

January 8, 2013

Low Cost / Profile High resolution Frequency Stability Measurement Test Set

Pico Second Resolution Instrument

Easy-to-Use RF Device & User-Friendly Windows Software



APPLICATIONS

Calibration | Oscillator/Clock Characterization | TIE Measurements | Lab Instrument

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1. INTRODUCTION

Picotime-1U 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.

PicoTime-1U 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, small volume and 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. PicoTime-1U / RS SYSTEM DESCRIPTION

PicoTime-1U measures the time difference between a reference of 10 MHz 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.**

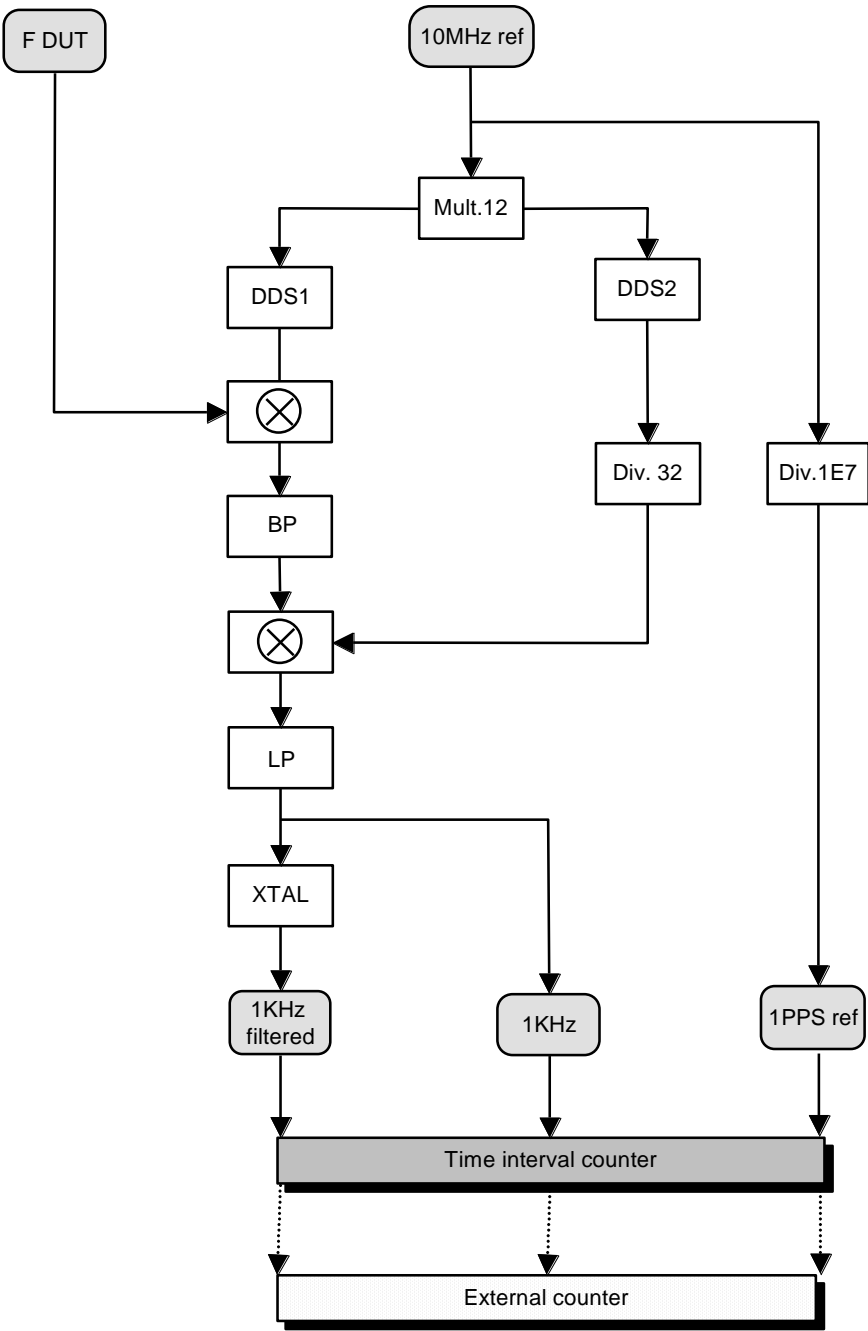


Fig. 1 : PicoTime-1U / RS block diagram

3. PicoTime-1U / RS INSTALLATION

3.1 Safety !



- Use proper ESD precautions
- Ensure that all cables are properly connected
- Ensure PicoTime-1U connected to earth through the RS interface before power supply connection.

3.2 Unpacking

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

Unit supply:

- 1 PicoTime-1U unit
- 1 Power supply 230V/50Hz-12VDC
- 1 Cable SUB-D 9 pins male/female
- 1 PicoTime-1U installation software
- 1 User manual + Specifications
- 1 Euro power cable
- In option Stable32 software
-

Cables required:

Two coaxial cables terminated at one end with male BNC connectors. The other end should have the appropriate connector as determined by your application. Try to use the shorter cables as possible to obtain the most appropriate conditions for measurements.

