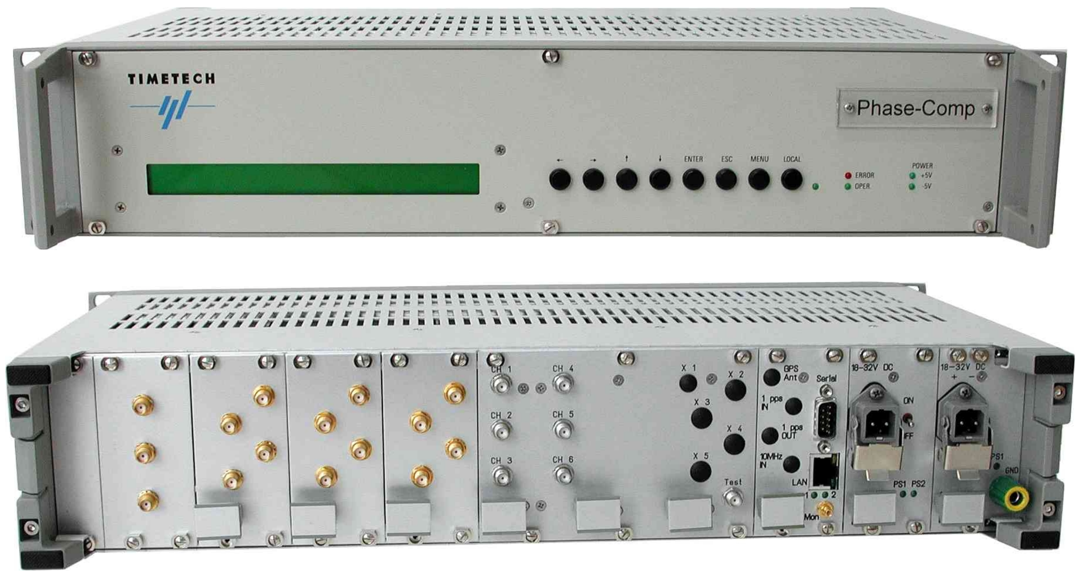
Phase Comparator

6 channels, 100 MHz with 5/10 MHz Option

Part No: 10265



Key features:

- High resolution and low noise
- Arbitrary definition of the reference channel
- 6 inputs at 100 MHz on SMA connectors
- M&C software on external PC
- Data files compatible to STABLE32 software
- Configurable sampling rate: 2/s or 20/s
- Monitor & control software on external PC under WINDOWS 2000 or up
- Display Software providing phase, frequency, and ADEV per
- Display Software providing facility for defining virtual channels

The photo shows a PCO with 3 multiplier modules being equipped (option 3) and with dual DC supply (option 5). In slot #1 (left hand side) there is the input to the three multiplier modules. In the final product the input to the multiplier module is on the panel of the multiplier module itself.

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Key Features of the Frequency Multiplier Option:

- Low phase noise frequency multiplication generating 4 outputs of 100 MHz from a single 5/10 MHz input per multiplier module.
- Manual configuration (by the control SW) of the input frequency 5 MHz or 10 MHz.
- 5/10/100 MHz inputs of the PCO configurable by patch cables.
- Power monitors on input port and on the output ports of the multiplier modules.
- Configurable attenuator on the input port of the multiplier module.

Product Options:

Option	Feature of the option
1	Six channel 100 MHz PCO with **1** frequency multiplier modules 5/10 MHz to 100 MHz.
2	Six channel 100 MHz PCO with **2** frequency multiplier modules 5/10 MHz to 100 MHz.
3	Six channel 100 MHz PCO with **3** frequency multiplier modules 5/10 MHz to 100 MHz.
4	Six channel 100 MHz PCO with **4** frequency multiplier modules 5/10 MHz to 100 MHz.
5	A second DC input module instead of the AC input module in slot #10.
6	Three-corner-hat software

The PCO System consists of three parts

1. **The PCO Hardware**.
   The PCO hardware is providing the high precision phase comparison measurements at the 100 MHz level. One of the input signals is used as a reference signal. The remaining five channels are compared to that reference channel. By means of an auxiliary frequency of a little less than 100 MHz every measurement channel is passed a cascade of an analogue and a digital mixer to produce an intermediate signal being suitable for input to a time interval counter (TIC). Two TIC's are used in parallel for every measurement channel. A coarse one is providing a wide measurement range and a fine one is providing a high measurement resolution.
   As options up to four frequency multipliers can be added in the same rack-mount case. Each of these multipliers has one input at 5 or 10 MHz (configurable) and four outputs at 100 MHz. By patch cable the multipliers outputs can be connected to the PCO's 100 MHz inputs.
   For controlling the PCO a LCD display and 8 push buttons are present on the front side of the PCO hardware.

