

September 30, 2019

Smart, low-Cost & high-Performance GPS Rubidium Reference Source

GPSReference-2000

Smart GPS/SRO Reference Source
SmarTiming+®1ns-Resolution Disciplining Technology Inside



APPLICATIONS

Synchronization | Timing | Reference/Test Source | Time/Frequency Source

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1. Introduction

The GPSReference-2000 has been specifically designed for cross industry applications, including telecom and calibration, requiring extremely stable and precise timing or frequency source.

The GPSReference-2000 integrates a GPS receiver, a smart GPS-disciplined SRO-100 Rubidium clock, and distributes multiple output signals, either phase or frequency aligned depending on the operating modes.

2. Definitions

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

| Words | Definitions |
|-------------------|---|
| GPSReference-2000 | Unit or product |
| Unit | GPSReference-2000 |
| System | GPSReference-2000 and its integrated modules |
| Rb | Rubidium |
| Rubidium clock | Refers to the smart SRO model |
| Rubidium | Rubidium clock |
| SRO | Rubidium clock, model SRO-100 |
| 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, please immediately contact us.

Unit Supplies

- 1x GPSReference-2000 unit
- 1x GPS patch antenna with 5 meters (16.4') cable with standard option,
 Note: For optional Rooftop GPS Antenna (Ordering 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
- Cables SUB-D male/female for PC serial COM
- 1x Power cable
- 2x 19" rack mountable ears or tabletop feet
- 1x Operating Manual + Specifications

3.2 Safety!



- Use proper ESD precautions
- Ensure that all cables are properly connected

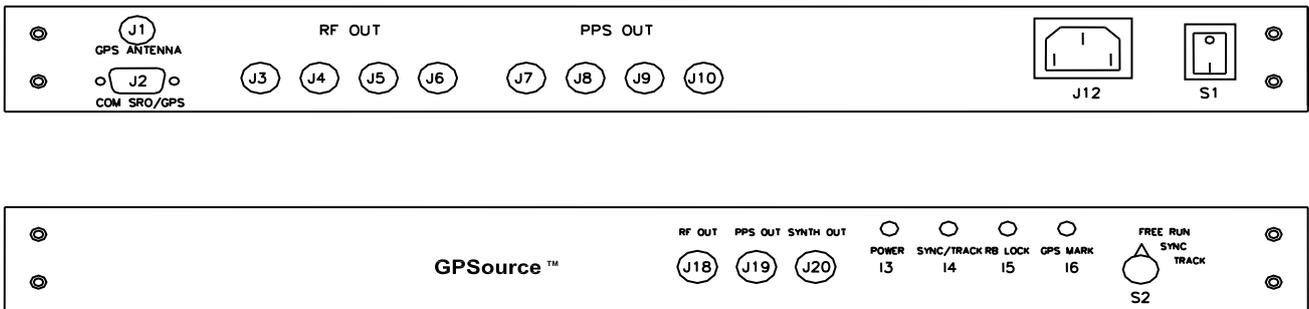
- The equipment contains small quantities of rubidium metal hermetically sealed inside the glass lamp and cell assemblies, hence, any dangers arising from ionizing radiation are caused for human health (exemption set in article 3 to Council directive 96/29/Euratom).
For further information, ask for the «*rubidium product data sheet*».
- Handling the product in a reasonably foreseeable conditions do not cause any risk for human health, exposure to the SVHC (substances of very high concern) would require grinding the component up.

3.3 Environmental Responsibility

- The equipment contains materials, which can be either re-used or recycled.
- Do not deposit the equipment as unsorted municipal waste. Leave it at an authorized local WEEE collection point or return to Orolia Switzerland SA to ensure proper disposal.
- To return the appliance :
 - a. Download and fill up the RMA form (from www.spectratime.com) and send it to WEEE@spectratime.com
 - b. Once the RMA is approved, we will contact you with shipment process details.

3.4 Installation Procedure

3.4.1 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) GPSReference-2000 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) Switch On the system S1.

