Operation and Service Manual

Analog Summing Amplifier

SIM980

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.

Service

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Contents

General Information

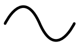
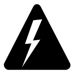
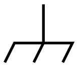
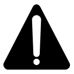
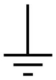
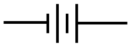
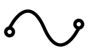
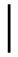
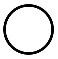
The SIM980 Summing Amplifier, part of Stanford Research Sysetems' Small Instrumentation Modules family, is a four-input, unity-gain amplifier for combining multiple analog signals from DC to 1 MHz.

Service

Do not install substitute parts or perform any unauthorized modifications to this instrument.

The SIM980 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:

- Front-panel buttons are set as [Chan 1].
- Front-panel indicators are set as *OVLD*.
- 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 SIM980 are set as `straight teletype font`, while responses received by the host computer from the SIM980 are set as *`slanted teletype font`*.

Specifications

Performance Characteristics

Number of inputs	4
Function	Inverting, non-inverting, or off
Gain	1×
Input impedance	1 MΩ
Bandwidth	DC to 1 MHz
Output voltage noise	30 nV/$\sqrt{\text{Hz}}$@ 1 kHz, max.
Crosstalk	−80 dB @ 1 kHz
Offset voltage	±100 μV (after 5 min. warm up)
Input range	±10 V before overload
Output range	±10 V before overload
Input slew rate	40 V/μs
Total Harmonic Distortion	0.01% (−80 dB) max. @ 1 kHz
Output slew rate	75 V/μs
Operating temperature	0 °C to 40 °C, non-condensing
Power	+5 V (100 mA)
	±15 V (300 mA)

General Characteristics

Interface	Serial (RS-232) through SIM interface
Connectors	BNC (5 front, 1 rear)
	DB–15 (male) SIM interface
Weight	1.5 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 SIM980 Summing Amplifier.

In This Chapter

1.1 Introduction to the Instrument

The SIM980 Summing Amplifier is a four-input, unity-gain amplifier for combining multiple analog signals from DC to 1 MHz.

1.1.1 Overview

The basic function of the SIM980 is to add or subtract up to four analog signals. Each input channel can be separately configured for inverting or non-inverting operation, or switched off. Each input is 1 MΩ and DC-coupled, and accepts signals between ±10 V.

1.1.2 Power-on State

The SIM980 stores its operation state (input channel configuration) in non-volatile memory. At power-on, the SIM980 will return to its previous configuration after a brief system check and initialization.

1.2 Front-Panel Operation

The front panel of the SIM980 (see Figure 1.1) provides a simple operator interface.

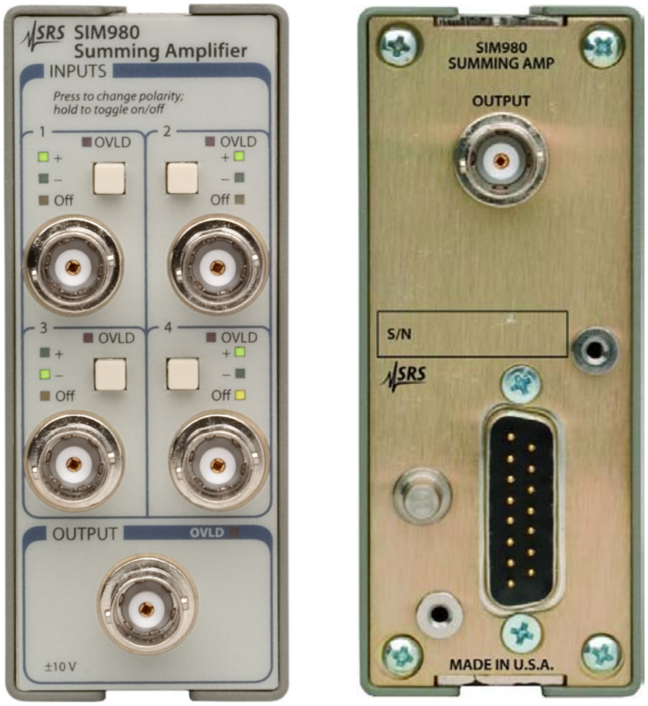


Figure 1.1: The SIM980 front and rear panels.

1.2.1 Inputs

Each of the four input channels of the SIM980 has a front-panel block consisting of the BNC input connector, a control button, and several LED indicators.

