

Low Cost, High Resolution Frequency 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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1. INTRODUCTION

GPS PicoReference test set procures an attractive solution for the characterization of quartz crystal oscillators, atomic clocks or entire systems. It can also be used for the calibration of high stable oscillators and atomic clocks.

GPS PicoReference test set includes two modules, a frequency reference module and a measurement module.

The frequency reference module includes a Rubidium atomic clock and a GPS receiver.

The module has three basic modes of operation: “Free Run”, “Track” and “Sync”. The first mode is the free running of the Rubidium clock, “Track” is used for GPS frequency alignment while “Sync” is used for phase alignment applications.

The measurement module is based on a heterodyne architecture with a double frequency conversion to reach a resolution around the pico-second level. The frequency range of the device under test is any values between 1MHz to 30MHz which characterize the flexibility of the system.

It is designed for ease of use, configures itself the system and collects data to allow post-processing. According to the standard serial COM interface, wide range input frequency, the automatic operation, the system is very flexible and easy to use.

The user software is able to show the time stability results as well as the frequency or phase samples in real time. In addition, the data are stored into a file which is completely compatible with conventional post-processing software.

2. Definitions

This is a list of words and related definitions used in this manual to help the user understand the content:

Words	Definitions
GPS PicoReference	Unit or product
Unit	GPS PicoReference
System	GPS PicoReference and its integrated modules
Rb	Rubidium
Rubidium clock	Refers to the smart SRO model
Rubidium	Rubidium clock
SRO	Rubidium clock, model SRO-100
Reference module	Rubidium clock + GPS receiver
Measurement module	PicoTime
Track mode	Frequency alignment between a reference and an output signal, regardless of the relative phase position of the two signals. Also known as “syntonization”
Sync mode	Phase alignment between a reference and an output signal. Also know as “synchronization”
Free-run mode	Rubidium clock not locked to any reference, including GPS
Holdover mode	Rubidium clock that was previously locked to a GPS reference but lost it or is no longer present

3. BEFORE GETTING STARTED


3.1 Unpacking

Unpack and carefully inspect the unit. Check for physical damage. If physical damage is observed, then immediately contact Spectratime SA.

Unit supply:

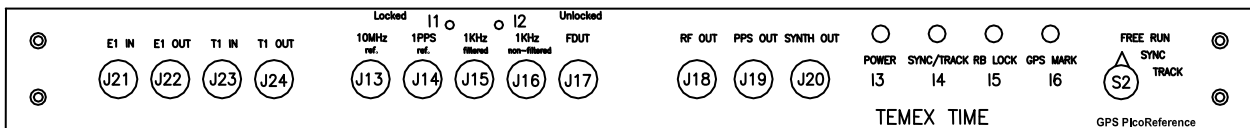
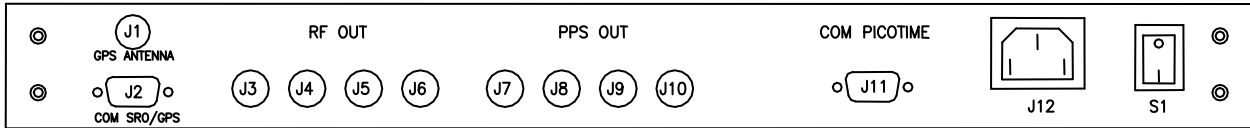
- 1x GPS PicoReference unit
- 1x GPS patch antenna with 5 meters (16.4') cable with standard option,
Note: For optional Rooftop GPS Antenna (Option code: RA)
This kit contains the following items:
 - 1x roof antenna
 - 1x cable of 15 meter (49')
 - 1x cable of 5 meter (16.4')
 - 1x lightning arrestor
- 1x Cables SUB-D male/female for PC serial COM
- 1x Power cable
- 2x 19" rack mountable ears or tabletop feet
- 1x Software – PICOTIME installation (Measurement module control) on CD-ROM
- 1x Software iSyncMgr (Reference module control) on CD-ROM
- 1x Operating Manual + Specifications on CD-Rom
- In option Software – Stable32 (**Option code ST32**) on CD-Rom

3.2 Safety !

	<ul style="list-style-type: none">- Use proper ESD precautions- Ensure that all cables are properly connected
---	--

3.3 Installation procedure

3.3.1 Connections



- 1) Connect power 100-240V 50-60Hz to J12.
- 2) Connect GPS antenna to J1 GPS antenna. Install the included patch antenna close to a window.

Notes:

- a) If the installed antenna is in a region susceptible to lightning, a surge arrestor must be installed. For the installation, please refer to section “Safe GPS Antenna installation”.
 - b) Customize GPS Antenna. The customer can install their own desired Antenna. In such case, the antenna connector of the device supplies 5V/30 mA for the amplifier.
 - c) GPS PicoReference is CE tested only for an antenna cable less than 30 meters (98’).
- 3) Connect a COM cable between J2 and one COM available of your computer for RS232 commands and monitoring (if required).
 - 4) Place S2 in position “Free run”.
 - 5) Connect a COM cable between J11 and one COM available of your computer for control of the Measurement module.
 - 6) Switch On the system S1.

3.3.2 Software Installation

There is two software, one for commands and monitoring of the Reference module which is not necessarily required and a second one for the control of the Measurement module.

3.3.2.1 Reference module : iSyncMgr Application

The Reference module operates independently. However, the smart integrated rubidium clock can be monitored through iSyncMgr application, which is included in the CD-ROM or the latest version can be downloaded from www.spectratime.com. To start the application, please follow procedure below:

- Verify a COM cable between J2 and one COM available of your computer is connected.
- Start the application with Internet Explorer

By default, the serial port is COM1. If a warning window pops up before the application iSyncMgr starts, the COM1 is not free and another port has to be selected. How? Go to “Serial Port \ PortNo” menu, then select another available port.

- Once the serial port number is properly working, click on the “Refresh” button. The Identification, Serial Number and Status of the smart SRO rubidium clock inside the GPS PicoReference should be displayed as Figure 1 below:

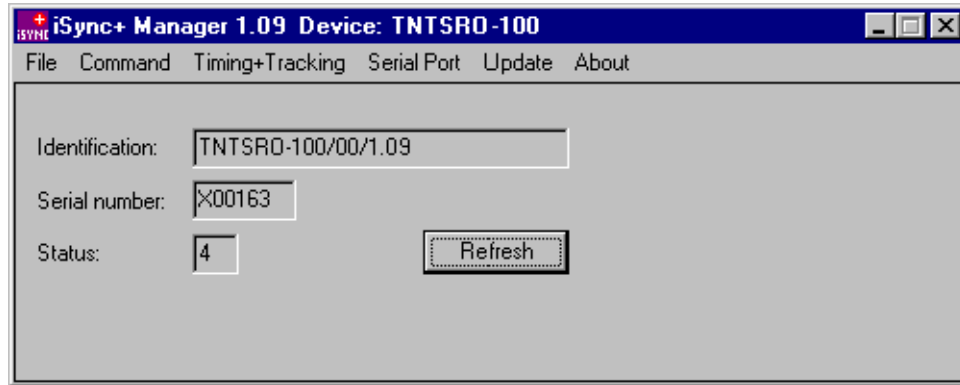


Figure 1 - iSyncMgr.exe

Notes:

- a) iSyncMgr gives full monitoring access to the smart SRO rubidium clock
- b) Changes through these commands should be avoided: TCddddd or MCsxx...

3.3.2.2 Reference module : RS232 Terminal Communication Interface

The user can also use a serial communication RS232 to monitor the parameters of SRO rubidium clock or to send specific commands. For example, a hyper terminal communication can be used as follows:

RS232 protocol is:

- 9600 bits/s
- 8 data bits
- No parity
- 1 stop bit
- No handshake

Notes:

- 1) See RS-232 Application Note at www.spectratime.com for different configurations (tip: keyword search “RS-232”)
- 2) See chapter 5 for the list of commands

Generally, the Reference module does not required any commands and monitoring due to its built-in smart timing algorithm.

3.3.2.3 Measurement module : PicoTime Application

- Connect a COM cable between J11 and one COM available of your computer.
- Close all applications and run the **Setup.exe** in the directory **PicoTime** from the CD-ROM and follow the instructions. The program PicoTime will be installed in the start menu by default. This software control the measurement module.

4. Reference module Operations

4.1 Operating Modes

The GPS Picoreference integrates a smart SRO rubidium clock and a GPS receiver. It provides 4 basic modes of operation as follows:

1. **Free Run:** When the Rubidium clock is not locked to a GPS reference and, thus, is free running
2. **Track:** When the GPS reference is used to perform frequency alignment applications. It uses the PPS_GPS as a reference (PPSREF) to align the frequency of the Rubidium clock, but the phase is not aligned.
3. **Sync:** When the GPS reference is used to perform phase alignment applications. The PPSOUT of the GPS PicoReference is aligned in phase with the GPS PPSREF input through the internal PPSINT reference signal, which uses the SmarTiming+™ algorithm to 1) compare the PPSOUT against the PPSREF signal at 1ns resolution within a +/- 500ns dynamic range and 2) auto-adaptively align them.
4. **Holdover:** When the GPS signal is not present (NO PPSREF). The last averaged frequency value is used for performance enhancement by the SmarTiming+™ algorithm

4.2 Operating Mode Setup

The user can set up the operating mode in 2 ways:

- Hardware:** Select desired operation mode through the Switch 2. This mode overrides any software setup. Example: if the Switch 2 is set in Track mode, the unit will work in tracking mode, even though the user sets up the Free-Run or Sync mode through the iSyncMgr application or send a RS-232 command to the unit.
- Software:** Select desired operation mode through the iSyncMgr application or send RS-232 commands.

4.3 Alarm Indicators Description

Operation modes	LED status				Switch 2 positions			Troubleshooting Actions
	Power	Sync/Track	Rb Lock (red)	GPS Mark	free run	Sync	Track	
Free Run	-	-	-	-	-	-	-	Check power supply
	√	-	√	-	√	-	-	Wait for 15 minutes, if I5 is still red then send back the GPS PicoReference to factory
	√	-	-	-	√	-	-	Bad installation of GPS antenna
	√	-	-	Blinking	√	-	-	Normal free run situation
Track/Sync	√	-	-	√		√	-	Wait 10 minutes, if I4 still not green, maybe a bad configuration, please contact us
	√	-	-	√			√	Wait 10 minutes, if I4 still not green, maybe a bad configuration, please contact us
	√	green	-			√	(√)	Normal Sync/Track situation

Holdover	√	-		-		√	In holdover mode. No GPS signal detected. If the signal comes back, I6 should blink again and I4 will become green. It doesn't mean that the holdover time was too long. In such case, set the Switch S2 in Free-Run and then back in Sync or Track
	√	-		-		√	

5. Reference module Description

The GPS Picoreference Reference module consists of a GPS receiver disciplined to a smart rubidium clock (model SRO-100).

5.1 Principle of Operation

The Rubidium atomic clock essentially consists of a voltage-controlled crystal oscillator (VCXO) which is locked to a highly stable atomic transition in the ground state of the Rb87 isotope. While the VCXO is oscillating at a convenient frequency of 60 MHz, the Rb clock frequency is at 6.834...GHz in the microwave range. The link between the two frequencies is done through a phase-stabilized frequency multiplication scheme whereby a synthesized frequency is admixed to enable exact matching.

