPOF command.

Example:
```
EXON?
ON
```

2.4.5 Battery commands

These commands directly query and control the battery system of the SIM928.

BCOR

Battery charger override

Forces the SIM928 to switch the active output battery.

BCOR follows the same rules as the front-panel [Battery Override] button (see section 1.2.2.2). In particular, the command will only be operative if one of the batteries is in the “ready” state (see BATS?, below). Furthermore, the SIM928 may delay initiating BCOR by up to 1 s for internal synchronization.

To verify that BCOR has actually initiated a battery switch, the user program should:

1. Query OVSR? to clear the "Battery Switch" flag;
2. Issue the BCOR command;
3. Wait at least one second;
4. Query OVSR? again to check for the "Battery Switch" flag.

Example: `BCOR`

BATS?

Battery State

Query the battery status of the SIM928.

The response is return in the format:
`<a>,<b>,<x>`
where <a>and <b> correspond to batteries "A" and "B", and are equal to `1` for in use, `2` for charging, and `3` for ready/standby.

The third parameter, `<x>`, is normally `0`; it is set to `1` if the *service batteries* indicator is lit.

Example:

```
BATS?
2,1,0
```

BIDN? z

Battery Identification

Query the battery identification parameter z.

Valid parameters to query are:

Value	Definition
PNUM 0	Battery pack part number
SERIAL 1	Battery pack serial number
MAXCY 2	Design life (# of charge cycles)
CYCLES 3	# charge cycles used
PDATE 4	Battery pack production date (YYYY-MM-DD)

The `MAXCY` parameter returns the estimated maximum number of charge-discharge cycles that *each* battery in the pack can sustain before suffering a significant reduction in charge capacity. The `CYCLES` parameter reports the actual number of cycles used by the "most used" battery in the pack. Typically, both batteries in the pack will have the same number of cycles (within ±1), but it is possible, through power-cycling at odd times, to have one battery see more overall use than the other.

Example:

```
BIDN? PDATE
2005-05-16
```

2.4.6 Serial communication commands

BAUD(?) {*i*}

Baud Rate

Set (query) the baud rate {to *i*}.

At power-on, the baud rate defaults to 9600.

Actual baud rate settings depend on implementation details of the SIM928, based on modulo prescalars of the 10 MHz system clock. As a result, queries of BAUD? will in general be slightly different from the set values. For example, after setting BAUD `9600`, the query BAUD? will respond `9470`. The functional requirement for successful asynchronous serial communication is no greater than ∼ 5 % mismatch in baud rates.

Example: `BAUD 9600`

FLOW(?) {*z*}

Flow Control

Set (query) flow control {to *z*=(`NONE 0`, `RTS 1`, `XON 2`)}.

At power-on, the SIM928 defaults to FLOW `RTS` flow control.

Example: `FLOW 0`

PARI(?) {*z*}

Parity

Set (query) parity {to *z* = (`NONE 0`, `ODD 1`, `EVEN 2`, `MARK 3`, `SPACE 4`)}.

At power-on, the SIM928 defaults to PARI `NONE`.

Example: `PARI EVEN`

2.4.7 Status commands

The Status commands query and configure registers associated with status reporting of the SIM928. See Section 2.5 for more details.

*CLS

Clear Status

*CLS immediately clears the ESR, CESR, and the OVSR.

Example: `*CLS`

***STB? [*i*]**

Status Byte

Reads the Status Byte register [bit *i*].

Execution of the *STB? query (without the optional bit *i*) always causes the −STATUS signal to be deasserted. Note that *STB? *i* will *not* clear −STATUS, even if bit *i* is the only bit presently causing the −STATUS signal.

Example:

```
*STB?
16
```

***SRE(?) [*i*,] {*j*}**

Service Request Enable

Set (query) the Service Request Enable register [bit *i*] {to *j*}.

Example:

```
*SRE 0,1
```

***ESR? [*i*]**

Standard Event Status

Reads the Standard Event Status Register [bit *i*].

Upon executing *ESR?, the returned bit(s) of the ESR register are cleared.

Example:

```
*ESR?
64
```

***ESE(?) [*i*,] {*j*}**

Standard Event Status Enable

Set (query) the Standard Event Status Enable Register [bit *i*] {to *j*}.

Example:

```
*ESE 6,1
ESE?
64
```

CESR? [*i*]

Communication Error Status

Query Communication Error Status Register [for bit *i*].

Upon executing a CESR? query, the returned bit(s) of the CESR register are cleared.

Example:

```
CESR?
0
```

CESE(?) [*i*,]{*j*}

Communication Error Status Enable

Set (query) Communication Error Status Enable Register [bit *i*] {to *j*}.

Example:

```
CESE?
0
```

OVCR? [*i*]

Overload Condition

Query Overload Condition Register [for bit *i*].

Example: `OVCR?`
1

OVSR? [*i*]

Overload Status

Query Overload Status Register [for bit *i*].

Upon executing a OVSR? query, the returned bit(s) of the OVSR register are cleared.

Example: `OVSR?`
1

OVSE(?) [*i*,]{*j*}

Overload Status Enable

Set (query) Overload Status Enable Register [bit *i*] {to *j*}.

Example: `OVSE 3`

PSTA(?) {*z*}

Pulse −STATUS Mode

Set (query) the Pulse −STATUS Mode {to *z*=(`OFF 0`, `ON 1`)}.

When PSTA `ON` is set, any new service request will only *pulse* the −STATUS signal low (for a minimum of 1 μs). The default behavior is to latch −STATUS low until a *STB? query is received.

At power-on, PSTA is set to `OFF`.

Example: `PSTA?`
OFF

2.4.8 Interface commands

---

*RST

Reset

Reset the SIM928 to default configuration.

The following commands are internally executed upon *RST:

- VOLT `0`
- EXON `OFF`

Example: `*RST`

CONS(?) {*z*}

Console Mode

Set (query) the Console mode {to *z*=(`OFF 0`,`ON 1`)}.

CONS causes each character received at the Input Buffer to be copied to the Output Queue.

At power-on and Device-Clear, CONS is set to `OFF`.

Example:

```
CONS?
0
```

***IDN?**

Identify

Read the device identification string.

The identification string is formatted as:
`Stanford_Research_Systems,SIM928,s/n******,ver#.#`
where `******` is the 6-digit serial number, and `#.#` is the firmware revision level.

Example:

```
*IDN?
Stanford_Research_Systems,SIM928,s/n003075,ver1.1
```

***OPC(?)**

Operation Complete

Operation Complete. Sets the OPC flag in the ESR register.

The query form *OPC? writes a `1` in the output queue when complete, but does not affect the ESR register.

Example:

```
*OPC
```

LEXE?

Execution Error

Query the last execution error code. Valid codes are:

Value	Definition
0	No execution error since last LEXE?
1	Illegal value
2	Wrong token
3	Invalid bit

Example:

```
*STB? 12; LEXE?; LEXE?
3
0
```

The error (3, "Invalid bit,") is because *STB? only allows bit-specific queries of 0–7. The second read of LEXE? returns `0`.

