January 8, 2013

Low Cost, Pico Resolution GPS/Rb Reference Test Set

Pico Second Resolution Test Set

Easy-to-Use RF Device & Compact light weight

APPLICATIONS

Calibration | Oscillator/Clock Characterization | TIE Measurements | Instrument

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KEY FEATURES

- GPS disciplined Rb clock : Auto-adaptive SmarTiming+ loop time constant, running at 1ns resolution
- Power supply voltage : AC input 85-264VAC / 47-63Hz
- Compact : 1U rack mount chassis
- Testing Frequency Range : 1-30 MHz
- Reference Frequency : Integrated GPS-locked Rubidium clock
- Phase time resolution and noise : ≤ 2ps rms
- Output Frequency : 4x 10MHz / 4x 1PPS or 8 x 10 MHz
- User programmable SYNTH output
- Integrated smart auto calibration
- Internal Bit Alarm
- RS232 standard interface : 9600 b/s
- Software : Windows 98, XP
- GPS antenna types : Patch or rooftop

SPECIFICATIONS

ELECTRICAL

Spec	GPS PicoReference	
Reference module	**Standard**	**Options**
RFOUT Frequency Number of Output	10MHz 4x backplane 1x faceplate	10MHz 8x backplane 1x faceplate **(ordering code: 8RF**)
PPSOUT Functionality Number of Output	1PPS See SmarTiming section 4x backplane 1x faceplate	1PPS **(ordering code: 8RF**) 1x faceplate
Short Term Stability 1s 10s 100s	 3E-11 1E-11 3E-12	**(ordering code: S**) 1E-11 3E-12 1E-12
Phase Noise (dBc/Hz) *(RFOUT: 10 MHz)* 1Hz 10Hz 100Hz 1kHz 10kHz	 -75 -95 -125 -145 -145	**(ordering code: S)** -80 -100
Aging *(Measured after 3 months of continuous operation)*	< 5E-11 / month *(typical: 3E-11 / month)*	
Frequency Retrace Off/On *(In stable temperature, gravity, pressure and magnetic field conditions)*	< 5E-11 24 hr / 1 hr	
RFOUT Levels Output Impedance Harmonics Spurious $f_0 \pm$ 100kHz (SYNTH Off)	 Sine wave, 0.5 Vrms (±10% / 50 Ω), 1x faceplate **Sine wave, 1.0 Vrms (±10% / 50 Ω), 4x backplane **(** ordering code: 8RF 8x**)** 50 Ω ±20% < -25dBc < -80dBc	
SYNTHESIZER (SYNTH) Output level Frequency range Resolution Spurious	 Square wave 3.3V LV CMOS 0 to 20 MHz 3.97mHz (Fout= N×60'000'000/2^{32}) -35dBc (1-10 MHz) -30dBc (10-20 MHz)	
GPS Antenna Connector	SMA	

Measurement module	**Standard version**
Reference Frequency	10 MHz
DUT Center Frequency Range	1 MHz – 30 MHz
Clock Recovery circuit	E1 & T1
Measurement Noise @10MHz (Maximum Relative Frequency Deviation During Measurements < $1x10^{-9}$)	< 2ps
Measurement Noise @10MHz (Maximum Relative Frequency Deviation During Measurements < $1x10^{-7}$)	< 10ps
Typical System Noise @10MHz (± 2°C temp. Change during measurement)	See typical measurement figure 1
Input Signal Level	+3 dBm to +17 dBm
Input Impedance	50 Ohms ±20%
Connectors Type	BNC
PC Port	Standard 9600 b/s – Serial (COM1 or COM2 or COM3 or COM4)

SMARTIMING+® FUNCTIONALITY

Spec	GPS PicoReference
	Standard
PPSOUT Output level Pulse width (PW) or duty cycle	1PPS CMOS 0-5V (+- 20 mA sink/source) User settable, 0 to 1s in 133ns/step
PPSOUT to PPSREF Sync Error In Sync mode	< 50 ns No GPS PPSRef noise, ± 1°C temp fluctuations
PPSOUT to PPSREF (DE) Programmable delay (In Track mode)	 0 to 1 s in 133 ns steps
PPSOUT Holdover Time Stability	Within ± 2°C 1 µs/24 hr
Smart Loop Time Constant Phase/Frequency User settable	Auto-adaptive 1000 to 100,000 sec User settable Sync/Track mode ** Selected by RS232 interface ** *Sync: phase/time alignment; Track: frequency alignment*