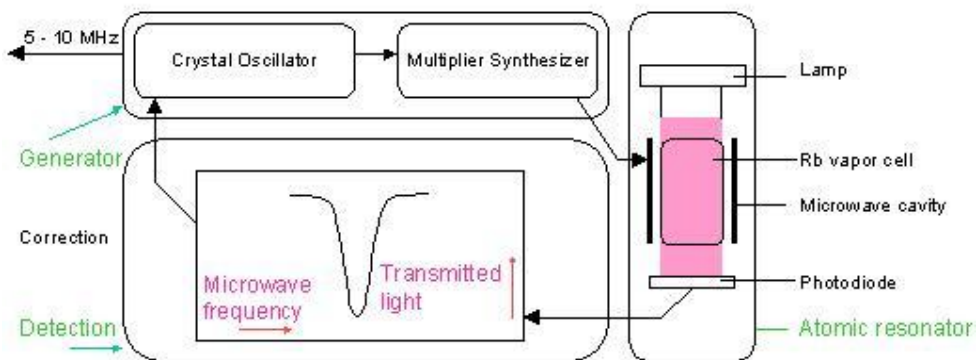


Figure 2 - Rubidium atomic clock block diagram.

5.2 Physics Package

The main design characteristics of the physics package are its low power consumption, small size and mass, along with minimal environmental sensitivities and mechanical ruggedness.

Other design features contributing to the compact design are:

- Use of the integrated filter technique (IFT)
- Use of a magnetron-type microwave resonator

The integrated filter technique combining the optical filtering and pumping in one cell contributes also to the reliability, the configuration is simplified and the number of components is reduced. The thermal capacitance of the cell assembly is relatively low. Thus the necessary power during warm-up is greatly reduced.

The magnetron resonator is a cylindrical cavity loaded with a concentric capacitive-inductive structure (annular metal electrodes). It allows smaller cavity dimensions and concentrates the microwave field at the right region of the cell.

The Rb lamp is an electrode-less RF-discharge lamp, a heated glass bulb, containing Rb and a starter gas surrounded by an RF-coil.

5.3 Electronics Package

The clock transition of a Rubidium (Rb) resonator is a microwave transition at 6.834 GHz.

The microwave resonance occurs as a dip in the optical signal - i.e. in the Rb lamp light which, after transiting the cell, is detected by a photodiode.

The basic purpose of the electronics package is to synchronize the entering microwave frequency, derived from a quartz crystal oscillator, to this absorption dip. This is achieved by tuning the microwave frequency to maximum optical absorption.

The clock microwave frequency of the Rb atoms in the vapor cell has a nominal value of 6834.684 MHz. This frequency is generated from a voltage controlled quartz oscillator (VCXO) oscillating at 60 MHz.

A serial interface connection, monitoring and tuning the internal parameters and the PPS facilities, is provided to the user.

The correct operation of the unit can be checked by an output signal called "lock monitor". This lock monitor information is generated by the micro-controller and is a function of the following parameters:

- Light level intensity
- Rb signal level (detected signal)
- Heaters supply voltages

The different alarm threshold levels, corresponding to the different internal electronics and physics parameters, are programmed during the automatic adjustment procedure at the factory.

5.4 Timing & Tracking System

The reference module includes extended PPS (Pulse Per Second) facility. The hardware of the PPS facility consists of two modules as follows:

The first module is a timer clocked at 7.5 MHz. This timer tag the PPSREF connected to the GPS receiver and generates two other PPS. The first one is called PPSINT and is used internally. The second one is called PPSOUT and appears on the back and faceplate.

The second module is a phase comparator with 1ns resolution and 1µs range. This module compares the phase between PPSREF and PPSINT. The phase information is used for the perfect tracking of a low noise PPSREF and for computing the noise of this PPSREF. The computation is used to adjust the time constant of the tracking loop. This way, the GPS antenna can be directly connected to the system without hardware and software adjustments.

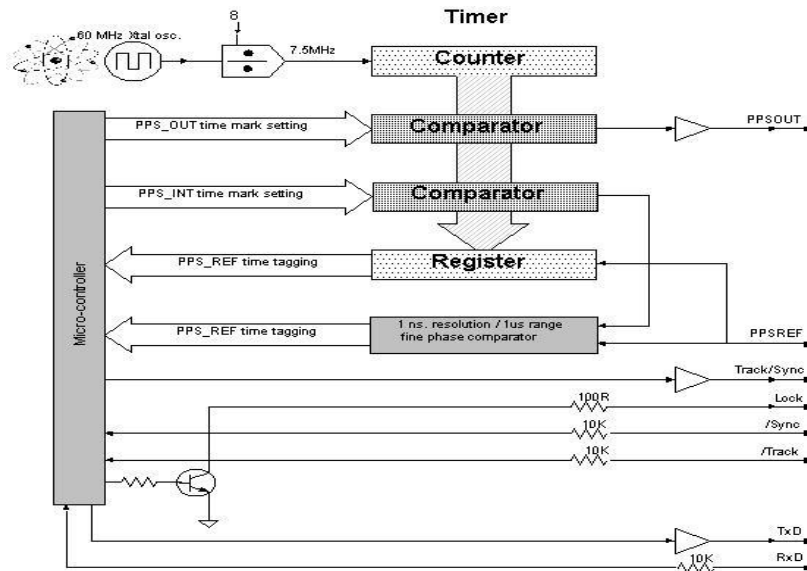


Figure 3 - Timing System

5.4.1 Free Run, Track & Sync Modes

The reference module has 3 basic modes of operation:

- Free Run
- Track
- Sync

When the first mode, Free Run, is set up, the Rubidium clock is not locked to a reference.

When the second mode, Track, is set up, the PPSINT is aligned to the PPSREF within 133ns. Then the phase comparator starts its mid-term frequency stability analysis of the PPSREF. The tracking loop time constant is auto-adaptively adjusted accordingly, and the unit starts to track the PPSREF. During this process, the position of the PPSOUT is not changed. The PPSREF timer works on an independent way. Thus the PPSOUT will not suddenly jump when the module starts to track a PPSREF.

When the third mode, Sync, is set-up, the PPSOUT is aligned to PPSINT. The Sync mode can only be set up when the unit is already successfully tracking a PPSREF. If the Sync mode is set up just after the unit starts to track a PPSREF, the phase-time difference between PPSOUT and PPSREF can be as big as 133ns. However, the tracking loop will reduce this difference and will bring it nearly to zero if the noise of the PPSREF is low.

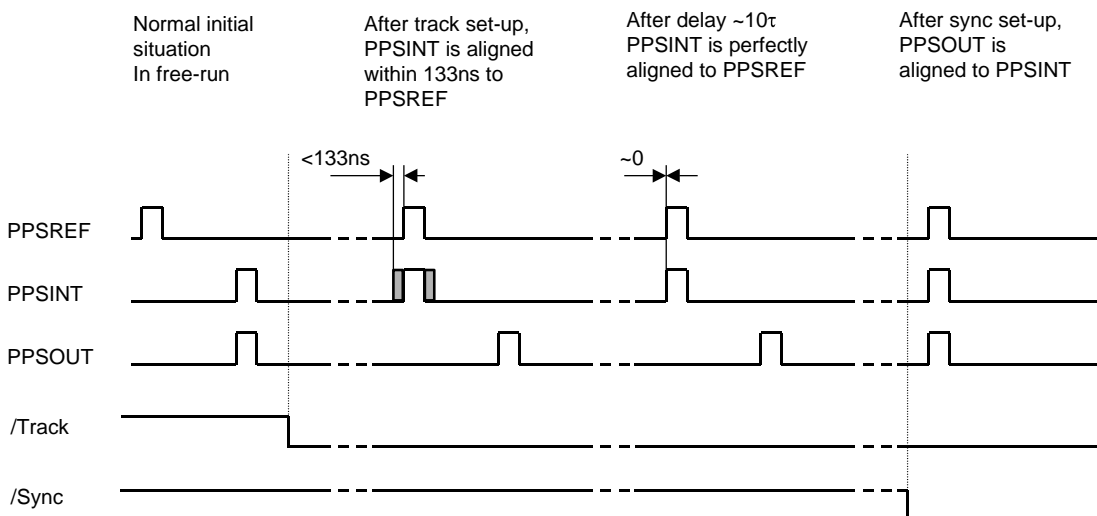


Figure 4 – Track vs. Sync Mode

5.4.2 The Frequency Learning

When the unit is tracking the PPSREF of a GPS, it aligns to the frequency of the GPS. The learning process is simply the memorization of the GPS' frequency from time to time to use it after a reset or Power-On. By default, when the unit is continuously and successfully tracking a PPSREF, the average value of the frequency is saved in EEPROM every 24 hours. Through the command FSx<CR>, a user can cancel the learning process or immediately save the average value of the frequency.

5.4.3 The Frequency in Use

With the PPSREF facility, a different frequency can be in use in different situations. Let's assume that the frequency currently in use is located in a single register, and that this register can be read by a user. The command to read this register is: FC+99999<CR>. Through the serial interface, a user can follow the evolution of the tracking through the instructions given below.

The frequency or frequency correction in use in different situations is the following:

- After a Reset or Power-On, the frequency correction is copied from the EEPROM to the RAM and then is used
- After the start of a tracking, the internal frequency correction is the one of the EEPROM
- During a tracking, the frequency correction in use changes continuously to align as close as possible the PPSINT to the PPSREF. By default, the average value is saved in EEPROM every 24 hours
- If the unit is stopped in its tracking, and put in FREE RUN mode by a user, with the command TR0 for example, the frequency correction in EEPROM is retrieved and loaded in RAM to be used
- If the tracking is stopped because the PPSREF signal disappears suddenly or is strongly degraded, the integral part value of the regulation loop becomes active. This is to avoid a frequency jump in case the PPSREF signal comes back again. This mode of operation is called holdover.

5.4.4 User Frequency Correction

This correction is only possible in Free Run mode and is performed with the command FCsxxxxx. The command has 2 effects as follows:

- Memorization of the asked frequency in EEPROM
- Immediate use of the new frequency

5.4.5 The PPS Tracking Loop

The unit is equipped with a numerical PI regulation loop to track the PPSREF. The time constant of the tracking loop is either set automatically or forced by a user with the command TCxxxxxx.

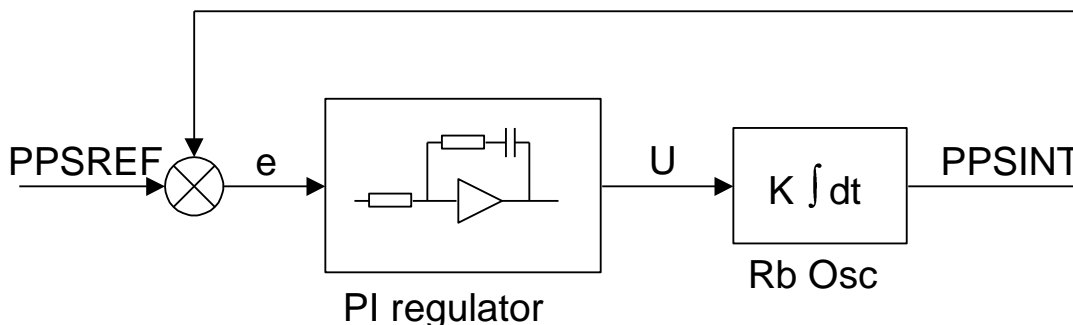


Figure 5 - Schematic of the PPSREF Regulation Loop

By default, the optimum loop time constant is computed by the unit from information such as the PPSREF noise and temperature fluctuations. In this case, if the fine phase comparator cannot give valid information, the time constant is forced to 1000s. But the loop time constant can also be forced by a user to a fixed value. In this case, the time constant the one manually set by a user. The command to do this is TCxxxxxx<CR>.