2. **The Monitor & Control Software**.
   This SW is used to control the functions of the PCO, monitor the integrity of its HW functions and configure the input frequency of the frequency multipliers. This SW is designed to run on an external PC. It provides the same functions that are implemented with the front panel control facility on the PCO hardware, however, providing a more user friendly screen display and a menu based control facility.

3. **Display Software**.
   This SW is used to provide a real time monitor of the function of the PCO. It shows the current phase measurement data and a current ADEV value over time based on a sliding window analysis of the received measurement data. This data is continuously provided for every channel. The Display Software runs on an external PC.

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Phase Comparator

6 Channels, 100 MHz with 5/10 MHz Option

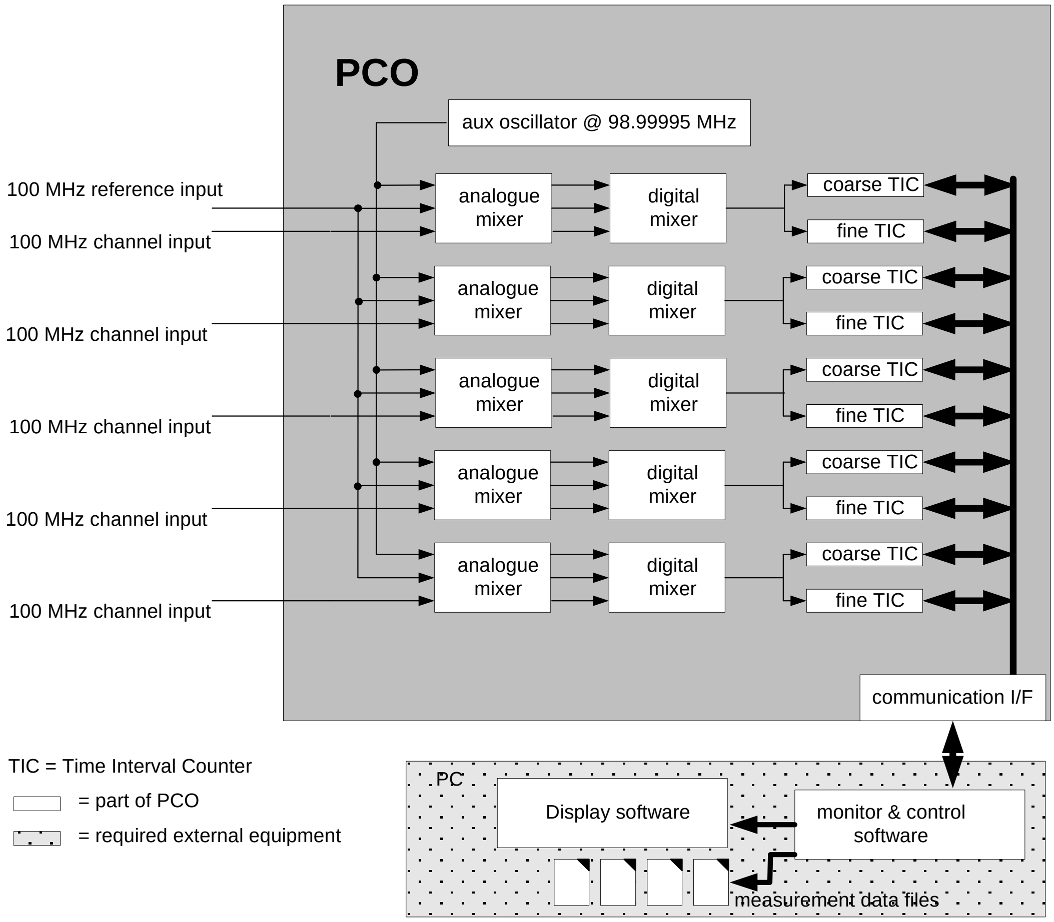
Part No: 10265

The Phase Comparator allows state of the art high precision phase and frequency comparison.

