PRS10 Rubidium Frequency Standard

- Low phase noise (<-125 dBc/Hz at 10 Hz)
- Time-tags or phase-locks to a 1 pps input
- Slewable 1 pps output with 1 ns resolution
- RS232 for diagnostics, control and calibration
- Long lamp life and established reliability
- Low cost ($1495, Quantity 1, U.S. list)

The PRS10 is an ultra-low phase noise 10 MHz frequency standard that disciplines a crystal oscillator to a hyperfine transition in the ground state of rubidium.

The device fulfills a variety of communication, synchronization, and instrumentation requirements. The phase noise of the 10 MHz output is low enough to be used as the reference source for synthesizers. The unit's short-term stability and low environmental coefficients make it an ideal component for network synchronization. Its low aging rate makes it an excellent timebase for precision frequency measurements.

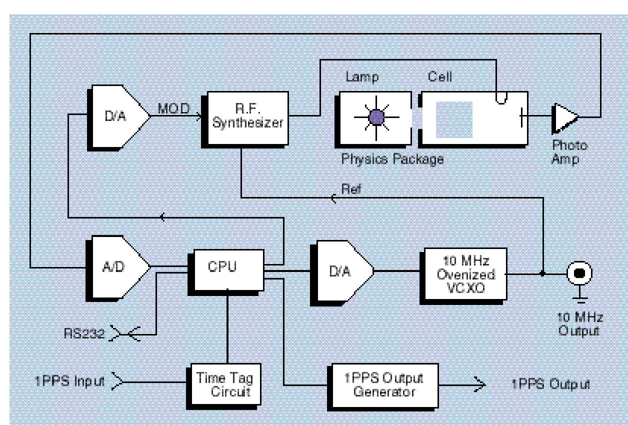
The PRS10 can time-tag an external 1 pps input with 1 ns resolution. These values may be reported back via RS232 or used to phase-lock the unit to an external reference (such as GPS) with time constants of several hours. This feature can provide Stratum 1 performance at a very low cost.

The PRS10 establishes a new level of features and performance in atomic frequency standards. Its design provides the lowest phase noise, greatest versatility, and easiest path to system integration of any rubidium frequency standard available.

PRS10 Operation and Design

All commercial rubidium frequency standards operate by disciplining a crystal oscillator to a hyperfine transition at 6.834,682,612 GHz in rubidium. The amount of light from a rubidium discharge lamp that reaches a photodetector through a resonance cell will drop by about 0.1% when the rubidium vapor in the resonance cell is exposed to microwave power near the transition frequency. The crystal oscillator is stabilized to the rubidium transition by detecting the light dip while sweeping an RF frequency synthesizer (referenced to the crystal) through the transition frequency.

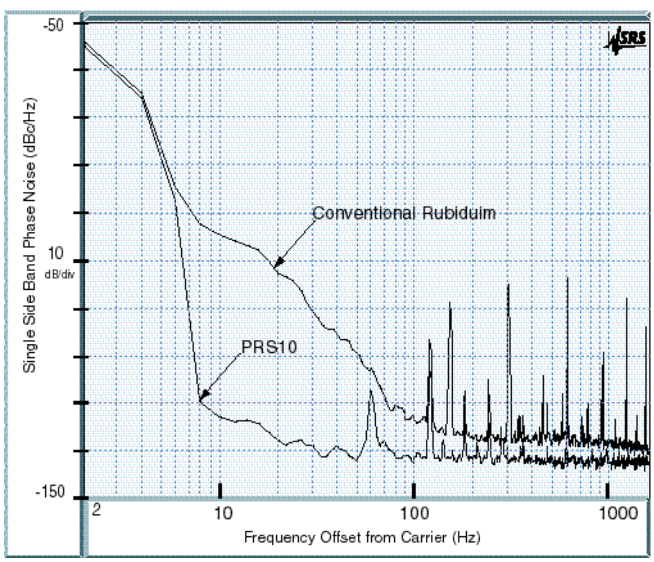
The PRS10 uses a microcontroller, clocked at 10 MHz, to control all aspects of operation and to allow diagnostics, measurement, and closed case calibration via an RS232 interface. The processor sweeps the RF synthesizer, synchronously detects the optical signal from the physics package, and servos the 10 MHz crystal oscillator to the rubidium transition via a 22-bit DAC and a varactor.



PRS10 Block Diagram

When turned "on", the processor applies a voltage to the varactor corresponding to the last locked value. The frequency-lock servo is disabled until a useful resonance signal is detected from the physics package, providing a smooth transition to the final frequency as the unit warms up. In the case of a problem with the physics package, the unit will suspend the frequency servo and hold the varactor voltage at the last locked value.

