53100A Phase Noise Analyzer User's Guide

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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics, to open a list of available online help files.

PURPOSE OF THIS GUIDE

The 53100A Phase Noise Analyzer User's Guide provides basic recommendations for measuring high performance frequency and timing products. The guidelines in the document are generic because specific product requirements vary between applications.

This material consists of a brief description of the 53100A supported by block diagrams, installation guidelines, and unit operation.

WHO SHOULD READ THIS GUIDE

This document is intended for engineers and telecommunications professionals who are designing, installing, operating, or maintaining time, frequency, and synchronization systems that require precise characterization of a frequency generator.

To use this document effectively, you must have a good understanding of digital telecommunications technologies, analog frequency generation, and synthesis techniques.

DOCUMENT LAYOUT

This guide contains the following sections:

- **Chapter 1. "Product Overview"**:
- **Chapter 2. "Making Measurements"**:
- **Chapter 3. "Phase- and Frequency-Difference Traces"**:
- **Chapter 4. "Phase Noise, AM Noise, and Jitter"**:
- **Chapter 5. "TimeLab Command Reference"**:
- **Chapter 6. "53100A Measurement Roles"**:
- **Chapter 7. "JavaScript API Function Reference"**:
- **Chapter 8. "Accessing the 53100A & TimePod Remotely"**:
- **Appendix A. "53100A Dual 100 MHz Reference (Option IR)"**:
- **Appendix B. "Legal and Regulatory Notices"**

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	<u>*File>Save*</u>
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
Italic Courier New	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`

	Represents code supplied by user	`void main (void)`
		`{ ...`
		`}`

WARNINGS, CAUTIONS, RECOMMENDATIONS, AND NOTES

Warnings, Cautions, Recommendations, and Notes attract attention to essential or critical information in this guide. The types of information included in each are displayed in a style consistent with the examples below.

WARNING
To avoid serious personal injury or death, do not disregard warnings. All warnings use this style. Warnings are installation, operation, or maintenance procedures, practices, or statements, that if not strictly observed, may result in serious personal injury or even death.

CAUTION
To avoid personal injury, do not disregard cautions. All cautions use this style. Cautions are installation, operation, or maintenance procedures, practices, conditions, or statements, that if not strictly observed, may result in damage to, or destruction of, the equipment. Cautions are also used to indicate a long-term health hazard.

Note: All notes use this style. Notes contain installation, operation, or maintenance procedures, practices, conditions, or statements that alert you to important information, which may make your task easier or increase your understanding.

WHERE TO FIND ANSWERS TO PRODUCT AND DOCUMENT QUESTIONS

For additional information about the products described in this guide, please contact your Microchip representative or your local sales office. You can also contact us on the web at https://microchip.my.site.com/s/.

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Manual updates are available at: www.microchip.com

RELATED DOCUMENTS AND INFORMATION

See your Microchip representative or sales office for a complete list of available documentation. To order any accessory, contact the Microchip Sales Department. If you encounter any difficulties installing or using the product, contact Microchip Frequency and Time Systems (FTS) Services and Support:

North and South America

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3870 North First Street San Jose, CA

95134-1702

Toll-free in North America: 1-888-367-7966, Option 1

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER SUPPORT

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- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at:
http://www.microchip.com/support.

DOCUMENT REVISION HISTORY

Revision A (August 2020)

- Initial release of this document as Microchip DS50002991A.

Revision B (February 2021)

- Updated for the release of TimeLab 1.502.

Revision C (March 2021)

- Updated Figure 1-4.
- Updated the text of **Section 5.4.18 “Refresh <F5>”**.

Revision D (May 2022)

- Updated for the release of TimeLab 1.6.

Revision E (February 2023)

- Added `/timerec` parameter and save command descriptions to TSERVE section.
- Revised 53100A measurement role descriptions.
- Added Option IR specifications.

Revision F (January 2024)

- Additional instructions for Option IR user calibration.
- Added *Display>Frequency Y axis labels in Hz* and `DisplayYAxisHz()` descriptions.
- Revised the 100 MHz internal oscillator specifications.

NOTES:

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Appendix B. Legal and Regulatory Notices

Chapter 1. Product Overview

1.1 INTRODUCTION

The 53100A Phase Noise Analyzer measures the amplitude, phase and frequency stability of high-performance RF sources. Carrier frequencies from 1 MHz to 200 MHz are supported with direct front-panel access to all four measurement channels. The 53100A tells you everything you need to know about the stability characteristics of your devices, at timescales ranging from femtoseconds to days.

Measurements made by the 53100A include the following:

- Real-time 'strip charts' of phase and frequency differences at sub-picosecond precision.
- Absolute frequency counts at 13+ digits per second, 17 digits maximum.
- Allan deviation (ADEV).
- Modified Allan deviation (MDEV), Hadamard deviation (HDEV), and time deviation (TDEV).
- Fast realtime computation of Maximum Time Interval Error (MTIE).
- Phase noise and AM noise at offsets from 0.001 Hz to 1 MHz.
- RMS-integrated time jitter.
- 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. 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 that can run at any frequency within the supported range, with no calibration required by the instrument itself.

1.2 SPECIFICATIONS

Input Frequency and RF Level: 1 MHz – 200 MHz, 0 dBm to +15 dBm, 50Ω N-F

Reference Frequency and Level: 1 MHz – 200 MHz, 0 dBm to +15 dBm, 50Ω N-F

Input/Reference VSWR (≤100 MHz): 1.5:1 or better

Input/Reference Port Isolation (10 MHz): 130 dB or better

Maximum DC Voltage at Any Input: ±24V

Allan Deviation (1 MHz – 200 MHz, t=1s):
7E-15 specified, 5E-15 typical (cross ADEV),
7E-14 specified, 5E-14 typical (standard)

Allan Deviation (1 MHz – 200 MHz, t=1000s):
2E-16 specified, 1E-16 typical (cross ADEV),
5E-16 specified, 2E-16 typical (standard)

Phase Stability (5 MHz): Less than 10 ps/hour after 2 hour warmup, Typically below 2 ps/hour

Residual Phase Noise Floor (5 MHz):
–140 dBc/Hz @ 1 Hz, < –142 dBc/Hz typical
–175 dBc/Hz @ 10 kHz, < –177 dBc/Hz typical

Residual Phase Noise Floor (100 MHz):
–120 dBc/Hz @ 1 Hz, < –122 dBc/Hz typical
–170 dBc/Hz @ 10 kHz, < –172 dBc/Hz typical

Residual AM Noise Floor (5 MHz):
–160 dBc/Hz @ 10 kHz, < –165 dBc/Hz typical

Spurious Responses (5 MHz to 100 MHz): Less than –100 dBc (phase noise) or –90 dBc (AM noise), Typically below –120 dBc

Physical Dimensions: 344 mm x 215 mm x 91 mm, 3.2 kg; 13.5” x 8.5” x 3.6”, 7 pounds

Power Requirements: 90VAC – 264VAC, 47 Hz – 63 Hz, <40W 3-pole AC inlet IEC320-C14

Ambient Temperature: +15°C to +35°C operating, –20°C to +50°C storage; +60°F to +95°F operating, 0°F to +125°F storage

Note: Due to the use of cross correlation to cancel instrument noise, the performance depends strongly on measurement time and available signal levels. Specifications are based on measurements made at +15 dBm after a two-hour warmup period with trace smoothing and overlapped acquisition. Under these conditions, 5 MHz to 10 MHz signals are typically measurable to better than –175 dBc/Hz at offsets >10 kHz after fewer than 5 minutes. Lower-amplitude signals, signals near the frequency-coverage limits, and measurements of very low close-in noise may require more time to converge.

1.2.1 Option IR Specifications

Output Frequency (Both Channels): 100 MHz sine wave

Output Power (Both Channels): +13 ±2 dBm into 50Ω

Channel Isolation (100 MHz): >100 dB specified, >110 dB typical output match

VSWR: < 1.2:1

Spurious Outputs within 1 MHz of Carrier: < –100 dBc specified, < –110 dBc typical

Spurious Outputs (Non-Harmonic, DC-1 GHz): < –80 dB typical

Harmonic Outputs: < –40 dBc typical at 200 MHz, < –70 dBc typical at >200 MHz

Operating Modes (INT REF 1): Free run, Lock to optional internal atomic standard (STD), Lock to external 10 MHz at REFERENCE IN jack, Lock to external 1PPS at rear-panel 1PPS IN jack

Operating Modes (INT REF 2): Free run, Lock to INT REF 1

Lock Time Constant: 0.1s to 10000s (both channels independently adjustable)

Frequency Error (Base): Initial = < ±1.00E-8, Aging = < 5E-10/day after 30 days, Aging = < 5E-8/year

Frequency Error (Option STD): Initial = < ±1.00E-10, Aging = < ±1.00E-11/day after 90 days, Aging = < 5E-9/year

Allan Deviation (Free-Running or Option STD): < 1E-12 @ t=1s, < 8E-13 typical.

< 4E-12 @ t=10s, < 5E-12 @ t=100s.

Allan Deviation (Option STD Only): < 5E-12 @ t=1000s

Phase Noise (100 MHz): < –89 dBc/Hz @ 1 Hz, < –91 dBc/Hz typical.
< –130 dBc/Hz @ 100 Hz, < –135 dBc/Hz typical.
< –165 dBc/Hz @ 100 kHz, < –169 dBc/Hz typical.

Typical Allan Deviation Measurement Floor: < 2E-13 @ t=1s.
< 5E-13 @ t=10s.
< 5E-12 @ t=100s.
< 5E-12 @ t=1000s (Option STD only).

PN Measurement Floor: (10 MHz):
< –120 dBc/Hz @ 1 Hz, < –125 dBc/Hz typical.
< –170 dBc/Hz @ 10 kHz, < –175 dBc/Hz typical.

PN Measurement Floor (100 MHz):
< –100 dBc/Hz @ 1 Hz, < –110 dBc/Hz typical.
< –170 dBc/Hz @ 10 kHz, < –175 dBc/Hz typical.

> **Note:** Stability specifications with Option STD atomic standard assume t ≥ 200s loop time constant. All specifications apply after 24 hours stabilization in a laboratory environment. Measurements in disciplined mode inherit accuracy and stability of external reference. Typical residual stability approximately 2E-13/tau (INT REF 1 output, t=1s, 10 MHz external reference with loop time constant=0.1s). All internal sources support both factory-level and user-level calibration.

1.3 GETTING STARTED

1.3.1 What's in the Box?

Please check the contents of the package carefully upon arrival. Each 53100A Phase Noise Analyzer unit should be accompanied by the following items:

- (1) USB 2.0 cable, A Male/B Male
- (1) Flash drive with User's Guide and latest version of TimeLab Software
- (1) Power supply
- (2) N-M/BNC-F coax adapters
- (4) 1” (25.4 mm) SMA-M/SMA-M coax jumpers (pre-installed)

Additionally, each 53100A delivered to North American customers includes a standard IEC320/NEMA 5-15P power cord for 120V service. For operation in other countries, the 53100A's power supply accepts 50/60 Hz AC power at all standard line voltages from 100V to 240V and is compatible with IEC320-C14 power cords available locally.

Documentation shipped with each unit includes:

- Certificate of conformance
- Base test report
- IR test report (Internal reference versions only)
- Calibration certificate (Internal reference versions only)

1.3.2 USB Driver and Software Installation

The current TimeLab release may be downloaded from the Microchip product web page. Please install the most recent version of TimeLab before using the 53100A.

1.4 INSTALLING TIMELAB™

TimeLab is a compact Windows application designed for general-purpose phase/frequency stability and noise measurement. It runs on Intel® or AMD® x86-based PCs equipped with Microsoft Windows® 7 SP1 or later versions. TimeLab supports a wide variety of time and frequency measurement instrumentation in addition to the 53100A, including the TimePod 5330A cross-spectrum analyzer and the 5115A/5120A/5125A phase noise test sets from Microchip.

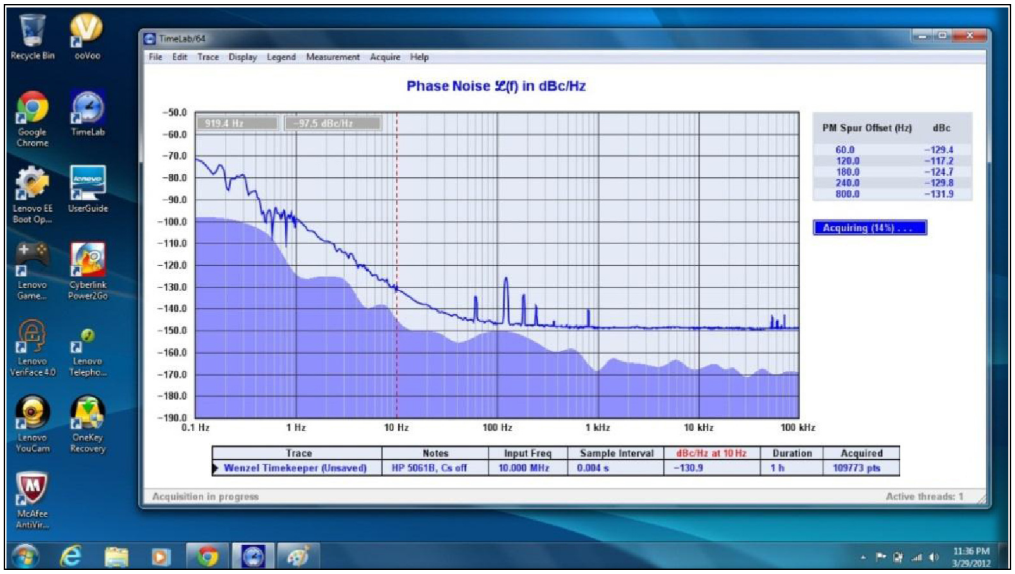
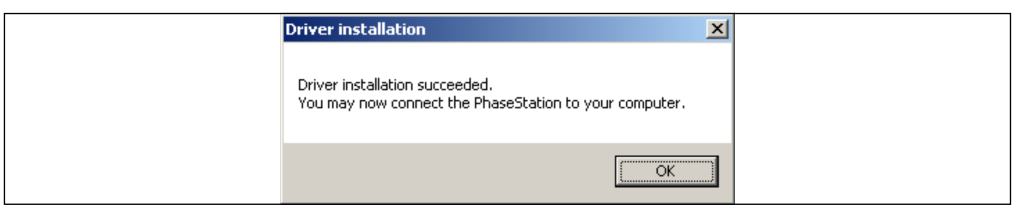


FIGURE 1-1: TimeLab Interface.

Minimum system requirements are 100 MB of disk space, 1 GB RAM, and a CPU with SSE2 support. For use with the 53100A, a processor with four or more physical cores is recommended.

By default, TimeLab will automatically check the Microchip web site on a weekly basis and inform you if a newer version is available for download. Updates are always free of charge. To configure or disable automatic update notifications, select *Help>Check for Updates*.

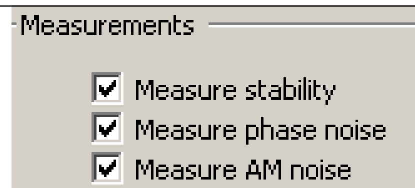
For best results, TimeLab should be installed prior to connecting the 53100A to your PC’s USB port for the first time. Before exiting from the install program, make sure that the box labeled Install 53100A USB Driver is checked. This will help Windows locate the USB driver without further intervention when the 53100A is connected. After the driver has been successfully installed on your system, a confirmation message will appear.



1.5 PERFORMANCE NOTES

Measurements made with the 53100A rely on multi-threaded signal processing operations that can place significant performance demands on the host PC. 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. In practice, this means that a 2.0 GHz Intel Core 2 Duo or faster processor is required. Additional CPU cores are often more helpful than higher clock speeds.

Use of a system with inadequate CPU performance may result in acquisition errors, often accompanied by a flashing red fault indication of the 53100A'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 measurement, uncheck the Measure phase noise and Measure AM noise boxes in the acquisition dialog, as shown at right. By default, the 53100A will measure phase noise, AM noise, and phase/frequency stability simultaneously.



It is strongly recommended to select the "High performance" power plan in the Windows control panel, particularly when the PC is running on battery power. The System power control on the **Additional Options** page of the 53100A acquisition dialog provides a convenient way to switch to the high-performance power plan during acquisition. When a given power plan is selected with System power, the power plan specified in the Windows control panel will be restored automatically when the measurement ends. Using the System power control to select the power plan for use during measurements also guards against modification or reversion of the power plan selection by the operating system or any other applications.

When noise measurements on slower PCs are required, another strategy to improve reliability is to uncheck the Overlapped acquisition box in the **Additional Options** page of the acquisition dialog. Doing so will increase the averaging time required to achieve extremely low noise floors, but will have little effect on most measurements. Note that overlapped acquisition is turned off by default.

For improved performance, a 64-bit version of TimeLab will automatically be installed on x64-based systems. If you need to record long phase records with the 53100A (or any other equipment supported by TimeLab), an x64 system with several GB of RAM is recommended.

1.6 FRONT PANEL FEATURES

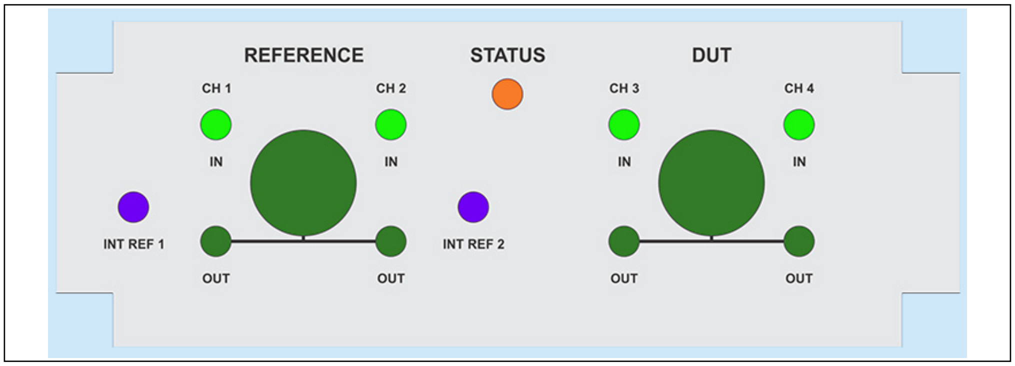


FIGURE 1-2: *Front Panel Controls and Features.*

The 53100A's front panel includes the following features, located as shown in the color-keyed image above:

- Two AC-coupled N-F input jacks (large, dark green circles) that correspond to the primary REFERENCE and DUT signal inputs. Measurements of RF signals from a single DUT and a single reference source will normally use these two jacks as inputs.
- Each of the N-F input jacks is connected to an internal power splitter with two output ports, which in turn are routed to a pair of SMA-F output jacks below (small, dark green circles).
  It's important to note that the jacks associated with the power splitters are unconnected to anything else internally. They are provided for operational convenience. Each splitter presents a nominal 50Ω load at its input port[1], where the signal is fed to two independent, identical amplifiers whose outputs are also source-terminated at 50Ω. Net gain from each N input jack to its corresponding SMA output jacks is 0 dB nominal. These active splitters offer advantages over traditional resistive or Wilkinson implementations in cross-correlated noise measurement applications, including high isolation and well-defined port impedances with minimal differential-mode noise.
- Four AC- or DC-coupled SMA-F input jacks that drive the individual ADC channels (small, light green circles).
  By default, each of these input jacks is strapped to the output jack directly beneath it. This effectively divides the four-input 53100A into two independent two-channel instruments for cross-correlated phase noise and AM noise measurements. By sending identical copies of the reference signal to channels 1 and 2 and the DUT signal to channels 3 and 4, uncorrelated noise in all four channels will average out over time. In principle, only the noise at the splitter input terminations is common to the two "instruments," corresponding to –177 dBc/Hz with a 0 dBm input.
  Note that the above describes only one of several possible measurement configurations. A number of other measurement roles, including multichannel stability measurements, are also possible. These are discussed in **Chapter 6. "53100A Measurement Roles"**.

Note 1: Specifically, both the DUT and REFERENCE 'N' jacks are coupled to their respective input splitters via 'L' networks consisting of 6.8 nF, 100V capacitors and 22 µH inductors. The four SMA input jacks are capacitively coupled as well when the instrument is configured for RF carrier measurement. At power-up time, the 53100A will momentarily switch the SMA inputs to the alternate signal path for DC-10 MHz baseband analysis, which presents a resistive load of approximately 10 kΩ. Both the RF and DC paths can tolerate DC voltages up to ±24V.

- Units equipped with the dual internal reference option (purple) are provided with two SMA-F output jacks for these 100 MHz sine wave reference signals. Typical output level is +12 dBm.
- 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 53100A's internal clock oscillator warms up.
  - **White:** The 53100A 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.
  - **Purple (Flashing):** Excessive power is present at either the REFERENCE or DUT inputs or at one or more of the channel input jacks, causing signal clipping in one or more ADC channels. An unexpected increase in signal level after measurement has begun can cause this indication. The acquired data is questionable.
    While the inputs are protected against DC potentials up to 24V, the maximum recommended RF power at any front-panel input jack is +15 dBm. Damage may occur at RF input levels greater than +20 dBm.
  - **Red (Flashing):** A USB data overrun has occurred. 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 noise or stability measurement options in the acquisition dialog.

1.7 REAR PANEL FEATURES

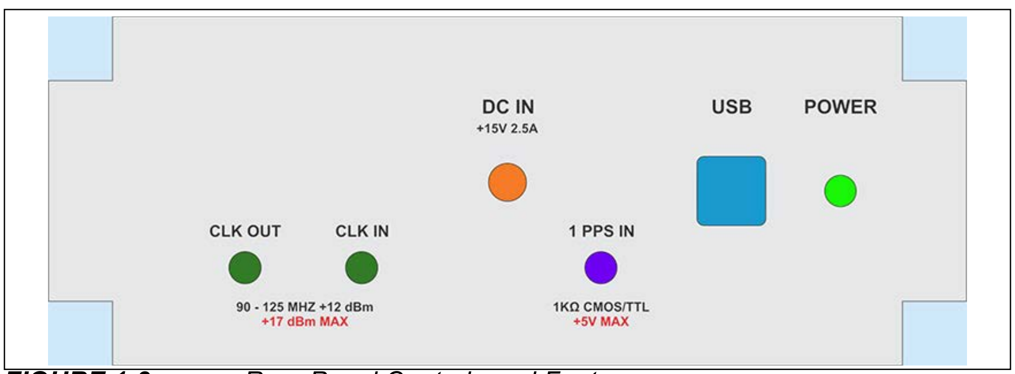


FIGURE 1-3: *Rear Panel Controls and Features.*

The 53100A's rear panel includes the following features, located as shown in the color-keyed image above:

- The 2.1 mm DC input jack (orange) is intended for use with the provided 15V external power supply. Note that the 53100A's power supply is equipped with a locking power connector. To prevent inadvertent disconnection, it is strongly suggested that you secure the locking ring to the threaded portion of the input jack when connecting the power supply. Use the power switch to turn the 53100A Phase Noise Analyzer on and off, rather than repeatedly connecting and disconnecting the barrel connector.
- Two SMA-F input jacks (dark green) are reserved for future use.
- One SMA-F input jack (purple) for synchronization and calibration applications associated with the dual-channel internal reference option.

- A USB Series 'B' receptacle (blue) is provided for PC connectivity. Guidelines for PC selection appear in **Section 1.5 "Performance Notes"**.

> **Note:** USB 2.0 High Speed support is required for all 53100A acquisitions. In most cases the use of passive or active USB hubs with the 53100A is acceptable, but if connection problems occur, you may find it helpful to connect the supplied USB cable directly to the host PC, or try a different USB port.
> In general, measurement errors are much more likely to be caused by insufficient CPU resources than by USB connectivity problems.

1.8 GUIDELINES FOR INPUT SIGNAL CONNECTIONS

Although the N-F and SMA-F input jacks offer superior mechanical stability, BNC-N coax adapters are also supplied with the 53100A for operator 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, RG174 and other common single-shielded cables can cause artifacts in stability and noise plots, particularly with longer cables.

Input signals should be greater than 0 dBm for best performance; +5 dBm to +15 dBm is recommended. While the 53100A is intended for use with sine wave oscillators, it's possible to measure logic-level clocks as well if you equip them with suitable matching networks. It's a good practice to measure an oscillator with a load that's similar to what it will encounter in its ultimate application, keeping in mind that most logic-level sources are not specified to drive 50Ω loads at all. Overloading of the source, the 53100A, or both can occur if these devices are connected directly to the instrument's input jacks. Consult the manufacturer's data for the source in question to determine its output impedance and/or current drive capability.

The required matching network can be as simple as a resistive series termination or voltage divider, but the Phase Noise Analyzer's own spur performance and broadband noise floor will likely be degraded when measuring non-sinusoidal sources unless you provide additional bandpass filtering. Careful shielding of matching networks, buffers, and other interfacing elements is also necessary, since isolation of DUT and reference signals from stray RF signals (and from each other) is a prerequisite for clean measurements. Experimentation will likely be required to achieve the desired results with non-sinusoidal signals.

1.9 CHOOSING REFERENCE SOURCES

In addition to the host PC and an appropriate power source, measurements made with the 53100A require either one reference signal to be supplied at the REFERENCE jack or two reference signals supplied at the CH 1 IN and CH 2 IN jacks. Virtually all aspects of measurement performance—accuracy, repeatability, noise floor, spurious responses—depend on the ability to provide the best reference signal(s) possible.

The "best reference possible" depends on the goals of your measurement. Very few reference sources are ideal for both short-term and long-term measurements. Typical house clocks that distribute 5 MHz or 10 MHz signals at levels between +5 dBm and +15 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.

Furthermore, 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, or even better, two of them, for phase noise and AM noise measurements.

Unlike most other stability and noise analyzers, the 53100A can work with any reference whose frequency lies within its specified RF carrier range (1 MHz to 200 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 a 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, it will still measure –160 dBc/Hz and ADEV=3E-12 if you switch to a 10 MHz reference, or one at any other frequency.

One complication, however, 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 effect that classically applies when a signal undergoes 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 the reference after any applicable $20*\log10(f_{DUT}/f_{REF})$ correction should be at least 8 dB to 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.[2]

Bear in mind that lower-frequency crystal oscillators will usually exhibit better close-in noise than those at higher frequencies, even when the 20*log(N) rule is taken into consideration. This is a consequence of the physical properties of the crystals themselves. For example, the highest-quality 5 MHz and 10 MHz OCXOs on the market can perform at levels below –130 dBc/Hz at 1 Hz from the carrier. These oscillators make superior references for HF frequency stability and close-in noise measurement, easily outperforming the best VHF oscillators. But at the same time, they will be less effective than low-noise VHF oscillators as references for broadband noise measurement of VHF sources. Low-frequency reference oscillators have no inherent advantages at offsets beyond a few kilohertz where crystal Q no longer dominates, and the 20*log(N) principle will work against them when measuring higher-frequency DUTs.

An additional consideration when specifying reference oscillators is that industry-standard frequencies such as 5 MHz, 10 MHz, and 100 MHz benefit from a larger selection of crystals at the factory. Within a given product line, oscillators at unusual frequencies will rarely outperform units manufactured at standard frequencies.

2: 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 TimeLab'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.

1.10 WORKING WITH DUAL REFERENCE SOURCES

The use of dual references carries significant advantages in noise measurement due to the instrument's use of cross spectrum averaging to remove the influence of uncorrelated reference sources over time. Multiple references can be helpful in stability measurement as well, because the 53100A can easily acquire the multichannel data necessary for so-called "three-cornered hat" processing.

For a detailed "case study" featuring the use of dual reference sources in both stability and noise measurement roles, please refer to Application Note 3526, *Dual Reference Noise and Stability Measurements with the 53100A*. Also, please see **Appendix A. "53100A Dual 100 MHz Reference (Option IR)"**. It contains helpful information and guidelines that apply to all dual reference configurations, not just the factory-installed internal reference option module.

The use of dual independent references relaxes some of the constraints on the stability and/or noise performance of the reference signal sources, but the advantages come with a new requirement: the references must be truly independent and uncorrelated. Otherwise, cross-correlated phase noise and AM noise measurements will not converge at the DUT's true noise level, and three-cornered hat measurements will not benefit from the statistical independence required to separate the frequency variances at the individual channels.

Two OCXOs running from the same power supply, for instance, may not be as independent as they look. They may even injection-lock to each other through their power supply connections if decoupling isn't adequate. When working with dual references, consider enclosing each of them in its own RF-tight box or other sealed metal container. Use high-quality DC feedthrough capacitors rather than conventional power jacks or connectors. These precautions are always a good idea, but they're absolutely mandatory with OCXOs whose output signals are obtained from discrete pins or SMT pads rather than coaxial outputs.

53100A instruments equipped with optional dual internal references are particularly easy to set up because reference channel isolation isn't a concern. There are no inherent performance differences associated with the choice of external versus internal reference pairs, but the internal reference option offers the practical advantage of allowing the Phase Noise Analyzer to measure high-performance sources with no connections other than USB, power, and the DUT itself.

Internal and external reference jack configurations are shown in **Chapter 6. "53100A Measurement Roles"**. When reviewing the dual-reference measurement role descriptions, note that the REFERENCE, CH 1 OUT, and CH 2 OUT jacks remain unconnected when dual references are used, whether internal or external, except when a 10 MHz external standard is connected to the front-panel REFERENCE jack to discipline the Option IR internal reference sources. As with the DUT, CH 3 OUT, and CH 4 OUT connectors on the right side of the front panel, these jacks correspond to the input and output ports of an internal RF splitter. The REFERENCE and DUT channel splitters are provided for user convenience, and have no other internal connections, except as noted above.

Dual-channel references used with the 53100A do not have to operate at the same frequency. That being said, when working with external dual-channel sources it can sometimes be helpful to either phase-lock them together with a loop bandwidth well below the narrowest noise offset of interest, or separate them by several dozen hertz or more. If the oscillators are only a few hertz apart, it may be difficult to spot crosstalk problems in the external RF or power connections.

Finally, note that basic single-reference frequency stability measurements don't use the second (CH 2) reference or the second DUT input (CH 4) at all. The CH 2 reference may be powered down or left unconnected if noise measurements are disabled in the acquisition dialog and no DUT channels are using CH 2 as a stability reference. Stability measurements that demand the ultimate in Allan deviation performance can take advantage of the CH 2 and CH 4 inputs through the use of measurement roles that support cross Allan deviation. See **Section 6.7 “Measure Single DUT with Cross ADEV Statistics”** for more information.

1.11 MAKING YOUR FIRST MEASUREMENTS

The 53100A hardware is easy to work with after 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 TimeLab.

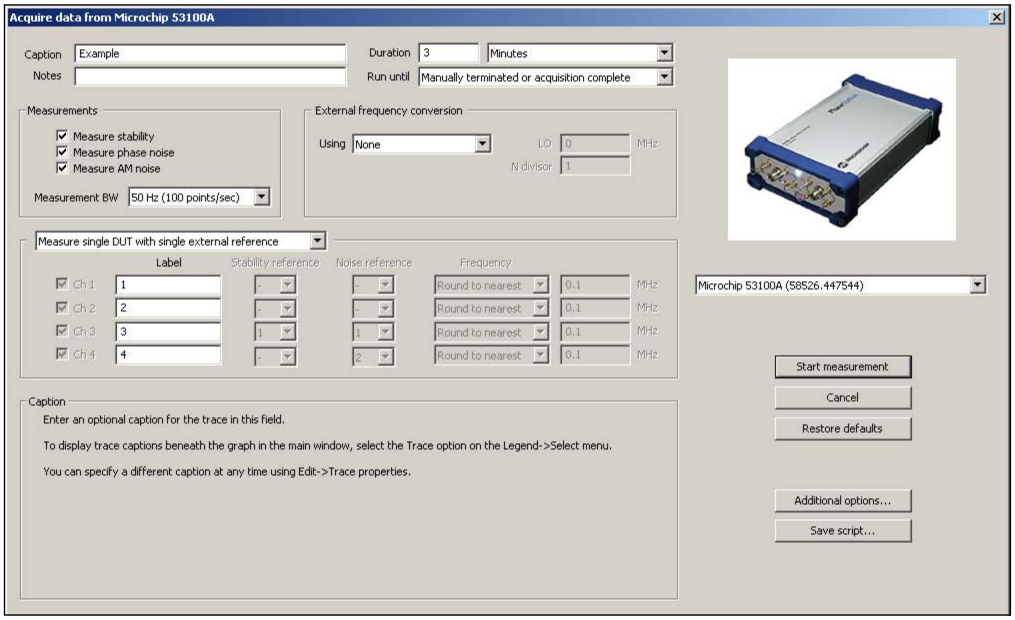


FIGURE 1-4: *The 53100A Phase Noise Analyzer Acquisition Dialog.*

Getting started with the 53100A is as easy as connecting the 53100A’s USB cable to your PC and launching TimeLab. Once TimeLab is running, select the *Acquire>Microchip 53100A* menu option. The dialog box that pops up should contain a list of available 53100A device(s) in a dropdown box at upper right, just below the instrument photo.

Assuming the appropriate 53100A instrument is selected, the acquisition parameters are all valid, you’ve connected stable reference and DUT input sources to the 53100A, and you’ve allowed at least a few minutes’ warmup time, all you need to do is press the **Start Measurement** button. The acquisition dialog will disappear and the STATUS indicator on the 53100A should change from white to green. Over the next ten seconds or so, various informational messages will appear in the TimeLab status bar at the bottom of the program’s main window as the software characterizes the device under test (DUT) and reference input signals.

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.

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 measurement options in the acquisition dialog, all of the different graph types should be accessible, 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 TimeLab 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 `.TIM` file with *File>Save Image or .TIM File* (s). A `.TIM` 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 `.TIM` file or load another `.TIM` file for display alongside the existing plot(s) that have been loaded or acquired.
- Use *File>Load .TIM file* to read the `.TIM` file you just saved. Now you should have two copies of the same plot in memory. At the left edge of the legend table entry for the most recently-initiated or loaded plot, you'll see a black triangular cursor, indicating the plot that's currently selected for editing, browsing, or other forms of control interaction in TimeLab. In the figure below, the most-recently loaded plot has been automatically selected:

Trace	Notes	Input Freq	ADEV at 1s	Duration	Elapsed	Acquired	Instrument
Example (Unsaved)		5.0 MHz	7.12E–14	3 m	20 s	1949 pts	PhaseStation 53100A
▶ Example		5.0 MHz	6.61E–14	3 m	5 s	534 pts	PhaseStation 53100A

FIGURE 1-5: *Selection Cursor.*

If the measurement is still in progress, you can left-click on the original plot's row in the Legend table or press the Up arrow key to re-select it, then switch to the phase or frequency 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 TimeLab 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 as described above. 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 Arrow> or <Down Arrow> keys (*Display>Select Next Plot in Chart*/*Display>Select Previous Plot in Chart*). The small black triangular cursor at the leftmost edge of the legend table moves up and down and the plot that it points to becomes visible. You can also select a new plot by left-clicking on its row in the table. 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 in *Display>Overlay* mode, 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> function.
- To avoid confusion the *Display>Toggle Visibility of Selected Plot* <v> function 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.
- Regardless of the choice of *Display>Browse* or *Display>Overlay* mode or the visibility status of any given plot, the "selected plot" is 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 TimeLab are surprised to discover that a single `.TIM` 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 TimeLab 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 .TIM file* <s> when the latter command is used to save a `.png, .bmp, .tga, .gif`, or `.pcx` image of the entire screen.

1.12 TIPS FOR NEW USERS

- In TimeLab, 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.
- Use the 53100A in an environment with good ambient temperature control for best results. Avoid placing the hardware near HVAC vents or other sources of drafts when making sensitive measurements.
- Avoid placing the 53100A 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 +35°C to +40°C 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 TimeLab'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 retake.
- At startup time, TimeLab will open any `.TIM` file(s) specified on the `timelab[64].exe` command line. Alternatively, a JavaScript program filename ending in `.JS` may be specified for execution.
- Every measurement in TimeLab 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 53100A acquisition takes about 16 MB/sec of USB bandwidth and two cores' worth of CPU power.
- When equipped with multiple USB host controllers, the fastest available PCs can

acquire data from up to four 53100A devices concurrently. Most PCs will be limited to two concurrent acquisitions at most.

- The acquisition dialogs in TimeLab all have large mouseover help windows. The mouseover help text serves as the primary hardware-specific documentation for the various analyzers and counters supported by TimeLab. Read it carefully before changing any fields from their default values.
- Attempting to run 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 Microchip for technical support, it's a good idea to attach `.TIM` file(s) associated with the issue, rather than image files. `.TIM` files greater than 3 MB in size should be zipped or otherwise compressed.

1.12.1 Next Steps

Two application notes are provided to illustrate specific measurement techniques and applications that almost all 53100A users will find helpful. These are AN3502 (*Oscillator Measurement and Calibration with the 53100A*) and AN3526 (*Dual Reference Noise and Stability Measurements with the 53100A*).

If your 53100A is equipped with the optional dual 100 MHz internal reference module (Option IR), please review **Appendix A. "53100A Dual 100 MHz Reference (Option IR)"** for helpful usage guidelines and measurement tips.

1.13 BLOCK DIAGRAM

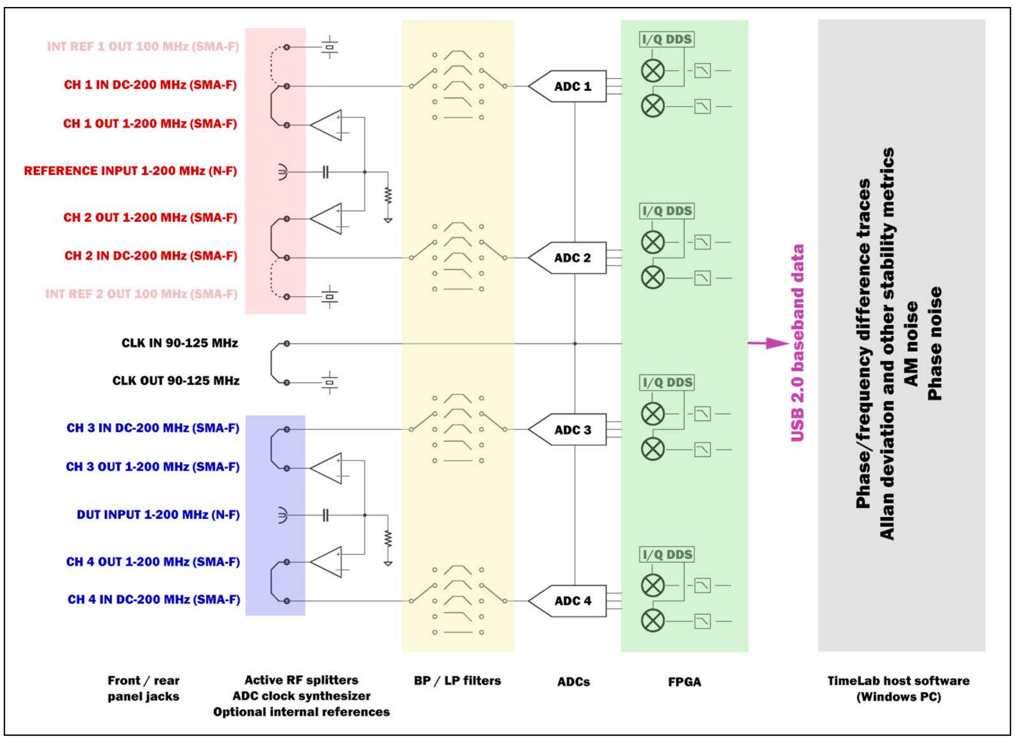


FIGURE 1-6: Functional Block Diagram.