3.3 Software installation

- Close all applications and run the **Setup.exe** and follow the instructions. The program PicoTime-1U will be installed in the start menu by default.

3.4 Connections

- Connect the **10MHz** reference and the **DUT** to the FSMS unit.
- Connect the male SUB-D-9 to the unit and female SUB-D-9 to the computer. The system can be connected to **COM1** to **COM4**. Connect the power supply to the unit.
- Connect the DUT, the PicoTime-1U and the computer to the same ground without using galvanic insulation.

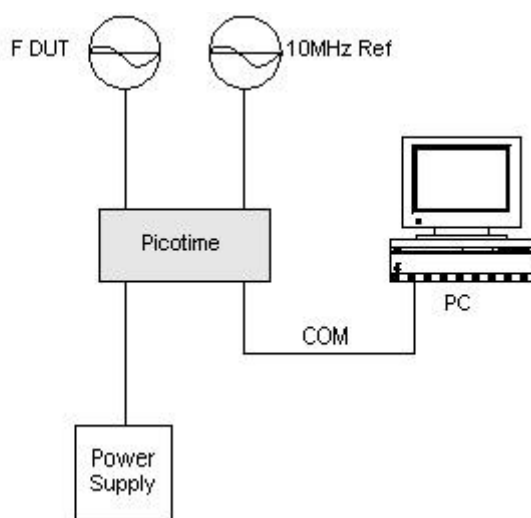


Fig. 2 : Connections

Spectratime recommends the users to warm up PicoTime-1U **several hours** before starting any measurements. For very short term stability measurements, the warm-up time does not need to be very long because the temperature fluctuations will not be apparent on very short time analysis.

When the power supply is applied to the PicoTime-1U unit, the red led switches on.

Three more interfaces are available on the front panel which correspond to the following signals:

- 1 PPS reference
- 1 KHz filtered after initialization / FDUT before initialization
- 1 KHz non-filtered after initialization

It offers the possibility of using the system with an external counter to allow different kind of measurements.

Spectratime recommends to not use these interfaces if the internal counter of the PicoTime-1U unit is preferred.

To start a measurement, click on **PicoTime-1U RS** from the start menu. The PicoTime-1U application appears on the screen. See section operation to set and use the system correctly.

4. PicoTime-1U / RS OPERATION

PicoTime-1U is designed for ease of use, it configures itself the system and collects data.

The unit 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-1U 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

The following figure shows the hierarchy of the software.

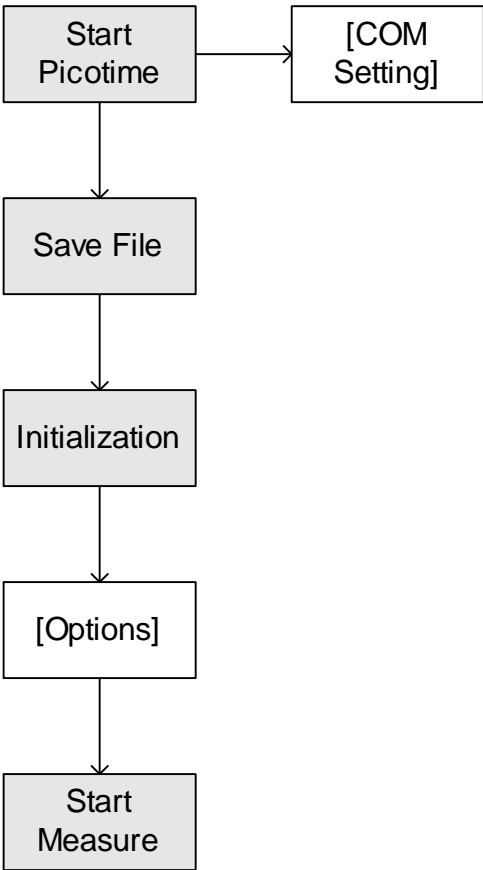


Fig. 3 : Software hierarchy

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.

4.1 Definition of the menus and parameters

Figure 4 shows the display when the user runs PicoTime-1URS from the start menu of Windows.

