3120A Phase Noise Test Probe

User Guide
3120A Test Probe
098-00520-000 Rev. A
19 November 2012

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Revision History

Revision	Date	Description
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Introduction

The 3120A Phase Noise Test Probe measures the amplitude, phase and frequency stability of RF sources and two-port devices at frequencies from 0.5 MHz to 30 MHz.   Results can be viewed at timescales ranging from femtoseconds to days.

Measurements made by the 3120A Test Probe include the following:

- Real-time ‘strip charts’ of phase and frequency differences at subpicosecond precision
- Absolute frequency counts at 13+ digits per second, 17 digits maximum
- Allan deviation (ADEV) typically less than 1E-13 at t=1s
- Modified Allan deviation (MDEV), Hadamard deviation (HDEV), and time deviation (TDEV)
- Phase noise and AM noise at offsets from 1.0 Hz to 100 kHz and levels below -170 dBc/Hz
- RMS-integrated time jitter with less than 100 fs residual jitter from 0.01 Hz to 100 kHz
- RMS-integrated phase noise, residual FM, and SSB carrier/noise ratio

Using high performance host-based DSP techniques on a Windows® PC, all of these measurements can be made simultaneously. Real-time results appear as you watch – and you can save, view, compare, export, or print them at any time.   Accuracy and stability are inherited from a user-supplied external reference which can run at any frequency within the supported range, with no calibration required by the instrument itself.

To get a jump start on setting up your 3120A Test Probe and taking measurements, see "Making your first measurements" on page 13.

Note: For brevity, throughout the rest of this user guide, 3120A Phase Noise Test Probe will be referred to as 3120A Test Probe, and 3120A Phase Noise Test Software will be referred to as 3120A Test Software.

Options

The 3120A Phase Noise Test Probe is very flexible. The 3120A Test Probe comes with a basic measurement capability. Through the purchase of additional measurement options, the 3120A Test Probe measurement capability can be customized to meet the user's needs.

Four options are available to extend the measurement capabilities of the standard 3120A Test Software. Each option is enabled by a unique license key which is available for purchase from Symmetricom at any time. For example, on a manufacturing test line there may be several 3120A Test Probes, each with its own combination of licensed options. Measurements made by each individual 3120A Test Probe include any optional features or data types that were licensed for that particular instrument. For example, probe A could have the Signal Statistics option enabled through entry of an appropriate license key, while probe B might lack this option. Plots acquired by probe A would support measurements such as integrated jitter or modified Allan deviation (MDEV), while those acquired by probe B would not. When viewing the resulting measurements in the 3120A Test Software, the plots acquired by probe B will lack the optional traces and graph legend fields that are visible in plots from probe A.

Option licenses

The 3120A Phase Noise Test Probe can be purchased as a basic instrument, for which up to four options can be purchased. Each option has a license associated with it. The license is issued at the time the option is purchased. All options are field-installable by the end user.

Part numbers for the option licenses available are:

- 920-05330-01 (AM Noise)
- 920-05330-02 (Signal Statistics)
- 920-05330-03 (Frequency Counter)
- 920-05330-04 (Mask Test)

This user guide has been written as if all four licenses have been purchased.

AM Noise:

This option allows the 3120A to measure the AM noise spectrum of the input signal. Results are displayed in dBc/Hz at offsets from 1 Hz to 100 kHz, with typical instrument noise below -165 dBc/Hz at 10 kHz (-160 dBc/Hz specified performance). Applications include evaluation of high-performance HF oscillators, signal generators, and frequency standards, as well as residual AM measurement of distribution amplifiers and other two-port devices.

Signal Statistics:

The Signal Statistics option provides additional statistics for advanced stability monitoring and characterization. These include modified Allan deviation (MDEV), Hadamard deviation (HDEV), and time deviation (TDEV) for frequency stability measurements, as well as jitter, residual FM, and SSB carrier/noise levels between user-specified integration limits in phase noise measurements. As with all of the 3120A's standard measurement views, results are displayed and updated in real time.

Frequency Counter:

This option adds a real-time chart of absolute frequency measurements to the Frequency Difference graph. The chart is continuously updated at averaging times from less than one second to over 1000 seconds. Accuracy is determined solely by the external reference, with usable precision typically greater than 13 digits per second. The Frequency Counter option turns the 3120A into a dramatically superior alternative to traditional counters in high-performance HF measurements, including calibration of atomic frequency standards and ultra-high performance HF oscillators.

Mask Test:

The Mask Test option takes the visual guesswork out of performance optimization and production testing. With this option, measurements made by the 3120A are automatically evaluated against user-definable limit lines for phase noise, AM noise, Allan deviation, and other graph types. Pass/fail results and margins are continuously updated in the graph legend table as the measurement progresses.

Mapping options to measurements

Aiming to be comprehensive, this manual has been written with the assumption that all four options have been keyed into the probe. When that particular probe is then connected to a PC running the 3120A Test Software, everything in this manual applies.

The following gives an approximate mapping of measurent tests available for each option.

- **AM Noise** option with the “**Phase Noise, AM Noise and jitter** “ section.
- **Signal Statistics** option with the "**What is Allan Deviation ADEV**“ section.
- **Frequency Counter** option with the “**Working with phase and frequency difference traces**“ section.
- **Mask Test** option with all of the sections.

This manual was written to provide an overall understanding of the 3120A Test Probe.

Specifications

Input frequency and level	0.5 MHz – 30 MHz, -5 dBm - +20 dBm, 50 ohm TNC-F
Reference frequency and level	0.5 MHz – 30 MHz, -5 dBm - +20 dBm, 50 ohm TNC-F
Input/reference VSWR	(0.5-25 MHz)1.5:1 or better
Input/reference port isolation(10 MHz)	130 dB or better
Maximum allowed DC at any RF input	+/- 5V
Allan deviation (5 MHz-25 MHz t=1s)	1E-13 minimum, 5E-14 typical (50 Hz ENBW)
Allan deviation (5 MHz-25 MHz, t=1000s)	5E-15 minimum, 1E-15 typical
Phase stability (5 MHz)	Less than 10 ps/hour after 2 hour warmup. Typically below 3 ps/hour
Residual phase noise floor (5 MHz, 1 Hz)	-140 dBc/Hz minimum, < -145 dBc/Hz typical
Residual phase noise floor (25 MHz, 1 Hz)	-130 dBc/Hz minimum, < -135 dBc/Hz typical
Residual phase noise floor (5 MHz, 10 kHz)	-170 dBc/Hz minimum, < -175 dBc/Hz typical
Residual phase noise floor (25 MHz, 10 kHz)	-165 dBc/Hz minimum, < -170 dBc/Hz typical
Residual AM noise floor (5 MHz, 10 kHz)	-160 dBc/Hz minimum, < -165 dBc/Hz typical
Spurious responses (5 MHz, 1 Hz-100 kHz)	Less than -100 dBc (phase noise) or -90 dBc (AM noise) Typically below -120 dBc
Physical dimensions	280 mm x 120 mm x 75 mm, 1 kg 11” x 5” x 3”, 2 pounds
Power requirements	3-pole AC inlet IEC320-C14 90-264 VAC, 47-63 Hz, < 25W Caution: Use only the Mean Well MN P25A14E-R1B Power Supply supplied with this unit. Use of a different power supply could cause damage to the unit. Attention : Utilisez uniquement la moyenne bien MN R1B-P25A14E d'alimentation fourni avec cet appareil. Utilisation d'une alimentation différente peut endommager

	l'unité.
Ambient tem-perature	60F to 95F operating, 0F to 125F storage90-264 VAC, 47-63 Hz, < 25W
Certifications	FCC, CE, KCC, VCCI

Note: Due to the use of cross correlation to cancel instrument noise, the phase noise and AM noise floors depend strongly on the measurement time and available signal levels. Residual specifications assume that measurements are made after a two-hour warmup period in a temperature-stable environment with +15 dBm at both INPUT and REF IN jacks and Trace→Smooth noise traces enabled. Under these conditions, 5-10 MHz signals are typically measurable to better than -170 dBc/Hz at offsets > 10 kHz after less than 10 minutes. Quieter signals, lower-amplitude signals, signals near the frequency-coverage limits, and measurements of very low close-in noise may require more time to converge.

Getting Started

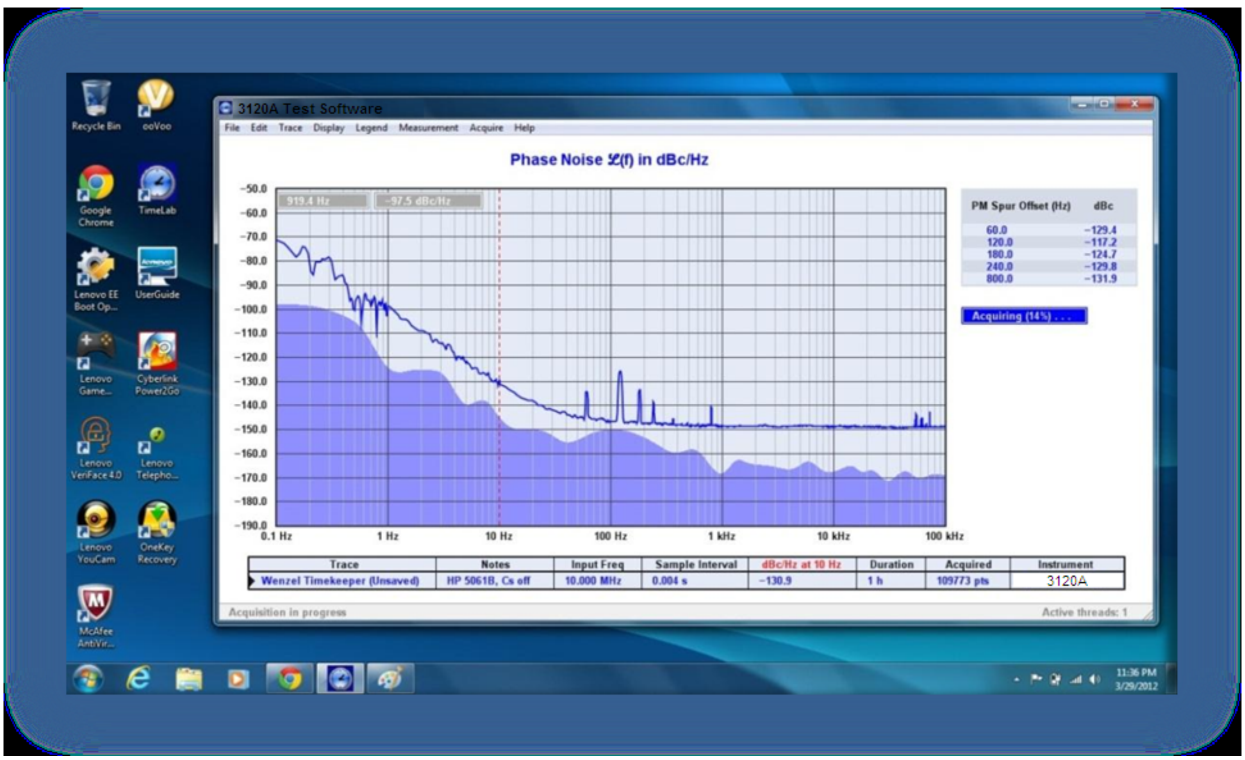
What’s in the box?

Please check the contents of your package carefully upon arrival. Each Symmetricom 3120A unit should be accompanied by the following items:

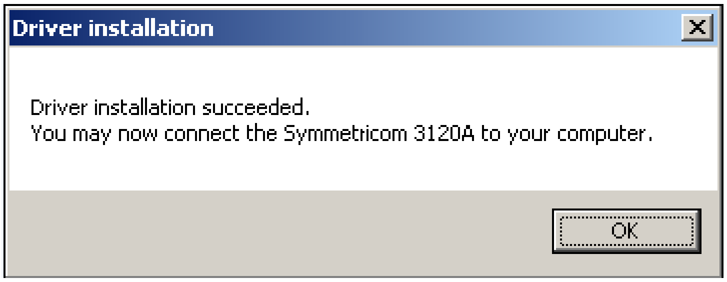
- (1) USB 2.0 cable, A Male / B Male
- (1) Power supply
- (2) TNC-M / BNC-F coax adapters
- (2) 1” (25.4 mm) SMA-M / SMA-M coax jumpers (preinstalled)
- CD-ROM with user guide

Additionally, each 3120A Test Probe delivered to North American customers includes a standard IEC320 / NEMA 5-15P power cord for 120V service.

USB driver and software installation



3120A Test Software runs on Intel® or AMD® x86-based PCs equipped with Microsoft Windows® XP SP2 or later versions. Minimum system requirements are 100 MB of disk space, 1 GB RAM and a CPU with SSE2 support. A dual- or quad-core processor is strongly recommended.



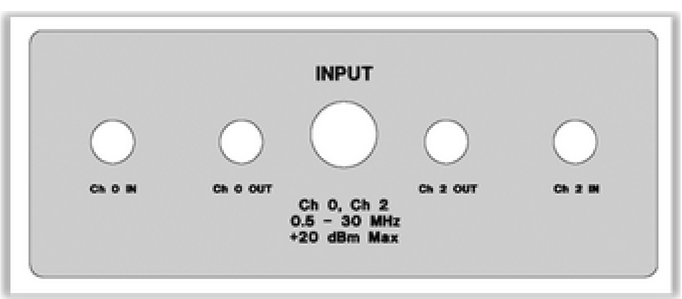
For best results, 3120A Test Software should be installed prior to connecting the 3120A Test Probe to your PC's USB port for the first time. Before exiting from the install program, make sure that the box labeled **Install 3120A Test Probe USB Driver** is checked. This will help Windows locate the USB driver without further intervention when the 3120A Test Probe is connected. After the driver has been successfully installed on your system, a confirmation message will appear.

To perform measurements with the 3120A Test Probe, an Intel Core 2 Duo or faster processor is required. Referring to the benchmarks at http://www.cpubenchmark.net/common_cpus.html, the minimum PassMark score for reliable acquisition falls in the 1,600 to 2,000 range.

Use of a system with inadequate CPU performance may result in acquisition errors, often accompanied by a flashing red fault indication on the 3120A's status LED. It may be necessary to disable one or more measurement types to achieve reliable operation in such cases. For example, if you are interested only in phase/frequency stability, uncheck the Phase Noise and AM Noise boxes in the Available Measurements area of the 3120A Test Software acquisition dialog.

For improved performance, a 64-bit version of 3120A Test Software will automatically be installed on x64-based systems. If you need to record long phase records with the 3120A (or any other equipment), an x64 system with several GB of RAM is recommended.

Front panel features



Four SMA jacks and one TNC jack are present on the 3120A Test Probe's input jack panel. In most applications, the input signal from the device under test should be applied to the centrally-located TNC jack labeled INPUT.

Internally, the INPUT jack is connected to a 50-ohm 0° RF splitter whose two outputs are routed to the SMA jacks labeled Ch 0 OUT and Ch 2 OUT. These jacks are normally connected to the adjacent Ch 0 IN and Ch 2 IN jacks using two SMA jumpers.

Although TNC interconnects offer superior mechanical stability, BNC-TNC adapters are also provided for convenience. Regardless of your choice of coax fittings, double-shielded cables such as RG223 or RG400 are recommended for low-level measurements that may be affected by crosstalk and environmental interference. Use of RG58 and other single-shielded cables can cause artifacts in stability and noise plots.

Input signals should be greater than 0 dBm for best performance -- +5 to +15 dBm is recommended. The 3120A Test Probe's specifications assume that sine-wave signals from 50 ohm sources are applied to the INPUT and REF IN jacks, but you can also measure CMOS and other square-wave clocks with the help of a simple L-network (resistive or otherwise) to attenuate the signal and increase the load impedance where necessary.[1]

Spur performance may be compromised with non-sinusoidal inputs. This is especially true at lower frequencies where multiple harmonics fall within the 0.5 – 30 MHz passband.

Why the added complexity?

Wouldn't a single input jack be enough?

The 3120A is really two identical instruments in one box. Each of these two "instruments" consists of a pair of software-defined HF receivers for the DUT and reference input signals. All four receiver channels are implemented with high performance 16-bit RF ADCs. During cross-correlated phase noise and AM noise measurements, the even-numbered channels (0 and 2) are assigned to the input ADCs, while odd-numbered channels (1 and 3) are associated with the reference ADCs.

Because the instrument noise originating within each ADC tends to be uncorrelated with the noise from that ADC's counterpart in the other "instrument," the differential-mode noise falls out of the cross-spectrum average, approaching zero amplitude over time. Ideally, only the desired phase and amplitude information will remain.

Like the input-channel ADCs (0 and 2), ADC channels 1 and 3 are fed identical copies of the signal at the REF IN jack through an RF splitter, but this signal path is only routed internally. Making the individual input ADC channels available with the Ch 0 IN and Ch 2 IN jacks is worthwhile, though, because it opens up some possibilities for advanced measurements.

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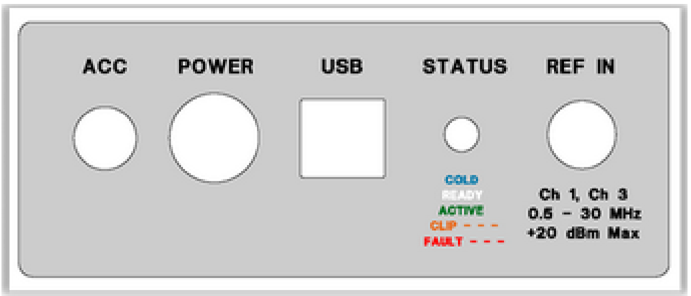
[1]Both the INPUT and REF IN jacks are coupled to their respective input splitters via 0.1 uF 100V capacitors. These capacitors are also present at the Ch 0 IN and Ch 2 IN jacks. However, application of DC levels greater than 5V peak to any RF signal input is not recommended.

For example, you can make low-noise measurements at VHF and microwave frequencies far beyond the 3120A's rated 30 MHz limit by using two identical downconverters to mix the DUT signal down to an IF in the supported 0.5 – 30 MHz range. If the Ch 0 and Ch 2 downconverter local oscillators are uncorrelated, their phase noise and AM noise contributions will disappear from the cross spectrum average over time, just like the ADC noise!

Rear panel features



The rear jack panel provides a TNC-F input for the external reference signal required in all 3120A Test Probe measurements. All guidelines regarding signal levels and interconnect choices for the INPUT jack also apply to the REF IN input. Suggestions for choosing appropriate reference sources appear in "Choosing an external reference" on page 11.

Additionally, the 3120A Test Probe's rear panel provides a 5-pin DIN jack for connection to the power supply (POWER), an 8-pin Mini DIN jack for future accessory expansion (ACC), and a USB Series 'B' receptacle for PC connectivity (USB).

The STATUS indicator is a high-brightness RGB LED that reveals the instrument status at a glance:

Blue	Present for the first few minutes while the 3120A Test Probe's internal OCXOwarms up.
White	The 3120A Test Probe is ready to acquire data. Stability measurements at 50 Hz and higher bandwidths may be performed as soon as the LED turns from blue to white, although a 30-minute warmup period is recommended. Input/reference drift warnings may occur with shorter warmup periods.
Green	A measurement is either pending or in progress. No fatal errors have occurred.
Flashing **purple**	Excessive signal level is present at either INPUT or REF IN, causing input clipping in one or more ADC channels. An unexpected increase in signal level after measurement has begun can cause this

	indication. This is not a fatal error, but acquired data is questionable. Damage may occur at input levels greater than +20 dBm.
Flashing **red**	A USB data overrun has occurred. This is a fatal error. Insufficient CPU power (or disconnection of the USB cable during a measurement) is typically responsible. You may be able to run the measurement successfully if you uncheck one or more of the Available Measurements options in the acquisition dialog.

USB 2.0

USB 2.0 High Speed support is required for all 3120A acquisitions. In most cases the use of passive or active USB hubs with the 3120A is acceptable, but if connection problems occur, you may find it helpful to connect the supplied USB cable directly to the host PC.

In general, measurement errors are much more likely to be caused by insufficient CPU resources than by USB connectivity problems.

Choosing an external reference

In addition to the host PC and an appropriate power source, all measurements made with the 3120A Test Probe require an external reference to be supplied at the REF IN jack. Virtually all aspects of measurement performance – accuracy, repeatability, noise floor, spurious responses – depend on your ability to provide the best reference signal possible.

But what does the "best reference possible" mean? It depends on the goal(s) of your measurement. Few reference sources are ideal for both short- and long-term measurements. Typical "house clocks" that distribute 5 or 10 MHz signals at levels between +5 and +20 dBm often work well for ADEV and other time/frequency measurements, but atomic and GPS standards that are often used as sources for centralized clock distribution may exhibit more short-term phase noise than an undisciplined crystal oscillator. Distribution amplifiers can also add substantial noise of their own, as well as phase drift at longer timescales due to temperature sensitivity. Finally, even when using the best standards, distribution amps and double-shielded cables, it's almost impossible to build a large clock distribution network that's free of environmental spurs. As a result, you should consider using a standalone low-noise OCXO for phase noise and AM noise measurements.

Unlike most other stability and noise analyzers, the 3120A Test Probe can work with any reference whose frequency lies within its specified range (0.5-30 MHz), regardless of the input frequency from the device under test (DUT). Frequency readings and phase noise levels are always referred to the frequency at the INPUT jack. For example, if your 10 MHz DUT's phase noise when measured with a 5 MHz reference is -160 dBc/Hz at 10 kHz and its

Allan deviation is 3E-12 at t=10s, you will still measure -160 dBc/Hz and ADEV=3E-12 if you switch to a 10 MHz reference, or one at any other frequency.

The only complication is the need to handicap the reference's phase noise and FM/PM spur amplitudes by 20*log10(F_{DUT}/F_{REF}) dB when the DUT and reference frequencies differ. This is the same consideration that applies at all other times when a signal undergoes broadband frequency multiplication or division. The effective phase noise and spur performance of the reference source would be 6 dB worse in the example above where a 5 MHz reference is used to characterize a 10 MHz device. Likewise, the reference's long-term stability characteristics (e.g., Allan deviation) would be degraded by a factor of 2.

Ideally, the phase noise of your reference after any applicable 20*log10(F_{DUT}/F_{REF}) correction should be at least 8-10 dB lower than the expected performance of the DUT at the offsets of interest. The reference's phase noise will not affect the measurement to any great extent as long as this margin is maintained.[1]

[1] This being said, it's sometimes useful to measure the phase noise or stability of a DUT by using an identical device as the reference. In such a case, where the phase noise of the reference and DUT is presumed to be identical but uncorrelated, the resulting PN graph will be 3 dB too high, while Allan deviation and related measurements will be artificially elevated by a factor of sqrt(2). You can use the Rescale Phase field in 3120A Test Software's Edit→Trace properties dialog to correct the ADEV of two identical devices by scaling the phase data by 0.707. Similarly, the phase noise may be corrected by entering -3 in the PN Gain field to lower the trace by 3 dB.

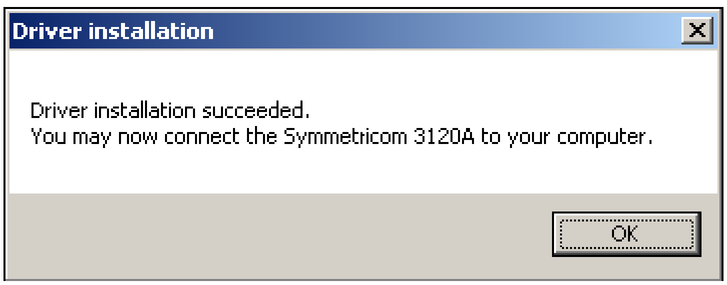
Making your first measurements

The 3120A Test Probe hardware is easy to work with once some basic measurement concepts are understood. As an introductory exercise – or a quick operational check – you may wish to perform a measurement using the default acquisition parameters in 3120A Test Software.

1. Load the 3120A Test Software

a. Insert the 3120A CD-ROM into a disk drive on your PC.

b. The Symmetricom 3120A Phase Noise Test Software will auto-run with an installation wizard. After a successful software load, you will see the following image.



Note: If the software does not auto-run, run the Setup.exe program on the CD-ROM.

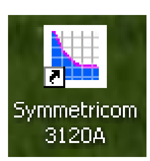
2. Connect 3120A to PC

a Connect the supplied USB cable between the 3120A Test Probe and a vacant USB port on your PC.

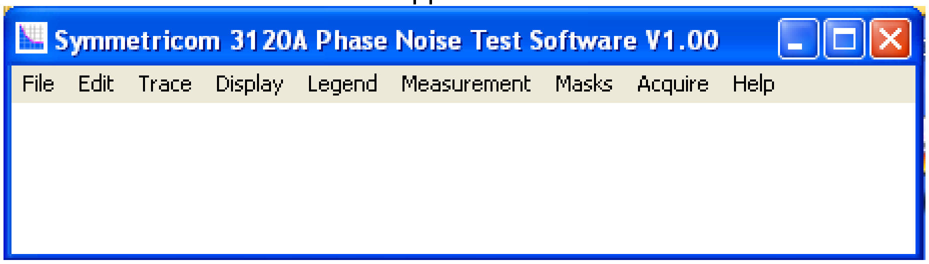
b. Connect the 3120A Test Probe to the supplied power source.

3. Launch the 3120A Test Software

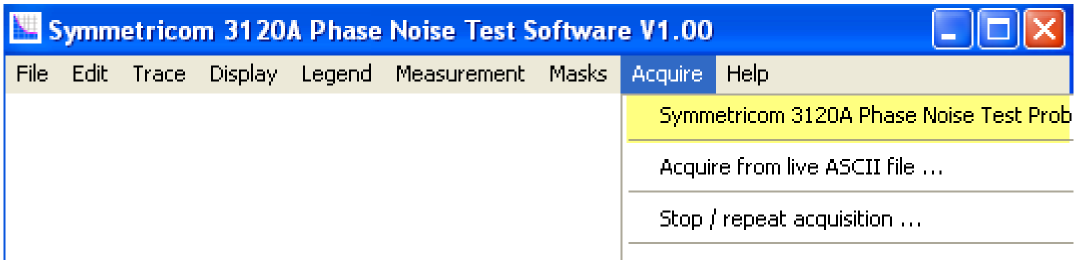
a. Double-click the Symmetricom 3120A software icon:



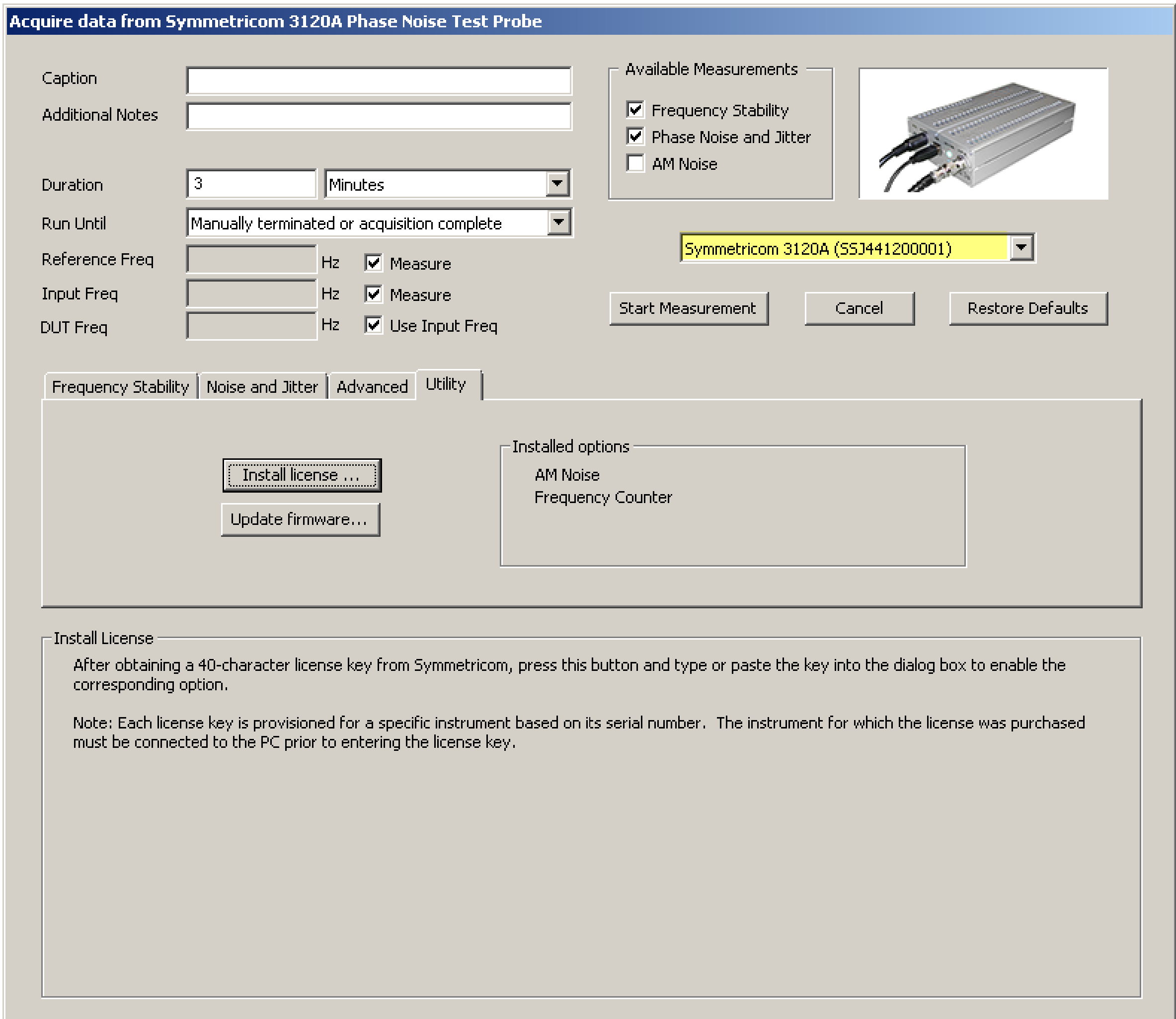
b. The software will launch and appear as follows.



c. In the menu bar of the image above, select **Acquire** > **Symmetricom 3120A Phase Noise Test Probe...** as highlighted below.



d. The 3120A measurement setup window opens.



e. Select the Symmetricom 3120A Test Probe as highlighted in yellow above.