The diagram above provides an overview of the signal and data pathways that lie between the DUT and reference signals supplied to the 53100A and the results that ultimately appear on the screen. Although the block diagram may appear complex at first, the features most likely to be of interest are the signal connections available to the user, all of which are shown at left. Front-panel jacks typically connected to the device(s) under test are highlighted in blue, while those associated with internal or external reference signals are shown in red.

Other notable aspects of the block diagram include the following points.

- The four SMA M-M jumpers shown in the DUT and reference input areas are depicted in their factory-default configuration. With these connections, signals applied to the two N-female connectors on the front panel are split into two identical paths in the classical topology for cross-correlated noise measurements. Many other connection possibilities are available, however, since all four ADC channel inputs are accessible to the user. These will be discussed later.
- Active splitters are used at the two N-F input jacks rather than typical resistive or Wilkinson types. The active splitters present a well-defined load to the input signals as well as a consistent source impedance to filters and other components in the analog front end. Reverse isolation is approximately 70 dB at 100 MHz, which helps to minimize load-impedance fluctuations caused by attenuator and filter selection when a measurement begins. These load variations can affect the stability of devices being measured, and they can also interfere with other equipment connected to the DUT or reference sources.
  Additionally, the active splitters do not present a differential-mode source of Johnson noise at their outputs, which may help prevent certain artifacts in measurements at extremely low noise levels near the thermal floor of –177 dBm/Hz. The shared load resistors do act as a common-mode noise source at the thermal floor, however. It’s uncommon for real-world measurements with the 53100A to reach this limit, but the SMA jumpers may be used to connect other types of splitters supplied by the user if required. The use of the internal splitters is always optional.
- On instruments equipped with the dual independent internal reference option, the reference channel jumpers may be moved to connect the two internal 100 MHz OCXOs directly to the input jacks. In this configuration, no connections are made to the CH 1 OUT and CH 2 OUT jacks. However, an external 10 MHz frequency standard may be connected to the REFERENCE input jack to serve as a disciplining source for the 100 MHz INT REF 1 and/or INT REF 2 outputs.
- The CLK IN and CLK OUT jacks on the rear panel are also depicted on the left side of the block diagram. These jacks are intended to provide access to the internal ADC clock signal path for future applications. These jacks are unpopulated by default.
- The SMA-F jacks labeled CH 1 IN, CH 2 IN, CH 3 IN, and CH 4 IN are connected to identical banks of switched filters and attenuators that condition the input signals and pass them to the individual ADCs. While the active splitter inputs at the N-F jacks are AC-coupled, the filter banks associated with the four SMA-F input jacks include lowpass elements that permit coverage down to DC.

1.14 A BRIEF ARCHITECTURAL NOTE

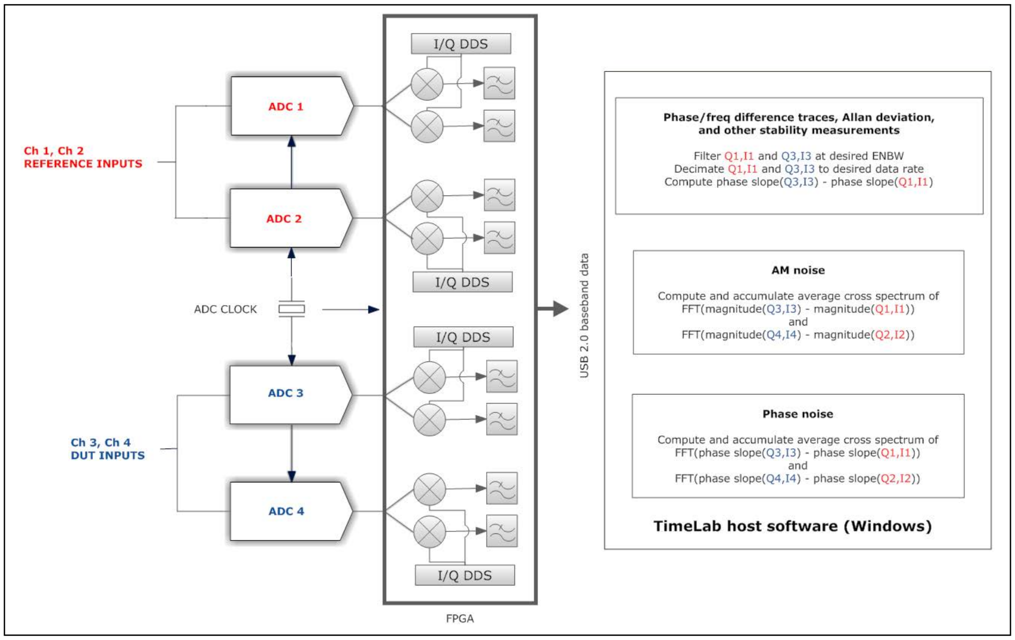


FIGURE 1-7: *Digital Processing Pipeline.*

It can be helpful to understand some basic details about the 53100A's DSP topology, especially when measurements may be constrained by available memory and CPU resources. A key observation is that the two basic measurement categories corresponding to the **Measure Stability** and **Measure Phase Noise/Measure AM Noise** options in the TimeLab acquisition dialog use completely separate data records and internal processing pipelines.

The "phase record" mentioned in the documentation and help text has nothing to do with phase noise measurements, for example. Instead, the phase record is a block of low-bandwidth phase difference samples from a single DUT/reference channel pair. It is used only for stability measurements, which include ADEV, MDEV, TDEV, HDEV, and MTIE as well as the frequency- and phase-difference plots.

The diagram above represents a more detailed view of the right half of the block diagram from the preceding section. While TimeLab allows phase records from multiple channel pairs to be recorded during a single measurement, the most common measurements yield a single phase record created from two parallel streams of complex data samples arriving from one DUT input channel (Q3,I3) and one reference input channel (Q1,I1). Channels 2 and 4 do not participate in single-DUT stability measurements by default unless a measurement role supporting cross ADEV stability measurements has been selected. The two streams from channels 1 and 3 are decimated to accommodate the requested measurement bandwidth (ENBW), typically 5 Hz to 500 Hz, with rates up to 50 kHz supported through the use of additional decimation to avoid excessive phase data record sizes. The phase differences between corresponding samples in the two decimated streams are then calculated and used to construct the various xDEV plots as well as the phase- and frequency-difference plots.

So, when you save a measurement to a `.TIM` file that was made with the Measure stability option checked, 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/phase-difference plots will be recalculated, but nothing will happen to the phase noise or AM noise plots. The noise traces are normally based on the phase and/or amplitude differences for all four baseband streams—Q1,I1, Q2,I2, Q3,I3, and Q4,I4—which are processed at the full baseband data rate exceeding 200 kS/s. The resulting data is then passed to the FFT and cross-spectrum averaging routines.

Because it would be impractical to retain the original high-bandwidth complex base-band data or any phase or amplitude information derived from it, only the averaged FFT output bins are written to the `.TIM` file when saving the phase noise or AM noise portion of a measurement.

NOTES:

Chapter 2. Making Measurements

Three views of the same 53100A Phase Noise Analyzer measurement appear below, revealing the performance secrets of some of the industry's highest quality crystal oscillators.

The Allan Deviation plot displays frequency stability at intervals from milliseconds to days, while the Phase Noise plot renders the signal's spectral signature at offsets ranging from 0.001 Hz to 1 MHz. In this example, dual references help the 53100A's noise measurement floor approach –150 dBc/Hz at 1 Hz from the carrier.

Meanwhile, a mixture of short-term and long-term stability trends can be examined in the Frequency Difference display. The 53100A's frequency count chart offers over 13 digits per second of usable precision at gate times from 0.1 second to 3000 seconds.

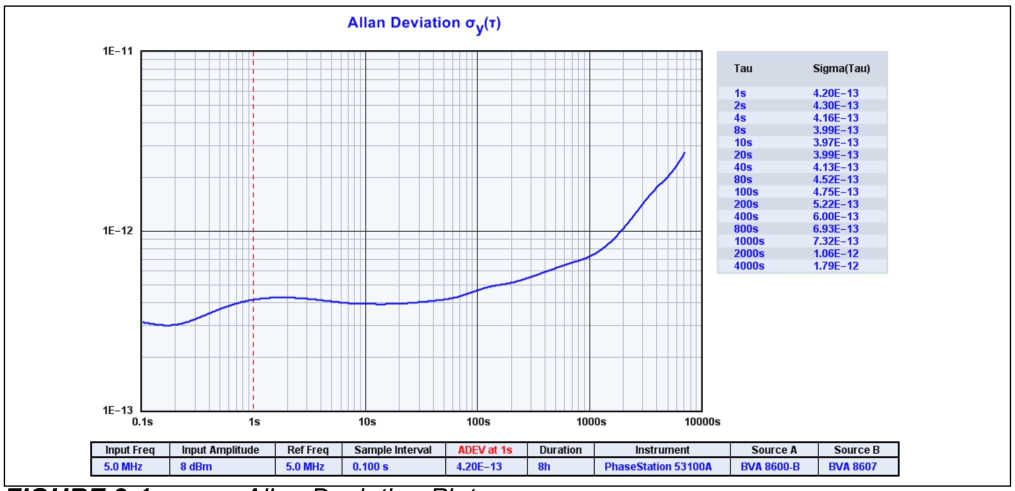


FIGURE 2-1: *Allan Deviation Plot.*

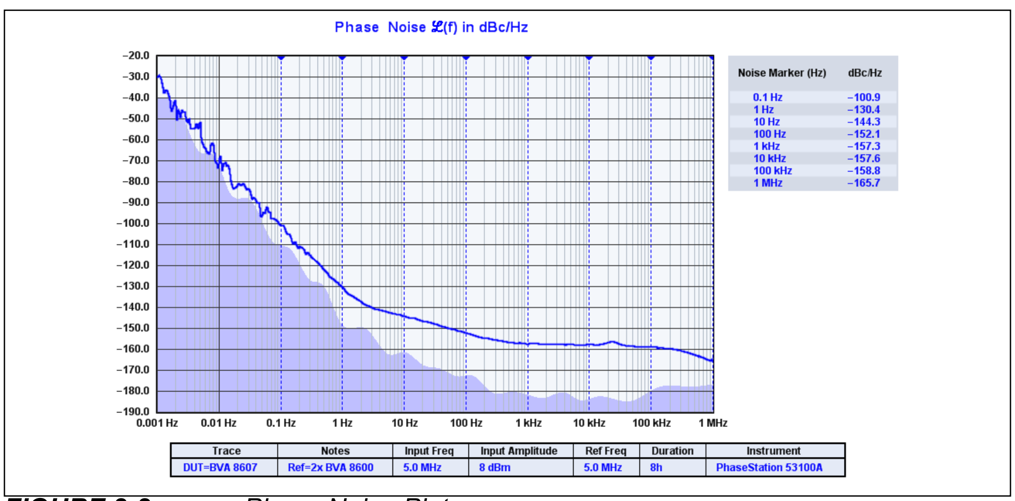


FIGURE 2-2: *Phase Noise Plot.*

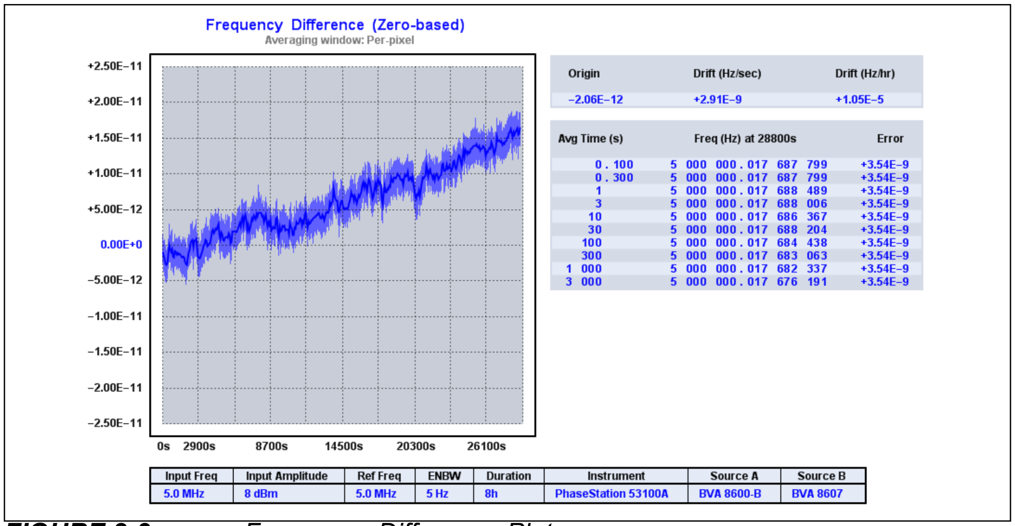


FIGURE 2-3: *Frequency Difference Plot.*

2.1 FREQUENCY AND TIME DEVIATION MEASUREMENTS

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 TimeLab.

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!"

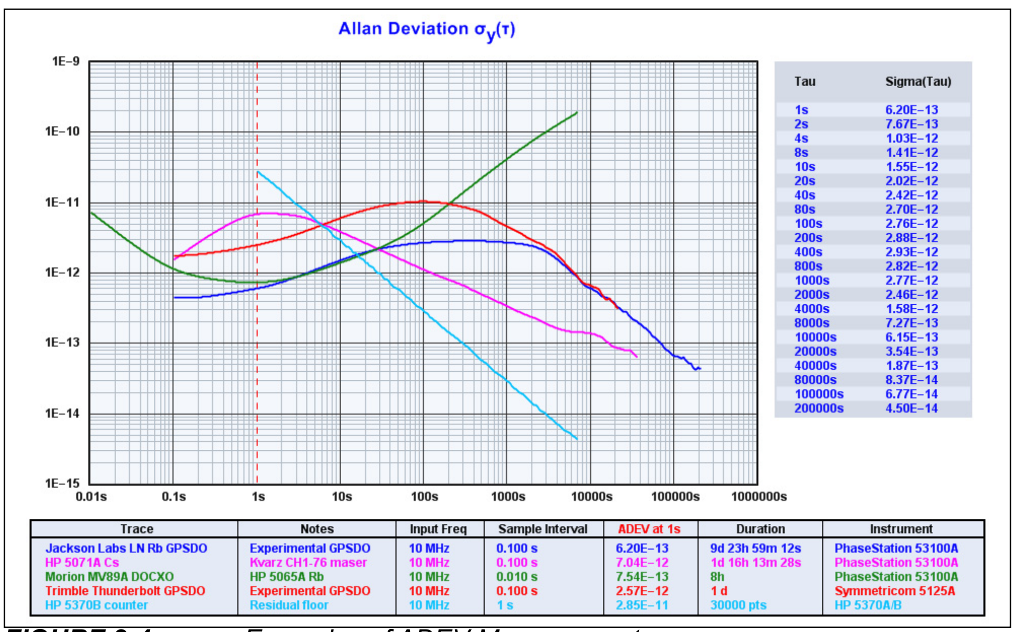


FIGURE 2-4: *Examples of ADEV Measurements.*

The answer is that these plots are not simply linear depictions of frequency drift over time. In TimeLab, 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. 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 TimeLab and other ADEV applications.

TimeLab's statistical capabilities aren't limited to Allan Deviation. The Measurement menu allows you to view any of five types of statistical plots, during or after acquisition. Formulas exist[1] to calculate Allan Deviation and other statistics on the basis of both phase and frequency samples. TimeLab 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 TimeLab, the statistical plots are updated simultaneously in real time.

2.1.1 Allan Deviation "ADEV" <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.

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

2.1.2 Modified Allan Deviation “MDEV” (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 intervals 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.

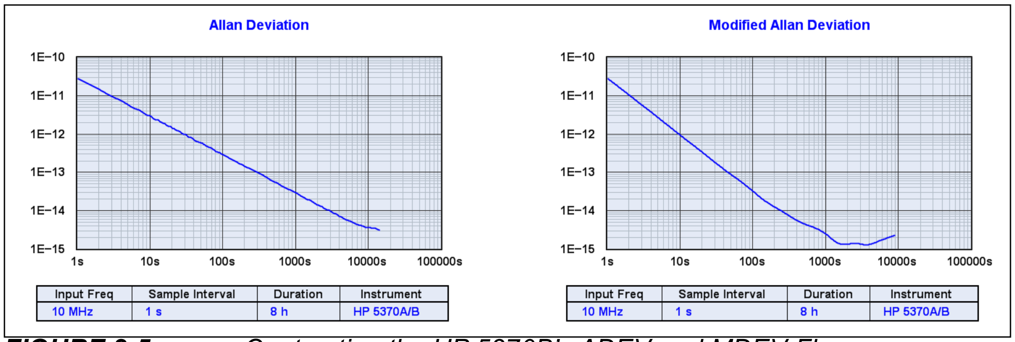


FIGURE 2-5: *Contrasting the HP 5370B’s ADEV and MDEV Floors.*

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.

2.1.3 Hadamard Deviation “HDEV” <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.

2.1.4 Time Deviation “TDEV” <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 Time Interval Error (TIE) statistic used by the telecommunications sector.

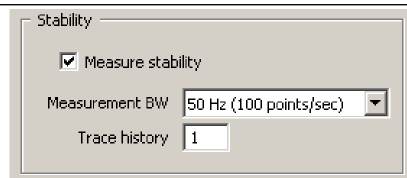
2.1.5 Maximum Time Interval Error <M>

Simply put, MTIE represents the worst-case timing performance of the clock under test over the tau intervals covered by the measurement, as observed by sliding windows of the corresponding tau durations through the phase record. Like TDEV, MTIE is frequently encountered in telecommunications standards specifications.

Along with the other stability metrics supported by TimeLab, the MTIE plot is computed on an incremental basis as successive data points arrive from the counter or phase-difference analyzer and updated in real time. Because MTIE calculations are more time-consuming than the other stability metrics supported by TimeLab, they are performed on only the first 10,000 points of the phase record by default. This limitation can be removed by deselecting the *File>Limit MTIE processing to 10K points* option.

2.2 EXAMINING CHANGES IN STABILITY OVER TIME

To make basic dynamic ADEV measurements(2), refer to the help text for the **Duration** and **Run Until** fields in the acquisition dialog, as well as the Trace History field shown below.



Specifying a Trace History value greater than 1 causes TimeLab 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. Values displayed on the *Sigma(Tau)* chart apply to the most recent trace.

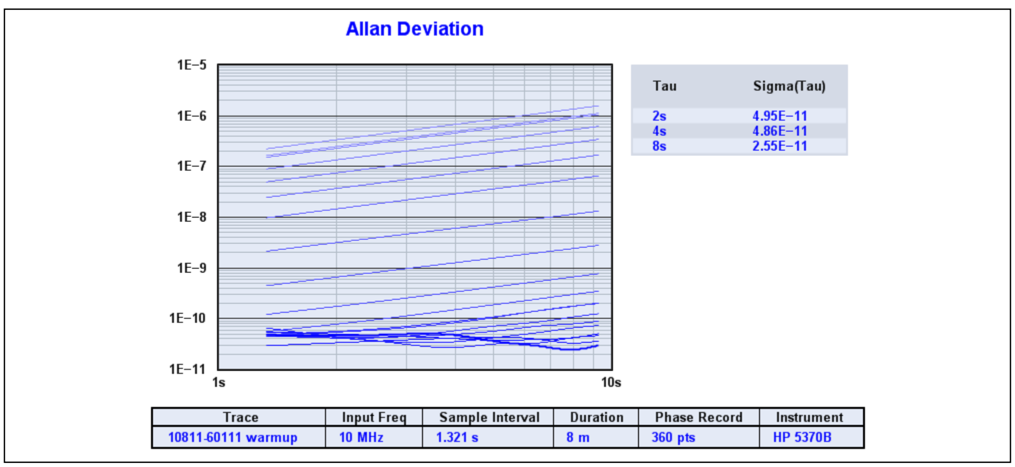


FIGURE 2-6: *Dynamic Allan Deviation.*

2: 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

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 for offline analysis.

2.3 COMMON ARTIFACTS IN ADEV AND RELATED MEASUREMENTS

High-resolution plots captured by the 53100A 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 were not present.

2.3.1 Measurement Bandwidth and τ_0

One artifact that does originate in the Phase Noise Analyzer driver software is shown in the plot below. 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.

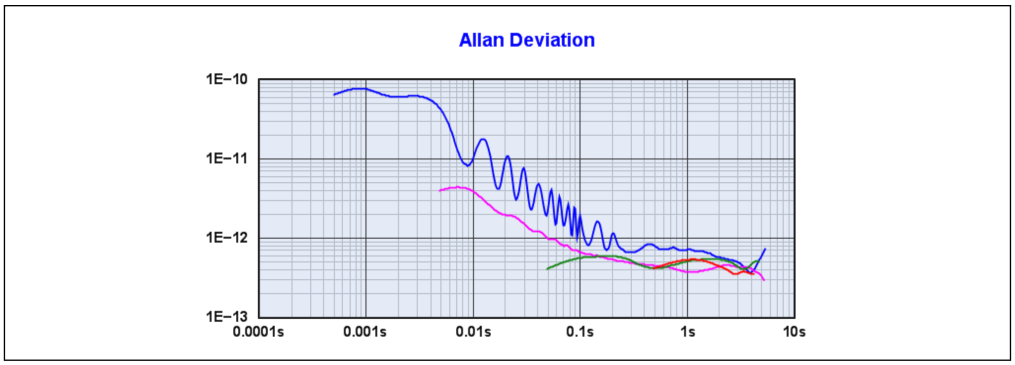


FIGURE 2-7: *Artifact Near the Beginning of Unclipped Traces.*

What causes this artifact? Stein[3] has shown that the optimum ENBW for a given ADEV τ_0[4] is simply the $1/(2 * \tau_0)$ Hz Nyquist rate. This bandwidth is unachievable with a non-ideal anti-aliasing filter, so the 53100A 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 anti-aliasing filter's response is easy to mistake for a real effect.

TimeLab 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 below, TimeLab does not render any portion of an xDEV trace at taus shorter than 1/(2 * ENBW) seconds.

3: *The Allan Variance – Challenges and Opportunities*, Samuel R Stein, Symmetricom, Inc., Boulder, Colorado USA

4: 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.

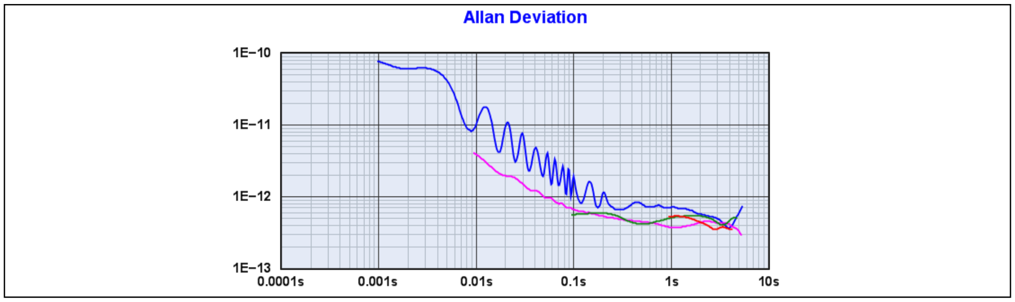


FIGURE 2-8: Traces Clipped by Bandwidth.

Additionally, the 53100A 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 **Additional Options** page of 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.

Decimation factors of 2:1 or greater also have the effect of satisfying the previous $\tau_0 \geq 1/(2 * \text{ENBW})$ criterion. With the default Output Decimation value of 2:1 or any higher ratio, phase-difference data that's affected by lowpass 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.

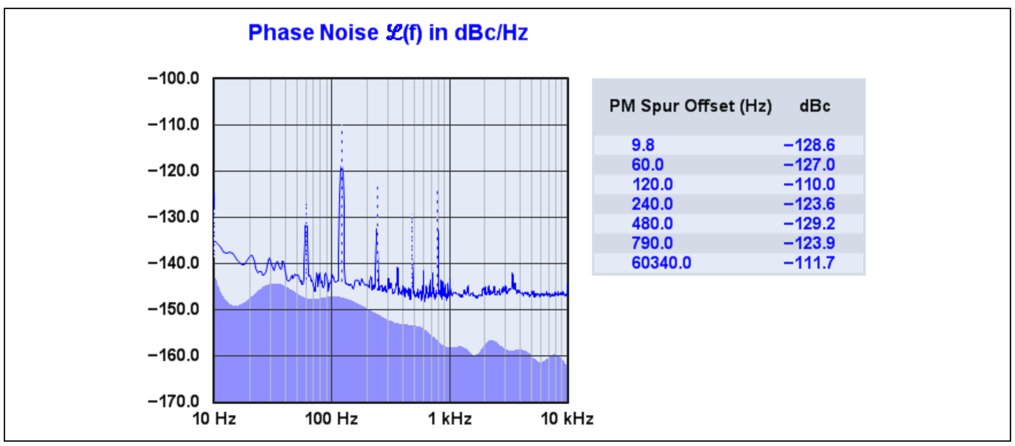


FIGURE 2-9: AC Line Interference Responsible for Ripple in ADEV Plots.

2.3.2 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.

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=0.010s 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 because all ports on the 53100A 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[5].

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, instrument, 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 a first resort. Less drastic solutions can usually be found that will allow the use of the available AC power. Try switching to MDEV, for instance. If you are measuring stable sources with sufficient warmup time, you can attenuate line spurs by selecting the 5 Hz Measurement BW option in the acquisition dialog. As another alternative, consider the *Edit>Apply Notch Filter to Phase Data* <n> command.

2.3.3 Other Environmental Effects on Measurements

In Figure 2-10,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. In another instance, a breadboarded RF amplifier undergoing residual noise testing was affected by a WiFi access point, with interference appearing as an intermittent train of low-level impulses near 10 Hz. Try to keep all RF radiation sources, intentional and otherwise, well away from your testing area.

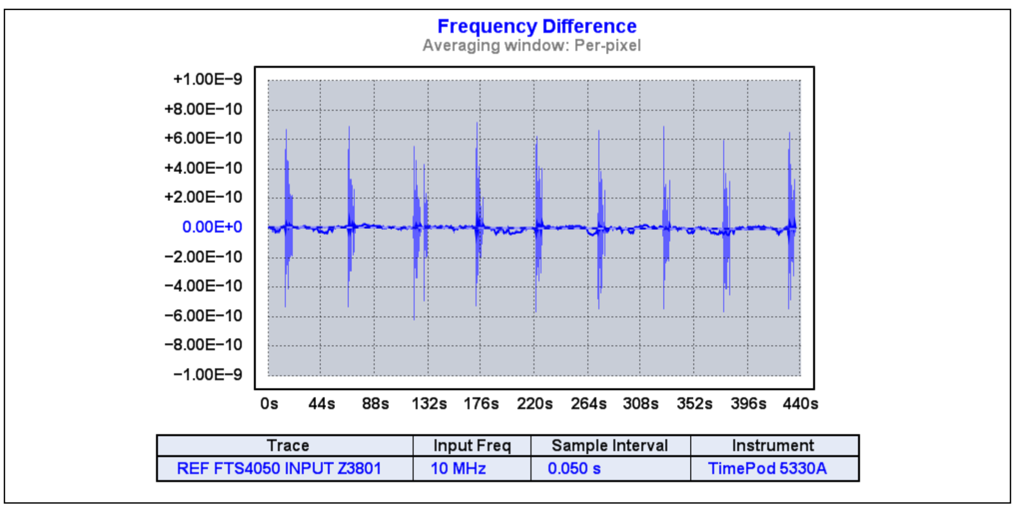


FIGURE 2-10: *Interference from Nearby Cellular Telephone.*

5: 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. Coaxial baluns turn loop antennas into dipole antennas.

2.3.4 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 direct-digital analyzers such as the 53100A Phase Noise Analyzer, crosstalk tends to appear when the signal frequencies at the input 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.

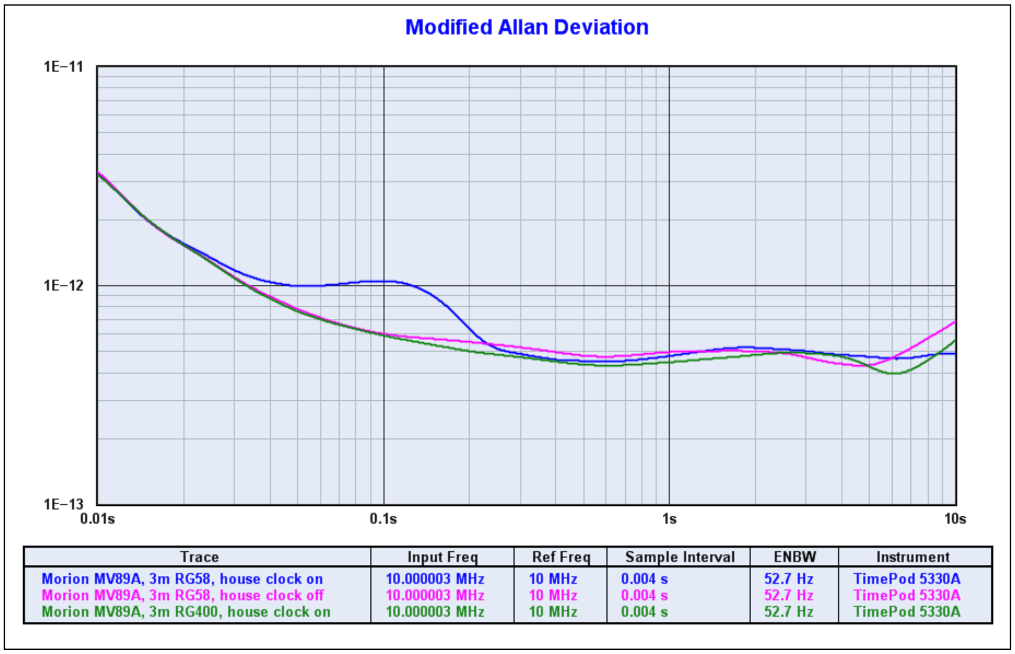


FIGURE 2-11: *Interference from External 10 MHz Source.*

Crosstalk can also occur when a third signal, incidental to the measurement environment, causes beatnote effects that are asynchronous to both test inputs.

Example: This case is illustrated in the plot above, where a 53100A 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 53100A's 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 53100A'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 these instruments is not born of excessive caution. Even plots acquired by conventional frequency and TI counters are vulnerable to crosstalk. With the widespread availability of GPS-

DOs and other inexpensive frequency standards, many facilities from international physics laboratories to ham shacks are equipped with 5 MHz and 10 MHz distribution networks. Don't use low-quality cables with high-performance instrumentation.

Note: Make it a habit to measure the end-to-end shield resistance of the coaxial cables that you use for time and frequency measurements, whether single- or double-shielded. Reject any that exceed a few tenths of an ohm.

2.4 HINTS FOR xDEV MEASUREMENTS

- The 53100A does not display its own measurement floor in the ADEV, MDEV, HDEV, TDEV, or MTIE 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 and the instrument noise floor in ADEV and other phase/frequency measurements. You may find it helpful to observe drift-prone sources or oscillator startup characteristics at 5 kHz or 50 kHz ENBW, but be aware that the stability noise floor will be somewhat 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 TimeLab to record several hours' worth of phase data at 500 Hz ENBW/1K points per second. Increasing the Output decimation value in the **Additional Options** dialog is a great way to reduce acquisition memory requirements, but it will not improve the xDEV noise floor.

Note: 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 TimeLab 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 TimeLab to render the xDEV trace as if much less data were available.
  In Figure 2-12, two copies of the same 3600-sample `.TIM` 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.

Note: 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, particularly those made at high data rates by instruments such as the 53100A.

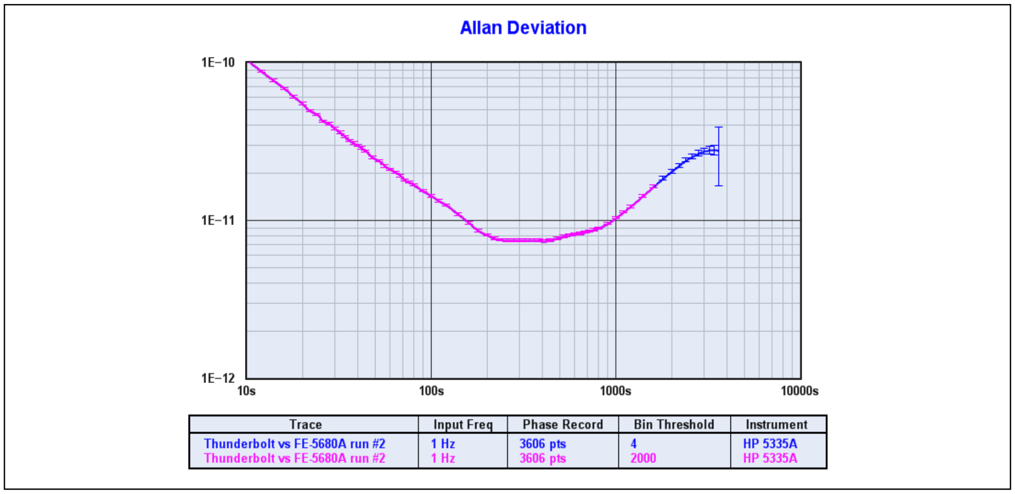


FIGURE 2-12: *Bin Threshold Adjustment.*

NOTES:

Chapter 3. Phase- and Frequency-Difference Traces

3.1 WORKING WITH PHASE- AND FREQUENCY-DIFFERENCE TRACES

Phase and frequency stability data acquired by TimeLab 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 TimeLab 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.

3.1.1 Phase Difference (Original) <w> Phase Difference (Unwrapped) <p>

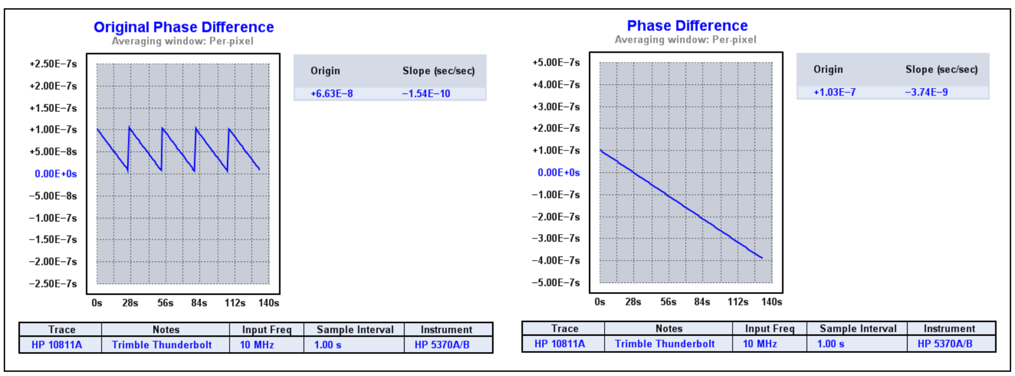


FIGURE 3-1: *Original Phase Data Received from TIC <w> Compared with Unwrapped View <p>.*

The distinction between these two measurement types is relevant when receiving time-interval data from a traditional counter, and not relevant when using the 53100A hardware. The Phase Difference (Original) <w> measurement shows the original TI samples as they arrive from the hardware. When acquired from a time interval 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 TimeLab.

Conversely, TimeLab'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.

Note:	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. When working with the 53100A and TimePod analyzers, the original and unwrapped phase difference displays are equivalent.

3.1.2 Frequency Difference <f>

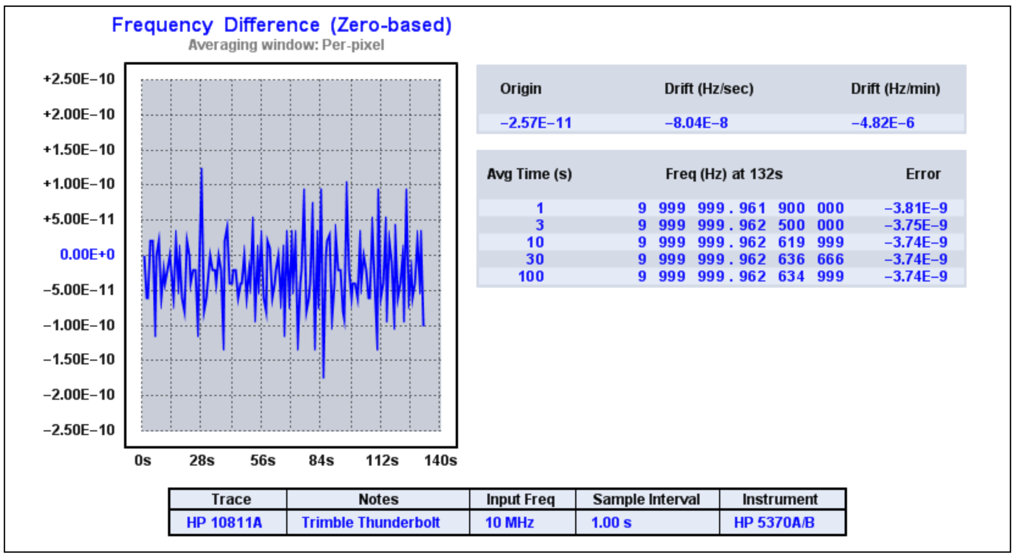


FIGURE 3-2: *Frequency Difference Measurement View with Count Chart.*

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>, TimeLab 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.

3.2 HOW DOES TIMELAB 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. Under most conditions this is the same value as the DUT frequency in the *Legend>Select* menu. If the measurement's DUT 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. All of these readings can be assumed to carry the same accuracy and precision.

When a time-interval counter (TIC) is used, however, TimeLab 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.

3.3 PHASE/FREQUENCY MEASUREMENTS WITH THE 53100A

On the 53100A, 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>Microchip 53100A* dialog allow you to specify the anticipated DUT and reference frequencies directly or measure them at a specified rounding precision. For more details, please see **Chapter 6. "53100A Measurement Roles"**.

3.4 EXAMINING TRACES IN DETAIL

Example: In Figure 3-3, a crystal oscillator was measured over a 12-hour period. The *Measurement>Phase Difference* <p> and *Measurement>Frequency Difference* <f> views appear side-by-side for comparison.