3.4.2 Software Monitoring

3.4.2.1 iSyncMgr Application

GPSReference-2000 operates independently. However, the smart integrated rubidium clock can be monitored through iSyncMgr application. The latest version can be downloaded from spectratime.com. To start the application, please follow the procedure below:

- Start the application with File 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 GPSReference-2000 should be displayed as Figure 1 below:

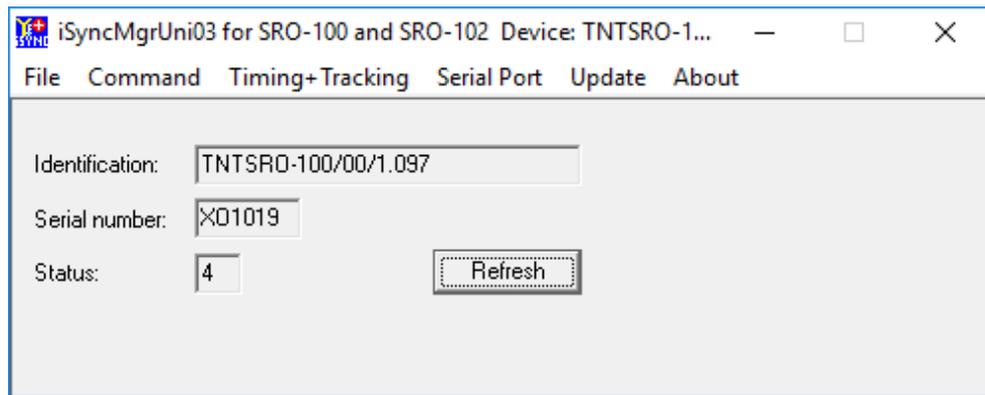


Figure 1 - iSyncMgr.exe

Notes:

- a) iSyncMgr gives full monitoring access to the smart SRO rubidium clock
- b) Changes through these Application should be avoided as the device was factory optimized

3.4.2.2 Monitoring Through 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

Note:

- 1) See chapter 6 for the list of commands

4. System Operations

4.1 Operating Modes

The GPSReference-2000 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 GPSReference-2000 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

Note:

a) See Chapter 4.3 for more detailed description

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 (see user interface location in Section 6). 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.

Note:

a) See Chapter 6 for a list of supported RS-232 commands

4.3 Alarm Indicators Description

| Operation modes | LED status | | | | Switch 2 positions | | | Troubleshooting Actions |
|-----------------|------------|----------------|-------------------|--------------|--------------------|------|-------|---|
| | L3: Power | L4: Sync/Track | L5: Rb Lock (red) | L6: GPS Mark | free run | Sync | Track | |
| Free Run | - | - | - | - | - | - | - | Check power supply |
| | √ | - | √ | - | √ | - | - | Wait for 15 minutes, if L5 is still red then send back the GPSReference-2000 to factory |
| | √ | - | - | - | √ | - | - | Bad installation of GPS antenna |
| | √ | - | - | Blinking | √ | - | - | Normal free run situation |
| Track/Sync | √ | - | - | Blinking | | √ | - | Wait for 10 minutes. If L4 still not green, set the Switch S2 in Free-Run and then back in Sync. If L4 still not green, please contact factory. |
| | √ | - | - | Blinking | | | √ | Wait for 10 minutes. If L4 still not green, set the Switch S2 in Free-Run and then back in Track. If L4 still not green, please contact factory. |
| | √ | green | - | Blinking | | √ | (√) | Normal Sync/Track situation |
| Holdover | √ | - | | - | | √ | | In holdover mode. No GPS signal detected. If the signal comes back, L6 should blink again and L4 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. System Description

The GPSReference-2000 unit consists of a smart rubidium clock (model SRO-100) disciplined to a GPS receiver.

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.