4. Run the software

Assuming:

- The appropriate 3120A Test Probe is selected
- The acquisition parameters are all valid
- You've connected a stable reference, and input sources to the 3120A
- You've allowed at least a few minutes' warmup time

a. Press the Start Measurement button. The acquisition dialog will disappear and the STATUS indicator on the 3120A should change from white to **green**. Over the next ten seconds or so, various informational messages will appear in the 3120A Test Software status bar at the bottom of the program's main window as the software characterizes the applied input and reference signals.

b. If all is well, the status bar message should soon change to "**Acquisition in progress**." Measurement data will now begin to appear in graphical form. Unless you've selected a different view from the Measurement menu, you will see an Allan deviation (ADEV) plot for your DUT, rendered in real time at 100 points per second.

c. Unless you changed the Duration value, the measurement will run for three minutes. This will be long enough to allow the ADEV trace to reach τ=one minute, and for the phase noise trace to reach 1 Hz. You can try any of these suggested actions at any time, either during the measurement or after it finishes:

- Left-click on the ADEV graph or any other log-log plot. Observe that the red spot cursor can be placed at any vertical column. The graph's Y value at the spot cursor will be displayed in the legend table beneath the graph area, updated in real time to reflect the latest reading. At the same time, ADEV values at assorted tau periods should be displayed in a chart on the right side of the graph.

- Left-click and drag a box anywhere on the plot. When you release the left mouse button, the view should zoom in to magnify the specified area. You can drag an edge (or a corner) of the box slightly outside of the graph area to expand the plot in that direction. Right-click to return to the unzoomed view.

- Try selecting a few of the different graph types in the Measurement menu. Assuming you didn't uncheck any of the Available Measurements options in the acquisition dialog, all of the different graph types should be visible, updating continuously in a "live" fashion as long as the measurement is still in progress.

- Now is a good time to start picking up the keyboard shortcuts. Instead of selecting Measurement→Frequency difference, try the f key. To return to the Allan deviation plot, use a. Uppercase A selects AM noise, while uppercase P selects phase noise. (In some cases, the 3120A Test Software features and commands described in this manual will be referenced by their hotkeys rather than their menu entry names, after the menu entries have been introduced.)

- Save the measurement data to a .TFF file with File→Save image or .TFF file (s). A .TFF file is an ASCII text file that contains the data needed to recreate all of the available graphs associated with a given measurement. This data includes the entire phase record, as well as the FFT bins from the phase noise and AM noise plots. You don't have to wait for the measurement to end; at any time during a measurement, you can save the available data to a .TFF file or load another .TFF file for display alongside the existing plot(s) that have been loaded or acquired.

- Use File→Load .TFF file to read the .TFF file you just saved. Now you should have two copies of the same plot in memory. If the measurement is still in progress, you can switch to the p)hase or f)requency difference views to watch its phase record continue to grow while the saved copy remains unaffected.

For "power users," three of the most common commands in 3120A Test Software are Display→Browse plots one at a time (b), Display→Overlay all loaded plots (o), and Display→Toggle visibility of selected plot (v). Like many other commands, the b, o, and v commands operate on the so-called "selected" plot. If you've followed along with the suggested command demonstrations above, then you should have two (or more) plots loaded, and you can experiment with these concepts.

- First, select any desired Measurement view and press the b key to enter Browse mode. Observe that only one of your plots is now visible.
- Furthermore, notice that two things happen when you press the up/down arrow keys (Display→Select next plot in chart / Display→Select previous plot in chart). A small black triangular cursor at the leftmost edge of the legend table moves up and down… and the plot that it points to is also the one that becomes visible. In Display→Browse mode, entries in the legend table corresponding to all of the unselected plot(s) are grayed out, and those plots aren't shown in the graph.
- You can put things back to normal by pressing o to return to Display→Overlay mode. The idea of a "selected" plot still exists, but it no longer determines which plots are visible in the legend table and graph areas.
- In Display→Overlay mode, all of the loaded plots are visible, all of the time, unless individually hidden with the Display→Toggle visibility of selected plot (v) feature. To avoid confusion the v key doesn't do anything in Display→Browse mode, but in Display→Overlay mode it does just what it sounds like – it toggles the visibility of the selected plot in both the graph area and the legend table. This panoply of options may seem confusing at first, but it's nothing compared to the jumble of line segments and shaded areas that can appear on the graph when all nine available slots in the legend table are populated with visible plots!
- Regardless of the choice of Display→Browse or Display→Overlay mode or the visibility status of any given plot, the "selected plot" concept is still useful for indicating which plot should contribute to the frequency-count chart in the Measurement→Frequency Difference (f) view, the sigma-tau charts in the various xDEV measurement views, and the spur tables in the noise measurement views. The selected plot is also the only one that's saved, exported, modified, edited, or moved up and down in the legend table when the corresponding commands are issued.

The last point above is an important one – many users new to 3120A Test Software are surprised to discover that a single .TFF file doesn't represent an entire screen full of plots. Each plot must be saved, loaded, and otherwise processed individually. None of the commands on the File or Edit menus in 3120A Test Software operate on more than one plot at a time, except for File→Close all plots (Home) and the various image-based operations like File→Print image (Ctrl-p), File→Copy image to clipboard (Ctrl-c), and File→Save image or .TFF file (s) when the latter command is used to save a .png, .bmp, .tga, .gif, or .pcx image of the entire screen.

Tips for new users

- In 3120A Test Software, almost everything you can do from the menus has a keyboard equivalent, in many cases a single key. Time spent becoming familiar with the keyboard shortcuts will be rewarded!
- The acquisition dialog (Acquire→Symmetricom 3120A Phase Noise Test Probe) contains a Utility tab with a button labeled Update Firmware which will upload new .FX2 or .BIT files to nonvolatile memory on the 3120A. .FX2 files contain 8051 firmware for the onboard USB 2.0 controller, while .BIT files contain FPGA configuration data.
- Use the 3120A in a room with good ambient temperature control for best results. Avoid placing the hardware near HVAC vents or other sources of drafts when making high-performance measurements.
- Also for best results, avoid placing the 3120A Test Probe immediately next to equipment that may operate at high temperatures, as well as equipment that should not be exposed to heat. Normal case temperatures may reach 40C to 45C after several hours' operation.
- Do not disturb the measurement setup mechanically, move cables around, or otherwise interact with the environment unnecessarily during acquisition. After the measurement ends, you can use 3120A Test Software's phase-record editing features to get rid of known glitches, but nothing can be done to restore a corrupted noise plot. Any glitches that affect the phase noise or AM noise plots will require a restart.
- Every measurement in 3120A Test Software runs in its own background thread, so you can load, save, and manipulate plots or even launch additional acquisitions with other instruments while an acquisition is running. This is subject to available memory and CPU resources, of course. A typical 3120A Test Probe acquisition takes about 16 MB/sec of USB bandwidth and about one core's worth of CPU horsepower.
- When equipped with multiple USB host controllers, the fastest available PCs can acquire data from up to four 3120A Test Probes concurrently. Most PCs will be limited to two concurrent acquisitions at most.
- The acquisition dialogs in 3120A Test Software all have large "mouseover" help windows. The help text serves as hardware-specific documentation for the various analyzers and counters supported by the3120A Test Software. Read it carefully before changing any fields from their default values.
- Attempting to run Frequency Stability measurements with large phase records and high data rates may result in "Couldn't allocate phase record" or similar messages indicating a lack of available RAM. Running on an x64 system can help avoid memory problems, as they can access much more RAM than legacy 32-bit Windows systems.
- When contacting Symmetricom for technical support, it's a good idea to attach .TFF file(s) associated with the issue, rather than image files. .TFF files greater than 3 MB in size should be zipped or otherwise compressed. If you don't receive a reply within 48 hours, please email again (without the attachment) to confirm delivery.

Updating the 3120A's internal firmware

Should it become necessary to reinstall or upgrade the 3120A's operating firmware, start the 3120A Test Software application and select Acquire->Symmetricom 3120A Phase Noise Test Probe from the menu. Ensure that the target instrument is connected to the PC and that the PC is operating on AC power, or is otherwise protected from power loss or interruption during the update process. Select the 'Utility' tab in the acquisition dialog and press the 'Update firmware...' button. A Windows file dialog box will appear, allowing you to browse for either .BIT files or .FX2 files.

Firmware files supplied by Symmetricom technical support may consist of .BIT files, .FX2 files, or both. .BIT files contain the FPGA firmware responsible for measurement data processing on the 3120A, while .FX2 files contain firmware related to USB device connectivity. In either case, the firmware installation process should take less than a minute. It's not necessary to power-cycle the 3120A after firmware installation.

Installing an option license key

After obtaining a 40-character license key from Symmetricom, start the 3120A Test Software application and select Acquire->Symmetricom 3120A Phase Noise Test Probe from the menu. Ensure that the target instrument is connected to the PC. Select the 'Utility' tab in the acquisition dialog, then press the 'Install license...' button. A dialog box with a text input field will appear. Type or paste the 40-character license key into the field and press 'OK.' The 3120A Test Software will then confirm the presence of the newly-installed options.

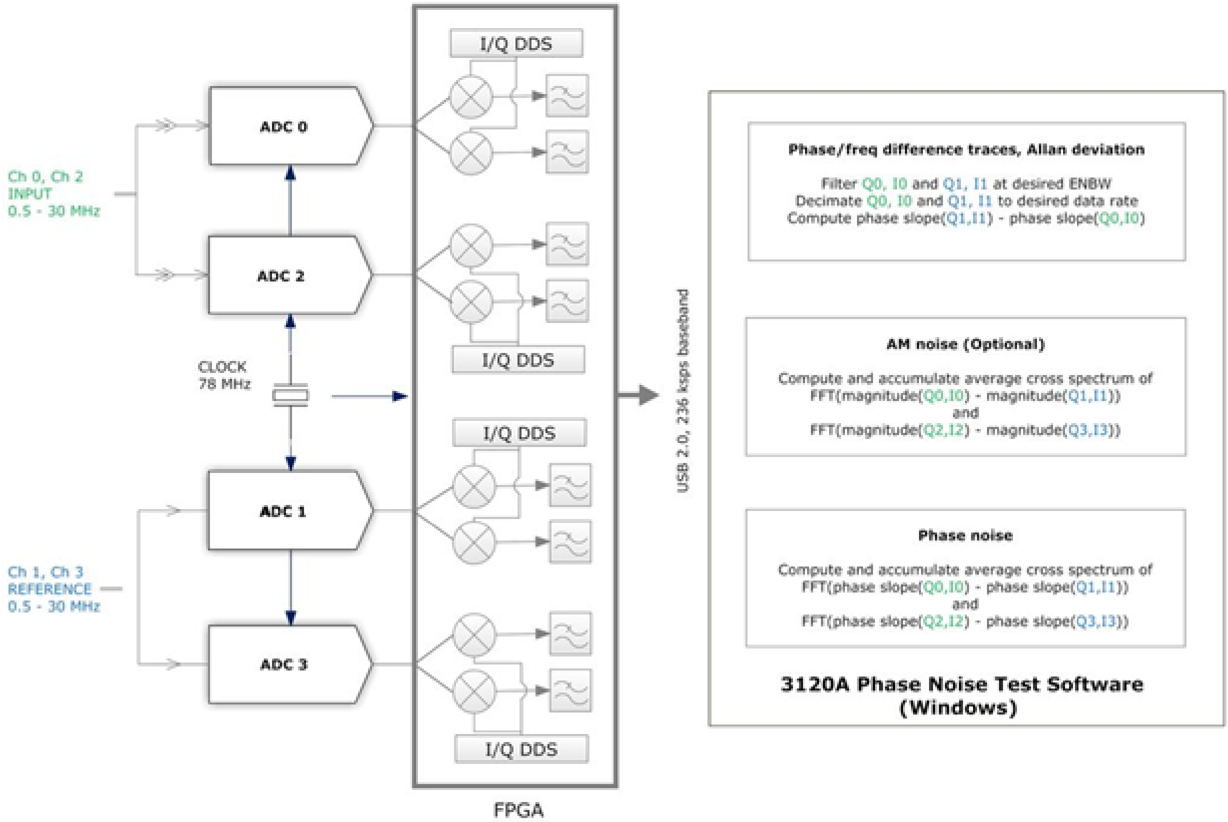
When the AM Noise option is installed, the AM Noise check box will become available for selection in the 'Available Measurements' area of the acquisition dialog, as long as the instrument for which the option is licensed is connected to the PC and selected in the acquisition dialog's dropdown list.

When the Signal Statistics option is installed, the Hadamard deviation, time deviation, and modified Allan deviation traces will be displayed during Frequency Stability measurements acquired by the instrument for which the option was licensed. During phase noise measurements, you will be able to view integrated noise and jitter measurements in the legend table below the graph by selecting the Residual FM, RMS Integrated Noise (Degs), RMS Integrated Noise (Rads), RMS Time Jitter, and/or SSB Carrier/Noise fields in the Legend menu.

The frequency count chart will be visible in the Measurement -> Frequency Difference (f) view when the selected trace corresponds to a measurement made by a 3120A with the Frequency Counter option installed.

Finally, when the Mask Test option is installed, the Mask Result and Mask Margin fields in the legend table below the graph will be updated when a valid mask for the current measurement type is selected in the Masks menu. As with the other options, Mask Test and Mask Result data will be present only when the selected trace corresponds to a measurement made by a 3120A with the appropriate option installed. Otherwise, these fields will remain blank.

A brief architectural note



It can be helpful to understand some basic details about the 3120A Test Probe's DSP topology, especially when measurements may be constrained by available memory and CPU resources. A key observation is that each of the three basic measurement types -- Frequency Stability, Phase Noise and Jitter, and AM Noise -- uses a completely separate data record and internal pipeline.

The "phase record" mentioned in the documentation and help text has nothing to do with Phase Noise measurements, for example. Instead, the phase record and its associated controls are used only for Frequency Stability measurements. These include ADEV, MDEV, TDEV, and HDEV, as well as the frequency- and phase-difference plots.

Referring to the diagram above, the phase record is created from two parallel streams of 236 ks/sec complex data samples arriving from one input channel (Q0,I0) and one reference channel (Q1,I1). These two streams are decimated to accommodate the requested measurement bandwidth (ENBW) – typically 5 to 500 Hz.   The phase differences between corresponding samples in the two low-bandwidth streams are then calculated and used to construct the various xDEV plots as well as the frequency-difference plot.

So, when you save a Frequency Stability measurement to a .TFF file, you're actually saving these low-bandwidth phase differences. If you use Edit→Remove selected or zoomed phase data (F4) or the various flattening or trend-removal functions to edit parts of the phase record after acquisition, the xDEV and frequency-difference plots will be recalculated, but nothing will happen to the phase noise or AM noise plots. These graphs are created by calculating phase and/or amplitude differences for all four baseband streams -- Q0,I0, Q1,I1, Q2,I2, and Q3,I3 – at the full 236 ks/sec data rate. The resulting data is then processed by FFT and cross-spectrum averaging routines. Because it would be impractical to retain the original high-bandwidth complex baseband data or any phase or amplitude information derived from it, only the averaged FFT output bins are written to the .TFF file when saving the phase noise or AM noise portion of a measurement.

Making measurements

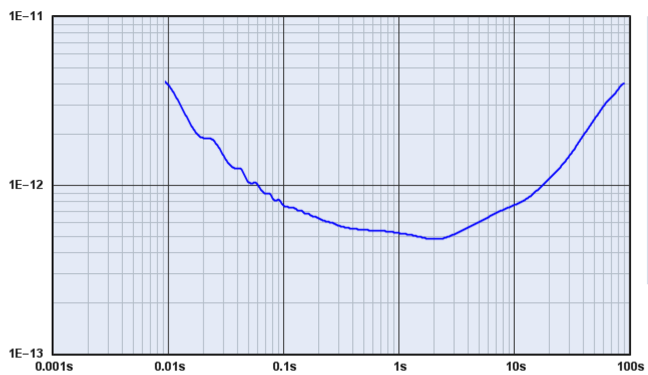
Three views of the same measurement appear below, in which a GPS-disciplined oscillator was used as a reference to measure a high-quality HP 10811 OCXO.

The Allan Deviation plot can reveal frequency stability at timescales from milliseconds to days, while the Phase Noise plot can show you the signal’s USB spectral signature at offsets from 0.01 Hz to 100 kHz. (Here, the GPS clock dominates the noise and spur picture by a wide margin!)

Valuable insights can be gained by looking at your data from more than one point of view. For instance, the visible ADEV ripple below 0.1 second corresponds to the 60-Hz and 120-Hz AC line spurs in the phase noise plot.

Meanwhile, drift and sporadic instability can be examined in the Frequency Difference display. When using a 3120A Test Probe, the frequency-count chart offers over 13 digits per second of usable precision at “gate times” from 0.1 second to over 1000 seconds.

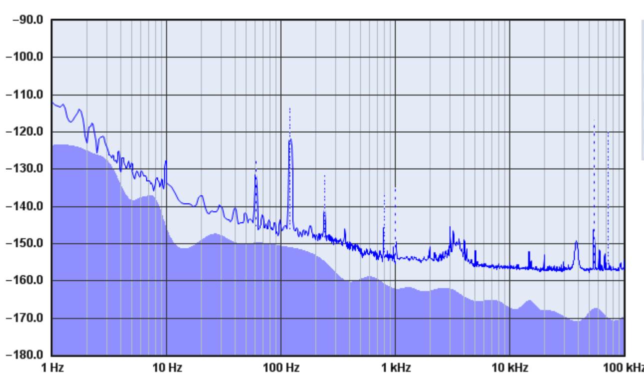
Allan Deviation



Tau	Sigma(Tau)
0.01s	3.87E−12
0.02s	1.94E−12
0.04s	1.26E−12
0.08s	8.43E−13
0.1s	7.63E−13
0.2s	6.42E−13
0.4s	5.58E−13
0.8s	5.37E−13
1s	5.26E−13
2s	4.85E−13
4s	5.69E−13
8s	7.24E−13
10s	7.73E−13
20s	1.11E−12
40s	2.02E−12
80s	3.78E−12

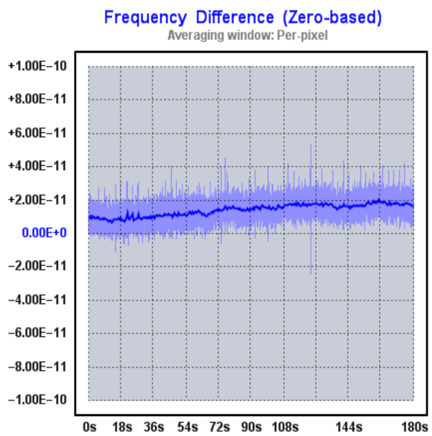
Trace	Input Freq	Input Amplitude	Ref Freq	Sample Interval	ENBW	Elapsed	Instrument
HP 10811-60109	10.000 MHz	13 dBm	10.000 MHz	0.004 s	52.7 Hz	3m 0s	3120A

Phase Noise ℒ(f) in dBc/Hz



PM Spur Offset (Hz)	dBc
60.0	−126.6
120.0	−113.2
240.0	−131.7
800.0	−137.0
1000.0	−135.1
54910.0	−116.8
72810.0	−119.6

Trace	Input Freq	Input Amplitude	Ref Freq	Sample Interval	ENBW	Elapsed	Instrument
HP 10811-60109	10.000 MHz	13 dBm	10.000 MHz	0.004 s	52.7 Hz	3m 0s	3120A



Origin	Drift (Hz/sec)	Drift (Hz/min)
+8.64E−12	+6.14E−7	+3.68E−5

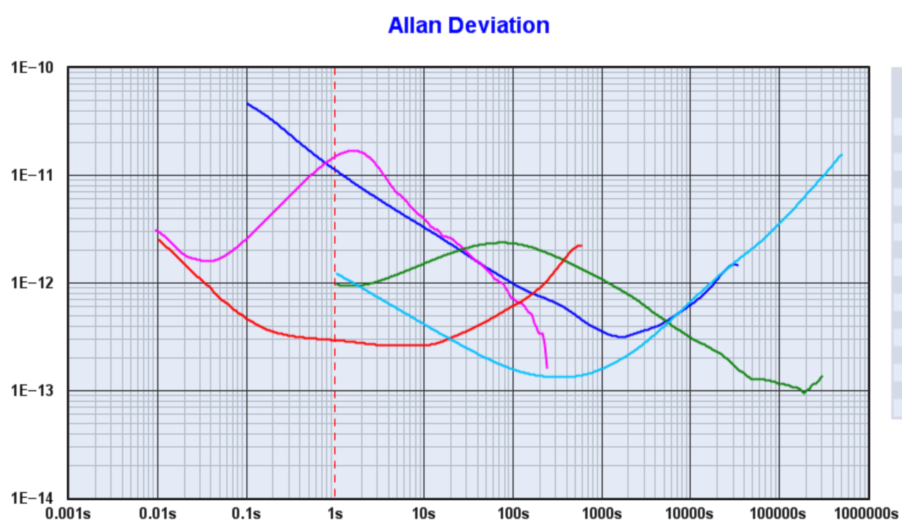
Avg Time (s)	Freq (Hz) at 180s	Error
0 . 100	10 000 000 . 013 018 839	+1.30E−9
0 . 300	10 000 000 . 013 017 127	+1.30E−9
1	10 000 000 . 013 019 862	+1.30E−9
3	10 000 000 . 013 023 891	+1.30E−9
10	10 000 000 . 013 027 977	+1.30E−9
30	10 000 000 . 013 032 110	+1.30E−9
100	10 000 000 . 013 020 335	+1.30E−9

Trace	Input Freq	Input Amplitude	Ref Freq	Sample Interval	ENBW	Elapsed	Instrument
HP 10811-60109	10.000 MHz	13 dBm	10.000 MHz	0.004 s	52.7 Hz	3m 0s	3120A

What is Allan Deviation (ADEV)?

Here are a few tips to help you understand what Allan deviation (ADEV) graphs really tell you, and how to get the most out of the statistical deviation measurements made by 3120A Test Software.

Allan deviation is defined as the two-sample deviation of fractional frequency differences at a given time interval. While technically correct, such definitions may be unenlightening to new users. Often, the first question asked is something like, “Why did my plot stop at 1000 seconds? It took an hour to run!”



Tau	Sigma(Tau)
0.1s	4.74E−11
0.2s	3.22E−11
0.4s	2.01E−11
0.8s	1.29E−11
1s	1.13E−11
2s	7.63E−12
4s	5.27E−12
8s	3.70E−12
10s	3.31E−12
20s	2.31E−12
40s	1.59E−12
80s	1.11E−12
100s	9.96E−13
200s	7.62E−13
400s	5.79E−13
800s	3.95E−13
1000s	3.58E−13

Trace	Notes	Input Freq	Sample Interval	ADEV at 1s	Duration	Instrument
LPRO-101 Rb	HP 5065A Rb	10 MHz	0.1 s	1.13E−11	20 h	A3120A
SRS PRS10 Rb	HP 10811-60109 in 5061A	10 MHz	0.004 s	1.53E−11	8 m	A3120A
HP 5061A Cs	Active maser	5 MHz	1.0 s	9.82E−13	7 d	TSC 5110A
Wenzel Timekeeper	Oscilloquartz BVA 8607/008	10 MHz	0.01 s	2.99E−13	20 m	TSC 5120A
Oscilloquartz BVA 8607/008	HP 5065A Rb	5 MHz	1.0 s	1.25E−12	12 d	TSC 5110A

The answer is that these plots are not simply linear depictions of frequency drift over time. (In 3120A Test Software, that's the purpose of the Measurement→Frequency Difference (f) view.) Nor are they depictions of a single Allan deviation measurement that describes the clock's stability from one interval of a given duration to the next. Instead, ADEV and similar statistical graphs usually portray an entire collection of deviation measurements, each based on a list of phase or frequency data points spaced at an interval unique to that measurement.

Imagine that you own a watch that exhibits a certain accuracy in parts per million from one minute to the next. To arrive at this figure, you've checked your watch against a better clock several times, waiting one minute between each trial, and then calculated the Allan deviation of the resulting list of phase errors. (You might have used conventional standard deviation, but in this case you've heard, correctly, that STDEV has major drawbacks for timekeeping work.)

You're fairly certain you'll get a different result if you calculate the Allan deviation for a set of readings taken one week apart, and still another result for a series of readings taken annually. So you record at least a few data points at these intervals as well.

Now you'd like to draw a graph that shows off your watch's performance, perhaps for bragging rights at the neighborhood pub. What sort of plot would be needed to portray everything you've learned about the watch? The X axis obviously needs to be logarithmic, given that your timescales of interest range from minutes to years. The deviation figures will need to be plotted on a log axis as well, because they might be thousands of times worse at one-year intervals than they are at one-minute intervals. Finally, even though you recorded several years' worth of annual readings, your graph will need to end at the one-year point. There's simply not enough data to describe the watch's behavior at longer timescales.

If you keep these guidelines in mind as you graph your data, you'll end up with a legitimate ADEV plot. It will have three data points, each containing the result (sigma) of an independent calculation based on at least a few samples of the clock's frequency that were taken at a specific interval (tau). Lines or curves can be fitted to this collection of discrete points, and the result will be a plot like those drawn by 3120A Test Software and other ADEV applications.

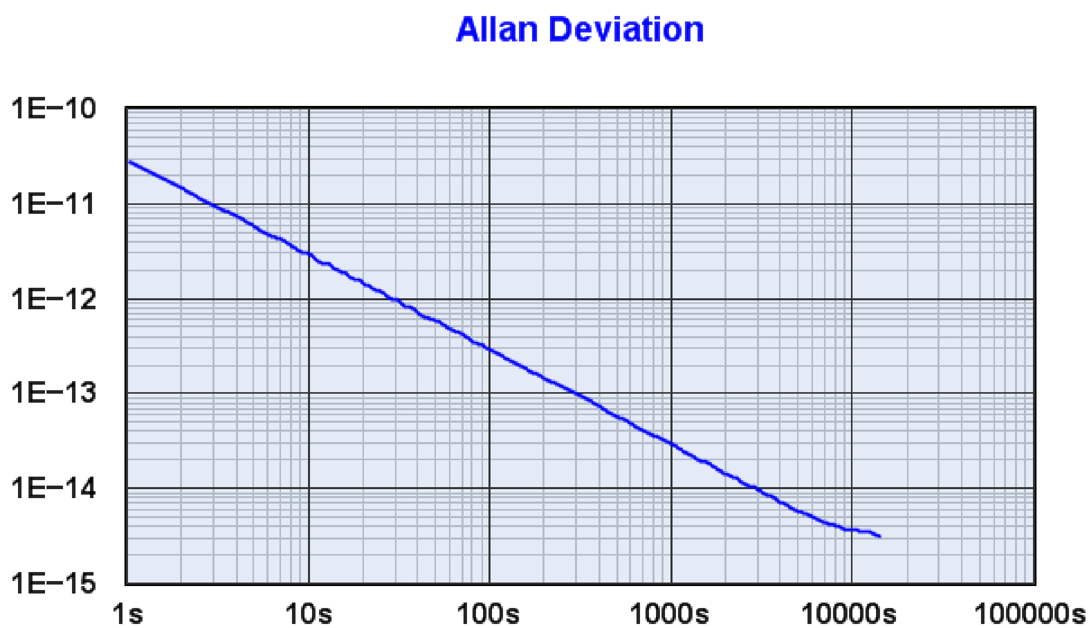
3120A Test Software's statistical capabilities aren't limited to Allan deviation -- the Measurement menu allows you to view any of four types of deviation plots, during or after acquisition. Formulas exist[1] to calculate Allan deviation and other statistics on the basis of both phase and frequency samples. 3120A Test Software always works with phase data internally, using incremental calculations for fast processing and overlapped algorithms for high statistical quality. As with other measurements made by 3120A Test Software, the statistical plots are updated simultaneously in real time.

[1]W. J. Riley, Handbook of Frequency Stability Analysis (http://tf.nist.gov/general/pdf/2220.pdf)

Allan Deviation (a)

Allan deviation, or ADEV, is the square root of the Allan variance, $\sigma^2_y(\tau)$. Like its related statistics MDEV and HDEV, ADEV describes the fractional frequency deviation (σ, or sigma) of a set of samples taken at an interval τ (tau).

ADEV has a few disadvantages that are addressed by other deviation types, such as inability to distinguish white PM and flicker PM noise. It also exhibits relatively low confidence in the presence of smaller sample sizes, compared to some newer statistics. Still, ADEV is among the most commonly-used performance metrics for high-performance clocks and frequency standards.

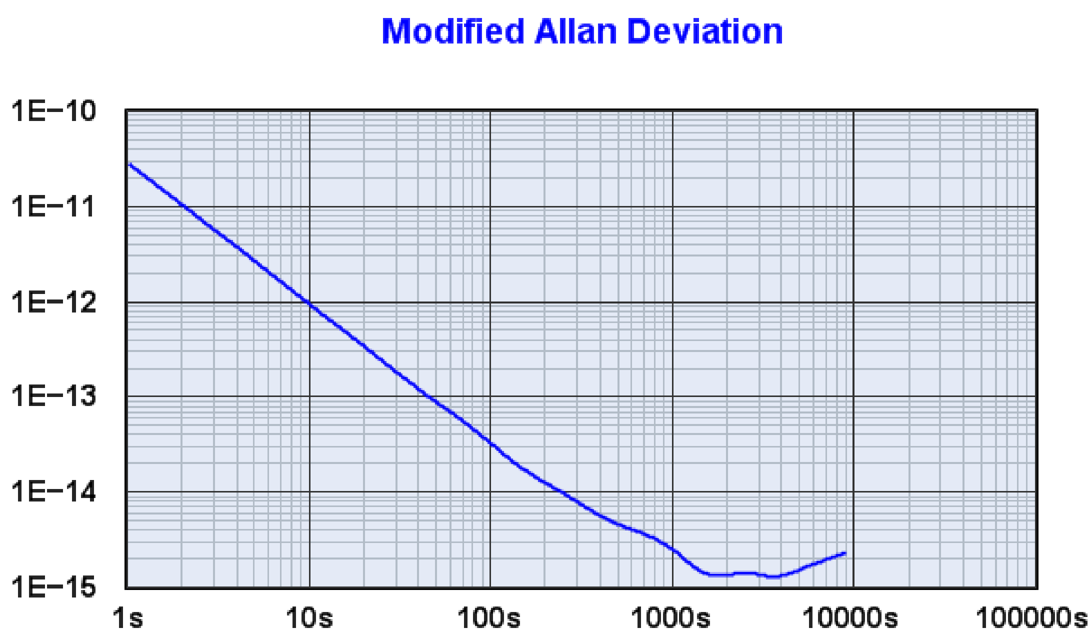


Input Freq	Sample Interval	Duration	Instrument
10 MHz	1 s	8 h	HP 5370A/B

Modified Allan Deviation (m)

MDEV, or Mod $\sigma_y(\tau)$, is a slight variation on ADEV that can discriminate between white PM and flicker PM noise. Both ADEV and MDEV render flicker PM noise at a slope of τ^{-1}. White PM noise is also rendered by ADEV at τ^{-1}, but it appears as a steeper downward slope of $\tau^{-3/2}$ in MDEV. Consequently an ADEV plot may appear artificially elevated when either of these two noise types is present. Switching to Measurement→Modified Allan Deviation (m) will render the two noise types separately, at the timescales where they belong.