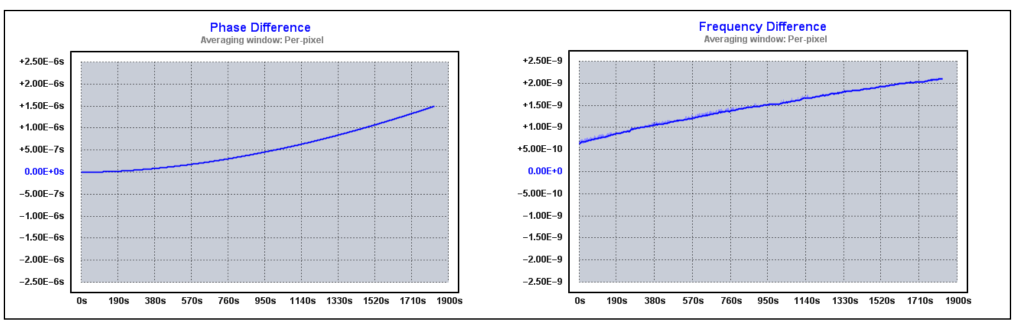


FIGURE 3-3: *Two Views of the Same Phase Data Record.*

Not much detail is visible in either trace. Some sporadic frequency jumps are present, but they're not easily examined because their height is such a small fraction of the plot's overall magnitude. 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.

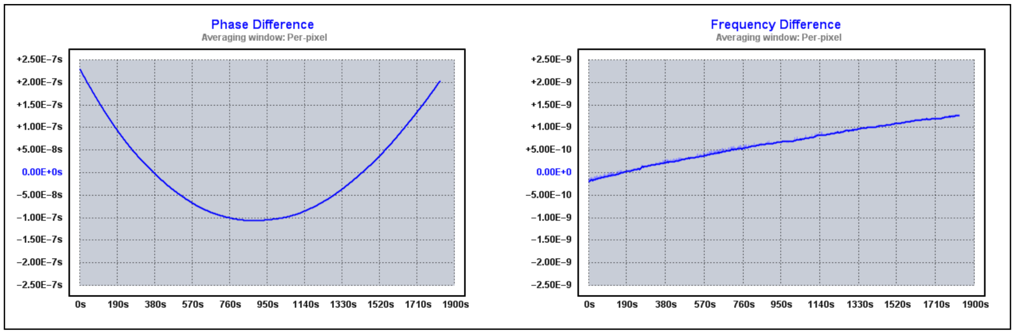


FIGURE 3-4: *Subtracting the Linear Phase Trend.*

In fact, one can achieve 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, Subtract Global Linear Phase Trend (frequency offset) <Ctrl-o> is not a commonly-needed command. At first glance, Subtract Global Linear Frequency Trend (drift line) <Ctrl-l> seems more useful.

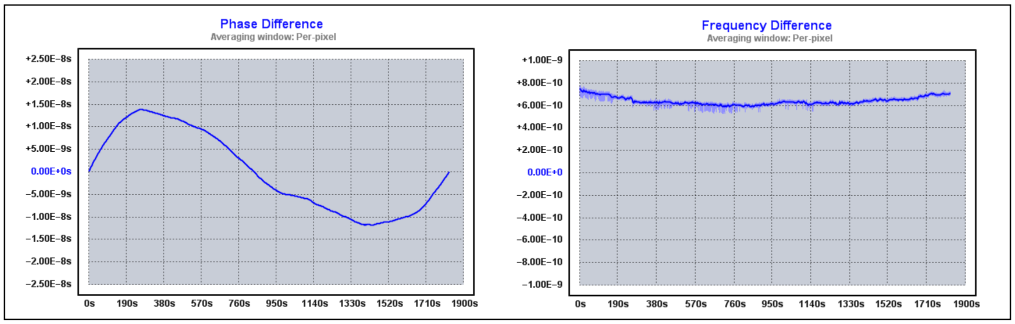


FIGURE 3-5: *Removal of Linear Frequency Drift.*

Essentially, 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.

Note 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.

3.5 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 the left, the result is the zoomed view at the right.

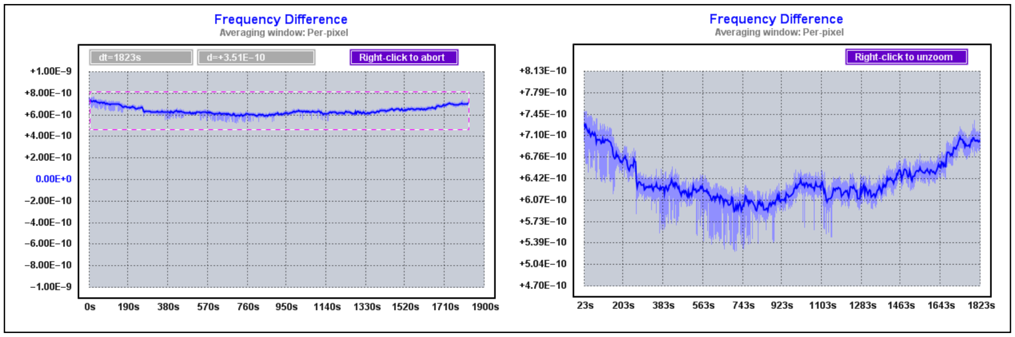


FIGURE 3-6: *Zooming In.*

TimeLab is designed to take full 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 navigate 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 TimeLab 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.

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. *Trace>Phase/Frequency Traces Begin at Zero* (z) offers a better alternative with a single keystroke.

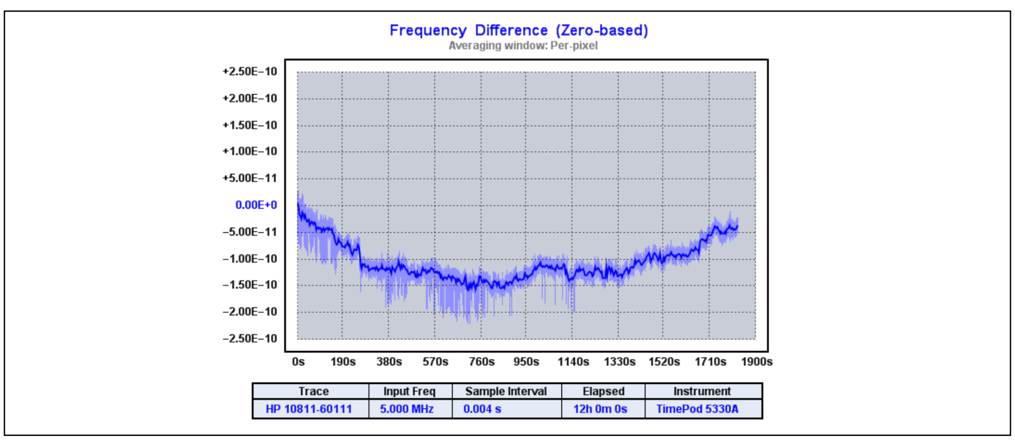


FIGURE 3-7: *The 'z' Zero Baseline Mode.*

To sum up, selecting *Measurement>Frequency Difference* <f>, applying Subtract Global Linear Frequency Trend (drift line) <Ctrl-l>, and enabling *Trace>Phase/Frequency Traces Begin at Zero* <z> can reveal details that 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.

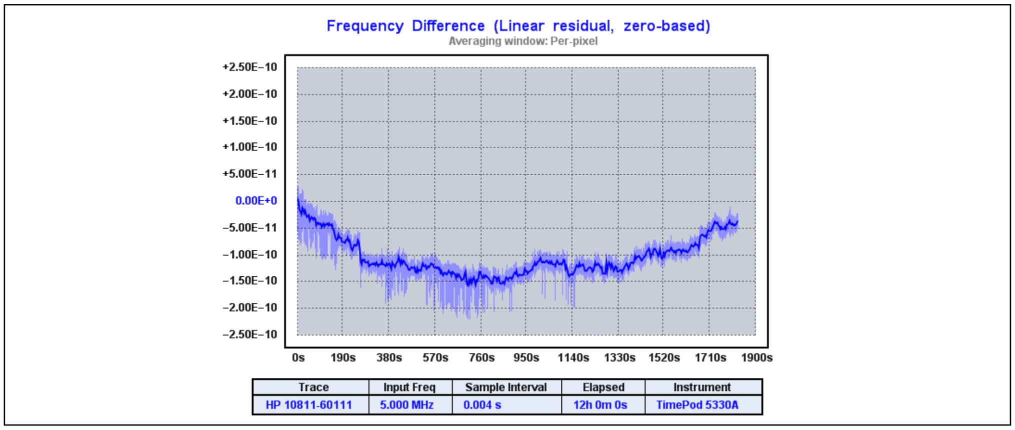


FIGURE 3-8: *Linear Residual Display.*

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[2]. Keep the <r> and <z> keys in mind while working with these traces, and experiment with them frequently.

3.6 HINTS FOR PHASE/FREQUENCY STABILITY MEASUREMENTS

- Due to slight variations in FPGA/USB interface temperature that occur when acquisition begins, the 53100A'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 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.
- 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 TimeLab with no menu-based equivalent.

2: 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 Subtract global linear frequency trend (drift line) (Ctrl-l) commands, and can be even better at revealing details in plots like this one.

- 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.

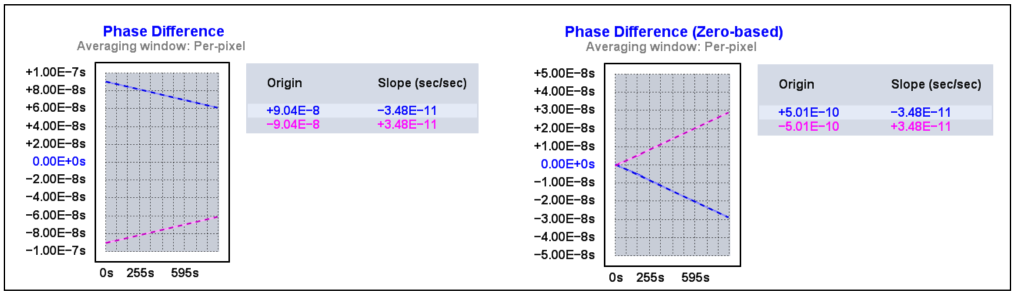


FIGURE 3-9: *Phase Inversion.*

NOTES:

Chapter 4. Phase Noise, AM Noise, and Jitter

Thanks to cross-spectrum averaging, the 53100A can measure exceptionally low levels of phase noise and AM noise on HF and VHF signals. Below are some guidelines to help you make the most of this capability.

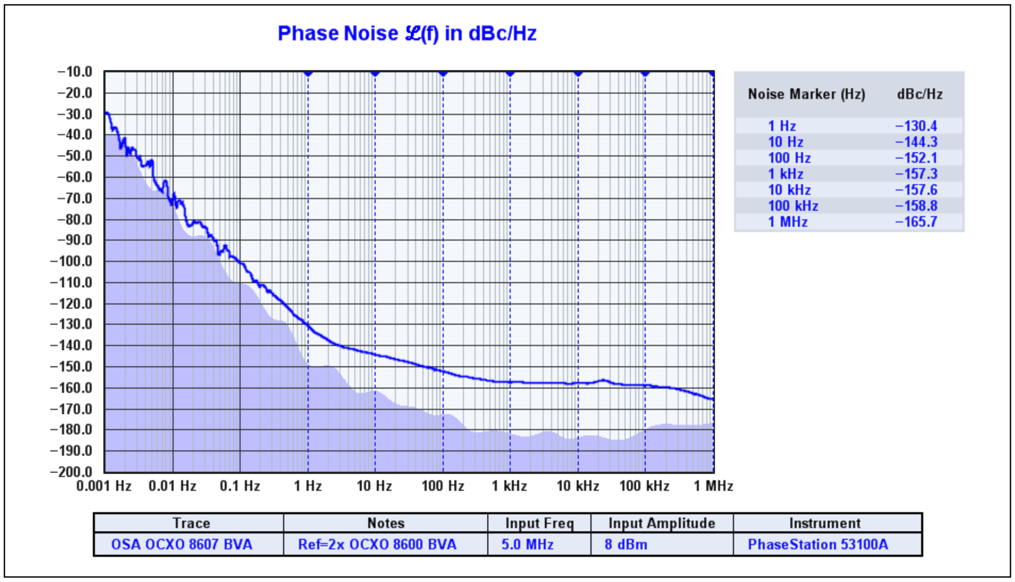


FIGURE 4-1: *Phase Noise Plot.*

4.1 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 fields in the *Legend>Select* menu:

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

When one or more of these parameters is enabled for display in the legend table, two spot cursors will appear in blue, as shown in Figure 4-2. You can move these lower and upper limit cursors with <Ctrl-left click> and <Ctrl-right click>, respectively.

To gain insight regarding the integrated jitter and noise distribution versus offset frequency, use *Display>Show integrated PN traces* in conjunction with one or more of the above parameter selections in the *Legend>Select* menu. Color-coded traces will be overlaid on the graph that corresponds to the integrated noise levels that would be reported if the lower limit of integration were moved right-to-left along the X axis, starting with the upper limit offset and progressing toward the user-specified lower limit cursor location.

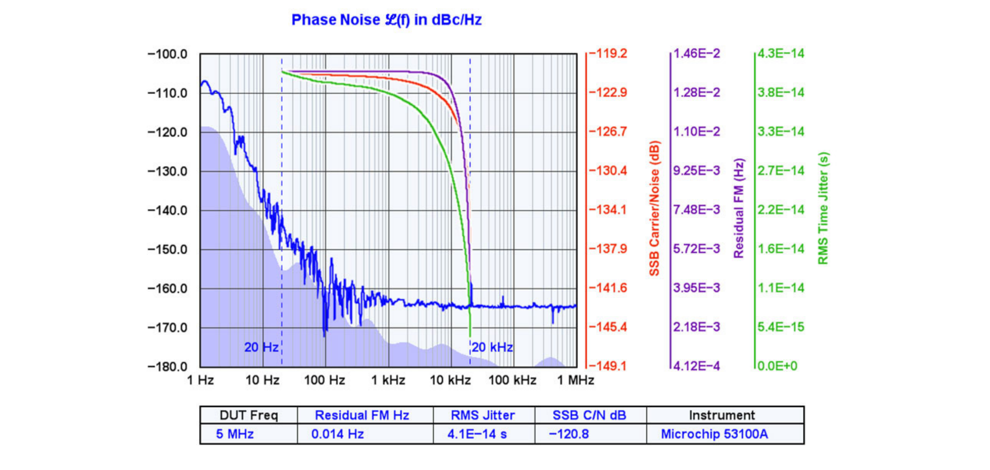


FIGURE 4-2: Measuring Jitter from 20 Hz to 20 kHz with RMS Noise Integration and Display>Show Integrated PN Traces.

Note:	TimeLab 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, MT-008: Converting Oscillator Phase Noise to Time Jitter from Analog Devices provides a concise summary of the math behind phase-noise integration.

4.2 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.

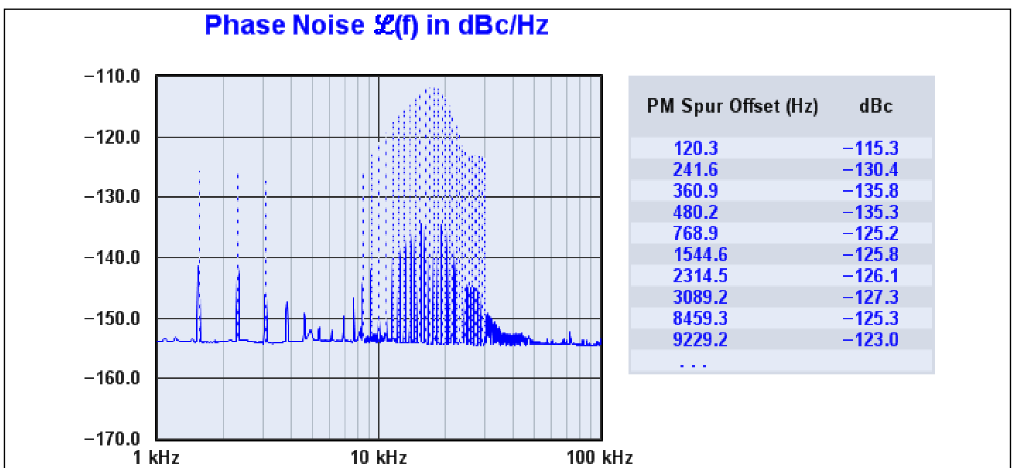


FIGURE 4-3: Typical Phase Noise Measurement with Accompanying Spur Table.

The default Spur Threshold value of 6 dB, specified in the **Additional Options** page of the 53100A 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 in the figure above, *Trace>Suppress Spurs in Noise Traces* <Ctrl-s> is disabled, and *Trace>Mark Spurs in Noise Traces* <Ctrl-m> is turned on.

4.3 SHOW OR HIDE KNOWN SPURS

Several commands in TimeLab 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 will not 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, TimeLab 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.

4.4 SPUR MEASUREMENT OPTIONS

The **Additional Options** page in the 53100A's acquisition dialog contains four controls that influence how spurs are recognized and recorded.

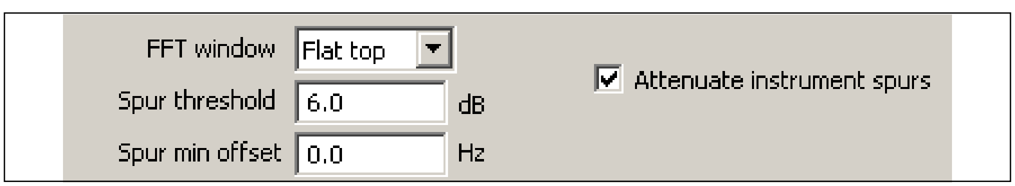


FIGURE 4-4: *Window and Spur Controls.*

- The choice of FFT Window implies a compromise between the accuracy at which a given spur's offset frequency and amplitude are reported. The default 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.
- The Spur threshold field defaults to 6.0 dB. It 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. Lowering the threshold to 3 dB can sometimes be helpful when tight mask-test requirements need to be met.

- Spur min offset is normally 0.0 Hz. It can be set prior to acquisition by entering an offset frequency below which spurs will not be logged for processing. The minimum spur offset can also be adjusted in the *Edit>Trace Properties* dialog at any time after acquisition is complete. This feature can be especially helpful when large bumps in the flicker noise region are incorrectly classified by TimeLab as either real spurs or instrument spurs. 1 Hz is a reasonable value to start with in these cases.
- When the **Attenuate instrument spurs** option is checked, the 53100A driver software will use the phase component of a given spur's peak FFT bin to attempt to classify it as an instrument artifact or a genuine result of the measurement. Instrument spur discrimination is enabled by default and discussed in detail below.

Additionally, note that both spur-identification performance and acquisition time will be affected if the **Edit Segment Table** button is used to change the FFT kernel sizes used in the individual noise-trace segments. While lower-resolution segment definitions can result in faster measurements, they can also cause large elevated regions to appear where "forests" of discrete spurs are too closely-spaced to resolve.

4.4.1 Identifying Spurs

Identifying genuine spurs while disregarding false ones is a difficult problem in the general case, and no spur-discrimination algorithm is infallible. The 53100A's DSP software may occasionally 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 in other parts of the trace where an obvious baseline is not clearly discernible.

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).

As mentioned above, you can also tell TimeLab to ignore spurs close to the carrier with the Min Spur Offset field in the *Edit>Trace Properties* dialog. This option can also be specified at acquisition time in the 53100A acquisition dialog's **Additional Options** page.

4.4.2 Understanding Instrument Spurs

While TimeLab 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 53100A 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 53100A's typical performance is much better than this. Any spurs with amplitudes above –120 dBc that remain visible as the measurement converges are likely to be 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 –130 dBc. There are simply too many potential sources of coherent artifacts to rule out in most cases. Still, spurs that originate within the 53100A can sometimes be identified manually. An informal technique that may help determine whether a given spur or spur cluster originates within the 53100A hardware itself is illustrated in the side-by-side plots in Figure 4-5.

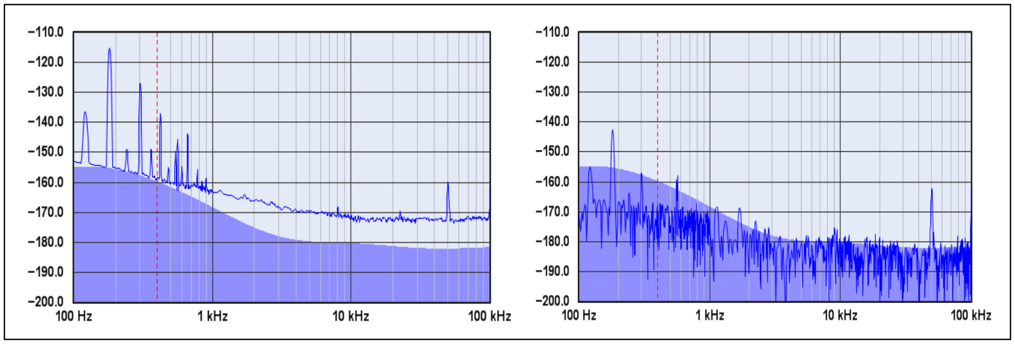


FIGURE 4-5: *Imaginary and Real Components of the Cross-Correlated Noise Spectrum.*

At the left, the phase noise of a crystal oscillator has been measured over the course of several hours. Most of the visible spurs are below the 53100A's specified limits, so it isn't clear which ones the instrument may be responsible for.

However, because complex signals are used throughout the 53100A's DSP pipeline, we can take advantage of a mathematical observation[1]. While the cross spectrum of a physically-realizable signal should fall on the real axis of the Argand plane, at least some instrument spurs are caused by data-conversion errors that can show up elsewhere in phase space. Like random ADC noise, the numerical distribution of these errors is not limited to the real axis; but unlike random noise, the real amplitude of some of these spurs may not average to zero over time. These spurs appear on the graph as instrument artifacts.

Switching to the *Trace>Show Imaginary Part of Cross Spectrum Display* <Ctrl-F3> view at right reveals the noise and spurs that correspond to the imaginary part of the cross-spectrum average, specifically the absolute value of the Q-component at each bin. Ordinarily this data is used only to create the shaded area used by the *Trace>Show Estimated Instrument Noise* <F2> feature, after undergoing heavy averaging. But <Ctrl-F3> lets us view the imaginary part of the cross spectrum at full resolution. It's readily apparent that the spur near 50 kHz has almost the same amplitude in the imaginary cross spectrum as it does in the real measurement.

This is a strong indicator that the spur is an instrument artifact. When **Attenuate Instrument Spurs** is selected in the 53100A Acquisition dialog, spurs with high imaginary amplitude components are removed from the plot regardless of the state of all other smoothing and spur-suppression options.

There are other spurs in the imaginary cross spectrum that correspond to similar spurs in the real plot, but most appear to be AC line harmonics that both the 53100A and the sources under test are exposed to, and their amplitudes are substantially different. Although the <Ctrl-F3> technique isn't foolproof, it can offer some valuable insight when you need to account for unanticipated low-level spurs.

Note 1: See Rubiola and Vernotte, The cross spectrum experimental method, and Grove *et al.*, Direct-digital phase noise measurement

4.4.3 Manual Spur Removal

As noted above, instrument spurs can be overlooked by the software for several reasons. They may be below the spur-detection amplitude, Fourier offset thresholds specified in the instrument's acquisition options dialog (where applicable), or they may be too low in amplitude to be recognized as a spur at all. At the same time, a spur that is recognized may not be correctly flagged and removed as an instrument spur if its phase lies close to the real axis.

These cases often resolve themselves if the measurement is allowed to run long enough for the SNR to improve. If not, the *Edit>Flatten selected noise region* <Ctrl-F8> command can help in particularly stubborn cases. For instance, when an unrecognized artifact must be removed in order to pass a mask test or when a trace with excessive noise variance needs to be cleaned up for publication. Refer to the *Edit>Flatten selected noise region* command description for more information.

4.5 USING NOISE MARKERS

To add up to 10 noise markers at specified offset frequencies, hold down the <Shift> key and left-click on the graticule area of the noise plot near the desired column. A marker will appear at the top of the graticule area. If the selected plot includes valid trace data at the specified offset frequency, a corresponding entry will appear in the noise marker table at right, displaying the offset frequency and noise power at that point in the trace.

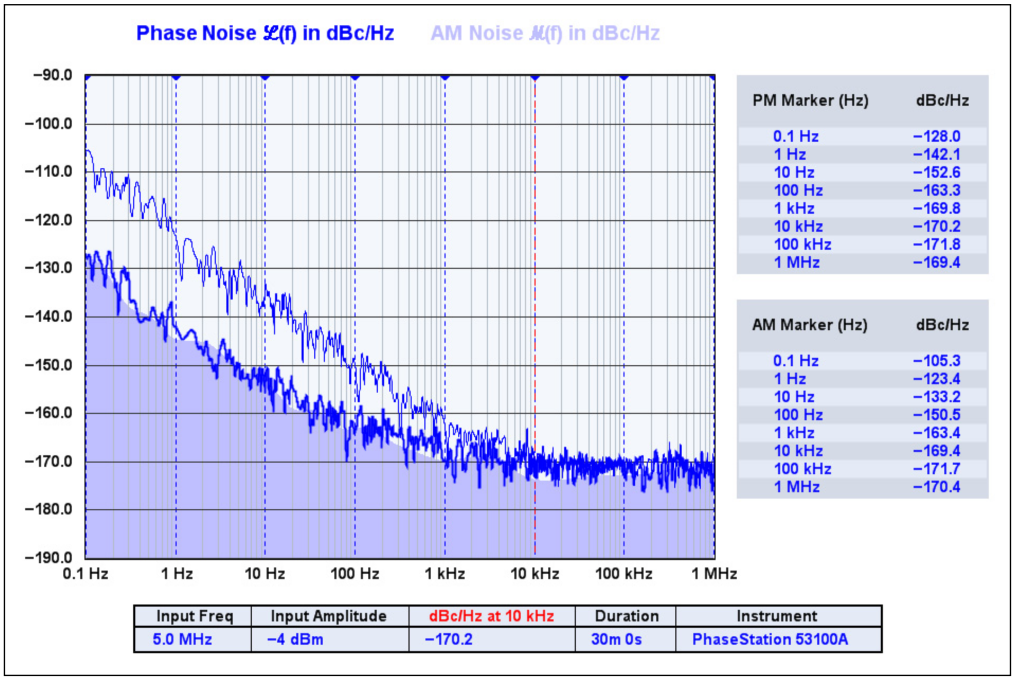


FIGURE 4-6: *Noise Markers.*

To remove an existing noise marker, simply <shift-left click> near the marker's column on the screen. All of the currently defined markers may be cleared with *Display>Clear Noise Markers* <Ctrl-F4>.

The visibility of the noise marker table can be toggled with *Display>Show Numeric Tables* <Ctrl-n>. If the noise marker table is not visible despite being enabled, ensure that at least one marker is placed at an offset that lies within the limits of the selected trace. Markers located at offsets where no trace data exists will be shown on the graticule, but will not appear in the table. When no noise markers are eligible for display, the table itself will not be rendered.

4.6 HINTS FOR NOISE MEASUREMENTS

- The 53100A can render an estimate of its own noise floor in AM/PM noise plots if you enable *Trace>Show Estimated Instrument Noise* <F2>. See **Section 5.3.14 "Show Imaginary Part of Cross Spectrum"** 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. See **Section 2.3.2 "Line-Related Spurs"** for a discussion of causes and cures.
- TimeLab has a graph-smoothing feature (*Trace>Smooth Noise Traces* <Ctrl-w>) but it's not always needed with a cross-correlating analyzer such as a 53100A Phase Noise Analyzer, TimePod, or Microchip 5120A/5125A. The best way to obtain a smoother trace with these instruments is often to let your measurement run longer. Low-noise 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 53100A users with faster PCs: enable the **Overlapped Acquisition** option in the **Additional Options** page of the acquisition dialog. Overlapped Acquisition provides much more efficient utilization of incoming data by the FFT routines, but requires significantly more CPU time. Note that FFT overlapping is different from the algorithm used in overlapped Allan deviation and other stability statistics. Overlapped statistical calculations are always performed, while overlapped FFT processing in noise data acquisitions is turned off by default.
- 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). *Trace>Smooth Noise Traces* <Ctrl-w> will automatically suppress spurs.

NOTES:

Chapter 5. TimeLab Command Reference

Virtually all of the menu-based commands in TimeLab also have single-key shortcuts for faster, more interactive workflow. When present, the shortcut key is generally shown after the name of the menu option.

5.1 FILE MENU

The File menu helps you work with data files and images. Supported actions include opening, saving, closing, and deleting plots stored in `.TIM` 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 on this menu.

5.1.1 Load .TIM File <l>

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

For frequency stability measurements made with counters or timing analyzers, the `.TIM` 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 `.TIM` file contains the FFT bin contents needed to render the applicable graphs.

5.1.2 Save Image or .TIM File <s>

This command can either save the selected plot as a `.TIM` file, or save the current contents of the TimeLab window as an image file in `.PNG`, `.GIF`, `.TGA`, `.PCX`, or `.BMP` format.

By default, `.TIM` 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 TimeLab. If a trace caption was either provided at acquisition time or added with *Edit>Trace Properties* <e>, it will be used as the default filename.

> **Note:** The `.PNG` format is best for saving images from TimeLab 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.

5.1.3 Copy Image to Clipboard <Ctrl-c>

This command offers a handy shortcut for cutting/pasting TimeLab 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.

5.1.4 Import .RES or .PNP Phase Noise Data <N>

This command can be used to import a `.RES` file created by the HP 3048A, an industry-standard phase noise analysis system, or a `.PNP` file saved by `pn.exe`, a popular freeware phase-noise measurement application from the KE5FX GPIB Toolkit.

The latter option supports phase noise plots from various RF spectrum analyzers not otherwise recognized by TimeLab.

5.1.5 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 TimeLab phase record, and may be rendered, manipulated, and saved as a `.TIM` file.

As with other acquisition dialogs, TimeLab'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.

5.1.6 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. When working with cross ADEV plots, both primary and secondary phase records may be exported, if required.

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 TimeLab, 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.

5.1.7 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 TimeLab, 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.

5.1.8 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 TimeLab.

5.1.9 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 TimeLab.

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. TimeLab will then continue to run normally.

> **Note:** Temporary files created by TimeLab are cleaned up when TimeLab exits, so it's advisable to leave TimeLab running until after the third-party analysis application has exited.

5.1.10 Export ASCII 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.

5.1.11 Export ASCII AM/PM Noise Trace Export ASCII Integrated PN Data

Available in the *Measurement>Phase Noise* <P> and *Measurement>AM noise* <A> views, the *File>Export ASCII AM/PM noise trace* 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. 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 because the data is obtained from the displayed graph. 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. If TimeMonitor headers have been enabled, the default suffix will be `.TXT` instead.

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.

File>Export ASCII integrated PN data operates in a similar fashion, but exports one or more integrated phase noise traces rather than the standard L(f) phase noise trace.

5.1.12 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.

See **Section 4.4 "Spur Measurement Options"** for more about spur detection and measurement.

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

5.1.13 Exported ASCII Files Include Headers for Microchip TimeMonitor

When enabled, this option causes text files written by Export ASCII xDEV Trace, Export ASCII AM/PM Noise Trace, Export ASCII Frequency Data, and Export ASCII Phase Data to be prefixed with a comment header that will be recognized by the Microchip TimeMonitor application.

The default filename suffix for exported ASCII files will be `.TXT` when this option is active, rather than `.CSV`. By default, this option is turned off.

5.1.14 Print Image

After displaying a standard dialog box for printer selection and configuration, this command prints the current contents of the TimeLab 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.

5.1.15 Scale File Dialogs by Window Size

When this option is enabled, common file dialogs in Windows XP will be centered in the TimeLab window and resized proportionally. In later Windows versions, the option has no effect. This function is disabled by default.

5.1.16 Confirmation Prompts Default to Yes

When this option is enabled, the default button in most confirmation prompt dialog boxes will be **Yes** rather than **No**. This function is disabled by default.

5.1.17 Limit MTIE Processing to 10K Points

When this option is enabled, MTIE calculations will stop after the first 10,000 points in the phase record have been processed. This helps avoid excessively long trace refresh periods when loading `.TIM` files or refreshing plots. This function is enabled by default.

5.1.18 Warn Before Exiting with Unsaved Plots

If enabled, this option causes TimeLab to prompt for confirmation before exiting if any plots have been acquired or edited but not saved. This function is enabled by default.

5.1.19 Warn Before Retriggering Measurement in Progress

If enabled, this option causes TimeLab to prompt for confirmation before acting on the *Acquire>Keep and Retrigger Selected Acquisition* <Ctrl-k> or *Acquire>Abort and Retrigger Selected Acquisition* <Ctrl-a> commands. This function is enabled by default.

5.1.20 Reset All Parameters, Options, and Settings at Next Startup

This option causes a dialog box to appear when you exit from TimeLab, 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 TimeLab and all of its instrument drivers will be deleted, forcing them to be recreated with default values when the program is relaunched. This function is disabled by default.

If desired, the `.INI` files used by TimeLab and its instrument drivers may be copied, backed up, or edited manually. The location of the directory where TimeLab stores its `.INI` files varies depending on the operating system version. In Windows 7, these files are normally located at `c:\Users\<user name>\AppData\Local\Miles Design\TimeLab`, also accessible at `%LOCALAPPDATA%\Miles Design\TimeLab`. In Windows XP, the `.INI` files are normally located in the hidden directory `c:\Documents and Settings\<user name>\Local Settings\Application Data\Miles Design\TimeLab`.

Note that TimeLab does not generally store configuration data in the Windows registry or anywhere else besides its `.INI` files; only installation-related data is stored in the registry.

5.1.21 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 `.TIM` 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.

5.1.22 Close All Visible Plots <Home>

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

5.1.23 Delete Selected Plot's .TIM File <Ctrl-Del>

After prompting for confirmation, this command unloads the selected plot's data from memory and also deletes its associated `.TIM` 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.

5.1.24 Quit <q or Esc>

Exits from TimeLab. 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, TimeLab 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 `TIMELAB.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 `TIMELAB.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 `TIMELAB.INI` at program termination, 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.

5.2 EDIT MENU

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

5.2.1 Trace Properties <e>

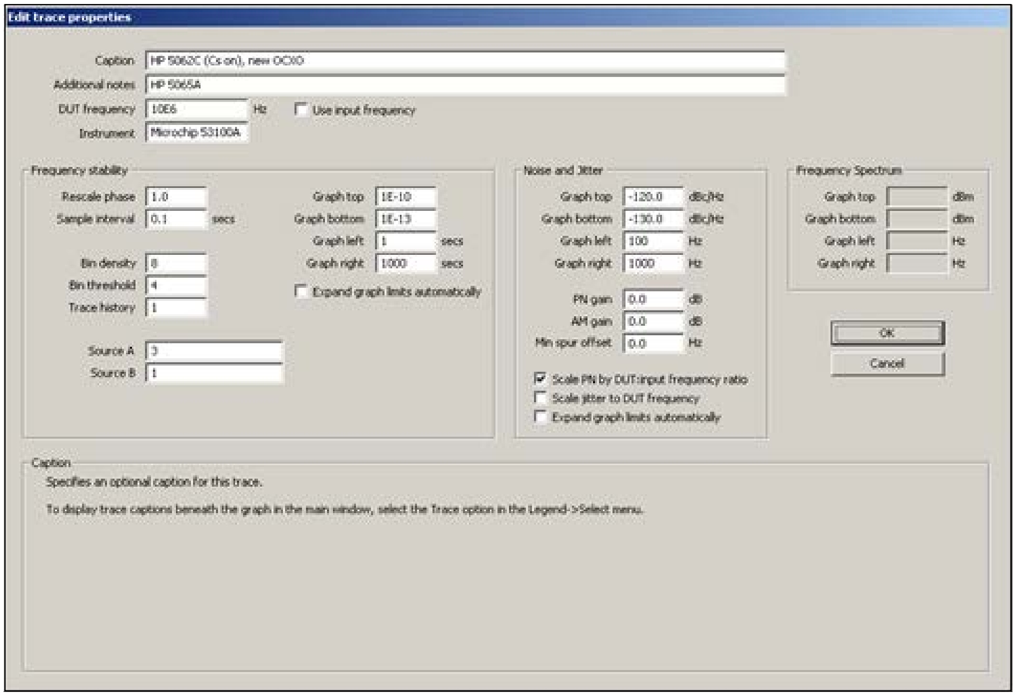


FIGURE 5-1: *Editing the Properties of the Selected Trace.*

As seen in Figure 5-1, 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 will typically vary from the image shown above. The dialog has extensive mouseover help text that is maintained alongside TimeLab 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, as well as on the status of particular dialog controls. Also, certain properties—including the controls 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.

5.2.2 Flatten Selected Noise Region <Ctrl-F8>

This feature allows you to remove known spurs and other artifacts from a phase noise or AM noise plot. It can be helpful in cases where the automated spur identification process falls short, such as when a PN or AM noise mask test is failing due to a low-level instrument artifact or a known external interference source.

Figure 5-2 shows a phase noise mask test that has failed with a –0.4 dB margin due to an unrecognized spur at an offset near 25 Hz. This spur is too close to the surrounding noise to be flagged and suppressed by TimeLab, either as a real spur or an instrument artifact, but it’s strong enough to exceed the limit line and cause a test failure. Pressing <Ctrl-F3> (*Trace>Show imaginary part of cross spectrum*) reveals that the spur is a low-level instrument artifact. It is not only visible in the imaginary part of the cross spectrum, but its amplitude is actually stronger there. This spur is a good candidate for manual removal.

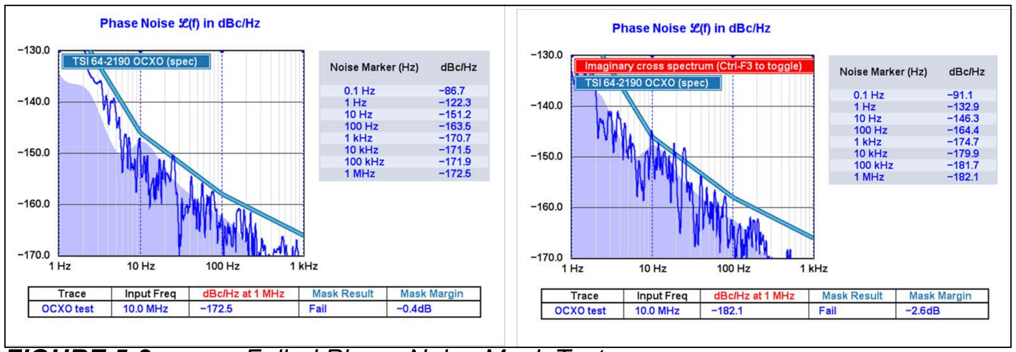


FIGURE 5-2: *Failed Phase Noise Mask Test.*

Figure 5-3 illustrates the workflow: after switching back to the real cross spectrum with <Ctrl-F3> and pressing <F2> to hide the noise-floor estimate for better visibility (*Trace>Show estimated instrument noise*), simply drag a box to zoom in on a portion of the plot containing the base of the spur in question. Then, hold down the <Shift> key and left-drag to create a flat line segment that spans the area to be flattened. Choose endpoints that will blend effectively with the areas of the trace to be retained.