GPS ANTENNA

Spec	GPS PicoReference	
	Standard	**Option**
Antenna Types Cable Length Lightening Surge Protector	Patch antenna kit 5 m / 16.4' Not applicable	Rooftop antenna kit 5+15m / 16.4' + 49' Included **(ordering code: RA)**

POWER

Spec	GPS PicoReference
	Standard
Power Supply	AC input 85-264VAC
Power Input Fluctuation	±10% of nominal supply voltage (230V~)
Input Frequency	47 – 63 HZ
Power Consumption @25°C	< 25W after warm-up
Connector Type	IEC plug

ENVIRONMENT

Spec	GPS PicoReference
	Standard
Operating Temperature	0 to 40°C *(Relative humidity: 10-85%)*
Storage	-25 to 55°C
Transportation	-25 to 70°C

PHYSICAL

Spec	GPS PicoReference	
	Standard	**Option**
Size	445 x 300 x 44 mm (1U) 17.52 x11.81x1.73 in.	
Weight	2.2 kg / 4.85 lbs	
Mounting	Tabletop feet	19" rack mountable ears **(ordering code: E)**

SYSTEM SUPPLY

Type	GPS PicoReference	
1x	GPS PicoReference	
1x	GPS patch antenna kit (with option code RA : Rooftop antenna kit)	
1x	Cables SUB-D male/female for PC serial COM	
2x	19" rack mountable ears or tabletop feet	
1x	iSyncMgr software & PicoTime software & Operating manual & specifications	
1x	In option Software – Stable32 (**Option code ST32**)	
1x	Euro Power Cable Standard	US Power Cable **(ordering code: US)** China Power Cable **(ordering code: CN)** Swiss Power Cable **(ordering code: CH)**

SOFTWARE UPGRADES

GPS PicoReference
Download the latest software upgrades at www.spectratime.com

ORDERING INSTRUCTIONS

GPS PicoReference / XX / YY / …..

Type Option 1 Option 2

The GPS PicoReference includes 2 modules: a Frequency Reference module and a Measurement module.

REFERENCE MODULE DESCRIPTION

The module integrates a smart Rubidium atomic clock and a GPS receiver. It has 3 basic modes of operation: Free Run, Track and Sync. The Free Run mode is when the Rubidium clock is not locked to a reference, and thus free running. The Track mode is when the reference is used to perform frequency alignment applications, whereas the Sync mode is when the reference is used to perform phase alignment applications.

As illustrated in Figure 1, when the module works in Track mode it uses the PPS_GPS as a reference (PPSREF) to align the frequency of the Rubidium clock. The frequency alignment is computed by an internal phase-time error signal that is generated by an internal PPS signal (PPSINT), which measures the signal at 1ns resolution through its SmarTiming+™ technology. The PPSINT then aligns the PPSREF phase.

In the Sync mode, the reference module phase aligns the PPSOUT to the PPSREF with the PPSINT reference signal, which uses SmarTiming+™ algorithm to 1) compare the PPSOUT and PPSREF signals at 1ns resolution within a +/-500ns dynamic range and 2) auto-adaptively align them.

The module has also the capability to dynamically analyze the stability of the PPSREF signal through the excellent mid-term frequency stability of the Rubidium technology. Thus, the 1PPS-GPS reference can be directly fed to the Rubidium clock without specific analysis of the internal optimization parameters of the GPS engine - i.e., number of satellites in view, signal to noise ratio, etc.

Figure 2 illustrates the typical frequency stability performance of the reference module, using its built-in 10MHz Rubidium reference clock.

