Operation and Service Manual

Rubidium Frequency Standard

SIM940

SRS Stanford Research Systems

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

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

Contents

Addendum: PRS10 Manual

General Information

The SIM940 Rubidium Frequency Standard, part of Stanford Research Systems' Small Instrumentation Modules family, is a 10 MHz frequency standard with an estimated 20-year aging of less than 0.005 ppm.

Service

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

The SIM940 is a double-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
$\sim$	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 indicators are set as *Overload*.

- Remote command names are set as ID?.

- Literal text other than command names is set as OFF.

Specifications

Performance Characteristics

Output	Output frequency	10 MHz sine, 10 µs wide 1 pps pulse
	Amplitude (±10 %)	0.5 Vrms (+7 dBm) into 50 Ω
	1 pps pulse amplitude	2.5 V into 50 Ω, 5 V into high-Z
Noise	Phase noise (SSB)	< -130 dBc/Hz (10 Hz)
		< -140 dBc/Hz (100 Hz)
		< -150 dBc/Hz (1 kHz)
		< -155 dBc/Hz (10 kHz)
	Spurious	< -100 dBc (100 kHz BW)
	Harmonics	< -60 dBc
	Short term stability (Allan variance)	$< 2 \times 10^{-11}$ (1 s)
		$< 1 \times 10^{-11}$ (10 s)
		$< 2 \times 10^{-12}$ (100 s)
Accuracy	Accuracy at shipment	$\pm 5 \times 10^{-11}$
	Aging (after 30 days)	$< 5 \times 10^{-11}$ (monthly)
		$< 5 \times 10^{-10}$ (yearly)
		5×10^{-9} (20 years, typ.)
	Holdover	72 h Stratum 1 level (1×10^{-11})
	Frequency retrace	$\pm 5 \times 10^{-11}$ (72 h off, then 72 h on)
Control	Settability	$< 5 \times 10^{-12}$
	Trim range	$\pm 2 \times 10^{-9}$ (0 to 5 VDC)
		± 0.5 ppm (remote interface)
	Warm-up time	< 6 minutes (time to lock)
		< 7 minutes (time to 1×10^{-9})

Interfaces

Front-panel LEDs	Locked	Indicates frequency is lock to rubidium
	Unlocked	Indicates frequency is unlocked
	1 pps input	Blinks with each 1 pps reference input applied to rear panel
	1 pps sync	Indicates 1 pps output is synchronized within $\pm 1\,\mu$s of 1 pps input
Rear Panel (BNCs)	Frequency Adjust	0 to 5 VDC adjusts frequency by ± 0.002 ppm
	1 pps input	100 kΩ input. Requires CMOS level pulses (0 to 5 VDC). If an external 1 pps input is applied, lock is maintained between the 1 pps input and 1 pps output with computer adjustable time constant from 8 minutes to 18 hours.
	1 pps output	50 Ω pulse output
	10 MHz outputs	Three 50 ohm isolated 10 MHz sine outputs
	SIM (DB–15/male)	power and communications
Operating	Temperature	+10 °C to +40 °C
	Temperature stability	Δ f/f $< \pm 1 \times 10^{-10}$ (+10 °C to +40 °C)
	Storage temperature	−55 °C to +85 °C
	Magnetic field	Δ f/f $< \pm 2 \times 10^{-10}$ for 1 Gauss field reversal
	Relative humidity	95 % (non-condensing)

General Characteristics

Interface	Serial (RS-232) through SIM interface
Power	+24 VDC
Supply current	2.2 A at start-up, 0.6 A after warm-up period
Weight	5 lbs
Dimensions	1.5″ W × 3.6″ H × 7.0″ D

1 Overview

This chapter gives the necessary information to get started quickly with the SIM940 Rubidium Frequency Standard.

In This Chapter

1.1   Introduction to the Instrument

The SIM940 is a 10 MHz frequency standard with an estimated 20-year aging of less than 0.005 ppm. The module integrates an SRS PRS10 Rubidium Frequency Standard in a standard double-width SIM module. The module's low aging eliminates the need for an external frequency reference in many applications; however moduless can phase-lock to an external 1 pps signal (such as GPS) for ageless performance or periodic calibration as required.

The SIM940 provides exceptionally low phase noise 10 MHz sine outputs as well as a low-jitter 1 pps output. The three 10 MHz outputs have a phase noise of < -130 dBc/Hz at 10 Hz offset from carrier, dropping to < -155 dBc/Hz at 10 kHz offset. The Allan variance is less than 2×10^{-11} at one second and 2×10^{-12} at 100 seconds. The 1 PPS OUT outputhas less than 1 ns of jitter and may be set with 1 ns resolution.

An asynchronous serial interface allows for direct communication with internal PRS10 frequency standard via the SIM900 mainframe. This interface is used for frequency calibration, 1 pps timing and status determination. A Windows application program is provided.

The SIM940 will time-tag the rising edge of a user supplied 1 pps input, which usually comes from a GPS receiver. The module can phase-lock to this input to cancel long-term aging. The time-tag results may be read back via the serial interface. Timing is referenced to the leading edge of the 1 pps output pulse. The 1 pps output pulse will be moved into coincidence with the user supplied 1 pps input after 256 input pulses. Thereafter, the SIM940 will adjust its frequency to maintain the phase lock between the 1 pps input and the 1 pps output. The phase lock algorithm uses an adjustable natural time constant (from 8 minutes to 18 hours) which may be adjusted via the serial interface.

Several thousand PRS10's have been operating in various OEM applications with a demonstrated MTBF several hundred thousand hours and so a malfunction of the PRS10 is very unlikely. In the event of a failure of the "physics package" the 10 MHz output will be provided by the unit's ovenized SC-cut 10 MHz crystal oscillator with typical aging of 0.05 ppm/year.

The SIM940 will find application as an autonomous frequency standard in virtually any calibration or R&D laboratory where precision time or frequency measurements are made, or in any other situations requiring an accurate frequency standard. The low cost of the unit, together with its extremely low aging, will allow customers to deploy precision frequency references without the need to install cables or

antennas.

1.2   Quick Start Guide

1. Turn off the SIM900 mainframe.

2. Install the SIM940 in the SIM900 mainframe. (Use slots #7 & #8 if available for best thermal environment and shortest connection for 10 MHz to SIM900 timebase input.)

3. To lock the SIM900 mainframe timebase to the SIM940 Rubidium Frequency Standard, connect a SIM940 10 MHz output to the SIM900 mainframe Timebase input with a short BNC cable.

4. Turn on the SIM900 mainframe.

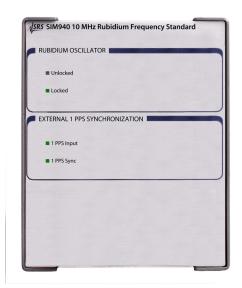5. The SIM940 should indicate *Locked* within six minutes.