The high number of input channels allows monitoring of a complete clock ensemble with only one phase comparator. Typical applications are:

- High-resolution phase and frequency measurements
- Long-term clock monitoring and data logging
- Clock characterisation using 3-clock method
- Clock-ensemble monitoring
- Oscillator temperature characterisation
- Oscillator adjustment
- Oscillator ageing monitoring
- Monitoring of network synchronisation

Block Diagram of the PCO



Block diagram of the phase comparator in its basic configuration showing the signal flow of the phase measurement data.

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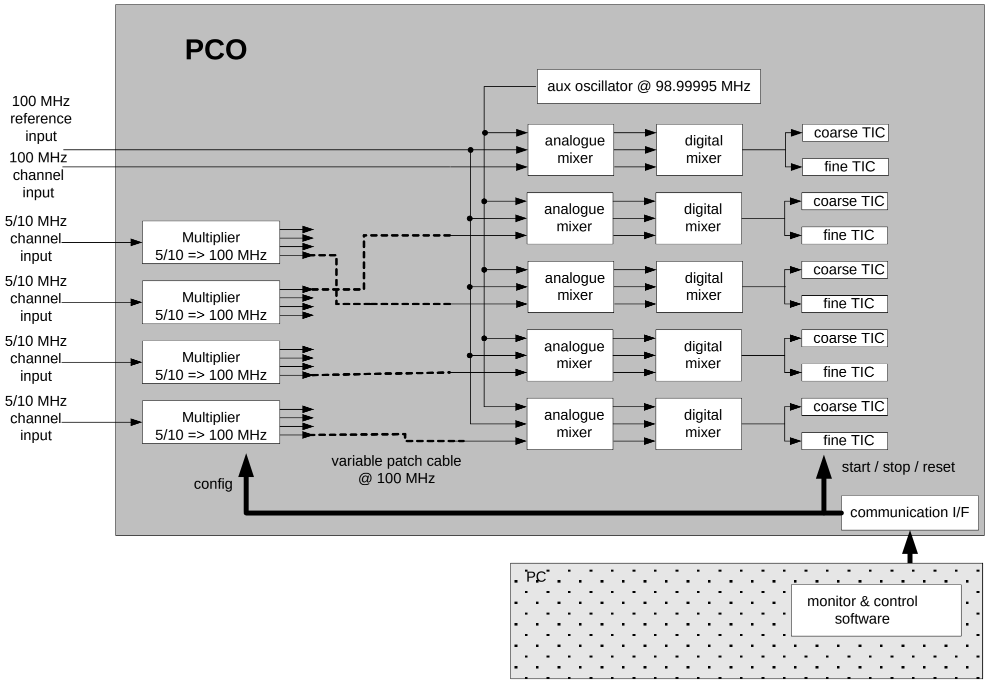
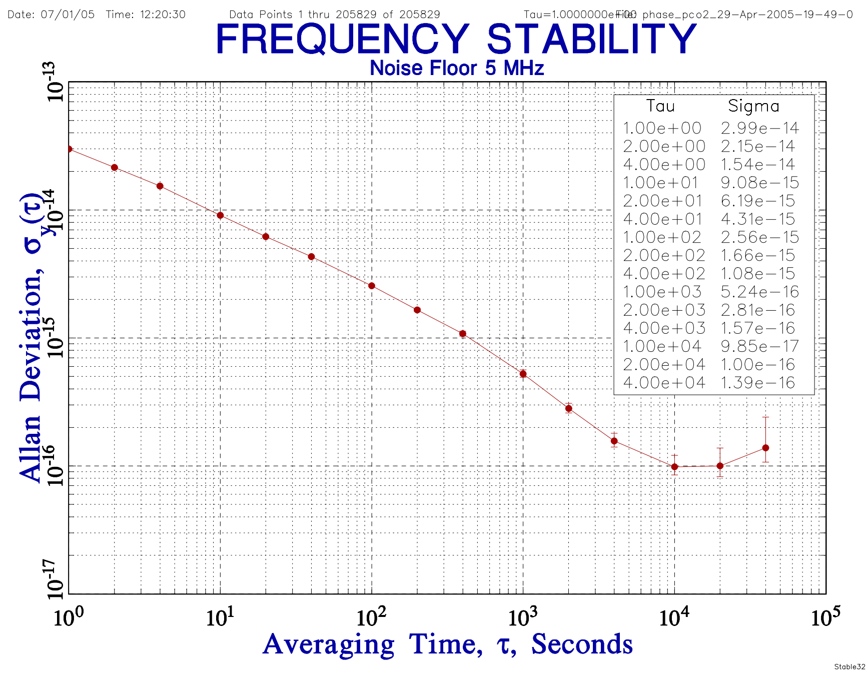