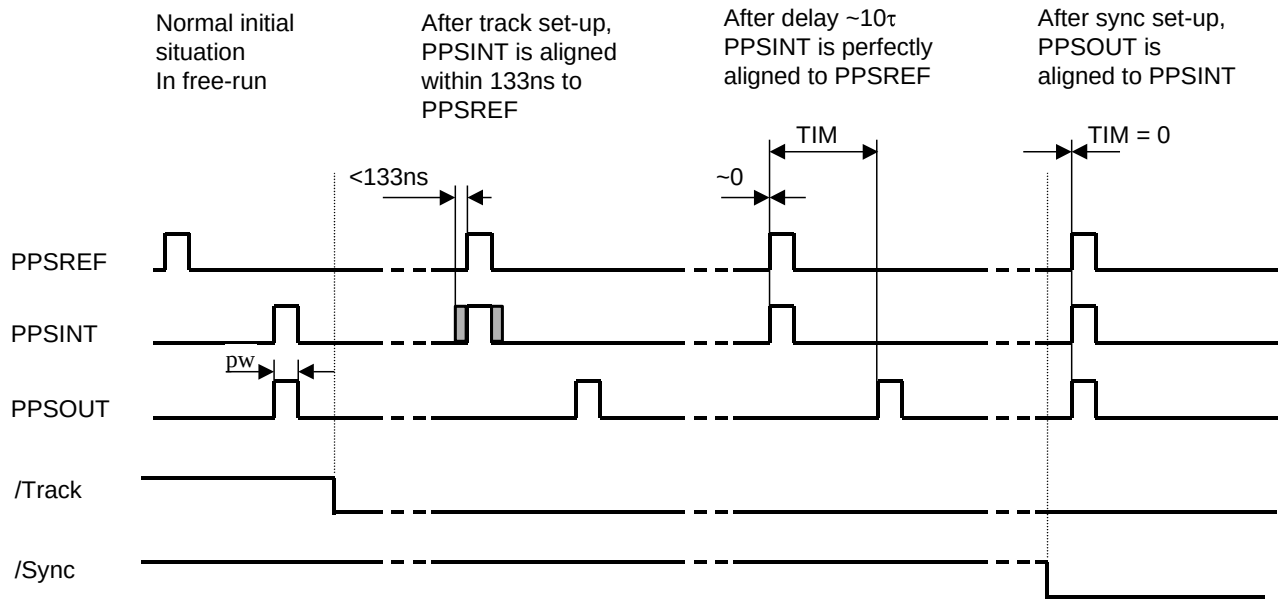


Figure 1 - Track & Sync Modes

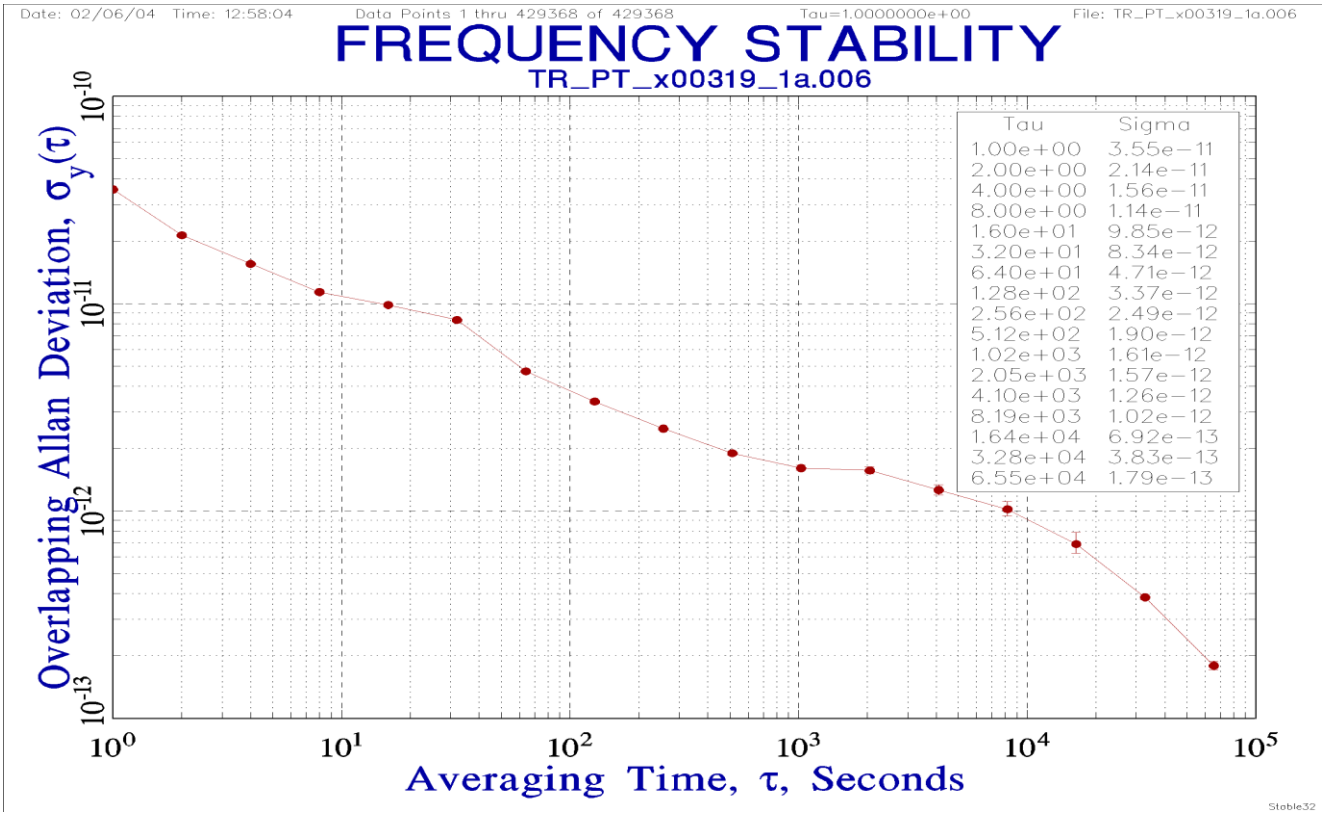


Figure 2 - Frequency Stability Performance

Frequency Adjustments & Rb Loop Monitoring Functions

The working and monitoring parameters of the Frequency Reference module are accessible for read and write operations through the serial RS-232 port (9600 bits/sec., no parity, 1 start bit, 8 data bits, 1 stop bit).

There are 2 basics commands as follows: *M* and *Cxxxx*

M<CR><LF>: monitors the basic internal signals of the atomic clock.

The returned answer is:

HH GG FF EE DD CC BB AA <CR> <LF>

Of which each returned byte is an ASCII coded hexadecimal value, separated by a <Space> character. All parameters are coded at full scale.

HH:	Read-back of the user provided frequency adjustment voltage on pin 2 (0 to 5V)
GG:	reserved
FF:	peak voltage of Rb-signal (0 to 5V)
EE:	DC-Voltage of the photocell (5V to 0V)
DD:	varactor control voltage (0 to 5V)
CC:	Rb-lamp heating current (Imax to 0)
BB:	Rb-cell heating current (Imax to 0)
AA:	reserved

Cxxxx<CR><LF>: output frequency correction through the synthesizer, by steps of 5.12×10^{-13} , where xxxx is a signed 16 bits word in hexa coded ASCII. This value is automatically stored in a EEPROM as last frequency correction which is applied after RESET or power-ON operation.
In Track mode this correction is not in use. The function **FC**sddddd does the same, but the data format is different.

There is a command to set the SYNTH output frequency:
Txxxxxxxx<CR><LF>: Where xxxxxxxx is an unsigned 32 bits in hexa coded ASCII stored in EEPROM. The frequency is changed after a reset $Frequency = \frac{xxxxxxxx}{2^{32}} \cdot 60MHz$

Timing & Locking Control Commands

Using the same data interface, the Reference module can accept the following basic ASCII commands: Data is in decimal ASCII code.