LCME? Device Error

Query the last command error code. Valid codes are:

Value	Definition
0	No command error since last LCME?
1	Illegal command
2	Undefined command
3	Illegal query
4	Illegal set
5	Missing parameter(s)
6	Extra parameter(s)
7	Null parameter(s)
8	Parameter buffer overflow
9	Bad floating-point
10	Bad integer
11	Bad integer token
12	Bad token value
13	Bad hex block
14	Unknown token

Example:

```
*IDN
LCME?
4
```

The error (4, “Illegal set”) is due to the missing “?”.

LBTN? Button

Query the last button-press code. Valid codes are:

Value	Definition
0	no button pressed since last LBTN?
1	[On/Off]
2	[100 mV ▲]
3	[100 mV ▼]
4	[10 mV ▲]
5	[10 mV ▼]
6	[1 mV ▲]
7	[1 mV ▼]
8	[Battery Override]

Example:

```
LBTN?
1
```

TOKN(?) {*z*}

Token Mode

Set (query) the Token Query mode {to *z*=(**`OFF 0`**, `ON 1`)}.

If TOKN `ON` is set, then queries to the SIM928 that return tokens will return the text keyword; otherwise they return the decimal integer value.

Thus, the only possible responses to the TOKN? query are `ON` and `0`.

At power-on, TOKN `OFF` is set.

Example: `TOKN OFF`

TERM(?) {*z*}

Response Termination

Set (query) the ⟨term⟩ sequence {to *z*=(`NONE 0`, `CR 1`, `LF 2`, **`CRLF 3`**, `LFCR 4`)}.

The ⟨term⟩ sequence is appended to all query responses sent by the module, and is constructed of ASCII character(s) 13 (carriage return) and/or 10 (line feed).

At power-on, TERM `CRLF` is set.

Example:

```
TERM?
3
```

2.5 Status Model

The SIM928 status registers follow the hierarchical IEEE–488.2 format. A block diagram of the status register array is given in Figure 2.1.

There are three categories of registers in the SIM928 status model:

Condition Registers :	These read-only registers correspond to the real-time condition of some underlying physical property being monitored. Queries return the latest value of the property, and have no other effect. Condition register names end with CR.
Event Registers :	These read-only registers record the occurrence of defined events. When the event occurs, the corresponding bit is set to 1. Upon querying an event register, any set bits within it are cleared. These are sometimes known as “sticky bits,” since once set, a bit can only be cleared by reading its value. Event register names end with SR.
Enable Registers :	These read/write registers define a bitwise mask for their corresponding event register. If any bit position is set in an event register while the same bit position is also set in the enable register, then the corresponding summary bit message is set. Enable register names end with SE.

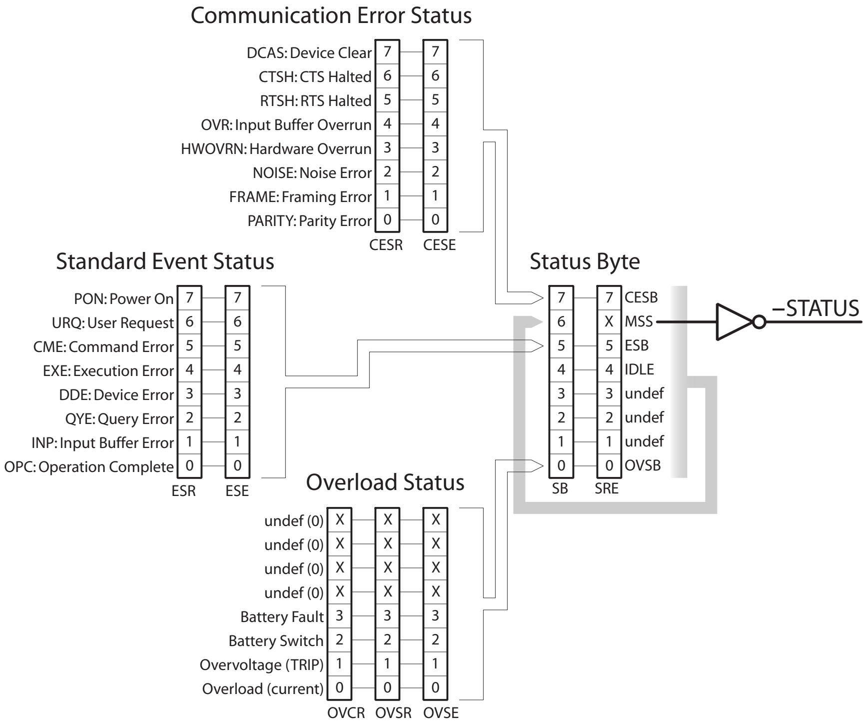


Figure 2.1: Status Register Model for the SIM928.

2.5.1 Status Byte (SB)

The Status Byte is the top-level summary of the SIM928 status model. When masked by the Service Request Enable register, a bit set in the Status Byte causes the −STATUS signal to be asserted on the rear-panel SIM interface connector.

Typically, −STATUS remains asserted (low) until a `*STB?` query is received, at which time −STATUS is deasserted (raised)[1]. After clearing the −STATUS signal, it will only be re-asserted in response to a *new* status-generating condition.

Weight	Bit	Flag
1	0	OVSB
2	1	undef (0)
4	2	undef (0)
8	3	undef (0)
16	4	IDLE
32	5	ESB
64	6	MSS
128	7	CESB

OVSB : Overload Status Summary Bit. Indicates whether one or more of the enabled flags in the Overload Status Register has become true.

IDLE : Indicates that the Input Buffer is empty and the command parser is idle. Can be used to help synchronize SIM928 query responses.

ESB : Event Status Bit. Indicates whether one or more of the enabled events in the Standard Event Status Register is true.

MSS : Master Summary Status. Indicates whether one or more of the enabled status messages in the Status Byte register is true. Note that while −STATUS is released by the `*STB?` query, MSS is only cleared when the underlying enabled bit message(s) are cleared.

CESB : Communication Error Summary Bit. Indicates whether one or more of the enabled flags in the Communication Error Status Register has become true.

Bits in the Status Byte are *not* cleared by the `*STB?` query. These bits are only cleared by reading the underlying event registers, or by clearing the corresponding enable registers.

---

[1] but see the `PSTA` command

2.5.2 Service Request Enable (SRE)

Each bit in the SRE corresponds one-to-one with a bit in the SB register, and acts as a bitwise AND of the SB flags to generate the MSS bit in the SB and the −STATUS signal. Bit 6 of the SRE is undefined—setting it has no effect, and reading it always returns 0. This register is set and queried with the `*SRE(?)` command.

This register is cleared at power-on.

2.5.3 Standard Event Status (ESR)

The Standard Event Status register consists of 8 event flags. These event flags are all "sticky bits" that are set by the corresponding event, and cleared only by reading or with the `*CLS` command. Reading a single bit (with the `*ESR?` *i* query) clears only bit *i*.

Weight	Bit	Flag
1	0	OPC
2	1	INP
4	2	QYE
8	3	DDE
16	4	EXE
32	5	CME
64	6	URQ
128	7	PON

OPC : Operation Complete. Set by the `*OPC` command.

INP : Input Buffer Error. Indicates data has been discarded from the Input Buffer.

QYE : Query Error. Indicates data in the Output Queue has been lost.

DDE : Device Dependent Error. Indicates a SIM928 had a delayed execution error, due to an illegal mode state. The error code can be queried with `LDDE?`.