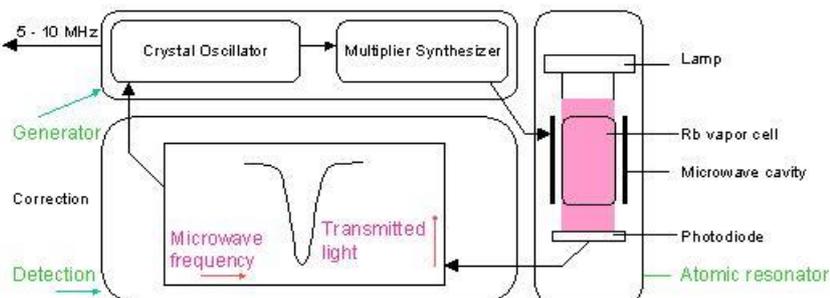


Figure 2 - Rubidium atomic clock block diagram.

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 tags 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 1 μ s 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.

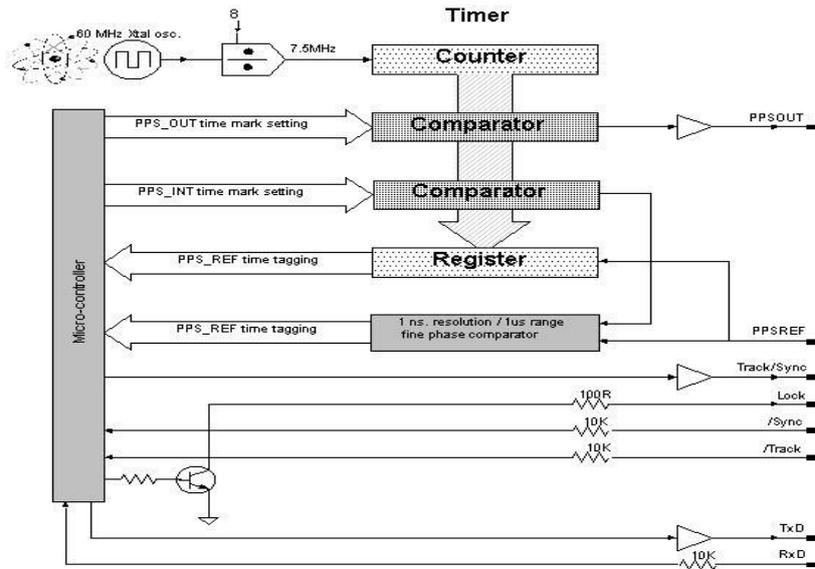


Figure 3 - Timing System

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.

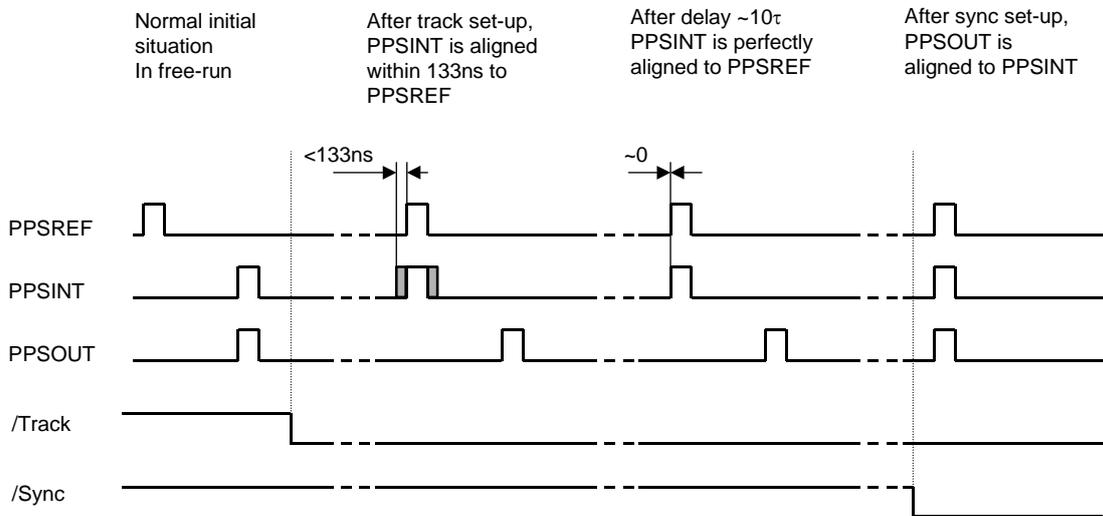


Figure 5 – Track vs. Sync Mode

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.