Command name	Syntax command	Data field (if any)	Response syntax	Response data (if any)
Identification	**ID**<CR><LF>	-	**TNTSRO-**aaa/rr/s.ss <CR><LF>	aaa: 100 rr: revision number s.ss: software version
Serial number	**SN**<CR><LF>	-	xxxxxx<CR><LF>	xxxxxx : 6 digits serial nbr
Status	**ST**<CR><LF>	-	**s**<CR><LF>	s:Status s=0 :warming up s=1 :tracking set-up s=2 :track to PPSREF s=3 :synch to PPSREF s=4 :Free Run. Track OFF s=5 :FR. PPSREF unstable s=6 :FR. No PPSREF s=7 :factory used s=8 :factory used s=9 :fault or Rb OOL
Set Tracking PPSINT - PSSREF	**TR**x<CR><LF>	x=0 : Track never x=1 : Track now x=2 : Track ever x=3 : Track now + ever x=9 : Interrogation	x<CR><LF>	x:Tracking commands status x=0 : Track OFF x=1 : Track ON (when Status 9 -> 4
Set Synchronisation PPSOUT – PPSINT	**SY**x<CR><LF>	X=0 : Synch. never x=1 : Synch. now x=2 : Synch. ever x=3 : Synch. now + ever x=9 : Interrogation	x<CR><LF>	x:Sync. commands status x=0 : Synch. OFF x=1 : Synch. ON (When Status 1 -> 2)
Set PPSOUT delay	**DE**ddddddd<CR><LF>	ddddddd=delay by 133ns step. Max 7499999 **DE**0000000 :synch to PPSREF	ddddddd<CR><LF>	ddddddd=delay by 133ns step. Max 7499999
Set PPSOUT Pulse Width	**PW**ddddddd<CR><LF>	ddddddd=pulse Width by 133ns step. Max 7499999 **PW**0000000: no pulse	ddddddd<CR><LF>	ddddddd=Pulse Width by 133ns step. Max 7499999 0000000: no pulse
Time of day	**TD**<CR><LF>	-	hh:mm:ss<CR><LF>	hh:hours mm:minutes ss:seconds
Set time of day	**TD**hh:mm:ss<CR><LF>	hh:Hours mm:Minutes ss:seconds	hh:mm:ss<CR><LF>	hh:hours mm:minutes ss:seconds
Date	**DT** <CR><LF>		yyyy-mm-dd	yyyy : year mm : month dd : day
Set date	**DT** yyyy-mm-dd <CR><LF>	yyyy : year mm : month dd : day	yyyy-mm-dd	yyyy : year mm : month dd : day
Beat every second on serial port.	**BT**x<CR><LF>	x=0 : Stop beat x=1 : Effective Time interval PPSOUT vs PPSREF x=2 : Phase comparator x=3 : Both x=1 & x=2 x=4 : Beat Time of day x=5 : Beat status x=6 : Beat <CR><LF> x=7 : Beat Date, Time, Status x=A : Beat NMEA $PTNTA, x=B : Beat NMEA $PTNTS,B,	ddddddd<CR><LF> or sppp<CR><LF> or ddddddd sppp <CR><LF> or hh:mm:ss<CR><LF> s<CR><LF> <CR><LF> yyyy-mm-dd hh:mm:ss s	ddddddd : delay in 133ns step sppp:phase error in ns s: +/- signe hh:hours mm:minutes ss:secondes s: status yyyy:year, mm:month,dd:day
Set frequency adjustment	**FC**sddddd<CR><LF>	s=+/- signe ddddd = limited within range : +32767/-32768 **FC**+99999 : interrogation	sddddd<CR><LF>	s: +/- signe ddddd : frequ. Adj. in 5.12 x 10^{-13} step