5.4.6 Tracking Limits & Alarms

If the frequency between the unit and a GPS to track is too large after a while, the phase time error between PPSINT and PPSREF can become too large for some applications. Thus there are two limits as follows:

- a) If the phase time error becomes bigger than the first limit, an alarm is issued, but the tracking continues. This first limit is called “no alarm” window
- b) If the phase time error becomes bigger than the second limit, then the tracking stops. This second limit is called “tracking” window

The half value of the “no alarm” window can be changed by a user with the command Awxxx. By default its value is set to 015 counter steps or $\sim\pm 2\mu\text{s}$.

The half value of the “tracking” window can also be changed by a user with the command Twxxx. By default its value is set to 015 counter steps or $\sim\pm 2\mu\text{s}$.

For more details, see chapter “TIMING AND TRACKING COMMANDS”.

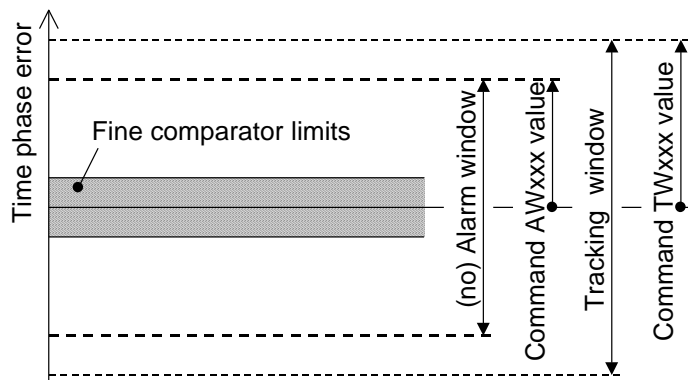


Figure 6 - Tracking Limits

5.4.7 Frequency Fluctuations while Tracking

To track a PPSREF the unit has to change its frequency. The allowed frequency variations are limited by factory to $\pm 1\text{E-}8$. This means the variations of the register DDSUSER are limited to ± 19531 during a tracking or in hexa to $\pm \$4\text{C}4\text{B}$. However, this value can be changed by factory setting to any other value upon request. The limitations are simply the limits of the signed integer DDSUSER. In other words, $+32767$ to -32768 or $\pm 1.6\text{-E-}8$ in relative frequency.

If during the tracking of a PPSREF, the unit reaches the frequency limit, its frequency will be limited to the frequency limit and no error will be issued as long the phase time error is staying in the “no alarm” window.

If the unit is connected to a terminal through the serial port, a user can read the actual frequency limitation in use by typing R14<CR> , R15<CR>. The returned values are the MSB and the LSB of a signed integer coded on 2 bytes, representing the allowed frequency variations in $5.12\text{E-}13$ steps. A user can also check if the DDSUSER is actually limited by typing R4F<CR>. If there is an issue, the bit 1 and bit 2 of the register will not be set to 0.

5.4.8 Fine Phase Comparator Offset

This fine offset adjustment can be used in case of precise phase calibration. The range of the offset is +127/ - 128 steps of the fine phase comparator. Since the fine comparator is analog, a step corresponds to approx. 1ns. The command to set the offset is COsddd <CR>

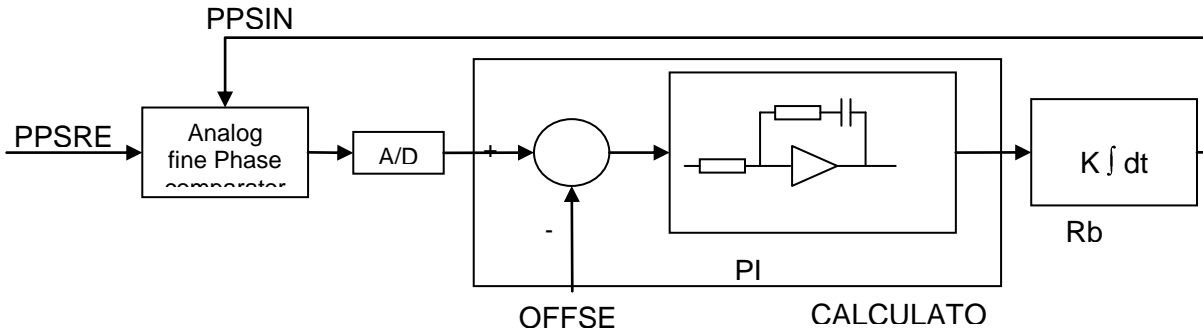


Figure 7 - Schematic of the Analog Fine Phase Comparator Regulation Loop

6. Reference module Communication

User can monitor the internal parameters such as identification, status and parameters by sending a command followed by a carriage return character through the serial interface.

6.1 Identification

ID<CR>[<LF>] : Identification
 Answer: **TNTSRO-aaa/rr/s.ss<CR><LF>**
 aaa: 100 if SRO-100, 075 if SRO-75 as Rb clock
 rr: revision number
 s.ss: software version
 Example: **ID<CR>**, answer: **TNTSRO-100/01/1.00<CR><LF>**

SN<CR>[<LF>] : Serial number
 Answer: **xxxxxx<CR><LF>**
 xxxxxx: 6 digits serial number of integrated SRO-100 in GPS PicoReference
 Example: **SN<CR>**, answer: **000098<CR><LF>**

6.2 General status of Rb clock module

ST<CR>[<LF>] : General Status
 Answer: **s<CR><LF>**
 s: status
 0: warming up
 1: tracking set-up
 2: track to PPSREF
 3: sync to PPSREF
 4: Free Run. Track OFF
 5: Free Run .PPSREF unstable
 6: Free Run. No PPSREF
 7: factory used
 8: factory used
 9: Fault or Rubidium out off lock

Example: **ST<CR>**, answer: **4<CR><LF>** (Free Run. No tracking)

The module can send through the serial port once per second or upon request its general internal status. The meaning of this status is:

- 0:Warming up. This happens when the system is just powered on and the temperature of the cells is not high enough.
- 1:Tracking set-up: The system is in this state when it goes from free-run status to the track status after a track set-up. The duration of this state should not exceed 3 minutes.
- 2:Track to PPSREF. PPSINT is aligned to PPSREF.
- 3:Sync to PPSREF. PPSINT and PPSOUT are aligned to PPSREF.
- 4:Free Run. Track off.
- 5:Free Run / Holdover. PPSREF unstable. The stability of the PPSREF is too low to be tracked.
- 6:Free Run / Holdover. No PPSREF was detected.
- 7:Factory used.
- 8:Factory used.
- 9:Fault or Rb Out Of Lock. This happens when the VCXO is scanning to find the Rb line.

6.3 Monitoring of internal parameters

The internal parameters monitoring is made via the serial interface and with the use of single command "M" followed by a carriage return character.

M<CR>[<LF>]

The module will respond to this single character command with an eight ASCII / HEX coded string which look like

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

Where 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 frequency adjustment voltage (0 to 5V)
 GG: reserved
 FF: peak voltage of Rb-signal (0 to 5V)
 EE: DC-Voltage of the photocell (5V to 0)
 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

- **DC-Frequency adjustment voltage .**
HH: o/p frequency adj. voltage (0 to 5V for \$00 to \$FF)
 This parameter corresponds to the frequency adjustment voltage.
- **Reserved**
GG:
- **Rb signal level.**
FF: Peak voltage of Rb signal level (0 to 5V for \$00 to \$FF)
 This signal monitors the rectified value of the AC signal produced by the interrogation process of the Rb dip absorption. During warm-up time this signal is approximately 0V and after it stabilizes to a nominal value of 1 to 5V. As long as this signal is too low the internal control unit sweeps the Xtal frequency in order to find the Rb absorption dip.
- **DC-Voltage of the photocell.**
EE: DC-Voltage of the photocell (5V to 0 for \$FF to \$00)
 This signal corresponds to the transmitted Rb light level. This is the light of the Rb lamp which is partly absorbed by the Rb cell. The nominal photocell voltage is in the range 2.0 to 3.5 V but must stay stable after the warm-up time. The photocell voltage is related to the internal reference 5 V voltage. The full scale corresponds to the coded value \$00 and the zero (no light) corresponds to the coded value \$FF
- **Frequency adjustment voltage.**
DD: VCXO control voltage (0 to 5V for \$00 to \$FF)
 This parameter corresponds to the voltage applied to the varicap of the internal VCXO.
 In normal operation this voltage is mainly temperature dependent in the range 2 to 3V in order to compensate the frequency versus temperature characteristic of the crystal resonator.
 During warm-up the control unit generates a ramp of this parameter from 0.3 to 5V and from 5V to 0.3V until the Rb dip absorption is found.
- **Rb lamp heating limiting current.**
CC: Rb lamp heating limiting current (Imax to 0 for \$00 to \$FF)
 This parameter corresponds to heating limiting current applied to the lamp heating resistive element. In normal operation, this current depends on the ambient temperature but should stay between \$1A and \$E6. During warm-up, this current is set to its maximal value \$00 (no current limiting).

- **Rb cell heating limiting current.**

BB: Rb cell heating limiting current (Imax to 0 for \$00 to \$FF)

This parameter corresponds to heating limiting current applied to the cell heating resistive element. In normal operation, this current depends on the ambient temperature but should stay between \$1A and \$E6. During warm-up, this current is set to its maximal value \$00 (no current limiting).

- **Reserved**

AA:

6.4 Center frequency adjustment via serial interface

A single character command is available to the user for center frequency adjustment.

Cxxxx <CR>[<LF>] : output frequency correction through the synthesizer, by steps of $5.12 \cdot 10^{-13}$, where xxxx is a signed 16 bits.

This value is automatically stored in a EEPROM as last frequency correction which is applied after RESET or power-ON operation.

- In track state, the user frequency correction is changed internally by the software for optimum alignment.
- The basic command FCsdddd do the same. See chapter 4.7.

Examples:

C0000<CR> : return to the nominal value (factory setting)

C7FFF<CR> : the actual frequency is increased of 16.7 ppb. 10'000'000.000 Hz become 10'000'000.167 Hz.

C8000<CR> : the actual frequency is decreased of 16.7 ppm. 10'000'000.000 Hz become 9'999'999.833 Hz.

6.4.1 Center frequency read-back

R05<CR>[LF] : read-back high byte of user frequency correction actually in use.

R06<CR>[LF] : read-back low byte of user frequency correction actually in use.

L05<CR>[LF] : read-back high byte of user frequ. corr. in use after RESET or power-ON.

L06<CR>[LF] : read-back low byte of user frequ. corr. in use after RESET or power-ON.

- In track state, the value of all of these registers is subject to change by the software for optimum alignment.

6.4.2 SYNTH out frequency setting

The module integrates a frequency synthesizer.

There is a command to set the SYNTH output frequency :

Txxxxxxxx<CR>[<LF>] : SYNTH OUT frequency setting. Where xxxxxxxx is an unsigned 32 bits in hexa coded ASCII stored in EEPROM.

$$Frequency = \frac{xxxxxxxx}{2^{32}} \cdot 60MHz$$

The SYNTH OUT frequency is changed after RESET or power-ON.

TIMING SERIAL INTERFACE

The module uses the same serial interface to set and control the PPS and timing facilities.

For this purpose, a more complex supervision of the device is introduced.

6.5 Commands of setting & control

The commands are not case sensitive. But they should have the exact length. The termination character is <CR>. An additional <LF> is tolerated and have no effect. Blank characters are not tolerated. Chained commands are tolerated if the total length is not exceeding ~30 characters.