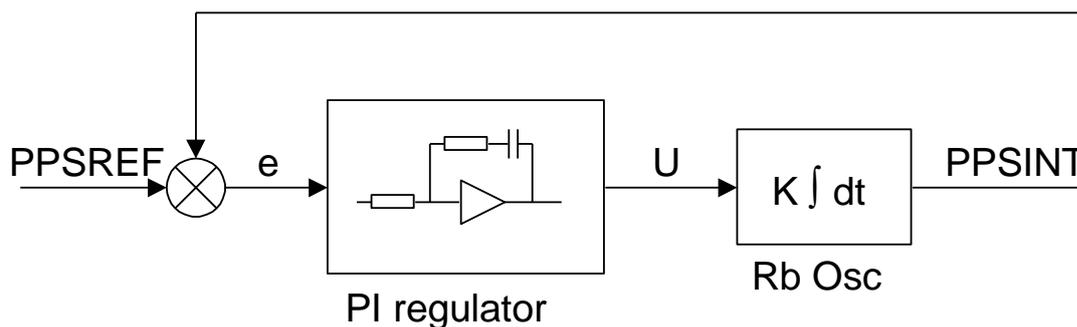


Figure 5 - Schematic of the PPSREF Regulation Loop

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”.

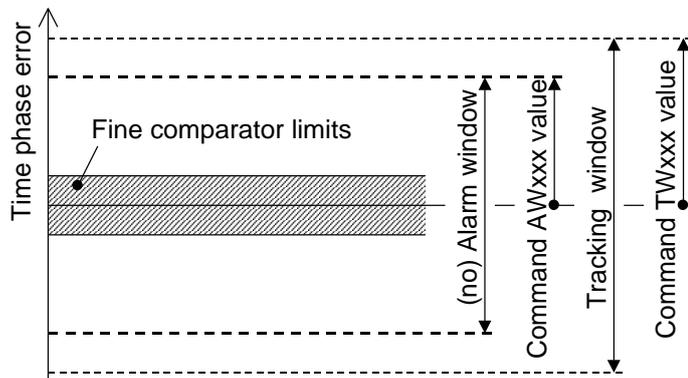


Figure 6 - Tracking Limits

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 $\pm 1.6\cdot\text{E-}8$ 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>

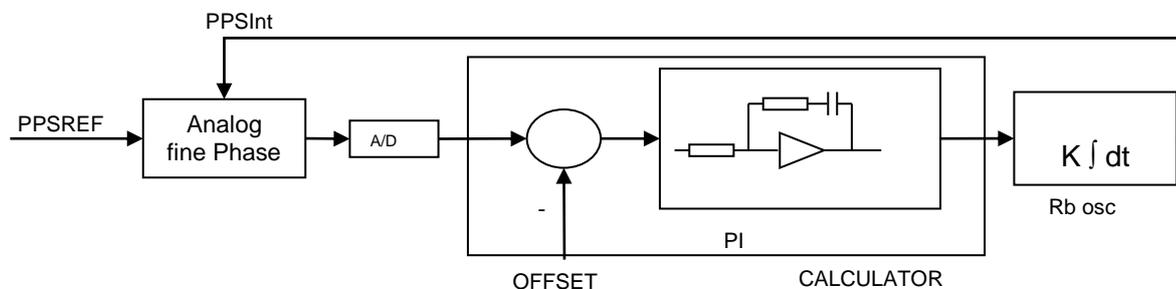


Figure 7 - Schematic of the Analog Fine Phase Comparator Regulation Loop

6. System 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
 rr: revision number
 s.ss: software version
 Example: **ID<CR>**, answer: **TNTSRO-100/00/1.096<CR><LF>**

SN<CR>[<LF>] : Serial number
 Answer: **xxxxxx<CR><LF>**
 xxxxxx: 6 digits serial number
 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 :

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

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

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 has 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 always. (1→EEPROM) *
 3: Track now + always (1→EEPROM) *
 ?: 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.