Command name	Syntax command	Data field (if any)	Response syntax	Response data (if any)
Set frequency save. Integral part, when Status = 2, 3	**FS**x**<CR><LF>**	x=0 : never save x=1 : save every 24 hours x=2 : save right now x=3 : save actual freq. now x=9 : interrogation	x**<CR><LF>**	x=0 : never save x=1 : save every 24 hours
Set Tracking Window	**TW**ddd**<CR><LF>**	ddd = Half Tracking Window by 133ns step. From 1 to 255 ddd = 999 : interrogation	ddd<CR><LF>	ddd : Half Tracking Window by 133ns step.
Set no Alarm Window	**AW**ddd**<CR><LF>**	ddd = Half no Alarm Window by 133ns step. From 1 to 255 ddd = 999 : interrogation	ddd<CR><LF>	ddd : Half no Alarm Window by 133ns step.
Set tracking phase loop time constant	**TC**dddddd**<CR><LF>**	dddddd = Time constant in seconds (001000 to 999999) TC000000 : change to auto. (<)TC001000 : no change	Dddddd<CR><LF>	dddddd : time constant in seconds
Set module customization	**MC**sxx [cc…c] <CR><LF>	s = L : Load parameter s = S : Store parameter ccc..c s = B : Load start behaviour s = A : Activate msg at start s = C : Cancel msg at start s = H : Load Help s = T : Load Data Type xx = 00..FF: msg number, ccc…c : new welcome message, up to 24 characters	cc..c<CR><LF> or d<CR><LF> or xy<CR><LF>	ccc..c : response to MCLxx or to MCHxx. d : 0, 1 response to MCBdd or xy : Data Type, response to MCTxx, x=0 RAM, x=1 eeprom, x=2 Flash, y=0 Byte, y=1 sByte, y=2 Word, y=3 sWoord, … y=8 string ASCII, y=9 strng binary
Set phase comparator Offset	**CO**sddd<CR><LF>	s :+/- signe ddd : limited with range + 127 / - 128 CO+999 : interrogation	sddd<CR><LF>	s :+/- signe ddd : offset in approx 1 ns steps
View PPSRef Sigma	**VS**<CR><LF>		ddd.d<CR><LF>	ddd.d : Sigma of PPSRef in ns. In tracking, Status 2, 3.
View Time constant	**VT**<CR><LF>		dddddd<CR><LF>	dddddd : Loop time constant now in use, in ns.
Raw phase adjust	**RA**sddd<CR><LF>	s :+/- signe ddd : limited with range + 127 / - 128	sddd <CR><LF>	s :+/- signe ddd : raw phase just asked in 133 ns steps
Reset micro controller	**RESET**<CR><LF>			(Identification & welcome message, GPS binary)

Standard GPS Antenna

A GPS patch antenna with 5 meters (16.4') of cable is included in the normal package. This antenna can be installed close to a window. If installed in a region susceptible to lightning, a surge arrestor must be installed. For the installation, please refer to our GPSReference user manual, section "Safe GPS Antenna installation".

Optional Rooftop GPS Antenna KIt (Ordering code: RA)

This kit contains the following items:

- a roof antenna
- a cable of 15 meter (49')
- a cable of 5 meter (16.4')
- a lightning arrestor

Custom GPS Antenna

The customer can install another antenna. In such case, the antenna connector of the device supplies 5V/30 mA for the amplifier. Please note that the device is CE tested only for an antenna cable less than 30 meters (98').

For the installation, please refer to our AppNote "Custom GPS Antenna Installation".

MEASUREMENT MODULE DESCRIPTION

This module is based on a heterodyne architecture with a double frequency conversion to reach a resolution around the pico-second level. The following figure shows the typical system noise. The module integrates autonomous software, enabling the GPS PicoReference to work with an external 10MHz reference or through its built-in 10MHz reference module. The flexible testing frequency range is any frequencies between 1 - 30 MHz.

Additionally, the following 3 outputs are available to perform extra measurements using an external frequency counter:

- 1KHz output, using a crystal-filter based PLL to restrict the bandwidth to only 1Hz
- 1KHz output, providing about 100KHz bandwidth
- 1PPS output

The module also contains a clock recovery interface circuit. It extracts the clock rate of a E1 (2048KHz) or T1 (1544KHz) line in order to be able to measure it with the measurement module.