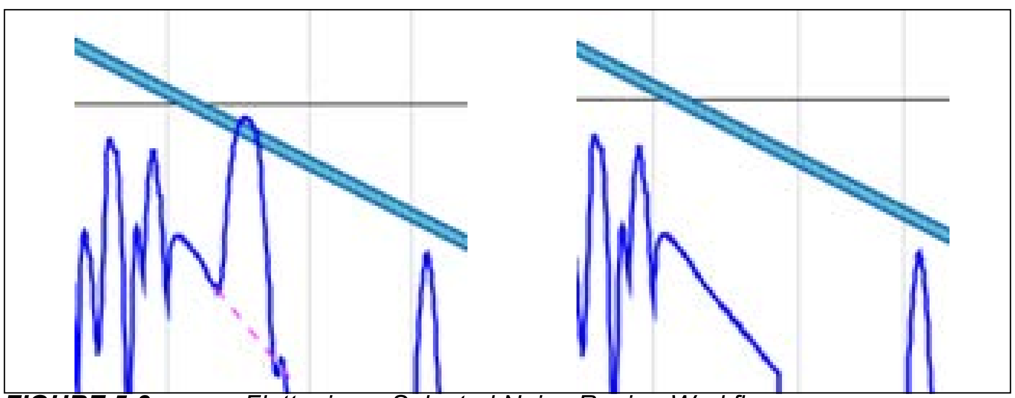


FIGURE 5-3: *Flattening a Selected Noise Region Workflow.*

Once the segment has been drawn in the desired location, use <Ctrl-F8> (*Edit>Flatten selected noise region*) to create a trace segment between the specified endpoints. Right-click anywhere in the window to zoom back out and observe that the mask test now passes, as shown in Figure 5-4.

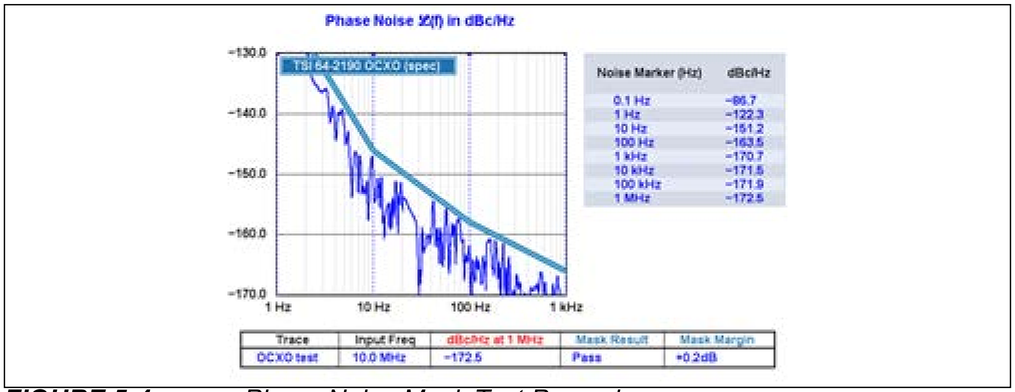


FIGURE 5-4: Phase Noise Mask Test Passed.

Internally, this command works by allocating an instrument spur record in the specified location. Up to 300 regions may be flattened, less the total number of real and instrument spurs in the measurement.

<Ctrl-z> (*Edit>Undo last flatten or subtract operation*) may be used to restore the most recently flattened noise segment, while <Ctrl-F9> (*Edit>Restore flattened noise regions*) will restore all manually flattened segments.

5.2.3 Restore Flattened Noise Regions <Ctrl-F9>

This command clears all flattened regions previously defined with *Edit>Flatten selected noise region* <Ctrl-F8>, restoring any manually removed spurs. It cannot be undone.

5.2.4 Flatten Selected or Zoomed Phase Data <Ctrl-f>

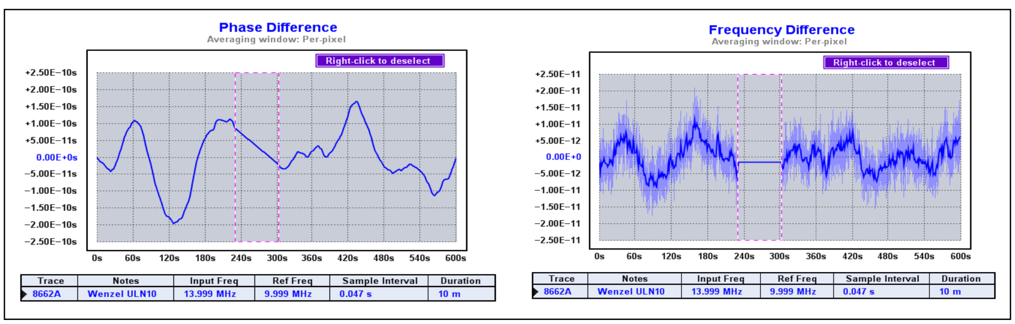


FIGURE 5-5: Flattening a Section of Phase Data.

Above, the Flatten Selected or Zoomed Phase Data <Ctrl-f> command has been used to replace the selected region of the phase record with a straight line. The result appears as a flat spot in the Frequency Difference 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 figure 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.

If the selected plot has any background tasks in progress when any of these commands are issued, an error message will be displayed. 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 `.TIM` 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.

5.2.5 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 `.TIM` 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. TimeLab 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 `.TIM` 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.

When the phase record associated with a cross ADEV measurement's primary or secondary plot is being altered by this command, the same region of data will automatically be removed from both of the phase records. See **Section 6.7 "Measure Single DUT with Cross ADEV Statistics"** 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.

5.2.6 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 **Section 3.4 "Examining Traces in Detail"**.

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 **Section 5.3 “Trace Menu”** 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.

Note that subtracting trends from data records that exhibit a large amount of variance relative to their overall slope—such as might be obtained from comparisons of GPSDO or atomic standards—can result in numerically unstable outcomes that vary randomly based on the number of points in the data record. You may wish to toggle the subtraction operation with *Edit>Undo Last Flatten or Subtract Operation* <Ctrl-z> to verify that the command performed as expected.

5.2.7 Apply Notch Filter to Phase Data <Ctrl-n>

This command applies a biquad notch filter with the specified center frequency and Q parameters to the phase data record. It is typically used to attenuate unwanted tonal artifacts such as crosstalk and AC line interference. The filter has no effect on phase noise or AM noise data.

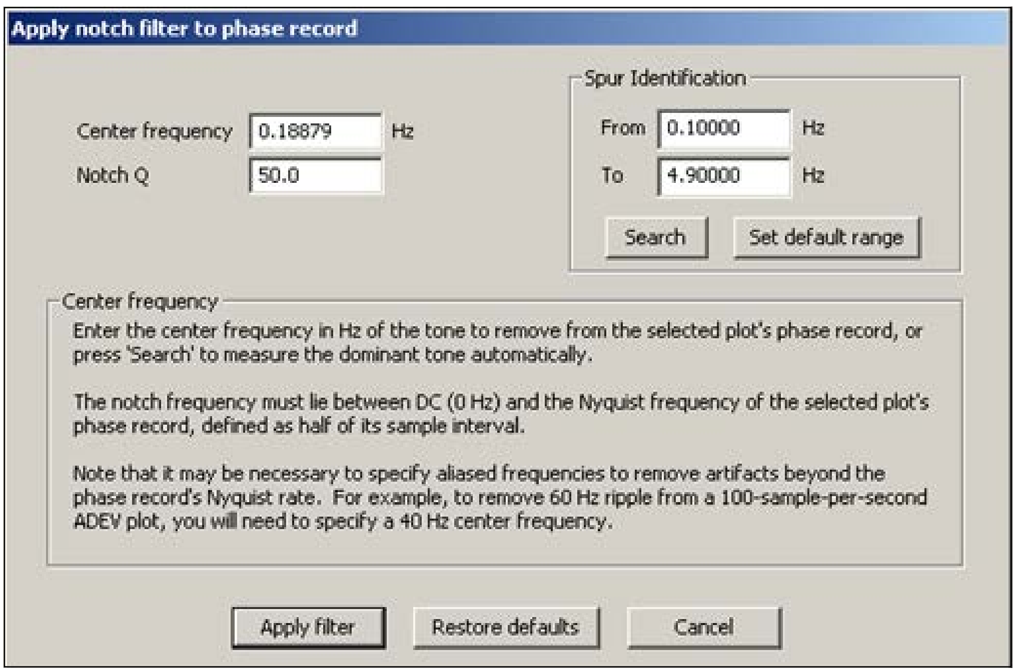


FIGURE 5-6: *Notch Filter Properties.*

In the dialog box above, the desired center frequency and Q should be entered in the fields indicated.

The **Search** button can optionally be used to identify the dominant tone within the specified frequency range and copy it to the Center Frequency field. When the Set default range button is clicked, the Frequency Range controls are prefilled with values based on the DC and Nyquist band limits for the selected plot’s phase record, leaving 2% margins at either endpoint. Tone frequencies lying outside this range can be entered manually into the Center Frequency field. Alternatively, the From/To fields can be adjusted manually to constrain the spur search within the desired limits.

When working with direct-digital test sets such as the 53100A Phase Noise Analyzer, line-frequency ripple can be particularly troublesome in ADEV plots captured at these instruments’ default measurement bandwidth of 50 Hz. Because decimation to the specified ENBW occurs prior to phase detection at twice the final sample rate, or

200 Hz, any content at 60 Hz will appear as an alias at 40 Hz in the final 100 Hz phase data record. This frequency, rather than 60 Hz, should be entered in the Center Frequency field in order to suppress fundamental interference from ground loops in countries that utilize North American power distribution standards.

Note that AC line-frequency interference in 50 Hz environments may appear as long-term artifact(s) with a period close to DC. If this is suspected, consider using the 5 Hz or 500 Hz measurement bandwidths instead. The former setting will eliminate most AC line interference adequately, while the latter setting will allow it to be removed with the notch filter.

The effect of the notch filter can be reverted with the Undo Last Flatten or Subtract Operation <Ctrl-z> command.

5.2.8 Undo Last Flatten or Subtract Operation <Ctrl-z>

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

- *Edit>Flatten Selected Noise Region* <Ctrl-F8>
- *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)
- *Edit>Apply Notch Filter to Phase Record* <Ctrl-n>

A second undo command will redo the last-reverted action in all cases except for flattening operations in AM noise or phase noise plots. These commands must be reissued manually.

If the selected plot has any background tasks in progress when this command is issued, an error message will be displayed.

5.3 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 menu 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.

5.3.1 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. Because auto-scaled Y axes in TimeLab are symmetrical about zero, this may allow the trace to occupy more of the visible graph area:

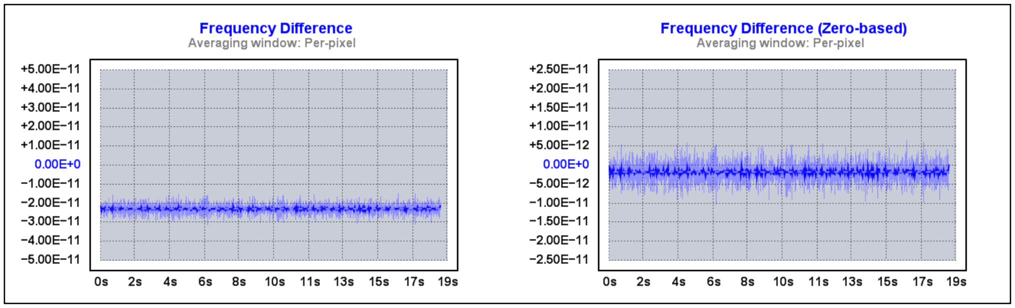


FIGURE 5-7: *Toggling the Zero-Baseline View <z>.*

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 in Figure 5-8.

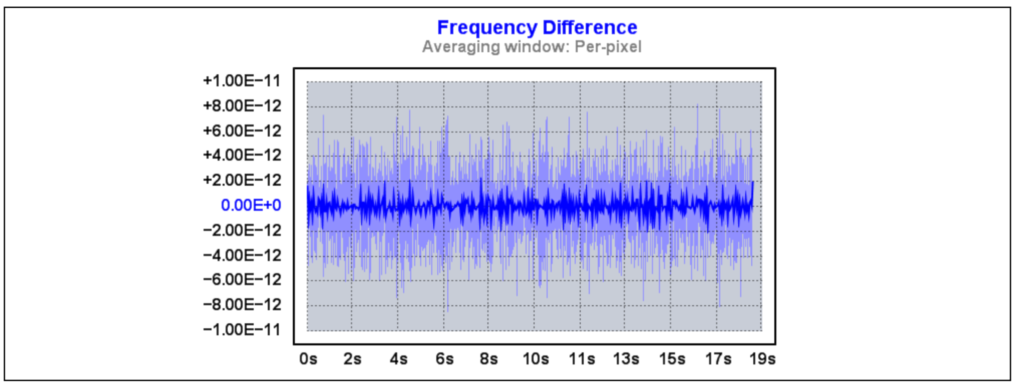


FIGURE 5-8: *Linear Trend Subtracted from the Phase Data.*

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>.

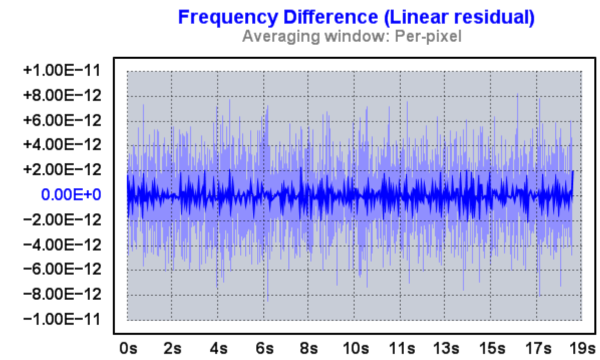


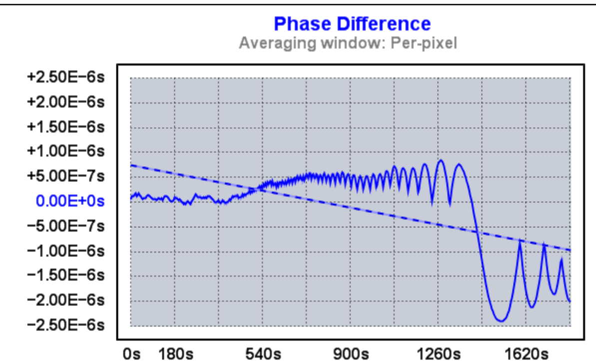
FIGURE 5-9: *Viewing the Removed Trend without Altering the Data.*

> **Note:** 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 in **Section 3.4 "Examining Traces in Detail"**.

Note that although only one Phase/Frequency Traces Begin at Zero <z> option appears on the Trace menu, Timelab maintains separate copies of the associated preference variable that retain the last change made in each of the respective views.

5.3.2 Show Linear Phase/Frequency Trend <Ctrl-t>

When enabled, this option causes TimeLab 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

FIGURE 5-10: *Viewing the Trend Line.*

The trend line is not displayed in magnified views, or when *Trace>Show Linear Phase/Frequency Residual* <r> is enabled.

Use caution when interpreting drift figures derived from linear or quadratic trends. Measurement traces that exhibit a large amount of variance relative to their overall slope, such as might be obtained from comparisons of GPSDO or atomic standards, can result in numerically unstable solutions that vary randomly based on the number of points in the data record.

5.3.3 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 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-auto-scaling 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 scroll the zoomed region in both the X and Y directions.

You can enable Y-axis auto-scaling 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 auto-scaling, and again to restore 2D navigation with the middle button, scroll wheel, or <[> <]> <{> <}> shortcuts.

5.3.4 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 up to 10000 seconds in length 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.

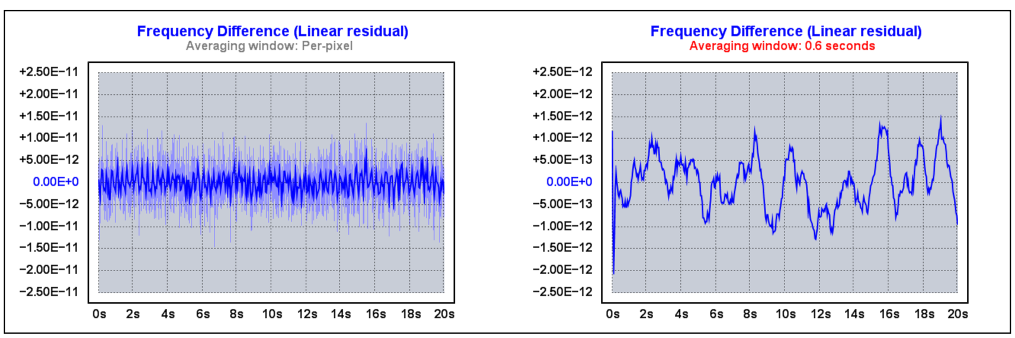


FIGURE 5-11: *Per-Pixel and Time-Based Averaging.*

As a reminder that averaging is a visual effect, non-zero 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, TimeLab 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 pixel column. Consequently 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.

5.3.5 Draw xDEV Traces with Spline Interpolation <i>

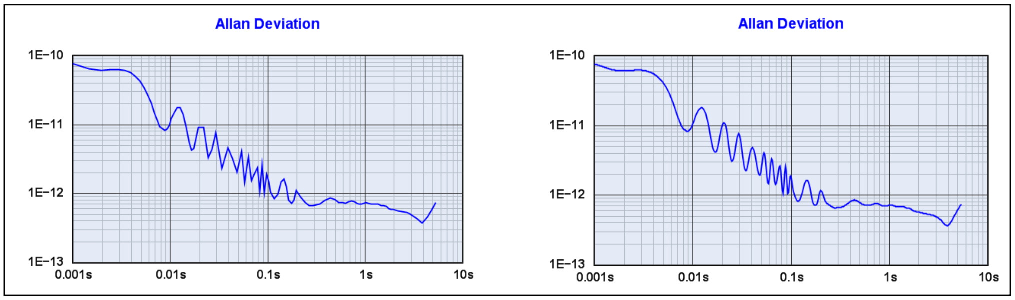


FIGURE 5-12: *Spline Interpolation.*

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 shift data points subtly, distort or exaggerate ringing artifacts, and cause 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 (above left).

Note:	Spline interpolation is not available when displaying MTIE plots, and should be used with particular care when viewing cross Allan deviation plots that have not yet fully converged to a continuous trace.

5.3.6 Show xDEV Error Bars <Ctrl-e>

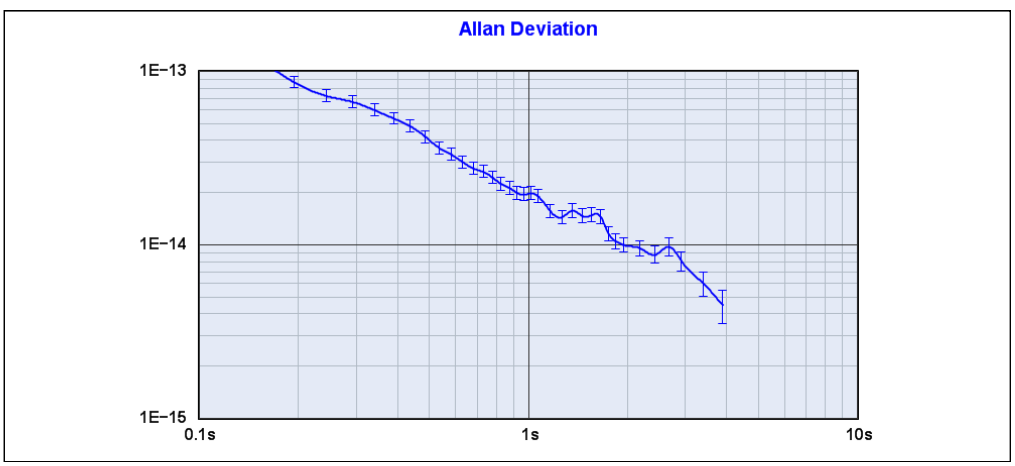


FIGURE 5-13: *Allan Deviation Error Bars.*

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 if your application requires better confidence-interval estimates.

5.3.7 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, because the data has been band-limited at a cutoff frequency below its Nyquist rate.

A discussion of this effect appears in **Section 2.3.1 "Measurement Bandwidth and τ0"**.

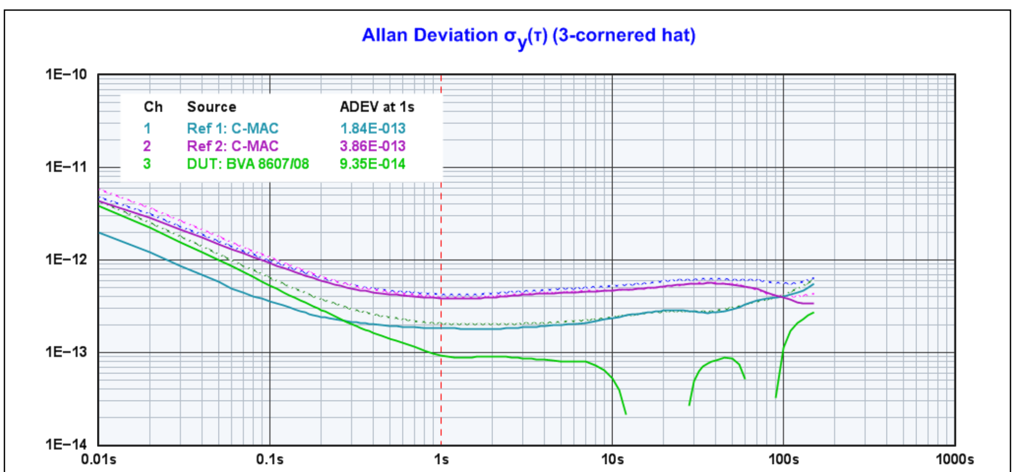
5.3.8 Clip xDEV Traces by Confidence <Ctrl-v>

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).

5.3.9 Show Separated xDEV Variances (N-Cornered Hat) when Available <Ctrl-h>

This display option provides an alternative way to view Allan deviation and other statistical traces. Under appropriate conditions, it can reveal aspects of oscillator performance that would otherwise be inaccessible in a conventional measurement with a single reference source.



Input Freq	ADEV at 1s	Duration	Instrument	Source A	Source B	Stability Ch
10.0 MHz	4.28E−13	10m 0s	PhaseStation 53100A	Ref 1: C-MAC	Ref 2: C-MAC	1-2
10.0 MHz	3.97E−13	10m 0s	PhaseStation 53100A	Ref 2: C-MAC	DUT: BVA 8607/08	2-3
5.0 MHz	2.06E−13	10m 0s	PhaseStation 53100A	DUT: BVA 8607/08	Ref 1: C-MAC	3-1

FIGURE 5-14: *Three-Cornered Hat Display.*

When the N-cornered hat view is enabled in the N=3 case as shown above, TimeLab will attempt to isolate and display the individual contribution of each of three devices to a set of three stability measurements. Although an in-depth discussion of this technique is outside the scope of this document, AppNote AN3526 (Dual-Reference Noise and Stability Measurements with the 53100A) presents a detailed case study in which the three-cornered hat methodology is used to provide mutual assessments of high-performance crystal oscillators.

Please refer to this application note for more information.

When viewing three-cornered hat traces, it is strongly recommended that only the three participating measurements are enabled for display. All other plots should either be cleared with *File>Close Selected Plot* <Del> or marked invisible with *Display>Toggle Visibility of Selected Plot* <v>.

To configure the 53100A for three-cornered hat measurements, see **Section 6.6 "Measure Three Independent DUTs (Three-Cornered Hat)"**. Note that four-cornered hat plots are supported by TimeLab, but require six concurrent measurements rather than three. Consequently, they cannot be acquired simultaneously by the 53100A due to its limitation of four concurrent plots.

Cross Allan deviation measurements are often preferable to the three-cornered hat methodology, particularly when the goal of the measurement is to gather data for only one DUT. See **Section 6.9 "Cross Allan Deviation Measurements"** for more information.

5.3.10 Show Cross ADEV Traces when Available <Ctrl-j>

Cross Allan deviation measurements take advantage of all four instrument input channels, potentially enhancing the short-term ADEV measurement floor by an order of magnitude. On the 53100A, these measurements are performed when the DUT and reference sources are routed to both of their respective front-panel input jack pairs with internal or external splitters and the **Measure single DUT with cross ADEV statistics** measurement role is selected.

Cross ADEV measurements are also performed by default with the dual-reference measurement roles, and by manually configured measurements that assign individual stability reference channels to DUT channels 3 and 4. If this option is toggled off, cross ADEV plots will be rendered as conventional ADEV measurements when the Allan deviation measurement view is selected with the <a> hotkey. Only the primary phase record from channels 3-1 will contribute to the display, and measurement performance enhancements associated with cross ADEV processing will be unavailable.

For more information about cross ADEV measurements with the 53100A, see **Section 6.7 "Measure Single DUT with Cross ADEV Statistics"**.

5.3.11 Show Original Traces in Computed xDEV Displays <F6>

This option can be used to show or hide the original xDEV traces that contribute to an N-cornered hat display, as seen in the example above.

Alternatively, when cross ADEV measurements are in use, this command determines whether the standard ADEV traces for the primary and secondary phase records are displayed alongside the primary trace that represents the cross ADEV solution. To avoid confusion, these traces are always rendered with a broken (dashed) line style. They can be hidden with <F6> or by simply toggling the entire plot's visibility with the **<v>** hot key.

5.3.12 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 53100A 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 5 * $\log_{10}$(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.

5.3.13 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 the 53100A Phase Noise Analyzer.

When acquiring noise plots on the 53100A, data for each visible FFT segment undergoes highpass and/or lowpass filtering based on the declarations in the segment table, accessible via the Additional options page in the 53100A 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 **Additional Options** button in the 53100A Acquisition dialog, followed by **Edit Segments**.

Most users will not need to edit the segment table.

5.3.14 Show Imaginary Part of Cross Spectrum

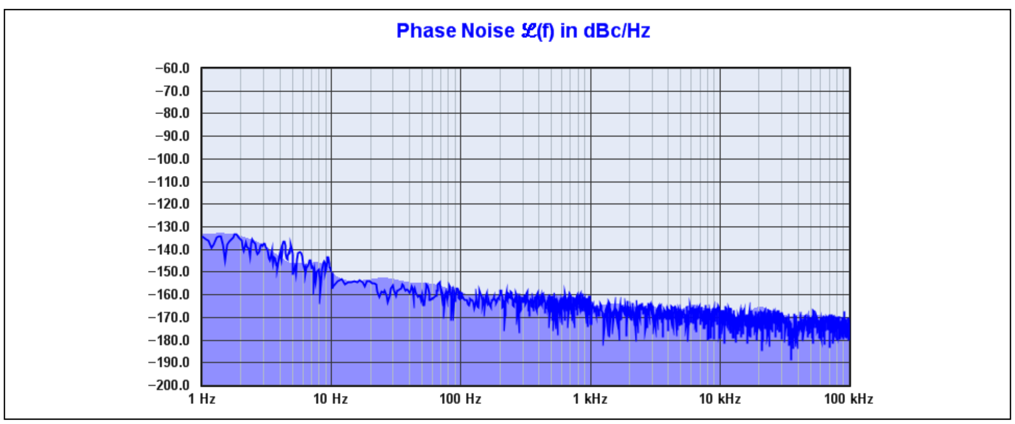


FIGURE 5-15: *Shaded Noise Floor Estimate.*

Phase noise and AM noise plots acquired with the 53100A, TimePod 5330A, and Microchip 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 53100A’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 **Section 4.4.2 “Understanding Instrument Spurs”**.

Use caution when relying on the noise floor estimate. While reasonably accurate, it may appear artificially high in the vicinity of instrument spurs. Conversely, certain 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 ASCII AM/PM Noise Trace* command will export the imaginary cross spectrum trace data rather than the normal AM noise or phase noise trace.

5.3.15 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 **Section 4.2 “The Spur Table”**.

5.3.16 Smooth Noise Traces <Ctrl-w>

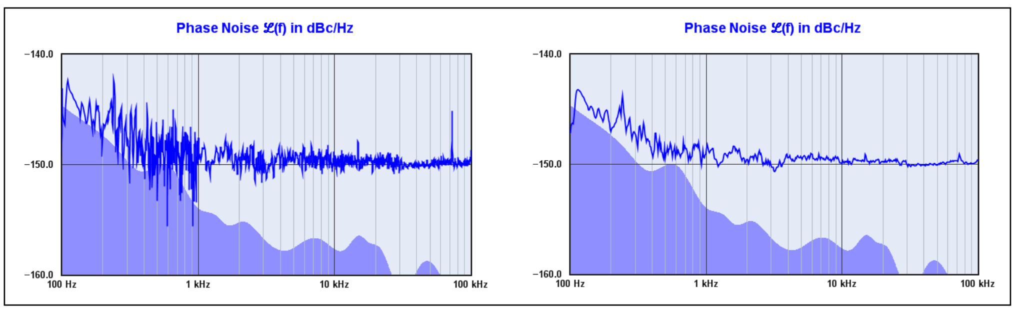


FIGURE 5-16: *Trace Smoothing.*

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 53100A, 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.”

5.3.17 Show Raw Noise Trace(s) <Ctrl-r>

This command displays the raw phase noise or AM noise spectrum from the ADCs in both measurement channels of the 53100A.

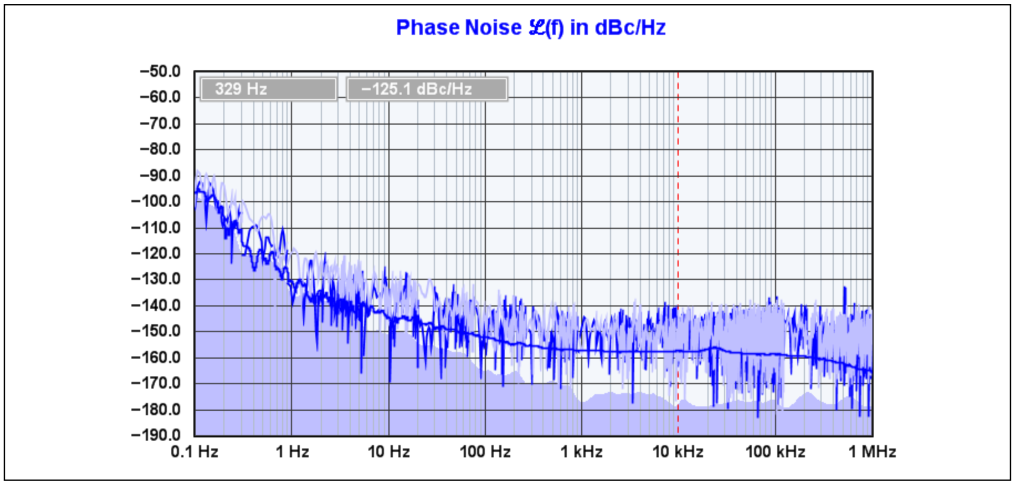


FIGURE 5-17: *Viewing the Raw ADC Noise Traces.*

Note that while the Trace menu option shows the raw ADC data traces alongside the actual measurement traces, the <Ctrl-r> keyboard shortcut cycles between measurement-only, measurement and raw, and raw-only displays.

Although intended primarily for instrument diagnostic purposes, the appearance of the raw trace can sometimes be helpful in tracking down intermittent problems in the DUT or reference source associated with one of the two channel pairs. The darker trace corresponds to the first DUT/noise reference channel pair, while the lighter trace corresponds to the second pair of inputs. Watching for “jumpy” behavior in the light trace, the dark trace, or both can help identify issues that don’t appear in the relatively low-bandwidth stability measurements.

5.3.18 Show AM Noise in PN View <F8>

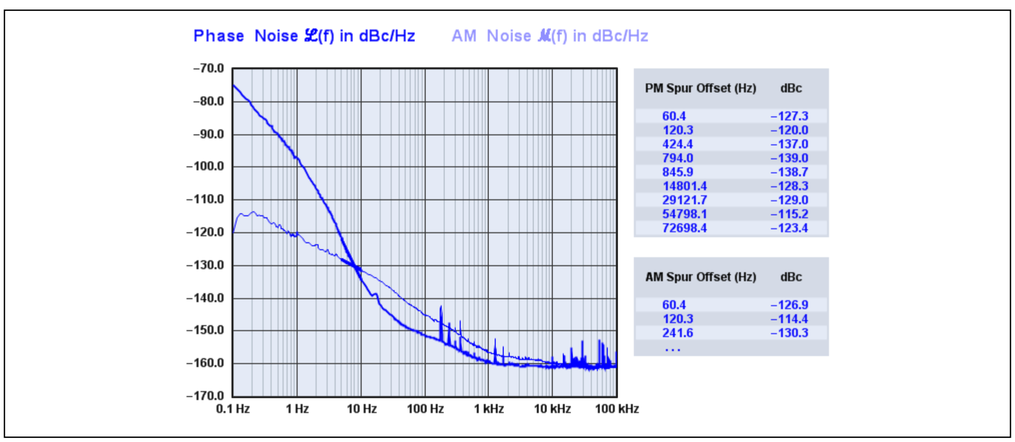


FIGURE 5-18: *Overlaying the AM and PM Noise Traces.*

When enabled, this command renders a copy of the AM noise trace in the *<u>Measurement>Phase Noise</u>* <P> view, using a lighter color or trace weight. Both PM and AM spur tables are displayed, space permitting.

5.3.19 Tick Marks <k>

This command toggles tick marks on and off, as shown below.

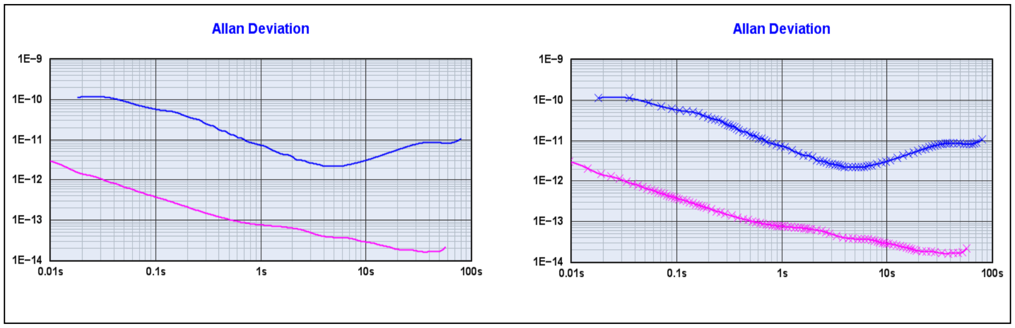


FIGURE 5-19: *Tick Marks.*

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, TimeLab'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.

5.3.20 Toggle Trace Thickness for Current Measurement <T>

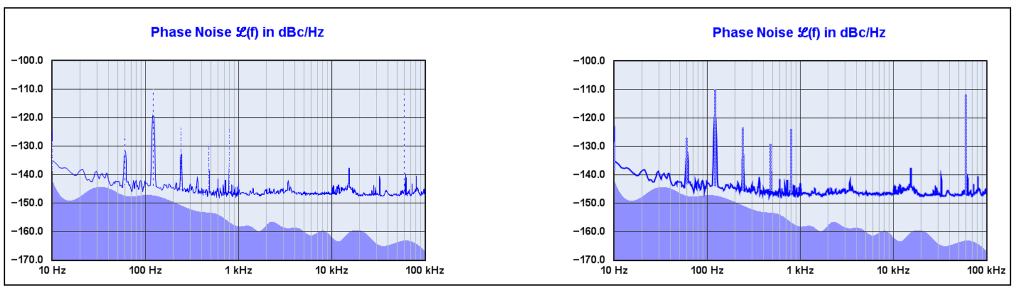


FIGURE 5-20: *Trace Thickness Options.*

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

In N-cornered hat displays, the trace thickness property controls the appearance of the original xDEV traces that contribute to the solution. Heavy traces are rendered with thin lines in this case, while light traces are rendered with broken lines.

5.4 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.

5.4.1 Edit Colors

This command leads to a second-level menu offering a choice of various graphical elements in the TimeLab 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 TimeLab window is updated in real time, making the color-selection process interactive and easy to use.

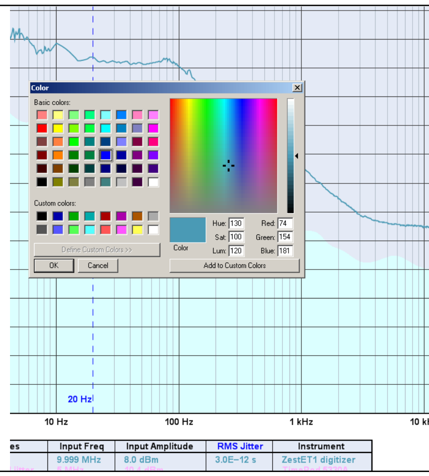


FIGURE 5-21: *The Color Palette Editor.*

5.4.2 Edit Selected Trace Color <E>

This command provides convenient access to the trace color options in the *Display>Edit Colors* submenu.

5.4.3 Restore Default Colors

This command restores the default color palette without resetting any other preferences or control states.

5.4.4 Restore Selected Trace Color

This command restores the default color for the selected trace without resetting any other colors, preferences, or control states.

5.4.5 High Contrast <c>

This command toggles the display 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.

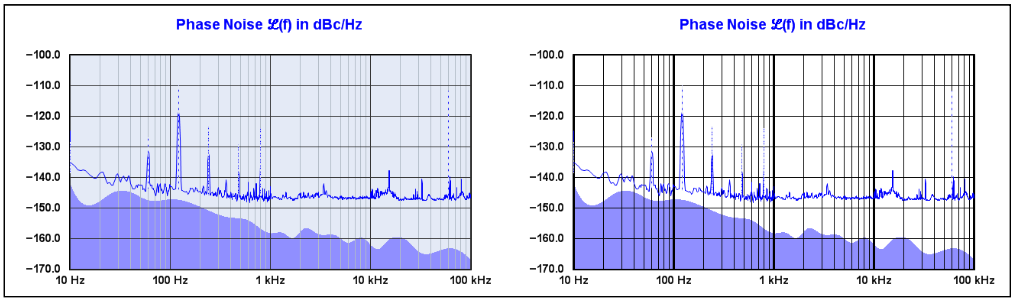


FIGURE 5-22: Contrast Adjustment.

5.4.6 Set Spot Cursor Positions <j>

This command opens a dialog box similar to the one shown in Figure 5-23, allowing the spot cursor and phase noise integration limit cursors to be placed at specific locations.

The spot cursor may be enabled for display by selecting the “Spot Cursor” field in the **Legend** menu. While it is normally placed by left-clicking within the graph area, *Display>Set spot cursor positions* <j> allows you to specify its location more precisely, as well as to place it at offsets not normally permitted (such as between minor divisions on the phase noise and AM noise graticules). Alternatively, left-clicking on the graph while the spot cursor is turned off will issue a prompt to enable it.

Refer to the mouseover help text in the dialog box for more information.

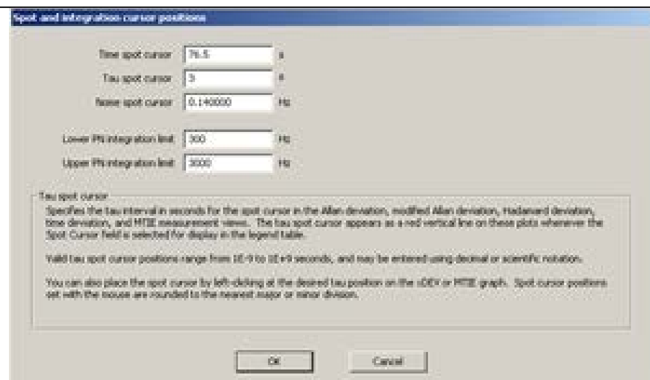


FIGURE 5-23: Set Spot Cursor Positions Dialog.