- The SRO-100 can also be set in tracking mode by grounding the pin 15 of the connector.
- Whatever from software or from hardware, the Track mode 1 has the priority. The answer takes this situation into account.
- The SRO-100 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 current tracking state. For that, use the command ST<CR>.(answers 2 <CR><LF> when tracking)
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated). But TR1 followed by TR0 don't write in NVM

Example: **TR3<CR>**, answer: **1<CR><LF>**. Will always be in tracking mode. If not yet in this mode, start to track PPSREF.
TR0<CR>, answer: **1<CR><LF>**.In tracking mode because pin 15 is grounded.

SYx<CR>[<LF>] * : Set synchronization PPSOUT to PPSINT mode.

- x: synchronization mode setting
 - 0: synchronize never (0->EEPROM) *
 - 1: synchronize now
 - 2: synchronize always (1->EEPROM) *
 - 3: sync. now + Always (1->EEPROM) *
 - ?: 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.
- The SRO-100 can also be set in sync. mode by grounding the pin 14 of the connector.
- 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 current sync. state. Therefore, use the command ST<CR>.(answer 3 <CR><LF> when synchronized.)
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated). But S1Y followed by SY0 don't write in NVM.

Example: **SY?<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.
 - ????????: interrogation.

Answer: **ddddddd**: Delay in 133 ns steps.
 ???????: Delay information not valid.
 0000000

Reset value:

Notes:

- When going into tracking state, the information delay become no longer valid and the SRO-100 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 DE???????<CR><LF>, the PPSOUT is delayed vs PPSINT and the answer is correct.

Example: **DE???????<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.
 ???????: interrogation.

Answer: **ddddddd**: Pulse width in 133 ns steps.
 Factory setting : 0001000 (133 us)
 Reset value : Last Value stored in EEPROM
 Example: **PW???????<CR>**, answer: **0001000<CR><LF>**

Notes:

- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

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 SRO-100 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 SRO-100 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 SRO-100 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

Answer: `yyyy-mm-dd<CR><LF>`
 `yyyy: Year mm: Month dd: Day`
 `yyyy-mm-dd<CR><LF>`
 Reset value: `yyyy: Year mm: Month dd: Day`
 `2000-01-01`

Notes:

- After reception of this command, the SRO-100 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

A: Beat Date, Time, Counter data in NMEA 0183 proprietary format

Answer: `$PTNTA,yyyymmddhhnnss,q,T3,rrrrrr,sfff,s,x,y*cs<CR><LF>`

(See NMEA PROPRIATARY FORMAT Chapter)

B: Beat Frequencies, Tra. loop parameters in NMEA 0183 proprietary format

Answer: `$PTNTS,B,s,ffff,iiii,aaaa,x,y,s,cccccc,ggg.gg,x,y*cs<CR><LF>`

(See NMEA PROPRIATARY FORMAT Chapter)

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 ???????<CR><LF> if no pulse is found.
- This can happen when the SRO-100 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.
 ??????: interrogation.

Answer: **sdddd<CR><LF>**
 sdddd: frequency correction currently in use.
 +00000
 Last value stored in EEPROM.

Factory setting:
 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:

- Since Ver. 1.096, it is possible to cancel the writing in eeprom of this command with the configuration parameter MCv06. See Chapter 2.4.9 for details. But a writing in eeprom of the frequency in use is always possible with the command FS3.
- 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??????).
- *Warning : This command can act into non volatile memory. Numbers of writings during the whole unit life time limited to 10'000 in total (all commands cumulated).

FSx<CR>[<LF>] *: Set frequency save mode.
 x: mode.
 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.
 ?: 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:
 Reset value: 1
 Last value stored in EEPROM.

Notes:

- In frequency save mode 1, the saving is only done if the SRO-100 is in track state. (General Status 2 or 3).
- If the PPSREF is missing or rejected, the 24 hours period is increased.
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

Example: **FS?<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.
 ????: interrogation

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

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

Notes:

- If the time interval PPSINT vs PPSREF becomes bigger than the tracking window, the tracking stop.
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

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.