Figure 1.1: The SIM940 front and rear panels.

1.3   SIM Interface

The primary connection to the SIM940 Rubidium Frequency Standard is the rear-panel DB–15 SIM interface connector. Typically, the SIM940 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 SIM940 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 (unused in SIM940)
4	CTS	SIM ⇒ MF	HW Handshake (unused in SIM940)
5	−REF_10MHZ	MF ⇒ SIM	10 MHz reference (unused in SIM940)
6	−5V	MF ⇒ SIM	Power supply (No connection in SIM940)
7	−15V	MF ⇒ SIM	Power supply (No connection in SIM940)
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 (unused in SIM940)
13	+5V	MF ⇒ SIM	Power supply (No connection in SIM940)
14	+15V	MF ⇒ SIM	Power supply (No connection in SIM940)
15	+24V	MF ⇒ SIM	Power supply

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

1.3.2   Direct interfacing

The SIM940 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 +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.

The SIM940 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 SIM940 independent of the SIM900 Mainframe, communication is usually possible by directly connecting the appropriate interface lines from the SIM940 DB–15 plug to the RS-232 serial port of a personal computer.[1] Connect RXD from the SIM940 directly to RD on the PC, TXD directly to TDS. 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 SIM940, 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 SIM940		Name
	DB-9/F	
10 ⟷	3	TxD
11 ⟷	2	RxD
	5	Computer Ground
	to P/S	
15 ⟷	+24 VDC	
1,8,9 ⟷	Ground (P/S return current)	

Table 1.2: SIM940 Direct Interface Cable Pin Assignments

1.3.2.2   Serial settings

The serial port settings at power-on are: 9600 baud, 8–bits, no parity, 1 stop bit, and no flow control. The serial settings cannot be changed on the SIM940.

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[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

2 Operation

Direct (local) control of SIM940 is described.

In This Chapter

2.1   Power

The module is powered from the SIM900 mainframe, which accommodates any voltage in the ranges 90 VAC to 260 VAC with a frequency in the range of 47 Hz to 63 Hz. In most applications, and for best performance, the mainframe should be left "on" at all times. The rubidium frequency standard is operating and outputs are available whenever the mainframe is "on".

The unit may also be powered by a user supplied +24 VDC power supply capable of providing 2.2 A during warm-up and about 0.6 A continuously. The +24 VDC should be applied to pin #15 and ground should be applied to pins # 1, 8 & 9 (see section 1.3.2.1).

2.2   Warm-up

The Rubidium Oscillator status LED (either *Unlocked* or *Locked*) will be on whenever power is applied to the unit. The status will change from *Unlocked* to *Locked* within six minutes after power is applied if the module is started from room temperature. Warm-up and locking will take longer if the module is started from a lower temperature. *Locked* indicates the unit is warmed up and its crystal oscillator has been locked to the rubidium physics package.

The output frequency will be about 200 ppm below nominal when power is first appllied to a cold module. The frequency will graduatlly converge on 10 MHz as the module warms up. After about 4 minutes (typically) the unit will reach operating temperature and lock the crystal oscillator to the rubidium hyperfine transition. Within seven minutes, the module will be locked to within 0.001 ppm of 10 MHz.

2.3   Connection to other instruments

All of the outputs on the rear of the SIM940 have a source impedance of 50 Ω and are intended to drive 50 Ω loads. Since the outputs have a source impedance of 50 Ω, termination into a 50 Ω load is not critical in most applications. Generally, the amplitude will approximately double if the output is not terminated into a 50 Ω load. Properly terminating into a 50 Ω load will reduce channel-to-channel crosstalk and will reduce the probability of multiple triggering on the 1 pps output.

If a single 10 MHz output is "daisy-chained" to several instruments it will be important that all of the instruments have a high-impedance (> 1 kΩ) and that a 50 Ω terminator be placed at the far end of the line.

Generally, it is better practice to use a separate output to each instrument to avoid cross-talk and amplitude variations due to uncertain loading and standing waves along the line.

Many instruments which generate or measure precise frequencies or time-intervals have a 10 MHz input, usually located on the rear of the instrument. Most of these instruments accept a sine input with the amplitude provided by the SIM940. Sometimes a rear panel switch or front panel configuration menu is required to "tell" the instrument to use the 10 MHz input as a reference instead of using the instrument's own time base. Improved accuracy can be achieved by using the SIM940 as an external time base to all of the instruments in a particular laboratory. In addition, all errors associated with the calibration of an individual instrument's time base are eliminated.

2.4   Connection to SRS Instruments

2.4.1   SIM900 Mainframe

The SIM900 will automatically sense the presence of a 10 MHz sine wave or square wave signal at its rear panel "TIMEBASE IN" BNC connector, and phase lock to it. For convenience, it is best to install the SIM940 in the slot 7 position of the SIM900 (filling slots 7 & 8), so that a short length of RG58 coax cable can tie one of the 10 MHz outputs of the SIM940 to the SIM900 TIMEBASE IN. The "TIMEBASE" status LED on the fron the the SIM900 should move from "Internal 10 MHz" to "External Lock."

2.4.2   SR620 Time Interval Counter

This instrument is "told" to use the external 10 MHz input via the front panel CONFIG menu. To configure the SR620 to use an external time base press the SEL key in the CONFIG section once to display CONFIG menus, then press SEL one more time to select the $c\,Al$ menu, which will flash when selected. Press the SET key twice to access the $cLoc\ \ Sour c E$ submenu. Press the arrow keys immediately to the left of the CONFIG menu (in the SCOPE AND CHART section) to select $r\,E\,Ar$, which is the rear panel time base input. Press the SET key in the CONFIG section once more to verify the expected time base frequency (5 MHz or 10 MHz). Press the arrow keys to select 10 MHz.

2.4.3   DS345 Synthesized Function Generator

The DS345 automatically detects the application of an external time base and phase locks to it. After applying a 10 MHz sine to the rear panel time base input, a front panel indicator will turn "on."

2.4.4   DG535 Digital Delay Generator

A rear panel switch is used to specify an external 10 MHz time base input. Some revisions of the DG535 required a 10 MHz square wave input, and may not operate properly with the 10 MHz sine wave output from the SIM940. The user should verify proper operation of the DG535 when locked to an external time base with an SR620 Time Interval Counter.

2.5   Direct Frequency Control of the SIM940

The frequency of the rubidium hyperfine transition is adjusted via a small magentic field in the physics package. The magnitude of the magnetic field is set by the microcontroller in the PRS10. The frequency offset is quadratic in the magnetic field but firmware in the PRS10 linearized the adjustment. The microcontroller reads the position of a calibration potentiometer, or responds to software commands via the serial interface, to set the magnetic field which controls the operating frequency.