1.2.1.1 Polarity toggle

Each input can be switched between inverting or non-inverting polarity by *briefly* pressing that channel's control button. When inverting, the − LED is illuminated; when non-inverting, + is lit. Note that the polarity is always displayed, independent of whether that channel is on or off.

1.2.1.2 On/Off toggle

Each input can independently be turned on or off by *holding* that channel's control button for ~1.5 seconds. When on, the channel is either added to or subtracted from the output (depending on polarity, section 1.2.1.1). When off, it does not contribute to the output signal at all. The *OFF* LED is lit to indicate when a channel is off.

Unused channels should be turned off rather than simply left unconnected, as the Johnson noise of the open 1 MΩ input resistor will dominate the output noise of the SIM980.

1.2.1.3 Offset autocalibration

The SIM980 uses an active input offset correction to trim all input circuitry as well as the summing circuitry of DC offsets. The user can initiate an autocalibration cycle by disconnecting all inputs and outputs from the SIM980, and pressing and holding any of the control buttons for ~5 seconds. The entire process takes approximately 1 minute, and is completed when the relays have stopped "clicking" for at least 10 seconds.

Note that it is important that all inputs be open (or, preferably, shorted to ground) before initiating an offset autocalibration cycle. If any input channel is above ~500 μV amplitude, the SIM980 will reject the autocalibration request.

1.2.1.4 Input Overload

Each of the four input channels of the SIM980 has an overload detection circuit. The input is considered overloaded when the signal magnitude exceeds ±10 V. This is indicated by the red *OVLD* LED at the top of each front-panel block.

1.2.2 Output

The resulting sum of the enabled input channels appears at the output BNC connectors on the front and rear panels. Each output connection is through a 50 Ω resistor. For normal operation, the user should not need to terminate the output. If a 50 Ω termination is applied, note that the output signal will be divided in half.

If the output signal exceeds ±10 V, the output overload detection is activated. This is indicated by the red *OVLD* near the top of the "OUTPUT" block on the front panel.

1.3 SIM Interface

The primary connection to the SIM980 Summing Amplifier is the rear-panel DB–15 SIM interface connector. Typically, the SIM980 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 SIM980 directly, without using the SIM900 Mainframe. This section provides details on the interface.

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, +5V=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 (No connection in SIM980)
6	−5 V	MF ⇒ SIM	Power supply (No connection in SIM980)
7	−15 V	MF ⇒ SIM	Power supply (analog circuitry)
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 (No connection in SIM980)
13	+5 V	MF ⇒ SIM	Power supply (digital circuitry)
14	+15 V	MF ⇒ SIM	Power supply (analog circuitry)
15	+24 V	MF ⇒ SIM	Power supply (No connection in SIM980)

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

1.3.2 Direct interfacing

The SIM980 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 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.

The SIM980 has no internal protection against reverse polarity, missing supply, or overvoltage on the power supply pins.

1.3.2.1 Direct interface cabling

If the user intends to directly wire the SIM980 independent of the SIM900 Mainframe, communication is usually possible by directly connecting the appropriate interface lines from the SIM980 DB–15 plug to the RS-232 serial port of a personal computer.[1] Connect RXD from the SIM980 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.

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 SIM980, 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.

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. The serial baud rate is fixed, but the word size and parity may be changed with the FLOW or PARI commands.

[1] 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

DB–15/F to SIM980		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	
14 ⟷	+15 VDC	
8,9 ⟷	Ground (P/S return current)	
1 ⟷	Signal Ground (separate wire to Ground)	

Table 1.2: SIM980 Direct Interface Cable Pin Assignments

2 Remote Operation

This chapter describes operating the SIM980 over the serial interface.