6.5.1 Commands of Timing &Tracking

TRx<CR>[<LF>] : Set tracking mode of PPSINT to PPSREF
 x: tracking mode setting
 0: Track never, Free Run. (0→EEPROM)
 1: Track now.
 2: Track ever. (1→EEPROM)
 3: Track now + ever (1→EEPROM)
 9: Interrogation

Answer: **x<CR><LF>**
 x: Tracking enable at power-up
 0: Not enabling tracking at power-up
 1: Enabling tracking at power-up

Notes:

- The tracking mode setting is kept in EEPROM.
- Whatever from software or from hardware, the Track mode 1 has the priority. The answer takes this situation into account.
- The module needs a few minutes to be in tracking state. During this delay, ST<CR> answers 1.
- The command TRx has no influence on the phase of PPSOUT if the command SY9<CR> answers 0<CR><LF>.
- When track mode is set to 1 by hardware or software, the tracking of PPSINT to PPSEXT starts when General Status goes from 9 to 4.
- This command doesn't give out the actual tracking state. For that, use the command ST<CR>.(answers 2 <CR><LF> when tracking)

Example: **TR3<CR>**, answer: **1<CR><LF>**. Will ever be in tracking mode. If not yet in this mode, start to track PPSREF.

SYx<CR>[<LF>] : Set synchronization PPSOUT to PPSINT mode.
 x: synchronization mode setting
 0: synchronize never (0->EEPROM)
 1: synchronize now
 2: synchronize ever (1->EEPROM)
 3: sync. now + Ever (1->EEPROM)
 9: interrogation

Answer: **x<CR><LF>**
 x: synchronize command status
 0: synchronization mode 0.
 1: synchronization mode 1.

Notes:

- The synchronization mode setting is kept in EEPROM.
- Whatever from software or from hardware, the synchronization mode 1 state has priority. The answer takes this situation into account.
- When sync. mode is set to 1 by hardware or software, the synchronization of PPSOUT to PPSINT happens when General Status goes from 1 to 2.
- This command doesn't give out the actual sync. state. Therefore, use the command ST<CR>.(answer 3 <CR><LF> when synchronized.)

Example: **SY9<CR>**, answer: **1<CR><LF>**. Sync. done when General Status goes from 1 to 2.

DEddddddd<CR>[<LF>] Set the delay of PPSOUT pulse vs PPSINT.

ddddddd: Delay in 133 ns steps.
 0000001: minimum delay.
 7499999: maximum delay .(approx. 1 s)
 0000000: sync. to PPSINT, the same as SY1.
 9999999: interrogation.

Answer: **ddddddd**: Delay in 133 ns steps.
 9999999: Delay information not valid.
 Reset value: 0000000

Notes:

- When going into tracking state, the information delay become no longer valid and the unit will respond 9999999<CR><LF>.
- In tracking state, after a command SY1<CR><LF>, PPSOUT is aligned to PPSINT and the answer is 0000000<CR><LF>.
- In tracking state, after a command DEddddddd<CR><LF>, the PPSOUT is delayed vs PPSINT and the answer is correct.

Example: **DE9999999<CR>**, answer: **0000000<CR><LF>**

PWddddddd<CR>[<LF>] : Set the PPSOUT pulse width.

ddddddd: Pulse width in 133ns steps.
 0000001: minimum pulse.
 7499999: maximum pulse.
 0000000: no pulse.
 9999999: interrogation.

Answer: **ddddddd**: Pulse width in 133 ns steps.
 Factory setting : 0001000 (133 us)

Reset value : Last Value stored in EEPROM

Example: **PW9999999<CR>**, answer: **0001000<CR><LF>**

6.5.2 Commands of timing Set-up

TD<CR>[<LF>] : Send out the time of day

Answer: **hh:mm:ss<CR><LF>**
 hh: Hours mm: Minutes ss: seconds

Notes:

- After reception of this command, the module responds following the rules of the command BTx. This means the answer is not immediate, but can be delayed up to 1 s.

Example: **TD<CR>**, answer: **16:30:48<CR><LF>**

TDhh:mm:ss<CR>[<LF>] : Set the time of day

hh:mm:ss<CR><LF>
 hh: Hours mm: Minutes ss: seconds

Answer: **hh:mm:ss<CR><LF>**
 hh: Hours mm: Minutes ss: seconds

Reset value: 00:00:00

Notes:

- After reception of this command, the module responds following the rules of the command BTx. This means the answer is not immediate, but can be delayed up to 1 s.

Example: **TD13:00:00<CR>**, answer: **13:00:00<CR><LF>**

DT<CR>[<LF>] : Send out the date
 Answer: **yyyy-mm-dd <CR><LF>**
 yyyy: Year mm: Month dd: Day
 Notes:

- After reception of this command, the module responds following the rules of the command BTx. This means the answer is not immediate, but can be delayed up to 1 s.

Example: **DT<CR>**, answer: **2003-12-08<CR><LF>**

- The calendar works from 2000-01-01 to 2099-12-31

DTyyyy-mm-dd<CR>[<LF>] : Set the date
 yyyy-mm-dd<CR><LF>
 yyyy: Year mm: Month dd: Day
 Answer: **yyyy-mm-dd<CR><LF>**
 yyyy: Year mm: Month dd: Day
 Reset value: 2000-01-01

Notes:

- After reception of this command, the module responds following the rules of the command BTx. This means the answer is not immediate, but can be delayed up to 1 s.

Example: **DT2003-12-08<CR>**, answer: **2003-12-08<CR><LF>**

- The calendar works from 2000-01-01 to 2099-12-31

BTx<CR>[<LF>] : Beat every second on the serial port
 x: parameter to beat.
 0: Stop beat.
 1: Beat effective time interval PPSOUT vs PPSREF.
 Answer: **ddddddd<CR><LF>**
 ddddddd: delay in 133 ns steps.
 2: Beat phase comparator value.
 Answer: **sppp<CR><LF>**
 s: +/- sign ppp: phase error, approx. in ns
 3: Beat effective time interval PPSOUT vs PPSREF + phase comparator value.
 Answer: **ddddddd sppp<CR><LF>**
 ddddddd: delay in 133 ns steps.
 s: +/- sign ppp: phase error, approx. in ns
 4: Beat time of day.
 Answer: **hh:mm:ss<CR><LF>**
 hh: Hours mm: Minutes ss: Seconds
 5: Beat general status.
 Answer: **x<CR><LF>**
 x: general status. (See command STx)
 6: Beat <CR><LF>.
 7: Beat Date, Time, Status
 Answer: **yyyy-mm-dd hh:mm:ss x <CR><LF>**

yyyy : Year mm: Month dd: Day

Notes:

- The answer is delayed a few ms after the PPSINT pulse. This delay can vary a little.
- When beating time interval PPSOUT vs PPSREF, the answer is 9999999<CR><LF> if no pulse is found.
- This can happen when the module is going to tracking state, General Status = 1.
- Regarding the phase comparator, no precision or linearity can be expected. This comparator just increases the resolution of the phase used by the tracking algorithm.

Example: **BT5<CR>**, answer **9<CR><LF> 9<CR><LF> ... 4<CR><LF> 4<CR><LF>**. This means the quartz oscillator is just locked to the Rubidium line.

6.5.3 Commands of control

FCsdddd<CR>[<LF>] : Set user frequency correction
 sdddd: frequency correction in $5.12 \cdot 10^{-13}$ step.
 +00000: no correction.
 +32767: highest pull-up, +16.7 ppb.
 -32768: lowest pull-down, -16.7 ppb.
 +99999: interrogation.

Answer: **sdddd<CR><LF>**
 sdddd: frequency correction actually in use.

Factory setting: +00000

Reset value: Last value stored in EEPROM.
 In free-run state, the last value stored with the commands FCsdddd or Cxxxx.
 In track state, the last value stored automatically or with the command FSx.

Notes:

- In track state the user frequency correction is changed internally by the software for optimum alignment.
- This command should never be used in track state. (Except FC+99999).

FSx<CR>[<LF>] : Set frequency value.
 x: parameter.
 0: no saving. (0→EEPROM)
 1: save integral part of tracking correction in EEPROM every 24 hours. (1→EEPROM)
 2: save integral part of tracking correction in EEPROM now.
 3: save user frequency in EEPROM now.
 9: interrogation.

Answer: **x: frequency save mode as written in EEPROM**
 0: no saving.
 1: save integral part of tracking correction in EEPROM every 24 hours.

Factory setting: 1

Reset value: Last value stored in EEPROM.

Notes:

- In frequency save mode 1, the saving is only done if the module is in track state. (General Status 2 or 3).
- If the PPSREF is missing or rejected, the 24 hours period is increased.

Example: **FS9<CR>**, answer **1<CR><LF>**.

TWddd<CR>[<LF>] : Set tracking window. Set the window in which time interval PPSINT vs PPSREF should stay. Stored in EEPROM.

ddd: half tracking window, from 1 to 255 steps of 133 ns.

999: interrogation

Answer: **ddd: half tracking window in 133 ns steps.**

Factory setting: 015 (~± 2µs)
 Reset value: Last value stored in EEPROM.
 Notes:

- If the time interval PPSINT vs PPSREF becomes bigger than the tracking window, the tracking stop.

Example: **TW020<CR>**, answer **020<CR><LF>**.

AWddd<CR>[<LF>] : Set alarm window.

An alarm is raised up if time interval PPSINT vs PPSREF become bigger than this value. Stored in EEPROM.

ddd: half alarm window, from 1 to 255 steps of 133 ns.

999: interrogation

Answer: **ddd**: half alarm window in 133 ns steps.

Factory setting: 015 (~± 2µs)

Reset value: Last value stored in EEPROM.

Notes:

- This command is limited to track state.
- The General Status becomes 5. (PPSREF unstable).
- The alarm window cannot be bigger than the tracking window. This window may be reduced by the command TWddd.

Example: **AW999<CR>**, answer **015<CR><LF>**.

Warning: This command can strongly degrade the initialization and current value of some parameters. Modifications of alarm window should be avoided.

TCdddddd<CR>[<LF>] Set tracking loop time constant.

dddddd: time constant in seconds.

000000: change to auto selection mode.

001000: minimum value, 1000 s.

999999: maximum value, 999999 s.

000099: interrogation.

Answer: **dddddd**: last time constant selected, in seconds.

Factory setting: 000000

Reset value: 000000

Notes:

- In auto selection mode, the time constant is automatically adapted to the PPSREF noise.
- In auto selection mode, if the time interval PPSREF vs PPSINT goes out of the phase comparator range, approx. +/-500 ns, the time constant is set to 1000 s.

Example: **TC000099<CR>**, answer **000000<CR><LF>**

Warning: This command can strongly degrade the initialization and current value of some parameters. Modifications of loop time constant should be avoided.

MCsxx[cc..c]<CR>[<LF>] Set module customization

s : action to do

L : Load message

S : Set message (user message only)

B : Load the behavior at the start of the clock

A : Activate a message at the start of the clock

C : Cancel a message at the start of the clock

H : Load Help message

T : Load data Type

xx : message number, from 00 to FF

Answer: cc...c : up to 24 ACSII character, to set the user message
 cc...c : message, answer to MCLxx or to MCHxx
 or
 0/1 : Behavior of a message at the start of the clock, answer to MCBxx
 or
 xy : data Type, answer to MCTxx
 x=0 in RAM, x=1 in eeprom, x=2 in Flash
 y=0 byte, y=1 sbyte, y=2 word, y=3 sword, y=4 dword, y=5 sdword,
 y=6 lword, y=7 slword, y=8 string ASCII, y=9 string binary

Pos.	Active.(Def)	Parameter(Default)	Comment
00	1	TNTSRO-100/00/1.07	Factory welcome message
01	0	Free for user message	User welcome message
02	--	05	GPS configuration delay
03	--	03	GPS configuration interval
07	--	01	Error message send
10	0	@ @En..	Time RAIM setup
11	0	@ @At..	Position hold, site survey
20	0	@ @Gd..	Position control message
21	0	@ @Gc..	PPS control message
22	0	@ @Ge..	Time RAIM algorithm
23	0	@ @Gc..	Time RAIM alarm message

- Pos. \$01 Message can be modified by the user and is stored in EEPROM.
- Pos. \$02 and \$03 Parameters are the delay, resp. the interval of time in second at witch the GPS configuration messages are sent out at Start up.
- Pos. \$10-\$11 are GPS messages to configure an Oncore, Jupiter-T or Jupiter-Pico receiver for timing application.
- Pos. \$20-\$23 are GPS messages to configure an M12+ receiver for timing application.
- This command was renewed and extend since Version 1.07.
- This command is best used with the free program iSyncMgr.exe, since Version 1.07.