5.4.7 Show Numeric Tables <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 a high-precision frequency-count chart are displayed, while only the former is available in the *Measurement>Phase Difference* <p> view. Finally, tables of user-defined noise markers and detected spurs are displayed in the phase noise and AM noise views.

5.4.8 Clear Noise Markers <Ctrl-F4>

This command clears the list of user-defined noise markers, removing it from phase noise and AM noise plots. To add a new noise marker, simply <Shift-left click> near the desired column on either the phase noise or AM noise plot.

5.4.9 Show Integrated PN Traces

Enables or disables the display of integrated SSB noise and RMS jitter traces when one or more of the integrated noise options is selected for viewing in the *Legend>Select* menu.

5.4.10 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>.

5.4.11 Phase/Frequency X Axis Labels in Ss format
Phase/Frequency X Axis Labels in Hh:Mm:Ss format
Phase/Frequency X Axis Labels in Hh:Mm format
Phase/Frequency X Axis Labels in Hh format

These options determine the resolution at which X-axis (time) units are labeled on the phase and frequency difference traces.

Supported X axis label formats include seconds only (the default), hours:minutes:seconds, hours:minutes, or hours only. The latter three options also include days, months, and years when appropriate.

5.4.12 Frequency Y Axis Labels in Hz <Z>

Determines whether the Y axis in the *Measurement>Frequency difference* <f> view is based on fractional frequency differences or absolute frequency differences in Hz. In both cases the frequency-difference values are relative to the frequency shown in the DUT Freq field in the legend table. By default, fractional frequency differences are displayed. In addition to the Y-axis labels, the spot cursor field in the legend table is also adjusted based on this setting, as are mouse-cursor queries shown at upper left in the graph area and the Origin column in the frequency slope table at upper right. However, the Error column in the frequency-count chart always displays fractional frequency differences. The frequency counts themselves are also not affected by this setting.

5.4.13 Tau Labels in Scientific Notation

Log-x plots used to display stability measurements in TimeLab are labeled with tau values in seconds corresponding to each decade, from 1E-6 (microseconds) to 1E+9 (billions of seconds). The decades may be labeled in scientific notation or as literal decimals (the default).

5.4.14 Browse Plots One at a Time <b> Overlay All Loaded Plots <o> Toggle Visibility of Selected Plot <v>

Because TimeLab 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 browse mode only the selected plot is rendered. In overlay mode, all loaded plots that haven't had their visibility toggled off are rendered, with the graph scale adjusted as necessary to accommodate them.

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

5.4.15 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 **Section 1.11 "Making Your First Measurements"**.

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. Because the trace colors in TimeLab 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.

5.4.16 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 scroll 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 TimeLab's zoom functionality, refer to **Section 3.5 "Navigating Zoomed Graphs"**.

5.4.17 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 hot keys, 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 TimeLab's display window.

5.4.18 Refresh <F5>

This command triggers a recalculation of the graph extents for Allan deviation and related log-log statistical plots when these measurement views are selected. Alternatively, when the phase noise or AM noise measurement view is selected, the extents for all visible noise plots will be reset to their user-defined graph limits.

If a trace-refresh or data acquisition operation is already in progress at the time the command is issued in a deviation measurement view, only the graph extents are recomputed. Otherwise, the bin contents will be recomputed first in order to ensure that the graph extents are sized correctly.

5.5 LEGEND MENU

The Legend menu contains only one command, *Legend>Select* <d>. This command opens a dialog box in which you can choose 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 explicitly.

Each TimeLab acquisition driver can contribute its own entries to the *Legend>Select* dialog based on the property values in the plots that it generates. When a plot is acquired or loaded from a `.TIM` file, TimeLab checks for the presence of any displayable properties that it hasn't yet encountered. Any unfamiliar properties are logged in `TIMELAB.INI` and added to the selection menu.

As a result, the content of the *Legend>Select* menu may vary from one TimeLab 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 TIMELAB.INI, reinstalling TimeLab does not erase the list of known *Legend>Select* menu entries. These entries can be cleared only by manually editing or deleting `TIMELAB.INI`, or by using *File>Reset All Parameters, Options, and Settings at Next Startup*. Refer to the latter command for more information about `TIMELAB.INI`.

The list of currently defined `.TIM` 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 TimeLab itself and will appear on the *Legend>Select* menu by default in all installations.

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES

Property	Function
Acquired	Number of acquired phase data points used for stability and deviation plots
ADC Clock	Specified, estimated, or measured acquisition clock rate in Hz
ADC Format	Data format used by ADCs
ADC Temperatures	Average ADC temperature with individual deviations
Add'l AM Gain	Optional user-specified gain value added to AM noise traces

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
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 Clock	True if the clock frequency was determined automatically
Auto DUT	True if the DUT frequency is considered to be the frequency at the instrument input jack
Auto Input	True if the input frequency was measured automatically
Auto Ref	True if the reference frequency was measured automatically
Automatic Configuration	True if the TimeLab driver should infer various measurement parameters based on the incoming data
Autoscale Deviation	True if statistical deviation graph should automatically accommodate the extents of all visible traces
Autoscale Noise	True if noise graph should automatically accommodate the extents of all visible traces
Autosense Rate	True if the TimeLab driver should automatically measure the sample interval
Beatnote	Amplitude in dBm of calibration beatnote
Bin Density	Determines the number and distribution of tau intervals in statistical deviation measurements
Bin Threshold	Minimum number of data points required to display the statistical deviation at a given tau
BIST Result	Result of last built-in self test operation
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 Auto	True if Ch 0 frequency should be measured automatically
Ch 0 Freq	Specified input frequency for channel 0
Ch 0 Label	User-assignable label for source connected to instrument channel 0
Ch 1 Auto	True if Ch 1 frequency should be measured automatically
Ch 1 Enabled	Enabled/disabled status for channel 1
Ch 1 Freq	Specified input frequency for channel 1
Ch 1 Freq Mode	Input frequency measurement mode for channel 1
Ch 1 Label	User-assignable label for source connected to instrument channel 1
Ch 1 Noise Ref	Reference for DUT channel 1 (Noise)
Ch 1 Rounding	Input frequency rounding parameter for channel 1
Ch 1 Specified Frequency	Input frequency specification parameter for channel 1
Ch 1 Stability Ref	Reference for DUT channel 1 (Stability)
Ch 1 Type	Input type for channel 1
Ch 2 Auto	True if Ch 2 frequency should be measured automatically
Ch 2 Enabled	Enabled/disabled status for channel 2
Ch 2 Freq	Specified input frequency for channel 2
Ch 2 Freq Mode	Input frequency measurement mode for channel 2
Ch 2 Label	User-assignable label for source connected to instrument channel 2
Ch 2 Noise Ref	Reference for DUT channel 2 (Noise)
Ch 2 Rounding	Input frequency rounding parameter for channel 2
Ch 2 Specified Frequency	Input frequency specification parameter for channel 2
Ch 2 Stability Ref	Reference for DUT channel 2 (Stability)
Ch 2 Type	Input type for channel 2
Ch 3 Auto	True if Ch 3 frequency should be measured automatically
Ch 3 Enabled	Enabled/disabled status for channel 3
Ch 3 Freq	Specified input frequency for channel 3
Ch 3 Freq Mode	Input frequency measurement mode for channel 3
Ch 3 Label	User-assignable label for source connected to instrument channel 3

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
Ch 3 Noise Ref	Reference for DUT channel 3 (Noise)
Ch 3 Rounding	Input frequency rounding parameter for channel 3
Ch 3 Specified Frequency	Input frequency specification parameter for channel 3
Ch 3 Stability Ref	Reference for DUT channel 3 (Stability)
Ch 3 Type	Input type for channel 3
Ch 4 Auto	True if Ch 4 frequency should be measured automatically
Ch 4 Enabled	Enabled/disabled status for channel 4
Ch 4 Freq	Specified input frequency for channel 4
Ch 4 Freq Mode	Input frequency measurement mode for channel 4
Ch 4 Label	User-assignable label for source connected to instrument channel 4
Ch 4 Noise Ref	Reference for DUT channel 4 (Noise)
Ch 4 Rounding	Input frequency rounding parameter for channel 4
Ch 4 Specified Frequency	Input frequency specification parameter for channel 4
Ch 4 Stability Ref	Reference for DUT channel 4 (Stability)
Ch 4 Type	Input type for channel 4
Ch 5 Label	User-assignable label for source connected to instrument channel 5
Channel	Identifies the (zero-based) channel number associated with a multichannel acquisition
Channel Attenuators	Comma-separated attenuation values in dB for each channel
Clock Nominal	True if the clock frequency is a nominal value that may be refined during self-calibration
Clock Oscillator Offset	Margin offset frequency in Hz for clock oscillator
Clock Signal Generator	Address of clock signal generator
Clock Signal Monitor	Address of clock signal monitor
Clock Stabilizer	True if clock duty cycle stabilization is enabled (certain instruments only)
CM Servo	Common-mode servo functionality for ADC inputs
Comment Prefix	ASCII text comment delimiter
Counter Connection Type	Interface used for acquisition from TIC or frequency counter
Cross ID	Binding identifier for cross-statistical measurement plots
Cross Stability Metrics	True if cross statistics should be applied to stability measurements Data Format Indicates the format of the incoming data (e.g., decimal, hex, binary)
Data Port	Instrument data port
Data Format	Indicates the format of the incoming data (e.g., decimal, hex, binary)
Data Type	Indicates the type of the incoming data (e.g., phase differences, frequency differences, or absolute frequency)
Decimation	Hardware decimation ratio
Device ID	Instrument serial number or other identifier
Dither Level	Level of dithering applied to reduce spurious responses in input signals
Driver	Identifies the TimeLab .TLL driver used for acquisition
Driver Version	Version of TimeLab driver used for data acquisition
Duration	Measurement duration
Duration Type	Measurement duration units
DUT Freq	Frequency of device under test (DUT) provided by user, prior to any conversion, multiplication, or division
EFC	Acquisition clock EFC DAC value
Elapsed	Elapsed time in the current measurement or measurement stage
ENBW	Equivalent noise bandwidth in Hz of recorded phase data
ENBW Factor	Equivalent noise bandwidth of recorded phase data, expressed as a fraction of the data rate
ENBW Index	Index or other identifier for a given noise-equivalent measurement bandwidth
EOS Character	End-of-string character for data source
Ext Converter	External frequency divider or mixer configuration

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
Ext LO	Specified frequency in MHz of local oscillator used for external mixing
Ext N	Specified division factor (N) used for external frequency division
FFT 0	Combination of physical ADC channel(s) contributing data to FFT channel 0
FFT 1	Combination of physical ADC channel(s) contributing data to FFT channel 1
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
Filename	Filename under which the `.TIM` file associated with each plot was most recently saved
FPGA Bitfile	Name of the .bit file used to configure the FPGA prior to acquisition
FPGA Temperature	Approximate FPGA core temperature reported by on-chip sensor
FPGA Version	FPGA firmware version
Frequency	Incoming data consists of absolute frequency readings
Frequency Difference	Incoming data consists of fractional frequency differences
FRQ Max Offset	Maximum offset frequency 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
I/O Block Size	I/O buffer size in bytes
I/O Blocks	Number of I/O blocks in ring buffer
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 Dither	True if input dithering is enabled (certain instruments only)
Input Estimated	True if the input frequency is a low-precision estimate that should be rounded for display purposes
Input Freq	Frequency of signal applied to primary input jack, often rounded for display
Input Precision	Round input frequencies to the specified # of digits to the right of the decimal point
Input Splitter	True if input channel amplitudes should be adjusted by 3 dB to correct for internal or external RF splitter
Input Splitter (DUT)	DUT Splitter
Input Splitter (Ref)	Reference splitter
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 offset applied when converting 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
Mask Margin	Amount by which the mask test has passed (positive) or failed (negative)
Mask Result	Result obtained by testing the currently-displayed mask against each visible trace
Max Sigma	Sigma value at top of statistical deviation graph
Max Tau (s)	Maximum tau value in seconds for statistical deviation graph (which will be rounded up to the nearest decade)
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

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
MJD	Modified Julian Date when the measurement was triggered
Multichannel Data Port	Instrument data port(s) used to acquire each measurement channel
Multichannel ENBW	Equivalent noise bandwidth in Hz for each channel in a multichannel measurement
Multichannel Input dBm	Approximate input amplitude in dBm for each channel in a multichannel measurement
Multichannel Input Estimation	True for input channels whose frequencies are low-precision estimates that should be rounded for display purposes
Multichannel Input Hz	DUT input frequency in Hz for each channel in a multichannel measurement
Multichannel Input Precision	Round input frequencies in each measurement channel to the specified # of digits to the right of the decimal point
Multichannel Ref dBm	Approximate reference amplitude in dBm for each channel in a multichannel measurement
Multichannel Ref Estimation	True for reference channels whose frequencies are low-precision estimates that should be rounded for display purposes
Multichannel Ref Hz	Reference frequency in Hz for each channel in a multichannel measurement
Multichannel Ref Precision	Round reference input frequencies in each measurement channel to the specified # of digits to the right of the decimal point
Multichannel Sample Interval	Time in seconds between successive data points in each channel of a multichannel measurement
Narrowband Mode	Narrow acquisition bandwidth option
New t0	Most recent tau-zero interval specified for resampled phase data
Notes	Additional notes that apply to a measurement, as specified at acquisition time or edited with *Edit>Trace Properties*
Optional Filters	True if optional filters in use
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 TimeLab driver
Overlap %	Overlap percentage between successive FFT buffers
Overlapped	True if overlapped FFT processing is enabled for faster measurement
Pathname	Pathname under which the `.TIM` file associated with each plot was most recently saved
Phase	Incoming data consists of phase-difference values
Phase Record	Maximum allocated size of in-memory phase data record used for stability and deviation plots
Pilot	True if pilot tone in use
Pilot Freq	Pilot tone frequency in Hz
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
Port Configuration	Configuration string for RS-232 COM port or other interface, if required
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
Query Instrument ID	True if TimeLab should request the instrument's ID string
Rate Index	Index or other identifier for a given sample interval (device-specific)
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 Ch	Physical channel(s) acting as reference

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
Ref Estimated	True if the reference frequency is a low-precision estimate that should be rounded for display purposes
Ref Freq	Frequency of signal applied to primary reference input jack, often rounded for display
Ref Precision	Round reference input frequencies to the specified # of digits to the right of the decimal point
Remaining	Remaining time in the current measurement or measurement stage
Rescale Factor	Most recent user-supplied rescale factor for phase data
Residual FM	Displays blue vertical cursors in the phase noise graph which can be moved by left/right-clicking with Control held down. The residual FM between these limits of integration will be displayed in units of Hz.
Rev	Detailed information available for plots acquired with certain instruments, including firmware version and/or options
RMS Integrated Noise (Degs)	Displays blue vertical cursors in the phase noise graph which can be moved by left/right-clicking with Control held down. RMS jitter between these limits of integration will be displayed in degrees.
RMS Integrated Noise (Rads)	Displays blue vertical cursors in the phase noise graph which can be moved by left/right-clicking with Control held down. RMS jitter between these limits of integration will be displayed in radians.
RMS Time Jitter	Displays blue vertical cursors in the phase noise graph which can be moved by left/right-clicking with Control held down. RMS jitter between these limits of integration will be displayed in units of seconds.
Role	Selected instrument configuration for a given measurement role
Sample Interval	Time in seconds between successive data points
Sample Rate	Incoming raw data rate from instrument in samples per second, where applicable
Scale Factor	Numeric scale factor used to convert acquired data, e.g., TI readings to seconds or frequency readings to Hz
Scale Jitter to DUT	True if jitter and carrier/noise values should be adjusted to compensate for external frequency conversion
Scale PN to DUT	True if phase noise values should be increased by 20 * log10 (DUT frequency/input frequency)
Scale Stability to DUT	True if stability measurements should be adjusted to compensate for external frequency conversion
Secondary stability plots	True if a copy of the secondary phase record for a cross ADEV measurement should be stored in a separate plot; false if only one plot should be generated
Segment Table	User-specified tag field from segment table used for noise acquisition
Setup String	ASCII text string(s) transmitted to device prior to acquisition
Source A	User-assignable label for first variance source in stability measurement
Source B	User-assignable label for second variance source in stability measurement
Specified Input Frequency	Exact input frequency in Hz provided by user
Specified Reference Frequency	Exact reference frequency in Hz provided by user
Spot Cursor	Displays a red vertical cursor in the graph window which can be moved by left-clicking. The value at the selected column will be displayed in the legend table.
Spur Min Hz	Minimum offset frequency at which spurs will be marked for reporting or removal
Spur Threshold	Minimum amplitude relative to average nearby trace amplitude at which a discrete spectral line will be recognized as a spur
SSB Carrier/Noise	Displays blue vertical cursors in the phase noise graph which can be moved by left/right-clicking with Control held down. The SSB carrier/noise ratio between these limits of integration will be displayed in units of dB.
Stability Channel	Input channel expression(s) for stability measurement
Stability Channel Count	Number of concurrent stability measurements associated with acquisition
Stability Channel ID	Field # or name used to identify channel in incoming data
Stop Condition	Termination condition for measurement
Syx Estimator	Estimator function used to render cross-spectrum FFT bins on log plots
Syx Estimator #	Index or other identifier for cross-spectrum estimator function

TABLE 5-1: CURRENTLY DEFINED TIM FILE PROPERTIES (CONTINUED)

Property	Function
Time/Date	Time and date when the acquisition was initiated
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 deviation traces displayed. More recent traces appear darker.
Trace Window	Number of phase data points per historical deviation trace. This will equal the phase record size when Trace History is set to 1.
TSC Measurement Type	Noise plot type requested from 51XXA test set or TSERVE
TSC Phase Data Rate	Phase data rate from TSC 512X-compatible timing analyzer
Unwrapped	True if phase data has been unwrapped by the instrument driver
Unwrapped Phase	Incoming data consists of monotonic phase-difference values that do not contain phase wraps
USB Version	USB firmware version
Use Input Rate	True if driver's data rate matches the incoming data rate from the instrument
Use Internal Clock Generator	True if internal clock generator should be enabled
User-Assigned Command	User-assignable command string
Warnings Treated as Errors	True if warnings during data acquisition should terminate the measurement
Wrap Period	Wraparound period in seconds for incoming timestamps

5.6 MEASUREMENT MENU

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

As discussed in **Section 1.11 “Making Your First Measurements”**, TimeLab plots (and their associated `.TIM` files) use independent data records for different measurement classes. The 53100A Phase Noise Analyzer can acquire data for all measurements supported by TimeLab, but most third-party instruments 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>, MTIE<M>, 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 TimeLab. After launching a 53100A acquisition with all of the available measurements 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 TimeLab 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 **Section 1.11 “Making Your First Measurements”** for more information on the measurement types supported by TimeLab.

5.7 MASKS MENU

The Masks menu is almost entirely user-configurable. It consists of a list of mask definitions for optional use in TimeLab. 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 53100A and other instruments supported by TimeLab.

At startup, Timelab constructs the Masks menu based on the contents of the user-editable file `masks.txt`. The folder's location will vary from one Windows version to the next. For example, in a typical Windows 7 installation on drive `C:` it can be found at `C:\Users\Public\Documents\TimeLab\Masks` at the command prompt, or *Libraries>Public Documents>TimeLab>Masks* in Explorer.

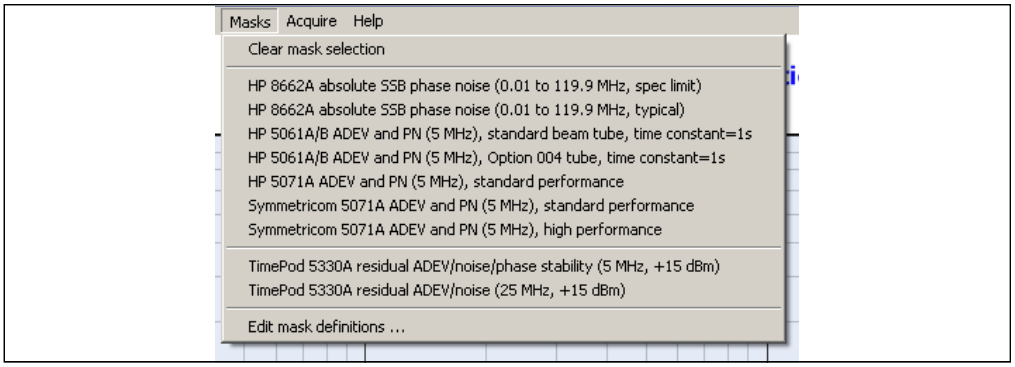


FIGURE 5-24: *User-Defined Mask Entries.*

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 TimeLab.

NOTICE
To preserve any user-created mask definitions, your existing `masks.txt` file will not be overwritten when a new copy of TimeLab 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 TimeLab. In such cases, the TimeLab setup program will make a backup copy of masks.txt in the same directory, under the name `masks_backup.txt`. Keep in mind that you will then need to transfer any user-created mask definitions from `masks_backup.txt` to the new `masks.txt` file.

In addition to the example user mask definitions in `masks.txt`, TimeLab also provides standard performance test masks for the 53100A and TimePod 5330A instruments, as well as numerous predefined masks corresponding to telecom industry standards. These mask definitions are stored in a separate file, `standard_masks.txt`, which is overwritten with the latest version at installation time. Consequently, user-created mask definitions should not be added to `standard_masks.txt`.

5.7.1 Clear Mask Selection

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

5.7.2 User-Defined Mask Entries

Menu entries appearing between *Mask>Clear Mask Definitions* and *Mask>Edit Mask Definitions* are defined in `masks.txt` and `standard_masks.txt`. Up to five masks may be selected at a time. Mask titles and limit lines will be visible only in measurement views corresponding to valid limit lines in a selected mask.

To see the results of the selected mask test, you'll need to select one of these views from the Measurement menu and enable *Legend>Mask Result*, *Legend>Mask Margin*, or both. 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 `standard_masks.txt`. The latest mask definition features and syntax for the current TimeLab release will appear as comments in this file (unlike `masks.txt`, the latest version of `standard_masks.txt` is always installed by the setup program).

5.7.3 Edit Mask Definitions

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

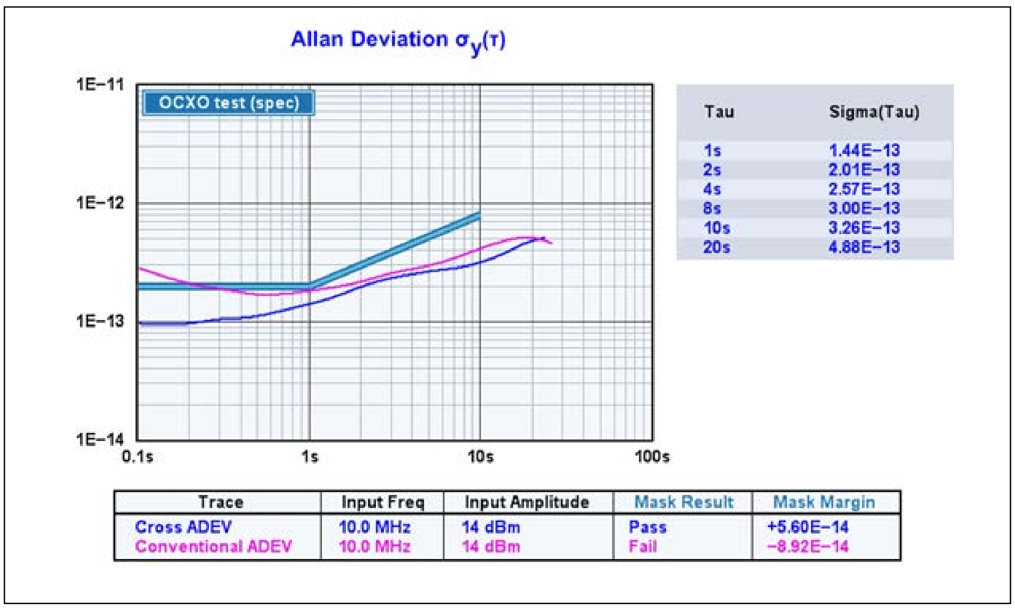


FIGURE 5-25: *Mask Test with Automatic Pass/Fail Evaluation.*

5.8 SCRIPTS MENU

TimeLab includes an embedded JavaScript engine that can run automated test scripts using the 53100A. Script-based access to other instruments such as time-interval counters is not currently supported. Numerous API functions are provided to support a variety of applications, ranging from performance verification procedures included with TimeLab to user-developed test scripts. The Scripts menu helps you edit, run, and otherwise manage your collection of test scripts.

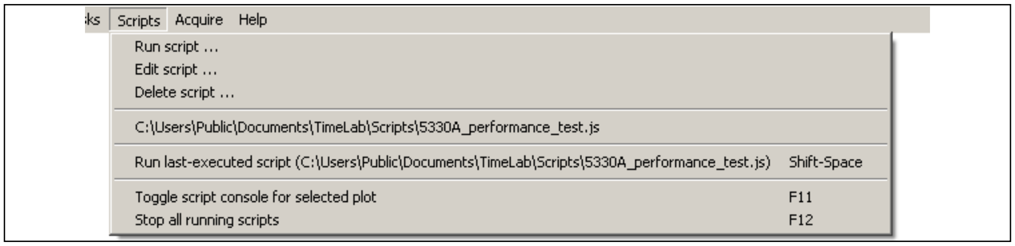


FIGURE 5-26: *Scripts Menu.*

5.8.1 Creating a New Test Script

The easiest way to create a new test script is to set up your measurement in the 53100A Acquisition dialog just as you normally would. Then, rather than selecting Start measurement, click the **Save Script** button. The Windows file dialog that appears will prompt you to save the current set of measurement parameters to a JavaScript (`.js`) file. When executed later with *Scripts>Run Script*, the script will launch a measurement with the same acquisition parameters and options.

As an alternative, you can use *Scripts>Edit Script* to create modified copies of the scripts that are included with TimeLab, such as `53100A_performance_test.js` and `5330A_ADC_test.js`. These programs are more elaborate than the elementary scripts created by Save script, but they were all originally created through that function. They exercise virtually all of the capabilities of the TimeLab script API as well as those of the instrument itself.

The script folder's location will vary from one Windows version to the next. For example, in a typical Windows 7 installation on drive `C:` it can be found at `C:\Users\Public\Documents\TimeLab\Scripts` at the command prompt, or *Libraries>Public Documents>TimeLab>Scripts* in Explorer.

Examples:

In addition to the performance test scripts, TimeLab includes two other examples showing how to accomplish various tasks under script control. `53100A_3_cornered_hat.js` demonstrates how to launch an automated 3-cornered hat stability measurement that will run for 12 hours, periodically saving the results while the test is running and `53100A_command_line_example.js` illustrates one way to create a complete automated test procedure by launching TimeLab to run a script from an external shell, application, or environment with specified parameters and termination behavior. Review the comments in these scripts to learn how to configure, run, and adapt them.

For a detailed listing of script API functions, refer to **Chapter 7. "JavaScript API Function Reference"**.

5.8.2 Run Script

To launch a test script, select *Scripts>Run Script* and choose the desired script's JavaScript file in the file dialog that appears. TimeLab will load the script into memory and execute its "global scope" to initialize any variables declared outside of functions or event handlers. Control then passes to the script's mandatory `EventRunScript()` function.

Once launched, the script will continue to run until one of the following conditions is true:

- A script exception or other fatal error occurs
- The `ScriptEnd()` API function is called by the script prior to returning from an event handler
- The script returns from an event handler function such as `EventRunScript()` or `EventAcqDone()` with no plots associated with it, either because the user closed the plot(s) manually or because the event handler did not launch any acquisitions. However, if the script has requested persistent timer service with `TimeSetTimer()`, it will be allowed to continue running.
- The script calls `FileExitApplication()`
- The *Scripts>Stop all running scripts* <F12> command is issued by the user
- The user closes the plot manually or presses the <Home> key to close all loaded plots
- The user exits from TimeLab

Any errors encountered during either loading or execution will be reported in the status line at the bottom of the TimeLab window.

5.8.3 Edit Script

This command simply launches an instance of Notepad on the specified `.js` file, allowing you to read, modify, and/or copy the script.

5.8.4 Delete Script

To delete a test script, select *Scripts>Delete Script* and specify the `.js` file to delete. The `.js` file will be deleted without further prompting.

5.8.5 Run Last-Executed Script <Shift-Space>

Using <Shift-Space> to re-run the most recently executed script is analogous to pressing the <Space bar> by itself to bring up the most recently used acquisition dialog. The script will be relaunched without further prompting from TimeLab.

5.8.6 Toggle Script Console for Selected Plot <F11>

When a measurement is started under script control, TimeLab will display an overlay containing any error or status messages issued by the script. This console overlay is shown by default whenever the measurement is otherwise visible on the graph.

As the script console overlay tends to obscure the data being plotted, the <F11> key provides a convenient way to hide or show the overlay for the currently selected plot.

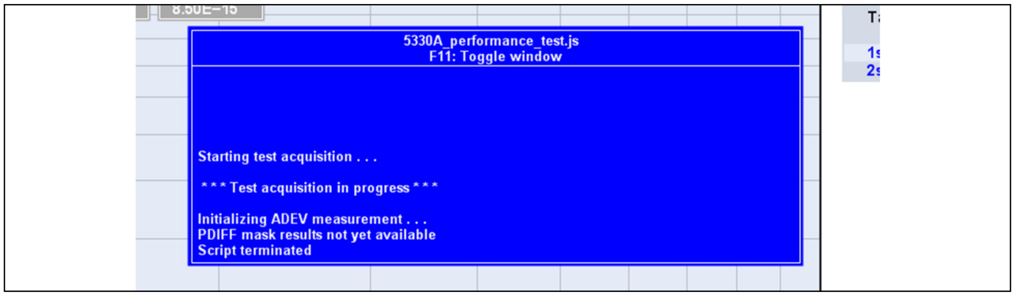


FIGURE 5-27: The Script Console.

5.8.7 Stop Running All Scripts <F12>

Stops any scripts that are currently running, as well as any measurements associated with those script(s).

5.9 ACQUIRE MENU

TimeLab's principal mission is to serve as the user interface for the 53100A Phase Noise Analyzer, but support for many other instruments is also provided. The Acquire menu includes a list of all instruments currently recognized by TimeLab, 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 TimeLab 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 TimeLab because 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.

5.9.1 Microchip 53100A

The 53100A uses real-time direct sampling techniques from the Software-Defined Radio (SDR) field to measure frequency stability, phase noise, and AM noise at levels substantially beyond the reach of traditional counters and timing analyzers. Depending on the measurement options selected in the 53100A Acquisition dialog, the 53100A can perform any (or all) measurements supported by TimeLab.

The dialog fields used to select and configure the 53100A's supported measurement roles are discussed separately in their own appendix, **Chapter 6. "53100A Measurement Roles"**.

5.9.2 Miles Design TimePod and Microchip 3120A

The TimePod 5330A and Microchip 3120A have been replaced by the 53100A, but continue to be fully supported by TimeLab. These legacy instruments offer similar performance capabilities at a limited range of carrier and offset frequencies, and provide a subset of the 53100A's connectivity and configuration options.

5.9.3 Acquire from Counter in Talk-Only Mode

This option allows you to acquire frequency, phase/TI, or timestamp readings from almost any GPIB- or RS232-connected counter that supports a Talk Only mode, in which ASCII readings are emitted autonomously with no interaction from a host controller. RS232-based timing analyzers such as the picPET are also supported by the Talk-Only option.

TimeLab supports GPIB connectivity through adapters from National Instruments or Prologix, including Agilent/Keysight GPIB adapters with NI488.2 compatibility enabled.

5.9.4 Acquire from Live ASCII File

Similar to the Talk-Only acquisition option, 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. TimeLab 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.

5.9.5 HP 53131A/53132A/53181A and 53220A/53230A
HP 5335A and 5370A/B
HP 5371A/5372A
Philips/Fluke PM6680
Picotest/Array U6200A series
Stanford Research SR620
Wavecrest DTS-2050/2070 series

These instruments are high-performance counters and timing analyzers whose acquisition capabilities are very similar from TimeLab's perspective. Frequency and phase-difference (TI) readings are supported by each. Depending on the instrument's I/O capabilities, available connectivity options may include the following:

- National Instruments NI488.2-compatible GPIB adapters
- Serial (COM) ports connected directly to the instrument
- Serial (COM) ports associated with Prologix GPIB-USB adapters
- IP addresses supported with Prologix GPIB-ETHERNET adapters
- Direct connections to TCP/IP-based instruments at the specified address

HP counters with serial interfaces connected via null-modem cables should use *Acquire>Acquire from Counter in Talk-Only Mode* instead.

5.9.6 Microchip 5115A/5120A/5125A (Frequency Stability)
Microchip 5115A/5120A/5125A (Phase Noise)

These digital phase noise analyzers provide advanced features and specifications similar to the TimePod and 53100A instruments. However, separate options in the Acquisition menu must be used to obtain data for xDEV and phase/frequency-difference plots and the Fourier spectrum used for phase noise plots. Phase/frequency data will be acquired continuously for the duration of the measurement, while phase noise acquisition will retrieve a snapshot of the analyzer's current phase noise trace, noise-floor estimate, and spur table.

As with other TimeLab acquisition processes, these acquisitions may be launched concurrently.

Note that the earliest versions of these test sets were developed and marketed by Timing Solutions Corporation, so they are often referred to as the "TSC 512x" family of instruments. Later instruments were produced with Symmetricom, Microsemi, and Microchip branding. The TimeLab drivers support all of these variations under the Symmetricom nomenclature.

This acquisition option is also useful for requesting phase noise and AM noise data from the TSERVE remote access server. See **Section 8.6 "Measurement Example: Phase Noise Plot Acquisition"**.

5.9.7 Stop/Repeat Acquisition <Space>

This context-sensitive command associates the 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 TimeLab 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.

5.9.8 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 if *File>Warn before Retriggering Measurement in Progress* is unchecked. They're assigned to control keys to make them harder to press accidentally.

5.9.9 Acquisition Options <Ctrl-F7>

This command brings up a dialog box that configures TimeLab's autosave and deferred-acquisition functionality.

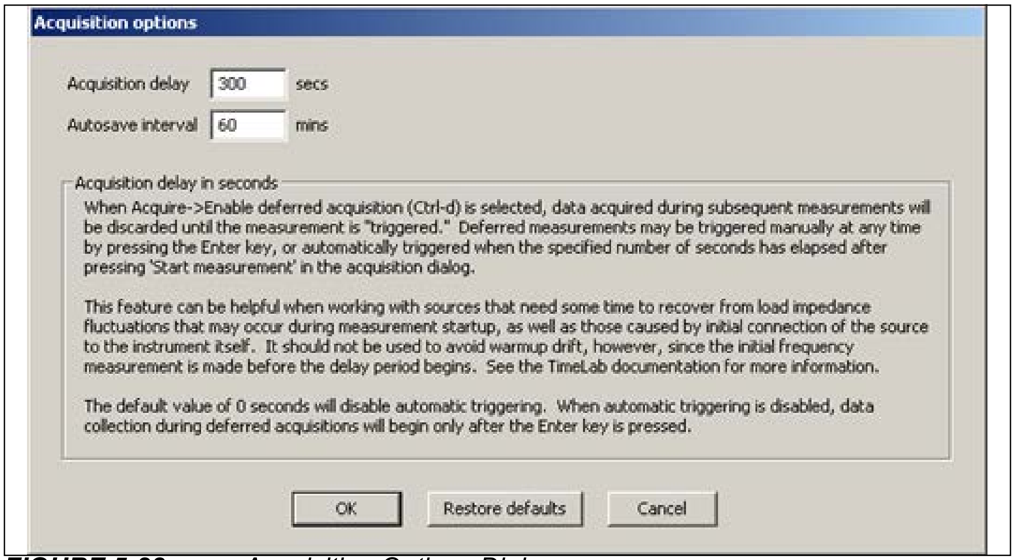


FIGURE 5-28: *Acquisition Options Dialog.*

When deferred-acquisition mode has been toggled on by the *Acquire>Enable deferred acquisition* <Ctrl-d> command, data from subsequent measurements will be discarded until the measurement is "triggered" manually with *Trigger deferred acquisition(s)* <Enter> or by canceling deferred execution with a second *Enable deferred acquisition* <Ctrl-d> command. The **Acquisition delay** field in the dialog box above provides an additional way to trigger a deferred measurement. By setting a non-zero Acquisition delay value in seconds, a deferred measurement will trigger itself automatically once a specified number of seconds has elapsed after initiation. With the default delay value of zero seconds, manual triggering is necessary in order to begin collecting data. Refer to the *Enable deferred acquisition* <Ctrl-d> command description for more information.

The autosave feature helps guard against data loss due to forced operating system updates, power failures, or other unexpected events that may occur during long-term measurements. When the **Autosave interval** field in the dialog box has been set to a value greater than or equal to 1 minute, the `.TIM` files associated with all subsequent measurements can be periodically saved to disk at the specified interval, just as if the user had issued a *File>Save image or .TIM file(s)* command manually.

The autosave interval can be specified at any time before or after the beginning of acquisition. However, only `.TIM` files can be automatically saved during the measurement, not image files. Additionally, each `.TIM` file to be automatically saved must be saved manually at least once in order to assign it a valid filename.

Measurements in progress that have not been saved manually at least once, or that are running with the autosave interval set to a value less than one minute, will not be automatically saved.

5.9.10 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, TimeLab will allow acquisitions to be launched as usual. However, each new measurement's incoming data will be discarded until all pending measurements are triggered. In Deferred Acquisition mode, triggering occurs at the expiration of a specified time interval specified in the Acquisition options <Ctrl-F7>

dialog, when the Trigger Deferred Acquisition(s) <Enter> command is issued, or when another Enable Deferred Acquisition <Ctrl-d> command is issued to return to Immediate Acquisition mode. Data will subsequently 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. Another common application for Deferred Acquisition is to wait for a given stabilization period to elapse after the instrument's attenuators and filters are configured at the beginning of the measurement process. Load impedance will be relatively constant at all times when using the 'N' female REFERENCE and DUT input jacks on the 53100A, due to the inherent isolation characteristics of the built-in active splitters. However, multichannel measurements will expose the reference and DUT sources to varying load conditions at the SMA-F channel input jacks during the startup phase, so Deferred Acquisition can be a useful tool in these cases.

Note that TimeLab doesn't specify the trigger latency associated with a group of deferred measurements. Triggered measurements made with time interval counters will normally start collecting valid data within one sample period, but this isn't guaranteed.

Also note that the DUT frequency is initially measured when the measurement begins, not when it is triggered. Attempting to measure an oscillator undergoing startup drift in a narrow measurement bandwidth will usually yield drift warning messages and questionable data regardless of the use of deferred acquisition. Always ensure that the measurement bandwidth is sufficiently wide to keep the DUT signal well within its passband during the deferral period, as well as the remaining duration of the measurement itself.