In This Chapter

2.1 Index of Common Commands

symbol	definition
i,j	Integers
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

Amplifier

CHAN(?) *i* {,*j*}	2 – 9	Channel Control
READ? [*i*]	2 – 9	Read Offset Voltage

Autocalibration

ARMC(?) [*z*]	2 – 10	Arm Autocalibration
ACAL	2 – 10	Perform Offset Autocalibration
OFST(?) *i* {,*j*}	2 – 10	Offset Value

Serial Communications

FLOW(?) {*z*}	2 – 11	Flow Control
PARI(?) {*z*}	2 – 11	Parity

Status

*STB? [*i*]	2 – 11	Status Byte
*SRE(?) [*i*,] {*j*}	2 – 11	Service Request Enable
*CLS	2 – 12	Clear Status
*ESR? [*i*]	2 – 12	Standard Event Status
*ESE(?) [*i*,] {*j*}	2 – 12	Standard Event Status Enable
CESR? [*i*]	2 – 12	Comm Error Status
CESE(?) [*i*,]{*j*}	2 – 12	Comm Error Status Enable
OVCR? [*i*]	2 – 12	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
*IDN?	2 – 14	Identify
*OPC(?)	2 – 14	Operation Complete
CONS(?) {*z*}	2 – 14	Console Mode
LEXE?	2 – 14	Execution Error
LCME?	2 – 15	Command Error

2.2 Alphabetic List of Commands

★

*CLS	2 – 12	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 – 11	Service Request Enable
*STB? [_i_]	2 – 11	Status Byte

A

ACAL	2 – 10	Perform Offset Autocalibration
ARMC(?) [_z_]	2 – 10	Arm Autocalibration

C

CESE(?) [_i_,]{_j_}	2 – 12	Comm Error Status Enable
CESR? [_i_]	2 – 12	Comm Error Status
CHAN(?) _i_ {,_j_}	2 – 9	Channel Control
CONS(?) {_z_}	2 – 14	Console Mode

F

FLOW(?) {_z_}	2 – 11	Flow Control

L

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

O

OFST(?) _i_ {,_j_}	2 – 10	Offset Value
OVCR? [_i_]	2 – 12	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

R

READ? [_i_]	2 – 9	Read Offset Voltage

T

TERM(?) {*z*}	2 – 16	Response Termination
TOKN(?) {*z*}	2 – 15	Token Mode

2.3 Introduction

Remote operation of the SIM980 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 summing amplifier 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 SIM980 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 64-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 SIM980 are buffered in a 64-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 SIM980 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 SIM900 SRST command; if directly interfacing via RS-232, then use a serial break signal. After receiving the Device Clear, the interface is reset and CONS mode is turned OFF. Note that this *only* resets the communication interface; the basic function of the SIM980 is left unchanged; to reset the instrument, see *RST.

2.4 Commands

This section provides syntax and operational descriptions for reomote 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
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 SIM980 are set as `straight teletype font`, while responses received the host computer from the SIM980 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 Amplifier Commands

CHAN(?) *i* {,*j*}

Channel Control

Set (query) input channel *i* {to state *j*=(-1, 0, +1)}.

Setting channel *i* to *j*=0 will turn that channel *off*. Setting *j*=+1 (or any positive value less than 32767) turns that channel *on*, and sets the polarity to non-inverting. Setting *j*=-1 (or any negative value greater than −32768) also turns that channel *on*, but sets the polarity to inverting.

All four channels can be set or queried simultaneously by setting *i*=0.

Example: In the following, all four channels are first commanded off, then channels 1 and 2 are turned on the opposite polarities. Finally, the single-channel and four-channel queries are shown.

```
CHAN 0,0
CHAN 1,+1
CHAN 2,-1
CHAN? 2
-1
CHAN? 0
1,-1,0,0
```

READ? [*i*]

Read Offset Voltage

Query the output voltage, in tenths of microvolts.

When the offset autocalibration circuitry is active, an internal high-gain amplifier is activated to monitor the SIM980 output. This signal is digitized by an internal analog-to-digital converter. The READ? query allows the user to directly record this measurement. When READ? is queried, the high-gain amplifier is turned on. When the query has finished averaging, the high-gain amplifier is turned off again.

The optional parameter *i* is the averaging time, in milliseconds. The valid range is 10 <*i*< 10000, with a default value of 1000 (1 second).

The query result is in integer tenths of microvolts. That is, READ? returns $V_{\mathrm{out}} \times 10^7/\mathrm{V}$. The total range is (roughly) −1260 <READ?< 27650, corresponding to output voltages in the range −1.26 mV through +27.6 mV.

Example:

```
READ?
-151
```

2.4.5 Autocalibration Commands

The SIM980 has an internal offset trimming circuit (see section 1.2.1.3). The following set of commands provides detailed control over this subsystem.

ARMC(?) [*z*]

Arm Autocalibration

Test and set (or query) the armed flag for autocalibration. If *z*=(`FORCE` 1), the armed flag is set without testing.