Example : MCS01An user message <CR>, MCA01 <CR> send the following message after start : An user message <CR><LF>

Warning: This command can strongly degrade the initialization and current value of some parameters. Modifications of mode customization should be avoided.

COsddd<CR>[<LF>] : fine phase comparator offset
 sddd: fine phase offset in approx. 1 ns steps
 +000: no offset
 +127: highest offset
 -128: lowest offset
 +999: interrogation.

Answer: **sddd<CR><LF>**
 sddd: phase offset actually in use.
 Factory setting: +000
 Reset value: Last value stored in EEPROM.

Notes:
 ▪ This command stores the value in EEPROM

VS<CR>[<LF>] : view the Sigma of PPSRef. In tracking Status 2 or 3.

Answer: **ddd.d<CR><LF>**
 ddd.d: Sigma in ns

VT<CR>[<LF>] : view the time constant of the tracking loop.

Answer: **dddddd<CR><LF>**
dddddd: Time constant in s

RA sddd<CR>[<LF>] : raw phase adjust
sddd: raw phase adjust in 133 ns steps
+127: highest adjust
-128: lowest adjust
+999: interrogation, ever +000

Answer: **sddd<CR><LF>**
sddd: raw phase adjust asked in 133 ns steps

Notes:

- This command offset the PPSINT by itself
- This command can be useful for some timing applications to bring the fine comparator into an area where it works
- This command don't move the PPSOUT pulse and don't modify the reading of BT1 or BT3
- This command have an influence on the delay value, command DE ddddddd, as the delay is in fact referenced to PPSINT

Example : **DE9999999 <CR>**, answer **0000000<CR><LF>** . Now we do **RA+003**, answer **+003 <CR><LF>**. And then we do **DE9999999<CR>**, the answer is **7499997<CR><LF>**

RAQUIK<CR>[<LF>] : this command quickly align PPSINT to PPSREF

Answer: **+000<CR><LF>**

Warning:

- This command can strongly degrade the initialisation and current value of some parameters
- This command can be useful when the device is used as timing machine and there is no time so that "TR1" takes effect
- This command is given to liking well but without guarantee none regarding the integrity and good continuation of the program. It is to the user to make sure that the parameters are initialised correctly after the use of this command

7. Reference module GPS Antenna Kit

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 GPS PicoReference user manual, section "Safe GPS Antenna installation".

7.1 Optional Rooftop GPS Antenna (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

7.2 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').

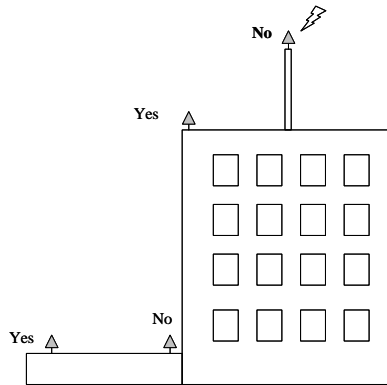
For the installation, please refer to our AN "Custom GPS Antenna Installation".

8. Safe GPS Antenna Installation

Below is described where and how to install safely a GPS antenna.

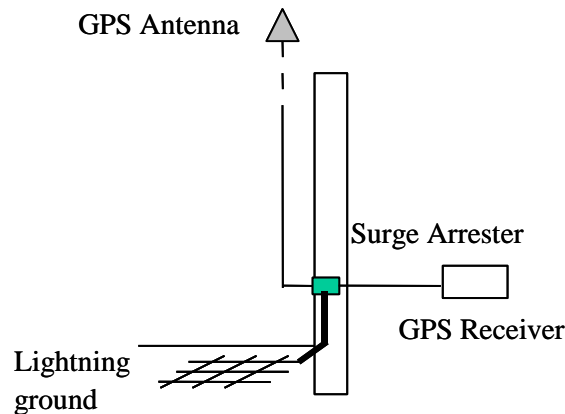
Where to install the GPS Antenna

The antenna must be located on a place with a direct view to the sky. Usually the best place is on the roof with no important masks due to other buildings for instance. However, to avoid lightning, it is important that the antenna is not the highest point in the surrounding.



Lightning protection

A lightning surge arrester must be installed at the entrance of the building. It must be grounded to a lightning ground, that is separated to the instrument ground. Please ask for your local regulation about this question. The surge arrester will not protect the GPS receiver against high voltage destruction, it is for human safety.



9. MEASUREMENT MODULE DESCRIPTION

The measurement module measures the time difference between the build-in 10 MHz reference or an external reference and a DUT with a frequency range between 1 to 30 MHz to plot the Allan deviation.

A frequency measurement is used for programming the DDS which divides the device frequency around 1 KHz by using two mixers. As the block-diagram shows, the whole system is based on a heterodyne architecture with a double frequency conversion. After that, the system measures several phase intervals to obtain more precise frequency measurement. With this new frequency value, the DDS are re-programmed to have a frequency beat the closest to 1KHz. The Allan deviation is plotted by measuring the phase difference between the PPS reference and the frequency beat of 1KHz. This way, the phase intervals are sampled to obtain the stability of the device under test.

The 26 bits time interval counter is controlled through the COM interface such as for the programming of the two DDS.

The reference and the DUT are connected to the system with two BNC, and three outputs are available for the user through three BNC connectors:

- 1 PPS ref.
- IF of 1 KHz with a BW of several 100KHz.
- IF of 1 KHz with a BW of only 1Hz / FDUT when the DDS are not programmed.

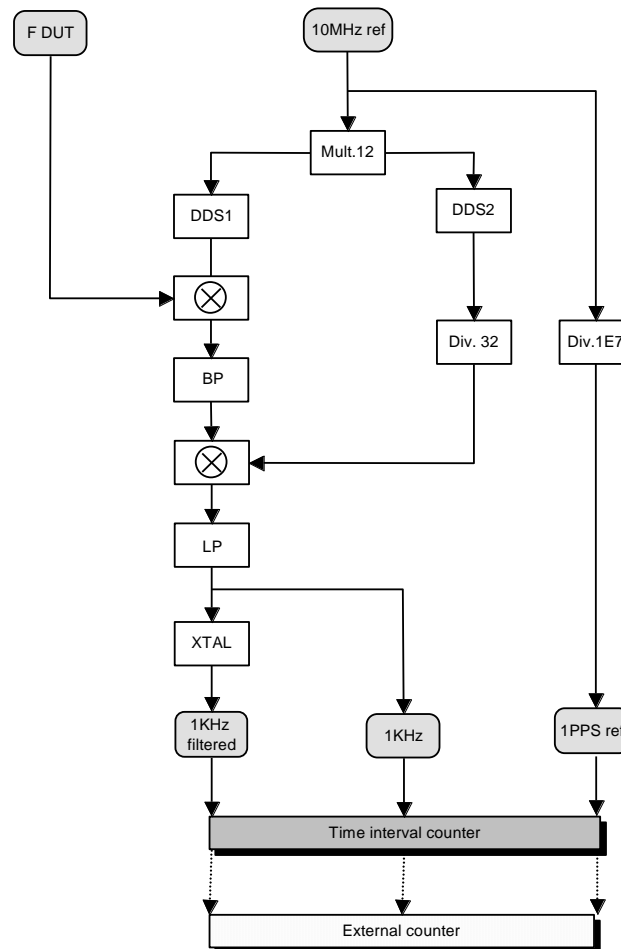


Figure 8 : Measurement module block diagram

In addition, the Measurement module has a clock recovery circuit for both E1 or T1 line extracting the clock rate of respectively 2048KHz and 1544KHz. This additional features allows to characterize the behavior in term of stability of a E1 or T1 line. The circuit is based on a clock recovery chip with a high quality factor LC tank tuned to the nominal line rate.

10. MEASUREMENT MODULE OPERATION

GPS-PicoReference is designed for ease of use, it configures itself the system and collects data.

The measurement module called hereafter PicoTime measures the frequency of the DUT to program a first time the internal DDS. Then, the system measures several phase differences between the 1PPS reference and the 1KHz non-filtered to obtain a fine measurement of the DUT frequency. Finally, the DDS are re-programmed with the precise frequency and the system waits for the locking of the quartz crystal filter in the case of the selection of the filtered mode. The Allan deviation plot, the Phase difference plot or the Frequency difference plot are displayed in real time and the data are stored into a file every new sample.

To obtain a complete analysis, post processing, Spectratime SA suggests to use Stable32 from Hamilton technical services. PicoTime writes a file with the extension “ *.DAT ” which contains the frequency data or phase data and is completely compatible with Stable 32.

The nature and the stability of the DUT define which 10MHz reference is able to be used, taking into account that the reference has to offer a better characteristic for the range of measurement. The frequency range of the DUT is any values between 1MHz to 30MHz inclusively.

The resolution of the system increases with the frequency of the device under test, at 1s the following resolutions are obtained in filtered mode.

F_{DUT}	Resolution in filtered mode
1MHz	2E-11
10MHz	2E-12
30MHz	< 2E-12

And in non-filtered mode following resolutions are obtained.

F_{DUT}	Resolution in non-filtered mode
1MHz	1E-10
10MHz	1E-11
30MHz	< 1E-11

10.1 Measurement module Connections

After having installed the PicoTime software (refer to section 3.3.2.3), proceed to the following connections :

- 1) Connect a COM cable between J11 and one COM available of the computer.
- 2) Interconnect J13 and J18 with a coaxial cable to provide 10MHz reference to the measurement module. If an external reference want to be used, connect it to J13.
- 3) Connect the device under test signal to J17.
 If the signal under test is coming from an E1 line, connect it to J21 and interconnect J22 with J17.
 If the signal under test is coming from an T1 line, connect it to J23 and interconnect J24 with J17.

Spectratime recommends the users to warm up the unit **several hours** before starting any measurements.

To start a measurement, click on **PicoTime** from the start menu. The PicoTime application appears on the screen.

The following figure shows the software hierarchy.

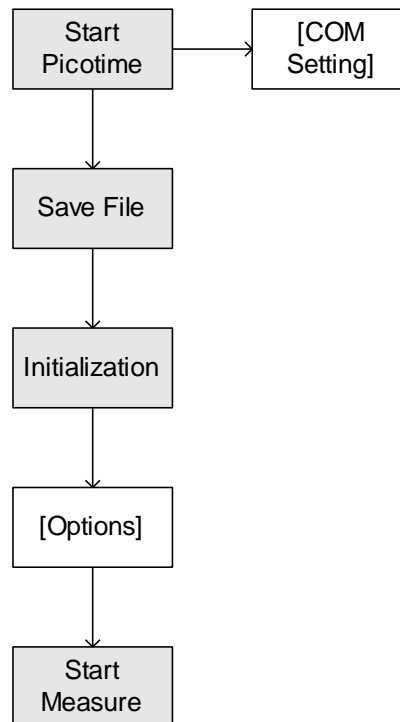


Fig. 9 : Software hierarchy

The easy to use software has been designed to achieve a very easy and fast measurement. COM number and several option settings are kept into memory to avoid repetitive setting and checking.