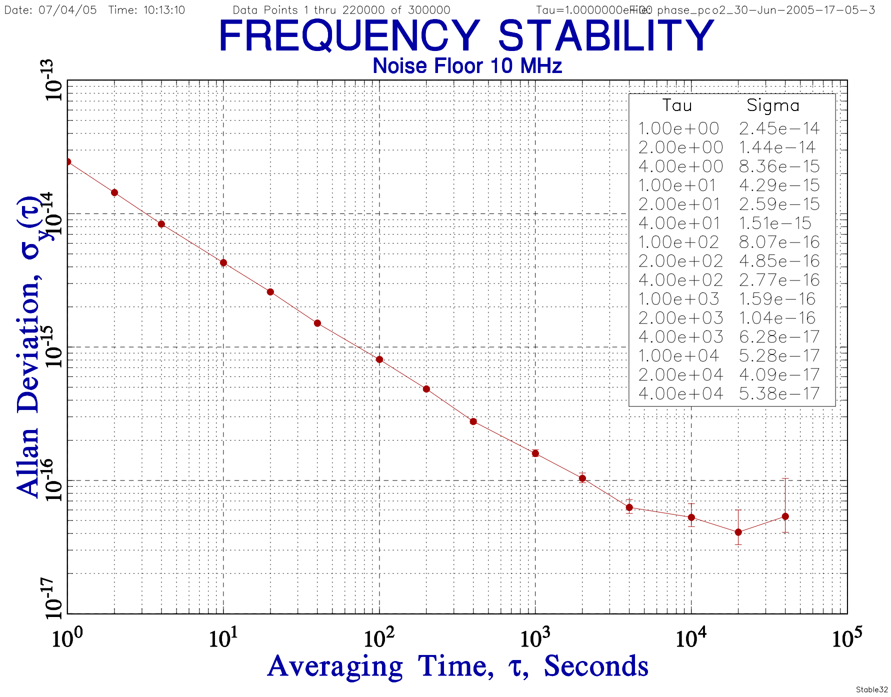
Block diagram of the phase comparator with optional frequency multipliers showing the control function data flow (option 4).

Measurement Results

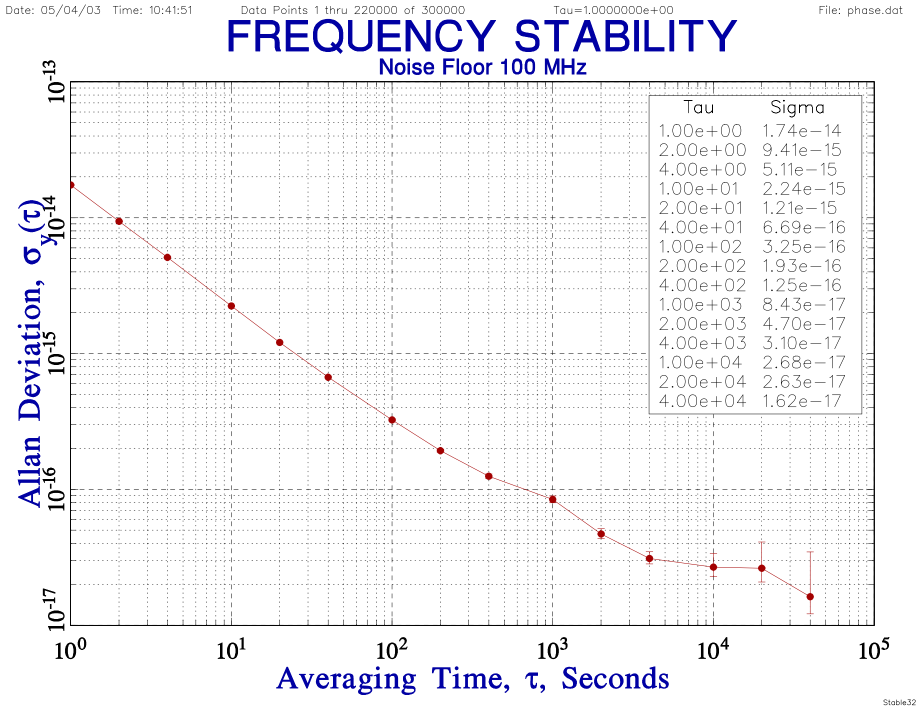
The following STABLE32 graphs show the results of noise floor measurements being done at 5 MHz, 10 MHz, and 100 MHz inputs.