EXE : Execution Error. Indicates an error in a command that was successfully parsed. Out-of-range parameters are an example. The error code can be queried with `LEXE?`.

CME : Command Error. Indicates a parser-detected error. The error code can be queried with `LCME?`.

URQ : User Request. Indicates a front-panel button was pressed.

PON : Power On. Indicates that an off-to-on transition has occurred

2.5.4 Standard Event Status Enable (ESE)

The ESE acts as a bitwise AND with the ESR register to produce the single bit ESB message in the Status Byte Register (SB). It can be set and queried with the `*ESE(?)` command.

This register is cleared at power-on.

2.5.5 Communication Error Status (CESR)

The Communication Error Status register consists of 8 event flags; each of which is set by the corresponding event, and cleared only by reading or with the `*CLS` command. Reading a single bit (with the `CESR?` *i* query) clears only bit *i*.

Weight	Bit	Flag
1	0	PARITY
2	1	FRAME
4	2	NOISE
8	3	HWOVRN
16	4	OVR
32	5	RTSH
64	6	CTSH
128	7	DCAS

PARITY : Parity Error. Set by serial parity mismatch on incoming data byte.

FRAME : Framing Error. Set when an incoming serial data byte is missing the STOP bit.

NOISE : Noise Error. Set when an incoming serial data byte does not present a steady logic level during each asynchronous bit-period window.

HWOVRN : Hardware Overrun. Set when an incoming serial data byte is lost due to internal processor latency. Causes the Input Buffer to be flushed, and resets the command parser.

OVR : Input Buffer Overrun. Set when the Input Buffer is overrun by incoming data. Causes the Input Buffer to be flushed, and resets the command parser.

RTSH : Undefined for the SIM928. Command Error. Indicates a parser-detected error.

CTSH : Undefined for the SIM928.

DCAS : Device Clear. Indicates the SIM928 received the Device Clear signal (an RS-232 ⟨break⟩). Clears the Input Buffer and Output Queue, and resets the command parser.

2.5.6 Communication Error Status Enable (CESE)

The CESE acts as a bitwise AND with the CESR register to produce the single bit CESB message in the Status Byte Register (SB). It can be set and queried with the `CESE(?)` command.

This register is cleared at power-on.

2.5.7 Overload Status (OVCR)

The Overload Condition Register consists of 3 single-bit monitors of conditions within the SIM928. Bits in the OVCR reflect the real-time values of their corresponding signals. Reading the entire register, or individual bits within it, does not affect the OVCR.

Weight	Bit	Flag
1	0	Overload
2	1	Overvoltage / TRIP
4	2	Battery Switch
8	3	Battery Fault
16	4	undef (0)
32	5	undef (0)
64	6	undef (0)
128	7	undef (0)

Overload : The output driver reached its current limit (∼ ± 15 mA).

Overvoltage / TRIP : The protection circuitry tripped off. This happens if the voltage across the outputs exceeds ±25 V, and typically can only occur if an external voltage is applied to the instrument.

Battery Switch : Indicates a battery switch-over event has occured, either due to the *On* battery being depleted, or a user-initiated [Battery Override] event.

Battery Fault : Indicates a gross battery failure (such as no battery installed). Detected at power-on only.

2.5.8 Overload Status (OVSR)

The Overload Status Register consists of (latching) event flags that correspond one-to-one with the bits of the OVCR (see above). Upon the transition 0 → 1 of any bit within the OVCR, the corresponding bit in the OVSR becomes set.

Bits in the OVSR are unaffected by the 1 → 0 transitions in the OVCR, and are cleared only by reading or with the `*CLS` command. Reading a single bit (with the `OVSR?` *i* query) clears only bit *i*.

2.5.9 Overload Status Enable (OVSE)

The OVSE acts as a bitwise AND with the OVSR register to produce the single bit OVSB message in the Status Byte Register (SB). It can be set and queried with the `OVSE(?)` command.

This register is cleared at power-on.

3 Parts Lists and Schematics

This chapter presents a brief description of the SIM928 circuit design. A complete parts list and circuit schematics are included.

In This Chapter

3.1 Circuit Description

The SIM928 isolated voltage source contains five distinct circuit blocks:

1. a microcontroller,
2. a battery charger circuit,
3. the battery pack,
4. an isolated voltage regulator circuit and
5. a front panel display.

3.1.1 Microcontroller

The single chip microcontroller U103 controls the battery charger, the isolated voltage regulator, the display, and responds to remote serial commands.

3.1.2 Battery charger

The SIM928 battery pack contains two identical 25.2 V NiMH batteries. During normal operation at least one battery is connected at any time to the isolated voltage regulator circuit. The other battery is either idle (disconnected) or connected to the charger circuit. Once the microcontroller detects that the battery in use is running low on charge (via opto U502A), it swaps the two batteries and connects the now depleted battery to the charger circuit.

Constant charge and discharge currents are used to maximize battery life and minimize electronics noise on the isolated voltage output. First the charger algorithm discharges a depleted battery to a fixed voltage endpoint (23.0 V) to ensure a well defined discharge state. It then charges the battery with a constant current until the charge termination endpoint is reached. Charging terminates on either total charge time or a zero of the NiMH dV/dt curve. The charger algorithm is designed to maximize battery life and ensure several years of uninterrupted operation with a single battery pack.

A complex state machine driven by a timer and battery monitoring signals implements the discharge-charge-idle cycle for each battery in such a way that the module is always available after an initial charge cycle. NiMH batteries suffer from self-discharge on the order of 1% per day. If the module has been powered down for several months, insufficient charge might remain in either battery to assure continuous operation, especially if the output is loaded with close to 10 mA current. The initialization algorithm tries to ensure the best possible availability by comparing the battery voltages to a minimum threshold and giving the user access to the batteries in such an order that operation disruptions are minimized.

3.1.2.1 Discharge/Charge circuit

Batteries are discharged with a 50 mA constant current discharge circuit made of Q205, U205 and current sense resistors R213/214. Power resistors R207–R209 dissipate excess heat during discharge to keep transistor Q205 within its max. power dissipation limits. It usually takes only a few minutes to deplete the battery from the 24.2 V useful end voltage to the discharge termination voltage of 23.0 V .

After discharge, the charger current source made, up of Q202, Q203, U201 and current sense resistor R205 delivers 45 mA current into the battery. A fully depleted battery of 150 mAh can be safely recharged in approx. 1.4 × 150 mAh/45 mA = 4.7, hours.

The charge and discharge circuits are essentially current sinks and sources referenced to the −15 V and +24 V power supply rails. The maximum voltage difference of 39 V available to a SIM module is required to charge the NiMH battery stacks, which can have as much as 21 cells × 1.5 V/cell = 31.5 V potential accross them while leaving enough headroom for transistor and sense resistor voltage drops.

3.1.2.2 Thermal considerations

Batteries are chemical storage devices with finite efficiency. They have temperature dependent efficiencies and life times. NiMH batteries are best operated at temperatures close to room temperature. The SIM928 power dissipation and the thermal environment of the SIM900 Mainframe will lead to a temperature rise of the batteries which is slightly above room temperature. Two particular heat sources will influence the battery temperature most:

1. During battery discharge the module dissipates an additional 1.2 W of heat and temperatures may rise somewhat. This is perfectly normal and the effect can not thermally damage either electronics or batteries if the external temperature is kept within the range guaranteed by the data sheet.
2. During charging, NiMH batteries will heat up slightly, especially towards the end of the charge cycle. This heating is usually longer than that associated with discharge and will last several hours. The maximum temperature rise is always safe and the charger algorithm will cut off the charging current before damage to the battery can occur.