10.2 Definition of the menus and parameters

Figure 4 shows the display when the user runs Picotime from the start menu of Windows.

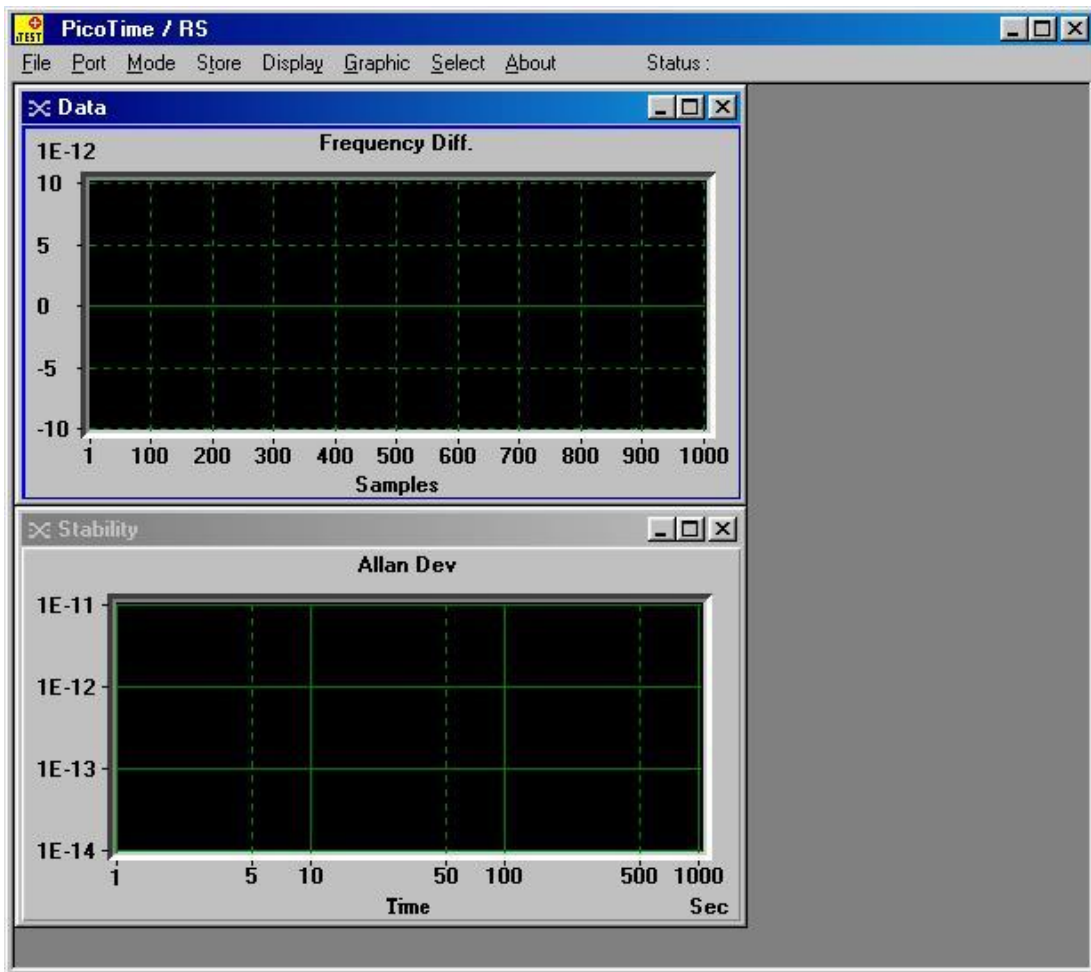


Fig. 10 : Starting display

The screen is composed of a main window which contains several menus and a status bar. Two graphic windows are loaded, one for the frequency or phase data and one for the computation of the Allan deviation.

10.2.1 File

The menu File is the main menu of PicoTime. Before any action, the COM interface has to be set once, refer to section 4.1.2.

The sub-menu **Save File as** is used to save the data into a selected file. A message box “Save file as” appears and allows the user to save a file with the extension *.DAT in which all the data are saved to be post processed for a complete stability analysis with a software such as Stable32.

Only after the Save action, the sub menu Initialization becomes enabled.

The file path, date, time, DUT frequency, tau, Mode and Data type are inserted in the header of the file to have all the parameters for the post processing analysis. The measurement data are saved after every new sample.

C:\Mes Documents\Demo.DAT	Date 3/20/03	Time 12:38:15 PM
DUT Frequency : 10000000	Tau : 1000.0 ms	
Mode : Filtered		
Data : Frequency Data		

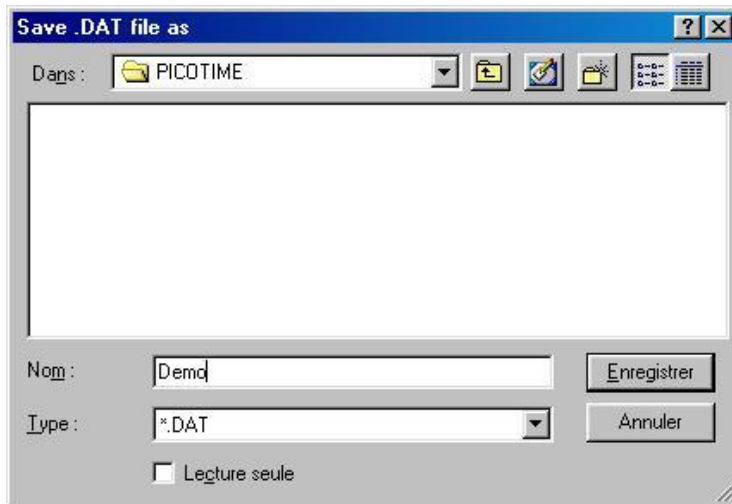


Fig. 11 : Save file as

The sub-menu **Initialization** becomes enabled only if the user has saved the measurement file. This function initializes PicoTime.

First, the frequency of the DUT is measured to program the internal DDS to achieve a frequency beat around 1KHz. If the DUT frequency is not in the range of 1MHz to 30MHz the status message “*Frequency out of range*” appears. After that, several phase points are measured to obtain a fine frequency measurement and finally the DDS are re-programmed with the fine DUT frequency which is displayed in a small window

The user has to wait until the locking of the quartz filter if the Filtered mode is selected. It needs several seconds. When the crystal filter is locked, the red led is switched off and the green one becomes lit. The status bar indicates : “XTAL filter locked”.

If the Non-Filtered mode is selected, after Initialization, the status bar indicates : “Ready to start”.

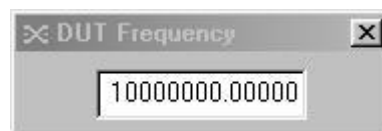
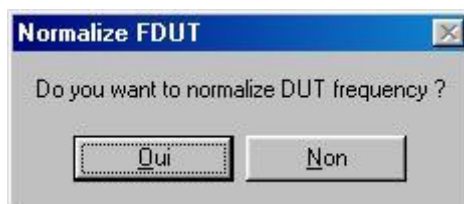


Fig. 12 : DUT Frequency

A message box automatically appears to inform the user that the **nominal frequency** could be **normalized**.



Yes : Refer to section 4.1.7, Normalize DUT Frequency.

No : The nominal frequency is set to the DUT frequency measured by PicoTime (Textbox figure 6).

Sub menu **Start Measure** starts the measurement with all the parameters entered in the other menus (refer to followings sections). The status bar indicates “Running...”

Stop Measure sub-menu stops the measurement without resetting the internal DDS. This way, the options could be changed and the measurement could restart immediately. The status bar indicates “Stop”.

Quit closes the application.

10.2.2 Port

Previously to start the application, the user has to connect the serial connector to one available COM interface on the computer (**COM1** or **COM2** or **COM3** or **COM4**). This COM interface is set by selecting the appropriate COM number in the Port menu. The operation is only required once because the COM selection is kept into memory and the same parameters will be loaded when the user restart the application.

10.2.3 Mode

Two modes are available, **Filtered** or **Non-Filtered**. In Filtered mode, the maximum relative frequency deviation of the DUT has to be $<1 \times 10^{-9}$ and in Non Filtered mode $<1 \times 10^{-7}$. In Filtered mode, the user has to wait the locking of the quartz crystal oscillator. The mode selection also remain in memory when the user exit the application.

10.2.4 Store

The menu allows to store the **Frequency data** or **Phase data** which are saved into a measurement file. The selection of the data type also remains in memory when the user exits the application.

10.2.5 Display

This menu permits to select the graphical display of the **Frequency difference data** or the **phase difference data** in real time. The nominal setting is set to Frequency difference data.

10.2.6 Graphic

When **Autoscale** sub-menu is ticked, the software performs an automatic scaling of the two graphics.

On the other hand, when **Limits** is ticked, a window appears allowing the edition of the global limits of the graphics. The limits are set when the user clicks on Start Measure from the File menu. The Limits value remain in memory after the exit of the application.

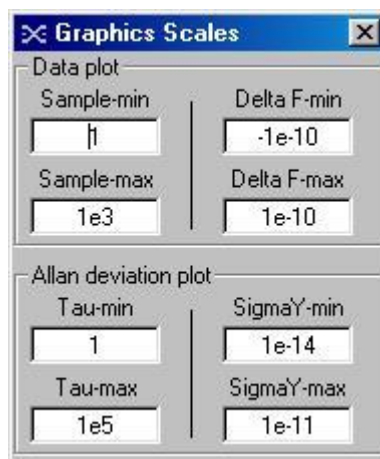


Fig. 13 : Graphics scales

The default setting is set to automatic scaling of the graphics.

Title sub-menu allows every time the user to edit the Titles of the graphics. This command is useful when printing the graphics.

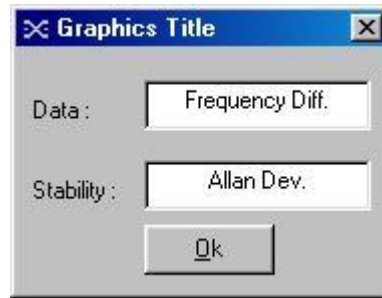


Fig. 14 : Title edition

Print allows to print the **Data plot** or the **Stability plot**. A printer dialog box is loaded to select the appropriate printer, the number of copies and the orientation. For best results, a **landscape** orientation is recommended.

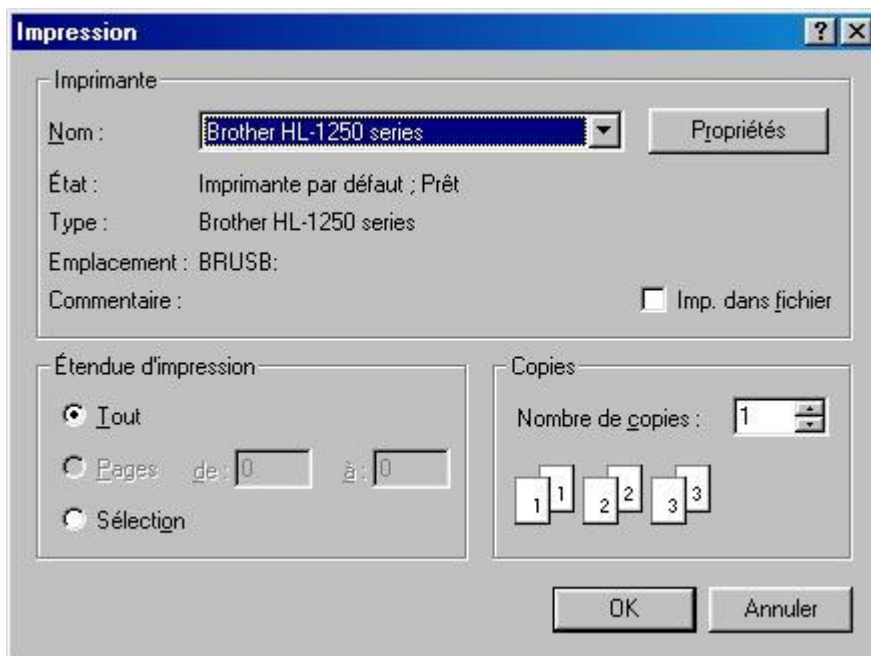


Fig. 15 : Printer dialog box

To save the graphics as a Bitmap format (*.BMP), use the sub-menu **Save Picture** and select the **Data plot** or **Stability plot**.