5 MHz ADEV noise floor (typical)



10 MHz ADEV noise floor (typical)



100 MHz ADEV noise floor (typical)

All measurements are taken in standard laboratory environment (temperature +18 to +24°C, ~4Kpp, no active air condition). The Phase Comparator was locked to a common source with a passive splitter.

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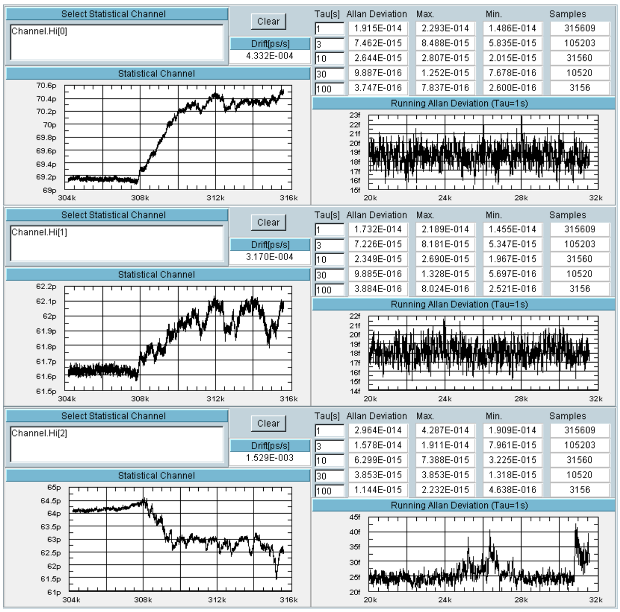
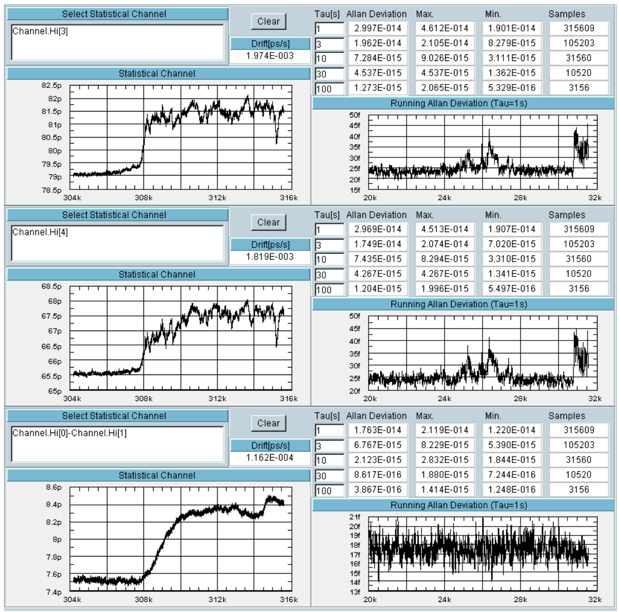
Display Software

The display software is used to monitor the integrity of the on–going measurements. It shows the current phase measurement data (“Statistical Channel”) and the current ADEV values for tau = 1 sec as a plot over time based on a sliding window analysis of the received measurement data (“Running Allan Deviation”). Furthermore it presents tables of the current ADEV, the minimum ADEV and the maximum ADEV being calculated in the sliding window analysis since start of the measurement for tau = 1 .. 100 sec. The number of phase samples the analysis is based on is given in the table as well. This data is continuously provided for every channel. In the examples shown below the reference channel is the channel #6. For this channel no direct measurement data is available. The display software, however, displays data for 6 channels. In the example the channel #6 displays the difference of the channels #1 and #2. The current frequency offset is displayed (“Drift[ps/s]”) for every channel.