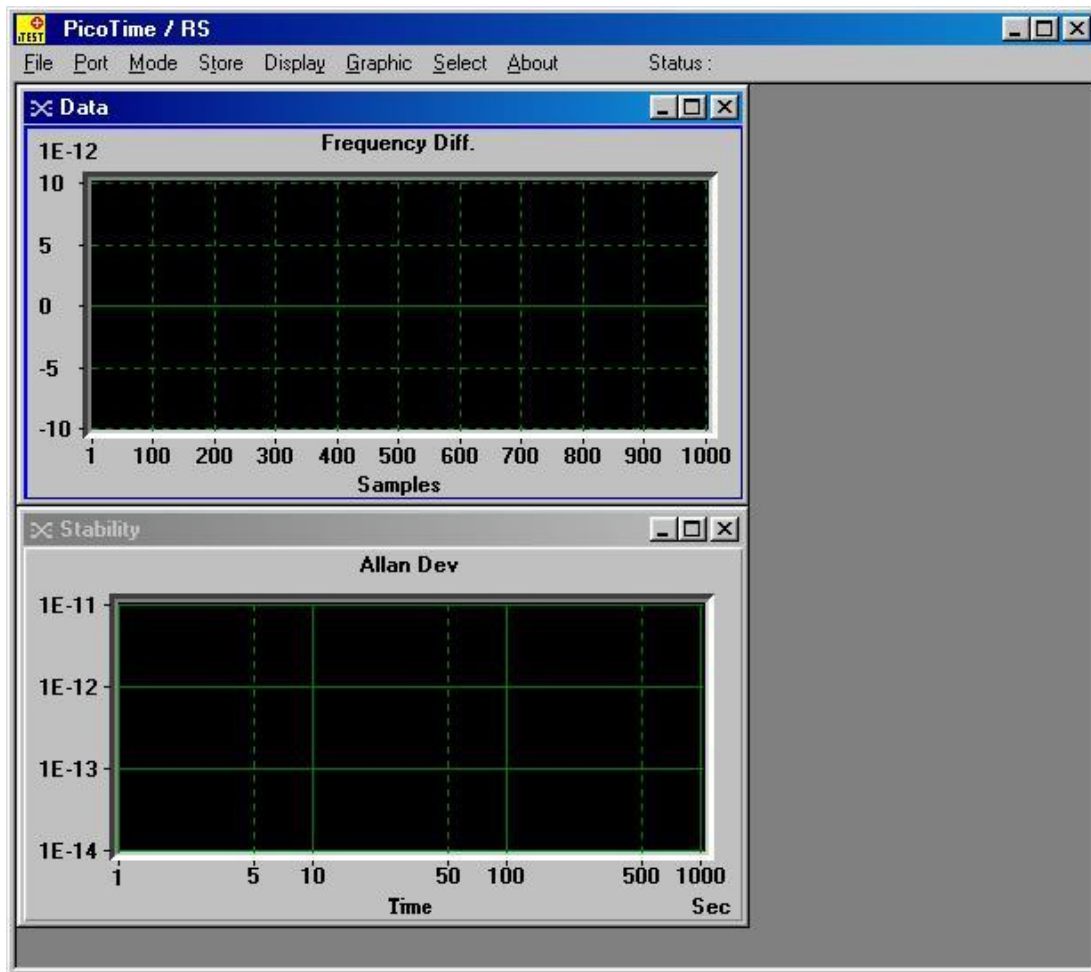


Fig. 4 : Starting display

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.

4.1.1 File

The menu File is the main menu of PicoTime-1U. 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	

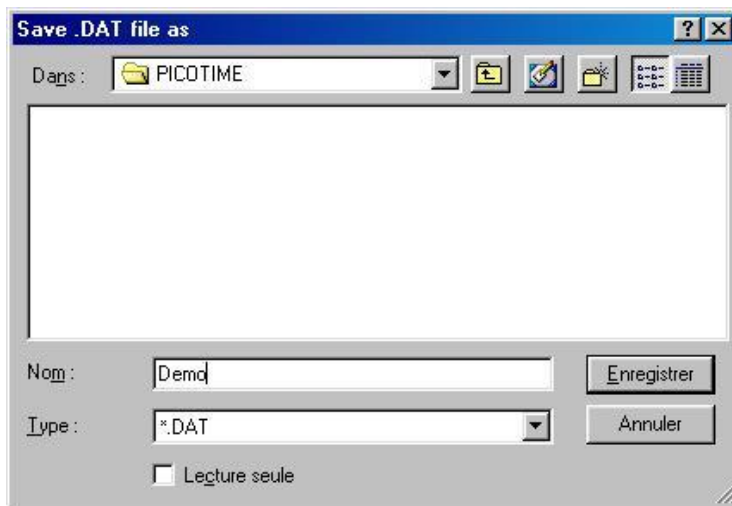


Fig. 5 : Save file as

The sub-menu **Initialization** becomes enabled only if the user has saved the measurement file. This function initializes PicoTime-1U.

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".

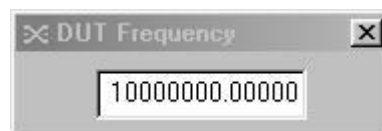
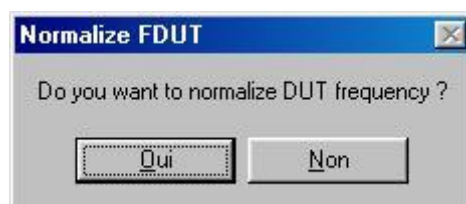


Fig. 6 : DUT Frequency

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-1U (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.

4.1.2 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.

4.1.3 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.

4.1.4 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.

4.1.5 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.

4.1.6 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.

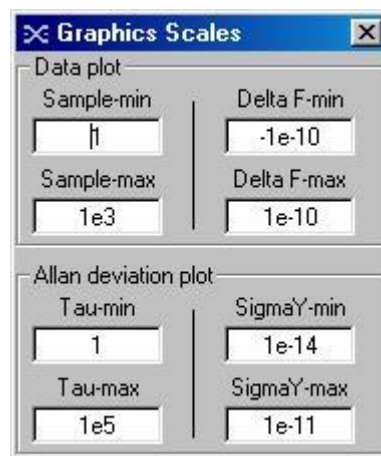


Fig. 7 : Graphics scales

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.