Battery lifetime is temperature dependent, especially at the higher end of the useful temperature range. Users concerned with maximizing the battery lifetime who are operating several SIM928 modules in the same SIM900 mainframe can reduce maximum temperatures by spreading out modules with higher power dissipation like the SIM928 evenly over the mainframe slots. In any case the effects on actual lifetime should be small.

3.1.2.3 Battery voltage monitoring

While the battery is connected to the charger circuit, its cathode is referenced to −15 V. A battery voltage monitor made of R216, R217, U203 and QN204 level shifts the battery anode voltage to comply with the microcontrollers internal ADC input range of 0 V to +5 V. The circuit is essentially a precision current mirror built with a 2.5 V voltage reference. The mirrored current creates a voltage drop across sense resistor R119 which is referenced to the microcontroller ADC's voltage reference (generated by U105). The circuit has a battery voltage range of approx. 20 V–35 V and is factory calibrated to have millivolt offset voltage and drift. The microcontroller's 10-bit internal ADC achieves a resolution of approx. 15 mV/LSB which is further increased by averaging. The effective voltage resolution per NiMH cell is better than 100 μV, allowing it to follow battery charging very precisely.

3.1.2.4 Switches and voltage regulators

The batteries are connected to the charger and the isolated voltage regulator through relays K201–K204. The microcontroller algorithm makes sure that only combinations of switches can be activated which isolate the charger from the isolated output stage. Coupling between input and output is therefore purely capacitive, albeit the capacitance of approx. 40 pF changes by a few picofarads, depending on the actual charger configration.

Since the batteries can be connected to different absolute potentials, these changes in potentials and capacitance can generate small current spikes during battery switching events. Similar but smaller spikes can occur when the charge/discharge circuits are activated. The module has a set of opticaly isolated Mosfet switches U204/205 with 1 MΩ series resistors R218–R221 which pre-charge the battery's stray capacitance to minimize these current spikes. However, user's who are very sensitive to charge transfers on the order of a few nanocoulombs need to take precations against these unavoidable artifacts by either shunting these charges against ground with a capacitor or by stretching them out with series resistors. Alternatively, the

SIM928 can be forced to switch in a fresh battery (see section 1.2.2.2) prior to connecting to the sensitive user system.

A fully charged, unloaded battery has a terminal voltage several volts higher than that of a loaded, almost fully discharged battery. During switch-over both batteries are connected to the isolated user regulator for approx. 30 seconds to ensure that the output voltage never drops out. Two discrete, low-drop voltage regulators (with Q207 and Q208 as series elements) equalize the battery voltages to 23.5 V and make sure that the maximum voltage jump at the output regulator power supply rail stays well below a few hundred millivolts.

3.1.3 Battery pack

Each SIM928 battery pack contains two sets of three 9 V NiMH batteries each. Each 9 V battery contains seven NiMH cells with a nominal voltage of 1.2 V. A fully charged battery will produce a voltage of approx. 21×(1.2 V ~ 1.3 V) = 25.2 V ~ 27.3 V. Under load this voltage quickly settles to a slowly falling ramp until the battery is nearly empty. At approx. 1.15 V per cell, the battery quickly starts losing voltage and the voltage detection circuitry signals the microcontroller (through U502A) that the battery needs to be switched over.

Each battery pack carries a non-volatile EEPROM with information about cell type, voltage, capacity, production date, charge cycles and serial number. This information is used by the microcontroller to determine the optimum charging time and when to turn on the ”Sevice Battery” indicator.

3.1.4 Isolated voltage regulator stage

The output stage is built around the low power, precision voltage reference U601, a 16-bit serial digital-to-analog converter U602, and a gain 10 output stage containing U604 as the central precision opamp. Precision is ensured by using a low temperature coefficient, adjustable, precision voltage divider network (R634–R642). Offset voltage compensation is partially digital by adding a digital offset word to the DAC code and partially analog by trimming of U604’s offset voltage.

U604 drives a current mirror Q610/Q608 used to translate its limited output voltage swing into a >20 V signal which can drive the voltage follower made of Q601 and Q602. The biased low current output stage is built with bipolar transistors and diodes that are specified for 400 V operation. Current and voltage sense transistors QN603/Q604 limit the maximum output current of this stage to <18 mA and make sure that overvoltages can not damage the output stage. On detection of a permanent overvoltage, the microcontroller disconnects the module's output from the source. While the circuit is designed to be safe for higher voltages, a set of gas discharge arrestors will limit any potential difference between the SIM chassis and the output terminals to approx. 60 V ∼ 80 V.

⚠ WARNING

DO NOT ATTEMPT TO EXCEED THE ±40 V EARTH/OUTPUT POTENTIAL!

An active floating ground reference made of U607 and Q613/Q614 creates a virtual 1.5 V grounding point (relative to the battery cathode) which allows the regulator to reduce the output voltage all the way to 0 V without loosing linearity and precision. Dual preregulators Q502/D503 and U506 increase common mode rejection and stability of the reference voltage source, the DAC and the feedback opamp.

The DAC's output voltage is programmed by the microcontroller through an optically isolated (U501–U504) serial interface. Since the batteries can only supply unipolar 24 V, polarity inversion is implemented with a relay switch K501/K502 by commutating the output terminals. The module's firmware makes sure that polarity switching only happens when the regulator output voltage is 0 V. A passive output filter L501,L502,C506,C507 limits output noise and increases stability for passive capacitive and inductive loads.