The offset autocalibration proceedure requires that all inputs to the SIM980 be at 0 V (that is, either open or shorted to ground). The ARMC command performs a test of all 4 channels to ensure that each input is less than ∼ 500 μV amplitude. If all four channels are okay, the armed flag is set; otherwise it is cleared. The entire test takes about 15 seconds to complete.

If ARMC `FORCE` is set, the armed flag will be set without performing any test of the input channels.

Example:

```
ARMC; ARMC?
1
```

ACAL

Perform Offset Autocalibration

If the armed flag is set (see ARMC, above), an ACAL command will initiate an offset autocalibration cycle. The entire process takes between 30 s and 90 s, and should ideally be performed only after the SIM980 has been allowed to warm up at least 30 minutes.

Example:

```
ACAL; *OPC?
1
```

OFST(?) *i* {,*j*}

Offset Value

Set (query) the low-level offset trim for channel *i* {to *j*=(`0...255`)}.

The result of the ACAL command is stored at 6 low-level offset trims. The OFST allows direct access to these values. The input-channel-specific offset for channels 1 through 4 are stored in *i*=1 through 4, respectively. For these settings, increasing *j* causes the input offset adjust to decrease by about 6 μV per count.

i=5 and 6 both adjust the summing node offset voltage. Increasing *j* for *i*=5 causes the output voltage to decrease (by about 4.4 μV per count), while increasing *j* for *i*=6 causes the output voltage to *increase* (with roughly the same sensitivity).

All 6 offset values can be simultaneously set to a single value *j* by OFST *0*,*j*. Note, however, there is no corresponding multi-channel query.

Values stored by OFST or ACAL are stored in non-volatile memory, and are *not* affected by power-cycling or *RST.

Example:
```
OFST? 4
106
```

2.4.6 Serial Communication Commands

FLOW(?) {*z*}

Flow Control

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

After power-on, modules default 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)}.

After power-on, modules default to PARI NONE.

Example:
```
PARI EVEN
```

2.4.7 Status Commands

The Status commands query and configure registers associated with status reporting of the SIM980.

*STB? [*i*]

Status Byte

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

Execution of the *STB? query (without the optinal 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. See also the PSTA command.

Example:
```
*STB?
16
```

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

Service Request Enable

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

Example:
```
*SRE 0,1
```

*CLS Clear Status

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

Example:

```
*CLS
```

*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*] Comm Error Status

Query Comm 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*} Comm Error Status Enable

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

Example:

```
CESE?
0
```

OVCR? [*i*] Overload Condition

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

Example:

```
OVCR?
3
```

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? 0
1
```

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

Overload Status Enable

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

Example:
```
OVSE 16
```

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

Interface commands provide generic control over the interface between the SIM980 and the host computer.

*RST

Reset

Reset the SIM980 to default configuration.

After *RST, all channels are set to positive polarity, and to off. This is equivalent to the following command sequence:
```
CHAN 0,1; CHAN 0,0
```

Example:
```
*RST
```

***IDN?**

Identify

Read the device identification string.

The identification string is formatted as:
`Stanford_Research_Systems,SIM980,s/n******,ver#.#`
where `******` is the 6-digit serial number, and `#.#` is the firmware revision level.

Example:

```
*IDN?
Stanford_Research_Systems,SIM980,s/n003075,ver1.21
```

***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
```

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
```

LEXE?

Execution Error

Query the last execution error code. A query of LEXE? always clears the error code, so a subsequent LEXE? will return `0`. Valid codes are:

Value	Definition
0	No execution error since last LEXE?
1	Illegal value
2	Wrong token
3	Invalid bit
16	Autocalibration not armed

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?

Command Error

Query the last command error code. A query of LCME? always clears the error code, so a subsequent LCME? will return 0. Valid codes are:

Value	Definition
0	No execution 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 channel number of the last button pressed. A query of LBTN? always clears the button code, so a subsequent LBTN? will return 0.

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 SIM module 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.

On reset, TOKN is set to OFF.

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 10 (line feed). The token mnemonic gives the sequence of characters.

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

Example:

```
TERM?
3
```

2.5 Status Model

The SIM980 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 SIM980 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.

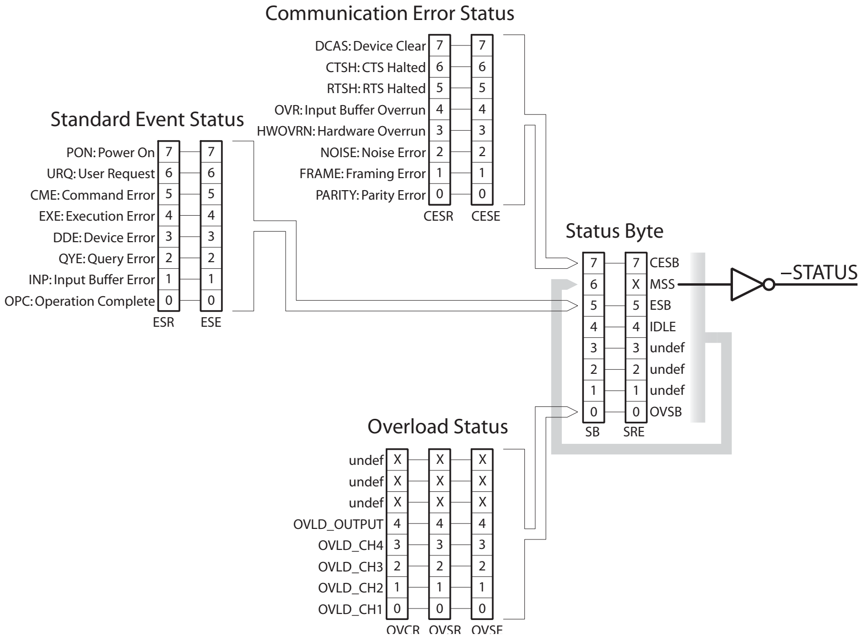


Figure 2.1: Status Register Model for the SIM980.

2.5.1 Status Byte (SB)

The Status Byte is the top-level summary of the SIM980 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 SIM980 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. This bit is undefined in the SIM980.

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 SIM980. Command Error. Indicates a parser-detected error.

CTSH : Undefined for the SIM980.

DCAS : Device Clear. Indicates the SIM980 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 5 single-bit monitors of conditions within the SIM980. 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 Channel 1
2	1	Overload Channel 2
4	2	Overload Channel 3
8	3	Overload Channel 4
16	4	Overload Output
32	5	undef (0)
64	6	undef (0)
128	7	undef (0)

Overload Channel *n* : The input buffer for Channel *n* is overloaded (input voltage exceeds ±10 V). Note that the overload detection is active even if the channel is off.

Overload Output : The output of the summing amplifier is overloaded (output voltage exceeds ±10 V). Note that the output can overload without any input channel overloading, and vice versa.

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 $0 \rightarrow 1$ of any bit within the OVCR, the corresponding bit in the OVSR becomes set.

Bits in the OVSR are unaffected by the $1 \rightarrow 0$ 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 Performance Tests

This chapter describes how to adjust the SIM980 to improve its offset and gain accuracy, and verify performance.

In This Chapter

3.1 Introduction

Under typical usage, only the internal autocalibration cycle is needed to keep the SIM980 operating within specifications (see section 1.2.1.3). If further adjustment is needed, this section describes the procedure.

3.2 Tools and preparation

The necessary tools for a complete recalibration are:

- a small flat-head screwdriver
- a voltmeter with microvolt resolution and stability (SIM970 or equivalent)
- a quiet DC voltage source (SIM928 or equivalent)
- a 1 MHz (minimum) sine generator (DS345 or equivalent)
- a 20 MHz bandwidth (minimum) oscilloscope
- several BNC patch cables
- 4 BNC-Tee adapters, or 3 Tees and 1 F/F barrel.

For the full offset calibration procedure the module should be running for at least 15 minute. The trimpots are accessible after removing the right side panel. It is easier to calibrate the module by connecting it through a cable to the SIM extension port, but the calibration can also be performed with the module located in the left-most slot (slot 1) of a SIM900 Mainframe with slots 2–5 empty.

3.3 Precalibration Values

If precalibration values are not required, skip ahead to section 3.4. Precalibration values should be recorded on a separate copy of the performance test record (page 3 – 7).

3.3.1 Offset Voltages

Begin by disconnecting all inputs from the SIM980, and connecting the output to the voltmeter. Switch all channels to OFF, and record the output voltage as “Offset Voltage: Output”. Enable Channel 1, set the polarity to +, and record the output voltage. Change the polarity to −, and subtract this output voltage from the previous value. Record the difference as “Offset Voltage:Channel 1”. Disable Channel 1, and repeat for the remaining 3 channels.

3.3.2 Calibration Words

Next, query the SIM980 over the remote interface to determine the calibration word values. Send the remote queries:

```
OFST? 1
...
OFST? 6
```

and record the results.

3.3.3 DC Gain Match

Set the DC voltage source to 2 V. Connect the BNC-Tee adapters together to form a 1-to-4 splitter. Connect the splitter to the DC voltage source, and connect the four SIM980 inputs to the splitter with equal-length cables (important for AC testing, later). Enable all four input channels, and set all input polarities to +. Note the output voltage as V_1^+. Then change all four input polarities to −, and note the output voltage as V_1^-.

Now switch the DC voltage source to −2 V, and with the channel polarities still set to − note the output voltage as V_2^-. Change all four input polarities to +, and finally note the output voltage as V_2^+.

Calculate the gain ratio mismatch as

$$\left(\frac{V_1^+ - V_2^+}{V_1^- - V_2^-} - 1 \right) \times 100\,\%$$

and record this value as the "DC mismatch".

3.3.4 AC Gain Match

Using the same 1-to-4 splitter from section 3.3.3, connect all four input channels to the sine generator, set to create a 1 MHz sine wave at 1 $\mathrm{V_{rms}}$ or 1 $\mathrm{V_{peak\text{-}peak}}$ amplitude (circle which). Unlike the DC case, here it is important that all four BNC cables leading to the channel inputs are of exactly the same length and type and that the splitting of the signal is accomplished in a symmetric manner. Differences in cable length will introduce phase shifts between inputs and falsify the result.

Connect the output of the SIM980 to the oscilloscope. Separately trigger the scope synchronously with the sine generator.

AC matching is measured pairwise between channels, with the two channels under test set to opposite polarity and the remaining two channels switched off. There are 12 such permutations, which can be labeled with a +−○○ notation. For example, setting Channel 1 non-inverting, Channel 3 inverting, and Channels 2 & 4 off is noted as “+○−○”. Measure the amplitude for each permutation, and record the results (circle either RMS or peak-to-peak)

3.4 Calibration

Prior to beginning calibration, photocopy a blank version of the performance test record (page 3 – 7).

3.4.1 Offset Adjustment

Calibration starts by disconnecting all inputs and resetting the electronic output offset calibration constants. This is accomplished by issuing the remote commands:

```
CHAN 0,0
OFST 5, 128; OFST 6, 127
```

which set the electronic trim-DAC outputs to midpoint. Connect the SIM980 output to the voltmeter, and adjust R245 to zero the voltage reading.

After nulling R245, an unconditional autocalibration cycle should be initiated. Issue the following remote commands:

```
ARMC FORCE; ACAL
```

to arm and start internal calibration. The autocalibration will complete in approximately one minute (wait for relays to cease switching for at least 10 seconds). The output voltage will fluctuate during calibration but settle to less than ±20 μV.

Verify that the calibration words are within the valid range 1–254 by repeating the queries of section 3.3.2. Nominally, all calibration words should be within the range 50–200; values of 0 or 255 indicate that the offsets have shifted outside of the adjustable range and the SIM980 may be damaged.

Input offset voltages should be measured directly by the procedure of section 3.3.1. Except for short term drift, the calibration should reduce input offset voltage errors to less than 10 μV. If the result is unsatisfactory, adjustment of the calibration constant may be attempted by manually issuing explicit OFST commands (see section 2.4.5). Manually adjusted constants should differ only slightly (±1 count) from the automatic result. Otherwise the module should be power-cycled and the adjustment procedure should be repeated.

Record the final offset values, and final calibration words, on the performance test record.

3.4.2 DC Gain Calibration

All resistors of the SIM980 gain network have a precision of 0.1%. Any two channels can therefore differ in their gain by up to 0.2%. Gain between + and − polarity settings can also differ by 0.2%. The common mode rejection of two channels set to take the difference of two signals is therefore limited to 0.2% or approximately −54 dB worst case. The module has one trimpot to equalize the average positive gain (over all channels) with the average negative gain and give the best overall match for any combination of channels.

To find the optimum setting, repeat the setup of section 3.3.3. Set the DC voltage source to approximately 2 V output, and set all four input channels to − polarity. Note the DC output voltage with at least millivolt precision (the value should be ∼ −8.00 V. Now switch all four channels to +, and adjust trimpot R268 to bring the output voltage to the same magnitude, but opposite polarity, as previously noted. Be aware that this procedure depends on neglecting the input offset voltages, so be sure to perform section 3.4.1 first.

After completing the calibration, measure the DC gain match according to section 3.3.3, and record the results.

3.4.3 AC Gain Calibration

The SIM980 amplifier bandwidth rolls off around 6 MHz. This is accomplished with a combination of fixed capacitors and one trimcap. The trimcap can be adjusted to equalize high-frequency gain below approximately 1 MHz, maximizing the average common mode rejection between channels.

Just as in case of the DC gain, the module achieves matching on the order of −60 dB. Above 1 MHz, high order effects begin to dominate and AC gains will vary from channel to channel by more than −50 dB. However, even the worst case channels typically achieve −40 dB (1% gain difference) suppression for any frequency below their −3 dB bandwidth as long as all amplifiers operate in small signal mode (i.e., the slew rate limit is not exceeded). For sinusoidal signals, this translates into 10 V amplitude at 500 kHz and 1 V at 5 MHz. Care must be taken with non-sinusoidal signals which have high slew rate.

For this adjustment a 1 MHz sine wave generator and an AC voltmeter or oscilloscope are necessary. Connect the instruments as previously in section 3.3.4.

Again, it is crucial that all BNC cables are of exactly the same length and type and that the splitting of the signal is accomplished in a symmetric manner. Differences in cable length will introduce phase shifts between inputs and falsify the result. If in doubt, as a check of symmetric cabling, the measurments may be repeated with the inputs being connected to all possible permutations of the four cables.

Inputs are pairwise set to − and + such that the overall AC signal is nulled. There are twelve possible gain combinations for two channel nulling:

+−○○ and −+○○,
+○−○ and −○+○,
+○○− and −○○+,
○+−○ and ○−+○,
○+○− and ○−○+,
○○+− and ○○−+.

The combination with the worst common mode rejection is optimized with trimcap C217 and all other combinations are re-checked. After a few iterations a solution with well distributed error can be found. The residual worst case AC voltage will typically be below $3\,\mathrm{mV_{rms}}$ for a $1\,\mathrm{V_{rms}}$ input.

After completing the adjustments, record the results.

Some users might want to improve DC and AC matching for a single combination of channels (e.g. channels 1 & 2) while sacrificing the matching for the others. This can be accomplished best by driving the two channels with the same signal and operating one in positive and the other one in negative mode while using R268 and C217 to minimize the difference signal at the output. Please note that reversing the polarity of these two channels will not result in an equally well matched result. The procedure works within a narrower-than-specified temperature range, and long term drift might make frequent re-calibration necessary.

3.5 Other tests and adjustments

The SIM980 internally generates two precision power supply voltages for the input buffer amplifiers. These +13.0 V and −13.0 V voltages can be tested at test points TP401 (+13.0 V), TP402 (−13.0 V) and TP403 (ground). R405 and R402 can be used to adjust the −13.0 V and +13.0 V voltage. There should be no need to ever actually perform this factory adjustment. If either voltage shows a large (> 100 mV) deviation from its ideal value, the module might have been damaged and should be sent to the factory for repair.