On-line monitoring channels 1 to 3

The inputs Hi[0] to Hi[2] are configured to these 3 display channels.



On-line monitoring channels 4 to 6

The inputs Hi[3] and Hi[4] and the difference Hi[0] - Hi[1] are configured to these 3 display channels.

The following screen shot shows the summary screen of the display software. It gives the Allan Deviation for tau = 1 .. 100 000 sec.

The number given below the headline (“Channel x”) gives the number of phase samples being analyzed. Current measurement values are given for both phase comparators, the low resolution one (“LoRes Pha[ps]”) and the high resolution one (“HiRes Pha[ps]”). Furthermore the current frequency offset is given (“Drift[ps/s]”). The beat note (“Beat Freq[Hz]”) allows the expert checking the integrity of the PCO functions. It is in the order of 10 kHz for the measured channels and it is almost zero (= difference of the both values) for the logical channel being the difference of two measured channels, here (“Channel 1 – 2”).

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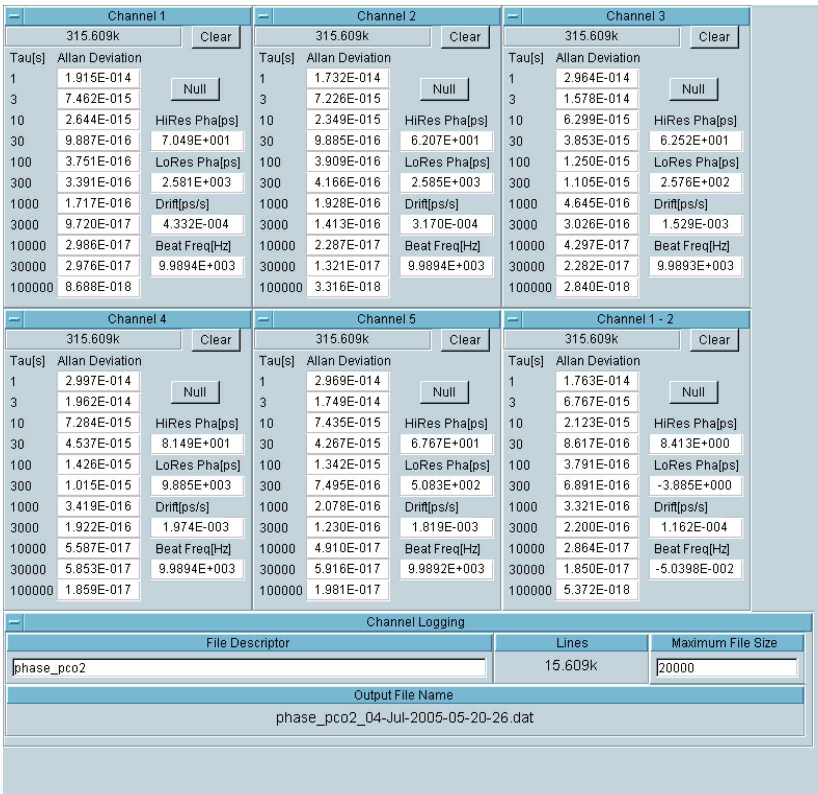

Summary screen of the Display Software

Three-Corner-Hat Software (Option 6)

When doing an ADEV measurement comparing the output of the device under test (DUT) to a single reference clock then the ADEV result reflects the joint instability of both clocks. For accurate measurements the reference clock needs to be far more stable than the DUT so that the contribution of the reference clock to the ADEV result can be ignored.

The Three-Corner-Hat method is used if the performance of almost equally performing clocks needs to be measured. Simultaneous phase measurements of any clock versus any other clock are made. With this data the performance of each single clock is calculated by the Three-Corner-Hat software.

The screen shot below shows an example measurement. For the measurement three ultra stable oscillators (USO) were locked to a stable reference frequency with the PLL loop control time constant at tau=10s. This means that the USO performs like free running for ADEV at tau=1s. The samples were taken at one second time intervals. The purpose of this test was to measure the ADEV at 1s for the USOs under test (i.e. USOs with the serial numbers 404, 199, and 102).

The traces in the screen shot show the running ADEV at 1s for each individual USO. The tables above the traces show the running ADEV (MIN, MAX) for several time intervals tau as well as the normal ADEV.