3.1.5 Display and buttons

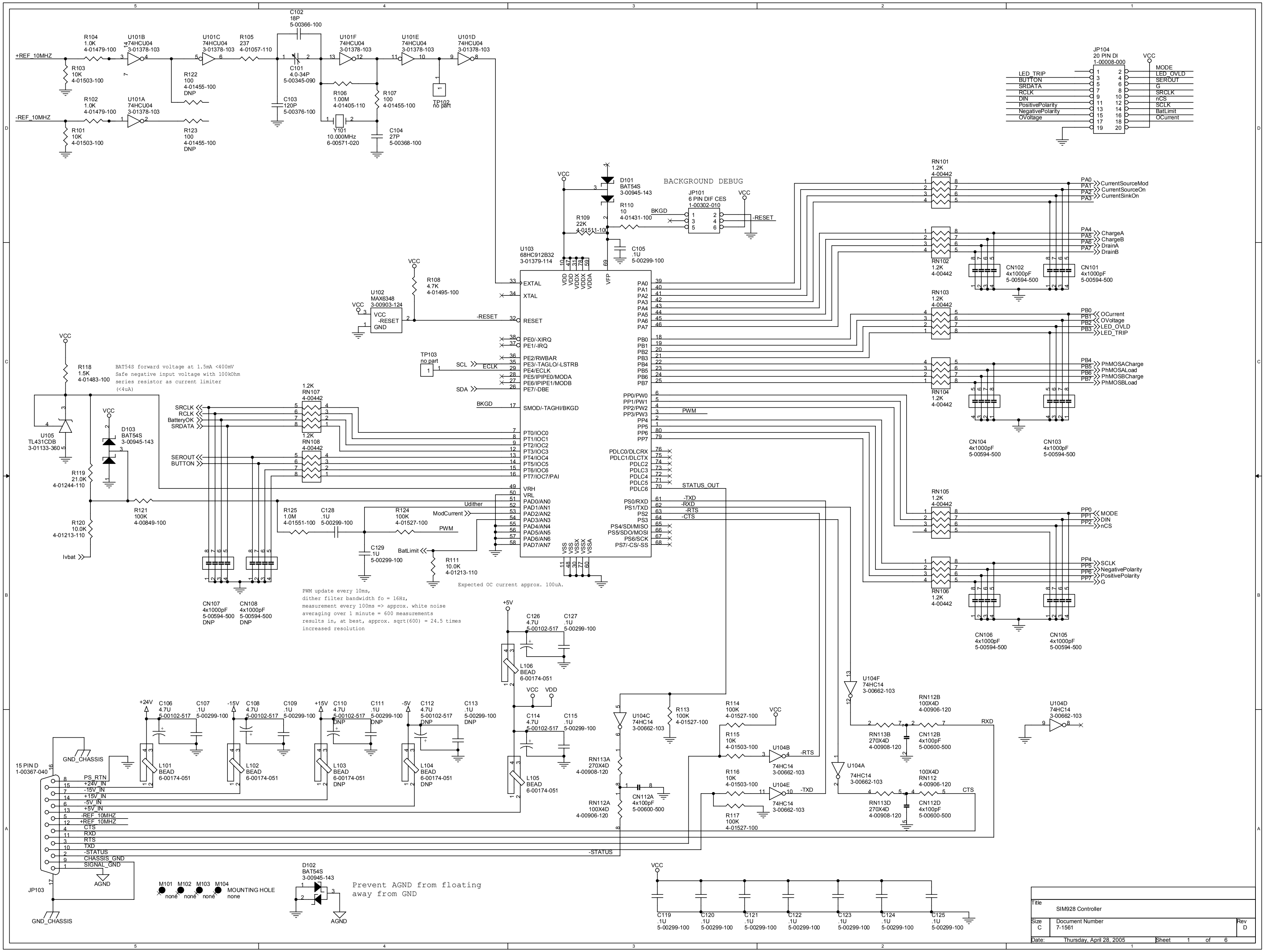
The SIM928 display is fully static to minimize noise. Display and LEDs are driven and buttons are read by shift registers which hold their state without firmware update. The microcontroller only reads from and writes to these registers when display updates are necessary or the user presses one of the buttons.