3.6 SIM980 Performance Test Record

This page should be photocopied to record results.

General

Name: ____________________

Serial Number: __________ Date/Time: __________

Offset Voltage

Output: __________ μV

Channel 1: __________ μV

Channel 2: __________ μV

Channel 3: __________ μV

Channel 4: __________ μV

Calibration Words

`OFST? 1` __________

`OFST? 2` __________

`OFST? 3` __________

`OFST? 4` __________

`OFST? 5` __________

`OFST? 6` __________

Gain

DC mismatch: __________ %

AC mismatch:
(@ 1 MHz, 1 V
rms / peak-peak)

+−○○: __________ mV (rms / peak-peak)

−+○○: __________ mV

+○−○: __________ mV

−○+○: __________ mV

+○○−: __________ mV

−○○+: __________ mV

○+−○: __________ mV

○−+○: __________ mV

○+○−: __________ mV

○−○+: __________ mV

○○+−: __________ mV

○○−+: __________ mV

4 Parts Lists and Schematics

This chapter presents a brief description of the SIM980 circuit design. A complete parts list and circuit schematics are included.

In This Chapter

4.1 Circuit Descriptions

4.1.1 Input circuitry

Each channel of the SIM980 Summing Amplifier contains a JFET unity gain input buffer amplifer (U201–U204) with input protection (D201–D204). These input buffers have 0.1 μV/°C offset voltage drift and are being automatically trimmed to zero offset voltage by means of an eight channel digital analog converter U403. Input buffer amplifiers are powered by LDO voltage regulators U401 and U402 which are set to +13.0 V and −13.0 V, respectively.

Discriminators U205–U208 provide under/overvoltage detection for each channel and U209 monitors the output voltage. The OVLDALL signal is generated by *or*-ing overload signals into a single channel. This signal restarts the module's microcontroller clock which is inactive in normal operation to minimize noise. The clock is also automatically activated by a button push or a serial command.

4.1.2 Summing circuitry

The buffered input signals are summed into precision (0.1%) resistor networks R200A–E and R201A–E which form a difference amplifier with gain 1 around the fast precision amplifier U210. The signal path is controlled by relays K201–K208. A combination of two dual-pole, dual-throw relays per channel allows enable/disable and polarity change with constant noise gain and signal bandwidth.

The difference amplifier U210 is buffered by the power buffer U211. This compound amplifier can drive 10 V signals into open and 5 V into two 50 Ω loads. The outputs on the front and back panel can be used simultaneously with resistive isolation between them. The independent 50 Ω series resistors at these outputs also guarantee unlimited stability for any possible passive load and overcurrent/thermal protection for shorted outputs. The combination of U210/U211 is rolled off at a bandwith of 4 MHz by the combintion of C220 and C202. Trim capacitor C217 is factory adjusted for best common mode suppression at high frequencies.

4.1.3 Output circuitry

Outputs as well as inputs are equipped with common mode filters (baluns) to reduce conducted EMI (electromagnetic interference) of RF noise currents on the shield of BNC cables attached to the module. For the same reason the BNCs are isolated from the SIM980's front and back panels. This design ensures the best DC and low frequency performance in noisy environments. Care must be taken not to load the ground connections with currents > 1 A which could destroy the differential pair wiring inside the module and disconnect the ground from the isolated BNC jacks. Such a fault could result in harmful voltages being present on the BNC shell.

The opamp/buffer combination U210/U211 does not by itself satisfy the offset voltage specifications of the SIM980. Offset voltage stability is therefore guaranteed by U212, a differential integrator which drives a differential current source, QN201A/B, to trim the input offset voltage of U210. The resulting amplifier combines the AC performance of U210 with the stability of the slow amplifier U212. Offset adjustment is performed by two outputs of digital-analog converter U403.

4.1.4 Offset measurement & control

Chopper stabilized amplifier U404 is set at a gain of 1000 to measure output offset voltages with the 10-bit, built in analog-digital-converter of microcontroller U101. In auto-calibration mode the microcontroller can resolve microvolt output voltages and set channels 1–6 of digital-analog-converter U403 to minimize any input and the output offset voltage. Chopper amplifier U404 is switched off during normal operation to eliminate the potential noise generated by its internal chopping circuit.

4.1.5 Digital control

The SIM980 is controlled by microcontroller U101.

A critical aspect of the design is the clock-stop circuitry implemented by U103 and U105. A simple RC-oscillator is enabled or disabled at pin 1 of U105, which is driven by synchronizing flip-flop U103B to ensure that no "runt" clock pulses are produced that would violate U101's minimum clock periods. Four separate clock-starting signals are combined by U106:

- Power-on reset
- Amplifier overload (any)
- Incoming serial data
- Front-panel button press

The fast start-time of the RC-oscillator ensures that incoming serial data will be correctly decoded by the microcontroller's UART, even when the clock is started by the serial start bit of the incoming data. When the microcontroller has completed all pending activity, it drives the STOP signal high (pin 71 of U101), effectively halting its own processor clock. In this way, the SIM980 guarantees no digital clock artifacts can be generated during quiescent operation.

4.2 Parts Lists

4.3 Schematic Diagrams

Schematic diagrams follow this page.