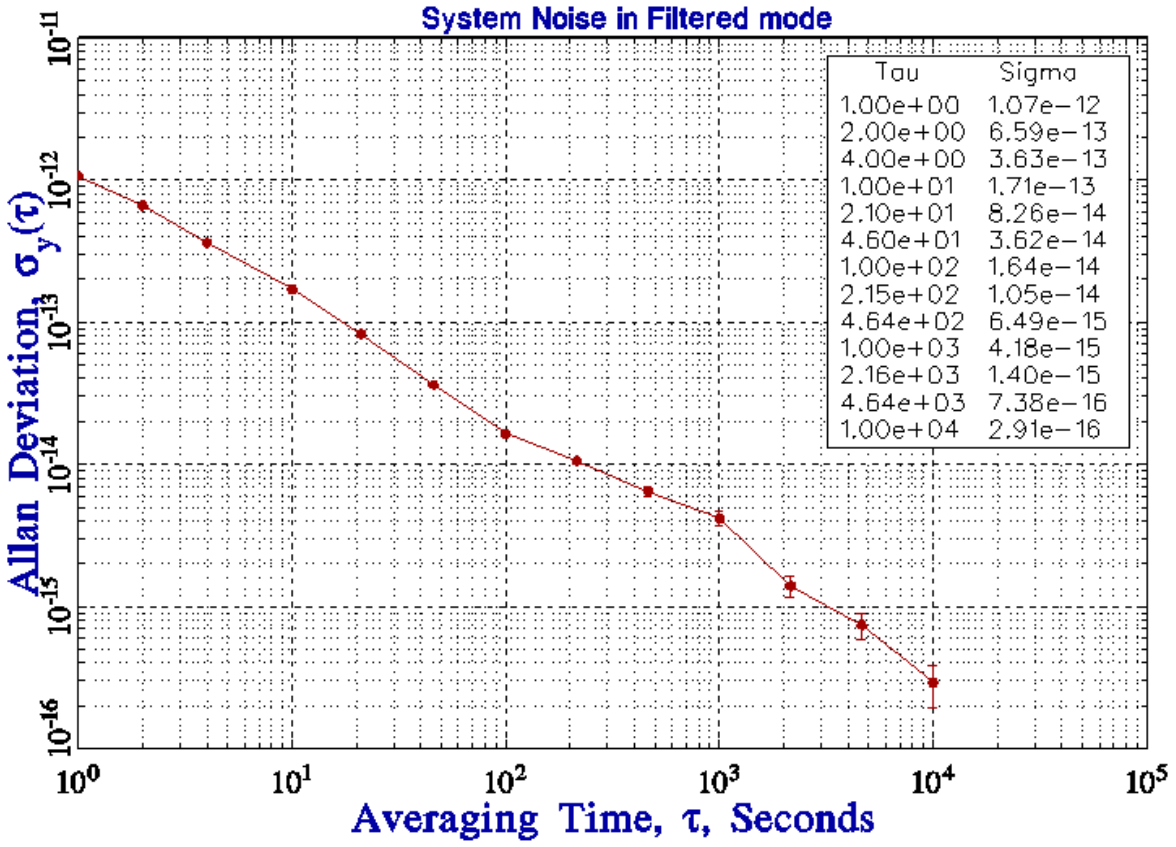
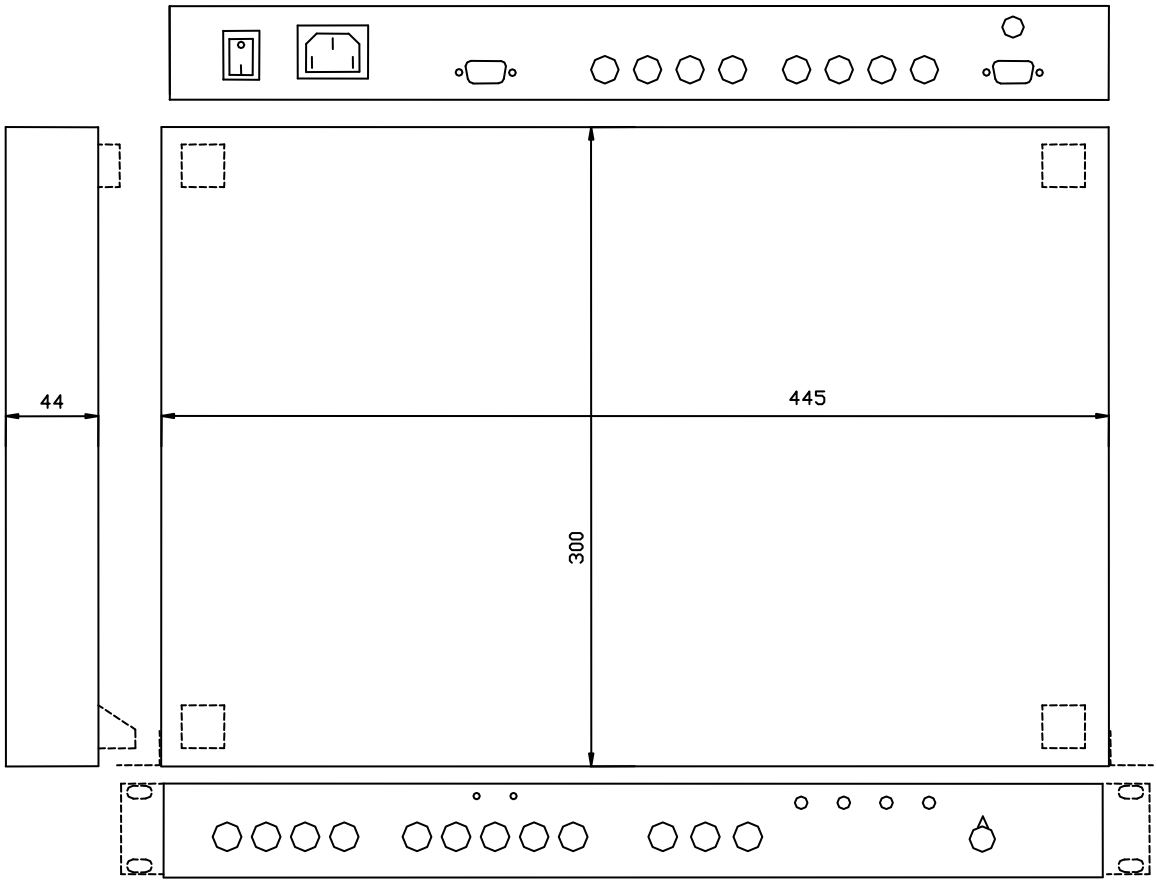
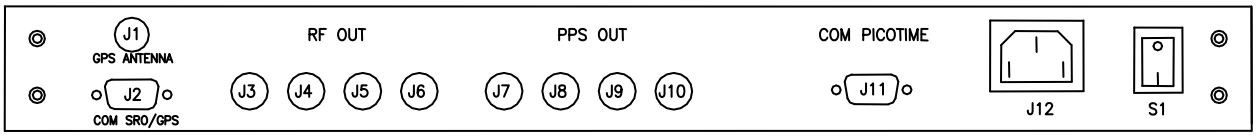