???: 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.
- A tracking alarm puts the pin 5 of the output connector to high. 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.
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

Example: **AW???**<CR>, answer **015**<CR><LF>.

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.

??????: 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.
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

Example: **TC??????**<CR>, answer **000000**<CR><LF>

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

s : action to do

L : Load parameter

S : Set parameter, only data Type is RAM or eeprom *

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

cc...c : parameter, up to 24 ACSII character if it is 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

Answer:

| Pos. | Active.(Def) | Parameter(Default) | Comment |
|------|--------------|------------------------------|---|
| 00 | 1 | TNTSRO-100/00/1.096 | Factory welcome message |
| 01 | 0 | Free for user message | User welcome message |
| 02 | -- | 05 | GPS configuration delay |
| 03 | -- | 03 | GPS configuration interval |
| 06 | -- | 00 | See Chapter 2.4.9 |
| 07 | -- | 01 | Error message send |
| 10 | 0 | @@En.. | Time RAIM setup (OnCore, Jupiter -T) |
| 11 | 0 | @@At.. | Position hold, site survey (OnCore, Jupiter -T) |
| 20 | 0 | @@Gd.. | Position control message (M12+) |
| 21 | 0 | @@Gc.. | PPS control message (M12+) |
| 22 | 0 | @@Ge.. | Time RAIM algorithm (M12+) |
| 23 | 0 | @@Gc.. | Time RAIM alarm message (M12+) |
| 30 | 0 | Binary | Quiet (Jupiter-Pico) |
| 40 | 0 | Binary #63 | InitLink, quiet (SuperStar II) |
| 41 | 0 | Binary #81 | Set mask angle (SuperStar II) |
| 42 | 0 | Binary #69 | Set timing parameter (SuperStar II) |
| 43 | 0 | Binary #80 | Set operating mode (SuperStar II) |

- Parameters in **bold** can be modified by the user
- 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 which the GPS configuration messages are sent out at Start up.
- Positions \$10-11, \$20-23, \$30, \$40-43, are messages that can be sent out by the SRO-100 at Start up to configure GPS receivers. If more information is needed, feel free to contact the SpectraTime support department.

Notes:

- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

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

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
 ?????: interrogation.

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

Notes:

- This command stores the value in EEPROM
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

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>**
 ddddd: Time constant in s

GFdddd<CR>[<LF>] * : Set and activate the go fast mode during the beginning of a tracking.

dddd: the time during this mode is active. In seconds.
 00000: mode not active.
 65534: maximum value, 65534 s.
 65535: mode always active.
 ?????: interrogation.

Answer: **dddd**: duration in seconds.
 Factory setting: 00000
 Reset value: Last value stored in eeprom

Notes:

- The device is going in tracking after the command TR1 or after grounding the pin 15.
- For the SRO-100, the tracking loop time constant is settled to 277 seconds in this mode.
- When this mode is active, the command VT answers 277.
- The countdown can be read back with the commands R48, R49.
- When this mode is active, the phase noise is degraded and large frequency changes are possible.
- *Warning : This command is acting into non volatile memory. Numbers of commands sent during the whole unit life time limited to 10'000 in total (all commands cumulated).

Example: **GF??????<CR>**, answer **00000<CR><LF>** Go fast mode not active

RA sddd<CR>[<LF>] : raw phase adjust
 sddd: raw phase adjust in 133 ns steps
 +127: highest adjust
 -128: lowest adjust
 ?????: interrogation, always +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 DEddddddd, as the delay is in fact referenced to PPSINT

Example : **DE???????? <CR>**, answer **00000000<CR><LF>** . Now we do **RA+003**, answer **+003<CR><LF>**. And then we do **DE????????<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

RESET<CR>[<LF>] : this command reset the SRO-100 micro controller

Answer: (Standard identification and welcome messages, may be followed by GPS configuration binary)