The operating frequency may be directly controlled over the range of ±0.002 ppm in four ways:

1. By the adjustment of a 15 turn potentiometer accessible from the side of the module (with the module cover removed). Turning the potentiometer clockwise will increase the frequency by about 0.0025 Hz per turn. The adjustment procedure is detailed in the calibration section.

2. By applying a voltage in the range of 0 VDC to 5 VDC to the rear panel FREQ CTL IN BNC. The nominal voltage is 2.50 VDC. The voltage on this BNC corresponds to the position of the 15 turn potentiometer described above. The voltage may be overridden by a user input. The tuning rate at 10 MHz is 0.008 Hz/V. The input/source impedance is between 10 kΩ and 35 kΩ depending on the potentiometer position.

3. By software command via the serial interface. The SF (Set Frequency) parameter allows the user to set the frequency with a resolution of $1:10^{-12}$. The parameter has a range of ±2000 which allows frequency control over the range of ±0.002 ppm. The position of the frequency adjustment potentiometer is used to set the SF parameter until a SF command is received via the serial interface or until phase locking to an external source is activated by the application of 1 pps inputs to the rear panel BNC. Control is returned to the potentiometer when the power is cycled. Details are available in the PRS operation and service manual.

4. By software calibration via the MO (Magnetic Offset) parameter. The MO parameter is summed in quadrature with the SF parameter to control the frequency of operation. At the factory, the MO parameter is calibrated so that the unit will operate at 10 MHz with an SF value of 0. The SF parameter is set by either the potentiometer or via serial interface commands, and will be zero when the potentiometer is centered. The MO parameter by be adjusted and retained in the PRS10 EEPROM, allowing frequency calibration via the serial interface. Details are available in the PRS10 operation and service manual.

2.6   Using an External 1 pps Reference

The SIM940 has sufficient accuracy (0.005 ppm estimated over 20 years) that most users will not need to use an external timing reference. However, for critical applications requiring a frequency accuracy which is better than 1×10^{-9}, or to provice continuous traceability, the SIM940 may be locked to an external 1 pps reference.

When a precise 1 pps signal is applied to the 1 pps input on the rear panel of the SIM940, the rubidium frequency standard will phase-lock to the signal. The 1 pps signal usually comes from a GPS receiver which can have a long-term accuracy of a few parts in 10^{-12}. Because the stability of the 1 pps reference in the short term can be much worse than that of the PRS10, the PRS10 phase-locks to the 1 pps with an adjustable time constant of from 8 minutes to 18 hours, which reduces the noise of the reference 1 pps by averaging.

The rear-panel 1 pps input to the SIM940 is a high impedance input that is discriminated by a CMOS Schmitt trigger, with a threshold of about 2.5 VDC. It is important to provide a 1 pps input with CMOS levels (0–5 VDC). The 1 pps input may not work reliably with a TTL input or the 1 pps output from another instrument (such as another SIM940) if the signal is terminated into 50 Ω.[1]

A classical 2nd order phase-lock control loop is implemented in firmware. The "phase comparator" is a time-tagging circuit which measures the timing of the 1 pps input with nanosecond resolution. A proportional-integral phase-lock algorithm controls the frequency of the rubidium frequency standard via the parameter SF (Set Frequency). Normally, the SF parameter is set by the firmware reading the calibration potentiometer. However, when a 1 pps signal is seen, the phase-lock algorithm "hijacks" the SF parameter to phase-lock the rubidium standard to the 1 pps input.

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[1] The 1 pps from another SIM940 will work fine, providing it is not terminated into 50 ohm.

The locking algorithm of the PRS10 proceeds as follows:

- The 1 pps PLL is enabled when the unit is turned-on or restarted if the PL parameter stored in the unit's EEPROM is 1 (this is the default value).

- The PLL will begin to control the frequency of the rubidium frequency standard when 256 consecutive "good" 1 pps inputs (i.e., 1 pps inputs which are within ±2048 ns of the first time-tag result, module 1 s) are received.

- After receiving 256 consecutive "good" 1 pps inputs, the 1 pps output pulse is moved to coincide with the last of the 256 time-tag values. The *1 PPS Sync* LED will turn on, as the 1 pps input and the 1 pps output are now within ±1 μs of each other.

- The unit will lock the frequency of the PRS10 to the "good" 1 pps input pulses. "Bad" 1 pps inputs (1 pps inputs with time-tags greater than 1024 ns from the last "good" 1 pps input) will be rejected. A digital filter is used to implement the classical 2nd order proportional/integral phase lock loop. The output of the digital filter controls the frequency of operation via the SF (Set Frequency) command, which is updated once a second.

- The PLL will be aborted and restarted if there are 256 consecutive "bad" 1 pps inputs. (This could happen if the 1 pps input is moved suddenly by more than 1024 ns.)

The time constant of the PLL is set with the PT command. The default value is 8, providing a "natural time constant" of about 2.25 hours. The PT value should be set to a smaller number if the 1 pps reference is very clean, for example, if the 1 pps reference is provided by another SIM940. Using a smaller PT value will reduce the peak-to-peak variations ("swimming") between the 1 pps input and the unit's 1 pps output. With a clean reference and a short time constant, the 1 pps output typically tracks the 1 pps input within a ±1 ns window.

The default time-constant of 2.25 hours is appropriate for locking to the typical GPS receiver. However, if there is a rapid change in the ambient temperature which causes the PRS to change frequency by 1×10^{-11} , the change will not be appreciably effected by the PLL during the first hour, and one would expect to see a drift between the 1 pps input and the 1 pps output on the order of 3600×10^{-11}, or 36 ns.

The SIM940 indicates that it is synchronized to the 1 pps input by a front panel LED. The unit will indicate that is synchronized when the 1 pps input is present and if it occurs within ±1 μs of the 1 pps output. (A single dropped pulse on the 1 pps input will cause the

unit to indicate that it is not synchronized, but there is no detrimental effect from missing a small number of 1 pps inputs.)

It is quite common for a unit to indicate that it has acquired, and lost, synchronization depending on the initial freqneyc offset between the SIM940 and the 1 pps reference. Suppose that a SIM940 is out of calibration by 1×10^{-9} and a 1 pps input is applied while using the default PLL time constant of PT8 or 2.25 hours. With this time-constant, the PLL algorithm has little effect on the SIM940's frequency of operation during the first hour of phase locking, and the 1 pps output will stray from the 1 pps input by about 3600×10^{-9}, or 3.6 μs. This is larger than the ±1 μs synchronization window, and so the unit will indicate that it is not synchronized. With the default time constant, the unit will pull its 1 pps output to within the ±1 μs synchronization window within a few hours, and will thereafter indicate that it is properly synchronized.