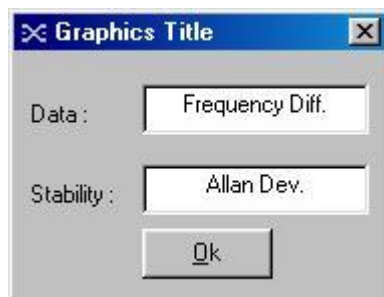


Fig. 8 : Title edition

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.

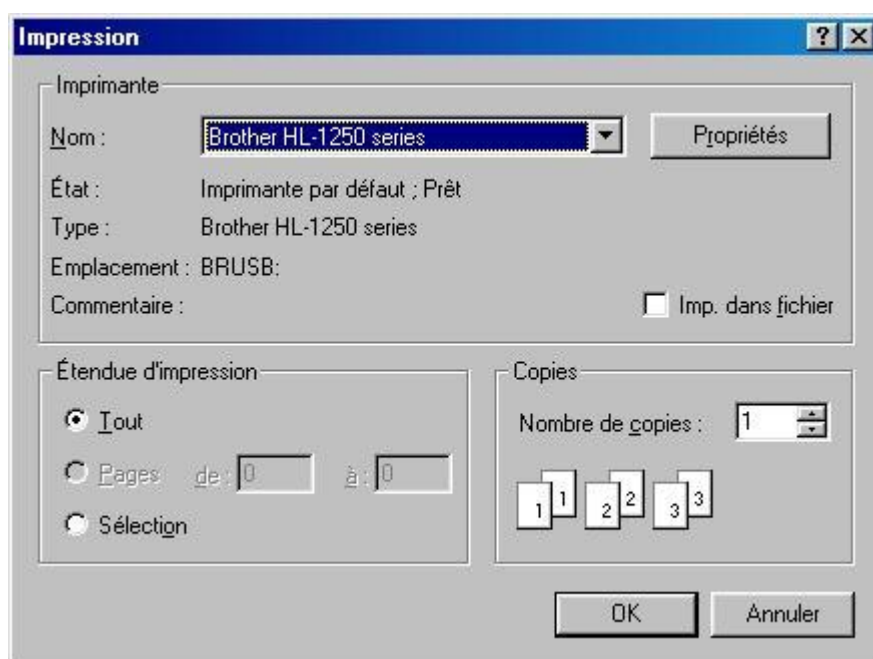


Fig. 9 : Printer dialog box

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

4.1.7 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. 10 : Tau select

The sampling rate needs to be selected according to the kind of stability analysis. In fact, PicoTime-1U 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 $\pm \varepsilon$).

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. 11 : Nominal DUT Frequency

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

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

4.1.8 About

To check the version of the PicoTime-1U 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. 12 : PicoTime-1U 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.