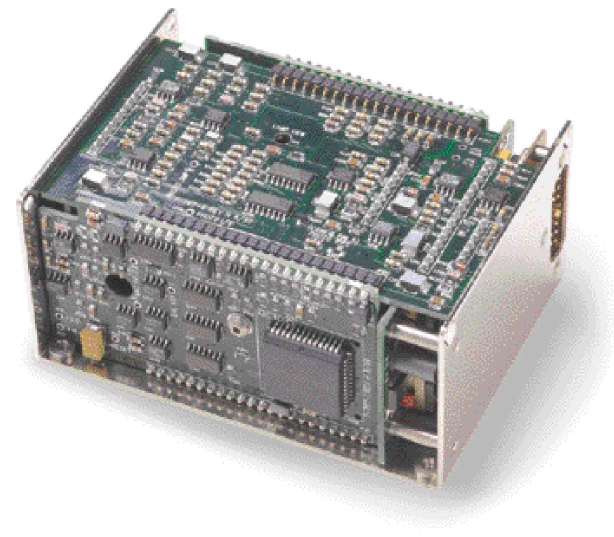
Manufacturers of rubidium frequency standards sometimes use a crystal frequency that is an exact sub-multiple of the hyperfine transition frequency in order to simplify the design of the RF frequency synthesizer. Some designs use a DDS synthesizer, clocked by the crystal, to generate the 10 MHz output. Often, the crystal frequency is modulated in order to sweep the synthesizer through the transition frequency. The crystals are usually operated in the fundamental mode and not temperature stabilized. While such approaches are simpler to design, the phase noise, short-term stability, and spur content of their outputs suffer.



Phase Noise Plots

In contrast, the 10 MHz output from a PRS10 comes directly from a 3rd overtone, stress-compensated (SC-cut) crystal oscillator operated in an oven at the plateau temperature. A dual-loop RF synthesizer, with a crystal IF at 22.482 MHz, is used to generate 359.72 MHz, and make 6.834 GHz via a step recovery diode. There are several advantages to this approach: the phase noise is very low (<-125 dBc/Hz @ 10 Hz offset), there are no spurious components, and the output will be well behaved should the physics package fail to provide a lock signal. (The aging will be about $5x10^{-10}$/day when not locked to rubidium.) The phase noise plot of a PRS10 shows a 37 dB reduction in phase noise at 10 Hz offset from the carrier at 10 MHz when compared to a conventional rubidium standard.

Historically, the lifetime of rubidium frequency standards has been dominated by rubidium depletion in the

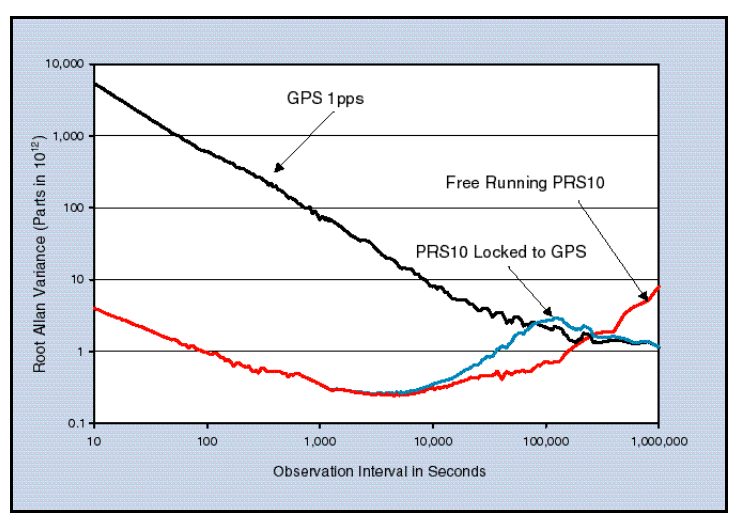


discharge lamp. To avoid excess flicker noise, manufacturers would load less than 100 µg of rubidium into spherical discharge lamps. The PRS10 uses a lamp with a side arm loaded with 1 mg of rubidium. This design eliminates rubidium depletion as a failure mechanism and provides better temperature control without excess flicker noise.

Phase-locking to GPS

Frequency offsets and long-term aging of the PRS10 can be eliminated by phase-locking to a source with better long term stability, such as the 1 pps from a GPS timing receiver. As shown in the Allan variance plot, the short term stability of GPS is poor (about $5,000x10^{-12}$) compared to the stability of the PRS10 (about $5x10^{-12}$.) However, over several hours, GPS is more stable, and so the stability can be improved by phase-locking it to GPS with a long time constant.