The table below shows the PLL parameters for the allowed values of the PT parameter. The right-most column, "Natural Time Constant," is the best measure of the PLL response characteristics. (The values shown are for the default stability parameter, $\zeta = 1$.)

PT Parameter	Integrator Time-Constant	Integral Gain	Prop. Gain	Natural Time-Constant
Parameter set by PT command	(hours)	(SF bits per hour per ns of time-tag)	(SF bits per ns of time-tag)	Characterizes PLL response (hours)
0	0.07	−14.063	−3.95	0.14
1	0.14	−7.031	−2.80	0.20
2	0.28	−3.516	−1.98	0.28
3	0.57	−1.758	−1.40	0.40
4	1.14	−0.879	−0.99	0.56
5	2.28	−0.439	−0.70	0.80
6	4.55	−0.220	−0.49	1.12
7	9.10	−0.110	−0.35	1.59
8	18.20	−0.055	−0.25	2.25
9	36.41	−0.027	−0.17	3.18
10	72.82	−0.014	−0.12	4.50
11	145.64	−0.007	−0.09	6.36
12	291.27	−0.003	−0.06	8.99
13	582.54	−0.002	−0.04	12.72
14	1,165.08	−0.001	−0.03	17.99

Table 2.1: Phase-lock loop parameter values

Further details of the phase-locking algorithm are provided in the PRS10 Rubidiumn Frequency Standard manual.

3 Monitor and Control

This chapter introduces the remote interface to the SIM940. The provided Windows^{TM} software, RbMon, is documented. For further details on the programming the internal PRS10 Rubidium Frequency Standard, see the PRS10 Operation and Service Manual.

In This Chapter

A Windows$^{\text{TM}}$ based program, `RbMon`, is provided on a $3^{1}/_{2}''$ floppy disc. The program may also be downloaded from the SRS web site at `www.thinkSRS.com`. The program facilitates monitoring, control, and calibration of the SIM940 Rubidium Frequency Standard via the computer's COM port over a serial RS–232 interface to the SIM900 mainframe.

Running the Install program will place the `RbMon` icon on the Desktop and in the Start Programs list and place the program components in the folder "RbMon". The (provided) Uninstall utility should be used to remove the program and its icons from your computer. System requirements include ≥150 MHz Pentium or comparable, Windows$^{\text{TM}}$ 95 or later, and an available COM port.

The default COM port is COM1. If your computer uses COM1 as a mouse port, you will need to change the COM port to COM2.

The SIM940 uses the PRS10 rubidium frequency standard, also manufactured by Stanford Research Systems. All commands sent to the SIM940 are passed directly to the PRS10. All commands received from the SIM940 come directly from the PRS10. No buffering or filtering of commands is performed by the SIM940. The PRS10 operation and service manual, which is an addendum to this document, serves as a programming reference for the SIM940.

3.1   Setting up communications

The PRS10 frequency standard can communicate operating and calibration settings, such as lock indicators, signal levels, heater control status, 1 pps time tags, status flags, and calibration parameters. This provides the systems' integrator with the ability to monitor and control the operation of the PRS10.

Communicating with the PRS10 is not required in most applications. The PRS10 comes from the factory calibrated to $\pm 5 \times 10^{-11}$, and the SIM940 provides front panel LEDs to indicate power, lock, and 1 pps synchronization.

You may want to communicate with the PRS10 to access advanced features or for evaluation of the PRS10 in an OEM application. For instance, when locking the PRS10 to an external 1 pps reference you may want to optimize the time constant and lock mode of the digital PLL to match the stability characteristics of your reference.

3.2   Getting connected

The SIM940 uses asynchronous serial interface for communication. In addition to providing power, the SIM900 mainframe acts as a com-
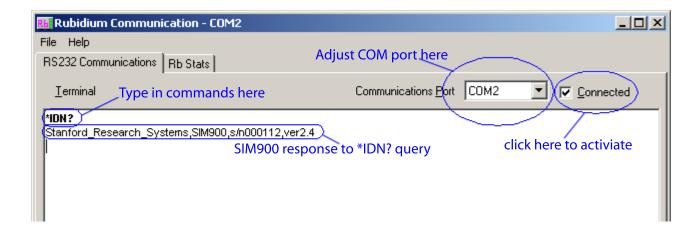
munications adaptor, translating the internal data format to standard RS–232 or IEEE–488 (GPIB) communications. The provided `RbMon` software is limited to communicating via RS–232, so your computer will need one unused serial port (COM port) for this purpose.

Most computers have one or more communications ports for this purpose. To establish communication you will need a standard, straight-through 9-pin RS–232 cable connected between your computer's communications port and the DB–9 "COMPUTER" connector on the back of the SIM900 mainframe.

Once the cable is in place, you need to tell the software which COM port you will be using to communicate with the SIM900. This is done with the pull down list box located in the upper right portion of the main window. Use the pull down list box to select the COM port. For most computers this will be either COM1 or COM2. Make sure that the "Connected" box is checked. This will activate the communications port.

3.3   Testing connection

Test the connection by sending a command to the SIM900 to see that it responds properly. Type the command *IDN? and press ⟨ENTER⟩. The SIM900 should respond with its identifier string. A typical screen shot with all the pertinent elements pointed out is shown below.

3.4   Connecting to the SIM940

Initially, the `RbMon` program will only be communicating with the SIM900 mainframe. To control a SIM940 installed in a mainframe slot, we must inform the SIM900 which slot number to communicate with. This is done with the CONN command. The format of this command is:

CONN ⟨*port number*⟩,⟨*esc string*⟩

where ⟨*port number*⟩ is the slot address of the SIM940 inside the SIM900 mainframe (this is the leftmost number above the module, when seated in the mainframe), and ⟨*esc string*⟩ is a quote-delimited string to cause the mainframe to terminate the connection.

Following the CONN command, issue a ID? to verify that communications are now established with the SIM940.

For example, if SIM940 is installed in slot 7 of the SIM900 mainframe (occupying the rightmost two slots), the screen should appear as below.

3.5   Terminal program

Use the tab labeled RS–232 Communications to send commands to the PRS10 manually. This tab is meant to provide the user with an easy method for manually typing commands to the PRS10. To use it, make sure that the proper communications port is selected, and that the "Connected" box is checked. Once that is complete, sending a command to the PRS10 is as simple as typing it in and pressing ⟨ENTER⟩.
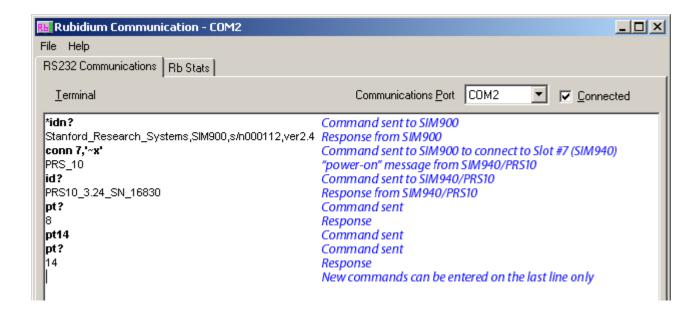
For ease of interpretation, commands that you type will be formatted in bold. Responses from the PRS10 will have normal formatting. Keep in mind that the PRS10 will not respond to all commands. It only responds to query commands—ones ending with a question mark (?).