When comparing the results for the three USOs it can be noted that the performance of the USO 404 is more than a factor two better than that of the USO 102 (for ADEV at 1s: 6.3×10^{-14} vs. 1.5×10^{-13}). This shows that the Three-Corner-Hat method is even able to resolve considerable differences in the performance between the measured clocks.

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Phase Comparator

6 Channels, 100 MHz with 5/10 MHz Option

Part No: 10265

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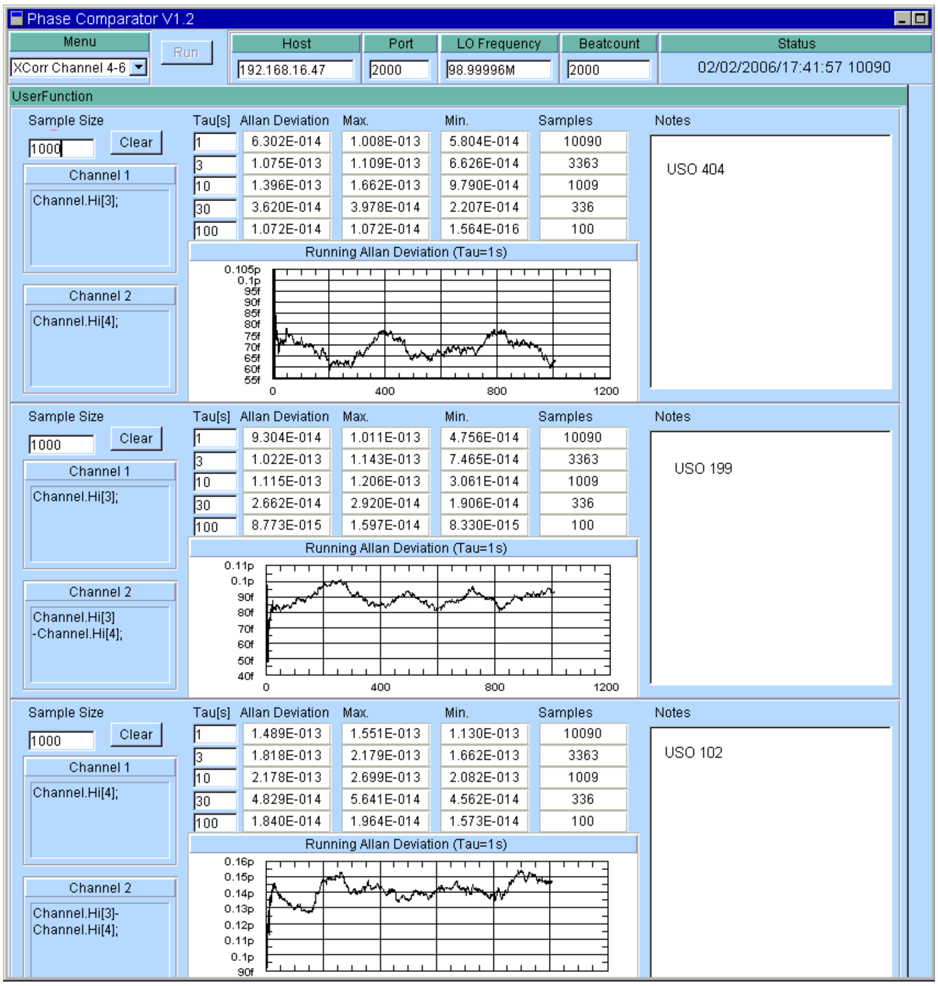

Three-Corner-Hat measurement example screen shot (for description see the text above)

Performance Specification

	5 MHz	10 MHz	100 MHz
Input level	+3 .. +15 dBm	+3 .. +15 dBm	+0 .. +7 dBm
… for optimal performance	+7 .. +15 dBm	+7 .. +15 dBm	+5 .. +7 dBm