As an example, here are ADEV and MDEV plots showing the residual noise of an HP 5370B time interval counter. For this test, the counter's START input was fed with a 1-pps divider, which was driven by a 10 MHz clock that was also connected to the STOP input using an RF splitter. The counter's noise floor consists almost entirely of white PM and flicker PM noise.



Input Freq	Sample Interval	Duration	Instrument
10 MHz	1 s	8 h	HP 5370A/B

The ADEV plot shows a consistent τ^{-1} slope to 10000 seconds, which could be indicative of either white PM or flicker PM noise. The MDEV plot renders the white PM noise at a slope of $\tau^{-3/2}$, transitioning to flicker PM near τ=400s or so. Limited sample availability beyond τ=2000s makes it difficult to draw further conclusions, but it's clear that MDEV reveals more about the counter's noise characteristics than ADEV.

Hadamard Deviation (h)

HDEV, expressed as $H\sigma_y(\tau)$, can be thought of as a 3-sample alternative to ADEV. HDEV plots of drift-free sources will generally appear similar to ADEV, but while ADEV fails to converge in the presence of linear drift, HDEV is unaffected by it. This means that switching from ADEV to HDEV will yield results similar to viewing ADEV after an Edit→Subtract global linear frequency trend (drift line) (Ctrl-l) operation. (The results will not be identical because HDEV also responds to some high-divergence noise types.)

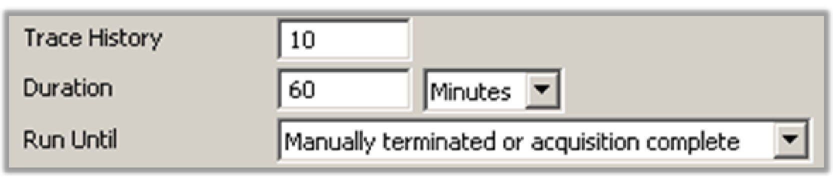
One interesting use for HDEV is predicting the ADEV performance of crystal oscillators that have not yet fully warmed up. Unless the oscillator is exhibiting frequency jumps or inconsistent drift characteristics, its short-term ADEV will eventually resemble the HDEV performance that was observed only a few minutes after power-up.

Time Deviation (t)

TDEV, or $\sigma_x(\tau)$, expresses the time stability of phase at the specified tau, in units of seconds. Numerically, TDEV is equal to (MDEV * τ) / sqrt(3). It's similar to the TIE (Time Interval Error) statistic used by the telecommunications sector.

Examining changes in stability over time

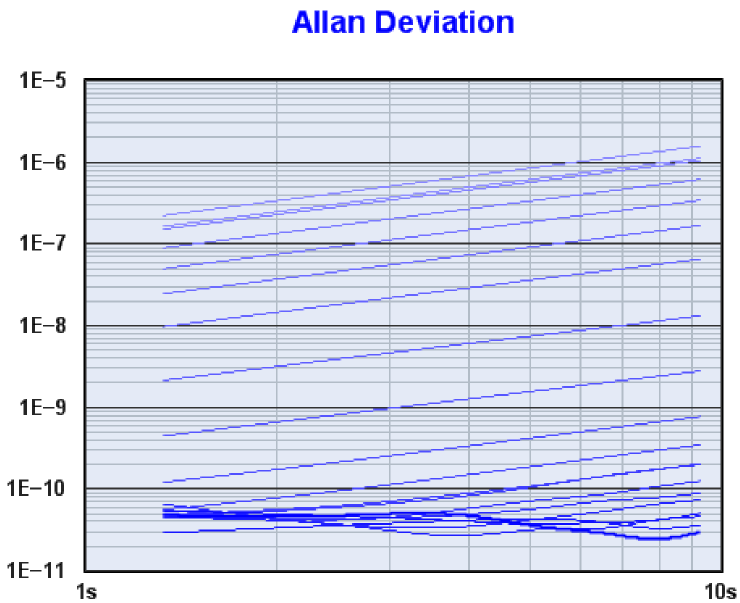
To make basic "dynamic ADEV" measurements[1], refer to the help text for the Duration and Run Until fields in the acquisition dialog, as well as the Trace History field. (In the Symmetricom dialog, Trace History is found on the Frequency Stability tab.)



Specifying a Trace History value greater than 1 causes 3120A Test Software to divide the phase record into the given number of regions. Subsequent displays of xDEV measurements will assign each region its own trace. As the measurement runs, more recently-acquired regions towards the end of the phase record are drawn in darker colors, revealing how the stability of a given device changes over time. (If Trace→Toggle trace thickness (T) is enabled, only the most recent region will be displayed with a heavy trace.)

You can specify a new Trace History value at any time after acquisition in the Edit→Trace properties (e) dialog. In the example below, eight minutes of frequency readings were taken from an OCXO shortly after power-up, and later rendered with Trace History set to 20. Consequently, each ADEV trace represents about 24 seconds of phase data. As the oscillator warms up, the later traces exhibit better stability.

[1]Galleani, L. , Tavella, P.; Interpretation of the dynamic Allan variance of nonstationary clock data, Frequency Control Symposium, 2007 Joint with the 21st European Frequency and Time Forum. IEEE International, pp. 992-997, 2007



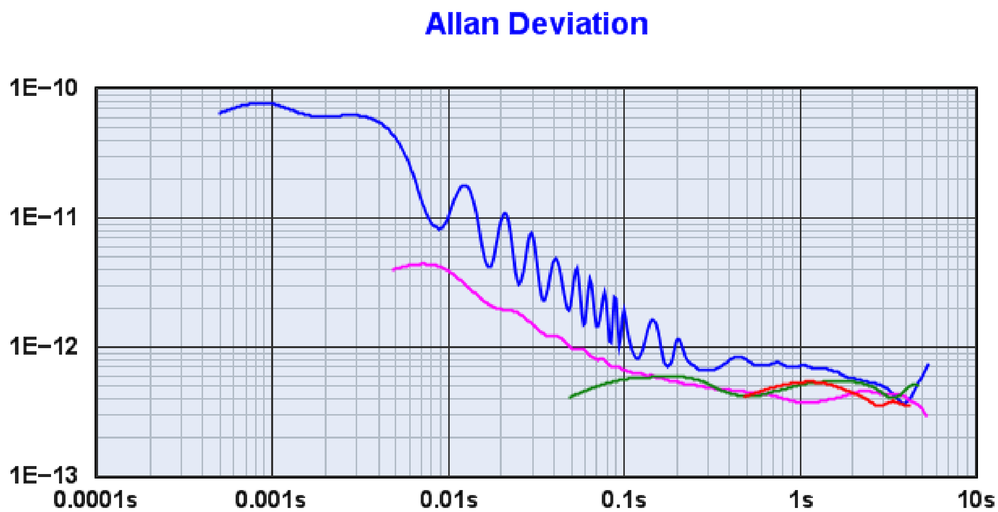
Tau	Sigma(Tau)
2s	4.95E−11
4s	4.86E−11
8s	2.55E−11

Trace	Input Freq	Sample Interval	Duration	Phase Record	Instrument
10811-60111 warmup	10 MHz	1.321 s	8 m	360 pts	HP 5370B

Values displayed on the Sigma(Tau) chart apply to the most recent trace.
For more advanced displays of dynamic AVAR/ADEV and related metrics as described in the literature, consider using the File→Export phase data to Stable32 (Ctrl-x) command described on page 59 for offline analysis.

Common artifacts in ADEV and related measurements

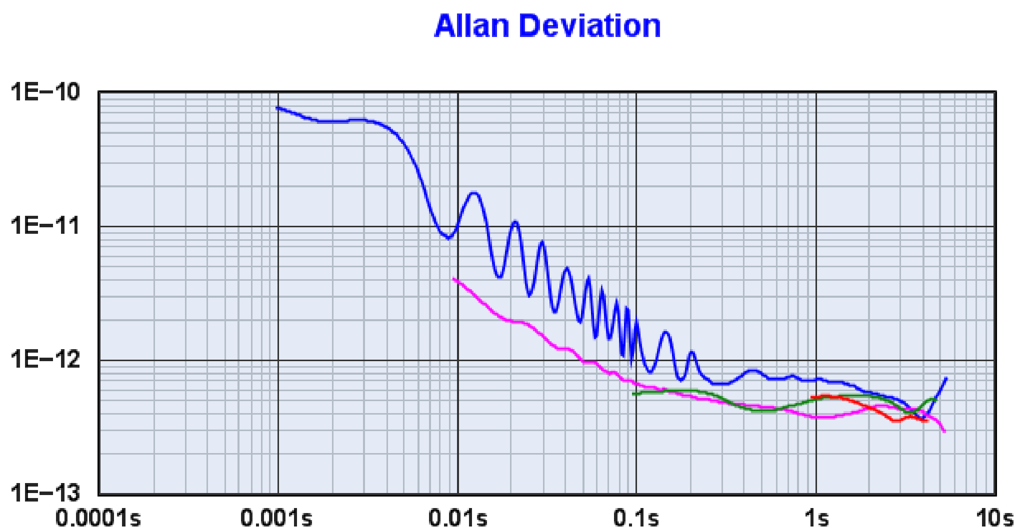
High-resolution plots captured by the 3120A can reveal artifacts that don't seem to be present when the same measurement is made by other instruments. For example, spurs due to AC power coupling or ground loops, discussed below, appear very different when acquired at high sample rates and rendered with 20 or more ADEV bins per decade. Line-related spurs may not have been resolvable before, but that doesn't mean they weren't present!



Trace	Notes	Sample Interval	ENBW	Instrument
GPS clock	OCXO	0.000486 s	514.1 Hz	3120A
GPS clock	OCXO	0.004 s	52.7 Hz	3120A
GPS clock	OCXO	0.047 s	5.2 Hz	3120A
GPS clock	OCXO	0.473 s	0.5 Hz	3120A

Measurement bandwidth and τ_0

One artifact that does originate in the 3120A's driver software is shown in the plot at right. Four successive ADEV acquisitions are shown, each conducted at a different noise-equivalent measurement bandwidth (ENBW) setting. Near the beginning of each trace, some "droop" is present that doesn't accurately reflect the behavior of the DUT.



Trace	Notes	Sample Interval	ENBW	Instrument
GPS clock	OCXO	0.000486 s	514.1 Hz	3120A
GPS clock	OCXO	0.004 s	52.7 Hz	3120A
GPS clock	OCXO	0.047 s	5.2 Hz	3120A
GPS clock	OCXO	0.473 s	0.5 Hz	3120A

What causes this artifact? Stein[1] has shown that the optimum ENBW for a given ADEV τ_0[2] is simply the $1/(2 * \tau_0)$ Hz Nyquist rate. This bandwidth is unachievable with a non-ideal antialiasing filter, so the 3120A driver internally acquires oversampled phase data that corresponds to an artificially short τ_0 interval relative to the selected ENBW. If allowed to appear on an ADEV plot, the antialiasing filter's response is easy to mistake for a real effect.

3120A Test Software supports two different ways to avoid displaying invalid data near τ_0. First, Trace→Clip xDEV traces by noise bandwidth (Ctrl-b) is enabled by default. (This option was turned off to demonstrate the issue above.) With noise bandwidth clipping enabled, as seen in the figure at left, 3120A Test Software does not render any portion of an xDEV trace at taus shorter than 1/(2 * ENBW) seconds.

Additionally, beginning with version 1.1 of 3120A Test Software, the Symmetricom 3120A driver can decimate the phase-difference data it acquires. Readings are collected by sampling the internal phase-difference data stream at a rate determined by the Output Decimation field in the acquisition dialog. This feature is primarily for convenience. It can be used to reduce the size of phase records generated by very long acquisitions, for example, or when high data rates must be used in order to track drifting sources. But decimation factors of 2:1 or greater also have the effect of satisfying the $\tau_0 >= 1/(2 * \text{ENBW})$ criterion. With the default Output Decimation value of 2:1, phase-difference data that's affected by lowpass

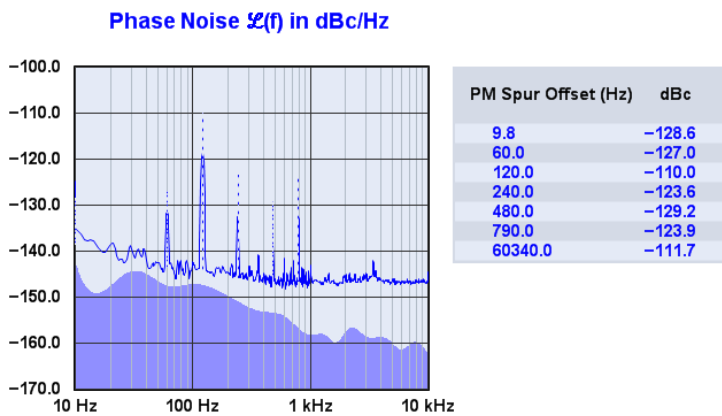
[1]The Allan Variance – Challenges and Opportunities, Samuel R Stein, Symmetricom, Inc., Boulder, Colorado USA (White paper available at www.symmetricom.com)
[2]τ_0 refers to the very first tau at the left end of an xDEV trace, which typically corresponds to the period of the phase or frequency samples being analyzed.

attenuation will be kept out of the measurement, even if Trace→Clip xDEV traces by noise bandwidth (Ctrl-b) is turned off.

Note that Trace→Clip xDEV traces by noise bandwidth (Ctrl-b) will have no effect on plots rendered with data captured from counters and other instruments that don't report their measurement bandwidth. It should be left enabled in most cases.

Line-related spurs

The most conspicuous artifact in the ADEV plots above is the "ripple" in the blue and magenta traces. This is caused by AC line interference, primarily a single 120-Hz spur:



Trace	Notes	Sample Interval	ENBW	Instrument
GPS clock	OCXO	0.004 s	52.7 Hz	3120A

Note that 1/120 Hz = 0.008s, which corresponds to the first (genuine) trough in the ADEV traces above. Depending on how they're introduced to the measurement, AC line spurs commonly appear at either the fundamental power-line frequency or its second harmonic. Users in the EU and other locales with 50 Hz power will see similar effects near τ=0.010 and 0.020s. In all of these cases, the device's "true" ADEV is close to an imaginary line drawn through all of the lowest points in the trace.

Getting rid of AC line spurs can be a challenge. Shielding at 50/60 Hz is usually impractical; if the interference is magnetically coupled into the measurement, there is probably no cure besides identifying the offending source(s) and moving sensitive equipment and cables away.

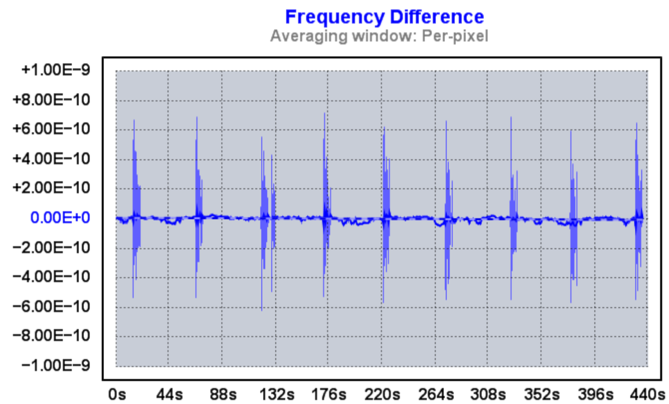
Ground loops are a more likely offender, since all ports on the 3120A have ground pins or shields that are bonded to the instrument's metal enclosure. If you can identify the offending loop, you may be able to break its RF path with a coaxial balun[1].

[1] E.g., http://www.minicircuits.com/pdfs/FTB-1-1+.pdf. When using coaxial baluns, make sure they're actually helping, though. In particular, watch out for elevated phase noise floors, crosstalk artifacts, and assorted spurious responses picked up by the now-ungrounded coax shield.

You can also attack the source of the loop by bonding all equipment to a common ground that's connected to the building's power distribution network in only one place. To do this, ensure that all devices participating in the measurement – DUT, reference, 3120A Test Probe, computer, and everything connected to them – are all part of the same AC circuit, preferably a power strip that allows all equipment to be plugged into a single outlet.

Using battery power can help, but batteries shouldn't be your first resort. Less drastic solutions can usually be found that will let you use the available AC power. (Try switching to MDEV, for instance.) If you are measuring stable sources with sufficient warmup time, you can eliminate line spurs by select the 5 Hz or 0.5 Hz Measurement BW option in the acquisition dialog.

Other environmental hazards



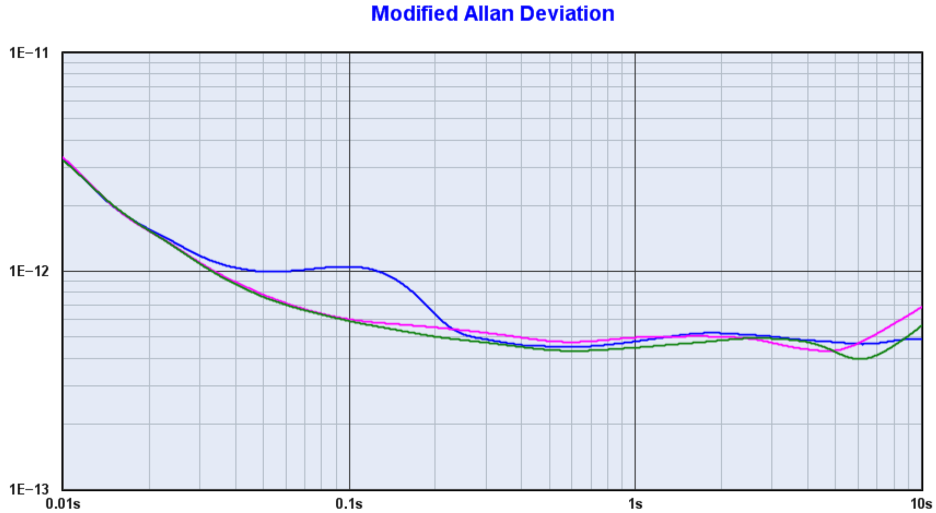
Trace	Input Freq	Sample Interval	Instrument
REF FTS4050 INPUT Z3801	10 MHz	0.050 s	3120A

Above, a measurement of two 10 MHz sources was interrupted by bursts of apparently-random noise at roughly 50-second intervals. The culprit turned out to be a cellular phone sitting on a nearby bench. Try to keep all RF radiation sources – intentional and otherwise! – well away from your testing area.

Crosstalk

Finally, don't confuse power-line spurs or other sources of low-frequency interference with crosstalk. This is an insidious artifact that may be observed in high-performance measurements – or worse, may go unnoticed.

When working with the 3120A, crosstalk tends to appear when the signal frequencies at the INPUT and REF IN ports are nearly the same, but not precisely. As the two signals' phases slowly approach, coincide, and separate, any coupling between them creates a spurious response at the difference frequency. Appearing at a similar magnitude in both AM and phase noise plots, these spurs also cause peaks and nulls in ADEV and related measurements.



Trace	Input Freq	Ref Freq	Sample Interval	ENBW	Instrument
Morion MV89A, 3m RG58, house clock on	10.000003 MHz	10 MHz	0.004 s	52.7 Hz	3120A
Morion MV89A, 3m RG58, house clock off	10.000003 MHz	10 MHz	0.004 s	52.7 Hz	3120A
Morion MV89A, 3m RG400, house clock on	10.000003 MHz	10 MHz	0.004 s	52.7 Hz	3120A

Crosstalk can also occur when a third signal, incidental to the measurement environment, causes beatnote effects that are asynchronous to both test inputs. This case is illustrated in the plot above, where a 3120A Test Probe was used to measure a high-stability OCXO against another one of similar quality.

In this case, while the OCXO driving REF IN was very close to 10 MHz, the OCXO driving the INPUT port was set approximately 3 Hz higher for demonstration purposes. Also present in the room (but not participating in the measurement) was a GPS-disciplined frequency standard and distribution amplifier supplying 10 MHz to various instruments through long cables.

The 3120A's reference source was connected with a double-shielded RG400 cable in all three trials. The blue trace and magenta traces were taken with the input source connected with a 3m length of RG58. A significant MDEV peak was visible in the blue trace… but when the GPSDO was powered down for the magenta trace, the spurious response vanished.

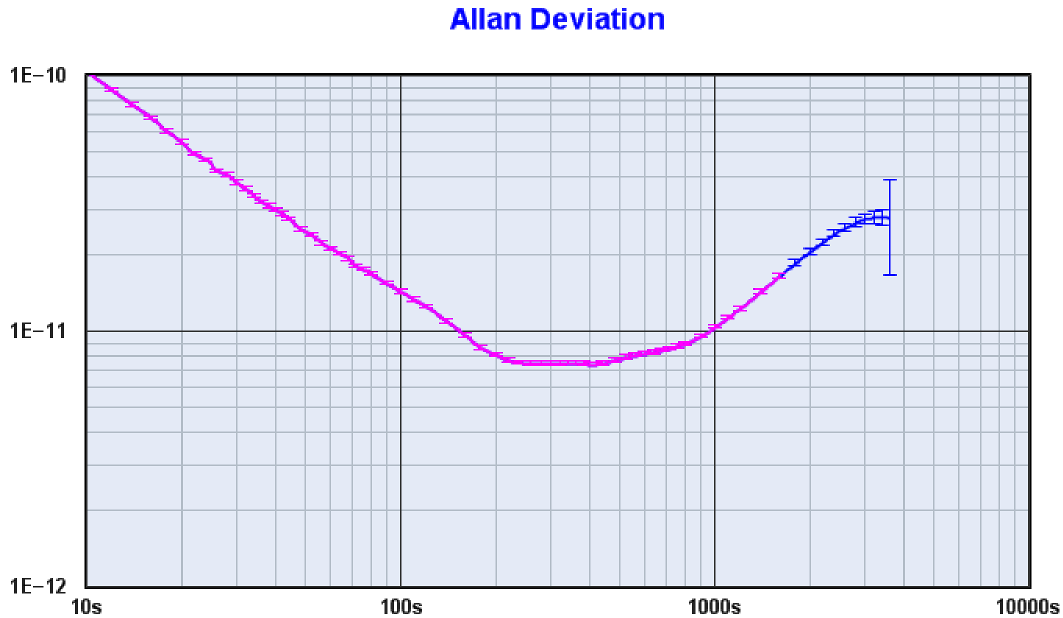
Likewise, as the green trace shows, replacing the RG58 input cable with an equal length of RG400 also eliminated the interference from the house standard.

As can be seen, the recommendation to use double-shielded cables with the 3120A Test Probe is not borne of excessive caution. Even plots acquired by conventional frequency and TI counters are vulnerable to crosstalk! With the widespread availability of GPSDOs and other inexpensive frequency standards, many facilities from international physics laboratories to ham shacks are equipped with 5- and 10-MHz distribution networks. Don't use low-quality cables with high-performance instrumentation.

Hints for xDEV measurements

- The Symmetricom 3120A does not display its own measurement floor in the ADEV, MDEV, HDEV, or TDEV views. Instead, you can (and should) make residual plots for measurements that may approach the instrument floor, using similar frequencies and signal levels. These residual plots can be saved, loaded and shown with Display→Overlay all loaded plots (o) next to your actual measurement traces.
- There's a direct relationship between measurement bandwidth (as selected on the Frequency Stability tab of the 3120A Test Probe acquisition dialog) and the 3120A Test Probe's measurement floor in ADEV and other phase/frequency measurements . You may find it helpful to observe drift-prone sources or oscillator startup characteristics at 500 Hz ENBW, but be aware that the noise floor will be higher. Again, a separate residual plot at the frequencies and signal levels of concern can tell you exactly where the limits are.
- The measurement bandwidth also influences the size of the phase record that must be allocated before a measurement of a given duration can begin. As a result, you may experience out-of-memory errors if you tell 3120A Test Software to record several hours' worth of phase data at 500 Hz ENBW/1K points per second. Increasing the Output Decimation value in the Frequency Stability tab is a great way to reduce acquisition memory requirements, but it will not change the xDEV noise floor. The only way to lower the xDEV floor is to select a narrower measurement bandwidth.
- Fewer samples are available to contribute to bins near the right end of an xDEV trace. As a result, measurement confidence decreases at longer tau intervals. To increase the minimum number of samples that must contribute to a given xDEV bin in order for that bin to be displayed, you can change the Bin Threshold parameter in the acquisition dialog, or use Edit→Trace properties (e) to specify a new value for the same field at any time after acquisition.

  However, because 3120A Test Software employs overlapped xDEV algorithms, small changes to Bin Threshold may have no effect. Once the phase record grows long enough to provide data at a given tau interval, each additional sample adds another data point to the corresponding xDEV bin. If this is an issue, try setting the Bin Threshold to a large fraction of the total phase record size. The idea is to force 3120A Test Software to render the xDEV trace as if much less data were available.



Trace	Input Freq	Phase Record	Bin Threshold	Instrument
Thunderbolt vs FE-5680A run #2	1 Hz	3606 pts	4	HP 5335A
Thunderbolt vs FE-5680A run #2	1 Hz	3606 pts	2000	HP 5335A

In the example at left, two copies of the same 3600-sample .TFF file have been loaded. The blue trace was rendered with the default Bin Threshold of 4, while the shorter magenta trace was rendered with Bin Threshold set to 2000. Enabling Trace→Show xDEV error bars (Ctrl-e) reveals the blue trace's low confidence at its longest tau.

Generally, as long as Trace→Clip xDEV traces by confidence (Ctrl-v) is enabled, it will not be necessary to alter the Bin Threshold value to display xDEV trace data of good statistical quality. The default bin threshold and clipping options will suffice for almost all measurements.

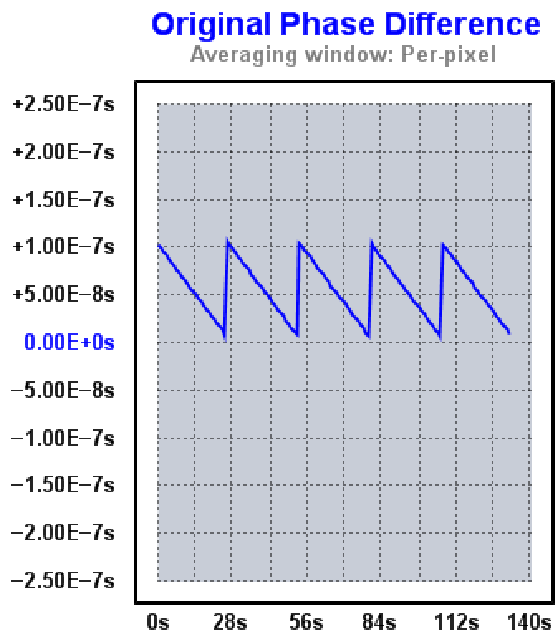
Phase and frequency difference traces

Phase and frequency stability data acquired by 3120A Test Software is represented internally as an array of phase-difference samples. This is true regardless of whether the data came from a frequency counter, a time-interval counter, or a direct-digital timing analyzer. (Frequency readings are converted to phase-difference samples on the basis of their deviation from the first frequency reading acquired.)

In addition to the statistical measurements such as Allan deviation that 3120A Test Software provides, "strip chart" views are available to give you a closer look at the raw phase-difference data. These views correspond to the Phase difference (Unwrapped) (p), Phase difference (Original) (w), and Frequency-difference (f) options on the Measurement menu.

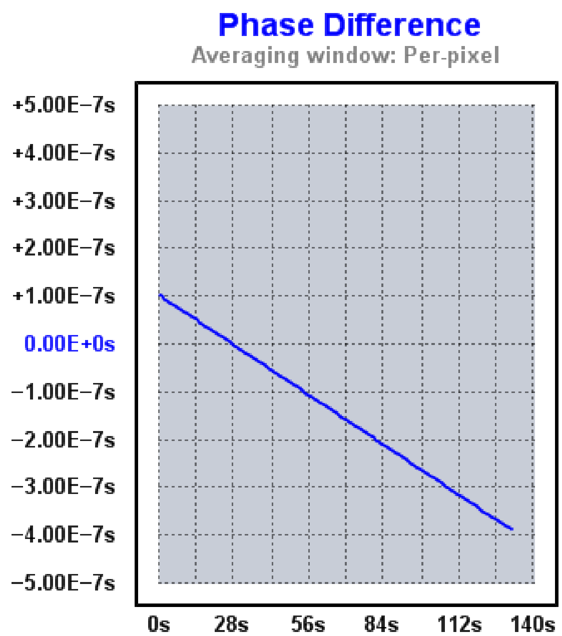
Phase difference (Original) (w)

Phase difference (Unwrapped) (p)



Origin	Slope (sec/sec)
+6.63E−8	−1.54E−10

Trace	Notes	Input Freq	Sample Interval	Instrument
HP 10811A	Trimble Thunderbolt	10 MHz	1.00 s	HP 5370A/B



Origin	Slope (sec/sec)
+1.03E−7	−3.74E−9

Trace	Notes	Input Freq	Sample Interval	Instrument
HP 10811A	Trimble Thunderbolt	10 MHz	1.00 s	HP 5370A/B

The distinction between these two measurement types is relevant when receiving time-interval data from a traditional counter. The Phase difference (Original) (w) measurement shows the original TI samples as they arrive from the hardware.

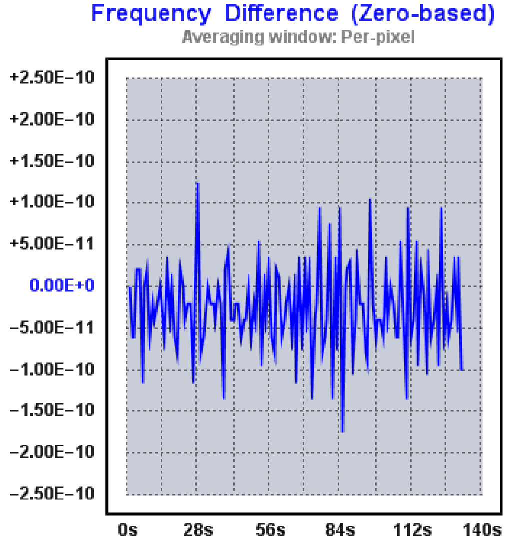
When acquired from a TI counter, these readings are subject to “wraparound” when they exceed the period of the signal that determines the START-to-STOP channel interval. For instance, if an oscillator near 10 MHz is measured against a drift-free source at exactly 10 MHz, the TI readings from the counter will increase or decrease from one trigger interval to the next. When the START-to-STOP interval exceeds 100 nanoseconds or falls below 0 nanoseconds, the TI readings will necessarily wrap back around to the opposite “rail.” This phenomenon gives rise to the sawtooth-shaped phase trace familiar to users of vector network analyzers. As seen in the measurement example above, the phase-wrapping effect is visible in the Phase difference (Original) (w) measurement view in 3120A Test Software.