7. System I/O Interfaces

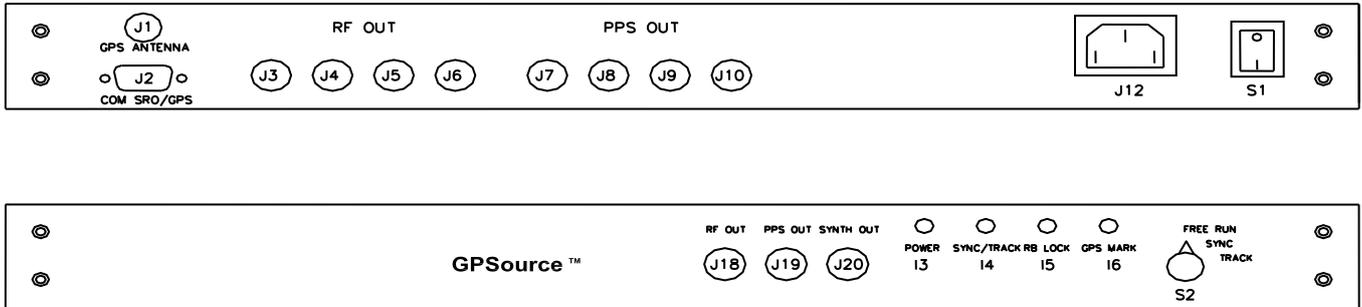


Figure 8 - GPSReference-2000 Interfaces

7.1 Back plate

| N° | Type | Definition | I/O |
|--------|----------|---|-----|
| J1 | SMA | GPS antenna connection | I |
| J2 | SUB-D9-F | 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 |
| J12 | IEC PLUG | Power connection | I |
| S1 | SWITCH | On/Off switch | - |

7.2 Face plate

| N° | Type | Definition | I/O |
|-----|-----------|--|-----|
| J18 | BNC | 10MHz sine reference output | O |
| J19 | BNC | 1PPS output | O |
| J20 | BNC | SYNTH output | O |
| 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 | - |

See separated GPSReference-2000 specification for characteristic of the outputs.

8. System 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 GPSReference-2000 user manual, section "Safe GPS Antenna installation".

8.1 Optional Rooftop GPS Antenna

The kits contain the following items:

Ordering code: RA :

- a roof antenna
- a lightning arrestor

Ordering code: CA :

- a cable of 15 meter (49')
- a cable of 5 meter (16.4')

8.2 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').

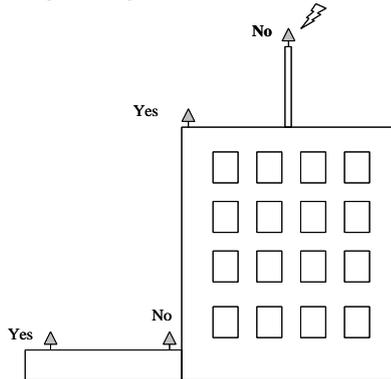
For the installation, please refer to our AN "Custom GPS Antenna Installation".

9. Safe GPS Antenna Installation

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

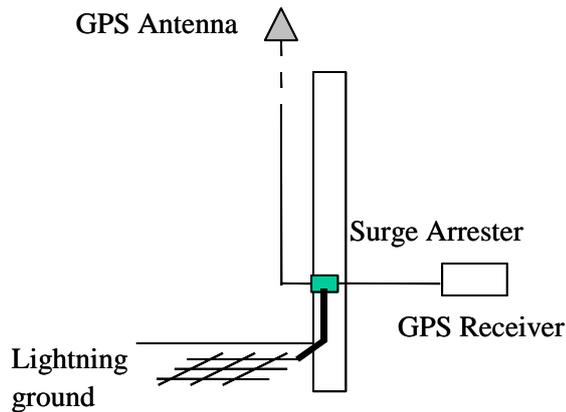
Where to install the GPS Antenna

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.



10. 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 |
| SRO | Synchronized Rubidium Oscillator |
| XTAL | Quartz crystal |
| .PDF | Portable Document Format, file extension to be used by Adobe Acrobat Reader |