10.2.7 Select

Sampling rate :

The sampling rate could be set with the sub-menu **Tau**. A list box is loaded allowing to select a Tau value.



Fig. 16 : Tau select

The sampling rate needs to be selected according to the kind of stability analysis. In fact, PicoTime has a limitation of the number of samples (999999). For this reason, if the user wants a very long term stability analysis, a relative high sampling rate has to be chosen. On the other hand, a very short term stability analysis is only possible with a short sampling rate. Remember that the sampling rate corresponds to the minimum *Tau* of the Allan deviation. Another point is that the time process to plot the data and the Allan deviation is proportional to the number of samples and it is never useful to work with files of several MBytes.

The default sampling rate is 1 second.

The possible sampling rates are the following:

Sampling rate (in second)
1
2
3
5
10
20
30
50
100
200
300

Normalize DUT Frequency :

The frequency beat obtained by the programming of the DDS is never exactly 1KHz (resolution of the DDS) For this reason, the phase data will be a slope (negative or positive) following the value of the frequency beat (1KHz ±ε).

The user has the possibility to enter a nominal DUT Frequency by clicking on the **Normalize DUT Frequency** menu. A window appears which is editable with a desired nominal frequency of the DUT. This way, the phase and frequency data during time will be normalized to the nominal frequency selected.



Fig. 17 : Nominal DUT Frequency

According to the reference used, the exact frequency of the DUT is the addition of the nominal frequency set and the real time relative frequency difference measured.

$$F_{exact} = F_{nominal} + F_{realTime}$$

10.2.8 About

To check the version of the PicoTime software, click on the menu **About**, the version is notified in the header of the window. The following window appears. The latest version can be downloaded – free of charge from Spectratime web-site: <http://www.spectratime.com>.



Fig. 18 : PicoTime software Version

All the setting windows could be closed by clicking on the cross in the up right corner of the corresponding window. This action does not change the setting. To disable the setting or the options, the respective menu has to be re-clicked (withdrawal of the tick).

The following figure shows all the parameters or options that could be implemented.

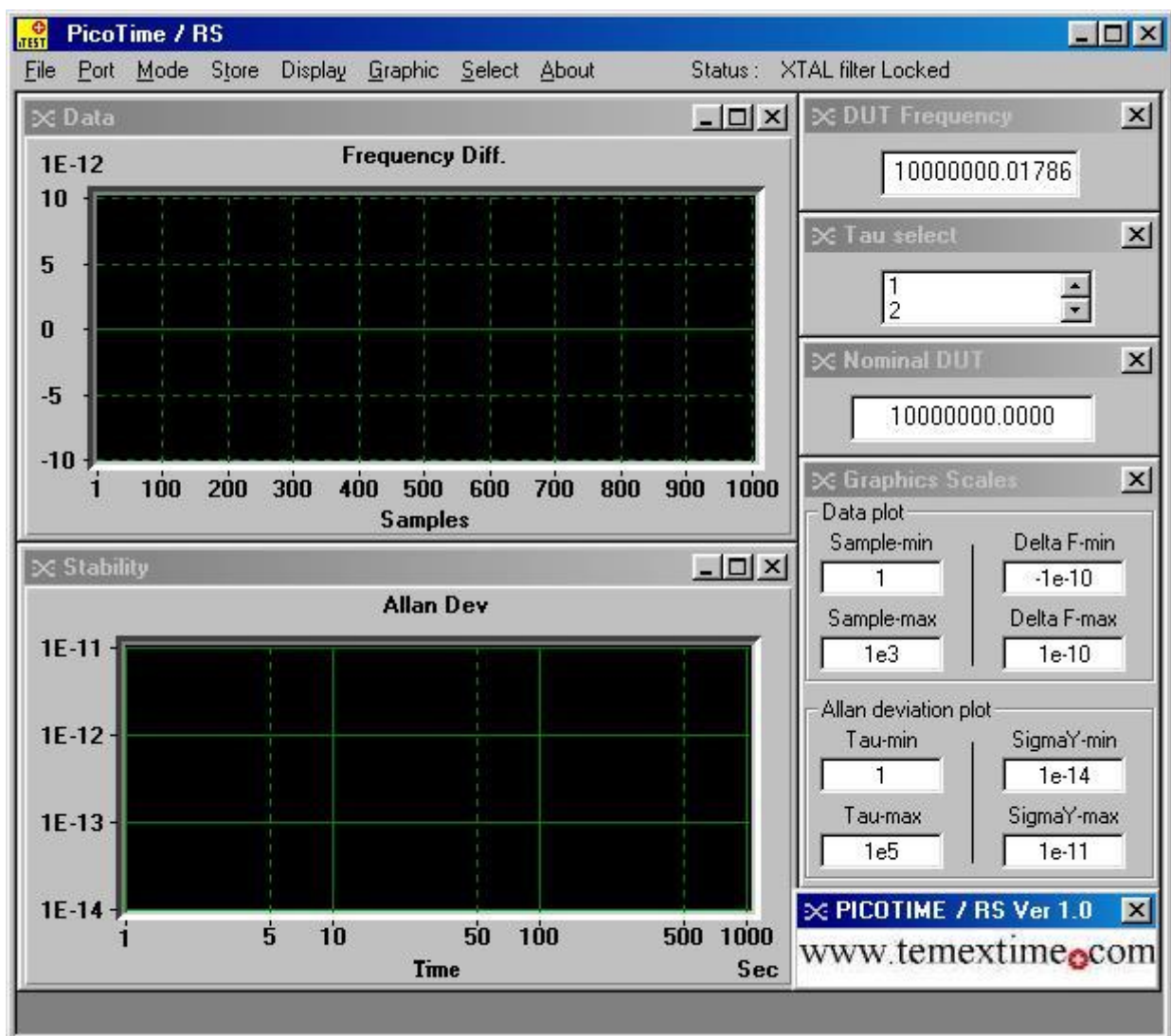


Fig. 19 : Graphics and parameters windows

10.3 During Measurement

After the **Start measure** command, the menus are disabled, the parameters are set and can not be changed without stopping the measurement. The status bar displays : "Running...".

10.3.1 Data plot

Following the setting of the display menu, the frequency or the phase difference is plotted in real time in the first graphic window. The graphic is updated every new sample.

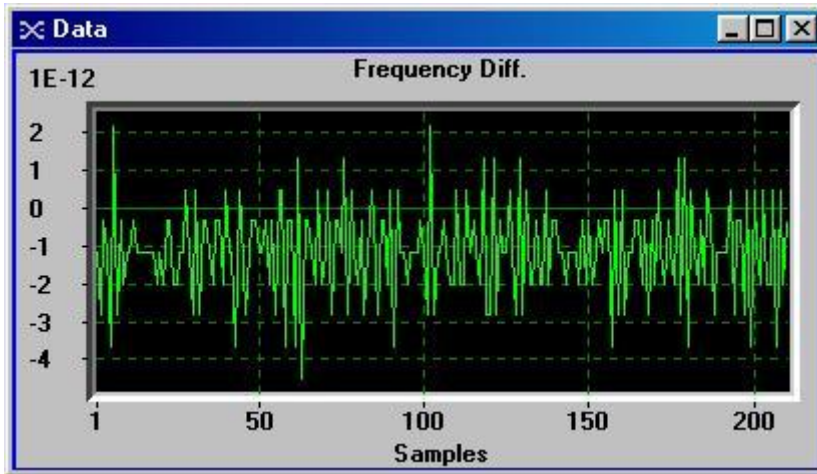


Fig. 20 : Frequency difference plot

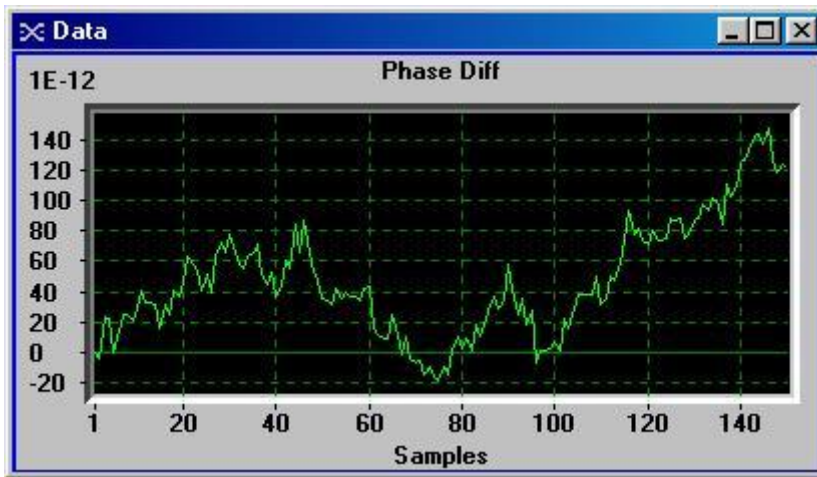


Fig. 21 : Phase difference plot

10.3.2 Stability plot

The Standard Allan Deviation is plotted in the second graphic window. See section 4.2.4 for the update of the graphic.

The Allan Deviation is displayed using Octave Tau increments.

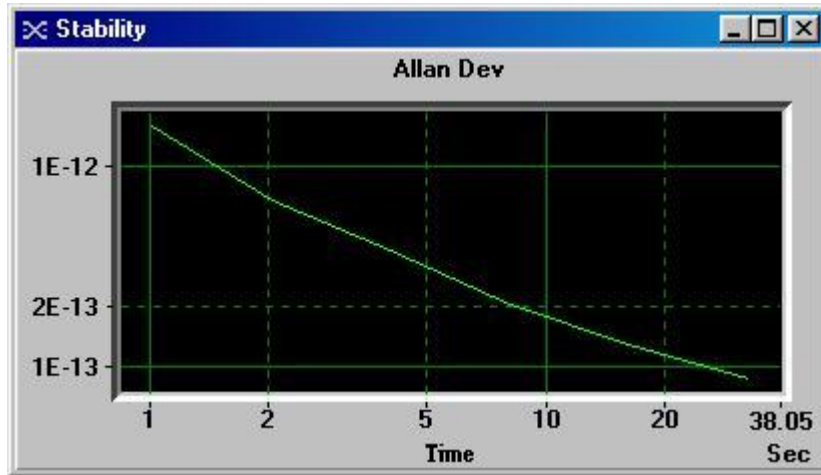


Fig. 22 : Standard Allan Deviation plot

10.3.3 Maximum number of samples

The maximum number of samples is restricted to 999999. For this reason, the sampling rate has to be selected accordingly to the kind of desired analysis.

After 999999 samples, the measurement are automatically stopped and the following message box appears to advise the user.



Fig. 23 : Sample 999999

10.3.4 Graphics update

The Data plot is updated every new sample. The Allan Deviation Plot is updated every 10 new samples for a sampling rate lower than 10 seconds and every 3 new samples for a sampling rate equal or higher than 10 seconds.

Warning

When 8192 samples have been available for calculating an Allan deviation point, this point will never be re-updated. The reason is to not use all the computer resources when calculating the Allan Deviation with a large number of samples.