Conversely, 3120A Test Software’s Measurement→Phase difference (Unwrapped) (p) view displays the TI samples in the form of phase data that’s been “unwrapped.” The sawtooth discontinuities are removed by adding or subtracting the input signal’s period whenever the sample-to-sample time difference exceeds half of that period.

It’s seldom necessary to refer to the original phase-difference graph except when troubleshooting configuration problems with live TI counter measurements. In most cases you should select the Measurement→Phase difference (Unwrapped) (p) view when you wish to inspect the principal phase record for your acquisition. Additionally, all of the flattening, detrending, and data-removal commands on the Edit menu work by replacing the original phase data with modified data based on the unwrapped record. After executing any of these commands, the p and u views will always be identical, just as if the data had been acquired from a frequency counter or direct-digital analyzer.

Further references to the phase-difference view in this manual will appear simply as Measurement→Phase difference (p), omitting the distinction between wrapped and original phase data.

Frequency difference (f)



Origin	Drift (Hz/sec)	Drift (Hz/min)
−2.57E−11	−8.04E−8	−4.82E−6

Avg Time (s)	Freq (Hz) at 132s	Error
1	9 999 999 . 961 900 000	−3.81E−9
3	9 999 999 . 962 500 000	−3.75E−9
10	9 999 999 . 962 619 999	−3.74E−9
30	9 999 999 . 962 636 666	−3.74E−9
100	9 999 999 . 962 634 999	−3.74E−9

Trace	Notes	Input Freq	Sample Interval	Instrument
HP 10811A	Trimble Thunderbolt	10 MHz	1.00 s	HP 5370A/B

Shown above is a third way to view the phase data from the earlier example. Each point on the Measurement→Frequency difference (f) trace is calculated by dividing the difference between successive pairs of phase-difference samples by the sample rate. Taking the time derivative of n adjacent phase-difference points in this manner yields a stream of n-1 frequency-difference points. Because of this differentiation process, the Measurement→Frequency difference (f) view of the phase record is often better at revealing glitches and other short-lived artifacts in the phase record than the actual phase-difference trace is. Long-term oscillator drift and temperature-dependent effects are also easily spotted.

When the optional chart to the right of the trace area is enabled with Display→Numeric table (Ctrl-n), 3120A Test Software can be used to emulate a frequency counter with impressive performance. The chart can be viewed at any time during or after acquisition. Its entries are computed in real time by integrating the frequency-difference values in the currently visible trace at successively longer intervals. The integration process moves from right to left, starting with the newest sample points and moving farther back in history as more data becomes available.

How does 3120A Test Software measure frequency?

It's important to understand that the "frequency differences" shown on the graph are actually fractional deviations from a value known as the input frequency. If the measurement's input frequency is exactly 10,000,000 Hz, then a frequency-difference reading of +1E-7 would mean that the absolute frequency is 10,000,001 Hz at that moment in time.

But what exactly is this "input frequency?" Where does it come from, and how accurate is it? When acquiring data with a frequency counter, it's easy enough to determine the nominal input frequency for the measurement: we simply use the first reading. All subsequent data points in the phase record are computed using the difference between the incoming frequency readings and the first one recorded… and all of these readings can be assumed to carry the same accuracy and precision.

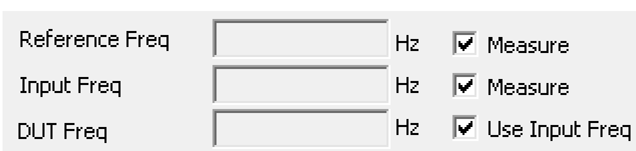
When a time-interval counter (TIC) is used, however, 3120A Test Software sees only a series of START-to-STOP interval times. It's impossible to infer the input frequency automatically. Instead, you must enter it into the appropriate field of the acquisition dialog, specifying at least as much precision as you expect to obtain when viewing the frequency count chart.

Phase/frequency measurements with the 3120A Test Probe

For Symmetricom 3120A users, the situation is a bit more complex. First it must be emphasized that the values on the Measurement→Frequency difference (f) plot have nothing to do with the difference between the absolute signal frequencies at the INPUT and REF IN jacks, as might be surmised. Instead, the frequency-difference plot reveals changes in the difference between these frequencies that occur after measurement begins.

On the 3120A, the process of determining the input frequency can be thought of as a choice between the frequency-counter and TIC methods. Options in the Acquire→Symmetricom 3120A Test Probe acquisition dialog allow you to enter an explicit REF IN frequency, both INPUT and REF IN frequencies, or neither. The choice between ultimate accuracy and "plug and play" convenience is left up to you.

Measurement initialization



To understand the compromises involved, let's look at some of the steps that the 3120A Test Software driver executes when you press the Start Measurement button. Refer to the figure above, taken from the Acquire→Symmetricom 3120A Test Probe acquisition dialog.

1. Using the nominal ADC clock frequency specified in the acquisition dialog -- typically 78.050 MHz or 76.050 MHz -- zero-crossing detectors are used to obtain a rough estimate of the signal frequencies at the INPUT and REF IN jacks.

2. If you unchecked the Measure option next to the Reference Freq field and entered an explicit reference frequency, this value replaces the estimated REF IN frequency. The difference between the estimated and entered reference frequencies is used to improve the estimate of the ADC clock frequency.
3. If you unchecked the Measure option next to the Input Freq field and entered an explicit input frequency, this value replaces the estimated INPUT frequency. (The INPUT frequency may be specified only if REF IN is also specified explicitly.)
4. The DDS cores on the FPGA are tuned to the estimated or entered input and reference frequencies.
5. The driver spends a few seconds measuring the actual input- and reference-channel baseband signals. For any frequencies you didn't specify explicitly, these baseband measurements are used to refine the current estimates. The DDS cores are then fine-tuned using the updated input, reference, and clock frequencies.
6. If an explicit reference frequency was specified, the reference channel's baseband frequency is measured once again. It should be very close to DC unless the ADC clock or the reference is drifting. If the reference-channel baseband frequency is greater than 5% of the selected measurement bandwidth, the observed difference is used to refine the ADC clock frequency estimate, under the assumption that an explicitly-specified reference frequency is likely to be much more stable than the 3120A's own clock. The driver returns to step (5) above in this case, looping indefinitely until the baseband signals are close enough to DC.

As the measurement begins, the Input Freq and Ref Freq fields in the legend table beneath the graph will be brought up to date based on the progress made through the steps above. Any estimated frequencies are displayed at 1-kHz precision, while any explicitly-specified frequencies are displayed at the precision given.

Some of the implications are rather subtle. For example, if you don't enter an explicit reference frequency, the accuracy of your frequency-count chart entries will depend on how close the actual reference frequency is to the 1-kHz rounded estimate used by 3120A Test Software. This means that if your REF IN jack is connected to an atomic or GPS standard whose output is nominally a multiple of 1 kHz, as is often the case, then the accuracy of your frequency-count chart entries will be as good as the reference itself.

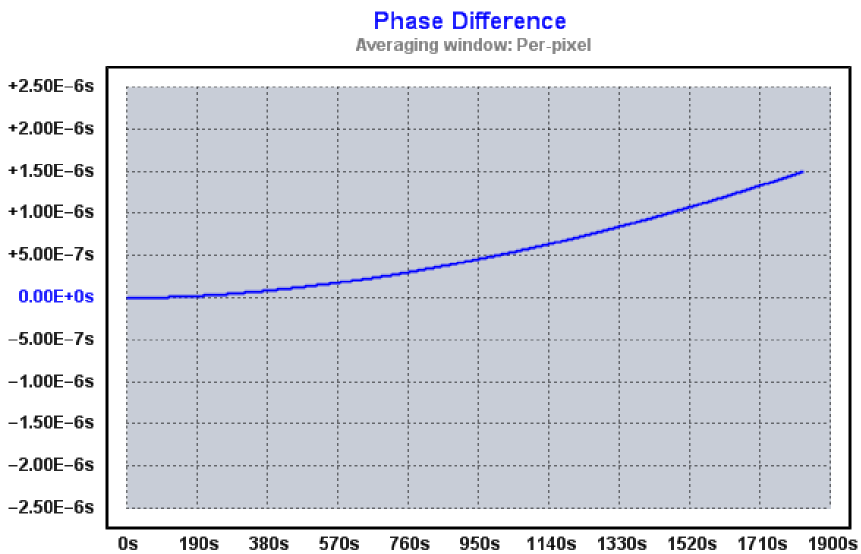
How does this work? The 3120A's internal estimate of the input frequency may not be very accurate, but it doesn't need to be. The slope of the phase differences measured by the 3120A is always equal to the frequency offset between the input and reference signals at baseband, regardless of how accurately or inaccurately their original RF frequencies were known when the measurement began. To the extent that the reference's actual frequency matches the rounded estimate used by 3120A Test Software, the frequency of the RF signal at the INPUT jack can be recovered simply by adding this offset. Once this is done, the frequency-difference graph points can also be scaled to conform to the Input Freq value that's displayed in the legend table. (Input Freq is also rounded to the nearest 1 kHz by 3120A Test Software, if not specified explicitly.)

There's one small catch: although the input frequency will be reported accurately in the frequency-count chart as long as the rounded REF IN frequency is correct, the overall slope of the Measurement→Phase difference (p) trace may be inaccurate unless you specify both the input and reference frequencies in the acquisition dialog[1].

In particular, two-port phase stability measurements often require very high phase-slope precision, as do measurements in which the 3120A's own residual phase drift is tested. You should enter the common test-source frequency into both the Input Freq and Reference Freq fields when making such measurements.

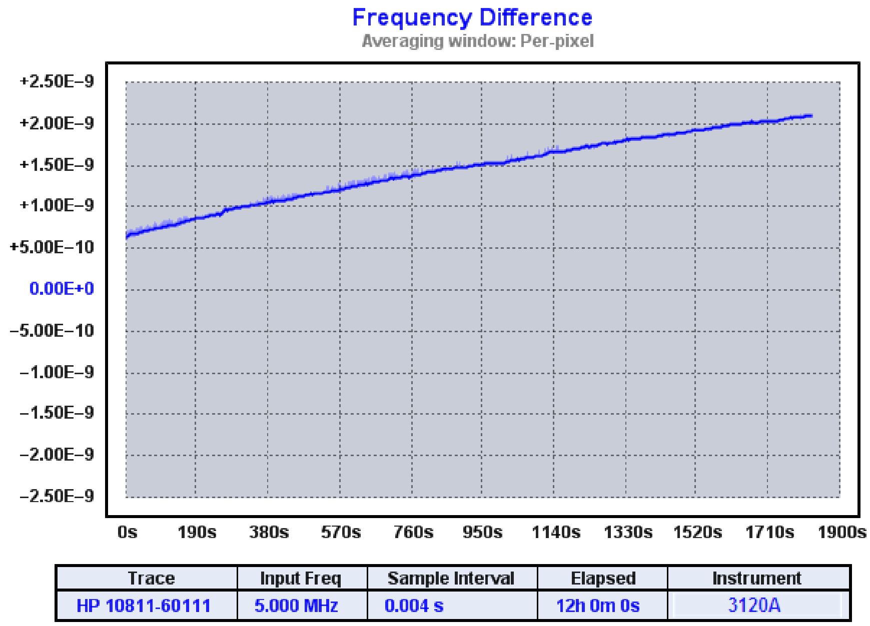
Examining traces in detail

In the plots below, a crystal oscillator was measured over a 30-minute period. The Measurement→Phase difference (p) and Measurement→Frequency difference (f) views appear side-by-side for comparison.

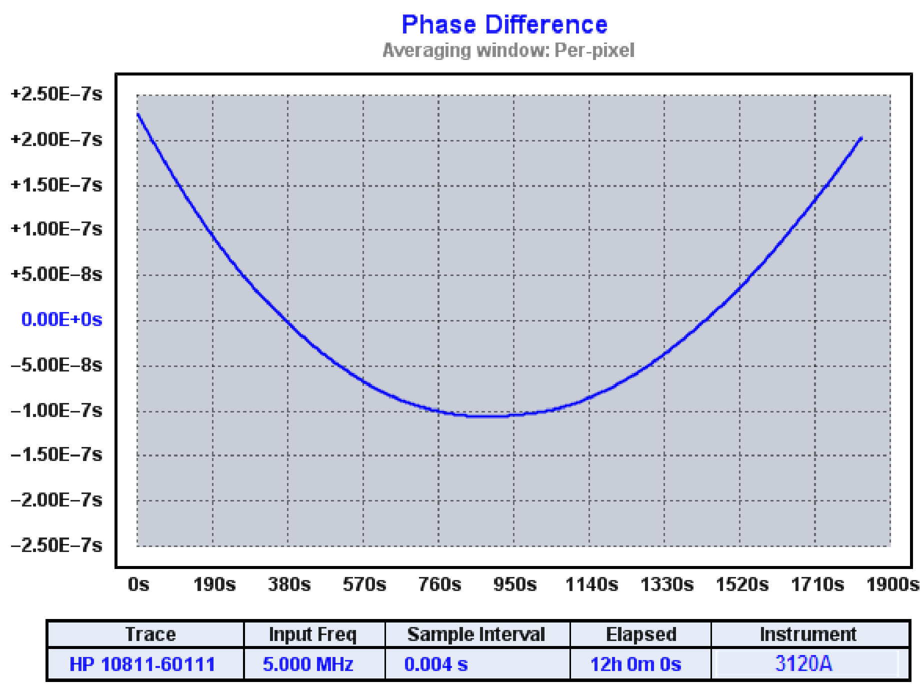


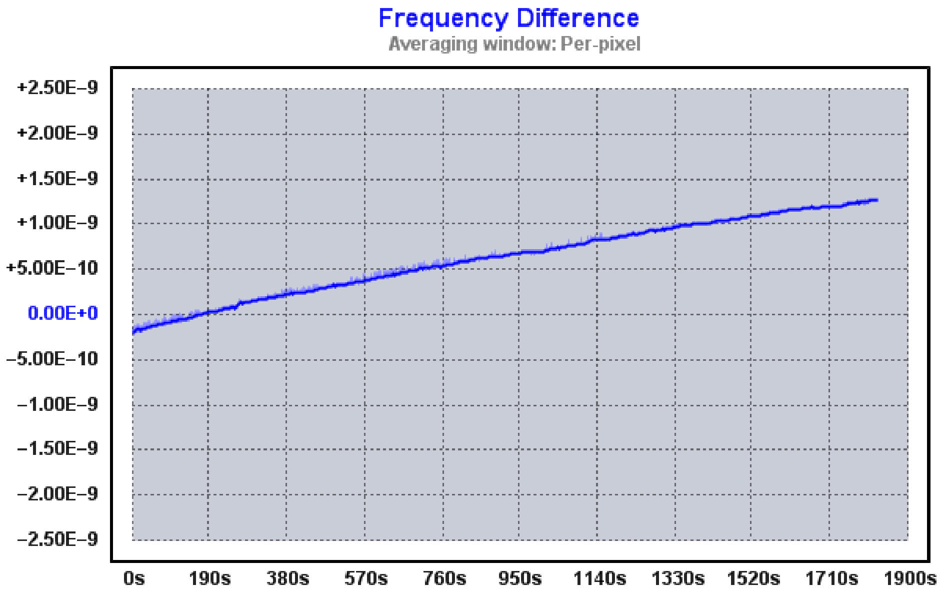
Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

[1]Since the phase-difference slope reflects any offset in frequency between the downconverted input and reference signals, both frequencies must be accurately specified to the 3120A Test Probe acquisition driver when making phase drift measurements at high precision. Even the slightest inaccuracy in estimation of the reference or input frequency during measurement initialization will add a nonzero bias to the baseband phase-difference slope.



Not much detail is visible in either trace. Some sporadic frequency jumps are present, but they're not easily examined since their height is such a small fraction of the plot's overall magnitude. Edit-> Subtract global linear phase trend (frequency offset) (Ctrl-o) command expands the phase-difference trace somewhat by removing its linear trend, but it only moves the frequency-difference trace down a bit:



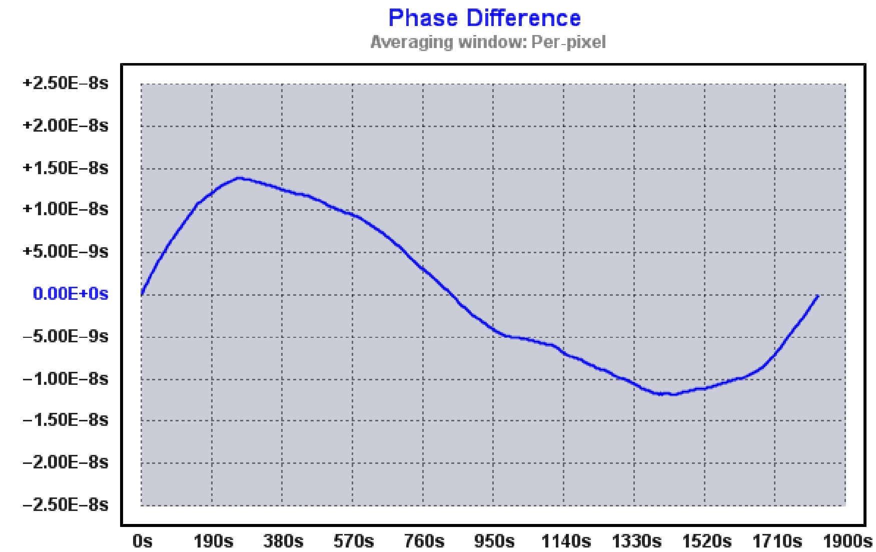


Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

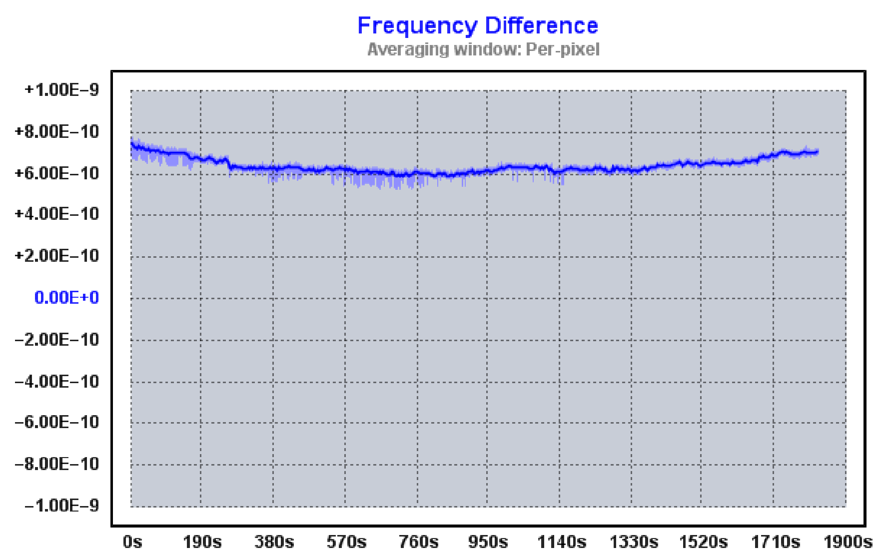
In fact, we could have achieved a similar effect without altering the phase record by viewing the phase-difference trace with Trace→Show linear phase/frequency residual (r), or by viewing the frequency-difference trace with Trace→Phase/frequency traces begin at zero (z).[1]

For these reasons, Edit-> Subtract global linear phase trend (frequency offset) (Ctrl-o) is not a commonly-needed command. At first glance, Edit-> Subtract global linear frequency trend (drift line) (Ctrl-l) seems more useful:

[1] The Trace→Phase/frequency traces begin at zero (z) option can actually be more useful – not only can it be toggled on and off without altering the phase data, but it also forces the beginning of the frequency-difference trace to midscale. See page 67.



Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

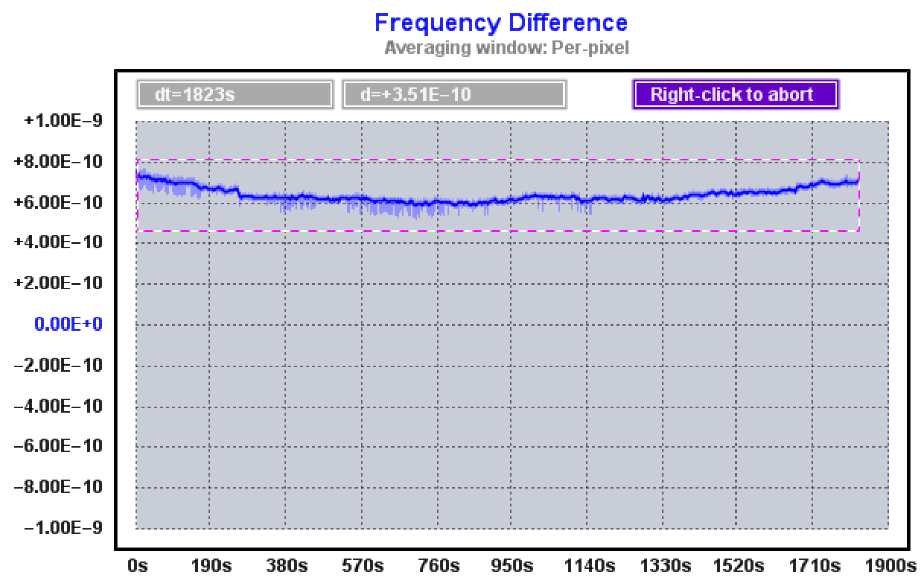


Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

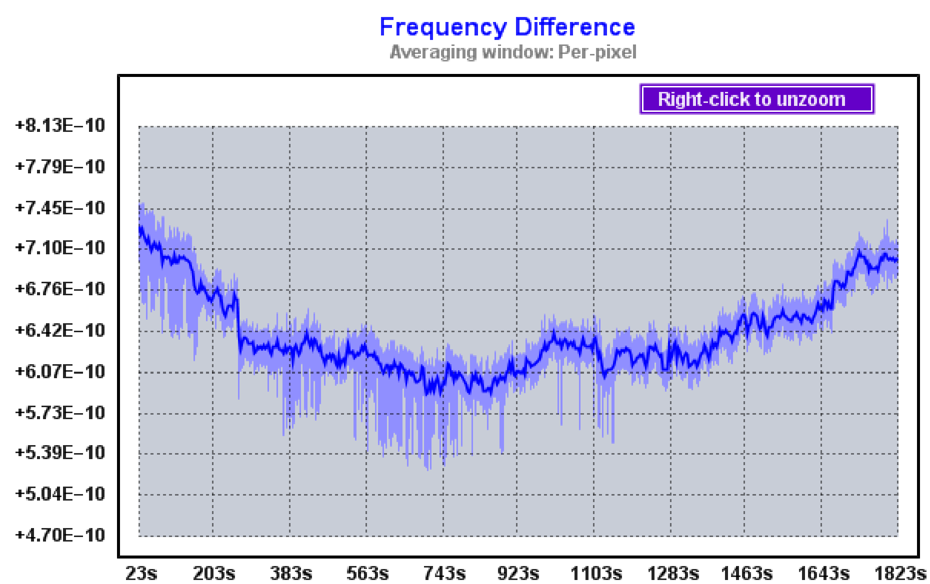
Essentially, Edit-> Subtract global linear frequency trend (drift line) (Ctrl-l) removes the quadratic trend from the phase record, which has the effect of removing the linear trend from the frequency-difference plot. But there’s still an arbitrary offset in the frequency-difference view that’s forcing the Y-axis scale to +/- 1E-9, and the artifacts we’d like to examine are much smaller than this.

Navigating zoomed graphs

One strategy is to unlock the Y-axis with Trace→Phase/frequency Y axis unlocked in zoom mode (y), and then use the left mouse button to drag a box around the trace. When the button is released in the view at left, the result is the zoomed view at right:



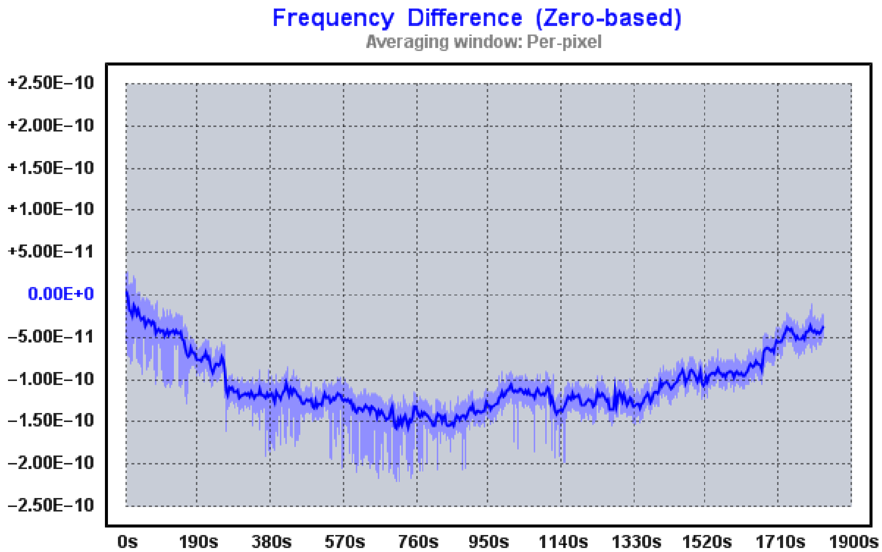
Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A



Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

3120A Phase Noise Test Probe is designed to take advantage of a PC mouse with three buttons and a scroll wheel. All of the graph types are “zoomable,” and you can always return to the unmagnified view by right-clicking anywhere on the plot. Unlike the xDEV and noise measurement displays, though, the phase- and frequency-difference measurement views support additional navigation options. You can expand and contract the zoomed area with the mouse wheel, or surf through the data by dragging with the middle button.

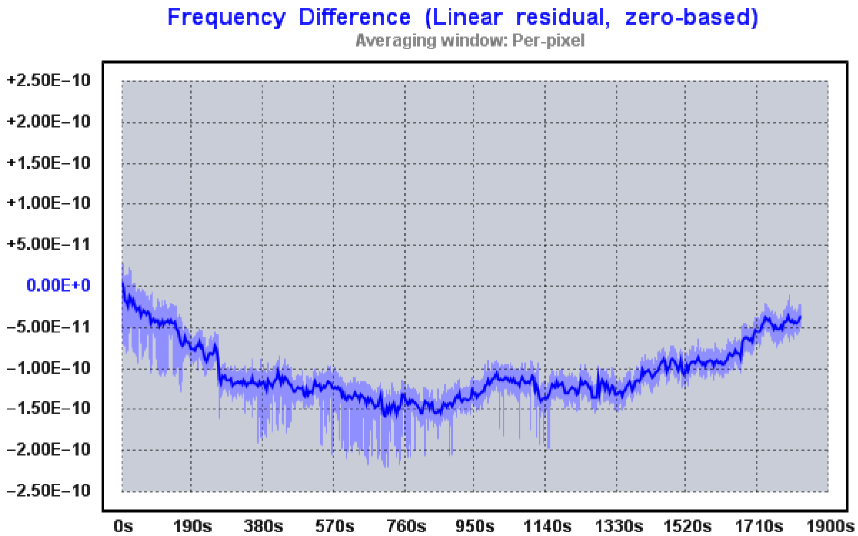
Unlocking the Y axis with Trace→Phase/frequency Y axis unlocked in zoom mode (y) keeps 3120A Test Software from constantly adjusting the Y axis to accommodate the graph's vertical range. With the Y axis unlocked, you can expand and scroll the graph in both directions with the mouse, rather than being limited to side-to-side navigation.



Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

In this case, though, unlocking the Y axis and drawing a box requires a lot of user interaction. Worse, you'll end up with an "unfriendly" Y-axis scale whose random-looking values make the graph difficult to interpret. Once again, Trace→Phase/frequency traces begin at zero (z) offers a better alternative with a single keystroke:

To sum up, selecting Measurement→Frequency difference (f), applying Edit-> Subtract global linear frequency trend (drift line) (Ctrl-l) , and enabling Trace→Phase/frequency traces begin at zero (z) can reveal details which are impossible to spot in the raw phase-difference trace. All of this being said, in order to get the same detailed view, we really only needed to enable Trace→Show linear phase/frequency residual (r) while viewing the frequency difference trace!



Trace	Input Freq	Sample Interval	Elapsed	Instrument
HP 10811-60111	5.000 MHz	0.004 s	12h 0m 0s	3120A

The Trace→Phase/frequency traces begin at zero (z) and Trace→Show linear phase/frequency residual (r) commands are both extremely useful. Enabling one or both of these features can give you a detailed view of most phase- or frequency-difference traces without altering the phase data itself[1]. Keep the r and z keys in mind while working with these traces, and experiment with them frequently.

Hints for phase/frequency stability measurements

- Due to slight variations in FPGA/USB interface temperature that occur when acquisition begins, the 3120A's own impact on critical residual-phase measurements can be minimized if you use Acquire→Enable deferred acquisition (ctrl-d) to force the acquisition to throw away incoming data until you press Enter to 'trigger' it. This feature is normally used to improve synchronization in multiple acquisitions, but you can also use it to force a single instrument to reach its equilibrium temperature before the software saves any data.

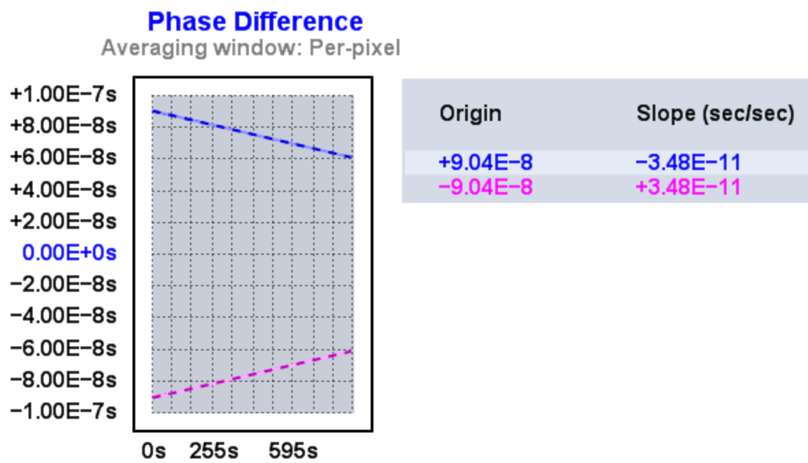
  You can accomplish the same thing by selecting the Measurement→Phase difference (p) view, using the left mouse button to select the first few minutes of data where the phase slope may be artificially degraded. When you release the button it will zoom to the selected area of the plot. You can then hit F4 to delete that chunk of data from the phase record. The ADEV and other phase-derived graphs will be recalculated. (This will not affect the phase noise or AM noise plots; as mentioned elsewhere, they are acquired with a completely different "signal path" than the one that decimates and records the phase-difference data.)