5.9.11 Configure Deferred Acquisition

As noted above, when deferred execution is selected, data from subsequent measurements is discarded until the measurement is triggered manually with Trigger Deferred Acquisition(s) <Enter> or by canceling deferred execution with a second Enable Deferred Acquisition <Ctrl-d> command. Configure Deferred Acquisition provides an additional way to trigger a deferred measurement.

With this option, the measurement triggers itself automatically once a specified number of seconds has elapsed after initiation. For example, this feature might be used to ignore the first few minutes of data when measuring oscillators with long warmup times or large startup transients. 53100A measurements have the option of using 5 kHz or 50 kHz measurement bandwidths for wide-range drift tracking, but other instruments may require some extra time.

5.10 HELP MENU

5.10.1 User Guide <F1>

This command launches the system's default web browser to display the product web page. Links on this page will allow you to download the latest version of TimeLab and access the latest edition of the 53100A Phase Noise Analyzer User's Guide.

When you install TimeLab, a local copy of the 53100A manual is also installed on your hard drive.

5.10.2 About TimeLab

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

5.10.3 Debug Mode

TimeLab contains some debugging/development-specific features that are not documented or supported for general use, and are likely to be removed or deprecated in the future. For example, *Measurement>Frequency Spectrum* is intended for debugging, rather than as a supported feature, because the TimePod firmware isn't optimized for general spectrum-analysis work and the 53100A doesn't support it at all. These debugging features will be inaccessible if *Help>Debug Mode* is turned off.

It's not recommended that you enable this debug mode under most circumstances, as it may disable important safeguards against measurement errors and cause other features to function in unexpected ways.

5.10.4 Check for Updates <Ctrl-u>

By default, TimeLab will automatically check the Microchip website on a weekly basis and inform you if a newer version is available for download. Updates to TimeLab are always free of charge. You can use the *Help>Check for Updates* <Ctrl-u> command to reschedule or disable these notifications.

Automatic update checks are never performed during JavaScript program execution.

NOTES:

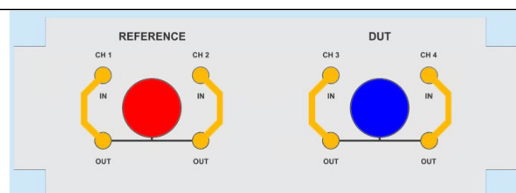
Chapter 6. 53100A Measurement Roles

The 53100A Phase Noise Analyzer differs from earlier direct-digital instruments in that all four of its internal ADC channel inputs are user-accessible. For simplicity's sake, the 53100A is typically operated in one of several predefined measurement roles, in which the individual channel inputs and jumper positions are assumed to be configured specifically for the selected task with their per-channel controls populated accordingly, or in a user-defined role in which the channel controls may be freely assigned. Not all of the information needed to take advantage of these capabilities can be accommodated in the acquisition dialog help text, so we'll look at the details here.

Color-keyed diagrams for each role appear below in which red corresponds to external reference source connections, blue to connections made to the device(s) under test, and orange to the SMA jumper positions associated with the role. All of the remaining jacks that do not appear on the diagram for a given measurement role may be left unconnected.

6.1 MEASURE SINGLE DUT WITH SINGLE EXTERNAL REFERENCE

This is the default measurement role for 53100A instruments without the dual 100 MHz internal reference option (Option IR). It is based on the factory-default jumper positions shown on the right. In this configuration, a single measurement will be recorded when the **Start Measurement** button is pressed. Depending on which measurement type(s) are selected, the measurement will include a phase data record based on the phase differences at channels 3 and 1, as well as cross-correlated phase noise and/or AM noise records based on independent acquisition of the signals present at channels 3-1 and 4-2.

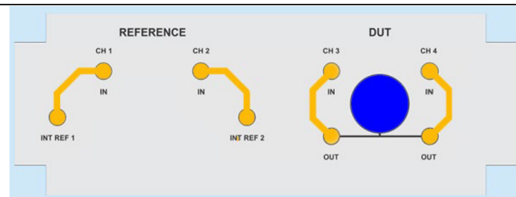


The DUT and reference frequencies displayed in the legend table will be rounded to the nearest 100 kHz by default. The frequency- and phase-difference plots will represent the measured fractional frequency difference between the actual DUT signal frequency and the rounded DUT frequency shown in the legend table. The frequency count chart will display the frequency of the signal at the first DUT input (3) with accuracy determined by the reference source at channel 1, which is assumed to be a multiple of 100 kHz.

Application note AN3502, Oscillator Measurement and Calibration with the 53100A provides a practical introduction to the single DUT/single reference measurement role, based on a wide variety of real-world test scenarios.

6.2 MEASURE SINGLE DUT WITH DUAL INTERNAL REFERENCES

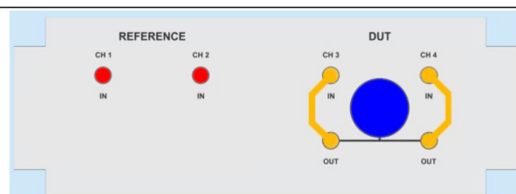
53100A instruments equipped with optional dual internal reference oscillators (Option IR) are configured as shown below by default. These instruments will default to the dual internal reference role if no other role has been selected. Cross-spectral suppression of reference noise as well as other instrument noise contributions. Stability measurements, including frequency-and phase-difference plots, HDEV, TDEV, MDEV, and MTIE, will be based on the phase differences between channels 3 and 1 as in the single-reference case. However, the Allan deviation measurement will be performed with phase records from both 3-1 and 4-2 channel pairs, unless the **Always use cross ADEV when possible** box is unchecked in the Additional options page.



Also as in the default measurement role, DUT and reference frequencies displayed in the legend table will be rounded to the nearest 100 kHz. The frequency count chart will display the true frequency of the signal at the first DUT input (3) at maximum available precision. Frequency count chart accuracy is determined by the reference source at channel 1, given the assumption that the reference frequency is in fact an exact multiple of 100 kHz. Refer to **Appendix A. "53100A Dual 100 MHz Reference (Option IR)"** for detailed information on dual-reference measurements.

6.3 MEASURE SINGLE DUT WITH DUAL EXTERNAL REFERENCES

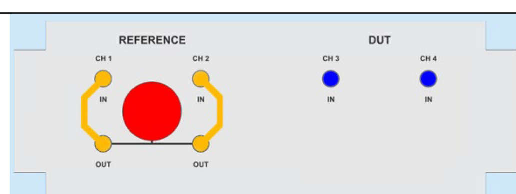
All 53100A instruments, including those equipped with optional dual internal reference oscillators, can be configured for use with a pair of user-supplied external references by connecting the reference sources to the channel 1 and 2 inputs as indicated below. All of the considerations described above apply, noting that the two external references do not need to operate at the same frequency.



Operationally, the dual internal reference and dual external reference measurement roles are identical. They differ only in the appearance of the graphical connection diagram shown in the acquisition dialog box. Please refer to Application Note AN3526 for important additional guidelines regarding external reference selection and usage, as well as **Section 1.9 "Choosing Reference Sources"** and **Appendix A. "53100A Dual 100 MHz Reference (Option IR)"**.

6.4 MEASURE TWO DUTS WITH SINGLE EXTERNAL REFERENCE

This measurement role will yield two separate stability plots, one based on the phase differences between channel 3 and channel 1 and the other based on the phase differences between channel 4 and channel 1. No noise measurement will be performed in this case.



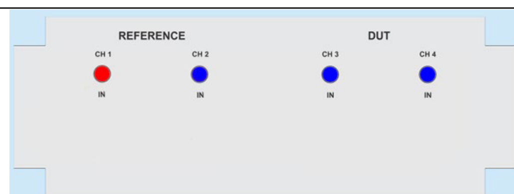
For each of the two plots, the DUT and reference frequencies displayed in that plot's legend table row will be rounded to the nearest 100 kHz. The frequency-difference traces will represent the fractional frequency differences between the measured DUT signals and the displayed DUT frequencies as usual. The frequency count charts for both plots will inherit the accuracy of the reference oscillator at channel 1, based on the assumption that the reference frequency is an exact multiple of 100 kHz.

Note that because channel 1 acts as a common reference for both stability plots, it's not necessary for the factory default reference-channel jumper configuration to be used as shown above. The reference can be supplied directly to CH 1 IN if desired, with CH 2 IN left unconnected. One advantage to using the N-channel splitter input, however, is that the reference will not experience significant load-pulling effects due to attenuator and filter selection as the measurement is initialized.

Additionally, if the instrument is equipped with the internal reference option, you may connect CH 1 IN to its adjacent INT REF output jack instead of using an external reference.

6.5 MEASURE THREE DUTS WITH SINGLE EXTERNAL REFERENCE

This measurement role is identical to the previous one, except that the CH 2 reference input jack is pressed into service as a third DUT input channel. Three stability plots (and no noise plots) will be generated when the **Start measurement** button is pressed.



As an example, ADEV and frequency-difference plots in which three high-performance crystal oscillators were measured simultaneously against a single cesium-beam frequency standard appear below. All three plots were generated by the same measurement using the Measure three DUTs with single external reference role. The HP 5061A frequency standard was connected to the CH 1 IN jack, while the three quartz oscillators were connected to CH 2 IN, CH 3 IN, and CH 4 IN.

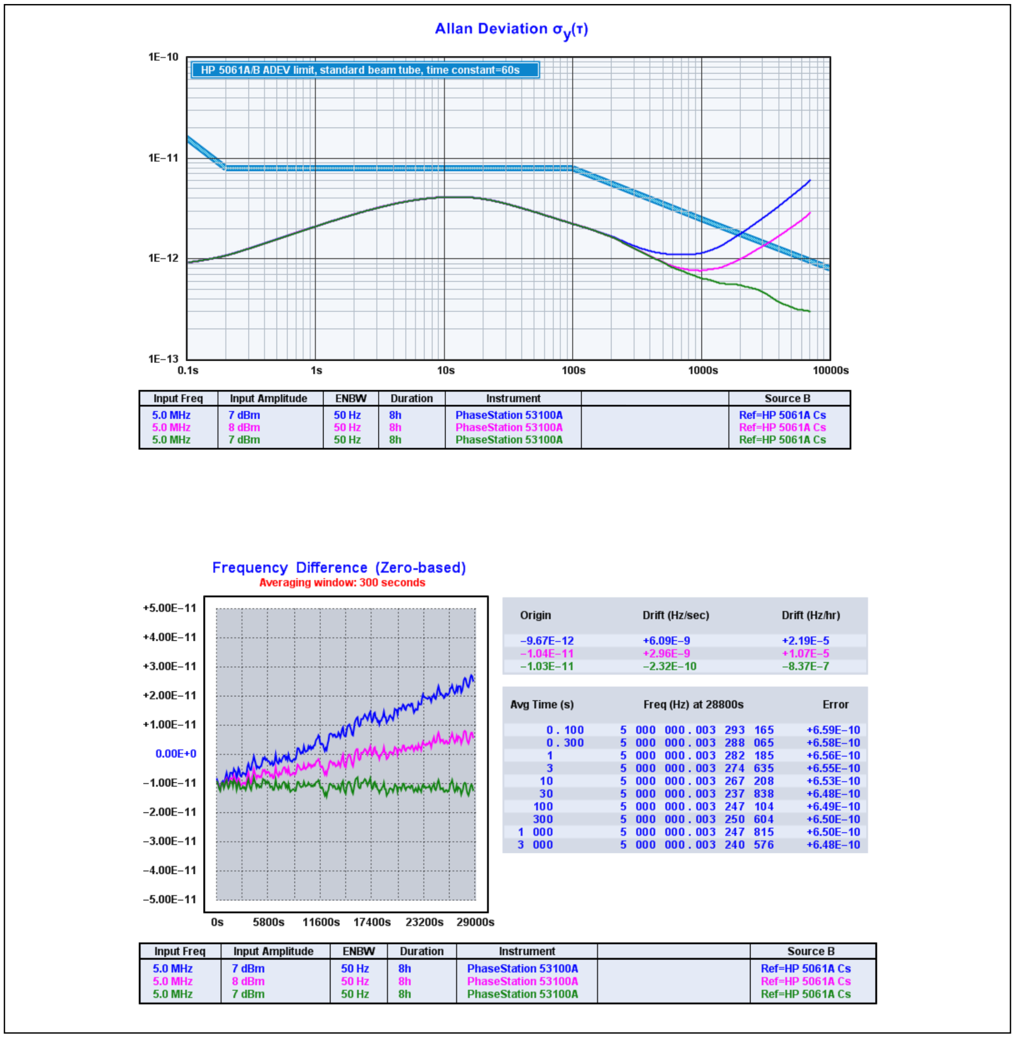
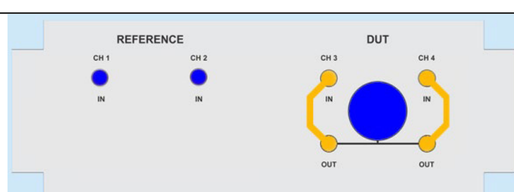


FIGURE 6-1: *Stability Plots of Three Crystal Oscillators Measured Simultaneously Against a Cesium-Beam Standard.*

6.6 MEASURE THREE INDEPENDENT DUTS (THREE-CORNERED HAT)

This measurement role is similar to **Measure single DUT with dual external references** and the other single-DUT roles, in that it is capable of performing a cross-correlated phase noise and/or AM noise measurement of a single device under test that is connected to channels 3 and 4 via an internal or external RF splitter. The phase noise and AM noise contributions from the two independent references connected to channels 1 and 2, whether internal or external, will be averaged out of the measurement over time.



However, three stability plots are generated in this role rather than only one. In these stability plots, unlike the AM and phase noise measurements, the three connected devices are treated as individual test sources. Each source is represented as a DUT in one of the plots, and each also serves as a reference source for one of the other plots.

The resulting trio of mutually dependent stability plots can be rendered by TimeLab In the usual fashion, appearing as three independent traces, or they can be rendered in a special display mode using the *Trace>Show Separated xDEV Variances (N-Cornered Hat)* <Ctrl-h> function. In this mode, TimeLab will attempt to display the stability characteristics of each device by itself, rather than showing traditional stability measurements based on two contributing sources.

Note that any phase noise/AM noise data obtained in this measurement role will be associated only with the first of the three stability plots. The remaining two plots will not contain any noise data.

As with the other dual-reference measurements, please refer to Application Note AN3526 for a discussion of three-cornered hat measurements in TimeLab with detailed examples.

If a three-cornered hat measurement is being performed in order to achieve the lowest possible measurement floor for a single device, consider using one of the dual-reference measurement roles instead. A single `.TIM` file contains all of the information necessary to display a cross ADEV measurement, eliminating the need to save all three files separately. Additionally, cross ADEV measurements improve the 53100A's own instrument floor over time, rather than only its references. See **Section 6.9 "Cross Allan Deviation Measurements"** for more details.

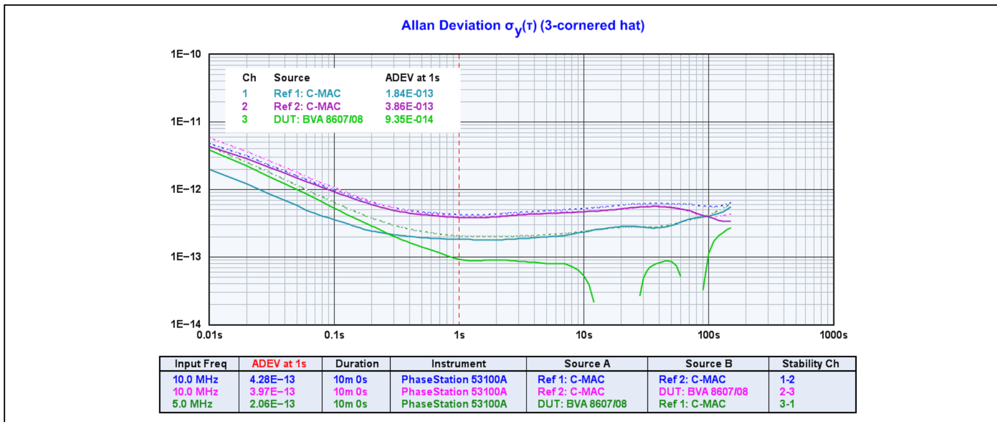


FIGURE 6-2: *Three-Cornered Hat Display.*

6.7 MEASURE SINGLE DUT WITH CROSS ADEV STATISTICS

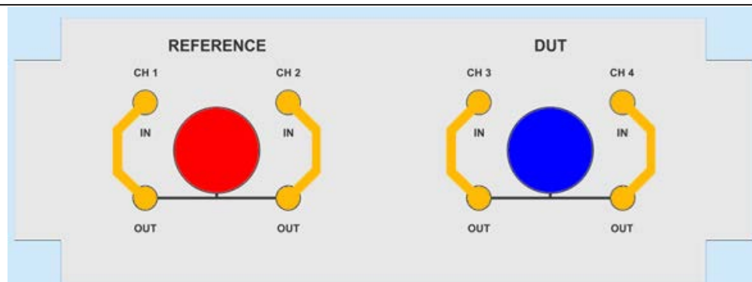


FIGURE 6-3: *53100A Front Panel.*

Selecting this role will cause the 53100A to perform a single-DUT stability measurement as in Measure single DUT with single external reference, using data from both the 3-1 and 4-2 channel pairs for cross ADEV computations even if the Always use cross ADEV when possible box is unchecked in the Additional options page.

Since this box is checked by default, it's normally unnecessary to select this role manually. See **Section 6.9 "Cross Allan Deviation Measurements"** for more details.

6.8 MANUAL CONFIGURATION

Selecting the Manual configuration measurement role will enable all of the dialog fields associated with channel assignment and frequency specification that are normally grayed out when working with predefined measurement roles. Any changes you make to these fields will be saved for recall whenever the **Manual configuration** role is selected in the future, as long as the **Restore defaults** button has *not* been pressed since the changes were made.

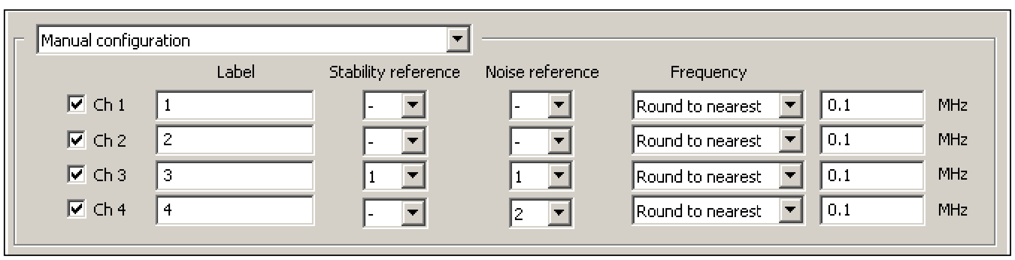


FIGURE 6-4: *Manual Configuration Controls.*

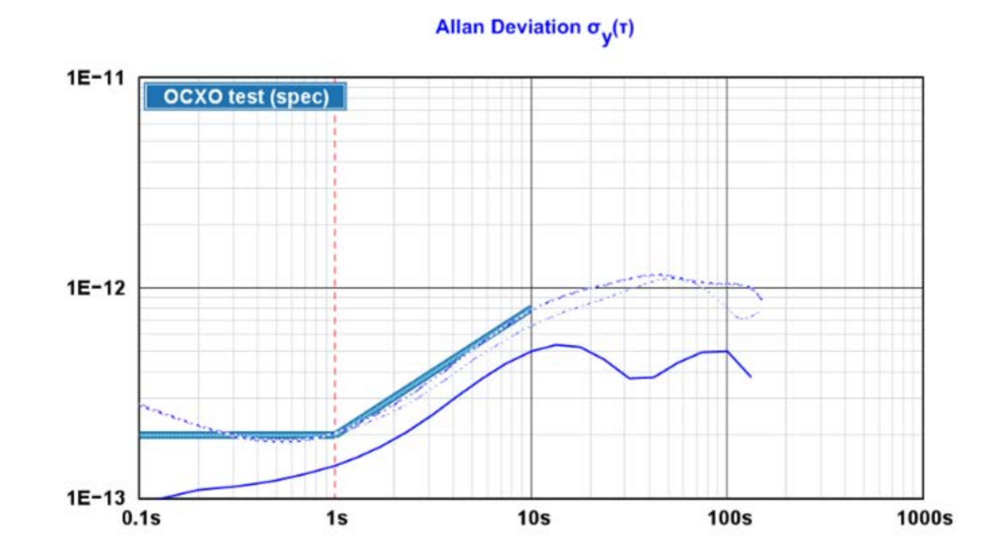
Most 53100A users will not need to configure these fields manually, as the predefined roles should cover the most common measurement scenarios. Cases in which manual configuration should be considered include:

- You need to connect DUT input jacks to reference sources, or vice versa
- You need to perform noise measurements with nonstandard channel input connections
- You wish to display DUT and/or reference frequencies in the legend table with more than the default 100 kHz rounding precision
- The nominal frequency of your reference source is not a multiple of 100 kHz
- You wish to specify precise DUT or reference input frequencies for any other reason

In these scenarios, the Manual Configuration role provides the required flexibility at some cost in complexity. As with other fields in the acquisition dialog, detailed online help can be obtained by hovering over any of the controls associated with manual role configuration.

Note that cross ADEV measurements may be performed in the Manual configuration role only if two conditions are met. **Always use cross ADEV when possible** must be checked in the Additional options page, and both channels 3 and 4 must be assigned unique stability reference channels (typically 1 and 2 respectively).

6.9 CROSS ALLAN DEVIATION MEASUREMENTS



Trace	Input Freq	ADEV at 1s	Duration	Instrument
Cross ADEV (S/N 001)	10.0 MHz	1.42E−13	10m 0s	Microchip 53100A

FIGURE 6-5: *Allen Deviation with Cross ADEV Statistics.*

Stability measurements performed by the 53100A normally rely on phase difference measured at a single ADC channel pair, typically based on a DUT connected to port 3 and a reference source connected to port 1. Measurements in this class include the frequency-difference and phase-difference “strip chart” plots, as well as modified Allan deviation (MDEV), time deviation (TDEV), Hadamard deviation (HDEV), and maximum time interval error (MTIE) graphs.

Allan deviation (ADEV) measurements made with the 53100A, however, can take advantage of all four ADC channels. Just as phase noise and AM noise measurements benefit from instrument- and reference-noise improvement through cross-spectral averaging over time, cross Allan deviation measurements can help to overcome the stability limitations imposed by both the reference oscillators and the 53100A’s own internal ADCs. Cross Allan deviation is not a separate measurement type with its own statistical basis; it is simply the result of computing the ADEV bin variances based on two independent phase measurements taken simultaneously, rather than squaring the phase differences obtained from a single measurement.

By default, the 53100A performs cross ADEV measurements in all single-DUT measurement roles in which both DUT channels 3 and 4 have stability reference channels assigned to them. These roles include **Measure single DUT with dual external references**, **Measure single DUT with dual internal references**, and **Measure single DUT with cross ADEV statistics**. Stability measurements made in all of these cases will include cross ADEV plots as long as the **Always use cross ADEV when possible** checkbox remains selected on the **Additional options** page of the 53100A’s acquisition dialog. If this box is unchecked, cross ADEV measurements are performed only when the **Measure single DUT with cross ADEV statistics** role is explicitly selected.

(The **Manual configuration** role can perform cross ADEV measurements only under certain conditions; refer to its description in **Chapter 6. “53100A Measurement Roles”** for details.)

When cross ADEV measurements are performed, two independent phase records are acquired during the measurement rather than only one. Both of these records are associated with the resulting plot and are stored in a single `.TIM` file. TimeLab uses data from both of these records when rendering a cross ADEV plot. The record associated with the 3-1 DUT-reference combination is considered the *primary* record, while the 4-2 channel pair contributes to the secondary phase record.

You can inspect the conventional Allan deviation traces for each record separately with the <F6> hotkey (*Trace>Show original traces in computed xDEV displays*). When this function is turned on, as shown in Figure 6-5, two dashed (broken) traces will appear in addition to the composite cross ADEV trace, assuming that cross ADEV displays have been enabled with *Trace>Show cross ADEV traces when available* <Ctrl-j>. The trace corresponding to the primary (3-1) channel pair is slightly thicker than the other trace which represents the secondary (4-2) channel pair.

The improvement in measurement floor performance can be substantial when both ADC channel pairs contribute. Figure 6-5 depicts a short-term stability measurement of a high-performance oscillator using two other examples of the same part as independent references. The two broken traces indicate what would be observed if the **Always use cross ADEV when possible** option had been unchecked at the time the measurement data was acquired. In fact, the heavier of the two broken traces also reflects what would be seen if *Trace>Show cross ADEV traces when available* <Ctrl-j> were used to toggle off the cross ADEV display.

Two distinct advantages of cross ADEV measurement can be observed here. First, the use of all four ADC channels rather than only two improves the performance dramatically between t=0.1s and t=1.0s. The conventional ADEV traces from the high-performance oscillator under test reveal the 53100A’s own performance floor in this region, while in the cross-ADEV trace, uncorrelated noise from the two independent ADC channel pairs has been averaged out of the measurement over time.

Second, as noted earlier, the averaging process also helps to cancel uncorrelated noise from the two independent reference oscillators. At taus beyond 1s where instrument noise doesn’t come into play, the result is reminiscent of what would be obtained from a three-cornered hat measurement

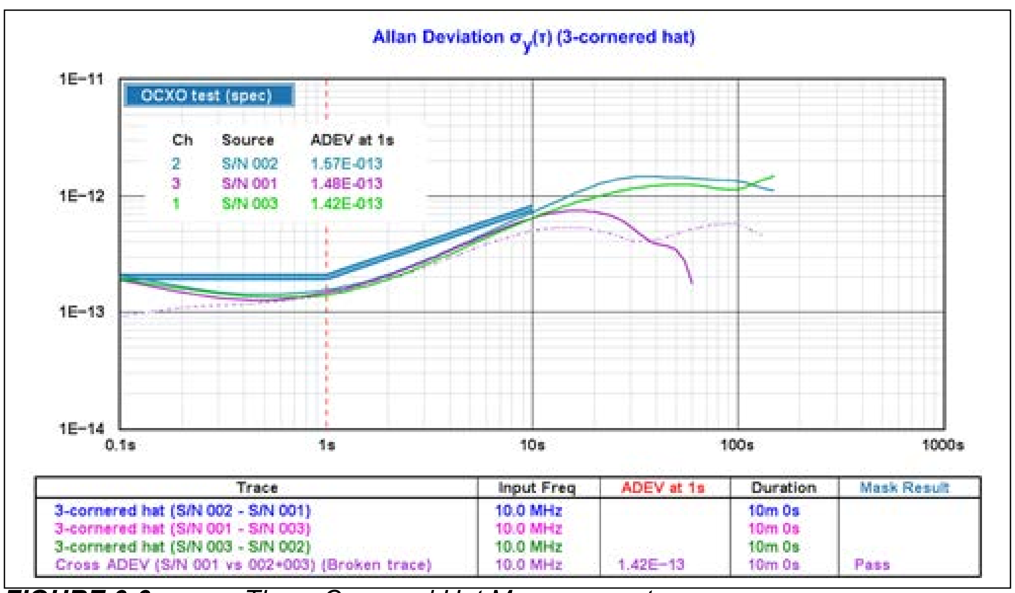


FIGURE 6-6: *Three-Cornered Hat Measurements.*

Given sufficient measurement time, it's likely that the violet traces would approach each other closely at taus greater than 1s, but only the cross ADEV technique can remove the instrument noise at shorter-term taus. Compare the two violet traces in Figure 6-6 with the two dark blue traces in Figure 6-5 to see this effect. The three-cornered hat solution remains limited by the 53100A's noise floor below t=1s, and it also does not support limit-line evaluation. Finally, three-cornered hat measurements also require three different `.TIM` files to be saved and reloaded for later inspection, making them less user-friendly than the cross ADEV approach in scenarios where only one DUT needs to be measured.

Although this technique is capable of exceptional performance, there are also some subtle conditions and caveats associated with cross ADEV measurements. Residual measurements of quiet DUTs (or the instrument itself) may show substantially more variance than a conventional ADEV measurement would. Cross ADEV plots are not subject to the fragmentation often seen in three-cornered hat measurements, but in cases where the actual device performance is similar to or better than that of the instrument itself, cross ADEV plots can display numerous divots and valleys at taus where the measurement has not yet had time to settle. This effect is unlikely to be of concern when measuring real-world frequency standards and sources, even at the most demanding performance levels, **but may be a consideration in two-port residual ADEV measurements where it risks underrepresenting the DUT's true stability performance**. Discretion is required when interpreting these plots.

Trace>Draw xDEV traces with spline interpolation <i> may be used if desired to smooth cross ADEV traces, but be aware of the potential for artifacts here as well. While the accuracy at taus corresponding to the actual bin locations is unaffected by spline interpolation, it may exaggerate the apparent trace amplitude elsewhere. Overshoot can be expected near high-variance degenerate bins when spline interpolation is enabled. Once again, longer measurements yield smoother traces.

In all other respects, cross ADEV measurements are similar to those obtained in the other measurement roles. When a single reference source is used, the primary and secondary phase- and frequency-difference records will be virtually identical to each other except for differences in instrument noise (although the secondary phase record is accessible only when the *Additional options>Create secondary-channel plots* box is checked in the 53100A acquisition dialog.) Phase noise and AM noise measurements are unaffected by the cross ADEV process or any other aspects of stability measurements. They will be performed as usual, based on the 3-1 and 4-2 channel pairs by default.

TimeLab's cross ADEV implementation can be thought of as a four-channel application of the Groslambert Covariance (GCov) methodology.[1, 2] As a general guideline, traditional three-cornered hat tests should be performed only when three concurrent measurements of independent sources are actually needed. When only one source needs to be measured against either one or two references, the cross ADEV role will almost always return superior results in less measurement time.

1: Vernotte and Lantz, "https://arxiv.org/abs/1810.01530" Three-Cornered Hat and Groslambert Covariance: A first attempt to assess the uncertainty domains.

2: Stein, "https://www.microsemi.com/document-portal/doc_view/133170-the-allan-variance-challenges-and-opportunities" The Allan Variance – Challenges and Opportunities

6.10 TWO-PORT RESIDUAL MEASUREMENTS

Residual noise and stability measurements with the 53100A can be conveniently performed in the Measure single DUT with single external reference or Measure single DUT with cross ADEV statistics role. Typically a two-way 0° RF splitter is used to feed a signal from a common reference source to both the REFERENCE jack and the input of the device under test. The device's output, in turn, is connected to the 53100A's DUT input jack. To the extent the device contributes its own phase drift, phase noise, or AM noise to the stimulus signal passing through it, the impact will be evident on the respective measurement traces.

Residual measurements are an integral part of the 53100A production and maintenance processes. Each 53100A Phase Noise Analyzer ships with a test report showing the result of a two-hour residual measurement with 5 MHz and +15 dBm applied to the DUT and REFERENCE input ports via a Mini-Circuits ZFSC-2-1 splitter. The following notes will be helpful when conducting your own proof-of-performance measurements.

- At 50 Hz ENBW, residual ADEV at 5 MHz should be in the high E-14s at t=1s. Thermal effects may push the slope out somewhat, especially in an unstable environment or when warmup time has been insufficient. A look at the phase difference graph will often show a consistent phase slope for the first 30 to 60 minutes of a measurement made after a cold start.
- Typical results near 5E-15 at t=1s are achievable using the cross ADEV role at 5 Hz ENBW. This technique can improve the short-term measurement floor by up to 10x in cases where the 53100A's ADC noise is either limiting the available performance or is being measured itself.
- Residual PN at 5 MHz should be below –145 dBc/Hz at 10 Hz after a few minutes.
- With a strong, clean input signal at 5 MHz to 10 MHz, the residual PN floor in the 10 kHz to 1 MHz decades will usually end up near –185 dBc/Hz after less than two hours. Expect lower performance near either end of the supported frequency range. When possible, both proof-of-performance tests and actual two-port device measurements should be made in the 5 MHz to 10 MHz range where the 53100A's own residual performance is optimal.
- If the PC can support overlapped FFT processing, consider enabling this option by checking the *Additional Options>Overlapped Acquisition* box in the 53100A Acquisition dialog. Very low close-in noise levels will require much less measurement time when overlapping is enabled.
- 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. Spurs in phase noise plots should not exceed –100 dBc in a 5 MHz residual measurement, and will normally be much lower.
- High-quality double-shielded cables and coaxial interconnects are vital for low-noise, high stability measurements. Cabling used in residual tests should be kept as short as possible.

Some typical residual performance test results are reproduced below.

FIGURE 6-7: *5 MHz Residual ADEV and Phase Drift.*

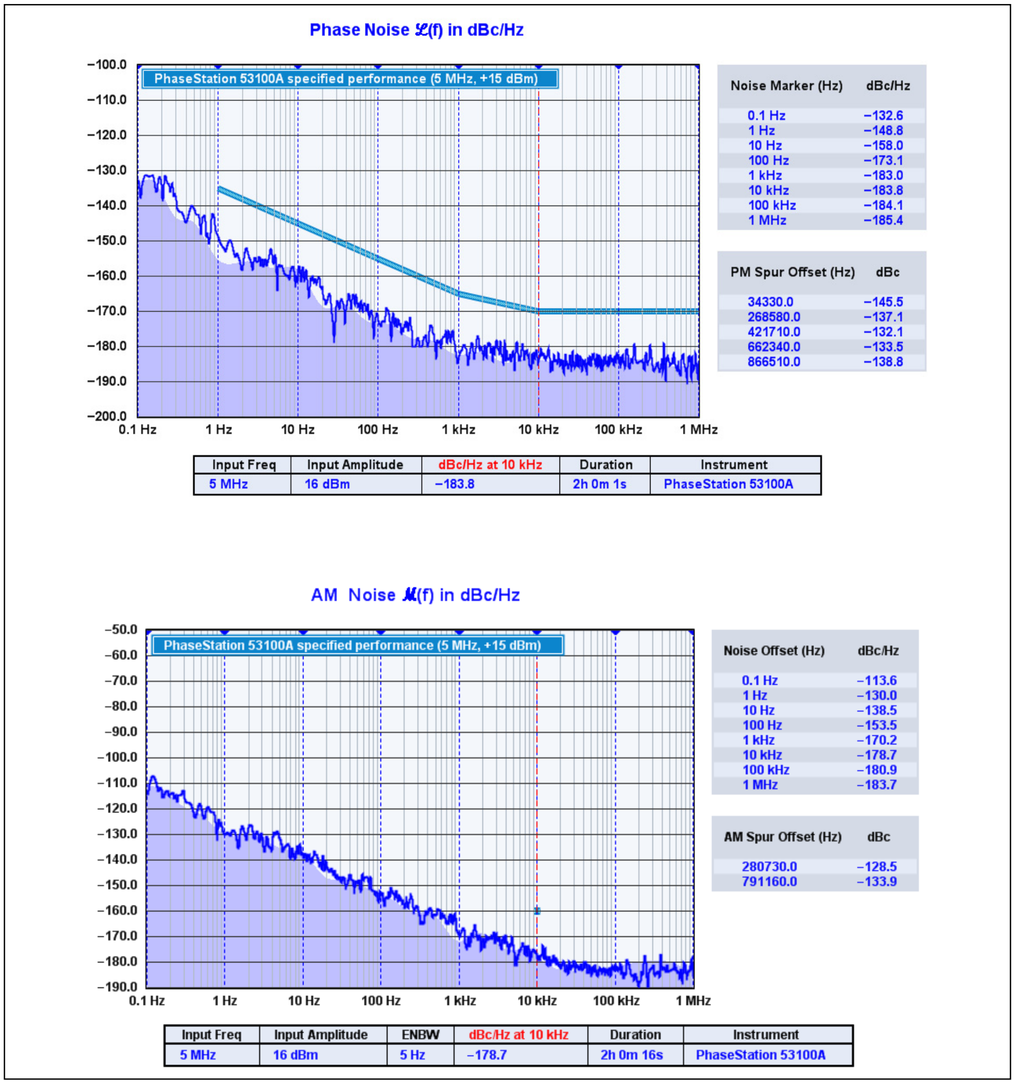


FIGURE 6-8: *5 MHz Residual Phase Noise and AM Noise.*

Note that the 53100A's Allan deviation performance limits are specified for both conventional and cross ADEV measurement roles. The best achievable ADEV performance floor is obtained in cross ADEV mode. Refer to **Section 6.9 "Cross Allan Deviation Measurements"** for more information and examples.

Chapter 7. JavaScript API Function Reference

TimeLab includes an embedded JavaScript[1] engine that can run automated test scripts using the 53100A Phase Noise Analyzer. The API functions listed below are useful in a variety of applications ranging from performance verification procedures to user-developed test scripts.

Usage examples for many of these API functions can be found in the `53100A_performance_test.js` script included with TimeLab, as well as `5330A_performance_test.js` and `5330A_ADC_test.js`. In addition to the user performance test scripts, TimeLab includes two other examples showing how to accomplish various tasks under script control. `53100A_3_cornered_hat.js` demonstrates how to launch an automated 3-cornered hat stability measurement that will run for 12 hours, periodically saving the results while the test is running, while `53100A_command_line_example.js` illustrates one way to create a complete automated test procedure by launching TimeLab to run a script from an external shell, application, or environment with specified parameters and termination behavior.

Review the comments in these scripts to learn how to configure, run, and adapt them. For more information on creating, editing, and running test scripts, refer to **Section 5.8 "Scripts Menu"**.

`AcqChannel([Number user_value, ] Number channel)`

Returns the position in the legend table beneath the graph, from 0 to 8, of the plot associated with the script instance's specified acquisition channel. Because plots being acquired under script control may be moved up and down in the legend table by the user like any other loaded plots, `AcqChannel()` is needed to obtain the value needed when calling `ScriptBindToPlot()` in multichannel acquisitions.

The `channel` parameter should range from zero to one less than the value returned by `AcqNumChannels()`. If two parameters are passed, the first is the `user_value` that was originally passed to `AcqStartAcquisition()` when the plot at the desired index was created.

Scripts that perform only standard single-channel acquisitions will not need to use this function.

`AcqCheckOptions(String option_name [{, String option_name}])`

This function is reserved for compatibility with Microchip/Symmetricom 3120A test scripts. It always returns TRUE in scripts associated with 53100A measurements.

`AcqClearParams()`

Each script instance maintains a dictionary of acquisition parameters that can be used to override any or all of the acquisition dialog parameters when `AcqStartAcquisition()` is called. `AcqClearParams()` clears this dictionary. It is normally called before issuing the `AcqSetParam()` call(s) needed to configure the measurement.

Acquisition parameters that the script does not explicitly set with `AcqSetParam()` will assume their default values when the measurement begins.

See `AcqNumParam()`, `AcqStrParam()`, and `AcqSetParam()` for more information.

1: https://v8.dev

AcqFreqErr([Number avg_secs])

This function retrieves the fractional frequency error from the count chart in the frequency-difference measurement view. The fractional frequency error is based on the value displayed in the legend table's **Input Freq** field, which is usually (but not necessarily) equal to the DUT frequency.

The averaging window specified by `avg_secs` begins at the most recently-received data point at the right end of the trace and extends backward in time. Omitting `avg_secs` or specifying a value of 0 will return the average fractional frequency error for the entire phase record.