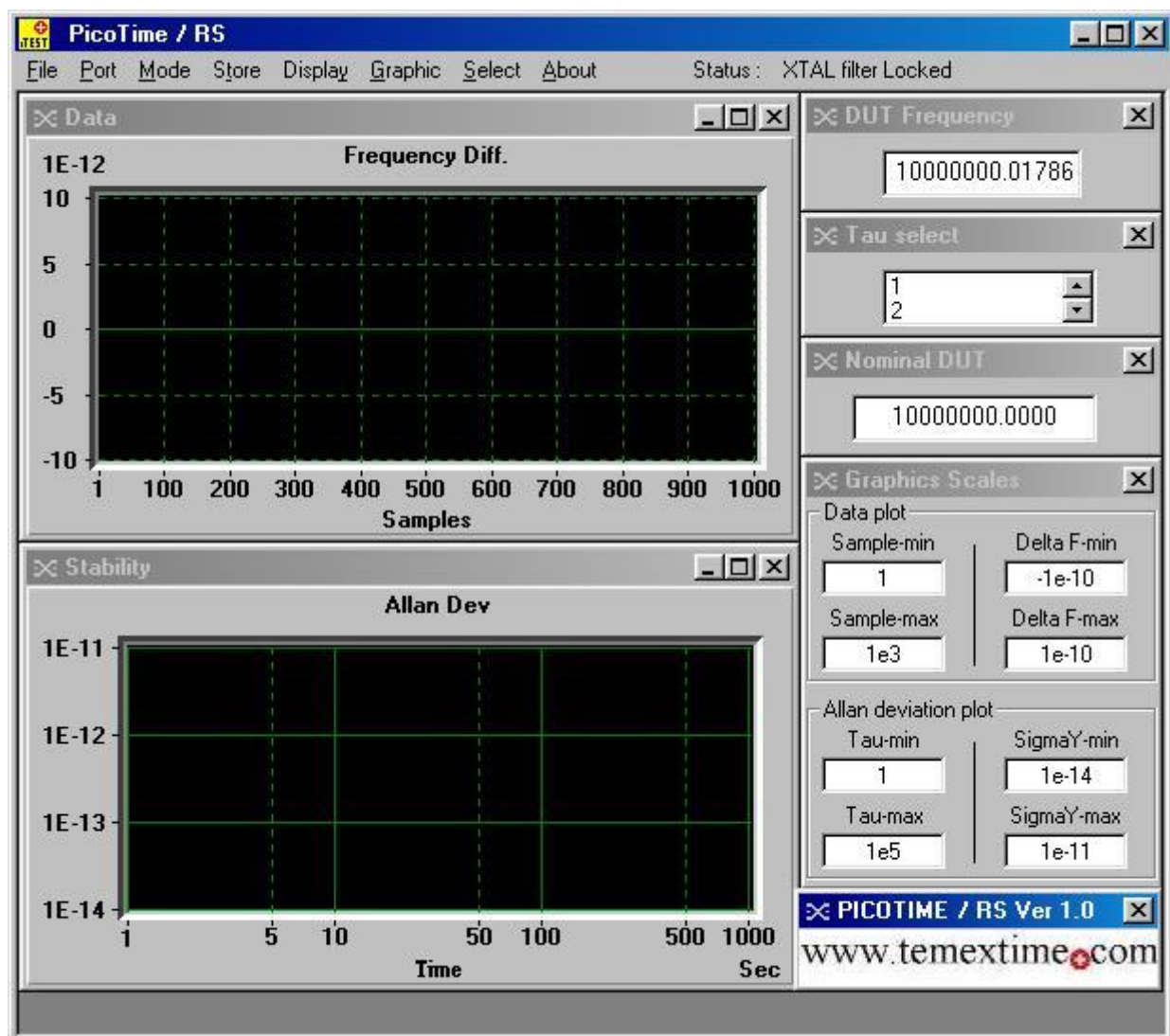


Fig. 13 : Graphics and parameters windows

4.2 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...".

4.2.1 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.

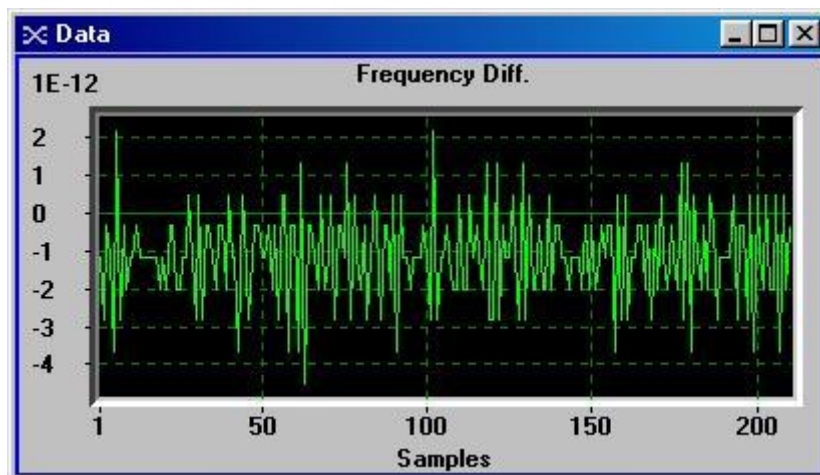


Fig. 14 : Frequency difference plot

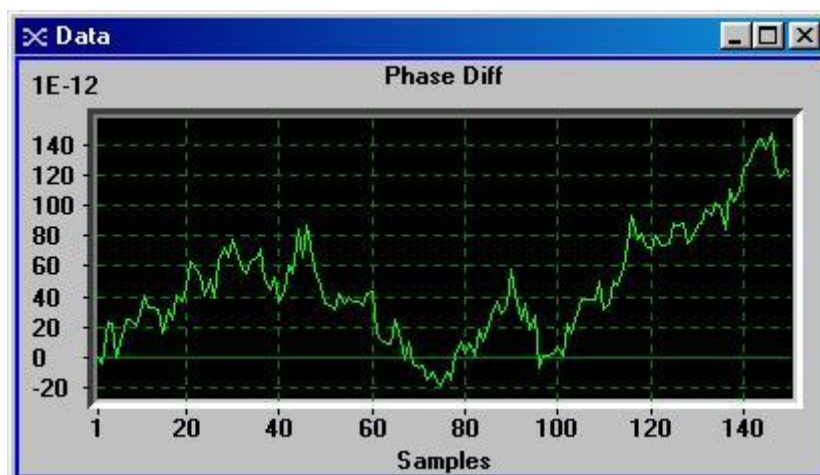


Fig. 15 : Phase difference plot

4.2.2 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.