The PRS10 can time-tag or phase-lock to a 1 pps input and provide a slewable 1 pps output. The input can be time-tagged



Root Allan Variance

with 1 ns resolution, and the result may be read back via the RS232 interface. When phase-locking to an external input, the time constant of the loop can be set from 5 minutes to 18 hours, and the stability factor can be set from 0.25 to 4.0. The 1 pps output may be moved with 1 ns resolution over the range of 0 to 999,999,999 ns via the RS232 interface.

When a 1 pps input is applied, the PRS10 will first "qualify" the input (by measuring 256 pulses spaced by N(±2μ)s, then will align its 1 pps output to 1 s after the 256th input pulse. The processor will continue to time-tag the input pulses and will phase lock the 1 pps output to the 1 pps input by controlling the frequency of the rubidium transition with a small magnetic field adjustment inside the resonance cell.

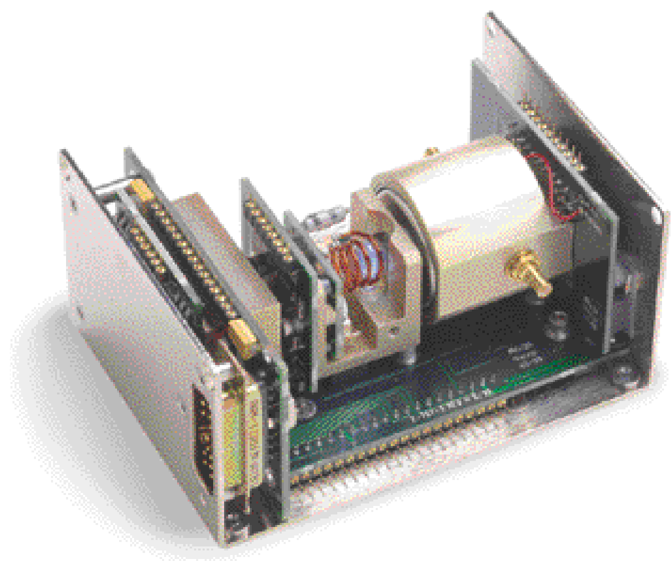
Pin	Description
1	Lock indication and 1 pps output
2	Ext. frequency control. 0-5 VDC for ^{3}f/f of $\pm 2\times10^{-9}$
3	Ground reference for external frequency control
4	RS232 data output or photo I/V monitor output
5	1 pps input for time-tagging or photo-amp output
6	+24 VDC supply for discharge lamp and heaters
7	RS232 data input or EFC monitor output
8	+5.00 VDC reference output for frequency control pot
9	+24 VDC supply for electronics (not heaters or lamp)
10	Case ground and power supply return
coax	10 MHz sine output