One important point to keep in mind is that commands can only be entered on the last line. Lines above the last line show the previous commands sent and responses received. These lines can not be over-written. Only the last line is available for typing in new commands.

Here is a sample screen shot pointing out the pertinent items of interest.
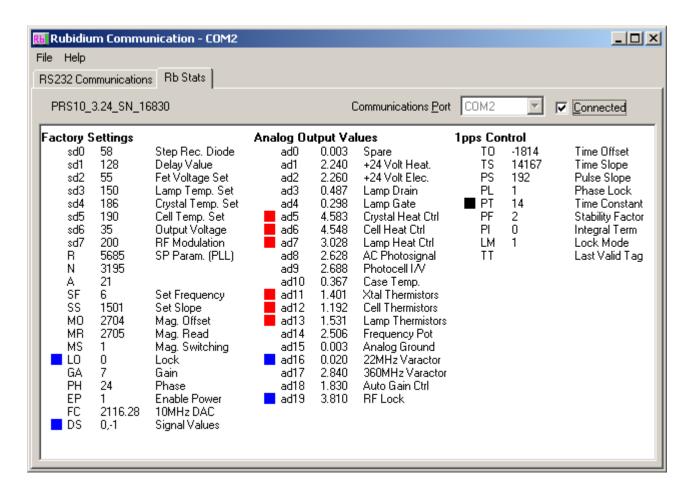
3.6   Rubidium Stats

The tab labeled "Rb Stats" is used to monitor virtually all of the PRS10's settings. To view the current PRS10 settings, click on the Rb Stats tab, make sure that the selected communications port is correct and that the SIM900 mainframe has been CONNected to the correct slot number (see section 3.4, and click the "Connected" check box to enable the connection. The screen should fill in with the current PRS10 settings. The settings will be continuously updated until you disconnect from the communications port by clicking on the "Connected" check box a second time to uncheck it.

A sample screen shot, taken while the PRS10 was warming up, is shown below.

The screen is divided into three main sections labeled Factory Settings, Analog Output Values, and 1 pps Control. Each section has three columns. The first column contains the command name, the second contains the current value of that parameter, and the third contains a brief description of the parameter. Colored boxes highlight various parameters that are out of the normal operating range. The three sections and the meanings of the colored boxes are briefly described below. For detailed descriptions of each of the commands, consult the PRS10 manual.

3.6.1   Factory Settings

This section includes calibration values and parameters for controlling the frequency of the PRS10. The most important parameter here is "LO", which indicates whether the PRS10 has locked to the Rb atomic hyperfine transition. In the screen shot, the value of LO is zero, indicating that the unit has not yet locked to the atomic transition. It is highlighted with a blue box to indicate that this value is lower than normal.

3.6.2   Analog Output Values

This section contains the current values of 20 internal voltage test points within the PRS10. These values allow you to monitor the heaters, temperatures, power supplies, phase lock loops, and lamp characteristics of the PRS10. In the example screen shot, the values AD5, AD6, and AD7 are highlighted with red boxes to indicate that the heaters are at maximum power. Values AD11, AD12, and AD13 indicate the current voltages on the temperature sensitive thermistors, and are highlighted with red boxes to indicate that these voltages are above normal. Highlighted boxes are a normal occurrence during the warm-up of the PRS10.

3.6.3   1 pps control tab

This section contains calibration parameters that control the PRS10's behavior when locking to an external 1 pps reference. In the example screen shot, PT is highlighted with a black box. This is meant to indicate that its current value, 14, is different from the value stored in EEPROM, which is the value it will have at start up. In this particular case, the command PT14 was entered manually in the RS–232 Communications tab to change the current value of PT from 8 to 14. The value for TT, the last valid time tag, is blank because the unit has not yet received a pulse on its 1 pps input. When a pulse is received, the TT command will report the time difference in nanoseconds between the input pulse and the 1 pps output.

3.6.4   Colored boxes

The colored boxes are visual cues to let the user know that a given parameter is outside the normal operating range. This most commonly occurs at start up, while the unit is warming up. After about 15 minutes of operation, the unit should be fully warmed up, and all red and blue boxes should disappear. After the initial warmup, the appearance of a colored box typically signals something unusual that should be looked into. If the unit was being operated in an oven, for example, the unit may not be able to properly regulate the temperatures of the crystal, cell, and lamp. Under these circumstances, one would expect blue boxes to appear next to AD5, AD6, and AD7, as the heaters are shut off.

The interpretation of the boxes is as follows:

■ (Red) Value is higher than normal.
■ (Blue) Value is lower than normal.
■ (Black)Value is different from the value stored in EEPROM.

3.7 `RbMon` menus

The `RbMon` application has two "pull-down" menus located at the top of the window frame.

3.7.1 File menu

The File menu has three options to choose from.

3.7.1.1 Print

The program can print out the current settings shown in the Rb Stats tab. To do this, make sure that the Rb Stats tab is visible and then select Print from the File menu. The current values displayed in Rb Stats will be sent to the printer. The formatting of the printed output is intended for standard 8 1/2 by 11 inch, Letter size paper. Printing on paper of other sizes is not supported, but not prevented.

3.7.1.2 Print Setup

Print Setup enables you to configure your printer for printing. You should choose Letter size paper (8 1/2 by 11 inch) and the Portrait orientation. Landscape orientation is not supported.

3.7.1.3 Exit

The Exit menu item will close the program.

3.7.2 Help menu

The Help menu has two options to choose from.

3.7.2.1 Contents

Choose this menu item to display help information.

3.7.2.2 About

Choose this menu item to display the program name and version information.

4 Calibration

This chapter describes the calibration procedure for the SIM940.

In This Chapter

There is a 15-turn potentiometer in the PRS10 rubidium frequency standard which adjusts the operating frequency. The potentiometer is accessible by removing the right-hand side cover from the SIM940 (the side closest to the "FREQ CTL IN" BNC connector). The total adjustment range using the potentiometer is 0.002 ppm or 0.02 Hz at 10 MHz. Turning the potentiometer clockwise will increase the 10 MHz output by about 0.0025 Hz per turn.