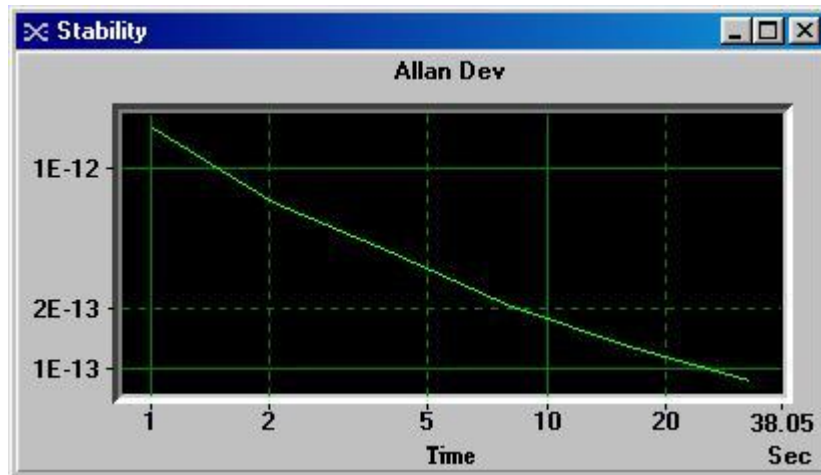


Fig. 16 : Standard Allan Deviation plot

4.2.3 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. 17 : Sample 999999

4.2.4 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-1U and cables must not be touched !

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

5. THEORY

5.1 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 $\sigma_y(\tau)$.

5.2 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-1U does not display the confidence interval. Stable 32 is more appropriate to obtain such results.

6. SYSTEM TESTS

To measure the system noise, a low noise, high spectral purity and stable oscillator or atomic frequency standard with an output of 10MHz is used. The signal is split in two using a high quality RF power splitter and is applied to the reference input and to the F_{DUT} input. This way, the noise of the reference and device under test are cancelled and only the noise of the PicoTime-1U unit is measured. To obtain the best performances, the environmental condition must be ideal in term of temperature change, magnetic and electromagnetic field, vibration, ...

Spectratime recommends to place PicoTime-1U unit in a proper environmental area. Following environmental condition have to be avoided :

- Fast temperature change,
- Vibration and micro-vibration,
- Magnetic and electromagnetic field,
- Presence of an airflow,
- Proximity of an RF source.

The user has also to be attentive to have the best quality connections between RF input signals and the PicoTime-1U unit.

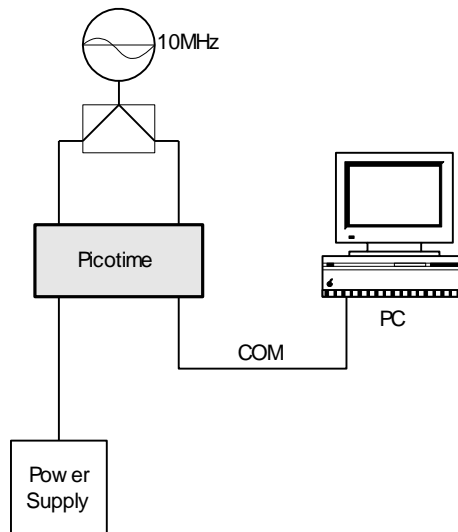


Fig. 18 : Connections for system noise measurements

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 $\sigma_y(1) \cong 1E^{-12}$.