3.2 Parts List

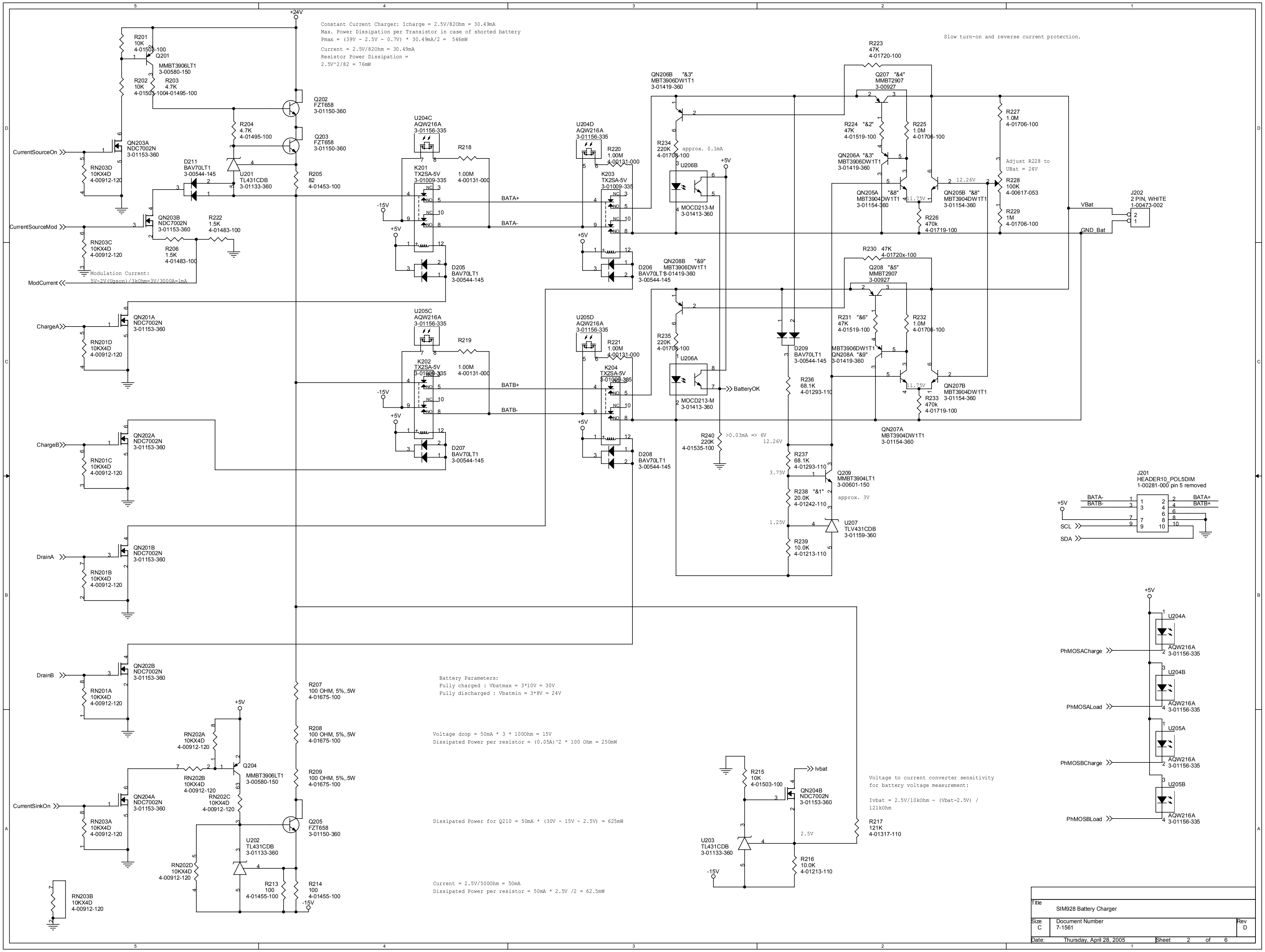
Reference	SRS P/N	Value
B301-B306	6-00635	NiMH 9V (8cell)
C101	5-00106	9.0-50P
C102	5-00366	18P
C103	5-00376	120P
C104	5-00368	27P
C105,C107,C109,C115, C119-C125,C127-C129, C301,C401-C404,C502, C602,C616	5-00299	.1U
C106,C108,C114,C126	5-00102	4.7U
C110,C112	5-00102	4.7U
C111,C113	5-00299	.1U
C501	5-00041	220U
C503	5-00025	100P
C504	5-00298	.01U
C505	5-00192	22U MIN
C506,C507	5-00599	10uF, 50V
C601	5-00267	1000U
C603,C610-C612,C615, C617	5-00525	1U
C604,C613,C614	5-00526	22U-T16
C605	5-00545	3.3N
C606	5-00572	330P
C607,C608	5-00525	1U
C619	5-00319	10U/T35
CN101-CN106	5-00594	4x1000pF
CN107,CN108	5-00594	4x1000pF
CN112	5-00600	4x100pF
D101-D103, D613	3-00945	BAT54S
D205-D209,D211,D501, D502,D603,D606-D608	3-00544	BAV70LT1
D401,D404-D409	3-00424	GREEN MINI
D410-D412	3-00426	YELLOW MINI
D413	3-00425	RED MINI
D503	3-00134	1N759A
D601,D602,D604,D605, D609,D610	3-01148	S1M
D611	3-01357	MMBZ5230
D612	3-01149	1SMA5913BT3
J201	1-00281	HEADER10_POL5DIM
J202,J503,J504	1-00473	2 PIN, WHITE
J301	1-00281	10 PIN DI
J401	1-01071	SMS-112-01-G-S
J501	1-01074	TMS-112-01-G-S-RA
J502,JP104	1-00008	20 PIN DI
JP101	1-00302	6 PIN DIF CES
JP103	1-00367	15 PIN D
K201-K204,K501,K502	3-01009	TX2SA-5V
L101-L106	6-00174	BEAD
L501,L502	6-00640	500uH/10mA
Q201,Q204	3-00580	MMBT3906LT1
Q202-Q205,Q601,Q608, Q610	3-01150	FZT658
Q207,Q208,Q613	3-00927	MMBT2907
Q209	3-00601	MMBT3904LT1
Q501-Q503,Q614	3-01421	MMBT2222
Q602,Q607,Q609	3-01152	FZT758
QN201-QN204	3-01153	NDC7002N
QN205,QN207,QN502, QN602,QN604,QN606, QN611	3-01154	MBT3904DW1T1
QN206,QN208,QN503, QN603,QN605	3-01419	MBT3906DW1T1
R101,R103,R115,R116, R201,R202,R215,R605-R609,R611,R622,R627, R628,R648	4-01503	10K
R102,R104,R655	4-01479	1.0K
R105	4-01057	237
R106	4-01405	1.00M
R107,R213,R214	4-01455	100
R108,R301,R302,R619	4-01495	4.7K
R109	4-01511	22K
R110	4-01431	10
R111,R120,R216	4-01213	10.0K
R113,R114,R117,R124, R626	4-01527	100K
R118,R206,R222	4-01483	1.5K
R119	4-01244	21.0K
R121	4-00849	100K
R122,R123	4-01455	100
R125,R503,R610,R612	4-01551	1.0M
R203,R204	4-01487	2.2K
R205	4-00997	56.2
R207,R208,R209	4-01675	100 OHM, 5%,.5W
R217	4-01320	130K
R218-R221	4-00131	1.00M
R223	4-01720	47K
R224,R231,R649	4-01519	47K
R225,R229,R232	4-01706	1.0M
R226,R233	4-01719	470k
R227	4-01401	909k
R228	4-00617	100K
R230	4-01720	47K
R234,R235	4-01708	220K
R236,R237	4-01264	34.0K
R238	4-01242	10.0K
R239	4-01184	4.99K
R240,R501,R502	4-01535	220K
R401	4-01489	2.7K
R402,R403	4-01480	1.1K
R508	4-01548	750K
R509,R510	4-01536	240K
R511	4-01435	15
R601,R602	4-00620	10
R603,R604,R647	4-01443	33
R613	4-01467	330
R614,R616	4-01491	3.3K
R615	4-01464	240
R617,R620	4-00849	100K
R618	4-01544	510K
R621	4-01489	2.7K
R623	4-00859	150K
R629	4-01447	47
R630,R631	4-01463	220
R632,R633	4-01406	0
R634	4-01050	200
R635	4-01590	33.2K
R636	4-00326	200
R637	4-01067	301
R638	4-01021	100
R639	4-00296	604
R640,R641	4-00217	1.000K
R642	4-01650	10.00K
R643	4-01651	100.0K
R644	4-01479	1.0K
R645	4-01557	1.8M
R646	4-01515	33K
R651	4-01462	200
R652	4-00012	20K
R653	4-01535	220K
R654	4-01519	47K
RN101-RN108,RN403,	4-00442	1.2K
RN404	4-00442	1.2K
RN112,RN602-RN604	4-00906	100X4D
RN113	4-00908	270X4D
RN201-RN203,RN501-RN503	4-00912	10KX4D
RN405-RN413	4-00407	2.7K
RT301,RT302	4-00766	RXE030
S401-S406,S408,S409	2-00053	B3F-1052
U101	3-01378	74HCU04
U102	3-00903	MAX6348
U103	3-01379	68HC912B32
U104	3-00662	74HC14
U105,U201-U203	3-01133	TL431CDB
U204,U205	3-01156	AQW216A
U206,U501-U504	3-01413	MOCD213-M
U207,U608	3-01159	TLV431CDB
U301	3-01458	24LC16B
U402-U406	3-00672	74HC595ADT
U407	3-01424	HDSP-A107
U408-U410	3-00290	HDSP-A101
U411	3-01157	74HC165
U412	3-01158	74HC133
U506	3-01415	LP2951CMM
U601	3-01451	ADR421AR
U602	3-01160	AD5541
U604	3-01370	OPA277UA
U606	3-01161	OPA336N
U607	3-01162	OPA244N
Y101	6-00571	10.000MHz

3.3 Schematic Diagrams

Schematic diagrams follow this page.



Title		
SIM928 Controller		
Size: C	Document Number: 7-1561	Rev: D
Date: Thursday, April 28, 2005	Sheet 1 of 6	



Constant Current Charger: Icharge = 2.5V/82Ohm = 30.49mA
Max. Power Dissipation per Transistor in case of shorted battery
Pmax = (39V - 2.5V - 0.7V) * 30.49mA/2 = 546mW

Current = 2.5V/82Ohm = 30.49mA
Resistor Power Dissipation =
2.5V^2/82 = 76mW

Slow turn-on and reverse current protection.

Adjust R228 to
UBat = 24V

Modulation Current:
5V-2V(Ugson)/3kOhm=3V/3000A=1mA

Battery Parameters:
Fully charged : Vbatmax = 3*10V = 30V
Fully discharged : Vbatmin = 3*8V = 24V

Voltage drop = 50mA * 3 * 100Ohm = 15V
Dissipated Power per resistor = (0.05A)^2 * 100 Ohm = 250mW

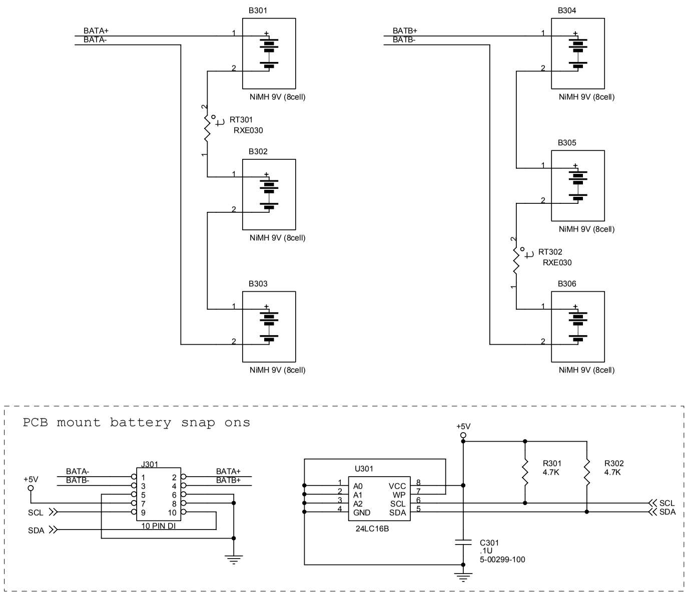
Dissipated Power for Q210 = 50mA * (30V - 15V - 2.5V) = 625mW