Example:

Tau = 1 second The first Allan dev. point will be at 1 second.

- The point at 1 second will be updated until 8192 samples, after the 8192nd sample, this point will not be updated.
- The point at 2 seconds will be updated until 16384 samples, after the 16384th sample, this point will not be updated.
- The point at 4 seconds will be updated until 32768 samples, after the 32768th sample, this point will not be updated.
- So on

The complete analysis could be done by using a post processing software like Stable 32 which is available in option.

Warning

During measurement, do not disturb PicoTime and cables must not be touched !

10.3.5 Graphics user interaction

Graphic windows offer several user interface commands, which help the user to navigate through a plot. The table below lists the default mapping of keyboard and mouse commands for several actions.

Please note, that the control needs to have the input focus (highlighted chart border) by clicking on the respective graphic window before it can accept any keystrokes.

c	Tab Left/right arrow key Shift+left/right arrow key f	Cursor on / off Second cursor / toggle cursors Move cursor Fast move cursor Cursors floating / locked on curve
Ctrl+arrow key Ctrl+shift+arrow key		Scroll and pan Fast scroll and pan
Ctrl+left mouse button Ctrl+left mouse button up Left mouse button up		Start mouse zoom Zoom Abort zoom operation
o	Not applicable in Autoscale mode	Original scale
t		Zoom out one step
z	Arrow key Alt+arrow key Enter Esc	Start kbd zoom Move zoom rectangle Size zoom rectangle Zoom Abort zoom operation

10.4 THEORY

10.4.1 The Allan Deviation

The most common time domain stability measure is the Allan variance (AVAR), $\pm\sigma_y^2(\tau)$, which gives a value for the fractional frequency fluctuations as a function of averaging time, τ .

It is defined as:

$$\sigma_y^2(\tau) = \frac{1}{2(M-1)} \sum_{i=1}^{M-1} [y_{i+1} - y_i]^2$$

Where $y(i)$ is the i th of M fractional frequency values averaged over the measurement interval τ .

In terms of phase data, the Allan variance may be calculated as:

$$\sigma_y^2(\tau) = \frac{1}{2(N-2)\tau^2} \sum_{i=1}^{N-2} [x_{i+2} - 2x_{i+1} + x_i]^2$$

Where $x(i)$ is the i th of the $N=M+1$ phase values spaced by the measurement interval τ .

The result is usually expressed as the square root of the Allan variance, this will be the Allan deviation $\sigma_y(\tau)$.

10.4.2 Confidence Interval

There is several different methods for setting the confidence intervals and errors bars in its stability analysis and plotting functions. The confidence interval for an Allan variance estimate depends not only on the Allan variance type (normal, overlapping, modified, or time) and nominal value, and on the averaging factor and number of data points, but also on the statistical confidence factor desired and the type of noise.

The simplest confidence interval approximation, with no consideration of the noise type, sets the $\pm 1\sigma$ (68%) error bars at $\pm\sigma_y(\tau)/\sqrt{N}$, where N is the number of frequency data points used to calculate the Allan deviation.

Picotime does not display the confidence interval. Stable 32 is more appropriate to obtain such results.

10.5 SYSTEM TESTS

To measure the system noise, the 10MHz reference (J18) is used. It signal is split in two using a power splitter and is applied to the reference (J13) input and to the F_{DUT} input (J17). This way, the noise of the reference and device under test are cancelled and only the noise of the PicoTime unit is measured.

The intrinsic stability of the system is characterized by a slope in approximately τ^{-1} with a stability at 1 second for 10MHz frequency device of $\sigma_y(1) \cong 1E^{-12}$.

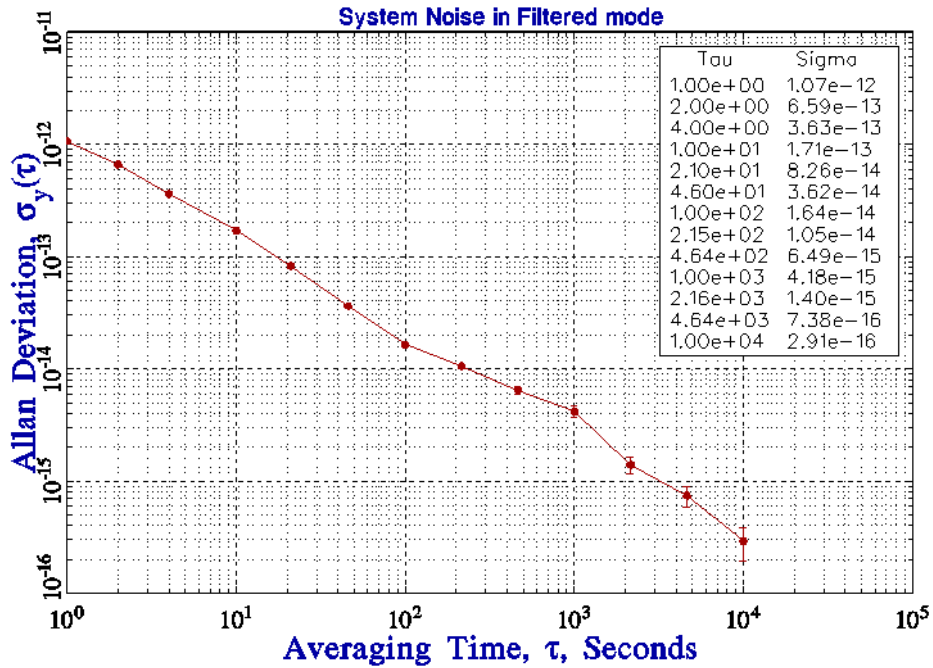


Fig. 24 : System noise 1

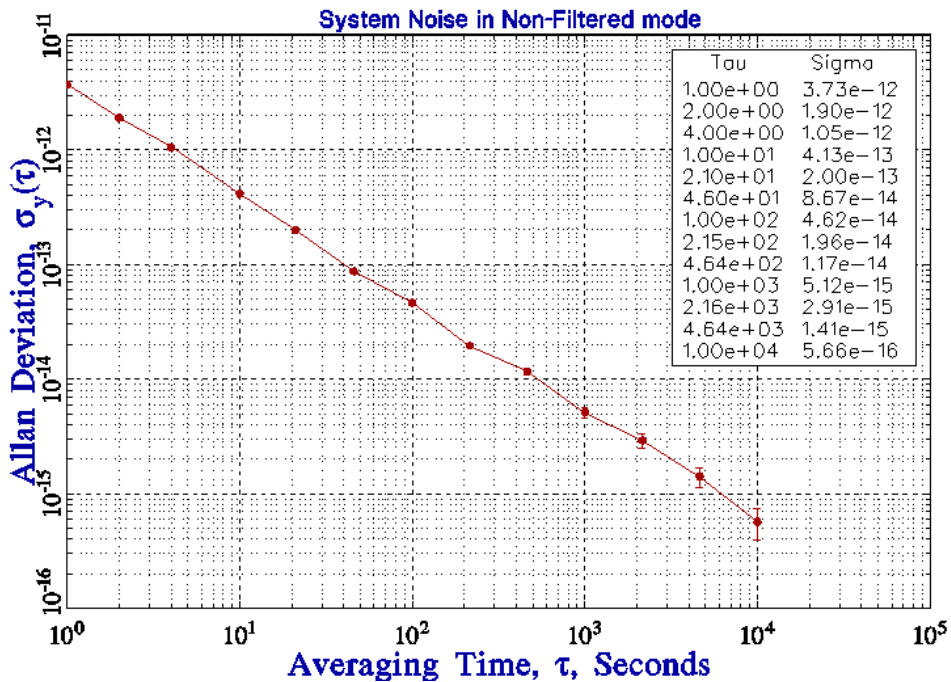


Fig. 25 : System noise 2

10.6 TROUBLE SHOOTING

Perform all of the following procedures before returning the unit for service. If the unit still appears to have a problem, then call Spectratime SA and request technical support. Have the serial number of your unit ready to give to a technical representative.

Note: This instrument does not require periodic calibration.

Check with power turned off

- 1) *Ensure the power source is turned off.*
- 2) *Check for visible damage in the unit, cables, plugs and connectors.*
- 3) *Ensure that all plugs and connectors are correctly installed and fastened.*
- 4) *Check to determine if any input power circuit breakers have been tripped.*

Do not forget to check the signal level of the DUT and the 10MHz reference.

Check with power on

- 5) *Connect the power supply. Check that the red LED or green LED on the unit is lit.*
- 6) *Start PicoTime software and be careful about trouble shooting messages.*

- **Frequency out of range**

The frequency of the reference must be 10MHz inclusively. On the other hand the DUT frequency must be in the range of 1MHz to 30MHz. If the DUT frequency exceeds this range, the following message will appear:

Frequency out of range

- **Wait the locking**

The output quartz filter needs several seconds to be locked. The green LED in the front panel is lit when the filter is locked. On the other hand the red LED is lit when the filter is not locked.

During the period of locking the following message will appear:

XTAL filter unlocked, wait...

If the filter never locked, try to exit and restart the initialization. If the lock indicator do not become green, start a Non-Filtered measurement to check if the relative DUT frequency deviation is greater than $<1 \times 10^{-9}$

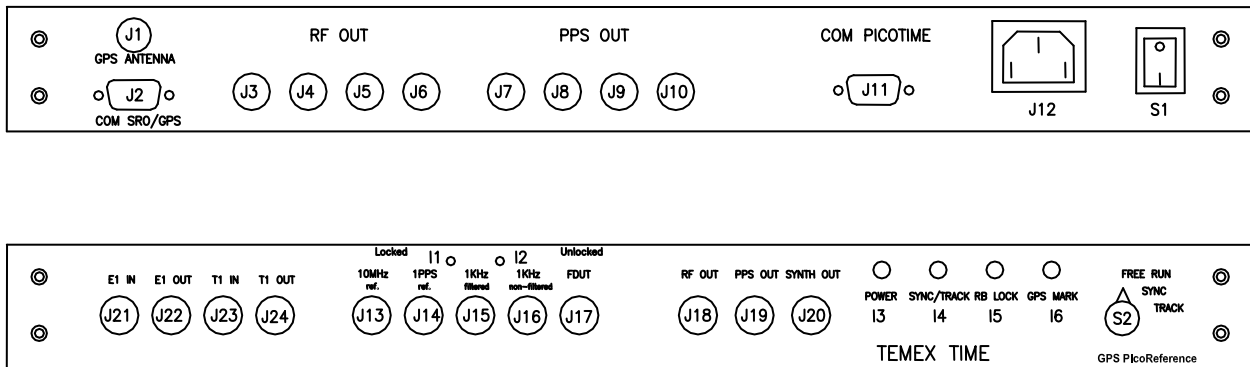
- **Sample 999999**

When the number of sample is 999999, a message box appears and the measurement is stopped

- **Printer failed**

If the Print menu is clicked and a printer is either not connected or not turned on, then a dialog box will appear on the screen. Check the printer and click CANCEL to close the dialog box.

11. GPS-PicoReference INTERFACES



11.1 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	-

11.2 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	-

12. GLOSSARY

Adobe Acrobat Reader	A software program that enables people to read and print files saved in the PDF format.
Allan Deviation	Square root of Allan Variance: It indicates the typical deviation from one measurement to the next.
DDS	Direct Digital Synthesizer
DUT	Device Under Test
FSMS	Frequency Stability Measurement System
IF	Intermediate Frequency
BP	Band Pass filter
LP	Low Pass filter
XTAL	Quartz crystal
SRO	Synchronized Rubidium Oscillator
.PDF	Portable Document Format, file extension to be used by Adobe Acrobat Reader.
Stable32	Stability analysis software