Residual ADEV	**5 MHz**		**10 MHz**		**100 MHz**	
	spec	typ	spec	typ	spec	typ
1 sec	$6.0 * 10^{-14}$	$3.0 * 10^{-14}$	$3.0 * 10^{-14}$	$2.5 * 10^{-14}$	$2.5 * 10^{-14}$	$1.8 * 10^{-14}$
10 sec	$1.5 * 10^{-14}$	$9.1 * 10^{-15}$	$6.0 * 10^{-15}$	$4.3 * 10^{-15}$	$3.5 * 10^{-15}$	$2.3 * 10^{-15}$
100 sec	$4.0 * 10^{-15}$	$2.6 * 10^{-15}$	$1.2 * 10^{-15}$	$8.1 * 10^{-16}$	$5.0 * 10^{-16}$	$3.3 * 10^{-16}$
1 000 sec(1)	$1.0 * 10^{-15}$	$5.2 * 10^{-16}$	$2.5 * 10^{-16}$	$1.6 * 10^{-16}$	$1.2 * 10^{-16}$	$8.4 * 10^{-17}$
10 000 sec(1)	$3.0 * 10^{-16}$	$9.9 * 10^{-17}$	$9.0 * 10^{-17}$	$5.5 * 10^{-17}$	$4.0 * 10^{-17}$	$2.7 * 10^{-17}$
100 000 sec(1)	$3.0 * 10^{-16}$	$9.9 * 10^{-17}$	$9.0 * 10^{-17}$	$5.5 * 10^{-17}$	$2.0 * 10^{-17}$	$5.5 * 10^{-18}$

Note 1: Measurements at these time intervals depend heavily on external temperatures. Specified values are guaranteed only in thermally controlled laboratory environment (+18 to +24°C, slopes < 0.2K/h, variation <0.5Kpp). Use of phase stable cables – such as FSJ1, TCOM-400, LMR-400) is mandatory for runs of more than 20 cm. Operation in standard non-climatised environment limits noise floor to some parts in 10^{-17} for the 100 MHz channels.

Frequency offset (operational)	$< 1 * 10^{-8}$
Frequency offset (full spec)	$< 1 * 10^{-12}$
Connectors	SMA

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System Specification

Measurements		
Number of channels	6	
Number reference inputs	1 (any one of the six channels)	
	Definition of the reference channel	Monitor & Control SW
Virtual channels	Any combination of two channels by use of Display Software	Display SW
Real time measurements	Phase, frequency, and ADEV per channel	Display SW
Measurement output	Phase data is collected in files the format of which is compliant to the needs of the STABLE32 software. Storage capacity of an external PC is required for this.	Monitor & Control SW

Electrical interface		
Supply voltage DC	18 to 32 V DC	As an option the device can be equipped with redundant (double) DC supply input.
Supply voltage AC	90 to 265 V AC, 47 to 65 Hz	
Source selection	Load sharing between AC and DC inputs	
Power Consumption	< 60 watts	

M & C interface		
Serial line	RS232, 9 pin Sub-D male	
Protocol	19200 bps, 8N1, plain ASCII	
Ethernet	10 Mbit twisted pair (RJ 45)	
TCP services	telnet (remote screen)	port 23
	command, data output	port 2000, 2001, configurable
UDP services	syslog client	port 514
	tftp server	port 69
	data output	port definable
	ntp client	port 123
Monitored items	ADEV, phase, frequency, instrument status & control	
Commandable items	Measurement start, stop, clear	

Front display	LCD display, 2 lines, 40 characters Monitor display per channel: signal presence + phase and frequency offset versus the reference channel. 8 push buttons for basic instrument setup and configuration.
Mechanical	
Outline, Weight	19 inch, 2 height units (448.8 mm ∗ 88 mm), depth 265 mm, weight 8 kg.
Environmental	
Transportation and Storage	
Temperature, Humidity	-20°C to +75°C, 10% to 90% (non condensing)
Shock	max 10g acceleration for 11 ms
Vibration	max. 0.15 mm at 5 to 8 Hz, max 1g acceleration at 8 to 500 Hz
Altitude	< 20000 m
Operation	
Temperature	0°C to +50°C (spec. valid for +18..+24°C, slope < 0.2K/h)
Humidity	20% to 90% (non condensing)
Altitude	< 3000 m

External PC requirements (not part of the PCO unit)	
System	WINDOWS 2000, XP, or higher, Processor clock >/= 1 GHz, RAM >/= 250 MB.
Measurement data volume	< 40 MB/day. The measurement data is segmented in daily or hourly files.
Availability requirement of PC and of the interconnection network	The external PC needs to be continuously available over all the measurement time interval. The measurement data is transmitted at a rate of 1 message per second.
Operation mode	Shared operation with the Monitor & Control SW running in the background is possible but not recommended. It is preferable to have a dedicated PC for data collection.

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