To operate the SIM940 with the potentiometer accessable, install the module in slot 1 of the SIM900 mainframe (the left-most slot), with the remaining 6 slots empty. When installing the module with the right-hand side cover removed, be careful to properly align the module in slot 1 so that the rear-panel DB–15 connecter mates cleanly. Alternatively, the SIM940 may be operated outside the SIM900 mainframe by providing +24 VDC and ground on the DB–15 connector, as described in section 1.3.2.1.

The position of the potentiometer may be determined by measuring the DC voltage on the center pin of the rear panel "FREQ CTL IN" BNC. The voltage will read 0 VDC at the counter-clockwise extreme, +5 VDC at the clockwise extreme, and +2.50 VDC when the potentiometer is centered. This voltage should be recorded before any calibration is attempted. This will allow you to return to the previous calibration if necessary and serves as a record of the frequency aging of the unit.

When the SIM940 is shipped from the factory, the potentiometer is set to its center position and the frequency is calibrated via the RS-232. The user can return the potentiometer to the center position by adjusting the potentiometer until the dc voltage on the center pin of the rear panel FREQ ADJ BNC measures +2.50VDC.

4.1 Calibration with a frequency counter

The procedure is to adjust the calibration potentiometer so that the SIM940 produces 10 MHz to within $\pm 1 \times 10^{-11}$ or 10 MHz $\pm$ 0.0001 Hz. Important details are list below:

1. Be certain that the SIM940 has been operated continuously for at least 24 hours.

2. If the SIM940 has been off for more than one week, it should be operated continuously for at least 72 hours before the adjustment is made.

3. Be certain that nothing is connected to the rear-panel FREQ CTL input.

4. Be certain that nothing is connected to the rear-panel 1 pps input.

5. Measure and record the dc voltage on the center pin of the FREQ CTL BNC.

6. Power cycle the SIM940 by switching off the SIM900 mainframe for at least three seconds. This will make certain that the unit will track the calibration potentiometer (which can be ignored if the unit was phase-locked to a 1 pps input or the frequency had been previously set via the SF command.) The unit should lock in less than a minute as it is warm from previous operation. Wait for at least one hour before proceeding with the calibration.

7. The frequency standard used in the calibration must have an accuracy of better than $\pm 1 \times 10^{-11}$ or 10 MHz $\pm$ 0.0001 Hz. A cesium standard or a well characterized rubidium or quartz standard referenced to GPS may be used.

8. The frequency counter must have sufficient resolution and accuracy to perform the measurement. This may require long gate times in the frequency measurement mode of operation. A 100 s gate is recommended when using an SR620 Time Interval Counter in the frequency mode.

9. Usually, the measurement can be done more quickly and accurately by comparing the phase of a 10 MHz reference to the phase of the SIM940 10 MHz output. A time-interval counter may be used for this purpose. In this case, the 10 MHz reference is used as a timebase for the time-interval counter. The inputs to the time-interval counter will be two 10 MHz signals; one from the 10 MHz reference and one from the SIM940. The time-interval counter should be set-up to report the average of 1000 measurements. The reported time-interval measurements will be between 0 and 100 ns (the period of a 10 MHz signal.) Using the SR620, the resolution and jitter of the average of 1000 time-interval measurements will be less than 1 ps rms, and values will be reported about once a second. Observe how the average time-interval measurement changes with time. If the reported time-intervals are changing by 1 ns per second then the two 10 MHz source are "off" by 1×10^{-9} or 0.001 ppm. Adjust the calibration potentiometer until the drift between time-interval measurements slows to less than 1×10^{-11} or 10 ps per second.

10. Measure and record the DC voltage on the center pin of the FREQ CTL IN BNC.

4.2   Calibration with a 1 pps reference (such as from a GPS receiver)

The SIM940 may also be calibrated by phase-locking the unit to the 1 pps signal from a GPS receiver. The calibration potentiometer will be adjusted so that the frequency control parameter, SF, matches the value determined by the phase-locking algorithm.

When a precise 1 pps signal is applied to the 1 pps input on the rear panel of the SIM940, the rubidium frequency standard will phase-lock to the signal. The 1 pps signal usually comes from a GPS receiver which can have a long-term accuracy of a few parts in 10^{12}. Because the stability of the 1 pps reference in the short term can be much worse than that of the PRS10, the PRS10 phase-locks to the 1 pps with a very long time constant of several hours or more.

A classical 2nd order phase-lock control loop is implemented in firmware. The "phase comparator" is a time-tagging circuit which measures the timing of the 1 pps input with nanosecond resolution. A proportional-integral phase-lock algorithm controls the frequency of the rubidium frequency standard with the SF parameter (Set Frequency). Normally, the SF parameter is set by the firmware reading the calibration potentiometer. However, when a 1 pps signal is seen, the phase-lock algorithm 'hijacks' the SF parameter to phase-lock the rubidium frequency standard to the 1 pps input.

To calibrate with a precise 1 pps input, the SIM940 will be phase-locked to the 1 pps input and the SF parameter will be read via the serial interface. Then, the 1 pps input will be removed, the unit will be power cycled (so that the SF is again set by the calibration potentiometer), and the potentiometer will be adjusted to provide the same SF value as was seen when the SIM940 was phase locked to the 1 pps.

To use this procedure you will need a source of a precise 1 pps signal, such as a GPS timing receiver. You will also need a way to communicate with the SIM940 via the serial interface, such as a PC or laptop computer with a serial port operating at 9600 baud. Any Windows computer together with the SIM940 application program, RbMon, will work well.

The procedure for frequency calibration using a precise 1 pps input is:

1. Be certain that nothing is connected to the rear-panel FREQ CTL input.

2. Be certain that nothing is connected to the rear-panel 1 pps input.

3. Power cycle the SIM940 by switching off the SIM900 mainframe

for at least three seconds. This will make certain that the unit will track the calibration potentiometer (which can be ignored if the unit was phase-locked to a 1 pps input or the frequency had been previously set via the SF command.) The unit should lock in less than a minute as it is warm from previous operation.

4. The position of the calibration potentiometer may be determined by measuring the dc voltage on the center pin of the rear panel FREQ CTL IN BNC. The voltage will read 0 V at the counter-clockwise extreme or +5 VDC at the clockwise extreme and will read +2.50 VDC when the potentiometer is centered. This voltage should be recorded before any calibration is attempted. This will allow you to return to the previous calibration if necessary and serves as a record of the frequency aging of the unit.

5. Connect the RS-232 serial cable between the SIM900 mainframe and the PC or laptop computer. Verify that you can "talk" to the SIM940 with RbMon by typing the ID? command in the "RS232 Communications" tab (see procedure in section 3.4).

6. Be certain that the SIM940 has been operated continuously for at least 24 hours (excluding the brief power-cycling.)

7. Send the command: LM1. This enables the 1 pps input digital pre-filter to reduce the noise of the 1 pps reference. (LM1 is the default value.)