[1] Note that the Subtract quadratic linear frequency trend (drift curve) (Ctrl-q) operation has no “view-only” equivalent. It operates in a manner similar to the Subtract global linear phase trend (frequency offset) (Ctrl-o) and Edit-> Subtract global linear frequency trend (drift line) (Ctrl-l) commands, and can be even better at revealing details in plots like this one.

- Pressing Scroll Lock will latch the current Y-axis limits, preventing them from changing regardless of the zoom status or Trace→Phase/frequency Y axis unlocked in zoom mode (y) option. This feature can be useful when you want to keep the view from being rescaled after removing, detrending, or flattening trace data, such as when similar modifications are being applied to multiple traces in an unzoomed view. Turning Scroll Lock off will restore the previous Y-axis control state.

  Most users will not need to latch the Y axis limits. Scroll Lock is one of the few operations in 3120A Test Software with no menu-based equivalent.

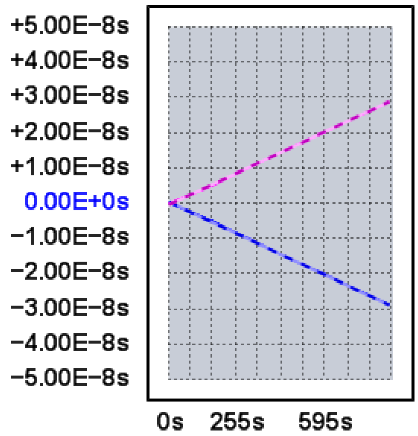
- To invert the phase slope, you can use the Edit→Trace properties… (e) dialog to specify a Rescale Phase value of -1. This will invert both the slope and the origin of the phase data, but you can still use Trace→Phase/frequency traces begin at zero (z) to display the inverted trace at a fixed origin of zero.



Trace	Notes	Input Freq	Instrument
ULN5	Original data	5.000 MHz	3120A
ULN5	Rescale Phase = -1	5.000 MHz	3120A

Phase Difference (Zero-based)

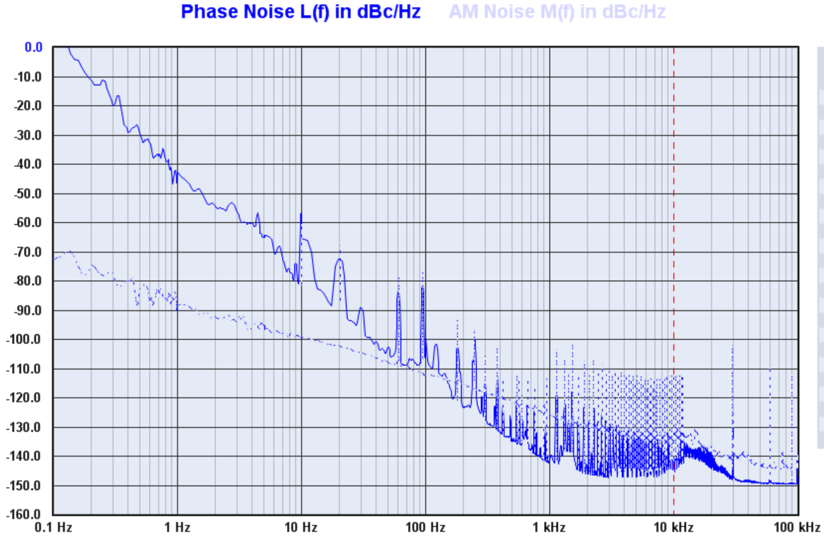
Averaging window: Per-pixel



Origin	Slope (sec/sec)
+5.01E−10	−3.48E−11
−5.01E−10	+3.48E−11

Trace	Notes	Input Freq	Instrument
ULN5	Original data	5.000 MHz	3120A
ULN5	Rescale Phase = -1	5.000 MHz	3120A

Phase noise, AM noise, and jitter



PM Spur Offset (Hz)	dBc
10.0	-60.6
20.0	-68.0
60.0	-78.9
94.0	-77.0
180.0	-93.7
250.0	-96.8
300.0	-105.7
380.0	-102.8
420.0	-112.9
540.0	-111.8
570.0	-113.6
600.0	-118.8
660.0	-113.7
750.0	-115.5
900.0	-122.9
940.0	-113.6
1130.0	-103.4
1320.0	-106.5
1420.0	-111.8
1520.0	-102.2
1700.0	-112.0
1890.0	-107.5
2070.0	-112.2
. . .	

Trace	Notes	Input Freq	Input Amplitude	Ref Freq	Ref Amplitude	dBc/Hz at 10 kHz	Instrument
HP 8640B (Unsaved)	HP 5061A	5098148.754 Hz	9.5 dBm	5000001.076 Hz	15.9 dBm	-140.8	3120A

To measure the phase noise of a drift-prone source such as this HP 8640B cavity-tuned signal generator, uncheck the Frequency Stability option in the acquisition dialog. This will allow greater drift tolerance, since it won't be necessary for the signal to remain within a narrow measurement-bandwidth passband

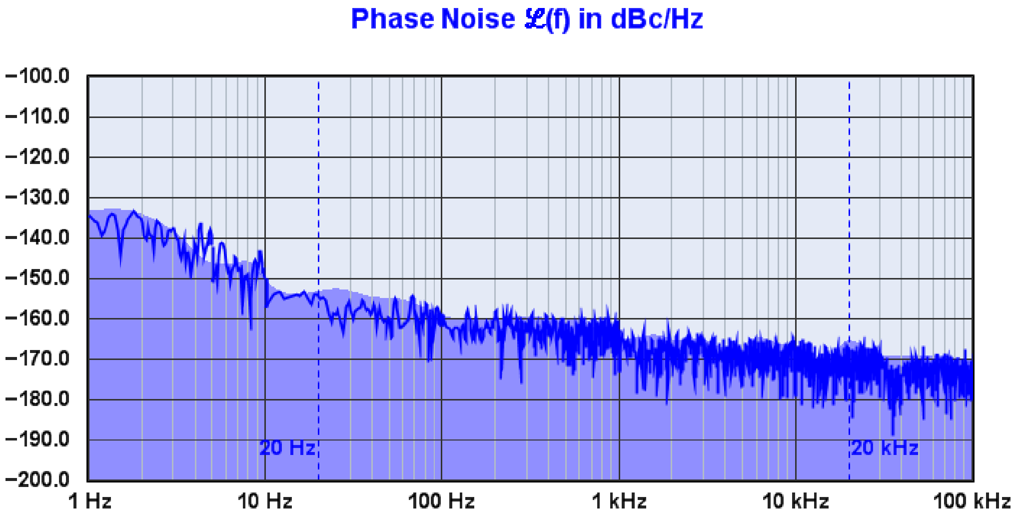
Thanks to the magic of cross-spectrum averaging, the Symmetricom 3120A can measure phase noise and AM noise on HF signals at exceptionally low levels. Below are some guidelines to help you make the most of this capability.

Integrated noise and jitter measurement

You can display various measures of integrated phase noise between two arbitrary offsets by enabling any or all of the following Legend menu fields:

- Residual FM
- RMS Integrated Noise (Degs)
- RMS Integrated Noise (Rads)
- RMS Time Jitter
- SSB Carrier/Noise

Note: AM Noise and integrated noise/jitter measurements are optional features.



Notes	Input Freq	Input Amplitude	RMS Jitter	Instrument
Residual jitter	5 MHz	10.4 dBm	2.4E−14 s	3120A

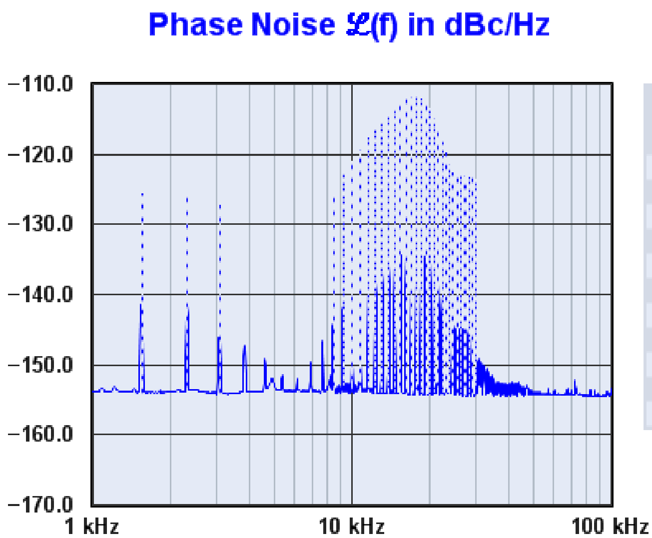
When one or more of these parameters is enabled for display in the legend table, two "spot cursors" will appear in blue. You can move these lower and upper limit cursors with Ctrl-left click and Ctrl-right click, respectively.

3120A Test Software does not make a distinction between random and deterministic jitter, so any spurs in phase noise plots are "integrated" as if they contained only random noise. Consequently, when viewing any of the RMS integrated noise values, you should use either Trace→Smooth noise traces (Ctrl-w) or Trace→Suppress spurs (Ctrl-s) to remove as much coherent energy as possible from the phase noise trace. Otherwise, time jitter and integrated-noise readings may be artificially exaggerated.

Along with many other sources, HP Application Note AN270-2 provides a concise summary of the math behind phase-noise integration.

The spur table

The spur table is a list of all coherent amplitude- or phase-modulated spectral components detected by the instrument in the course of measuring AM noise or phase noise, respectively. Each plot acquired from an instrument that supports spur detection has its own spur table. Spur levels are reported as CW power levels relative to the carrier, each at a given offset from the carrier frequency.



PM Spur Offset (Hz)	dBc
120.3	−115.3
241.6	−130.4
360.9	−135.8
480.2	−135.3
768.9	−125.2
1544.6	−125.8
2314.5	−126.1
3089.2	−127.3
8459.3	−125.3
9229.2	−123.0
. . .	

Typical phase noise measurement with accompanying spur table. The default Spur Threshold value of 6 dB, specified in the Noise and Jitter tab of the 3120A Test Probe acquisition dialog, ensures that artifacts of lower amplitude relative to neighboring areas of the trace are not classified as spurs. To illustrate the difference between coherent spur amplitudes and their apparent levels on the 1-Hz normalized noise trace, Trace→Suppress spurs in noise traces (Ctrl-s) is disabled and Trace→Mark spurs in noise traces (Ctrl-m) is turned on.

Show or hide known spurs

Several commands in 3120A Test Software determine how spurs are handled in phase noise and AM noise graphs.

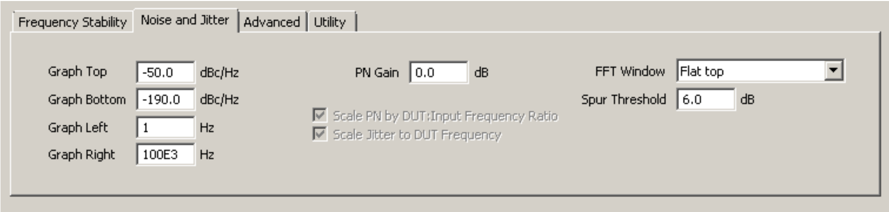
Trace→Mark spurs in noise traces (Ctrl-m) draws shaded or dashed lines, depending on the Trace→Toggle trace thickness for current measurement (T) setting, for each detected spur on the AM or phase noise graphs. These lines reflect the amplitude of each spur as reported in the spur table, which willnot be the same as the level of any corresponding bumps or spikes in the noise trace itself. Because phase noise and AM noise traces undergo normalization to 1 Hz bandwidth, the Y-axis labels don’t reflect the true amplitude of any coherent trace features. They must be recognized as spurs, and their amplitudes indicated separately.

Trace→Suppress spurs in noise traces (Ctrl-s) attempts to remove known spurs from phase noise and AM noise traces. As noted above, spurs that appear as artifacts in noise traces are not rendered at their true amplitude levels due to the use of FFT noise-bandwidth normalization. If you are concerned with spur amplitudes in a given measurement, you should use Trace→Suppress spurs in noise traces (Ctrl-s) to erase each detected spur from the graph and Trace→Mark spurs in noise traces (Ctrl-m) to replace them with vertical lines showing their true CW amplitude levels relative to the carrier.

Trace→Smooth noise traces (w) always implies Trace→Suppress spurs in noise traces (Ctrl-s). For better visual quality, the 3120A Test Software will attempt to erase any known spurs prior to smoothing the trace.

Display→Numeric table (Ctrl-n) can be used to show or hide the spur chart for the selected plot. Like the numeric charts and tables associated with other measurement types, the spur chart appears to the right of the graph area. The Ctrl-n command toggles table visibility for all measurement types, not just the currently visible one.

Spur measurement options



The Noise and Jitter tab in the 3120A Test Probe's acquisition dialog contains two parameters that influence how spurs are recognized and recorded. First, the Spur Threshold field defines the amplitude level, relative to the average level of nearby FFT bins, below which a given bin's amplitude will not be considered indicative of a coherent spur. Second, the choice of FFT Window implies a compromise between the accuracy at which a given spur's offset frequency and amplitude are reported. (The Flat top window excels at measuring spur amplitude levels, but the Hann window offers better frequency resolution, and may improve the odds of detecting a given spur as well.)

Finally, the 'Edit segment table' button in the Advanced tab allows you to change the FFT kernel sizes used in the individual noise-trace segments, which can affect both spur-identification performance and acquisition time.

Is it a spur, or isn't it?

Identifying genuine spurs while disregarding false ones can be a challenge. The 3120A's DSP software may fail to detect spurs when they occur in clusters near the FFT segment's resolution limits, in steeply-sloped areas of the noise trace, or near segment boundaries. You can lower the Spur Threshold for a given measurement, but the risk of misclassifying random noise spikes as coherent spurs will become greater. When you see random spurs appear and disappear from the spur chart over the course of a measurement, you can increase the Spur Threshold, try changing FFT window types, or simply wait for the measurement to run long enough to reduce the trace variance ("grass").

Understanding instrument spurs

While 3120A Test Software can sometimes overlook true spurs and report nonexistent ones, a third type of measurement error may need to be considered as well: the presence of spurs which originate within the instrument itself.

The spur-free dynamic range (SFDR) of the ADCs used in the 3120A Test Probe is approximately 100 dB, which determines the corresponding specification limit of the instrument as a whole. In principle, your noise plots may contain fictitious spurs as high as -100 dBc, but the 3120A Test Probe's typical performance is much better than this. Any spurs with amplitudes above -120 dBc that remain visible as the measurement converges are almost certainly "real" in the sense that they originate from the DUT, from the reference, or from environmental RFI.

Regardless of the equipment used, spur-free observations of AM noise and phase noise become challenging below -150 dBc. There are simply too many potential sources of coherent artifacts to rule out in most cases. Still, spurs that originate within the 3120A can sometimes be identified manually. An informal technique that may help determine whether a given spur or spur cluster originates within the 3120A Test Probe hardware itself is illustrated in the side-by-side plots on the next page.

Hints for noise measurements

- The 3120A can render an estimate of its own noise floor in AM/PM noise plots if you enable Trace→Show estimated instrument noise (F2). See page 76 for more information.
- For AM and phase noise, a good indication that the noise trace has converged on its final level is the variance of the trace, or its overall fuzziness/thickness. If you measure a conventional signal generator or noisy oscillator, you'll notice that the trace stops falling relatively quickly after the measurement begins, and then becomes smoother over time. This 'smoothing' effect is an important cue that tells you how trustworthy your noise measurement is. With quiet sources, close-in segments can take an especially long time to converge at a final, smoothed level, since they are updated much less often.
- Crosstalk and AC power-line interference can create discrete spurs on phase noise and AM noise graphs, just as they can degrade ADEV and other statistical plots.
- 3120A Test Software has a graph-smoothing feature (Trace→Smooth noise traces (ctrl-w)) but it's often not needed with a cross-correlating analyzer such as a Symmetricom 3120A or a Symmetricom 5120A/5125A. The best way to obtain a smoother trace with these instruments is to let your measurement run longer. Low-level residual plots can benefit from Trace→Smooth noise traces (ctrl-w), but many measurements don't need additional smoothing at all.
- Another tip for smoother phase noise and AM noise traces, suitable for 3120A Test Probe users with faster PCs: enable the Overlapped Acquisition option in the Noise and Jitter tab of the acquisition dialog. Overlapped acquisition provides better utilization of incoming data by the FFT routines, but requires significantly more CPU time.
- When overlaying several measurements on the screen, it can be helpful to run with spurs removed from the trace (Trace→Suppress spurs (Ctrl-s) enabled) and unmarked on the graph (Trace→Mark spurs (Ctrl-m) disabled).

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3120A Test Software command reference

Most of the menu-based commands in the 3120A Test Software also have single-key shortcuts for faster, more interactive workflow. When present, the shortcut key is shown after the name of the menu option.

File menu

The File menu helps you work with data files and images. Supported actions include opening, saving, closing, and deleting plots stored in .TFF files, saving image files, printing or copying the currently displayed window contents, and importing and exporting raw measurement data. Various “user preference” toggles are also provided.

Load .TFF file (l)

Loads a saved .TFF file. .TFF files are ASCII text files that contain all measurement data acquired or imported by the 3120A Test Software, together with any applicable metadata. Specific fields and tables within each .TFF file may vary depending on the measurement type (s) saved in the file.

For frequency stability measurements made with counters or timing analyzers, the .TFF file contains the phase record obtained from the instrument during acquisition. The phase record may have been derived from a series of frequency readings or other raw data stream formats. It may also have been decimated to conform to a specified measurement rate or bandwidth.

For phase noise and AM noise measurements, the .TFF file contains the FFT bin contents needed to render the applicable graphs.

Save image or .TFF file (s)

This command can either save the selected plot as a .TFF file, or save the current contents of the 3120A Test Software window as an image file in .PNG, .GIF, .TGA, .PCX, or .BMP format.

By default, .TFF files will be saved. To save an image file, simply add one of the suffixes above when you enter the filename. Keep in mind that image files do not preserve your original measurement data, and cannot be reloaded into 3120A Test Software.

Generally, the .PNG format is best for saving images from 3120A Test Software for email attachment or inclusion in other documents. .GIF and .PCX files will discard some color information, while .TGA and .BMP files are unnecessarily large.

When saving an image, all visible status and error messages, notifications, prompts, and mouse-cursor query values are removed. The black-triangle cursor associated with the currently selected plot will also be omitted from saved images.

Copy image to clipboard (Ctrl-c)

This command offers a handy shortcut for cutting/pasting 3120A Test Software screen images into other programs via the operating system's clipboard, avoiding the need to save an image file.

When copying the screen image to the clipboard, all visible status and error messages, notifications, prompts, and mouse-cursor query values are removed. The black-triangle cursor associated with the currently selected plot will also be omitted from the copied image.

Use caution when pasting images from the clipboard into email messages. Some clients may encode them in uncompressed form, resulting in messages too large to email reliably. When in doubt, consider attaching a saved .PNG file instead.

Import .PNP phase noise data (N)

Imports a .PNP file saved by PN.EXE, a popular freeware phase-noise measurement application from the KE5FX GPIB Toolkit. Phase noise plots from various RF spectrum analyzers not otherwise supported by 3120A Test Software may be imported from PN.EXE and rendered in 3120A Test Software.

Import ASCII phase or frequency data (L)

Reads an ASCII text file containing phase-difference, frequency, frequency-difference, or timestamp data, one entry per line. The imported data is converted to a standard 3120A Test Software phase record, and may be rendered, manipulated, and saved as a .TFF file.

As with other acquisition dialogs, 3120A Test Software's data-import dialog provides detailed mouseover help text for all fields. Refer to this help text for usage information.

To "watch" a continuously updated data file, use Acquire→Acquire from live ASCII file instead.

Export ASCII phase data (x)

This command is supported only when viewing the selected plot's phase record contents using Measurement→Phase difference (p) or Measurement→Frequency-difference (f). It will save an ASCII text file containing phase difference data in seconds, one entry per line, at 16 digits of precision to the right of the decimal point.

If a selected or zoomed area has been defined by dragging with the mouse, only that portion of the phase record will be exported.

By default, the exported phase data will be saved with the suffix .CSV for ease of reading into Excel and other spreadsheets. Exported data may be re-imported into 3120A Test Software, if necessary, by the File→Import ASCII phase or frequency data command. Select "All files" as the file type if the data was not exported with the suffixes .TXT or .DAT, then select Phase difference (sec) as the file data type.

Optionally, each sample in the ASCII phase data file can be timestamped with its absolute MJD or the number of elapsed seconds since the beginning of the phase record.

Export ASCII frequency data (X)

This command is supported only when viewing the selected plot's phase record contents using Measurement→Phase difference (p) or Measurement→Frequency-difference (f). It will save an ASCII text file containing absolute frequency readings in hertz, one entry per line, at 16 digits of precision to the right of the decimal point.
If a selected or zoomed area has been defined by dragging with the mouse, only that portion of the phase record will be exported.

By default, the exported frequency readings will be saved with the suffix .CSV for ease of reading into Excel and other spreadsheets. Exported data may be re-imported into 3120A Test Software, if necessary, by the File→Import ASCII phase or frequency data command. Select "All files" as the file type if the data was not exported with the suffixes .TXT or .DAT, then select Frequency (Hz) as the file data type.

Optionally, each sample in the ASCII phase data file can be timestamped with its absolute MJD or the number of elapsed seconds since the beginning of the phase record.

Export binary phase data

This command is supported only when viewing the selected plot's phase record contents using Measurement→Phase difference (p) or Measurement→Frequency-difference (f). It will save a binary file containing phase difference data in seconds, represented as a block of double-precision IEEE 754 values in little-endian (Intel) format.
If a selected or zoomed area has been defined by dragging with the mouse, only that portion of the phase record will be exported.

As with File→Export ASCII phase data (x), the default file suffix is .CSV. This is usually inappropriate for binary data; you should specify a suffix appropriate to your application. Exported binary phase data may not be re-imported into 3120A Test Software.

Export phase data to Stable32 (Ctrl-x)

This command is useful for transferring data from the selected plot's phase record directly into a third-party analysis application such as Stable32 from Hamilton Technical Services. Stable32 is a popular application for offline data analysis. It supports many statistical features and display options beyond the limited set implemented by 3120A Test Software.

This command works by exporting the selected plot's phase record to a temporary file using the same functionality as the File→Export ASCII phase data (x) command. If a selected or zoomed area has been defined by dragging with the mouse, only that portion of the phase record will be exported.

When the command is issued, a dialog box allows you to specify the location of the Stable32 executable or other third-party program, as well as the command line to be passed to it. The command line may contain various predefined variables described in the dialog box's help text, including placeholders for the name of the temporary file and the data rate (tau zero) in samples per second. Upon pressing the Launch Stable32 button, the temporary file will be generated and the specified program launched. 3120A Test Software will then continue to run normally.

Temporary files created by 3120A Test Software are cleaned up when 3120A Test Software exits, so it's advisable to leave 3120A Test Software running until after the third-party analysis application has exited.

Export xDEV trace

Available in the Measurement→Allan Deviation (a),Measurement→Modified Allan Deviation (m), Measurement→Hadamard Deviation (h), or Measurement→Time Deviation (t) views, this command creates an ASCII text file containing a tau, sigma(tau) value pair for each visible xDEV bin in the selected plot. One value pair is written per line; each value is rendered with 16 digits of precision to the right of the decimal point.

The number and distribution of xDEV bins may be specified prior to acquisition with the Bin Density field in the Frequency Stability tab of the acquisition dialog. Additionally, the selected plot's bin density may be adjusted after acquisition through the Edit→Trace properties dialog. See the help fields in these dialogs for details.

By default, the exported tau, sigma(tau) pairs will be saved with the suffix .CSV for ease of reading into Excel and other spreadsheets.

Export AM/PM noise trace

Available in the Measurement→Phase noise (P) and Measurement→AM Noise (A) views, this command creates an ASCII text file containing offset, dBc/Hz values corresponding to the visible noise trace for the selected plot. One value pair is written per line; each value is rendered with 16 digits of precision to the right of the decimal point.

One offset, dBc/Hz pair is written for each pixel column in the displayed graph. This means that if you zoom in on a portion of the phase noise or AM noise graph, only the trace data corresponding to the visible area of the selected plot will be exported. Conversely, if the graticule's X-axis boundaries extend beyond the minimum or maximum offset for the selected plot, no offset, dBc/Hz pairs outside the valid range will appear in the exported file.

By default, the exported offset, dBc/Hz pairs will be saved with the suffix .CSV for ease of reading into Excel and other spreadsheets.

Note that when Trace -> Show imaginary part of cross spectrum (Ctrl-F3) is active, the File→Export AM/PM noise trace command will export the imaginary cross spectrum trace data rather than the normal AM noise or phase noise trace.

Export AM/PM spur table

Available in the Measurement→Phase noise (P) and Measurement→AM Noise (A) views, this command creates an ASCII text file containing offset, dBc values corresponding to entries in the spur table for the selected plot. One value pair is written per line; each value is rendered with 16 digits of precision to the right of the decimal point.

By default, the exported offset, dBc pairs will be saved with the suffix .CSV for ease of reading into Excel and other spreadsheets.

Print image

After displaying a standard dialog box for printer selection and configuration, this command prints the current contents of the 3120A Test Software window.

The printed image will not contain any visible status or error messages, notifications, prompts, or mouse-cursor query values. The black-triangle cursor associated with the currently selected plot will also be omitted.

Scale file dialogs by window size

When this option is enabled, common file dialogs in Windows XP will be centered in the 3120A Test Software window and resized proportionally. In later Windows versions, the option has no effect. (Default: disabled)

Warn before exiting with unsaved plots

If enabled, this option causes 3120A Test Software to prompt for confirmation before exiting if any plots have been acquired or edited but not saved. (Default: enabled)

Reset all parameters, options, and settings at next startup

This option causes a dialog box to appear when you exit from 3120A Test Software confirming that you would like to reset all options, settings, colors, and dialog fields to their default values the next time the program is launched. If confirmation is given, the .INI files associated with 3120A Test Software and all of its instrument drivers will be deleted, forcing them to be recreated with default values when the program is relaunched. (Default: disabled)

Close selected plot (Del)

Closing the selected plot frees the memory it occupies and removes it from the graph and legend table. If the plot is associated with a saved .TFF file, the file is not deleted.

After closing a plot, the next plot in the legend table, if any, becomes the selected plot. Up to 9 plots may be loaded into memory at once; to acquire, load, or import additional plots, you must close at least one.

Close all visible plots (Home)

Closes all loaded plots at once, removing them from the graph and legend table.

Delete selected plot's .TFF file (Ctrl-Del)

After prompting for confirmation, this command unloads the selected plot's data from memory and also deletes its associated .TFF file, if any.

After closing a plot, the next plot in the legend table, if any, becomes the selected plot. Up to 9 plots may be loaded into memory at once; to acquire, load, or import additional plots, you must close at least one.

Quit (q or Esc)

Exits from 3120A Test Software. Depending on the setting of File→Warn before exiting with unsaved plots, a confirmation prompt may be issued.

Unless you hold the Shift key as the program exits, 3120A Test Software will write all of its global settings and dialog fields (as well as a list of known Legend menu entries and currently loaded plots) to a file called 3120A.INI. These properties will be restored when the program is next launched. The “Shift-exit” feature can be handy if you have opened or closed various plots or changed any options or colors, but don’t wish to retain the changes or otherwise lose your previous startup defaults.

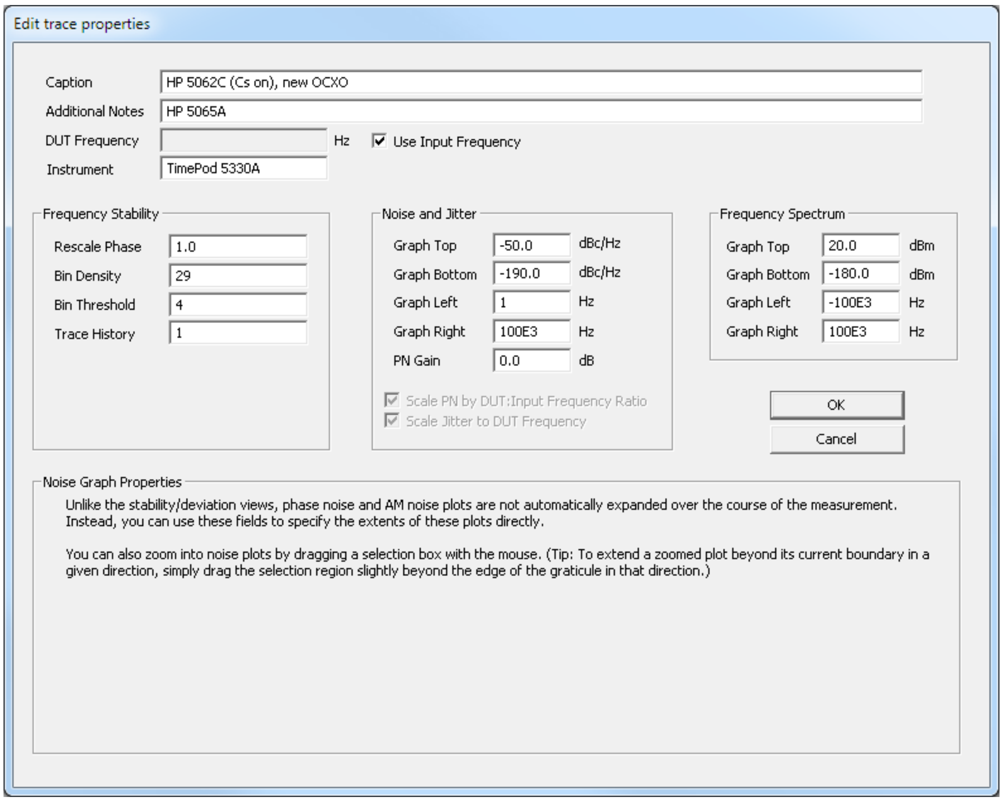
Note that acquisition and file-import dialog field contents are not backed up in 3120A Test Software.INI. The most recently used dialog entries associated with these operations are stored in instrument-specific .INI files. The instrument driver updates its .INI file as soon as you select Start Measurement or otherwise initiate an acquisition or import operation, not when the program exits.

After updating 3120A.INI, any temporary files that may have been created by instrument drivers or the File→Export phase data to Stable32 (Ctrl-x) command are deleted. For debugging purposes, temporary-file cleanup is also inhibited if you hold down the Shift key while the program terminates.