AcqFreqMHz([Number avg_secs])

Same as `AcqFreqErr` but returns the absolute frequency count in MHz over the specified window.

AcqGetAMSpurTable(Array offset_array, Array amplitude_array)

Populates `offset_array` and `amplitude_array` with a list of all detected AM spurs in the current measurement, returning the total number of AM spurs.

AcqGetPMSpurTable(Array offset_array, Array amplitude_array)

Populates `offset_array` and `amplitude_array` with a list of all detected PM spurs in the current measurement, returning the total number of PM spurs.

AcqGetXDEVBins(String selection, Array tau_array, Array sigma_array)

AcqGetXDEVChart(Array tau_array, Array sigma_array)

Populates `tau_array` and `sigma_array` with a list of sigma(tau) values from all valid bins in the specified statistical measurement, or from the most recently rendered sigma(tau) chart, depending on which function is called. The selection parameter passed to `AcqGetXDEVBins()` should be a string beginning with '`a`', '`h`', '`m`', or '`t`', corresponding to Allan Deviation, Hadamard Deviation, Modified Allan Deviation, or Time Deviation, respectively.

The `AcqGetXDEVBins()` function differs from `AcqGetXDEVChart()` in that `AcqGetXDEVChart()` returns results only for the 1, 3, 10 tau multiples beginning at t=1s that were displayed in the most-recently-visible numeric table for the measurement. Before calling `AcqGetXDEVChart()`, you should use `MeasurementSelectView()` or `MeasurementDeferSelectView()` to display the statistical measurement for which the chart contents should be returned. Additionally, `TraceShowNumTab(true)` should be called to ensure that the numeric table is visible, and the script must allow time for at least one frame to be rendered. `AcqGetXDEVBins()` does not have any of these constraints.

AcqNumAcquiredPoints()

Returns the number of acquired points in the phase data record.

AcqNumChannels()

Returns the number of acquisition channels in the measurement associated with the script instance.

In scripts that perform only standard single-channel acquisitions, this function always returns 1.

AcqParam(String key)

AcqStrParam(String key)

AcqNumParam(String key)

Each script instance maintains a dictionary of acquisition parameters that can be used to override any or all of the default acquisition dialog parameters when `AcqStartAcquisition()` is called. `AcqStrParam()` and `AcqNumParam()` return string or numeric values, respectively, for the specified acquisition parameter.

If an existing plot is associated with the script instance, these functions will return the specific value associated with the plot. Otherwise, if the script has not yet started a measurement, `AcqStrParam()` and `AcqNumParam()` will return the value from the dictionary of initial parameters that will be passed to `AcqStartAcquisition()`. In either case, an attempt to look up an unrecognized parameter value will return an empty string.

The `AcqParam()` function is equivalent to `AcqStrParam()`, and is deprecated as a function name. New scripts should use `AcqStrParam()` or `AcqNumParam()` instead, depending on whether the parameter should be evaluated as a numeric value or as an arbitrary string.

See `AcqSetParam()` and `AcqClearParams()` for more information.

AcqReadAMNoiseTrace(Number offset_Hz)

AcqReadPMNoiseTrace(Number offset_Hz)

These functions return the current AM noise or phase noise level in dBc/Hz at the specified offset from the carrier. A value greater than 0 indicates that data is unavailable, either because the AM noise or phase noise trace has not yet been displayed or because noise data from the FFT segment containing the specified offset frequency is not yet available.

Values returned by these functions are based on the most recent AM noise or phase noise trace rendered.

AcqReadAMNoiseFloor(Number offset_Hz)

AcqReadPMNoiseFloor(Number offset_Hz)

These functions return the estimated AM noise or phase noise floor in dBc/Hz at the specified offset from the carrier. A value greater than 0 indicates that data is unavailable, either because the AM noise or phase noise trace has not yet been displayed or because noise data from the FFT segment containing the specified offset frequency is not yet available.

Values returned by these functions are based on the most recent AM noise or phase noise trace rendered. The noise floor values undergo spline smoothing at a relatively low resolution, and should be treated as rough estimates rather than definitive limits.

AcqSetParam(String key, String value)

Each script instance maintains a dictionary of acquisition parameters that can be used to override any or all of the acquisition dialog parameters when `AcqStartAcquisition()` is called. `AcqSetParam()` updates the stored value for the specified acquisition parameter.

The best way to obtain a list of measurement parameter names and values for a given instrument is to use the Save Measurement Script button in the Utility tab of the acquisition dialog to create a script that will contain explicit `AcqSetParam()` statements for each supported parameter. Almost all parameters will have obvious counterparts in the instrument’s acquisition dialog; you can also refer to **Section 5.5 “Legend Menu”** for individual descriptions.

See `AcqStrParam()`, `AcqNumParam()`, and `AcqClearParams()` for more information.

`AcqStartAcquisition(String menu_entry, Boolean skip_dialog [, Number user_value])`

Starts a new measurement based on the script instance's current set of acquisition parameters.

The `menu_entry` parameter should correspond exactly to the name of the instrument as it appears on the Acquire menu, including any ellipsis (...) that follows it. Currently Miles Design TimePod ..., Jackson Labs PhaseStation ..., and Microchip 53100A ... are the only officially supported instruments for scripted measurements, so one of these strings must be supplied as the `menu_entry` value.

With a script-initiated measurement, the initial acquisition parameters are the same as the default values in a fresh TimeLab installation. These default parameters are then overwritten with any entries that appear in the script instance's acquisition-parameter dictionary, as described in `AcqNumParam()`, `AcqStrParam()`, and `AcqSetParam()`. Unlike a manual measurement, script-based measurements do not write their parameters back to the driver's `.INI` file. As a result, the dialog defaults that will appear in the next user-initiated acquisition will not reflect the parameters used for the last scripted acquisition.

Next, if `skip_dialog` is false, TimeLab will present the acquisition dialog to the user, allowing any parameters to be changed before the measurement begins. In most cases, `skip_dialog` should be set to true to allow the script to run without further user intervention. This will be the case for measurement scripts created with the Save script button in the acquisition dialog.

The `AcqStartAcquisition()` function will return true if the acquisition is initiated successfully, or false if an error occurred. Reasons for failure might include the lack of an available slot in the legend table for the plot(s) created by the acquisition, the use of an unrecognized `menu_entry` name, the specification of an invalid acquisition parameter value with `AcqSetParam()`, or (if `skip_dialog` is false) the user's selection of the **Cancel** button.

Once the measurement begins collecting data, the script's `EventAcqTriggered()` event handler (if any) will be called. Prior to this stage, the script's `EventAcqSetup()` handler will be called if one is defined. Because `AcqStartAcquisition()` returns immediately after launching the acquisition thread, measurement-specific parameters such as Input Freq will not be available to the script until `EventAcqTriggered()` is called.

Optionally, a third parameter may be passed, consisting of an arbitrary numeric `user_value` which will be made available to subsequent event handlers.

`AcqStopAcquisition()`

Immediately stops any acquisition associated with the running script instance and calls the script's `EventAcqDone()` handler (if any). Unless a fatal error occurs, the plot(s) will not be closed and the script will continue to run until `ScriptEnd()` is called.

`AcqSetupEnd()`

Applications that include `EventAcqSetup()` handlers must call `AcqSetupEnd()` when their setup phase is complete. Until `AcqSetupEnd()` is called, the 53100A driver will remain in an endless loop awaiting further setup commands from the script.

`DisplayFontSize([Number points])`

Sets or returns the size of the main display font size used in the TimeLab window. This is the same value that is adjusted by the commands on the **Display** menu.

If no parameter is specified, the current font size is returned without alteration.

DisplayNoiseMarkers([String marker_list])

Returns, and optionally clears or specifies, a comma-separated list of noise marker Fourier offset frequencies for the *Measurement>Phase Noise* and *Measurement>AM Noise* views.

If the `marker_list` argument is empty, the noise marker list will be cleared. Otherwise, the submitted string is treated as a list of offset frequencies that will replace the existing list (if any). In all cases, including when the argument is omitted entirely, the previous set of noise marker offset frequencies is returned as a comma-separated list.

DisplayOverlayMode([Boolean overlay_mode])

Equivalent to the *Display>Browse Plots One at a Time* <b> or *Display>Overlay All Loaded Plots* <o> command, depending on the `overlay_mode` parameter.

The `overlay_mode` parameter is optional; if it is not provided by the script, the function simply returns true in Overlay mode or false in Browse mode. If a new `overlay_mode` value is specified, the function returns the previous display mode.

DisplayPlotVisibility(Number selection [, Boolean status])

Returns the visibility status of the plot at the specified position in the legend table beneath the graph. True indicates that the plot is visible, while false indicates that its visibility has been turned off by the user or by a previous call to this function.

If the optional `status` argument is provided, the selected plot's visibility state will be set to that value before returning the previous visibility state.

DisplayShowIntTraces([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Display>Show integrated PN traces*.

To return the current flag value, call `DisplayShowIntTraces` with no argument.

DisplayShowNumTab([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Display>Numeric Table* <Ctrl-n>. Refer to this command for more information.

To return the current flag value, call `DisplayShowNumTab()` with no argument.

DisplayRefresh([Number mask])

Forces an immediate display refresh that includes the elements specified by `mask`. If no parameter is passed, all display elements are refreshed.

Currently defined display elements include the following:

```
const U32 RCF_STATUS    = 0x0001; // Status line
const U32 RCF_SELECTION = 0x0002; // Triangle cursor for
                                     selected plot in table
const U32 RCF_BANNERS   = 0x0004; // Colored status tags
const U32 RCF_CURSORS   = 0x0008; // Dragged selection cursors
const U32 RCF_MOUSEOVER = 0x0010; // Mouseover information
                                     display
const U32 RCF_TTY       = 0x0020; // Script TTY window
const U32 RCF_ALL       = 0x003F; // All elements above
```

DisplaySpotTau(Number secs)

Sets the location of the spot cursor on Allan deviation and related log-log statistical plots to the desired tau interval in seconds, returning the previous cursor location.

DisplaySpotTime(Number secs)

Sets the location of the spot cursor on phase- and frequency-difference plots to the desired X-axis value in seconds, returning the previous cursor location.

DisplaySpotOffset(Number Hz)

Sets the location of the spot cursor on phase noise and AM noise plots to the desired Fourier offset in Hz, returning the previous cursor location.

DisplaySpotLowerOffset(Number Hz)

Sets the location of the lower integration limit cursor on phase noise plots to the desired Fourier offset in Hz, returning the previous cursor location.

DisplaySpotUpperOffset(Number Hz)

Sets the location of the upper integration limit cursor on phase noise plots to the desired Fourier offset in Hz, returning the previous cursor location.

DisplayYAxisHz([Boolean status])

Sets and/or retrieves the status of the flag controlled by *Display>Frequency Y axis labels in Hz*. To return the current flag value, call `DisplayYAxisHz` with no argument.

EventAcqDone([success][,user])

This is an optional user-supplied function. `EventAcqDone()` is called when an acquisition ends, either because the requested measurement duration expired, because an error occurred, or because it was stopped manually by the user. The optional success parameter is a Boolean value that indicates whether the hardware driver reported any errors during the measurement. The optional user parameter receives the optional user variable passed to `AcqStartAcquisition()`.

See `EventRunScript()` for further information.

EventAcqSetup([user])

This is an optional user-supplied function. `EventAcqSetup()` is called after a measurement running on a 53100A has connected to the target instrument, but before it enters the pretrigger state in preparation for data acquisition. The optional user parameter receives the optional user variable passed to `AcqStartAcquisition()`.

During the setup phase, a number of additional setup-related API functions are available. The user setup handler typically uses these functions to communicate with the 53100A to query operational parameters, validate correct operation, and identify signal frequencies and amplitudes at the input jacks. The setup handler may also need to communicate with other equipment in certain applications.

In order to proceed to the pretrigger phase, the setup handler must exit by calling `AcqSetupEnd()`. Most scripts other than diagnostic applications will not need to implement a setup handler.

EventAcqTriggered([user])

This is an optional user-supplied function. `EventAcqTriggered()` is called when a measurement initiated by `AcqStartAcquisition()` begins collecting data. Typically this happens a few seconds after `AcqStartAcquisition()` is called by the user-provided `EventRunScript()` function, unless the deferred acquisition options on the Acquire menu have been used to postpone data collection. The optional user parameter receives the optional user variable passed to `AcqStartAcquisition()`.

Any errors that occur between `EventRunScript()` and `EventAcqTriggered()` automatically terminate script execution.

See `EventRunScript()` for further information.

`EventRunScript()`

This is a mandatory user-supplied function that must appear in every TimeLab script. It is called when the user issues ***Scripts>Run Script*** or a similar command, and serves as the entry point for script execution.

Typically, `EventRunScript()` does little more than set up the appropriate acquisition parameters and call `AcqStartAcquisition()`, returning immediately afterwards. Subsequently, the script's `EventAcqTriggered()` handler is called by TimeLab when the acquisition begins collecting data after the optional `EventAcqSetup()` phase. `EventAcqTriggered()`, in turn, may use `TimeSetTimer()` to arrange for periodic callback service to `EventTimer()`. Scripts that need to perform extensive measurement supervision and control operations normally do so within their `EventTimer()` handlers, while final result evaluation and report generation is done within `EventAcqDone()`.

For a detailed look at the operation and overall life cycle of test scripts, refer to the `53100A_performance_test.js` script provided with TimeLab, as well as the other API function descriptions in this section.

`EventTimer()`

This is an optional user-supplied function. `EventTimer()` is called periodically at a rate determined by the parameter passed to `TimeSetTimer()`.

Because TimeLab's scripting system relies on cooperative multitasking, most non-trivial scripts should carry out the majority of their processing work in their `EventTimer()` handler while their measurement(s) are in progress. For detailed examples of timer usage, refer to `53100A_performance_test.js` and `5330A_ADC_test.js`. Also see `EventRunScript()` for further information.

`FileCloseAllChannels()`

Closes all plot(s) acquired in the most recent measurement executed by the script, stopping any acquisition(s) that may still be in progress. For conventional single-channel measurements, `FileCloseAllChannels()` is equivalent to calling `FileClosePlot()` with no argument.

As an example, `53100A_performance_test.js` uses `FileCloseAllChannels()` in its `EventAcqDone()` handler to discard the two plots generated during the preliminary warmup acquisition that the script performs before running the actual test. Because the warmup acquisition has already terminated at this point, `EventAcqDone()` is not reissued. Simply calling `FileClosePlot()` here would have closed only the first of the two plots.

`FileCloseAllPlots()`

Equivalent to calling `FileClosePlot()` on all loaded plots. For example, `5330A_ADC_test.js` uses `FileCloseAllPlots()` to ensure that enough slots are available in the legend table to hold the four plots that it acquires for various ADC combinations.

`FileClosePlot([Number selection])`

If the optional `selection` parameter is specified, `FileClosePlot()` closes the plot at the specified position in the legend table, from 0 to 8. Because plots being acquired under script control may be moved up and down in the legend table by the user like any other loaded plots, `AcqChannel()` is needed to obtain the value passed to this function if the intent is to close any of the plot(s) that are associated with a measurement launched by the script.

Alternatively, `selection` may be omitted. In this case, the function closes the plot associated with the first channel of the most recent measurement executed by the script.

In both cases, calling `FileClosePlot()` on a plot associated with a given measurement will stop any acquisition(s) in progress that were initiated by that measurement. The script's `EventAcqDone()` handler, if any, will be called for any acquisitions that were terminated by `FileClosePlot()`.

`FileExecute[Wait](String path_to_file [, String params])`

`FileExecute()` attempts to execute or otherwise open the specified file using the "open" verb with the Win32 `ShellExecute()` API function. If `ShellExecute()` returns successfully, `FileExecute()` returns true; otherwise, if an error occurred, it returns false.

An alternative version of this function, `FileExecuteWait()`, pauses execution of TimeLab until the spawned process exits. `FileExecuteWait()` uses the Win32 `CreateProcess` and `WaitForSingleObject()` APIs rather than `ShellExecute()`, but otherwise behaves similarly.

The `path_to_file` parameter should be a fully qualified pathname. Optionally, a string consisting of one or more parameters may be passed to `ShellExecute()` via the `params` argument.

As an example, `FileExecute()` is used by `53100A_performance_test.js` to view the generated HTML report page on the system's web browser.

`FileExitApplication([code])`

When called, this function causes the TimeLab process to exit to the command shell or other launching process with the specified exit code. If no parameter is provided, the returned exit code is 0.

Process termination occurs when the JavaScript function that called `FileExitApplication()` returns. It is not necessary to clean up resources by calling `TimeSetTimer(0)` or `ScriptEnd()`; the calling function may return immediately after calling `FileExitApplication()` to request termination.

See the `EventTimer()` handler in `53100A_command_line_example.js` for a detailed usage example.

`FileExists(String path, [String subdir,] String filename)`

Returns a Boolean value of true if the specified file can be opened for reading, false otherwise.

By default, if `path` is empty, the user's Documents folder is treated as the path. This path must already exist. The `subdir` parameter is optional; it represents a subdirectory relative to `path` that contains the specified file. Unlike `path`, the `subdir` folder will be created automatically if it does not already exist.

This function can be used to poll for signals from external or host processes that create empty files with specific names. See the `EventTimer()` handler in `53100A_command_line_example.js` for a detailed usage example.

`FileExportASCIIData(String descriptor, String path, [String subdir,] String filename)`

This function writes phase-difference samples from the phase data record, sigma(tau) data from the ADEV, MDEV, HDEV, TDEV, or MTIE bins, or AM/PM noise or spur data to the specified ASCII text file, depending on which measurement has most recently been selected for display with `MeasurementSelectView()`. In most cases, the exported data comes from the plot that is currently associated with (bound to) the measurement script.

The `descriptor` parameter is a case-insensitive text string, in which the presence or absence of certain characters influences the composition of the exported data as outlined below.

Phase/frequency difference views: Each phase-difference or absolute frequency sample may be preceded by an optional timestamp. This will be the case if the `descriptor` string contains the characters “M”, indicating that Modified Julian Date timestamps should be written to the file prior to each exported sample, or “T”, indicating that each data point should be prefaced by its sample time in seconds relative to the beginning of the phase record. If the string contains a comma, the timestamp and sample values will be separated by a comma followed by a single space; otherwise, they will be separated by a single space.

Allan deviation and other stability measurements: The output file will consist of a series of individual bin records, each of which appears on its own line with the tau and sigma(tau) values. By default these values are separated by a single space, but if the `descriptor` parameter contains a comma, a comma followed by a single space will be used.

If a three-cornered hat display is currently visible at the time `FileExportASCIIData` is called, there will be a total of four columns in each exported line, consisting of the tau value followed by the separated deviation figures for each unique source in the measurement. If the `descriptor` parameter contains a “#” or “;” character, that character will appear at the beginning of a comment in the first line of the file which will contain the word “Tau” followed by the names of the sources associated with each column. Otherwise, no comment line will be written. Note that any degenerate bin values in three-cornered hat displays will be replaced with the placeholder “NaN” (Not a Number).

Phase noise and AM noise measurements: By default, each line in the exported file will consist of the Fourier offset frequency, a separator substring, and the L(f) or M(f) value in dBc/Hz at that offset frequency. As with other data types, the separator will be either a comma followed by a space if `descriptor` contains a comma, or a single space by itself if not.

If the `descriptor` string associated with an export operation in the phase noise view contains an “i” character, at least one integrated noise type has been selected for display in the legend table, and *Display>Show integrated PN traces* is enabled, then one or more files containing integrated phase noise data will be written instead of a single file containing offset and L(f) values. As before, a two-column format with optional comma separators is used, where the offset frequency appears in the first column and the integrated noise value appears in the second column. Each filename will consist of the portion of the specified filename prior to any suffix, followed by “_xxx” where xxx is the name of the selected integrated phase noise type (SSB_CNR_dB, RMS_rads, RMS_degs, resid_FM_Hz, or RMS_jitter_s) if more than one integrated noise type is visible, followed by the suffix portion of the specified filename.

Finally, if the `descriptor` contains the letter “s”, the spur chart for an AM or phase noise measurement will be exported instead of the noise data, again with each entry consisting of the offset frequency followed by the spur amplitude at that offset frequency.

By default, if `path` is empty, the user’s Documents folder is treated as the destination path. This path must already exist. The `subdir` parameter is optional; it represents a subdirectory relative to `path` in which the destination file will be saved. Unlike `path`, the `subdir` folder will be created automatically if it does not already exist.

The `FileExportASCIIData()` function returns a string containing the exported file's fully qualified pathname, or that of the last file written in the case where multiple integrated noise files are exported. Any errors that occur will not be reported to the script. They will result in a JavaScript exception which will terminate the script with an appropriate error message.

To export data from multiple plots in a multichannel measurement, you must use `ScriptBindToPlot()` to associate the script with the channel whose data is to be exported. See `53100A_data_export_example.js` for an example. The only exception to this is the three-cornered hat case described above, where all visible three-cornered hat traces will be exported regardless of the file associated with the script.

FileImageURI()

Returns a `.GIF` image of the current TimeLab display in the form of an HTML data URI.

FileLoad(String path, [String subdir,] String filename)

Reads the specified `.TIM` file into memory and allocates a plot for it, just as if the plot had been created by calling `AcqStartAcquisition()`. On success, the fully qualified pathname of the loaded file is returned.

Typically, `DisplayRefresh()` should be called after `FileLoad()` in order to display the newly loaded file and make the measurement data available to other JavaScript API functions.

An exception is thrown if the file could not be loaded or if the script is already bound to an existing plot. `ScriptUnbind()` must be called prior to `FileLoad()` in this case.

By default, if `path` is empty, the user's Documents folder is treated as the path. This path must already exist. The `subdir` parameter is optional; it represents a subdirectory relative to `path` that contains the specified file. Unlike `path`, the `subdir` folder will be created automatically if it does not already exist.

FileNumLoadedPlots()

Returns the number of currently loaded plots, from 0 to 9.

FileNumUnsavedPlots()

Returns the number of currently loaded plots, from 0 to 9, that have not been saved since being acquired or modified.

FileSave(String path, [String subdir,] String filename)

Based on the (case-insensitive) suffix of `filename`, `FileSave()` saves either a screen image in `.TGA, .GIF, .BMP, .PCX`, or `.PNG` format, or a `.TIM` file representing the measurement currently associated with the script.

By default, if `path` is empty, the user's Documents folder is treated as the destination path. This path must already exist. The `subdir` parameter is optional; it represents a subdirectory relative to `path` in which the destination file will be saved. Unlike `path`, the `subdir` folder will be created automatically if it does not already exist.

The `FileSave()` function returns a string containing the saved file's fully qualified pathname. Any errors that occur will not be reported to the script. They will result in a JavaScript exception which will terminate the script with an appropriate error message.

To save `.TIM` data from multiple plots in a multichannel measurement, you must use `ScriptBindToPlot()` to associate the script with channels other than the first one. See `53100A_performance_test.js` for an example.

FileSaveText(String path, [String subdir,] String filename, String contents)

The `FileSaveText()` function saves the ASCII `contents` string to `filename`. As with
`FileSave()` above, the user's Documents folder is treated as the destination folder if

`path` is empty. Any explicitly specified `path` must already exist. The `subdir` parameter is optional; it represents a subdirectory relative to `path` in which the destination file will be saved. Unlike `path`, the `subdir` folder will be created automatically if it does not already exist.

This function returns a string containing the saved file's fully qualified pathname. Any errors that occur will not be reported to the script. They will result in a JavaScript exception which will terminate the script with an appropriate error message.

As an example, `53100A_performance_test.js` uses `FileSaveText()` to save its HTML report.

`LegendSelect([String field_name] [,] [Boolean status])`

Controls and/or reports the visibility of a given parameter (`field_name`) in the legend table beneath the graph.

This function's arguments may consist of a single Boolean value, in which case it will select or deselect all legend fields in a manner similar to the *Legend>All* or *Legend>None* menu commands; a single String value, which will simply return the visibility state of the specified `field_name` without changing it; or both String and Boolean parameters, which will show (`status`==true) or hide (`status`==false) the specified `field_name` in the table and return its previous state.

`MaskResultMargin([Number mask_num])`

Returns a Number value representing the margin by which the measurement associated with the script is passing (if positive) or failing (if negative) the mask test selected by `MaskSelect()`. The returned value is based on the most recently rendered frame, so it is dependent on both the current measurement view and the specified mask.

Refer to **Section 5.7 "Masks Menu"** for more information about TimeLab's mask-test functionality. Up to five masks may be selected at once. The optional `mask_num` parameter ranges from 0 to 4, defaulting to 0 if not specified.

NOTICE
Keep in mind that JavaScript execution does not disable or inhibit the rest of the TimeLab user interface. While test masks are easy to create and use in TimeLab, script-based mask evaluation is complicated by the need to establish the correct measurement view, allow enough time for the display to update, and wait for valid results to become available for the X-axis range covered by the mask, all while allowing for the user's ability to switch measurement views, move plots up and down in the legend table, or alter other settings manually at any time.

Typically the best way to coordinate the necessary script actions while allowing for manual user intervention is to use an `EventTimer()` handler to check the mask results and the current measurement view selection at the same time, then make any changes (such as selecting the next measurement view for evaluation) at the very end of the timer handler. Script authors are strongly encouraged to use the `EventTimer()` handler in `53100A_performance_test.js` as a model for their own mask-test procedures.

`MaskResultValid([Number mask_num])`

Returns true if valid data is available from `MaskResultMargin()`, or false if the mask test was not ready for evaluation for any reason. For example, ADEV mask results will not be available if the measurement has not yet run long enough to return valid data at the tau corresponding to the left endpoint of the mask limit line, or if the user has turned visibility off for the plot associated with the script. Always check `MaskResultValid()` prior to calling `MaskResultMargin()`. The optional mask_num parameter ranges from 0 to 2, defaulting to 0 if not specified.

See `MaskResultMargin()` for other notes on scripted mask tests.

`MaskSelect([String mask_name [, Number mask_num])`

This function selects a mask for use with `MaskResultMargin()` and `MaskResultValid()`, returning the previously-selected mask if any. The `mask_num` parameter ranges from 0 to 2, defaulting to 0 if not specified.

Specifying an empty string ("") for `mask_name` will deselect the mask in the specified slot, or deselect all masks if `mask_num` is not specified. If `mask_name` is omitted, the function returns the currently-selected mask name for slot 0. The function will return an empty string if no mask was selected.

Mask names should be specified exactly as they appear in the `masks.txt` file accessed via *Masks>Edit Mask Definitions*, which also determines the names under which they are added to the Masks menu. See `MaskResultMargin()` for other notes on scripted mask tests.

`MeasurementSelectView(String hotkey)`

`MeasurementDeferSelectView(String hotkey)`

These functions accept a `hotkey` parameter that consists of the (case-sensitive) shortcut key for the desired measurement view as it appears in the Measurement menu. For example, `MeasurementSelectView("P")` will emulate the <P> keyboard shortcut (*Measurement>Phase Noise* <P>).

If your script is performing mask tests with multiple measurement types, it's a good idea to call `MeasurementDeferSelectView()` as the last action taken before returning from `EventTimer()`. Upon the next invocation of `EventTimer()`, your script should call `MeasurementView()` and evaluate the masks or other test parameters for that view, regardless of any changes to the measurement view that may have taken place between timer ticks. Script authors are encouraged to use the `EventTimer()` handler in `53100A_performance_test.js` as a model for test procedures that use multiple measurement types.

The difference between `MeasurementSelectView()` and `MeasurementDeferSelectView()` is that the latter will not take effect until after the event handler returns. This distinction is important when multiple instances of the same script may be executed at once. Essentially, deferring the view selection until after all script instances with the same `EventTimer()` interval have been serviced leaves a single script instance in charge of the view, reducing opportunities for confusion.

`MeasurementView()`

Returns the current measurement view as a String containing the hotkey for the view as it appears in the Measurement menu. For example, when viewing a phase noise plot, `MeasurementView()` will return "`P`", the shortcut key for *Measurement>Phase Noise*.

See `MeasurementSelectView()` for additional notes on measurement view selection.

`Print(…)`

Displays one or more user-specified values in the script console window associated with the currently bound plot. Multiple arguments may be separated by commas; a line feed will be inserted after each argument. To avoid this, you can use string concatenation rather than multiple `Print()` arguments.

Numerous usage examples for the `Print()` function appear in `53100_performance_test.js` and `5330A_ADC_test.js`.

`ScriptBindToPlot(Number selection)`

Associates the script instance with the plot at the specified position in the legend table, from 0 to 8.

Most script authors will not need to use `ScriptBindToPlot()`. It is required only in scripts that support multichannel plots, such as `53100A_performance_test.js` and `5330A_ADC_test.js`. A script can be associated (or bound) to only one plot at a time, and most operations performed by a script implicitly involve the currently bound plot. When a measurement initiated by a script specifies multiple stability channels, as in the TimePod and 53100A validation scripts mentioned, it's necessary to use `ScriptBindToPlot()` to access the plots that represent all channels of the measurement.

By default, scripts are bound to channel 0 of a multichannel acquisition. It's a good idea to restore the default channel 0 binding with `ScriptBindToPlot(AcqChannel(0))` before returning from any function or event handler that uses `ScriptBindToPlot()`.

Because plots in multichannel measurements may be moved up and down in the legend table by the user, `ScriptBindToPlot()` is normally used together with the `AcqChannel()` function. See the two performance test scripts mentioned above for further comments and usage examples.

`ScriptBoundToPlot()`

Returns the position in the legend table beneath the graph, from 0 to 8, of the plot to which the script is currently bound.

Most script authors will not need to use `ScriptBoundToPlot()`. It is required only in scripts that support multichannel plots, such as `53100A_performance_test.js` and `5330A_ADC_test.js`.

`ScriptEnd()`

Marks the script for cleanup by the TimeLab runtime JavaScript engine. Scripts that are associated with loaded plots must be terminated with a call to `ScriptEnd()` when finished. Otherwise, they will continue to run and consume resources until one of the following conditions is true:

- A script exception or other fatal error occurs
- The *Scripts>Stop All Running Scripts* <F12> command is issued by the user
- The user exits from TimeLab

`ScriptFilename(Boolean full_path)`

If `full_path` is true, `ScriptFilename()` returns a String containing the fully qualified path to the script's JavaScript (`.js`) source file. Otherwise, it returns only the filename itself.

`ScriptGetString(String heading, String message, Object user_text, String b1_text [, String b2_text [, String b3_txt]])`

Presents a modal dialog box to the user that accepts freeform text entry. An example appears below.

```
var trace_caption = { value:"(Some default text could go here)"
};
if (ScriptGetString( "OCXO Stability Test",
                     "Enter trace caption above, then click 'OK'
to continue.",
                     trace_caption,
                     "OK",
                     "Cancel") != 0)
{
ScriptEnd();
return;
```

```
}
```

When executed, the result is a dialog box of the form.

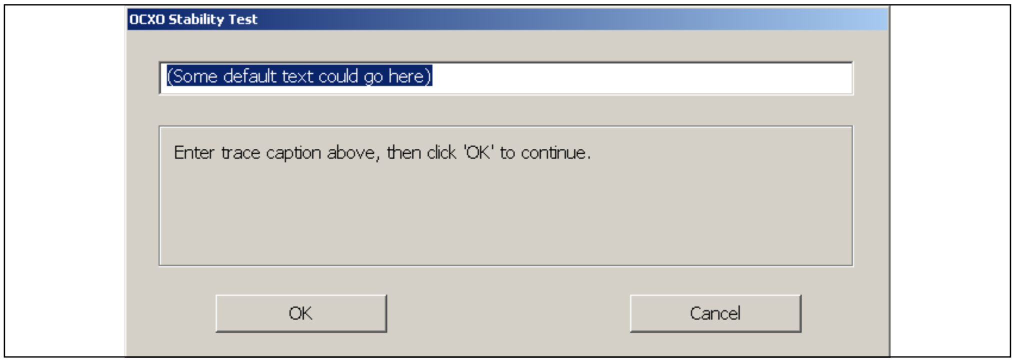


FIGURE 7-1: *ScriptGetString() Dialog.*

Text for one, two, or three buttons can be specified as the `b1_text, b2_text`, and/or `b3_text` argument(s) to `ScriptGetString()`. The returned value will equal the numeric index of the button selected by the user, beginning with 0 for the `b1_text` button.

All text fields accept up to 1024 bytes. Note that the `user_text` argument is an Object containing a String property called `value`, not a String in itself. The `value` property is used both as the default text used to initialize the edit control and for reception of the returned text. This is necessary because Strings are always passed by copy in JavaScript, while Objects are passed by reference and may be modified by the called function.

`ScriptHostFilename([bool full_path])`

Returns a String containing the TimeLab executable filename and version information. Either the full pathname or only the filename portion may be requested, depending in the value of the optional `full_path` parameter.

`ScriptLastStatusMessage()`

Returns a String containing the most recent status message displayed by TimeLab. This function may be useful for logging and report generation.

`ScriptMessageBox(String heading, String message, String b1_text [, String b2_text [, String b3_txt]])`

Presents a modal dialog box to the user that accepts button presses. An example appears below.

```
if (ScriptMessageBox( "Manufacturing Test",
                      "Connect input signals and click 'OK' to
continue.",
                      "OK",
                      "Cancel") != 0)
{
ScriptEnd();
return;
}
```

When executed, the result is a dialog box of the form.

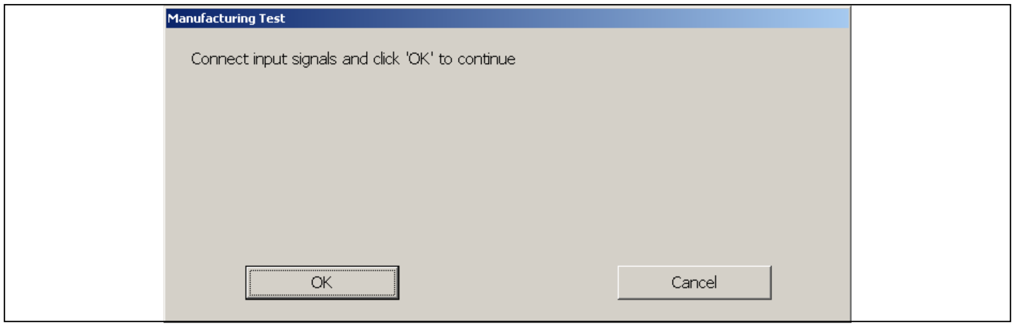


FIGURE 7-2: ScriptMessageBox() Dialog.

Text for one, two, or three buttons can be specified as the `b1_text, b2_text`, and/or `b3_text` argument(s) to `ScriptMessageBox()`. The returned value will equal the numeric index of the button selected by the user, beginning with 0 for the `b1_text` button.

`ScriptMinsToHMS(Number minutes)`

Returns a String representing the `minutes` argument as hours, minutes, and seconds.

Example: The following statement

```
Print(ScriptMinsToHMS(10.5));
```

will display:

```
10m 30s
```

`ScriptNumParam(Number n )`

Returns a Number corresponding to the floating-point numeric value of the nth (zero based) command line parameter following the JavaScript (.js) program name on the TimeLab command line. An exception will be thrown if the requested parameter is not present or is not representable as a numeric value.

See `53100A_command_line_example.js` for a detailed usage example.

`ScriptNumVal(String format_string, Number value)`

Returns a String consisting of the specified `format_string` with an embedded numeric `value`.

In operation, `ScriptNumVal()` passes its `format_string` and floating-point `value` arguments to the standard C `sprintf()` function, returning the resulting formatted string.

Example: The following statement

```
Print(ScriptNumVal("Pi = %.2lf", 3.1415926535));
```

will display:

```
Pi = 3.14
```

Additional usage examples appear in both `53100A_performance_test.js` and `5330A_ADC_test.js`. Refer to the `sprintf()` documentation in the C runtime library reference for a detailed discussion of the format and precision specifiers supported for floating-point values.

`ScriptParamCount()`

Returns a Number value representing the number of command-line parameters following the JavaScript (.js) program name on the TimeLab command line. The result will be zero if no script was specified on the TimeLab command line, or if no subsequent parameter strings were passed on the command line.

See `53100A_command_line_example.js` for a detailed usage example.

`ScriptPlaySound(String filename)`

Plays the specified sound file. Sound files for use with this function are typically stored in the `.wav` format.

If `filename` contains a backslash character, TimeLab assumes it consists of a fully qualified path name and plays the sound from the filename exactly as specified. Otherwise, filenames without backslash characters are played from the TimeLab installation directory.

`ScriptSetTTYHeader(Number linenum [, String text])`

Sets and/or retrieves the text displayed at the top of the script TTY window that is associated with the plot(s) bound to the script instance.

The `linenum` argument specifies which of the first two TTY lines will be retrieved or updated; it must equal 0 or 1. The `text` argument is optional. If present, it will replace the existing text for the specified TTY line. Regardless, the function will return the contents of the specified line at the time it was called.

Note that the script TTY is associated with the most recent plot that has been acquired by the script or otherwise bound to it. All channels in a multichannel acquisition share the same TTY. The `Print` function will write its output to the TimeLab status line if no TTY is associated with the script, but `ScriptTTYHeader()` will fail with an exception. In most cases, you should not attempt to write to the TTY before `AcqStartAcquisition()` has been called.

`ScriptSetWindowPos([String text])`

Returns the current position and size of the TimeLab window on the Windows desktop, optionally setting a new position and size if the `text` argument is provided.

As an example, the command

var prev_layout = ScriptSetWindowPos("0x0, 1, (-1,-1), (-1,-1), (10,10,1410,970)");

will move the TimeLab window to occupy the region on the desktop whose upper-left and lower-right corners are (10,10) and (1410,970) respectively. A descriptor string for the previous window position will be returned.

Fields in the descriptor string other than the last four are reserved for system use and should not normally be altered.

`ScriptSetWindowTitle([String text])`

Returns the current TimeLab window title string, optionally setting a new window title if the `text` argument is provided.

`ScriptShowTTY([Boolean show])`

Shows or hides the script TTY window that is associated with the plot(s) bound to the script instance, returning the previous visibility state. If the `show` argument is omitted, the function will return the current visibility state without changing it.

The script TTY window becomes visible by default upon successful execution of `AcqStartAcquisition()`. However, because the TTY can obscure a large portion of the TimeLab graph display area, simple scripts that report little or no status information may wish to hide the TTY window. The user will still have the option to select *Scripts>Toggle Script Console for Selected Plot* <F11> to show the TTY manually.

Unlike the other TTY functions, `ScriptShowTTY()` may be called at any time. The visibility state that it establishes will be inherited by any subsequent plots that the script acquires.

`ScriptStrParam(Number n )`

Returns a String corresponding to the contents of the nth (zero-based) command line parameter following the JavaScript (.js) program name on the TimeLab command line. An exception will be thrown if the requested parameter is not present.

See 53100A_command_line_example.js for a detailed usage example.

ScriptUnbind()

Removes the association between the script instance and any plot to which it is bound.

SetupDetectSignals

SetupDetectedValid

SetupDetectedAmpldBfs

SetupDetectedFreqHz

SetupMeasureSignals

SetupMeasuredAmpldBm

SetupMeasuredFreqHz

SetupSetDefaultAttenuation

SetupStrQuery

SetupNumQuery

These setup API functions are supported only by the 53100A, and only when called from within an EventAcqSetup handler. They are currently reserved for internal use.