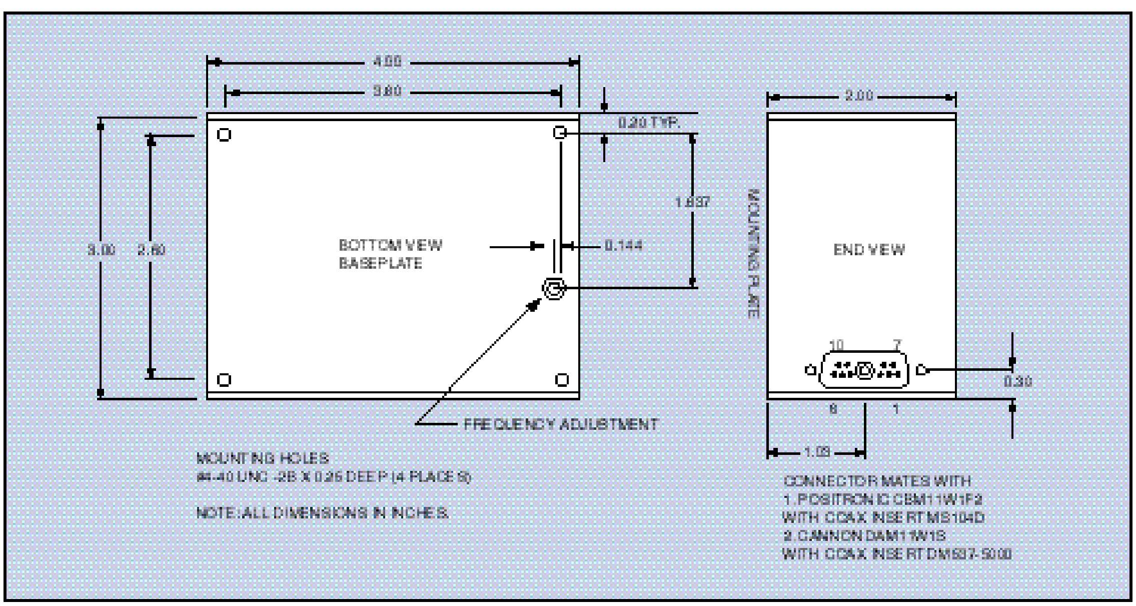
Standard Interface Connector

The interface connector and device form-factor are compatible with Efratom's Model FRS rubidium frequency standard. In its default configuration, the PRS10 uses pins #4 and #7 for the RS232 interface to provide a complete set of systems diagnostics and control. Internal hardware jumpers allow these pins to be configured as analog outputs to monitor the lamp intensity and varactor voltage for complete compatibility with the FRS.

More Information

The operation and service manual for the PRS10 rubidium frequency standard is posted on the SRS web site at www.thinkSRS.com. For additional technical or sales information, please call SRS at (408) 744-9040.





Unit Line Drawing

Output

Output frequency	10 MHz sine wave
Amplitude	0.5 Vrms, ±10% (approx. 1.41 Vpp or +7 dBm)
Phase noise (SSB)	<-125 dBc/Hz (10Hz) <-140 dBc/Hz (100 Hz)
Spurious	<-130 dBc (100 kHz B.W.)
Harmonic distortion	<-40 dBc
Return loss	> 25 dB @ 10 MHz
Accuracy at shipment	$\pm 5 \times 10^{-11}$
Aging (after 30 days)	$< 5 \times 10^{-11}$ (monthly) $< 5 \times 10^{-10}$ (yearly)
Short term stability (Allan variance)	$< 1 \times 10^{-11}$ (1 s) $< 1 \times 10^{-11}$ (10 s) $< 2 \times 10^{-12}$ (100 s)
Frequency retrace	$\pm 5 \times 10^{-11}$ (72 hrs off then 72 hrs on)
Settability	$< 5 \times 10^{-12}$
Trim range	$\pm 2 \times 10^{-9}$ (0 to 5 VDC) ±1 ppm (via RS232)
Warm-up time	< 5 minutes (time to lock) < 6 minutes (time to 1×10^{-9})
Voltage sensitivity	$< 2 \times 10^{-11}$ for a 1 VDC supply change

Electrical

Input voltage	+24 VDC (nom.), +22 VDC (min.), +30 VDC (max.)
Current	2.2 A (warmup), 0.6 A (steady-state) at 25 °C
Protection	±30 VDC to any pin except rf output
RF protection	100 mA (stable with any termination)
Cal reference out	5.00 ± 0.05 VDC
RS232	9600 baud, 8 bits, no parity, 1 stop bit, 0 to 5 volt levels with x-on/x-off protocol
1 pps measurement	±10 ns (accuracy), ±1 ns (resolution)
1 pps output set	±10 ns (accuracy), ±1 ns (resolution)

Environmental

Operating temperature	-20 °C to +65 °C baseplate
Temperature coefficient	$\pm 5 \times 10^{-11}$ (-20 °C to +65 °C baseplate)
Storage temperature	-55 °C to +85 °C
Magnetic field	$< 2 \times 10^{-10}$ for 1 Gauss field reversal
Relative humidity	95% (non-condensing)

Miscellaneous

Customer AQL[1]	0.26%
Customer MTBF[1,2]	1,600,000 hrs
Design life [3]	10 yrs
Size	2.00” x 3.00” x 4.00” (HWL)
Weight	1.32 lbs
Baseplate threads	4-40 (4 places)
Connector	Mates with ITT/Cannon DAM11W1S series
Warranty	Two year parts and labor on materials and workmanship.

1.Preliminary estimates for customer acceptance quality level (AQL) and mean time between failures (MTBF) are based on data from 750 units delivered over a 12 month period to a telecom equipment manufacturer. Two units of the 750 were returned following incoming inspection and environmental testing. Not all specifications were tested by the customer.

2. This MTBF represents a single unit failure in a lot of 748 units with a mean operating time of 90 days. In this customer’s application,any “unlock event”is considered a failure, and the unit is removed from service. Other failures, which are not relevant to this customer’s application,may not be detected.

3. Lamp lifetime is the dominant consideration in the design life estimate. The estimate is based on the measured reduction of lamp intensity and the elevation of lamp start voltage with time.

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