Current = 2.5V/500Ohm = 50mA
Dissipated Power per resistor = 50mA * 2.5V /2 = 62.5mW

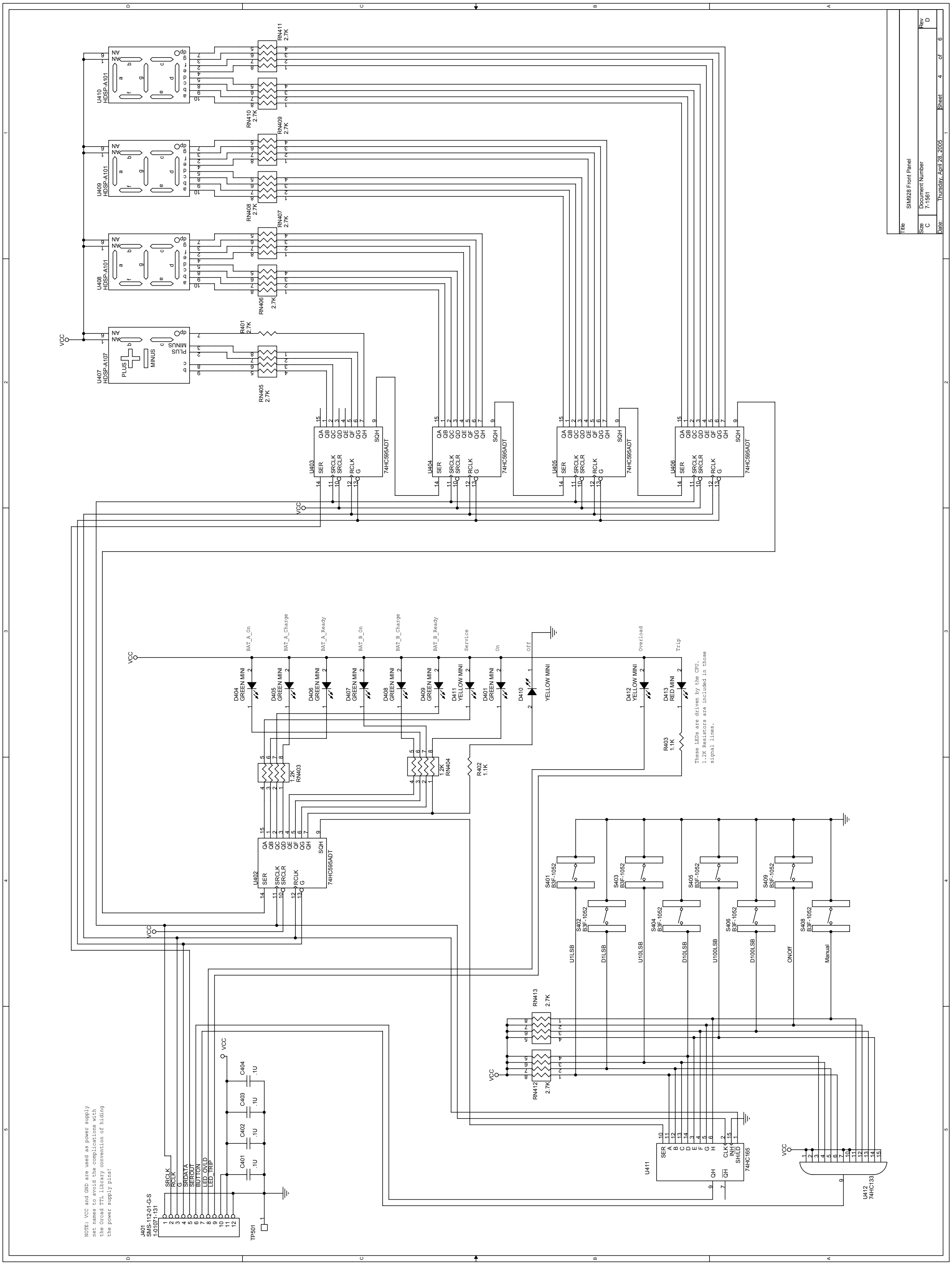
Voltage to current converter sensitivity
for battery voltage measurement:

Ivbat = 2.5V/10kOhm - (Vbat-2.5V) /
121kOhm

Title		
SIM928 Battery Charger		
Size: C	Document Number: 7-1561	Rev: D
Date: Thursday, April 28, 2005	Sheet 2 of 6	



Title SIM928 Battery Pack		
Size C	Document Number 7-1561	Rev D
Date: Thursday, April 28, 2005	Sheet 3 of 6	



These LEDs are driven by the CPU.
1.2K Resistors are included in those
signal lines.

NOTE: VCC and GND are used as power supply
net names to avoid the complications with
the Orcad TTL library convention of hiding
the power supply pins!