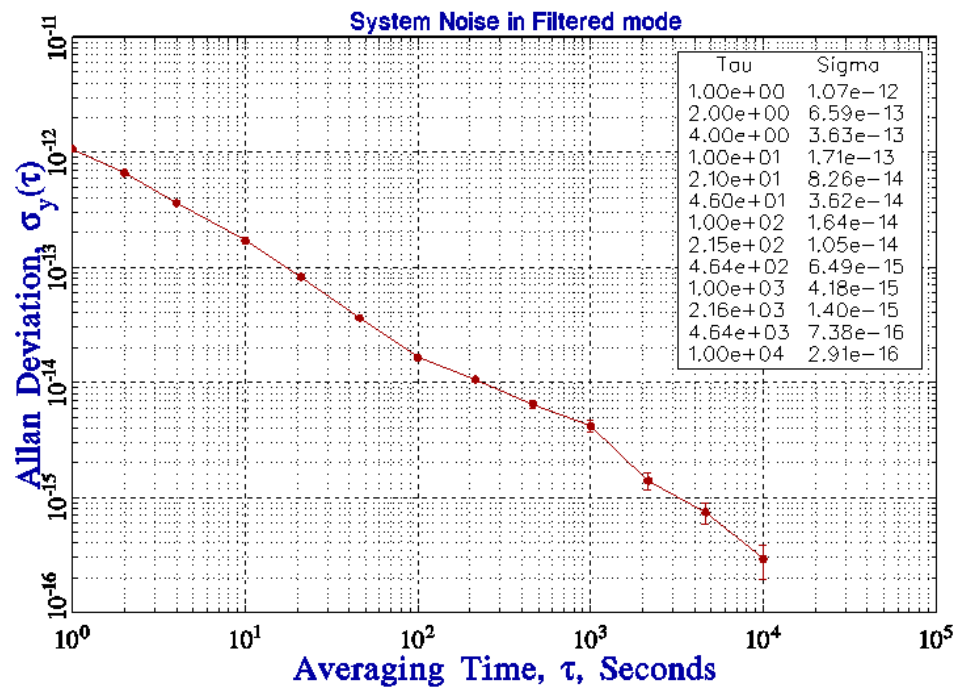


Fig. 19 : System noise 1 in ideal conditions

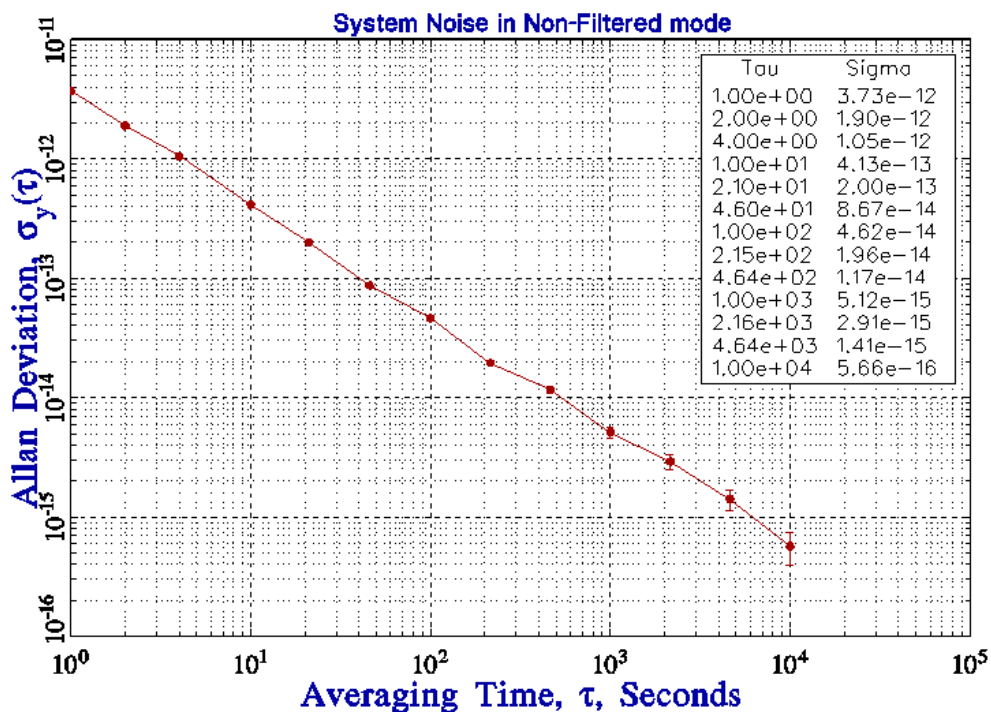


Fig. 20 : System noise 2 in ideal conditions

7. TYPICAL MEASUREMENT

The basic connections are the following :