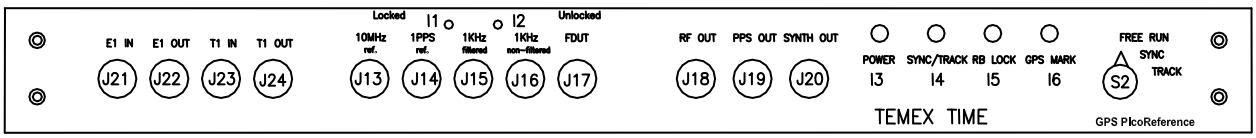
Figure 3 - Noise Measurement Performance @10MHz

MECHANICAL LAYOUT



I/O INTERFACES





Back Panel

N°	Type	Definition	I/O
J1	SMA	GPS antenna connection	I
J2	SUB-D9-F	Reference module Serial communication RS232	I/O
J3-J6	BNC	4x 10MHz sine reference outputs	O
J7-J10	BNC	4x 1PPS outputs (4x 10 MHz sine reference outputs with option code 8RF)	O
J11	SUB-D9-F	Measurement module Serial communication RS232	I/O
J12	IEC PLUG	Power connection	I
S1	SWITCH	On/Off switch	-

Front Panel

N°	Type	Definition	I/O
J13	BNC	Measurement module 10MHz reference	I
J14	BNC	Measurement module 1PPS reference for external counter	O
J15	BNC	1KHz filtered for external counter	O
J16	BNC	1KHz non filtered for external counter	O
J17	BNC	Device under test input signal	I
J18	BNC	10MHz sine reference output	O
J19	BNC	1PPS output	O
J20	BNC	SYNTH output	O
J21	BNC insulated	E1 clock recovery input	I
J22	BNC	E1 clock recovery output	O
J23	BNC insulated	T1 clock recovery input	I
J24	BNC	T1 clock recovery output	O
I1	Green LED	Measurement module locked indicator	-
I2	Red LED	Measurement module unlocked indicator	-
I3	Green LED	Power indicator	-
I4	Green LED	Sync or Track mode enabled	-
I5	Red LED	Rubidium clock locked alarm	-
I6	Green LED	1PPS GPS applied	-
S2	SWITCH	Free run, Sync or track selection switch	-