8. Send the command: PT8. This sets the "natural time-constant" of the PLL to about 2.25 hours, which reduces the noise of the 1 pps reference by averaging. (PT8 is the default value.)

9. If the SIM940 has been off for more than one week, it should be operated continuously for at least 72 hours before the adjustment is made.

10. Apply the 1 pps signal to the rear panel of the SIM940. The front panel *1 pps Input* LED should blink at 1 pps, and the *1 pps Sync* LED should light in about 5 minutes.

11. *The SIM940 should be phase-locked for at least 24 hours before proceding to the next step.*

12. Query the SF parameter via the computer interface. (SF? The response will be a number between ±2000). Write the number down. The SF parameter is being controlled by the phase-lock loop algorithm and has a resolution of 1:1012, so ±2000 corresponds to ±0.002 ppm. To set the SIM940 to 1:1011, you want to determine the correct value of SF to ±10, so check back

in a few hours to determine if the SF parameter has settled. Repeat as necessary.

13. When you have a satisfactory SF value, unplug the 1 pps input and power cycle the SIM940 to return control of the SF parameter to the potentiometer. While monitoring the SF parameter via the computer interface, adjust the calibration potentiometer to set the SF value to the value seen when the unit was phase locked to the 1 pps reference. Now, each time the unit turns "on", it will be operating at the same frequency as when it did when it was phase-locked to the 1 pps reference.

4.3   Calibration of the time-tag offset parameter

The SIM940 can time-tag the leading edge of a rear-panel 1 pps input. Results of the time-tag are returned over the serial interface, in response to the TT? command, in integer nanoseconds with respect to the 1 pps output. If the 1 pps input arrives 5 ns after the 1 pps output, the TT? should return a value of 5. If the 1 pps input arrives 5 ns before the 1 pps output, the TT? should return a value of 999999995. If no input was applied, and so no time-tag result is available, the TT? will return a value of −1.

There is a calibration parameter, TO, which is added to the measured time-tag before the result is returned over the serial interface. Offsets in time-tag results can be eliminated by adjusting the TO parameter.

Few users will need to perform this calibration, as fixed offsets of a few nanoseconds in the reported time-tags will have little consequence. Substantial offsets are usually caused by low or slow pulses provided to the 1 pps input: The 1 pps input should make a clean transition from 0 to 5 VDC with a rise time of less than 10 ns.

To calibrate the TO parameter:

1. Connect the RS-232 serial cable between the SIM900 mainframe and the PC or laptop computer. Verify that you can "talk" to the SIM940 with RbMon by typing the ID? command in the "RS232 Communications" tab (see procedure in section 3.4).

2. Send the PL0 to disable phase locking to the 1 pps input.

3. Verify that the PL0 command was received by typing the PL? command, which should return a "0", indicating that 1 pps phase locking is disabled.

4. Connect the 1 pps output directly to the 1 pps input with a 3′ RG58 coax cable. Do not use any 50 Ω terminators.

5. Query the time-tag with the TT? command. If the result is 5 ns, which is the time delay of 3′ of RG58 coax cable, then you are done.

6. If the result of the TT? is not 5 ns, then query the TO parameter with a TO? A typical value of the TO parameter is −1700 ns. This value is added to the time-tag measurement before is it returned via the serial interface.

7. If the result of the TT? was greater than 5 ns, then increase the magnitude of the TO parameter (making it more negative.) For example, if TT? returned 15 ns, and TO? returned −1700, then send TO–1710.

8. If the result of the TT? less greater than 5 ns, then decrease the magnitude of the TO parameter (making it less negative.) For example, if TT? returned 1 ns, and TO? returned −1700, then send TO–1696.

9. Iterate as necessary, adjusting TO, until the TT? returns 5 ns.

10. Save the TO parameter to EEPROM by sending the command TO!

11. Verify that the TO was saved to EEPROM by reading it back from EEPROM with the TO!? command.

5   SIM940 Circuit Description

This chapter presents a brief description of the SIM940 circuit design. A complete parts list and circuit schematics are included.

In This Chapter

5.1   Circuit Discussion

The SIM940 provides an operating environment for the PRS10 Rubidium Frequency Standard. The PRS10 operation and service manual details operation, circuits, and software interface for the rubidium frequency standard as an addendum to this manual.

5.1.1   Rubidium Logic Interface

J104 is the connector to the PRS10 rubidium frequency standard. The pin-out for J104 is detailed in the table below:

Pin No.	Name	Function
1	LOCK/1 pps OUT	TTL HIGH=UNLOCK. PULSES HIGH AT 1 pps
2	POT WIPER	0–5 VDC ANALOG FREQUENCY ADJUST
3	POT (−)	ANALOG GROUND VOLTAGE REFERENCE
4	TXD	RS–232 TRANSMIT OUTPUT (CMOS LEVELS)
5	1 pps IN	1 pps TIME-TAG INPUT FOR PHASE-LOCKING
6	+24 V HEATER	+24 VDC SUPPLY FOR HEATERS
7	RXD	RS–232 RECEIVER INPUT (CMOS LEVELS)
8	POT (+)	+5.00 VDC ANALOG REFERENCE
9	+24 ELECTRONICS	+24 VDC SUPPLY FOR ELECTRONICS
10	GROUND	POWER SUPPLY CURRENT RETURN

Table 5.1: Connector Pin Assignments, J104

In addition, there is an RF connector which is part of J104, which is used for the 10 MHz sine output from the unit. The connector shell of J104 is also grounded.

5.1.2   1 pps input

The rear panel 1 pps input is connected directly to the 1 pps input to the PRS10. The PRS10 can time-tag the rising edge of this input and report the time-tag values via the RS–232 with 1 ns resolution. The PRS10 can also phase-lock to the external 1 pps input by adjusting its frequency of operation.

The rear panel 1 pps input also triggers a $1\,\mu s$ one-shot (U5A) to detect the synchronization of the 1 pps input to the 1 pps output to within a $1\,\mu s$ window. (The 1 pps output also triggers a $1\,\mu s$ one-shot (U6A). If the two 1 pps pulses have rising edges within $1\,\mu s$ of each other the NAND gate (U4D) will re-trigger the 1.6 s one-shot (U6B) which holds the *1 PPS Sync* LED "on".

The $1\,\mu s$ one-shot triggered by the 1 pps input also triggers a 70 ms one-shot (U5B) which is used to blink the front panel *1 PPS Input*

LED. The 70 ms one-shot also holds off additional triggers of the 1 μs one-shot until it times-out, reducing the probability of false sync detection in the case that the user's 1 pps input is running much faster than 1 pps.