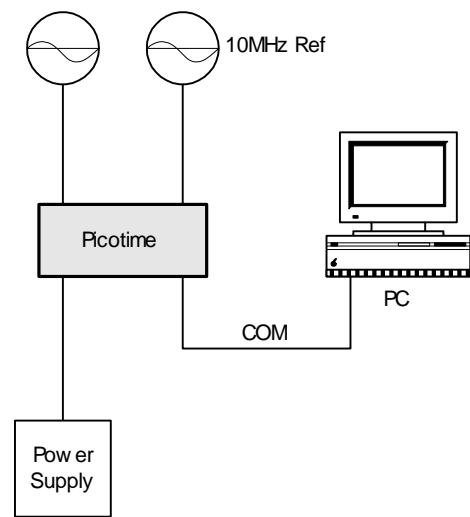


Fig. 21 : Typical measurements connections

Atomic Rubidium clock

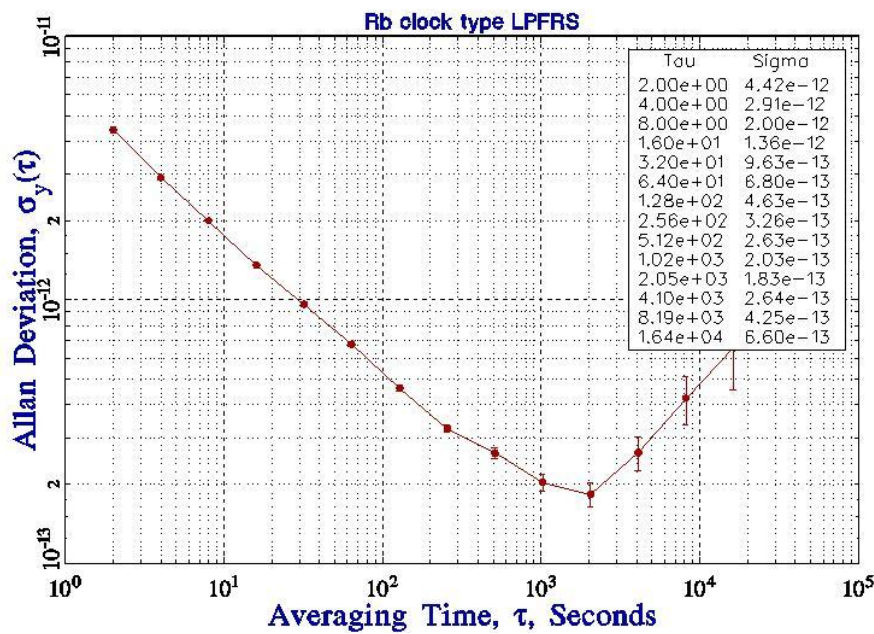


Fig. 22 : Rubidium atomic clock stability

State of the art Quartz Crystal Oscillator

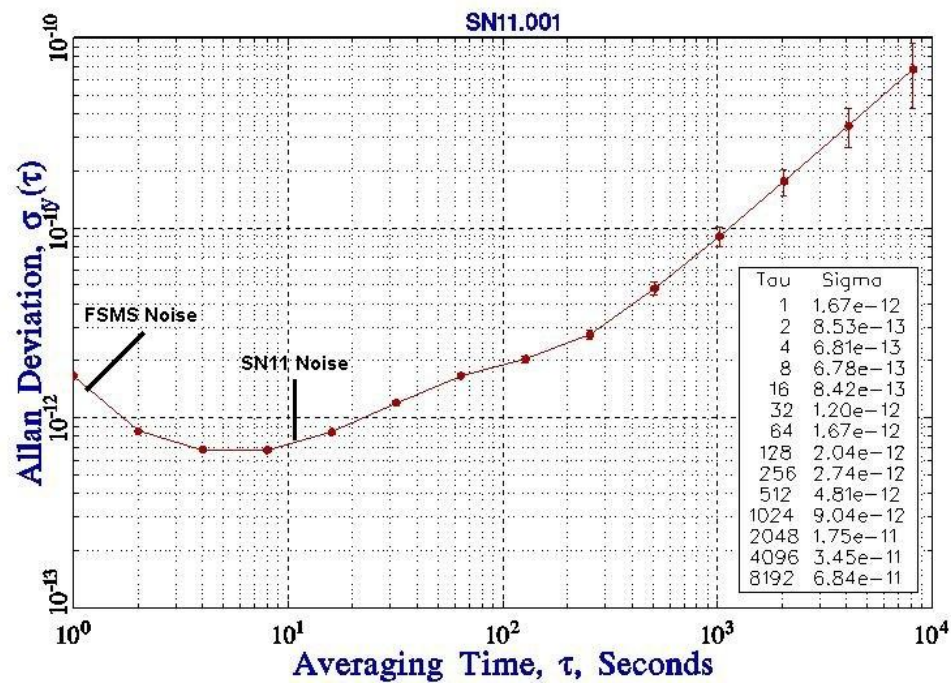


Fig. 23 : Quartz crystal oscillator stability

The PicoTime-1U system noise is visible before 4 seconds. From this measurement the Crystal oscillator stability at 1 second can be extrapolated as : $\sigma_y(1) = 6.8 \times 10^{-13}$.

8. 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-1U 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.

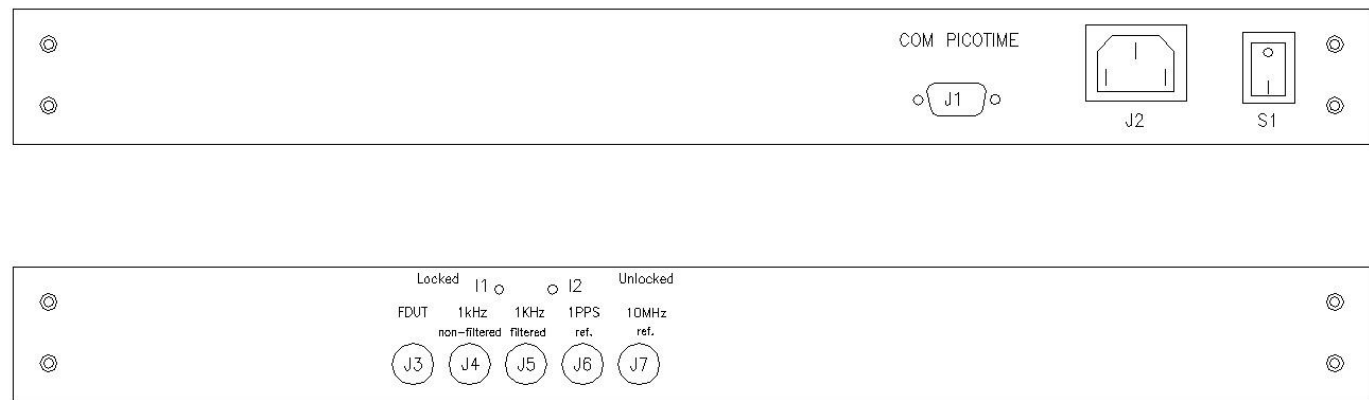
9. GLOSSARY

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
.PDF	Portable Document Format, file extension to be used by Adobe Acrobat Reader.
Stable32	Stability analysis software

10. PICOTIME-1U INTERFACES



10.1 Back Panel

N°	Type	Definition	I/O
J11	SUB-D9-F	Measurement module Serial communication RS232	I/O
J12	IEC PLUG	Power connection	I
S1	SWITCH	On/Off switch	-

10.2 Front Panel

N°	Type	Definition	I/O
J3	BNC	Device under test input signal (FDUT)	I
J4	BNC	1KHz non filtered for external counter	O

J5	BNC	1KHz filtered for external counter	O
J6	BNC	Measurement module 1PPS reference for external counter	O
J7	BNC	Measurement module 10MHz reference	I
I1	Green LED	Measurement module locked indicator	-
I2	Red LED	Measurement module unlocked indicator	-