Edit Menu

Plots that have been loaded or acquired in 3120A Test Software may be displayed with a variety of options and transforms. However, any changes to the measurement data or display parameters associated with a specific plot must be made through the commands in the Edit menu.

Trace properties (e)

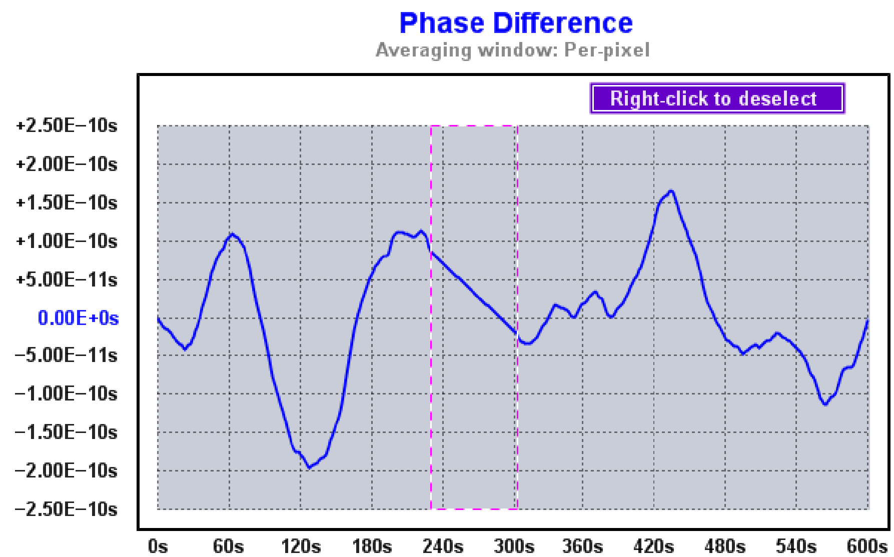


As seen above, the Edit→Trace properties (e) dialog lets you change various properties associated with the selected plot that determine how its measurement data is presented. These properties were assigned their initial values in the acquisition dialog before the measurement began. Like the various instrument-specific dialogs on the Acquire menu, the trace-properties dialog may vary from the image shown above.

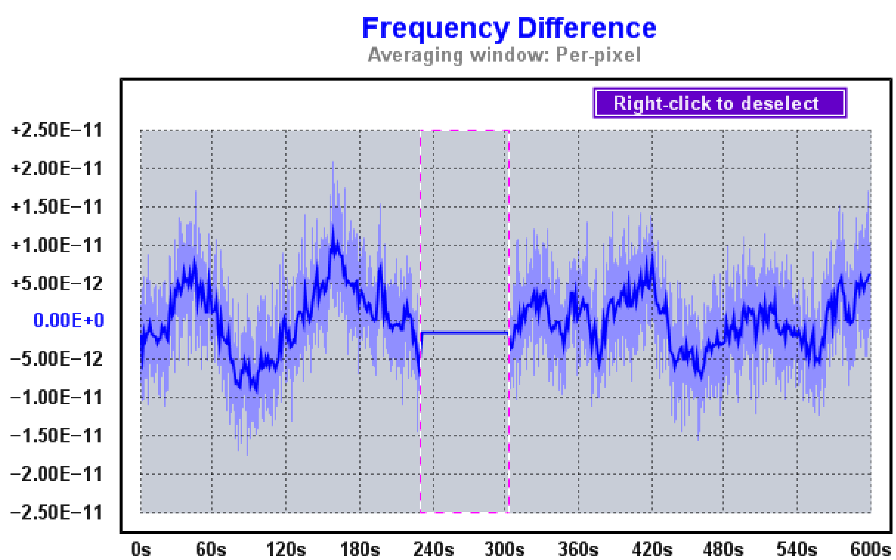
The dialog has extensive “mouseover help” text that is maintained alongside 3120A Test Software itself, so the individual fields will not be described here at length. Simply position your cursor over each field to learn more about it.

Some areas of the dialog may be disabled depending on the data type(s) available in the selected plot. Also, certain properties – notably those in the Frequency Stability area that determine the bin configuration for Allan deviation and other statistical measurements -- cannot be edited while acquisition is in progress. If you didn’t enter the desired values in the acquisition dialog before data collection began, you'll need to wait for the measurement to finish before you can change them.

Flatten selected or zoomed phase data (Ctrl-f)



Trace	Notes	Input Freq	Ref Freq	Sample Interval	Duration
8662A	Wenzel ULN10	13.999 MHz	9.999 MHz	0.047 s	10 m



Trace	Notes	Input Freq	Ref Freq	Sample Interval	Duration
8662A	Wenzel ULN10	13.999 MHz	9.999 MHz	0.047 s	10 m

Above, the Edit -> Flatten selected or zoomed phase data (Ctrl-f) command has replaced the selected region of the phase record with a straight line. The result appears as a flat spot in the Frequency Difference measurement view.

This command is supported only when viewing the selected plot's phase-record contents using Measurement→Phase difference (p) or Measurement→Frequency-difference (f). In addition, a region within the plot must first be specified. You can specify a region with a Shift-Left drag operation that leaves the region boundaries visible within the existing graph, as in the images above, or you can simply drag with the left mouse button to zoom in on the desired region. In either case, the command will replace the data within the specified region of the selected plot's phase record with a straight line segment that connects the data points at the region boundaries. As seen in the figures above, a straight line in the phase record corresponds to a flat region in the Measurement→Frequency difference (f) view.
You can use Edit→Flatten selected or zoomed phase data (Ctrl-f) to remove glitches and outliers from an acquisition. Subsequently, Edit→Undo last flatten or subtract operation (Ctrl-z) can be used to restore the flattened data. Unless you absolutely must preserve the original length of the phase record, though, it's better to use Edit→Remove selected or zoomed phase data (F4) in most cases.

No active background tasks may be under way for the selected plot at the time this command is issued. Active background tasks are those in which the plot's memory-resident phase record is being written, such as during initial acquisition and when reloading a saved .TFF file. If the phase record has finished loading but the xDEV statistical traces are still being refreshed, the refresh operation will be canceled, then restarted after the command finishes.

Remove selected or zoomed phase data (F4)

Like Edit→flatten selected or zoomed phase data (Ctrl-f), this command is useful for removing glitches and outliers from the selected plot's phase record. Instead of replacing the affected region with a straight line, however, Edit→Remove selected or zoomed phase data (F4) shortens the phase record by removing the data altogether.

This command has the same requirements and constraints as Edit→Flatten selected or zoomed phase data (Ctrl-f), except that it cannot be undone with Edit→Undo last flatten or subtract operation (Ctrl-z). Consider saving your original data to a .TFF file first so that it can be recovered if necessary.

When removing data from the middle of the phase record, you'll be asked if you want to maintain phase continuity. In virtually all circumstances you should respond "Yes" to this prompt. 3120A Test Software will then ensure a seamless transition between the two remaining regions by applying a constant offset to the phase data following the removed region. Otherwise, an abrupt phase change due to lost continuity may appear as a glitch in the data.

No active background tasks may be under way for the selected plot at the time this command is issued. Active background tasks are those in which the plot's memory-resident phase record is being written, such as during initial acquisition and when reloading a saved .TFF file. If the phase record has finished loading but the xDEV statistical traces are still being refreshed, the refresh operation will be canceled, then restarted after the command finishes.

Subtract global linear phase trend (frequency offset) (Ctrl-o)

Subtract global linear frequency trend (drift line) (Ctrl-l)

Subtract quadratic linear frequency trend (drift curve) (Ctrl-q)

These related commands are used to remove global offsets and trends from the selected plot's phase record. This is typically done to improve visibility of local trends and features whose magnitude is small compared to the Y-axis range. For detailed usage information and examples, as well as some alternative viewing methods that don't alter the phase record contents, see page 42.

Two commands on the Trace menu, Phase/frequency traces begin at zero (z) and Show linear phase/frequency residual (r), provide non-destructive functionality similar to the Edit→Subtract global linear phase trend (frequency offset) (Ctrl-o) command. See page 67 for more information

.

If the selected plot has any background tasks in progress when any of these commands are issued, an error message will be displayed. Background tasks are those in which the plot's memory-resident phase record is being accessed by a background thread during initial acquisition, when reloading a saved .TFF file, and when reconstructing the xDEV statistical traces after a previous modification to the phase record.

Undo last flatten or subtract operation (Ctrl-z)

This command rolls back the most recent change to the selected plot's phase record performed by any of the following other commands:

- Edit→Flatten selected or zoomed phase data (Ctrl-f)
- Edit→Subtract global linear phase trend (frequency offset) (Ctrl-o)
- Edit→Subtract global linear frequency trend (drift line) (Ctrl-l)
- Edit→Subtract quadratic linear frequency trend (drift curve) (Ctrl-q)
- Edit→Trace properties (e) (applies to Rescale Phase only)

A second "undo" command will redo the last-reverted action.

If the selected plot has any background tasks in progress when this command is issued, an error message will be displayed. Background tasks are those in which the plot's memory-resident phase record is being accessed by a background thread during initial acquisition, when reloading a saved .TFF file, and when reconstructing the xDEV statistical traces after a previous modification to the phase record.

Trace Menu

The Trace menu contains options that affect the way measurement data is processed and rendered as traces on the graph.

Unlike the Edit menu options, the Trace options apply to all visible traces, rather than only the selected plot, and they never alter the underlying measurement data. Most options on the

Trace menu apply only to a given measurement family – xDEV statistics, phase/frequency differences, or phase noise/AM noise measurements. For example, Trace→Averaging window for phase/frequency traces has no effect on phase noise or Allan deviation traces.

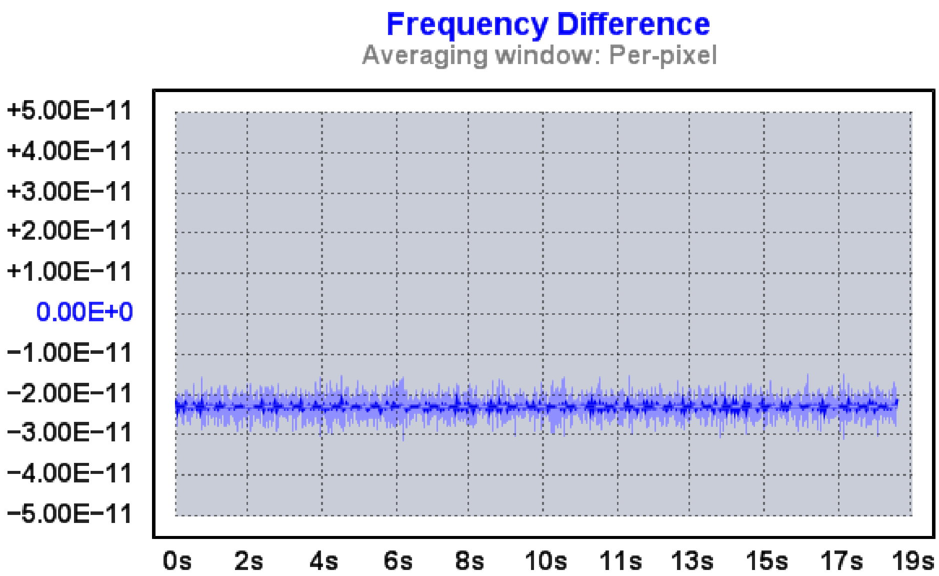
The majority of Trace options are simple on/off toggles. In the Measurement→Phase difference (p) display, for instance, applying the Edit→Subtract global linear phase trend (frequency offset) (Ctrl-o) command to each visible trace would have the same visible effect as Trace→Show linear phase/frequency residual (r), as discussed below. But Trace→Show linear phase/frequency residual (r) does not actually subtract the trend from the phase record. Issuing the command again will restore normal trace-rendering behavior.

Phase/frequency traces begin at zero (z)

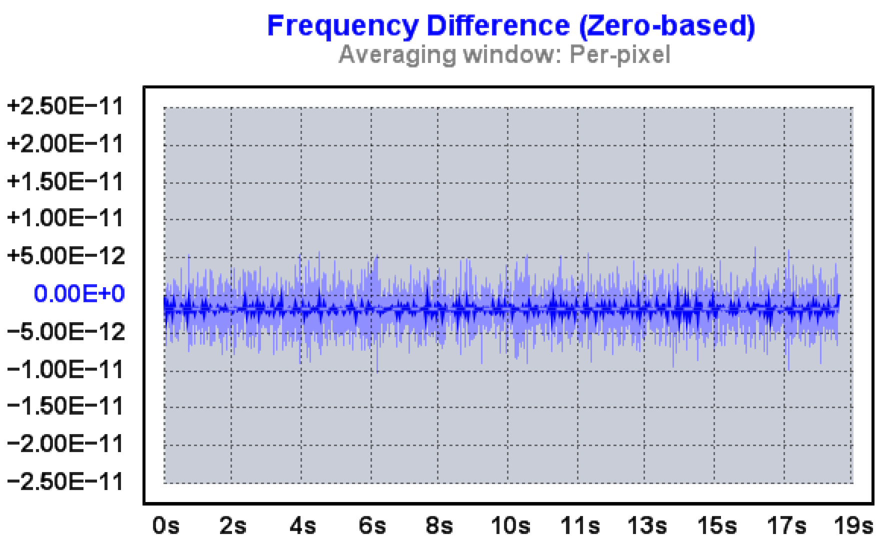
Show linear phase/frequency residual (r)

These two commands can be used individually or together to maximize visible detail in phase/frequency plots.

When enabled, Trace→Phase/frequency traces begin at zero (z) causes all phase- and frequency-difference traces to be displayed with their first data point pinned to Y=0.0. In unzoomed views – or in zoomed views with Trace→Phase/frequency Y axis unlocked in zoom mode (y) disabled to permit automatic Y-axis scaling – this will force the left end of the trace to the midpoint of the graph's Y axis. Since autoscaled Y axes in the 3120A Test Software are symmetrical about zero, this may allow the trace to occupy more of the visible graph area:

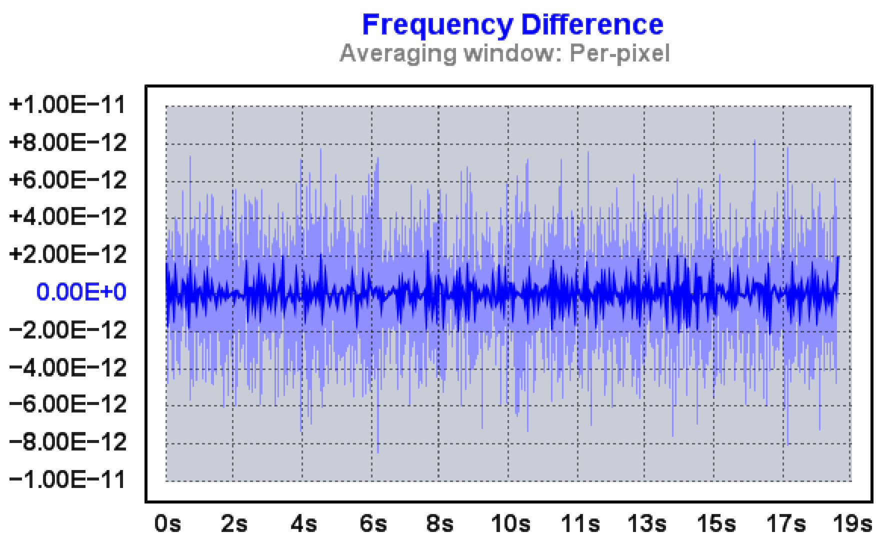


Input Freq	Sample Interval	Acquired	Instrument
10 MHz	0.004 s	3930 pts	3120A



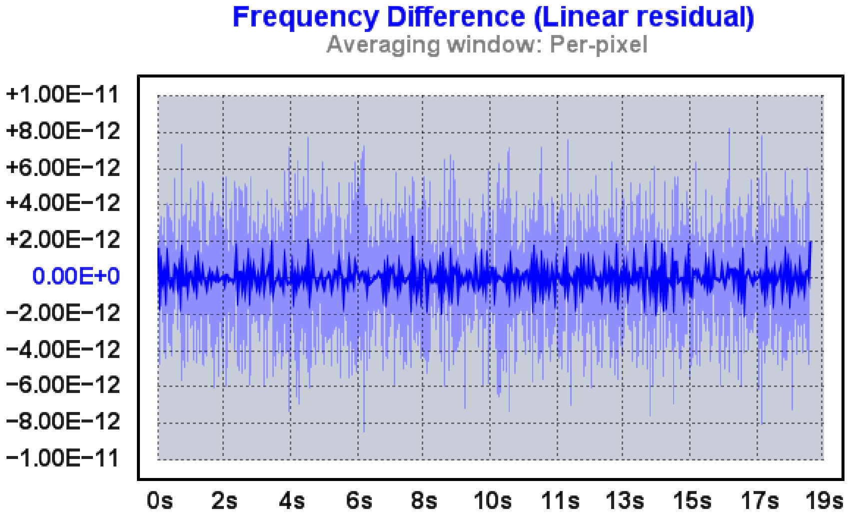
Input Freq	Sample Interval	Acquired	Instrument
10 MHz	0.004 s	3930 pts	3120A

When used in the Measurement→Frequency difference (f) view, the effect of Trace→Phase/frequency traces begin at zero (z) is somewhat similar to applying Edit→Subtract global linear phase trend (frequency offset) (Ctrl-o) to each visible plot. It's not quite the same, though, because a trace's first data point is not necessarily anywhere near its trend line. Subtracting the trend will often do a better job at centering individual traces symmetrically about the Y axis, as seen below.



Input Freq	Sample Interval	Acquired	Instrument
10 MHz	0.004 s	3930 pts	3120A

Of course, Edit→Subtract global linear phase trend (frequency offset) (Ctrl-o) has the drawback of altering the selected plot's phase data record and removing potentially useful information (namely the phase trendline). Fortunately, there's also a non-destructive global option that has the same visual effect, Trace→Show linear phase/frequency residual (r):



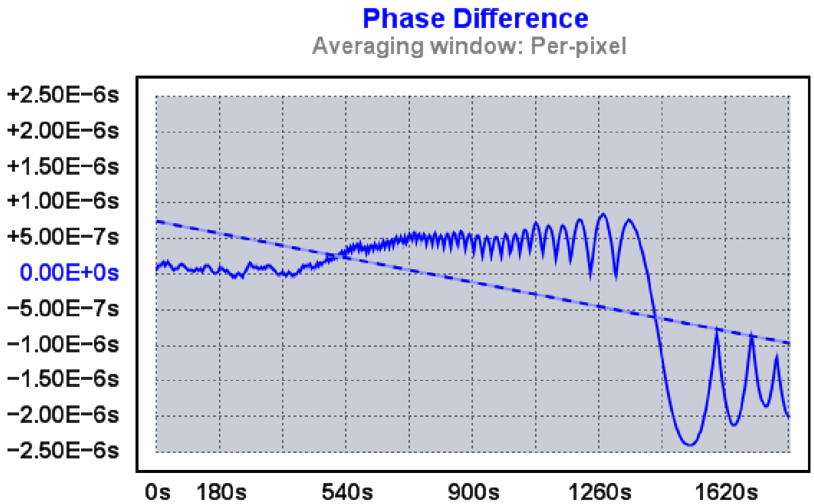
Input Freq	Sample Interval	Acquired	Instrument
10 MHz	0.004 s	3930 pts	3120A

These two commands, Show linear phase/frequency residual (r) and Phase/frequency traces begin at zero (z), are among the most commonly-used options on the Trace menu. If you spend much time working with phase- and frequency-difference traces, their r and z keyboard shortcuts will quickly become familiar. z can increase visible detail while preserving the graph's original shape, while r is better at revealing short-term noise and other effects that become harder to spot as the graph expands to accommodate a larger overall trend.

Some additional usage examples can be found on page 42.

Show linear phase/frequency trend (Ctrl-t)

When enabled, this option causes 3120A Test Software to display a dashed line on unzoomed phase- and frequency-difference traces to indicate the data's linear trend.



Trace	Input Freq	Acquired	Instrument
E1938A 4985 startup behavior	10 MHz	1800 pts	HP 5370A/B

The trend line is not displayed in magnified views, or when Trace→Show linear phase/frequency residual (r) is enabled.

Phase/frequency Y axis unlocked in zoom mode (y)

By default, the Y axis in phase- and frequency-difference measurement graphs is automatically scaled to accommodate the largest absolute value in all visible traces. The peak magnitude is rounded up to the next decade, half decade, or quarter decade, then mirrored to place zero at center scale. This approach allows the 10-division Y axis to be labeled in “nice” multiples of 1, 2, or 5.

When zooming in with the mouse to magnify a portion of the visible trace(s), it’s sometimes helpful to toggle the Y-autoscaling algorithm off by selecting Phase/frequency Y axis unlocked in zoom mode (y). This will have no effect on an unzoomed display, but when dragging with the left mouse button to magnify a desired area of the graph, you’ll be able to move in the both X and Y directions, instead of only being able to drag a pair of vertical cursors. When you release the button, the resulting zoomed view will conform to the specified extents in both directions.

With the Y axis unlocked, the Display→Y zoom in (}) and Display→Y zoom out ({) commands will be usable, and the scroll wheel will expand or contract the magnified region in both directions at once. Dragging with the middle mouse button will scrub the zoomed region in both the X and Y directions.

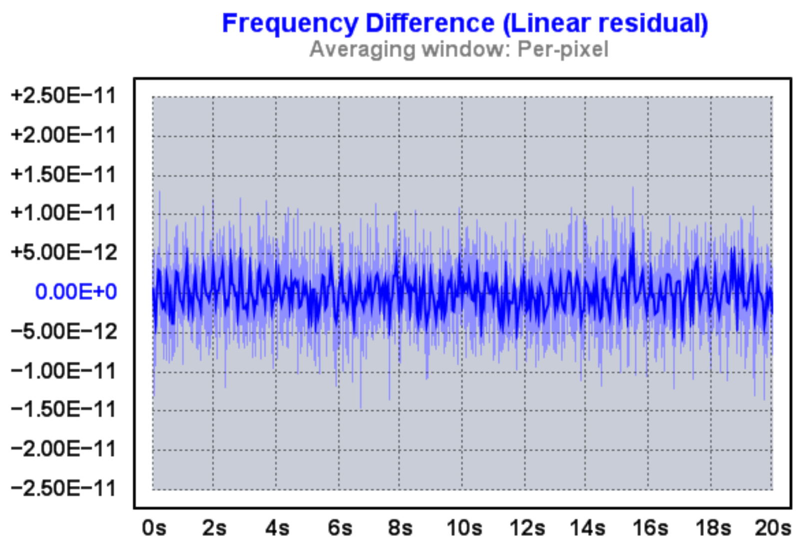
You can enable Y-axis autoscaling in zoom mode at any time. A quick way to “zoom out” in Y while maintaining the current X position and magnification factor is to tap the y key twice in succession – once to temporarily re-enable autoscaling, and again to restore 2D navigation with the middle button, scroll wheel, or ( ) { } shortcuts.

Averaging window for phase/frequency traces (g)

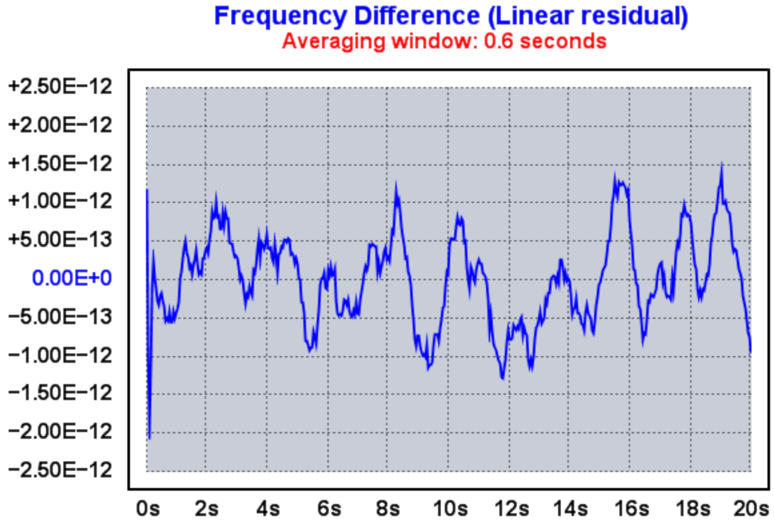
Increase averaging window (Ctrl +)

Decrease averaging window (Ctrl -)

These commands allow you to specify the length of an averaging window in seconds that will be applied to phase- and frequency-difference traces. The averaging process makes it easier to spot trends and patterns that may be obscured by short-term noise. Setting the window length to its default value of zero selects a hybrid “per-pixel” peak/average detection algorithm (discussed below.)



Input Freq	Sample Interval	Acquired	Instrument
10.000001 MHz	0.004 s	4268 pts	3120A



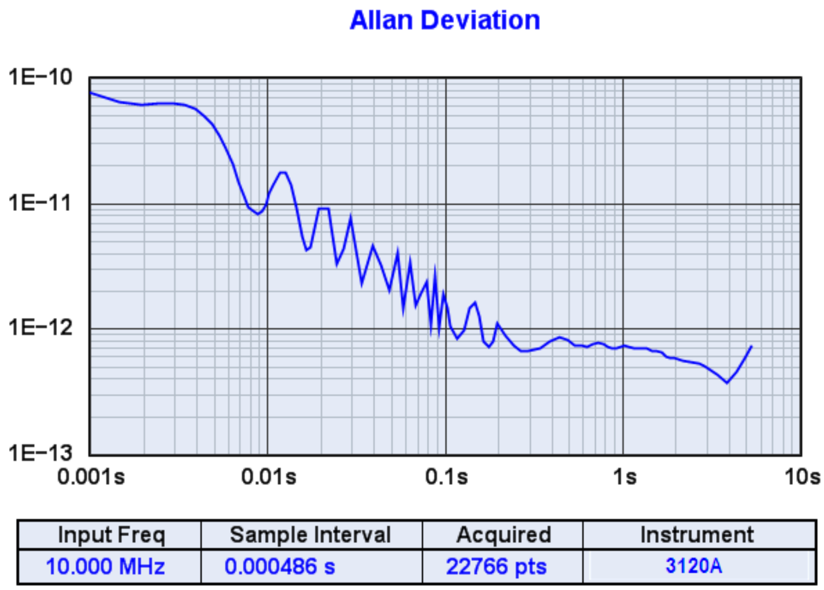
Input Freq	Sample Interval	Acquired	Instrument
10.000001 MHz	0.004 s	4268 pts	3120A

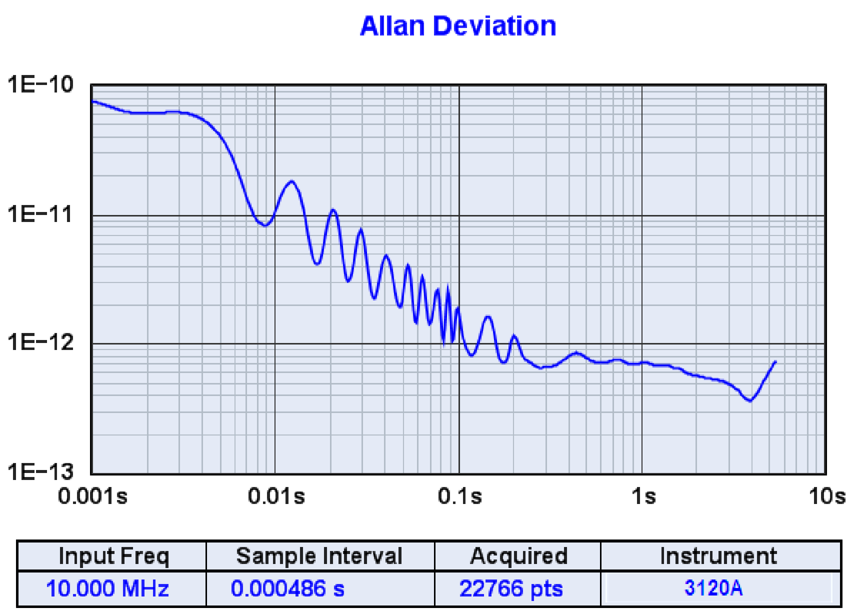
Warning: Averaging introduces time lag which may cause unexpected results with some commands and display options. It's recommend that averaging be disabled before selecting regions of the phase record for any operations, or when evaluating absolute phase differences or frequency differences. At long averaging times, a substantial baseline offset can exist between the beginning and end of the trace, since there's less historical data to contribute to the average near the beginning of the record. The trace may appear to "fall off a cliff," where noisy initial data gives way to a relatively-featureless trace as the averaging process takes effect. This effect is just beginning to appear in the 0.6s-averaged plot above.

As a reminder that averaging is in effect, nonzero averaging times will be displayed in red above phase- and frequency-difference graphs. You can quickly disable averaging with the keyboard sequence g 0 <Enter>.

Averaging also determines how phase records are decimated for display in the phase- and frequency difference views. When rendering a trace whose phase record length in samples exceeds the graph width in pixels, the samples that fall within each graph column must either be peak-detected or combined by averaging. When the averaging window is set to zero seconds, the 3120A Test Software effectively does both, using a "per-pixel" algorithm to provide as much information about the skipped phase-record samples as possible. As shown in the first plot above, a shaded vertical line is drawn in each pixel column that connects the minimum and maximum data values that fall within that column. The darker portion of the trace in the middle of the shaded area represents the average of all data points covered by each individual column. The effective averaging time is not fixed, but is equal to the duration of the visible portion of the trace divided by the width of the graph in pixels. This algorithm is simple, fast, and effective, but since the peak-detected line segments are drawn in a lighter shade of the trace color, it's easy to overlook brief glitches that fit within a single pixel column. Consider enabling Trace→Tick marks (k) when looking for outliers in per-pixel mode.

Draw xDEV traces with spline interpolation (i)

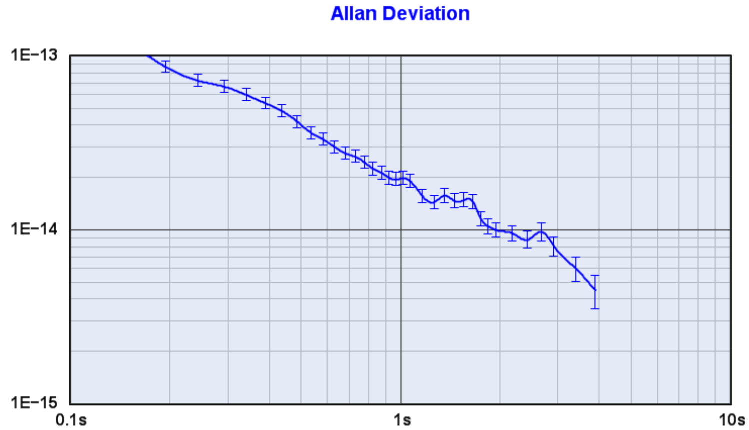




By default, screenspace points corresponding to the tau bins in Allan deviation and related statistical views are connected with a cubic spline. Spline interpolation results in a smooth, visually-appealing curve, but it can distort or exaggerate ringing artifacts and other abrupt transitions in the graph.