5.1.3 Lock and 1 pps output

The PRS10 outputs lock status and 1 pps on Pin 1. This output will have a CMOS high level (5 V) until the unit locks its crystal oscillator to the rubidium physics package. When the unit locks, Pin 1 will go to a CMOS low level (0 V) and pulse high for 10 μs at 1 pps.

An RC filter (R11 & C12) together with the Schmitt trigger (U3D) recovers the lock status and gates the 1 pps output "off" when the unit is unlocked. The Schmitt trigger also controls the *Unlocked* and *Locked* LEDs via U4A and U4B.

The 1 pps output from the PRS10 is gated by U4C and buffered by the octal driver U10. The 8 outputs of U10 are ganged together through two 100 Ω resistors (R36 & R37) to drive the rear panel 1 pps OUT via a balun (T5). The 1 pps output is intended to drive 50 Ω loads to 2.5 VDC requiring 50 mA of current during the 10 μs pulse. Care was taken to confine this large current pulse to the immediate area around the 1 pps driver: there is an isolated ground plane which is locally bypassed by a 330 μF capacitor (C45) and a .1 μF capacitor (C44), the system's +5 VDC supply is isolated by a 1 kΩ resistor (R35), and the balun (T5) "requires" that all of the output current returns to the local ground.

5.1.4 Serial Interface

The PRS10 can receive serial data on Pin 7 and transmit serial data on Pin 4. The serial interface uses 8 bits at 9600 baud, between 0 V & +5 V, with one stop bit, no parity, and X-on/X-off protocol. Conveniently, the default baud rate for communications between the SIM900 Mainframe and installed SIM modules is 9600 baud.

5.1.5 Power Supplies

The SIM940 is powered from the +24 VDC from the SIM900 mainframe. An L/C filter (L1 & C1) is used to reduce ripple from the mainframe's power supply. A p-channel MOSFET (Q100) is used to slow the inrush of the power supply to prevent a current trip in the mainframe as it charges C1. Three terminal regulators (U1 and U2) provide +20 VDC and +5 VDC for 10 MHz output buffers and logic circuits.

5.1.6   10 MHz Outputs

The PRS10 provides a 10 MHz sine wave output on an RF connector. The output has a source impedance of 50 Ω and amplitude of 1.41 Vpp with very low phase noise. The SIM940's 10 MHz output drivers were designed to maintain the low phase noise of the PRS10's output and to reduce the harmonic distortion with high output-to-output isolation.

The output amplifiers (LM7171's U7, U8 & U9) have high bandwidth, low distortion, low current noise, but rather high voltage noise ($14 \, \text{nV}/\sqrt{\text{Hz}}$). A tuned transformer (T1) is used to increase the voltage (and source impedance) of the PRS10's 10 MHz output to avoid degrading the output noise. The 10.7 MHz transformer is tuned down to 10 MHz by an additional capacitor on the primary side of the transformer. (The transformers have a 47 pF capacitor internally.) The 3.5:1 transformer increases the 10 MHz amplitude to about 5 Vpp, the source impedance to about 600 Ω, and reduces harmonic distortion. A 10 VDC bias is added to the transformer secondary so that the 5 Vpp output is centered in the common mode input range of the op amps, which are operated from +20 VDC.

The op amps are operated with a nominal gain of 2.73. The 10 MHz input amplitude can be adjusted with P1 to calibrate the amplitude of the rear panel 10 MHz outputs. The op amps drive 50 Ω loads via a tuned output transformer and a 3$^{\text{rd}}$ degree Cauer low pass filter. The transformer impedance matches the user load to the amplifier, reduces voltage noise, and insures that all of the output current will return to the isolated ground. Passive RC filters on each power supply improve channel-to-channel isolation. The output filter reduces the harmonic distortion by an additional 15 dB.

5.2 Component parts list

Reference	Value	SRS p/n
C1,C45	330UF	5-00516
C2,C3,C4,C5,C14,C46	2.2U-35V	5-00318
C6,C7,C8,C9,C11,C16,C17,C26,C35,C44	.1U	5-00299
C10,C12,C13	.001U	5-00387
C15,C21,C31,C39	27P	5-00368
C18,C27,C36	1P	5-00351
C19,C28,C37	2.2P	5-00355
C20,C23,C30,C33,C38,C42	100P	5-00375
C22,C24,C32,C34,C41,C43	220P	5-00379
C25,C29,C40	.01U	5-00298
D1	RED LED	3-00425
D2,D3,D4	GREEN LED	3-00424
J1	DB15-HM	1-00367
J2	CONN10M156	1-01057
J3	HEAD10	1-01056
J100	CONN10F156	1-01058
J200	CONNECTOR	1-01032
J201,J202,J203,J204,J205,J206	BNC	1-00003
L1	FIT68-1	6-00629
L2,L3,L4	.56UH	6-00595
P1	100-15T	4-00353
Q100	IRF4905	3-00944
R1,R4,R5,R6,R8,R12,R35,R38	1K	4-01479
R2	249	4-01059
R3	3.74K	4-01172
R7,R10,R13,R15	330	4-01467
R9,R14	1M	4-01551
R11,R39,R40,R41,R42,R43,R44	100K	4-01527
R16,R21,R26,R31	100	4-01455
R17,R18	10.0K	4-01213
R19,R24,R29,R34	499	4-01088
R20,R25,R30	47	4-01447

Reference	Value	SRS p/n
R22,R27,R32	604	4-01096
R23,R28,R33	866	4-01111
R36,R37	100/1%	4-01021
T1,T2,T3,T4	TOKO7P	6-00195
T5	T1-1	6-00009
U1	LM317	3-00149
U2	LM340-5	3-00112
U3	74HC14	3-00662
U4	74HC00	3-00902
U5,U6	74HC4538	3-01467
U7,U8,U9	LM7171	3-00819
U10	74HC540	3-00748
J104	DAM-11W1S	1-00342
COAX INSERT FOR ABOVE		1-00343

HARDWARE

RUBIDIUM STANDARD	FINISHED GOODS	PRS-10
PCB	REV "B"	7-01526
SIM FRONT PANEL	REV "A"	7-00053
SIM REAR PANEL	REV "B"	7-00063
INTERNAL BRACKET	REV "B"	7-00375
SIM TOP DUAL BRACKET	REV "A"	7-01380
SIM BOT DUAL BRACKET	REV "A"	7-01381
SIM SKINS		7-00932
SKIN SCREWS + PRS10		0-00371
FRONT PANEL SCREWS	4-40 SLOT	0-00148
PCB AND REAR PANEL	4-40 PHILIPS	0-00515
DB-15 CONNECTOR	4-40 FLAT	0-00208
SIM RUBBER FEET		0-00188
FRONT PANEL LEXAN		7-00654

5.3 Schematic Diagrams

Schematics for the SIM940 follow this page. For schematics of the PRS10, see the attached PRS10 Operation and Service Manual.