Title: SIM928 Front Panel

Size: C

Document Number: 7-1561

Rev: D

Date: Thursday, April 28, 2005

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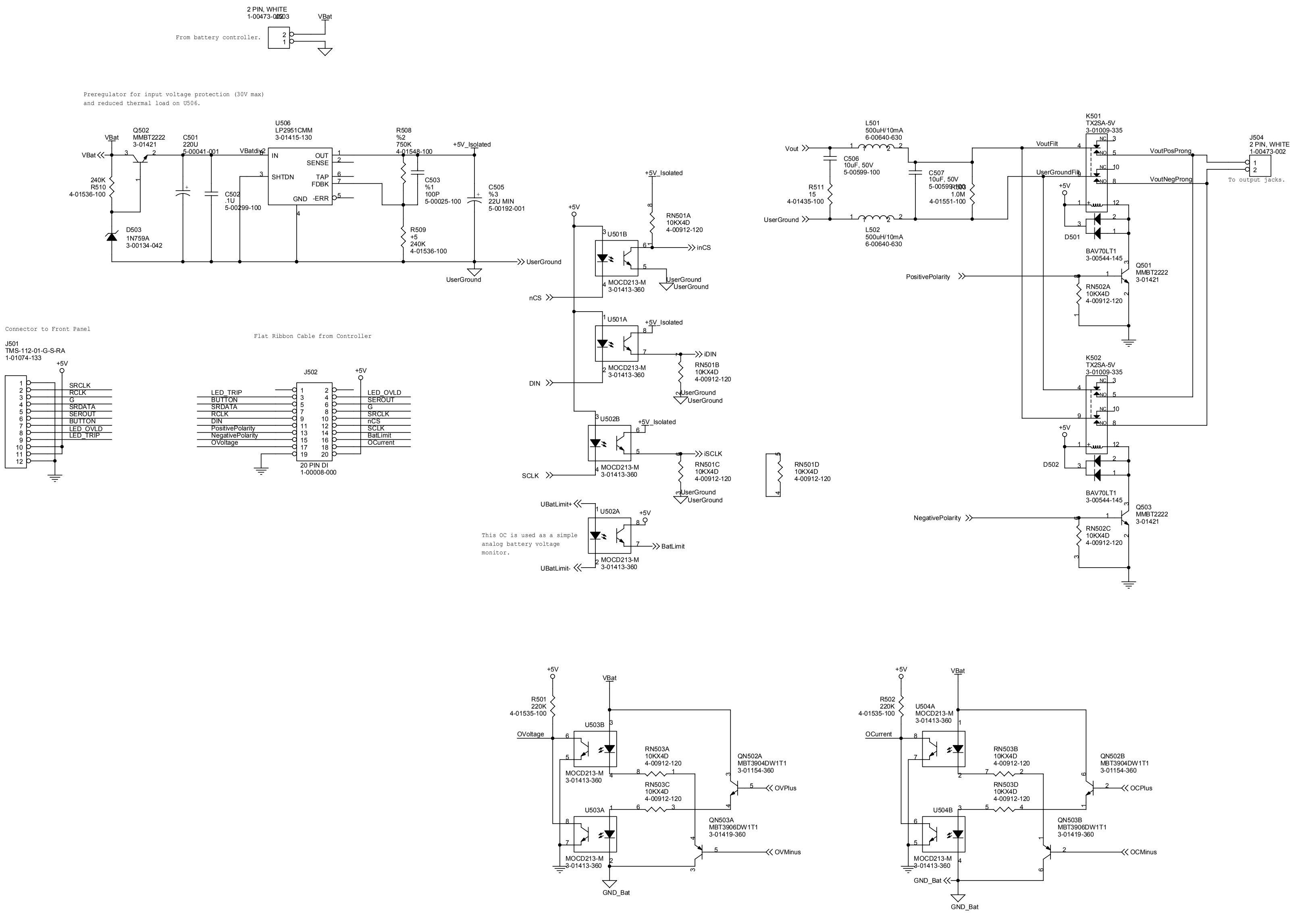

Isolation requirements:
Isolated power supply voltages:
  SIM mainframe side: +5V, GND
  User side: VBat, GNDBAT, USERGND
Isolation Distance: min. 2mm (80 mil)

Title	SIM928 Optical Isolation			
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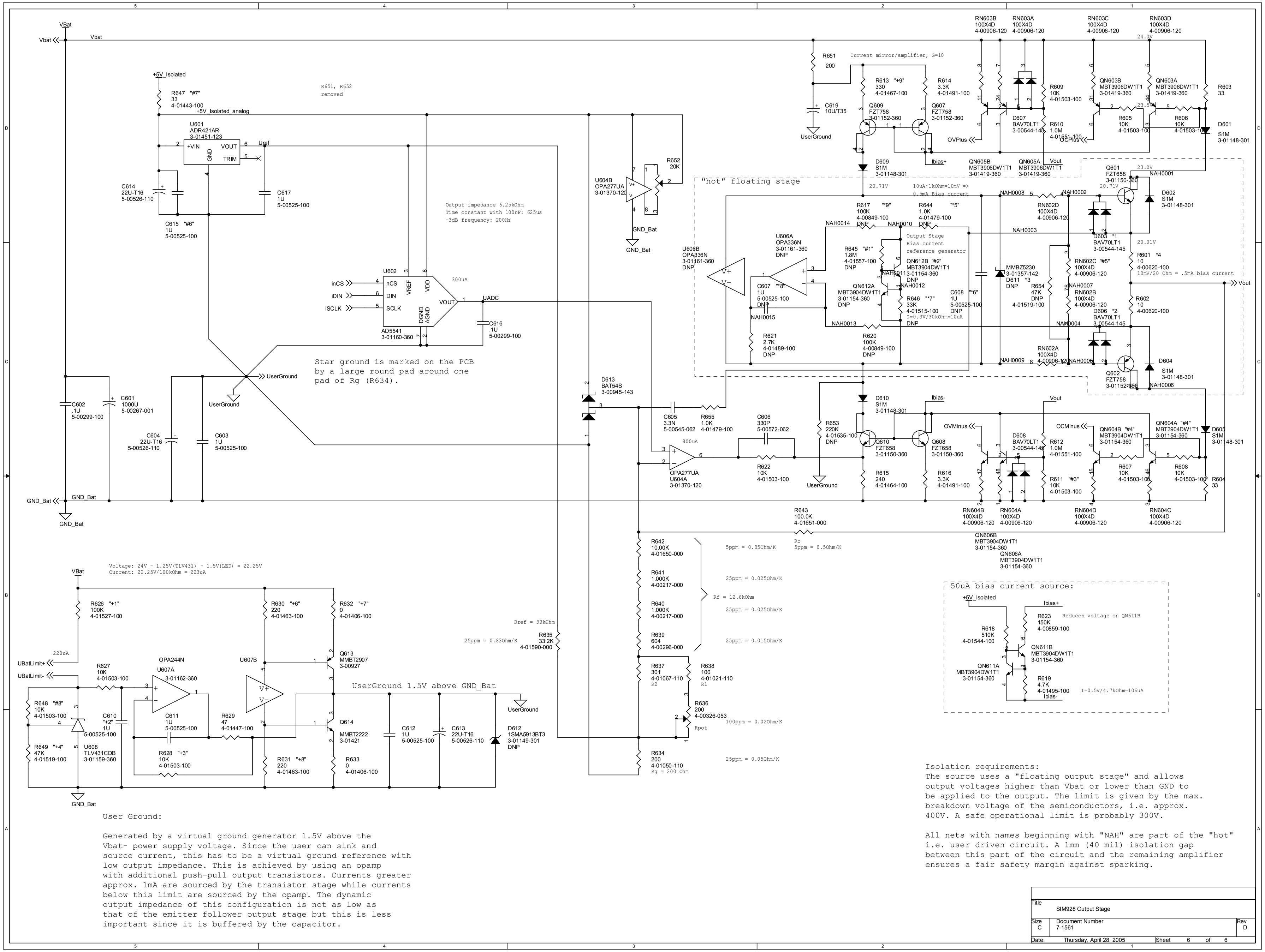

Star ground is marked on the PCB
by a large round pad around one
pad of Rg (R634).

UserGround 1.5V above GND_Bat

User Ground:

Generated by a virtual ground generator 1.5V above the Vbat- power supply voltage. Since the user can sink and source current, this has to be a virtual ground reference with low output impedance. This is achieved by using an opamp with additional push-pull output transistors. Currents greater approx. 1mA are sourced by the transistor stage while currents below this limit are sourced by the opamp. The dynamic output impedance of this configuration is not as low as that of the emitter follower output stage but this is less important since it is buffered by the capacitor.

Isolation requirements:
The source uses a "floating output stage" and allows output voltages higher than Vbat or lower than GND to be applied to the output. The limit is given by the max. breakdown voltage of the semiconductors, i.e. approx. 400V. A safe operational limit is probably 300V.

All nets with names beginning with "NAH" are part of the "hot" i.e. user driven circuit. A 1mm (40 mil) isolation gap between this part of the circuit and the remaining amplifier ensures a fair safety margin against sparking.

Title SIM928 Output Stage		
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