When Trace→Draw xDEV traces with spline interpolation (i) is toggled off, straight lines are used to connect the xDEV bins.

Show xDEV error bars (Ctrl-e)



Trace	Input Freq	Input Amplitude	ENBW	Acquired	Instrument
Residual	10.000 MHz	9.6 dBm	5.1 Hz	181 pts	3120A

When enabled, this option draws “error bars” at each tau bin in Allan deviation and other statistical plots. These bars approximate the ± one-sigma (68%) confidence interval at ±σ/sqrt(N/M), where N is the number of phase-record samples that contribute to each bin and M is the bin’s τ_0 multiple.

This calculation does not take either the deviation type or the noise slope into account, so it should be considered a rough estimate of the actual confidence interval obtainable through more sophisticated offline analysis. Consider exporting your phase data to Stable32 (page 59) if your application requires better confidence-interval estimates.

Clip xDEV traces by noise bandwidth (Ctrl-b)

This display option is used to suppress artifacts near the tau-zero points in Allan deviation and other statistical plots that can appear when incoming data is oversampled for lowpass filtering. xDEV values at tau intervals close to the sample rate may appear to “droop” in such cases, since the data has been band-limited at a cutoff frequency below its Nyquist rate. A discussion of this effect appears on page 30.

Clip xDEV traces by confidence (Ctrl-v)

This display option is used to avoid rendering Allan deviation and other xDEV traces beyond the point where insufficient data is available for good statistical confidence. It is enabled by default.

Specifically, when this option is enabled, the only xDEV bins that are drawn are those whose phase data sample count (N) is >= 2x their τ_0 multiple (M).

Show correlation gain for selected noise trace (Ctrl-g)

Intended primarily as a diagnostic aid, this option is supported when viewing phase noise or AM noise plots from instruments such as the Symmetricom 3120A that support real-time cross correlation. When enabled, the FFT segments in the selected phase noise or AM noise plot will be color-coded for identification. A table will appear as an overlay in the graph area that displays the number of cross-spectrum averages performed so far in each color-coded segment, along with the theoretical improvement in ADC noise expressed in dB.

The estimated improvement in each segment's effective noise floor is calculated as $10 * \log_{10}(\mathrm{sqrt}(N))$ dB, where N is the segment's number of averages.
Trace smoothing is not performed on the selected noise plot when this option is enabled.

Show FFT segment filter slopes (Ctrl-i)

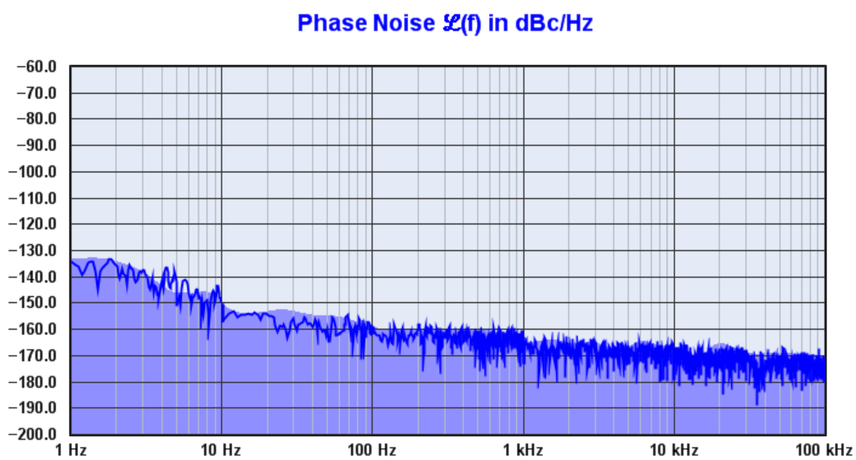
This option is a diagnostic aid intended for use when editing FFT segment table files for phase noise and AM noise acquisition with 3120A Test Probe hardware.

When acquiring noise plots on the 3120A, data for each visible FFT segment undergoes highpass and/or lowpass filtering based on the declarations in the segment table, accessible via the Advanced tab in the 3120A Test Probe acquisition dialog. By rendering the entire extent of each segment record, Trace→Show FFT segment filter slopes (Ctrl-i) provides a visual display of the filter skirts for each segment, as well as the overlap between them. In this mode, you can temporarily hide the skirts by holding the SHIFT key.

For detailed information about the segment table's format and contents, refer to the comments within the default segment table file. This file can be accessed by pressing the Advanced→Edit segment table button in the 3120A Test Probe acquisition dialog.
Most users will not need to edit the segment table.

Show imaginary part of cross spectrum (Ctrl-F3)

Show estimated instrument noise (F2)



Trace	Notes	Input Freq	Input Amplitude	Acquired	Instrument
Outgoing test	(Residual)	5 MHz	10.4 dBm	24780 pts	3120A

Phase noise and AM noise plots acquired with the Symmetricom 3120A and Symmetricom 512X analyzers can be displayed with a shaded area that provides an estimate of the instrument noise floor, if you enable Trace→Show estimated instrument noise (F2).

In the 3120A's case, the floor estimate is simply a heavily-smoothed rendition of the imaginary portion of the cross-spectrum average shown by the Show imaginary part of cross spectrum (Ctrl-F3) command. For more information about the imaginary cross spectrum and the Ctrl-F3 command in particular, see "Understanding instrument spurs" on page 54.

Use caution when relying on the noise-floor estimate. While reasonably accurate, it may appear artificially high in the vicinity of instrument spurs. Conversely, thermal effects can raise the real measurement floor slightly above the shaded floor estimate. As with ADEV measurements, the best way to obtain "proof of performance" for analyzers in this class is to run residual tests at similar frequencies and signal levels.

Particularly when viewing multiple traces in Display→Overlay (o) mode, it may be preferable to leave the floor display turned off in order to reduce display clutter.

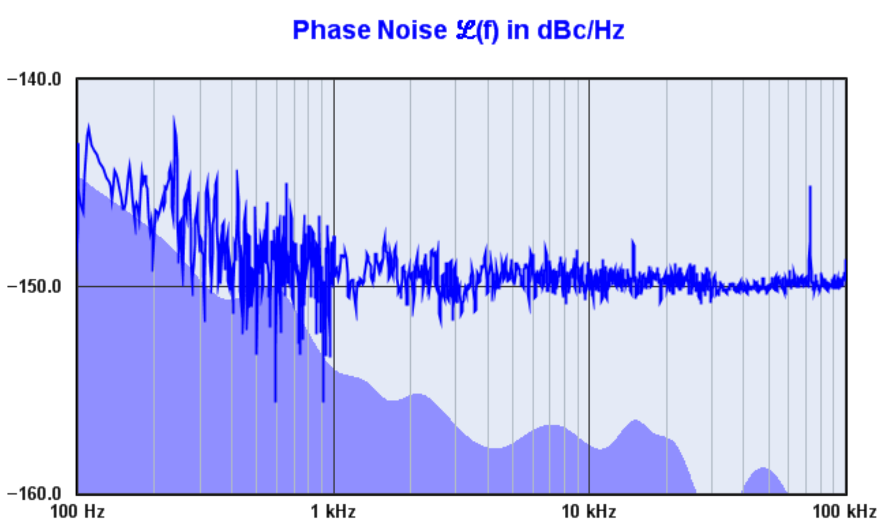
Note that when Show imaginary part of cross spectrum (Ctrl-F3) is active, the File→Export AM/PM noise trace command will export the imaginary cross spectrum trace data rather than the normal AM noise or phase noise trace.

Mark spurs in noise traces (Ctrl-m)

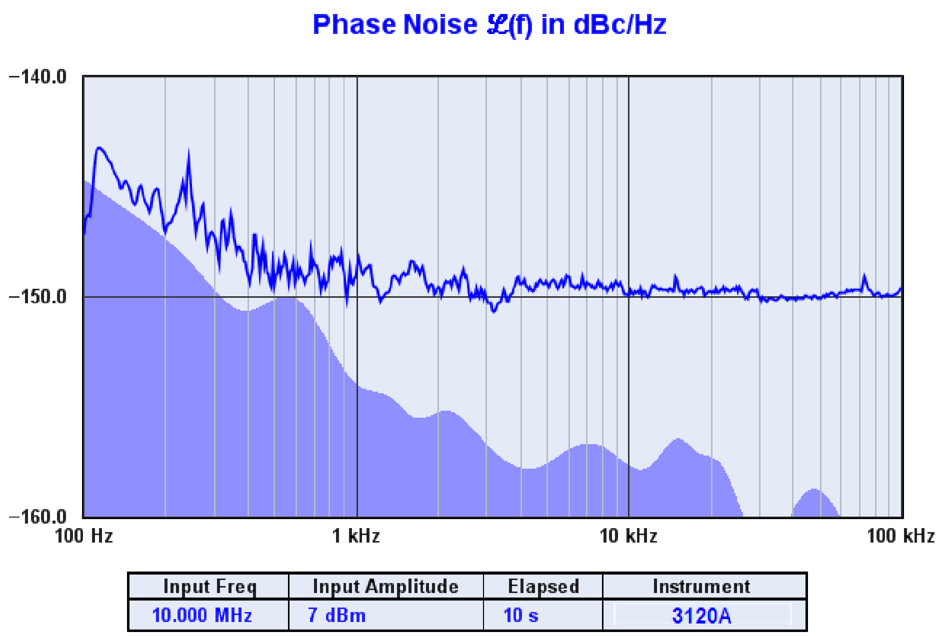
Suppress spurs in noise traces (Ctrl-s)

For a detailed discussion of these commands and other aspects of spur detection and rendering in phase noise and AM noise plots, see page 52.

Smooth noise traces (Ctrl-w)



Input Freq	Input Amplitude	Elapsed	Instrument
10.000 MHz	7 dBm	10 s	3120A



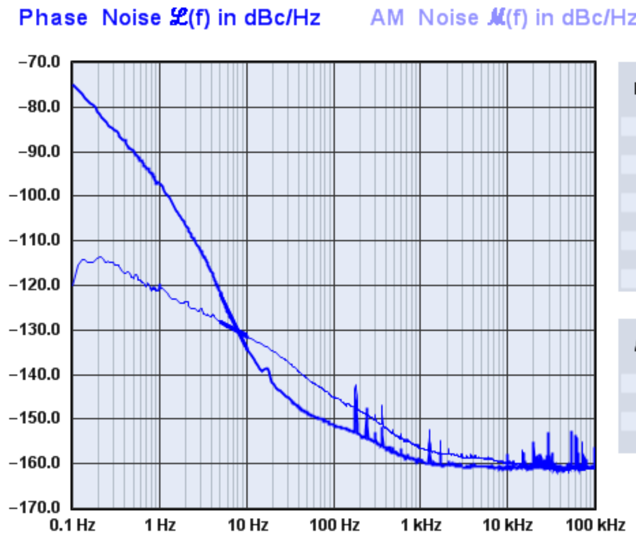
This command applies some light exponential smoothing to traces in the phase noise and AM noise measurement views. Detected spurs are always removed from smoothed traces. If enabled, smoothing is turned off automatically when the Trace→Suppress spurs in noise traces (Ctrl-s) command is used to toggle spur attenuation.

To obtain a smoother trace with cross-correlating analyzers such as the Symmetricom 3120A and Symmetricom 512x models, it's often better to let the measurement run longer. As the trace converges on the true noise level its variance will diminish, resulting in a more accurate measurement with less visible "grass."

Show raw PN channel trace(s) (Ctrl-r)

This command is intended for diagnostic purposes only. It displays the raw phase noise spectrum from the ADCs in both measurement channels of the 3120A.

Show AM noise in PN view (F8)



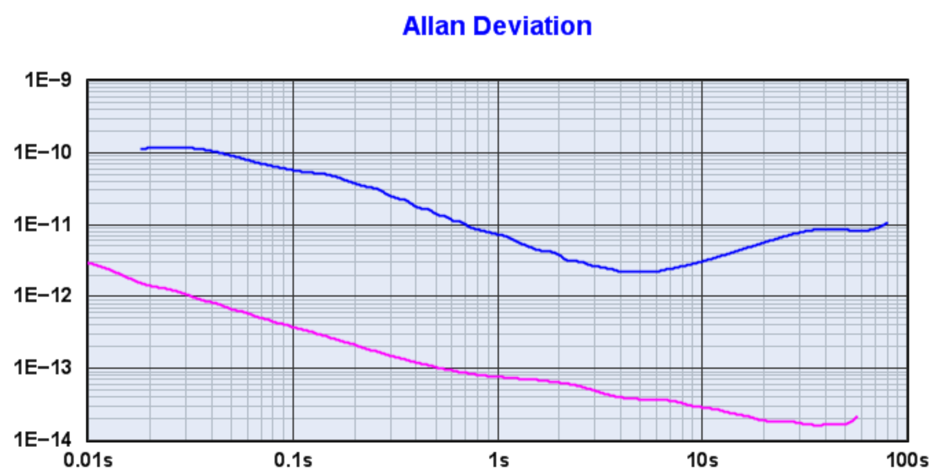
PM Spur Offset (Hz)	dBc
60.4	−127.3
120.3	−120.0
424.4	−137.0
794.0	−139.0
845.9	−138.7
14801.4	−128.3
29121.7	−129.0
54798.1	−115.2
72698.4	−123.4

AM Spur Offset (Hz)	dBc
60.4	−126.9
120.3	−114.4
241.6	−130.3
...	

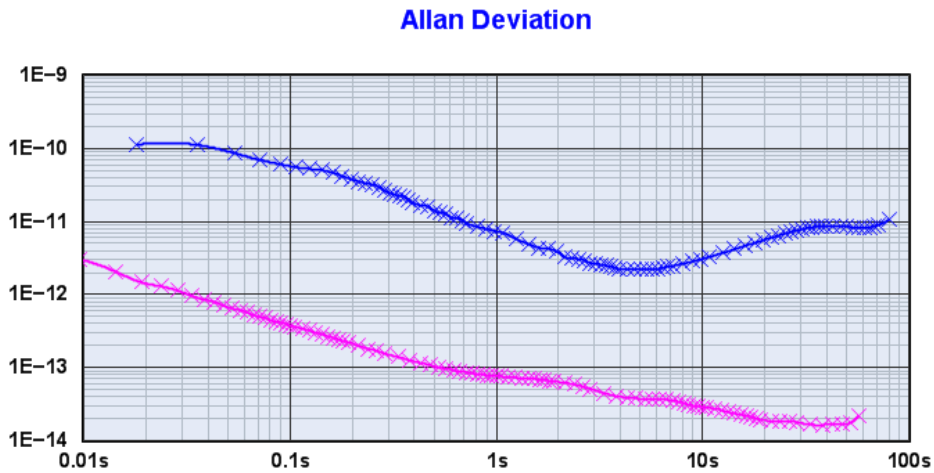
Trace	Notes	Input Freq	Input Amplitude	Instrument
5061B undisc	5065A	10.000 MHz	13 dBm	3120A

When enabled, this command renders a copy of the AM noise trace in the Measurement→Phase noise (P) view, using a lighter color or trace weight. Both PM and AM spur tables are displayed, space permitting.

Tick marks (k)



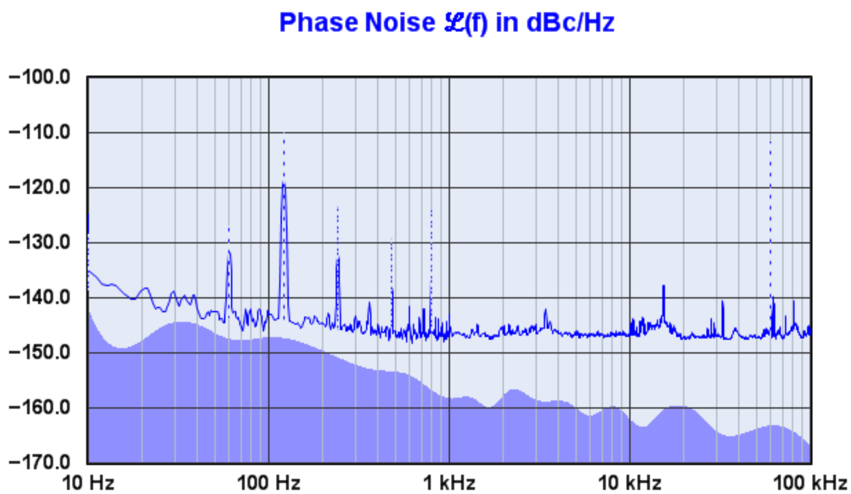
Trace	Input Freq	Input Amplitude	Sample Interval	Instrument
GPS clock #2	9.999 MHz	8.0 dBm	0.017 s	ADC test bed
Outgoing test	5 MHz	10.4 dBm	0.004 s	3120A



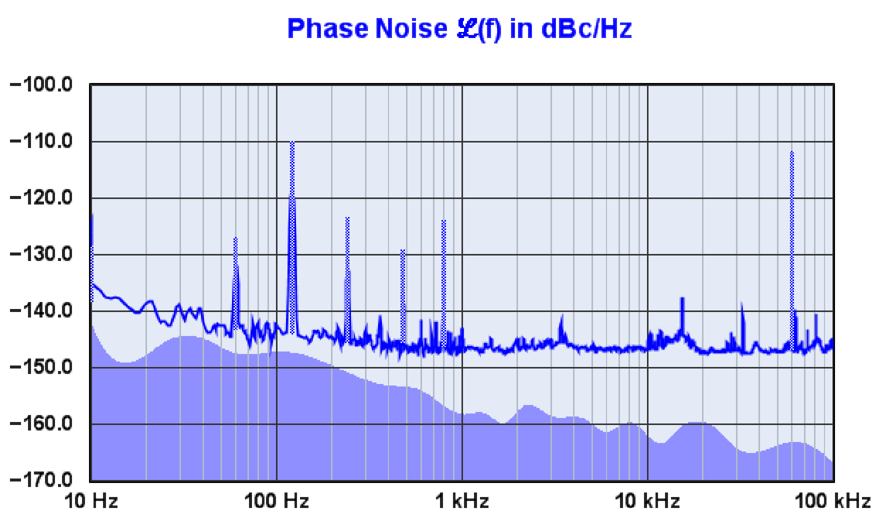
Trace	Input Freq	Input Amplitude	Sample Interval	Instrument
GPS clock #2	9.999 MHz	8.0 dBm	0.017 s	ADC test bed
Outgoing test	5 MHz	10.4 dBm	0.004 s	3120A

This command toggles tick marks on and off.
Tick marks are supported in most trace types and display modes. They can be especially handy when examining phase/frequency difference plots. In cases where many data points contribute to a single pixel column in the graph and no explicit averaging time has been specified, 3120A Test Software's "per-pixel" renderer displays the average of all of each pixel column's contributing points, while the maximum and minimum points that fall within each pixel column are rendered in a lighter shade of the same color. The k command can help you spot brief glitches and frequency jumps in these plots that would otherwise go unnoticed.

Toggle trace thickness for current measurement (T)



Trace	Input Freq	Input Amplitude	Instrument
GPS clock	10.000 MHz	13 dBm	3120A

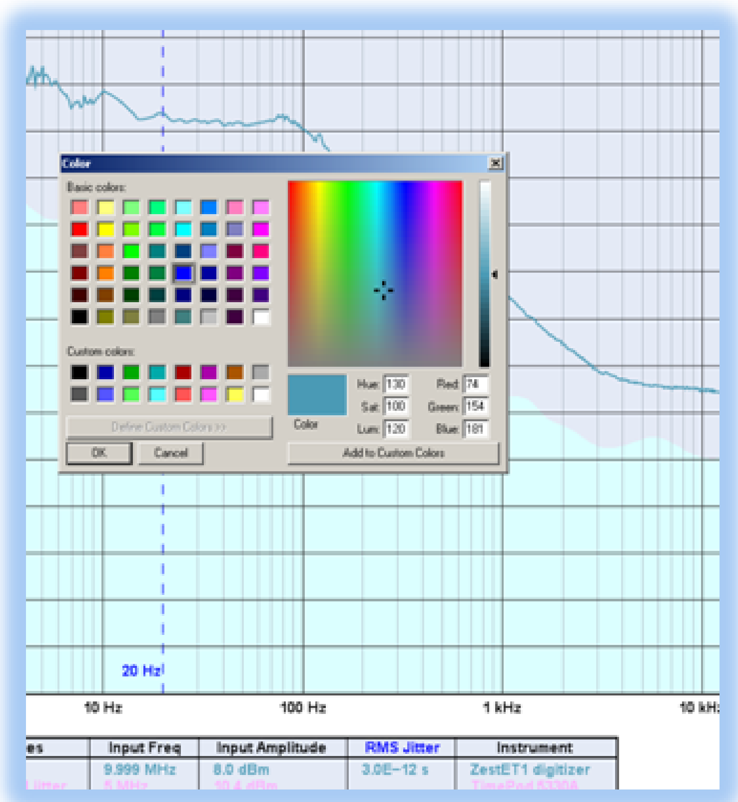


Trace	Input Freq	Input Amplitude	Instrument
GPS clock	10.000 MHz	13 dBm	3120A

This command switches between heavy and light traces in the currently-active measurement view. 3120A Test Software keeps track of the requested trace thickness for each Measurement menu entry.

Display Menu

Display-related options that aren't measurement-specific appear on the Display menu. Controls on this menu determine the visibility and selection status of loaded plots, the order in which plots appear in the legend table below the graph, and the choice of Display→Overlay (o) or Display→Browse (b) mode that determines whether all loaded plots are displayed or only the selected plot.

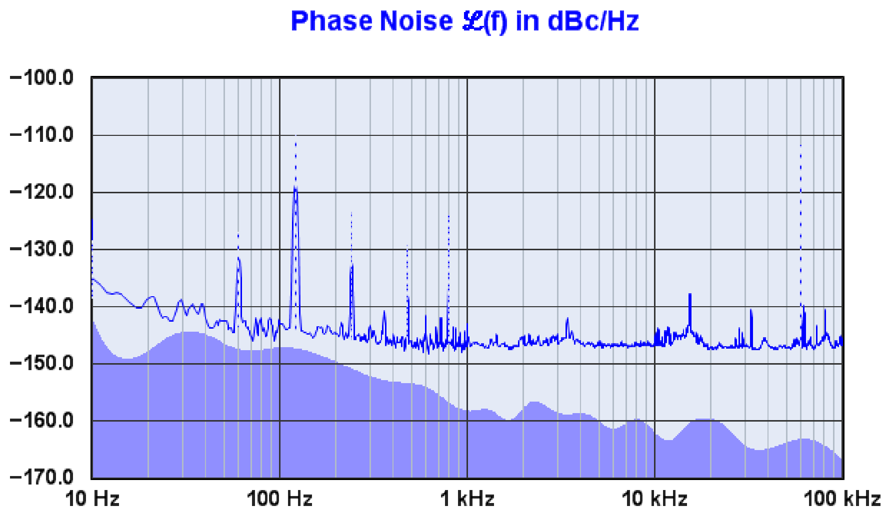


Color, contrast, font size, and graph-magnification options also appear on the Display menu, along with a choice of formats for the "mouseover" information at the upper left corner of the graticule.

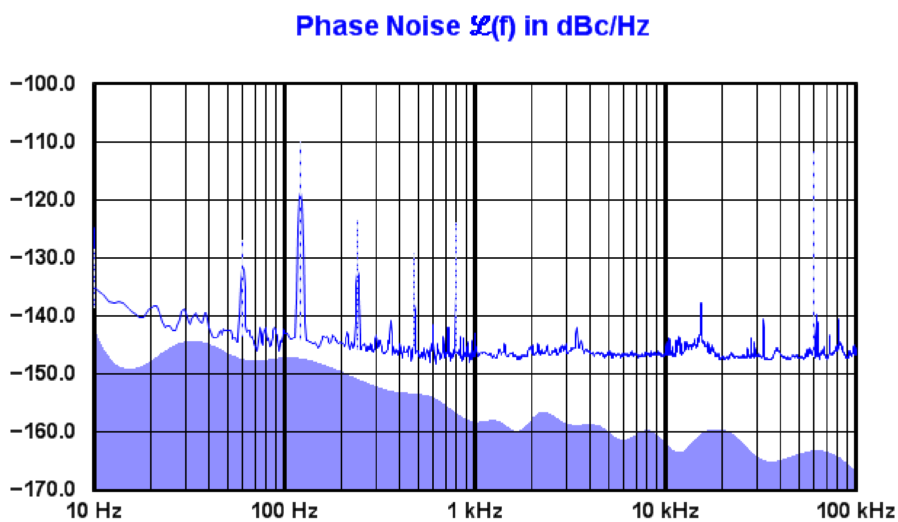
Edit colors

This command leads to a second-level menu offering a choice of various graphical elements in the 3120A Test Software window, from font and trace colors to table borders and backgrounds. Once an element is chosen, a standard Windows color palette dialog appears. As you click on the palette areas to change the selected color, the 3120A Test Software window is updated in real time, making the color-selection process interactive and easy to use.

High contrast (C)



Trace	Input Freq	Input Amplitude	Instrument
GPS clock	10.000 MHz	13 dBm	3120A



Trace	Input Freq	Input Amplitude	Instrument
GPS clock	10.000 MHz	13 dBm	3120A

This command toggles between normal and high-contrast rendering. The latter option may be desirable when saving screenshots for publications or Web pages whose color fidelity may not be sufficient to reveal details in the plot such as minor graticule lines.

Numeric table (Ctrl-n)

The numeric table appears to the right of the graph area in each measurement view, unless toggled off with this command. The format of the table is different for each measurement type. In the Allan deviation and other statistical views, a chart displays the sigma(tau) values at assorted tau intervals. In the Measurement→Frequency difference (f) view, both drift/trend statistics and an optional high-precision frequency-count chart are displayed, while only the former is available in the Measurement→Phase difference (p) view. Finally, a table of detected spurs is displayed in the phase noise and AM noise views.

Show cursor time (Ss)

Show cursor time (Hh:Mm:Ss)

Show cursor time/datestamp

Do not show cursor values

These options determine the content of the “mouseover” cursor readout display in the Measurement→Phase difference (p)and Measurement→Frequency difference (f)views. When the mouse cursor is within the graph area in these views, the readout at upper left displays the time and Y-axis value corresponding to its position. You can choose to display the number of seconds relative to the beginning of the phase record (Ss), the same elapsed time value in Hh:Mm:Ss format, or the absolute time/datestamp when the data at the mouse cursor location was logged.

Note that Display→Do not show cursor values turns off the cursor readout in all views. To re-enable the cursor readout in the xDEV and noise displays, select any of the other three options.

The mouse cursor readout is not rendered when saving image files or capturing images with File→Copy image to clipboard (Ctrl-c).

Browse plots one at a time (b)

Overlay all loaded plots (o)

Toggle visibility of selected plot (v)

Since 3120A Test Software allows up to nine plots to be loaded and displayed at once, these three commands are needed to maintain a legible display. They are often used together in rapid succession, so they will be described together and referenced in abbreviated form.

Simply stated, in b)rowse mode only the selected plot is rendered. In o)verlay mode, all loaded plots that haven’t had their v)isibility toggled off are rendered, with the graph scale adjusted as necessary to accommodate them.

It's common to switch between b)rowse and o)verlay mode when inspecting and comparing several plots, as the display can become rather crowded. At the same time, the v)isibility command is often needed when you want to view a subset of plots in o)verlay mode. b)rowse mode will exclude all but the selected plot from the display, while the v)isibility toggle gives you the control needed to display some, all, or none of the loaded plots in o)verlay mode. If you want to look at several overlaid plots while temporarily hiding one or two of them, the v)isibility toggle is the answer.

Select next plot in chart (+ or down arrow)

Select previous plot in chart (- or up arrow)

Move selected plot up (Ctrl-up arrow)

Move selected plot down (Ctrl-down arrow)

For an introduction to the "selected plot" concept and its related commands, refer to "Making your first measurements" on page 13.

The Ctrl-up/down arrow commands can be very helpful for organizing displays with multiple plots. Holding down the Ctrl key when you press an arrow key will not change the currently selected plot, but will instead move the selected plot up and down in the legend table. Since the trace colors in 3120A Test Software are assigned based on each plot's position in the legend table, this feature can be useful if you don't like the color of a particular plot, or if a plot farther down the table is obscuring data in an earlier plot. (The Ctrl-up/down arrow commands are frequently handy when using Trace→Show estimated instrument noise (F2), for instance.)

X zoom in ( ])

X zoom out ([ )

Y zoom in (})

Y zoom out ({)

The bracket and shift-bracket keys are useful for navigating zoomed phase- and frequency-difference traces on a laptop or other PC without a three-button scrolling mouse. These menu options can be thought of as placeholders for their respective keyboard shortcuts. Specifically, after a zoomed region has been selected by dragging with the left mouse button, these commands allow you to increase and decrease the "magnification factor" without returning to the unzoomed display.

On a desktop PC, a combination of scroll-wheel and middle-button input is normally the best way to navigate within phase/frequency traces. The scroll wheel expands and shrinks the magnification factor, while the middle mouse button allows you to "scrub" the zoomed trace data left and right

.

These commands have no effect in zoomed phase noise or AM noise measurement views, or in Allan deviation or other statistical views. For more about 3120A Test Software's zoom functionality, refer to "Navigating zoomed graphs" on page 46.

Decrease font size ((or Ctrl-mouse wheel)

Increase font size ( ) or Ctrl-mouse wheel)

Like the X zoom/Y zoom commands, the font-size control options are primarily meant as placeholders for their respective "hotkeys," the left and right parentheses. They provide easy access to a choice of several discrete font sizes. Also, as with most Web browsers and other newer Windows applications, scrolling with the mouse wheel while holding down the Ctrl key will expand or shrink the text within the 3120A Test Software's display window.

Legend Menu

The Legend menu determines which attributes are displayed for each visible plot in the legend table beneath the main graph. Some properties are flagged for display in the legend table by default, while others will not be displayed until you select them in the Legend menu.

Each 3120A Test Software acquisition driver can contribute its own entries to the Legend menu based on the property values in the plots that it generates. When a plot is acquired or loaded from a .TFF file, 3120A Test Software checks for the presence of any displayable properties that it hasn't yet encountered. Any unfamiliar properties are logged in 3120A.ini and added to the Legend menu.

As a result, the content of the Legend menu will vary – often greatly – from one 3120A Test Software installation to the next. (Note that after you select a property for display in the legend table, its value will be blank for all plots that don't include that particular property.)

As with other data stored in 3120A.ini, reinstalling 3120A Test Software does not erase the list of known Legend menu entries. These entries can be cleared only by manually editing or deleting 3120A.ini, or by using File→Reset all parameters, options, and settings at next startup. Refer to the latter command for more information about 3120A.ini.

The list of currently-defined .TFF file properties appears below. Many of these options are 'private' to a specific hardware driver and are not eligible for display on the legend table. They are listed here for reference only. A few of the properties are defined by 3120A Phase Noise Test Software itself and will appear on the Legend menu by default in all installations.

ADC Clock	Nominal acquisition clock rate in Hz
Add'l AM Gain	Optional user-specified gain value added to AM noise traces
Add'l PN Gain	Optional user-specified gain value added to phase noise traces

Address	Address of instrument used to acquire data
Attenuate Instrument Spurs	True if known instrument spurs are suppressed automatically
Auto DUT	True if the DUT frequency matches the frequency at the analyzer input jack
Auto Input	True if input frequency measured automatically
Auto Ref	True if external reference frequency measured automatically
Automatic Configuration	True if the 3120A Phase Noise Test Software driver should infer various measurement parameters based on the incoming data
Autosense Rate	True if the 3120A Phase Noise Test Software driver should automatically measure the sample interval
Beatnote	Amplitude in dBm of calibration beatnote
Bin Density	Determines the number and distribution of tau points in statistical deviation measurements
Bin Threshold	Minimum number of data points required to display the statistical deviation at a given tau
BW Index	Index or other identifier for a given measurement bandwidth
Cancel CM Drift	True if common-mode drift (e.g., due to ADC clock warmup) is corrected in software
Ch 0	Combination of physical ADC channel(s) contributing to FFT channel 0, as well as recorded phase data
Ch 1	Combination of physical ADC channel(s) contributing to FFT channel 1
Channel	Identifies the channel number associated with a multichannel acquisition
Counter Connection Type	Interface used for acquisition from TIC or frequency counter
Data Type	Indicates the type of the incoming data (e.g., phase, frequency differences, or absolute frequency)
Decimation	Hardware decimation ratio
Device ID	Instrument serial number or other identifier
Driver	Identifies the 3120A Test Software .TLL driver used for acquisition

Duration	Measurement duration
Duration Type	Measurement duration type
DUT Freq	Frequency of DUT provided by user, prior to any conversion, multiplication, or division
EFC	Acquisition clock EFC DAC value
ENBW	Equivalent noise bandwidth in Hz of recorded data
ENBW Factor	Equivalent noise bandwidth of recorded data, expressed as a fraction of the data rate
EOS Character	End-of-string character for data source
FFT Win #	Index or other identifier for FFT window function used for noise measurement
FFT Window	FFT window function used for noise measurement
Field #	Numeric field position from which data was extracted
FPGA Bitfile	Name of the .bit file used to configure the FPGA prior to acquisition
Frequency	Incoming data consists of absolute frequency readings
Frequency Difference	Incoming data consists of fractional frequency differences
FRQ Max Offset	Maximum offset frequencyy for spectrum display
FRQ Max Scale	dBm value at top of spectrum display
FRQ Min Offset	Minimum offset frequency for spectrum display
FRQ Min Scale	dBm value at bottom of spectrum display
HP 5313xA Mode	True if the TimeLab driver should ignore statistics data from an HP 53131A/53132A counter
Imported From	Name of file or device from which data was imported
Incoming Sample Interval	Time in seconds between successive data points from the instrument
Input Amplitude	Approximate input amplitude in dBm
Input Estimated	True if input frequency is a low-precision estimate that should be rounded for display purposes
Input Freq	Input frequency
Instrument	Instrument model used to acquire data

Interface	Configuration details for the GPIB adapter, serial or LAN adapter, or other physical interface
IP Address	IP address or hostname of instrument used to acquire data
L(f) Factor	Additional value used to convert dBc/Hz readings into L(f) SSB phase noise
L(f) Max Scale	dBc/Hz value at top of SSB noise graph
L(f) Min Scale	dBc/Hz value at bottom of SSB noise graph
LNA dB	Gain provided by LNA stage
Measure AM Noise	True if measurement contains AM noise data
Measure Frequency Spectrum	True if measurement contains two-sided frequency spectrum data
Measure PM Noise	True if measurement contains phase noise data
Measure Stability	True if measurement contains phase/frequency stability data
MJD	Modified Julian Date when the measurement was triggered
New t0	New tau-zero interval for resampled phase data
Notes	Additional notes that apply to measurement, specified at acquisition time or Edit->Trace properties
Options	Option codes associated with instrument
Output Decimation	Final decimation ratio for output samples
Output Sample Rate	Rate at which data samples are generated by the 3120A Test Software driver
Overlap %	Overlap between successive FFT buffers
Overlapped	True if overlapped FFT processing is enabled for faster measurement
Phase	Incoming data consists of phase-difference values
PN Max Offset	Maximum offset for SSB noise graph (which will be rounded up to the nearest decade)
PN Min Offset	Minimum offset for SSB noise graph (which will be rounded down to the nearest decade)
Port	IP port of instrument used to acquire data
Precision	Precision of incoming floating-point data (e.g., 0=single, 1=double)
Prologix Compatibility Mode	True if serial ports with FTDI D2XX drivers should be treated as Prologix GPIB-USB

	adapters.
Property Page	Selected property page number
Read Existing Data	True if any existing text from the file or device should be skipped prior to acquiring new data
Ref Amplitude	Approximate reference amplitude in dBm
Ref Estimated	True if reference frequency is a low-precision estimate that should be rounded for display purposes
Ref Freq	Reference frequency
Rescale Factor	User-supplied rescale factor for phase data
Rev	Detailed instrument information, including firmware version and/or options
RS-232 Setup	Configuration string for RS-232 COM port, if used
Sample Interval	Time in seconds between successive data points
Sample Rate	Incoming data rate from instrument in samples per second
Scale Factor	Numeric scale factor used to convert TI readings to seconds or frequency readings to Hz
Scale Jitter to DUT	True if jitter and carrier/noise values should be based on DUT frequency rather than input frequency
Scale PN to DUT	True if phase noise values should be increased by 20 * log10 (DUT frequency / input frequency)
Segment Table	User-specified tag field from segment table used for noise acquisition
Specified Input Frequency	Input frequency in Hz provided by user
Specified Reference Frequency	Reference frequency in Hz provided by user
Spur Threshold	Minimum amplitude relative to nearby average at which a discrete line will be recognized as a spur
Stop Condition	Termination condition for measurement
Time/Date	Time and date when the acquisition file was created
Timestamp	Incoming data consists of absolute timestamps in seconds

Trace	Trace caption text, as specified at acquisition time or edited with Edit->Trace Properties
Trace History	Number of historical xDEV traces displayed
TSC Phase Data Rate	Phase data rate from TSC 512X-compatible timing analyzer
Unwrapped	True if phase data has already been unwrapped by the instrument driver
Use Input Rate	True if driver's data rate matches the incoming data rate from the instrument
Warnings Treated as Errors	True if warnings during data acquisition should terminate the measurement
Wrap Period	Wraparound period in seconds for incoming timestamps

Measurement Menu

The Measurement menu selection determines how 3120A Test Software displays the data in any plots that have been acquired or loaded. One measurement type may be selected at a time.

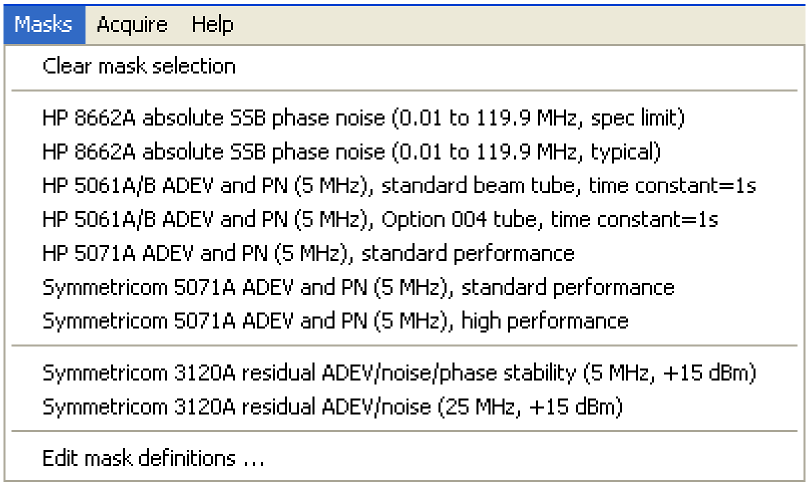
As discussed on page 19, 3120A Test Software plots (and their associated .TFF files) use independent data records for different measurement classes. Some instruments like the Symmetricom 3120A can acquire data for all measurements supported by 3120A Test Software, but most are limited to specific measurement types. For instance, acquisitions made with a frequency counter or TIC may be viewed with the Allan deviation (a), Modified Allan deviation (m), Hadamard deviation (h), Time deviation (t), Phase difference (p), or Frequency difference (f) selections on the menu, but not Phase noise (P) or AM noise (A).

Regardless of the instrument used, all supported measurement records are acquired and processed simultaneously by 3120A Test Software. After launching a 3120A acquisition with all of the Available Measurements options selected in the acquisition dialog, for example, you can switch between all of the entries in the Measurements menu to view your data as it arrives.

Plots that don’t include the necessary data for the selected measurement type will not be rendered. When the 3120A Test Software window is empty despite the presence of one or more loaded or acquired plots, a brief explanatory message will be displayed in the color associated with each plot to indicate why nothing is being drawn.

See “Making Measurements” on page 23 for a detailed discussion of the measurement types supported by 3120A Test Software.

Masks Menu



The Masks menu is almost entirely user-configurable. It consists of a list of mask definitions for optional use in 3120A Test Software. Masks are useful in production test applications where fast, reliable, and repeatable pass/fail judgments are required. You can also use mask testing for proof-of-performance verification of the 3120A Test Probe and other instruments supported by 3120A Test Software.

At startup, 3120A Test Software constructs the Masks menu based on the contents of the user-editable file masks.txt. The location of the directory where the 3120A Test Software stores masks.txt varies depending on the operating system version. In Windows 7, this file is normally located in c:\ProgramData\Symmetricom\3120A\Masks, also accessible at %PROGRAMDATA%\Symmetricom\3120A\Masks. In Windows XP, masks.txt is normally located in the hidden directory c:\Documents and Settings\All Users\Application Data.

Generally, the easiest way to read and modify masks.txt is by selecting the last entry on the Masks menu, Mask→Edit mask definitions. This option will open masks.txt in Windows Notepad. You can then create your own mask definitions, edit existing masks, remove masks from the menu, or simply review the mask-testing features and capabilities in the current version of 3120A Test Software.

Important: To preserve any user-created mask definitions, your existing masks.txt file will not be overwritten when a new copy of 3120A Test Software is installed. The only exceptions to this rule occur when new features are introduced that render the mask file format incompatible with newer versions of 3120A Test Software. In such cases, the 3120A Test Software setup program will make a backup copy of masks.txt in the same directory, under the name masks_backup.txt. You will then need to transfer any user-created mask definitions from masks_backup.txt to the new masks.txt file.

Clear mask selection

The first command on the Masks menu simply deselects any currently-selected mask, removing its limit line(s) from the applicable measurement views.

User-defined mask entries

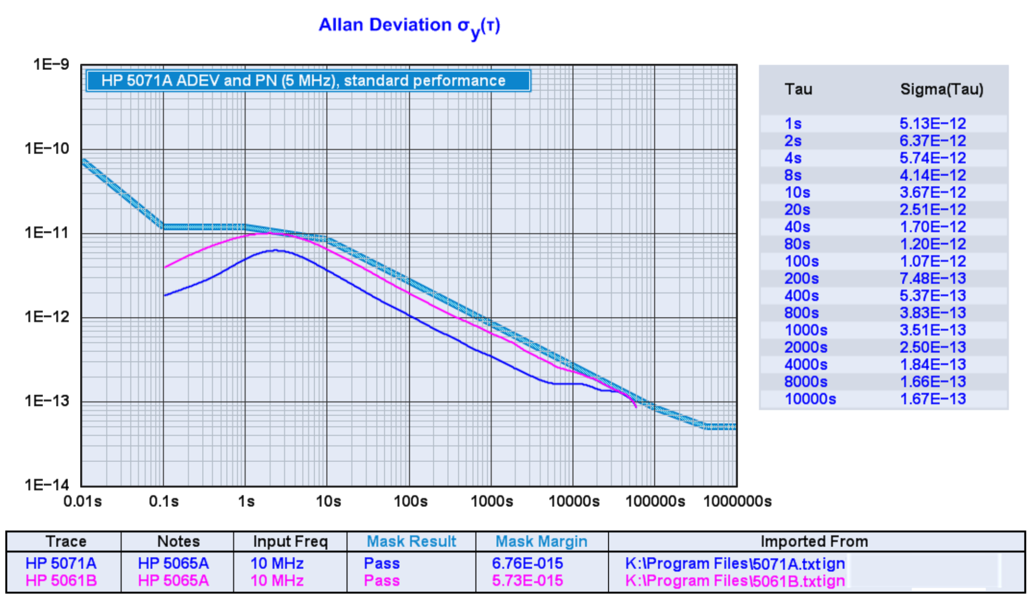
Menu entries appearing between Mask→Edit mask definitions and Mask→Edit mask definitions are defined in masks.txt. Only one mask may be selected at a time. Once selected, the mask's title and limit line will be visible only in measurement views corresponding to valid limit lines in the mask definition.

To see the results of the selected mask test, you'll need to select one of these views from the Measurement menu and enable the Legend→Mask Result, Legend→Mask Margin, or both. Assuming the Mask Test option has been licensed, pass/fail results and margins will then appear in the legend table below the graph, updated in real time as the measurement progresses.

For detailed instructions and hints, carefully review the comments in masks.txt. The latest usage guidelines for the current 3120A Test Software release will appear as comments in this file.

Edit mask definitions …

As noted above, the last command on the Masks menu opens masks.txt in Notepad for editing and review.



Acquire Menu

3120A Test Software's principal mission is to serve as the user interface for the 3120A Test Probe Programmable Cross Spectrum Analyzer from Symmetricom The Acquire menu includes a list of all instruments recognized by 3120A Test Software, followed by a small number of commands that manage acquisition operations.

When selected, each entry on the Acquire menu that corresponds to a given instrument will bring up an acquisition dialog. Acquisition dialogs are used to configure the instrument and initiate data collection. Every acquisition in 3120A Test Software runs in its own thread, so you can load or acquire other plots while data collection is in progress. Acquired data can be saved at any time, even during the measurement; likewise, all options on the Trace and Display menus apply equally to existing plots and those that are currently being acquired.

While acquisition dialogs are straightforward to work with, their layout and functionality varies greatly from one instrument to the next. Each dialog displays extensive help text that's refreshed as the mouse pointer enters each field. This "mouseover" text is the principal source of hardware-specific documentation in 3120A Test Software, since it's always up to date with the latest changes made to each hardware driver. It should be read carefully when using a given instrument or dialog option for the first time.

Symmetricom 3120A Test Probe

The 3120A Test Probe uses real-time techniques from the Software-Defined Radio (SDR) field to measure frequency stability, phase noise, and AM noise with specifications substantially beyond those offered by traditional counters and timing analyzers. Depending on the Available Measurements options selected in the 3120A Test Probe acquisition dialog, the 3120A Test Probe can perform any (or all) measurements supported by 3120A Test Software.

Acquire from live ASCII file

This option allows you to specify the location of a text file containing frequency, phase/TI, or timestamp data that's being written by another process. 3120A Test Software will open the file in read-only mode, process all existing data in the file if requested, and then continue to fetch data until the acquisition terminates. Only one reading per line is processed, but any numeric field within the line can be specified for processing.

As with other 3120A Test Software acquisition processes, these acquisitions may be launched concurrently.

Stop/repeat acquisition (Space)

This context-sensitive command associatesthe most common acquisition "verbs" with a single easy-to-remember keyboard shortcut.

- If deferred-acquisition mode is active and at least one acquisition is pending , the Space bar terminates all active acquisitions (after prompting).
- Otherwise, if the selected plot is associated with an acquisition in progress, the Space bar will terminate that acquisition (after prompting).

- If one or more acquisitions is running but the selected plot is not among them, the Space bar will offer to terminate the acquisition that was most recently started.
- If no acquisitions were running, the Space bar will bring up the most-recently-used acquisition dialog.

Because 3120A Test Software measurement sessions often involve repeated acquisitions with the same instrument, the Space bar shortcut will usually “do what you mean.” It will either stop collecting data if an acquisition is in progress, or start a new acquisition if data is not currently being acquired.

Abort and retrigger selected acquisition (Ctrl-a)

Keep and retrigger selected acquisition (Ctrl-k)

Like Acquire→Stop/repeat acquisition (Space) , these commands are normally accessed via their respective keyboard shortcuts. Often used when you accidentally disturb the equipment or remember an omitted step in the measurement procedure, Ctrl-a will restart the selected plot’s measurement immediately with no further interaction. Ctrl-k behaves similarly, but it will not discard the acquired data before relaunching the acquisition.

These commands operate as follows:

- If no plots are loaded, either command will bring back the most-recently-used acquisition dialog, as if the Space bar shortcut were used.
- Otherwise, if the selected plot is associated with an acquisition in progress, that acquisition will be terminated. (Any other acquisitions in progress will not be affected.)
- If the Abort (Ctrl-a) command was issued, the selected plot will be closed and its data discarded. A new acquisition will be started in its place, using the driver associated with the now-deleted plot. The new plot will retain the same position in the legend table.
- If the Keep (Ctrl-k) command was issued, the selected plot will not be closed. A new acquisition will be launched with its instrument driver. The resulting plot will appear in the next available slot in the legend table.

When applied to an acquisition in progress, both commands work immediately without prompting for confirmation. They're assigned to control keys to make them harder to press accidentally.

Enable deferred acquisition (Ctrl-d)

Trigger deferred acquisition(s) (Enter)

Deferred acquisition mode is toggled with the Enable deferred acquisition (Ctrl-d) command. In this mode, 3120A Test Software will allow acquisitions to be launched as usual. However, each new measurement’s incoming data will be discarded until all pending measurements are triggered with the Trigger deferred acquisition(s) (Enter) command, or another Enable deferred acquisition (Ctrl-d) command is issued to return to immediate-acquisition mode. Data will then be collected normally for the duration of the measurement (s).

Deferred-acquisition mode can be useful when you wish to launch multiple concurrent acquisitions – perhaps using different types of instruments with varying latency or setup time requirements – while synchronizing the beginning of data collection as closely as possible across all measurements. Enable deferred acquisition with Ctrl-d, start the desired measurements, then press Enter to trigger data collection in all acquisitions at once.

Note that 3120A Test Software doesn't specify the trigger latency associated with a group of deferred measurements. Triggered measurements will normally start collecting valid data within one sample period, but this isn't guaranteed.

Help Menu

About Symmetricom 3120A Phase Noise Test Software

This command displays an "About" box showing the program version, compilation date, and any supported command-line parameters.

Appendix: Some examples of residual performance

The gold-standard diagnostic resource for the 3120A Test Probe is a simple residual test, conducted after at least a 1-hour warmup, in which you drive the inputs at >= 10 dBm using a clean signal (i.e., without excessive broadband noise) fed through a passive splitter (Mini-Circuits ZFSC-2-1 or similar). The following observations don't reflect specification limits, but they will give you an idea of what to expect.

- At 50 Hz ENBW, residual ADEV at 5 MHz should be in the high E-14s at t=1s. Thermal effects will then push the slope out somewhat, especially in an unstable environment or when warmup time has been insufficient. A look at the p)hase difference graph will often show a curved phase slope for the first 30-60 minutes of a measurement made after a cold start.

- Residual PN at 5 MHz should be <= -150 dBc/Hz at 10 Hz after a few hours.

- With a strong, clean input signal at 5 to 10 MHz, the residual PN floor in the 10 kHz - 100 kHz decade will usually end up below -175 dBc/Hz after less than two hours. Expect lower performance near either end of the supported frequency range.

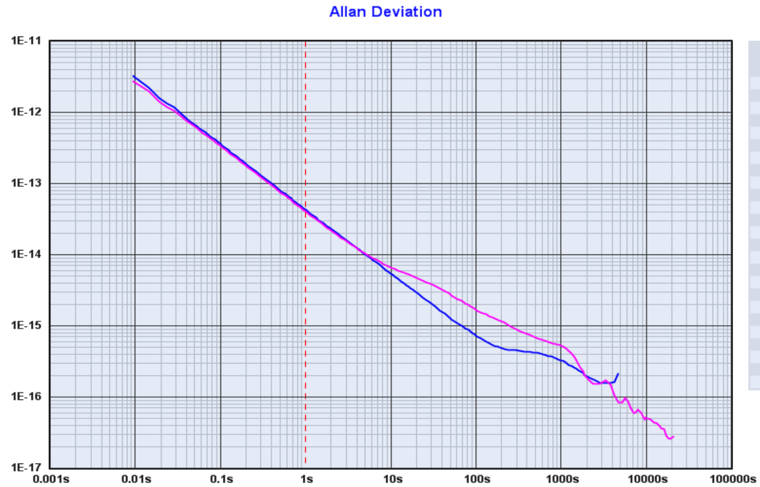
- Phase hits and large outliers in the frequency-difference trace are never normal in a residual test with a clean source signal. They should be investigated if they recur with no obvious explanation.

- Bear in mind that absolute phase-drift measurements require you to explicitly enter the same frequency in both the Input Freq and Reference Freq fields of the acquisition dialog, unchecking their corresponding Measure boxes. Otherwise, the slope of the phase difference measurement will reflect an arbitrary internal frequency estimate.

As an aid to troubleshooting and performance verification, some typical real-world residual measurements appear below.

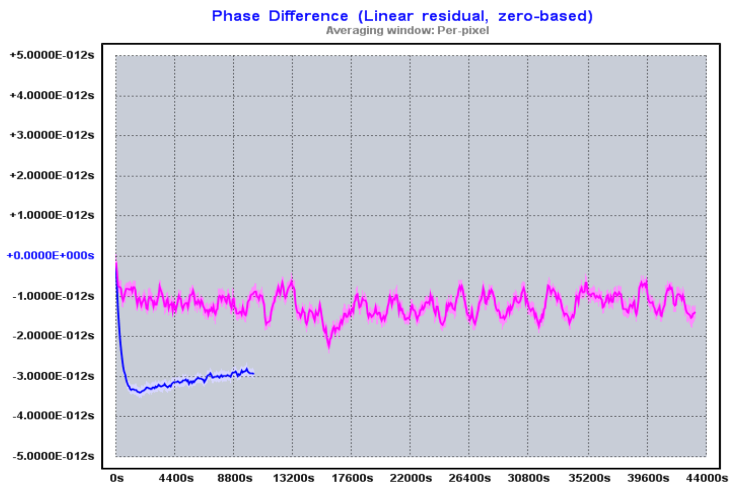
Blue trace: 25.68 MHz crystal oscillator, ZFSC-2-1 splitter, about 10 minutes' warmup time. Measurement was allowed to run for three hours.

Magenta trace: 5 MHz crystal oscillator, ZFSC-2-1 splitter, tested under near-ideal conditions with several hours warmup time. Measurement ran overnight (12 hours).



Tau	Sigma(Tau)
0.014s	2.24E-012
0.019s	1.58E-012
0.024s	1.32E-012
0.038s	8.64E-013
0.047s	7.15E-013
0.095s	3.78E-013
0.19s	2.00E-013
0.38s	1.05E-013
0.47s	8.53E-014
0.95s	4.49E-014
2s	2.42E-014
4s	1.31E-014
5s	9.84E-015
10s	5.48E-015
21s	2.78E-015
43s	1.48E-015
47s	1.34E-015
95s	7.69E-016
189s	4.99E-016
379s	4.38E-016
474s	4.27E-016
947s	3.36E-016
1894s	2.05E-016
3788s	1.57E-016
4735s	2.20E-016

Trace	Input Freq	Input Amplitude	Ref Amplitude	ENBW	ADEV at 1s	Acquired	Instrument
25 MHz residual, 3 hours	25680041.671 Hz	9 dBm	10 dBm	52.7 Hz	4.3E-014	2167272 pts	A3120A
5 MHz residual, 12 hours	5000000 Hz	12.3 dBm	12.3 dBm	52.7 Hz	4.1E-014	9119124 pts	A3120A

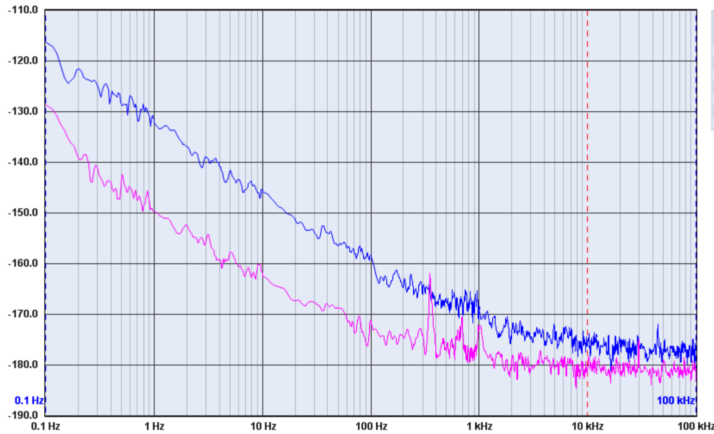


Origin	Slope (sec/sec)
-6.07E-012	-1.06E-013
-2.41E-012	+1.92E-017

Trace	Input Freq	Input Amplitude	Ref Amplitude	ENBW	Acquired	Instrument
25 MHz residual, 3 hours	25680041.671 Hz	9 dBm	10 dBm	52.7 Hz	2167272 pts	A3120A
5 MHz residual, 12 hours	5000000 Hz	12.3 dBm	12.3 dBm	52.7 Hz	9119124 pts	A3120A

Despite visible HVAC cycling, overall phase stability is within +/- 1 ps over the entire 12-hour 5 MHz run. The 25 MHz residual trace, on the other hand, was taken with inadequate warmup time. It begins with about 30 minutes of noticeable phase drift (about three picoseconds) until the 3120A Test Software's internal components reach thermal equilibrium. Slow drift in the opposite direction is then observed.

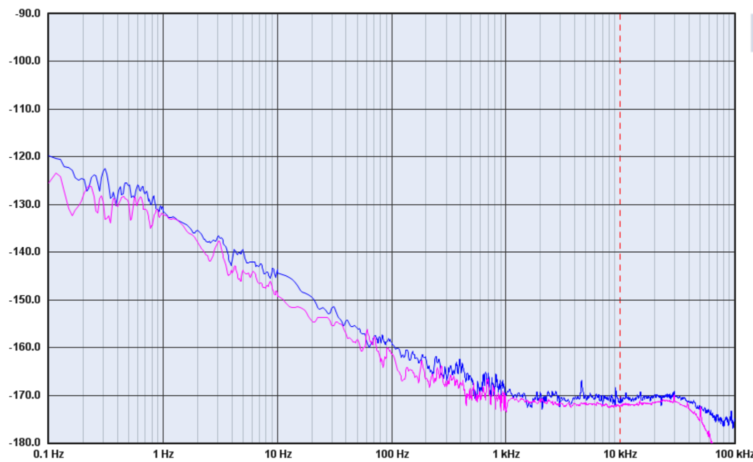
Phase Noise L(f) in dBc/Hz



PM Spur Offset (Hz)	dBc
4570.0	-145.2
13690.0	-139.2
14800.0	-136.8
16570.0	-152.6
22810.0	-146.3
27390.0	-144.9
29580.0	-139.7

Trace	Input Freq	Input Amplitude	Ref Amplitude	dBc/Hz at 10 kHz	RMS Jitter	Acquired	Instrument
25 MHz residual, 3 hours	25680045.355 Hz	9 dBm	9 dBm	-175.8	6.6E-015 s	2280682 pts	A3120A
5 MHz residual, 12 hours	5000000 Hz	12.3 dBm	12.3 dBm	-180.5	1.4E-014 s	9119124 pts	A3120A

AM Noise M(f) in dBc/Hz



AM Spur Offset (Hz)	dBc

Trace	Input Freq	Input Amplitude	Ref Amplitude	dBc/Hz at 10 kHz	Acquired	Instrument
25 MHz residual, 3 hours	25680045.355 Hz	9 dBm	9 dBm	-170.8	2280682 pts	A3120A
5 MHz residual, 12 hours	5000000 Hz	12.3 dBm	12.3 dBm	-172.2	9119124 pts	A3120A

Residual phase noise performance is improved when a strong 5 MHz signal is measured for 12 hours, compared to a weaker 25 MHz signal measured for 3 hours. The difference in AM noise isn't as pronounced in this case.

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Appendix: Legal and Regulatory Notices

Federal Communications Commission Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help

Changes or modifications not expressly approved by the party responsible for compliance may void the user's authority to operate the equipment.

EC Declaration of Conformity

Manufacturer:	Symmetricom 2300 Orchard Parkway San Jose, Ca, 95131, USA
Product:	Model 3120A Phase Noise Test Probe
Description:	Small/portable electronic instrument for laboratory use by qualified personnel, powered by external supply with UL/CUL/TUV/CB/CE approvals.
Directives:	• 2006/95/EC The Low Voltage Directive and its amending directives. • 2004/108/EC The Electromagnetic Compatibility Directive and its amending directives. • 2012/19/EU Waste Electrical and Electronic Equipment (WEEE) Directive of the European Parliament and Council. • 2011/65/EC Restriction of the Use of Certain Hazardous Substances (RoHS) Directive of the European Parliament and Council.
Standards:	• EN 61326-1:2006 Electrical Requirements for Electrical Equipment

for Measurement, Control and Laboratory Use – Part 1: General Requirements

Signature: I hereby certify that this equipment has been designed and manufactured in accordance with the above referenced Standards, and complies with all applicable requirements of the Directives.

Robert Mengelberg
Compliance Engineering
Symmetricom
29 October 2012

Performance Certification and Validation

Symmetricom certifies that this product met its published specifications at time of delivery. Because measurements made by the 3120A Test Probe are always based on differences between the signals applied to the INPUT and REF IN ports, no specific periodic calibration procedures are required. In the absence of errors reported by the measurement software, no specific maintenance procedures are necessary, including preventative or periodic maintenance.

For formal verification purposes, the procedures outlined in the default mask definition file (masks.txt) will permit customer verification of all operating features and specifications using commonly available test signals. For more information, select Masks→Edit mask definitions in 3120A Test Software to open the mask definition file and refer to the 3120A Test Probe performance test masks section.

Software License: 3120A Test Software

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