TimeHoursSinceTrigger()

TimeMinsSinceTrigger()

TimeSecsSinceTrigger()

These three functions return the elapsed time since the measurement currently associated with the script was triggered, if the measurement is still in progress. Otherwise, if the measurement is no longer in progress, the overall duration of the acquisition is returned.

The values returned are floating-point Numbers that equivalently represent the elapsed time in terms of hours, minutes or seconds.

TimeSetTimer(Number msec [, Boolean persist])

This function arranges for TimeLab to call the script's EventTimer() handler at regular intervals of msec milliseconds. Timer callbacks are made msec milliseconds after the previous call to the timer handler returned, meaning that if a timer handler runs for more than one service interval, missed intervals will not be made up.

Because TimeLab's scripting system relies on cooperative multitasking, most non-trivial scripts should carry out the majority of their processing work in their EventTimer() handler while their measurement(s) are in progress. For detailed examples of timer usage, refer to 53100A_performance_test.js and 5330A_ADC_test.js, as well as 53100A_command_line_example.js and 53100A_3_cornered_hat.js.

Prior to termination, a script that uses timer service should call TimeSetTimer(0) to discontinue further callbacks. By default, scripts are terminated automatically if a timer event occurs with no acquisition in progress. If the persist parameter is present and equal to true, automatic termination will not occur. This may result in script resource leakage if the user closes the script's plot(s) manually without terminating the script itself.

TraceAvgWindow([Number seconds])

Sets and/or retrieves the duration in seconds, from 0.01 to 10000.0, of the averaging window used for phase- and frequency-difference plots. An argument of 0 seconds disables averaging entirely.

The function returns the previous window duration. It may be called with no argument to return the current value without altering it.

See the *Trace>Averaging Window for Phase/Frequency Traces* <g> command for important information on trace averaging.

`TraceFreqZero([Boolean status])`

Sets and/or retrieves the `status` of the flag used by *Trace>Phase/Frequency Traces Begin at Zero* <z> when frequency-difference measurements are selected for viewing. Refer to this command for more information.

To return the current flag value for the frequency-difference view, call `TraceFreqZero()` with no argument.

`TraceMarkSpurs([Boolean status])`

Sets and/or retrieves the `status` of the spur-visibility flag controlled by *Trace>Mark Spurs in Noise Traces* <Ctrl-m>. Refer to this command for more information.

To return the current spur-visibility flag value, call `TraceMarkSpurs()` with no argument.

`TraceNCorneredHat([Boolean status])`

Sets and/or retrieves the status of the flag controlled by *Trace>Show separated xDEV variances (N-cornered hat)* <Ctrl-h>. Refer to this command for more information.

To return the current flag value, call `TraceNCorneredHat()` with no argument.

`TraceOverlayAMPM([Boolean status])`

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show AM Noise in PN View* <F8>. Refer to this command for more information.

To return the current flag value, call `TraceOverlayAMPM()` with no argument.

`TracePhaseFreqAutoY([Boolean status])`

Sets and/or retrieves the `status` of the flag controlled by *Trace>Phase/Frequency Y Axis Unlocked in Zoom Mode* <y>. Refer to this command for more information.

To return the current flag value, call `TracePhaseFreqAutoY()` with no argument.

`TracePhaseFreqResid([Boolean status])`

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show Linear Phase/Frequency Residual* <r>. Refer to this command for more information.

To return the current flag value, call `TracePhaseFreqResid()` with no argument.

`TracePhaseFreqTrend([Boolean status])`

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show Linear Phase/Frequency Trend* <Ctrl-t>. Refer to this command for more information.

To return the current flag value, call `TracePhaseFreqTrend()` with no argument.

`TracePhaseFreqZero([Boolean status])`

Sets and/or retrieves the `status` of the flag controlled by *Trace>Phase/Frequency Traces Begin at Zero* <z>. Refer to this command for more information.

To return the current flag value for the phase- or frequency-difference view, call `TracePhaseFreqZero()` with no argument.

`TracePhaseZero([Boolean status])`

Sets and/or retrieves the `status` of the flag used by *Trace>Phase/Frequency Traces Begin at Zero* <z> when phase-difference measurements are selected for viewing. Refer to this command for more information.

To return the current flag value for the phase-difference view, call `TracePhaseZero()` with no argument.

TraceShowCorrGain([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show Correlation Gain for Selected Noise Trace* <Ctrl-g>. Refer to this command for more information.

To return the current flag value, call `TraceShowCorrGain()` with no argument.

TraceShowCrossStatistics([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show cross ADEV traces when available* <Ctrl-j>. Refer to this command for more information.

To return the current flag value, call `TraceShowCrossStatistics()` with no argument.

TraceShowHatStatistics([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show separated variances (N-cornered hat) when available* <Ctrl-h>. Refer to this command for more information.

To return the current flag value, call `TraceShowHatStatistics()` with no argument.

TraceShowImag([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show Imaginary Part of Cross Spectrum* <Ctrl-F3>. Refer to this command for more information.

To return the current flag value, call `TraceShowImag()` with no argument.

TraceShowNoiseFloor([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show Estimated Instrument Noise* <F2>. Refer to this command for more information.

To return the current flag value, call `TraceShowNoiseFloor()` with no argument.

TraceShowOriginal([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show original traces in computed xDEV displays* <F6>. Refer to this command for more information.

To return the current flag value, call `TraceShowOriginal()` with no argument.

TraceShowRaw([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace→Show Raw PN Channel Trace(s)* <Ctrl-r>. Refer to this command for more information.

To return the current flag value, call `TraceShowRaw()` with no argument.

TraceShowSlopes([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show FFT Segment Filter Slope(s)* <Ctrl-i>. Refer to this command for more information.

To return the current flag value, call `TraceShowSlopes()` with no argument.

TraceSmoothNoise([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Smooth Noise Traces* <Ctrl-w>. Refer to this command for more information.

To return the current flag value, call `TraceSmoothNoise()` with no argument.

TraceSuppressSpurs([Boolean status])

Sets and/or retrieves the `status` of the spur-suppression flag controlled by *Trace>Suppress spurs in noise traces* <Ctrl-s>. Refer to this command for more information.

To return the current spur-suppression flag value, call `TraceSuppressSpurs()` with no argument.

TraceThickness([Number status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Toggle Trace Thickness for Current Measurement* <T>. Refer to this command for more information.

If a value other than 1 or 0 is passed, all traces will be rendered with heavy lines. Boolean true and false values may also be used. To return the current flag value, call `TraceThickness()` with no argument.

TraceTickMarks([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Tick Marks* <k>. Refer to this command for more information.

To return the current flag value, call `TraceTickMarks()` with no argument.

TraceXDEVBars([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Show xDEV Error Bars* <Ctrl-e>. Refer to this command for more information.

To return the current flag value, call `TraceXDEVBars()` with no argument.

TraceXDEVClipBW([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Clip xDEV Traces by Noise Bandwidth* <Ctrl-b>. Refer to this command for more information.

To return the current flag value, call `TraceXDEVClipBW()` with no argument.

TraceXDEVClipConfidence([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Clip xDEV Traces by Confidence* <Ctrl-v>. Refer to this command for more information.

To return the current flag value, call `TraceXDEVClipConfidence()` with no argument.

TraceXDEVSpline([Boolean status])

Sets and/or retrieves the `status` of the flag controlled by *Trace>Draw xDEV Traces with Spline Interpolation* <i>. Refer to this command for more information.

To return the current flag value, call `TraceXDEVSpline()` with no argument.

Chapter 8. Accessing the 53100A & TimePod Remotely

Using the TSERVE server application provided with TimeLab, phase noise and stability measurements with the 53100A can be configured, initiated, and recorded under the control of a remote Telnet client or other ASCII terminal application. This application note describes how to run TSERVE and how to access the services it provides. Compatibility with industry-standard phase noise test instrumentation is also demonstrated.

8.1 LAUNCHING TSERVE

`TSERVE.EXE` is a Windows console application. It is installed as part of the standard TimeLab software package and is suitable for use with any 32-bit or 64-bit Windows PC that is capable of running 53100A acquisitions in the full TimeLab GUI. Because TSERVE does not display graphics, provide extensive user interaction, or work with large data files, most dual-core PCs should be capable of running it reliably.

TSERVE can be launched from a Windows desktop shortcut or run manually at a command prompt "DOS box." Particularly during the familiarization process, you may find it easier to work with TSERVE at the command prompt. After you've determined what options and parameters are needed in your application, you can create a batch file or shortcut to launch TSERVE with the same parameters.

Unless you specified a different location during installation, you can find the program by opening a command prompt and changing the current directory to `C:\Program Files\Miles Design\TimeLab`. To do this, select *Start>Run in Windows* and enter `cmd` as the name of the program to run. Once the DOS box appears, you can drag its lower edge to expand the window to a more comfortable size. Then, enter the commands

```
cd "\program files\miles design\timelab"
tserve /?
```

As shown in Figure 8-1, the `/?` option causes TSERVE to display a brief list of the command-line options available in the current release. Throughout this document, black on white text indicates typed commands.

```
C:\Program Files\Miles Design\TimeLab>tserve /?

 53100A console server V1.12 of Apr 21 2022          Miles Design LLC
 Press ESC to terminate, SCROLL LOCK to view traffic        john@miles.io
 /? for help

Usage: tserve[64] [optional arguments]

Optional arguments:
             /serial:<sernum>                 Default: Any
             /logfile:<filename>              Default: server.log
             /data_port:<portnum>             Default: 1298
             /cmd_port:<portnum>              Default: 1299
             /file:<filename>                 Default: None
             /msglvl:<0-7>                    Default: 4
             /model:<name>                    Default: Microchip 53100A
             /phaserate:<1, 10, 100, 1000>    Default: 100
             /phasedec:<factor>               Default: 2
             /timerec:<secs>                  Default: 10000
             /inputfreq:<MHz> (0=auto)        Default: 0
             /referencefreq:<MHz> (0=auto)    Default: 0
             /roundfreq:<MHz>                 Default: 0.1
             /ch:<chanexpr>                   Default: 3-1
             /title:<string>                  Default: (Serial #)
             /chart:<secs>                    Default: 600
             /dateformat:<1,2,3>              Default: 1
             /timeformat:<12,24>              Default: 24
             /smooth:<0,1,2                   Default: 2
             /spur_dB:<dB>                    Default: 6
             /spur_Hz:<Hz>                    Default: 0
             /format:<P, F, TSC>              Default: TSC
             /timestamp:<s, MJD, UNIX>        Default: None
             /sep:<ASCII code>                Default: ,
             /duration:<secs> (0=indefinite)  Default: 0
             /am:<true,false>                 Default: True
             /warn
             /notify
             /noprompt
             /overlap
             /start
             /wait
             /update

C:\Program Files\Miles Design\TimeLab>
```

FIGURE 8-1: *Available Command Line Options.*

Note that both 32-bit and native 64-bit versions are installed on 64-bit Windows PCs. These can be launched by running TSERVE or TSERVE64, respectively. There is no functional difference between the 32-bit and 64-bit executables, but TSERVE64 may provide more reliable acquisition on slower systems due to its use of 64-bit processing.

8.2 TSERVE COMMAND LINE OPTIONS AND DEFAULTS

When TSERVE or TSERVE64 is launched without any command-line arguments, the program will listen for Telnet connections at port 1299. Although the command port is referred to as a "Telnet" port in this document, no Telnet-specific codes or protocol elements are required. Most ASCII terminals and other communications applications should be usable with TSERVE. Once a measurement has begun, ASCII phase data will be transmitted to any client(s) connected to port 1298. Parameters appropriate for emulation of the industry-standard Symmetricom/Microsemi/Microchip 5115A/5120A/5125A test sets will be used by default. In this mode of operation, TSERVE will transmit phase data samples in the TSC format, which consists of negative time interval values in seconds multiplied by the nominal input frequency. This default behavior can be modified with various command-line options, described below in alphabetical order.

/am:<true | false>

By default, TSERVE performs AM noise measurements as well as phase noise measurements, as in the TimeLab GUI application. AM measurements can be disabled to reduce CPU workload by specifying `/am:false` on the command line. The **show amspectrum** and **show amspurs** commands will display the error message *AM measurements are not enabled* in this case.

/ch:<chanexpr>

Specifies the channel configuration to be used for stability measurements.

By default, the channel expression is 3-1, indicating that a DUT connected to the 53100A's channel 3 input (or the DUT input splitter that drives it) should be measured using the reference connected to the channel 1 input or REFERENCE input splitter. It is possible to return data for up to 4 channel pairs, sampled simultaneously. For example, data for a three-cornered hat measurement of oscillators connected to channels 1, 2, and 3 could be obtained by specifying `/ch:1-2,2-3,3-1` on the command line as shown in Figure 8-2 below.

In the figure, the `/start` option has been used to initiate a measurement in the absence of any remote client connections, `/ch:1-2,2-3,3-1` is used to request separate measurements of three channel pairs, and `/format:P` requests phase-difference data in seconds. The <Scroll Lock> key has been pressed to display a subset of the outgoing data in the server console. Each column represents the phase slope over time that corresponds to the frequency of the DUT channels (1, 2, and 3 respectively) measured against the reference sources on channels 2, 3, and 1.

Phase noise and AM noise measurements in TSERVE are always performed using the default channel configuration for noise measurements in TimeLab; specifically, the DUT that drives channels 3 and 4 through an internal or external splitter is cross-correlated against the single or dual reference(s) present at channels 1 and 2.

FIGURE 8-2: *Example of Using the Channel Expression Command.*

`/chart:<secs>`

Specifies the maximum length of the data record returned by TSERVE in response to the **show phasediff** and **show freqdiff** commands.

By default, these commands will return the most recent 600 seconds of data. Values between 10 and 86400 seconds are accepted.

`/cmd_port:<port #>`

Specifies the TCP/IP port to be used for command input from a Telnet client or other ASCII terminal program.

The default port for Telnet command access is 1299. If the port number is 0, no command port will be opened, and TSERVE’s Telnet server functionality will not be available.

Up to three clients at a time may log on to the command port. Note that each client can control the measurement independently; TSERVE does not attempt to arbitrate or otherwise manage control authority between clients. To allow remote clients to initiate and control 53100A measurements made by TSERVE, you may need to configure your firewall or NAT gateway to open the specified command port. Instructions for doing so can be obtained from the equipment manufacturer.

/data_port:<port #>

After a measurement has been initiated through the use of the `/start` command-line option or the **start** Telnet command, TSERVE will begin broadcasting a continuous stream of frequency or phase-difference data on this TCP/IP port.

The stream consists of a series of double-precision real values in standard ASCII. Data is provided at the rate given by the `/phaserate` and `/phasedec` parameters (100 per second by default), using the format specified by the `/format` parameter. One reading per line is emitted, with each line terminated with a CR+LF pair. Optionally, each reading may be prefixed by a timestamp; see the `/timestamp` and `/sep` options for further information.

The default port for phase/frequency data streaming is 1298. If the port number is 0, TSERVE will not attempt to open a streaming data output port.

Up to eight clients at a time may receive data via the streaming port. TSERVE ignores any commands or other input received. To allow remote clients to receive data from TSERVE, you may need to configure your firewall or NAT gateway to open the specified data port. Instructions for doing so can be obtained from the equipment manufacturer.

/dateformat:<1,2,3>

Sets the format used by the **show date** command.

1 = dd (abbreviated name of month) yyyy

2 = mm/dd/yyyy

3 = dd/mm/yyyy

The default date format is 1.

/file:<filename>

Specifies the name of an optional ASCII text file to which streaming phase-difference or frequency readings will be written. If the specified file already exists, it will be overwritten. Typically, the file is shared with other applications that can access it in read-only mode while it's being written by TSERVE.

The data written to the file may be followed from within TimeLab by selecting *Acquire>Acquire from Live ASCII File*. You can also monitor the data written to the file with a command such as `tail -f <filename>` from Cygwin. Finally, pressing the **Scroll Lock** key will cause TSERVE to display the lines written to the file on the `stdout` device (i.e., the DOS console itself) at a maximum rate of 10 readings per second.

Example: `tserve64 /data_port:0 /cmd_port:0 /start /format:P /file:%HOMEPATH%\Documents\mydata.txt`

The command above writes a continuous stream of phase-difference readings to the file `mydata.txt` in the current user's Documents folder. No TCP/IP ports are opened for either data streaming or command input. You can then use TimeLab or another application to follow the file. Even if the acquisition fails or otherwise encounters problems, you can use the appropriate *File>Import* option to bring the data into TimeLab at any time.

/format:<P, F, TSC>

Specifies the type of measurement data that will be broadcast via the TCP/IP data port and/or logged to the specified file.

TSERVE writes Microchip/Symmetricom 51XXA-style phase-difference data by default (`/format:TSC`). This format consists of phase-difference values that have been inverted and multiplied by the input frequency. You can also generate conventional (unscaled) phase differences with `/format:P` or absolute frequency readings with `/format:F`.

Optionally, any warning or error messages can be forwarded to the connected TimeLab client(s) by TSERVE for display in the status line. This capability requires the use of the `/notify` option on the TSERVE command line. If `/notify` is not used, data sent to the TCP/IP streaming clients and/or shared file will always consist of numeric readings in the specified format.

/inputfreq:<MHz>

By default, the DUT and reference input frequencies are measured at acquisition startup time and rounded to the nearest 100 kHz. These nominal frequencies are reported by the **show inputs** command and used as the basis for phase-difference readings. If either frequency does not accurately reflect the nominal frequency of the corresponding input source, the discrepancy will appear as a nonzero slope in successive phase-difference readings. If the phase slope is due to insufficient DUT frequency precision, the `/inputfreq` option can be used to specify the precise DUT input frequency to be used instead of the estimated value. Alternatively, `/roundfreq` can be used to force the nominal input frequency to be logged at higher precision.

For example, if a DUT with a nominal frequency of 10.23 MHz is being measured and it is desirable to minimize the slope of the phase-difference readings, either `/inputfreq:10.23` or `/roundfreq:0.01` could be used.

Note that the accuracy of the absolute frequency readings obtained with the `/format:F` switch depends only on the reference source, regardless of the nominal input frequency reported by **show inputs**. Consequently, it is unaffected by the `/inputfreq` or `/roundfreq` options. As a result, the `/inputfreq` and `/roundfreq` options are not required in most TSERVE measurements. However, note that if the nominal reference frequency is not a multiple of 100 kHz, it is necessary to use `/referencefreq` to avoid inaccurate results regardless of the selected output format. See the `/referencefreq` option for more information.

/logfile:<filename>

Specifies the pathname for a logfile that will record status, warning, and error messages. If the `/logfile` parameter contains an absolute path specification, the log file is placed at that location. Otherwise, if `/logfile` specifies a filename by itself, the log file is placed in the user’s Documents directory. The location of the log file is displayed when TSERVE is launched.

The default logfile name used when no `/logfile` parameter is provided is `server.log`.

/model:<name>

Specifies the instrument name that will be returned by the **show version** command. The instrument name is also used to present a logon banner (“Welcome to the ____”) when a new connection is made to the Telnet command port.

The default model name is PhaseStation 53100A. The specified model name has no effect on any aspect of operation except as described above. A different model name may be required for compatibility with legacy software that expects to communicate with (e.g.) a Microchip/ Symmetricom 5125A:

Example: `tserve64 /model:”Symmetricom 5125A” /start`

/msglvl:<0-7>

Specifies the verbosity of informational, warning, and error messages that TSERVE will display on the server console. `/msglvl:0` will display all available status messages and notices including internal driver diagnostics, while `/msglvl:7` will display only fatal error messages. The default message level is 4.

Messages displayed at the server console are also written to the logfile. See the `/logfile` option for more information.

/noprompt

By default, clients attached to the Telnet command port will receive a command prompt containing the TSERVE host IP address. Issuing the **prompt off** command or specifying the `/noprompt` argument on the TSERVE command line will prevent the prompt from being displayed.

/notify

Optionally, any warning or error messages that occur during data acquisition can be forwarded to clients via the TCP/IP data port used for phase/frequency streaming. To enable this capability, include the `/notify` option on the TSERVE command line.

If `/notify` is not used, data sent to the TCP/IP streaming clients and/or shared file will always consist of numeric readings in the specified format.

/overlap

For maximum reliability on slower host PCs, overlapped FFT processing during phase noise measurement is turned off by default in TSERVE. Specifying the `/overlap` option can significantly improve the speed required for low-noise measurements to converge, at the risk of possible data overruns.

Specifying the `/overlap` option on the TSERVE command line is equivalent to checking the **Overlapped Acquisition** checkbox in the **Additional Options** page of the 53100A Acquisition dialog.

/phasedec
/phaserate

These options determine the default sample rate for frequency and phase-difference data streamed to TCP/IP clients connected to the data port.

When a client initially establishes a Telnet connection to the TSERVE command port, it inherits various global settings including the `/phaserate` parameter. In this case, the `/phaserate` parameter becomes the **phaserate** value for measurements initiated by that client. This value can be displayed with the **show phaserate** command or modified with the **set phaserate** command at any time prior to starting a measurement. Using either of these techniques, you can set the phase rate to 1 reading per second to conserve network bandwidth and/or disk space for use with extremely stable sources. Conversely, measurements of drift-prone sources may require phase data rates of 100 or 1000 readings per second to avoid acquisition failures.

The choice of phase data rate also determines the baseband measurement bandwidth for frequency and phase stability. In TSERVE, the equivalent noise bandwidth (ENBW) is half of the `/phaserate` interval, or 50 Hz by default. Note that the 53100A driver limits the minimum bandwidth to 5 Hz, even when `/phaserate:1` is used.

The `/phasedec` parameter provides some additional flexibility by allowing you to specify a larger-than-normal decimation ratio for the post-detection phase data. Its default value is 2, corresponding to the default Output Decimation property on the **Additional Options** page of the 53100A Acquisition dialog. The nominal phase rate options of 1, 10, 100, and 1000 readings per second are based on the default `/phasedec` value of 2. Setting `/phasedec` to larger values reduces the overall rate at which frequency and phase-difference data is streamed to TSERVE clients and any output file specified with the `/file` parameter, and also determines the tau0 interval for the **show adev** command. Regardless of any changes to `/phasedec`, the equivalent noise bandwidth is still determined by the **phaserate** value that was in effect when the measurement began.

If not overridden by a command-line argument, the `/phaserate` value defaults to 100 samples per second. Note that some legacy Microchip/Symmetricom/Microsemi 51XXA applications may require a phase data rate of 1000 samples per second. Unlike these test sets, any changes made to parameters such as **phaserate**, **tau0**, and **referencefreq** will not affect either queried or streamed data from the measurement in progress. As a result, the data rate must either be set from the command line when TSERVE is started, or by issuing a **set phaserate** command prior to the **start** command.

/referencefreq:<MHz>

TSERVE estimates the frequency of the signal at the 53100A's REFERENCE input by rounding it to the nearest 100 kHz. This provides an authoritative basis for calculation of the applied DUT input frequency, assuming that the reference source is indeed a multiple of 100 kHz. If this is not the case, you can use the `/referencefreq` option to specify the nominal reference frequency explicitly.

As with the `/phaserate` parameter, the reference frequency specified on the command line is inherited by Telnet command clients at connection time and used as the **referencefreq** parameter during subsequent measurements. Any changes made with **set referencefreq** while a measurement is in progress will have no effect on frequency-count or streamed frequency/phase-difference readings reported during the current measurement.

/roundfreq:<MHz>

By default, the DUT and reference input frequencies are measured at acquisition startup time and rounded to the nearest 100 kHz. These nominal frequencies are reported by the **show inputs** command and used as the basis for phase-difference readings. If either frequency does not accurately reflect the nominal frequency of the corresponding input source, the discrepancy will appear as a non-zero slope in successive phase-difference readings. If the phase slope is due to insufficient DUT frequency precision, the `/roundfreq` option can be used to force the nominal input frequency to be logged at higher precision. Alternatively, `/inputfreq` can be used to specify the precise DUT input frequency to be used instead of the estimated value. For example, if a DUT with a nominal frequency of 10.23 MHz is being measured and it is desirable to minimize the slope of the phase-difference readings, either `/inputfreq:10.23` or `/roundfreq:0.01` could be used. The show inputs command will report an input frequency of 10.23 MHz in either case.

Note that the accuracy of the absolute frequency readings obtained with the `/format:F` switch depends only on the reference source, regardless of the nominal input frequency reported by show inputs. Consequently, it is unaffected by the `/inputfreq` or `/roundfreq` options. As a result, the `/inputfreq` and `/roundfreq` options are not required in most TSERVE measurements. However, note that if the nominal reference frequency is not a multiple of 100 kHz, it is necessary to use `/referencefreq` to avoid inaccurate results regardless of the selected output format. There is no corresponding way to increase the reference frequency's rounding precision; the nominal reference frequency must be specified explicitly with `/referencefreq` if 100 kHz precision is insufficient.

/ sep:<character>
/ timestamp:<s, MJD>

These related options cause TSERVE to add a timestamp to each phase-difference or frequency reading that is written to a shared file or streamed to network clients.

By default, no timestamps are emitted. When `/timestamp:MJD` is specified, the Modified Julian Date (MJD) associated with each phase-difference or frequency value will be written as the first numeric field on each line, followed by a space character (ASCII 32), then the measurement value itself. MJD timestamps are generated with six digits of decimal precision, resulting in roughly 10 unique MJD values per second.

You can also use `/timestamp:s` to emit a simple numeric timestamp at one-microsecond precision. These timestamps begin at 0.000000 for the first reading acquired.

In either case, the difference between successive timestamps will be equal to the reciprocal of the `/phaserate` parameter, whose default is 100 readings per second, scaled further by any specified `/phasedec` ratio beyond its default value of 2:1. Refer to the description of the `/phaserate` parameter for more information.

The `/sep` option may be used to specify an additional separator character that will appear before the space between the timestamp and measurement value. If the client requires comma-separated values, for example, `/sep:,` would be useful. Any numeric value used as the `/sep:` argument is treated as an ASCII code; e.g. `/sep:9` generates a tab character.

Example: `tserve64 /start /phaserate:1000 /phasedec:200 /format:F /timestamp:s /sep:,`

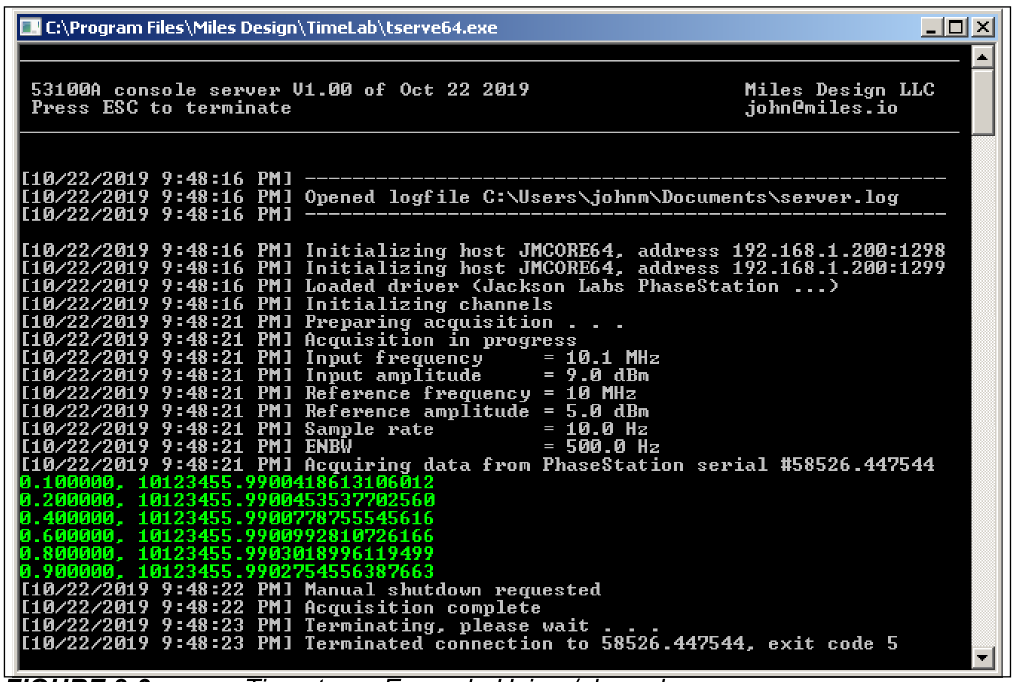


FIGURE 8-3: *Timestamp Example Using /phasedec.*

Note that without the `/phasedec:200` parameter, the timestamps shown in green in Figure 8-3 would have advanced at the rate of 0.001 second per reading rather than 0.1 second.

`/serial:<sernum>`

When more than one 53100A is connected to the server PC, you may need to use the `/serial` option to associate a given TSERVE instance with a specific instrument. Each instance of TSERVE supports only one acquisition at a time, but you can launch as many instances as desired.

Example: `tserve64 /serial:55908.304876 /cmd_port:1234 /data_port:1235`

The command above will launch an instance of TSERVE for use with the 53100A whose serial number is 55908.304876. To avoid addressing conflicts, each TSERVE instance must specify unique TCP/IP ports for command and data traffic.

/smooth:<0,1,2>

The `/smooth` option determines the filtering operations applied to phase noise data returned by the **show spectrum** command.

0 = No smoothing or spur suppression

1 = Spurs are removed from the trace but no smoothing is applied

2 = Spurs are removed from the trace and smoothing is applied (default)

In most cases the smoothing parameter should be left at its default value of 2. Spurs that are present in the phase noise spectrum have undergone the same 1 Hz normalization process as the noise data itself, so they will rarely appear at their true amplitudes. Use the **show spurs** command to retrieve the offsets and amplitudes of detected spurs.

/spur_dB:<dB>

This parameter corresponds to the "Spur Threshold" field in the **Additional Options** page of the 53100A Acquisition dialog. It determines the amplitude above the local average phase noise level at which a discrete spectral line is recognized as a coherent spur. The default spur detection threshold is 6.0 dB.

/spur_Hz:<Hz>

This parameter corresponds to the "Spur Min Offset" field in the **Additional Options** page of the 53100A Acquisition dialog. Spurs with offset frequencies below this value in Hz will not be removed from the plot or added to the spur chart. This may be helpful when one or more spurs close to the carrier are being erroneously flagged. The default minimum spur offset is 0 Hz, which disables the feature.

/start

Causes TSERVE to begin an acquisition immediately after launch.

If `/start` is not specified on the command line, no measurement will begin until a client logs onto the Telnet command port and issues a **start** command.

/timeformat:<12,24>

Sets the format used by the show time command. `/timeformat:12` specifies 12-hour time while `/timeformat:24` specifies 24-hour time.

/timerec:<s>

Determines the size of the internal phase record used for ADEV calculation.

ADEV calculations performed by TSERVE are based on a 1-2-4 distribution of tau bins in each decade, using a minimum threshold of 4 samples per bin. Assuming that the `/phasedec` parameter is left at its default value of 2, ADEV results will be returned for tau intervals ranging from the minimum t0 value given by the reciprocal of the `/phaserate` parameter (100 seconds by default, yielding t0=0.01 seconds) to a maximum of 1/5 of the `/timerec` parameter (10000 seconds by default, yielding tmax=2000 seconds).

Note that `/phasedec` parameter values larger than the default (2) will increase the minimum tau interval while leaving the maximum interval unchanged. For example, if TSERVE was launched with `/timerec:100` and `/phasedec:20`, ADEV values from t=0.1s to t=20s will be available.

Also note that since TSERVE must scroll the phase record in memory during long-term measurements, increasing the `/timerec` and `/phaserate` parameter values simultaneously may result in measurement termination due to USB buffer starvation. Should this occur, you may find it helpful to lower the `/phaserate` value or increase the

`/phasedec` value proportionately when increasing the phase record size. (Both `/phaserate` and `/phasedec` affect the t0 interval, but a reduction in `/phaserate` will also lower the measurement bandwidth.)

The `/timerec` parameter also determines the maximum size of the phase record in `.TIM` files written by the save command. Refer to the save command description for more information.

/timestamp:<s, MJD, UNIX>

See `/sep`.

/title:<string>

Establishes the title text returned by the **show title** command.

By default, the title is the reserved string (Serial #), which causes the serial number of the connected instrument to be returned by **show title**. Refer to the **show title** command description for more information.

/update

The `/update` function is useful in scenarios where `TSERVE[64].EXE` may need to be recompiled, upgraded, or otherwise replaced over a network without manual intervention at the server console. When `/update` is present on the command line, TSERVE will periodically check for the presence of a file called `TSERVE[64].EX1` in the same directory as the executable. If `TSERVE[64].EX1` is ever found, the program will terminate with exit(2), reporting the message “Server terminated due to release of new version.”

This feature depends on the use of a batch file or script to launch `TSERVE[64].EXE`. Upon detecting exit code 2, the batch file or script should overwrite the program executable with a copy of `TSERVE[64].EX1`, then delete the `TSERVE[64].EX1` file and relaunch the new `TSERVE[64].EXE` process with the same set of command-line parameters. When any other exit code is returned by the program, the batch file or script can exit normally or take other actions.

As an example, `TSC.BAT` is provided in the TimeLab installation directory to demonstrate the use of the `/update` and `/model` options. Any additional command-line options specified by the user are passed along to the program as well. `TSC.BAT` appears below in its entirety.

```
@echo off

rem
rem Batch file to emulate a Symmetricom 5125A with the PhaseStation 53100A
rem

:start

rem
rem If tserve64.ex1 exists in the directory, rename it to tserve64.exe and run it
rem (passing any command-line arguments that were originally used with tsc.bat)
rem
```

```
if not exist tserve64.ex1 goto serve
copy tserve64.ex1 tserve64.exe >nul
del tserve64.ex1
:serve
if not exist tserve64.exe goto bail

tserve64 /model:"Symmetricom 5125A" /update %*

rem
rem If stream server exits with code 2, it means that the /aut-
oupdate option
rem detected a new copy of tserve64.ex1 in the directory.  Go
back and launch
rem the new version without any manual intervention
rem

if errorlevel 2 goto start
:bail
```

/wait

If the `/wait` option is specified on the TSERVE command line, the program will prompt for a keypress before terminating, except when the `/update` mechanism has been triggered by the appearance of a newer executable version. See the description of the `/update` option below for more information.

Typically, the `/wait` option is used to keep Windows from discarding useful status or error information by closing the console window immediately upon termination. It is not necessary when TSERVE is launched directly at an MS-DOS prompt, but may be helpful when launching from a desktop shortcut.

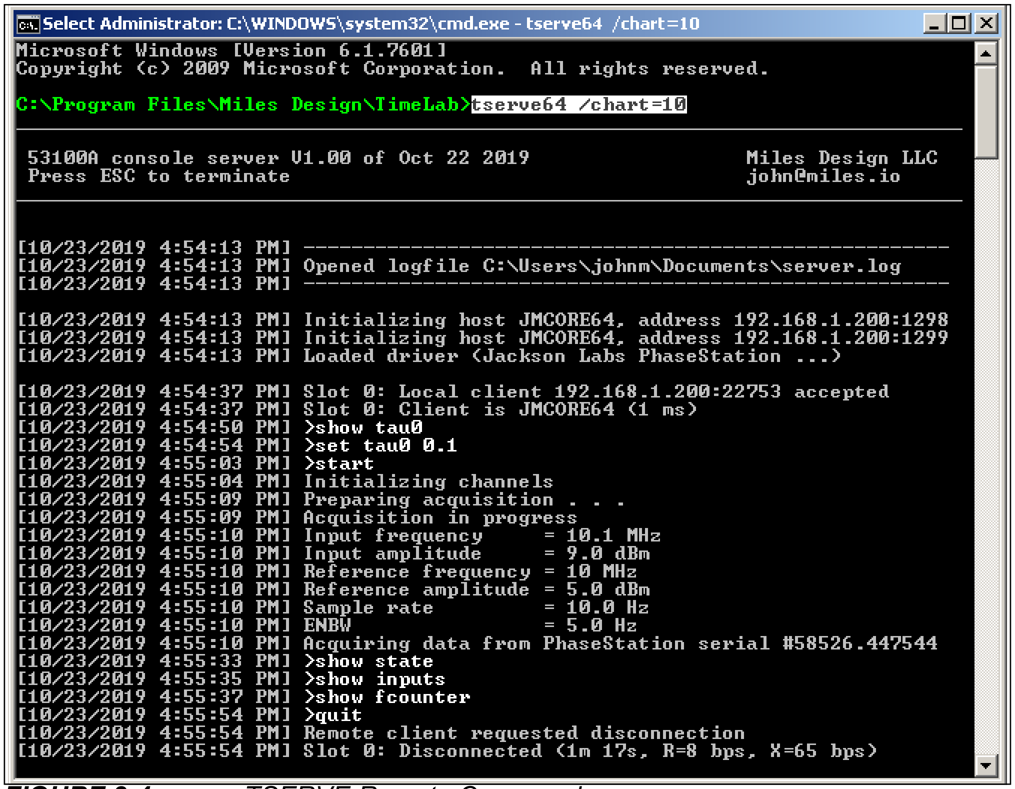
/warn

By default, a TSERVE-hosted measurement will stop If any significant changes in signal amplitude or frequency are observed at either the DUT or REFERENCE input ports. Using the `/warn` option will allow the measurement to continue running when non-fatal anomalies are encountered. This option is equivalent to unchecking the All Warnings Fatal option in the **Additional Options** page of the 53100A Acquisition dialog.

When a measurement stops due to an error condition, any streaming data connections will remain open, and any Telnet or terminal clients will remain connected. Clients attached to the command port can query the status of the measurement with the **show state** and **show message** commands, while clients connected to the streaming data port will receive error and warning messages if the `/notify` option was specified on the TSERVE command line.

8.3 TSERVE REMOTE COMMANDS

A variety of commands and queries may be issued by a Telnet or other ASCII terminal client connected to the TSERVE command port. These commands will appear in the console TTY display as shown in Figure 8-4 below, and will also be written to the server log file.



```
Select Administrator: C:\WINDOWS\system32\cmd.exe - tserve64  /chart=10
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Program Files\Miles Design\TimeLab>tserve64 /chart=10

 53100A console server V1.00 of Oct 22 2019                    Miles Design LLC
 Press ESC to terminate                                        john@miles.io


[10/23/2019 4:54:13 PM] -----------------------------------------------------
[10/23/2019 4:54:13 PM] Opened logfile C:\Users\johnm\Documents\server.log
[10/23/2019 4:54:13 PM] -----------------------------------------------------

[10/23/2019 4:54:13 PM] Initializing host JMCORE64, address 192.168.1.200:1298
[10/23/2019 4:54:13 PM] Initializing host JMCORE64, address 192.168.1.200:1299
[10/23/2019 4:54:13 PM] Loaded driver (Jackson Labs PhaseStation ...)

[10/23/2019 4:54:37 PM] Slot 0: Local client 192.168.1.200:22753 accepted
[10/23/2019 4:54:37 PM] Slot 0: Client is JMCORE64 (1 ms)
[10/23/2019 4:54:50 PM] >show tau0
[10/23/2019 4:54:54 PM] >set tau0 0.1
[10/23/2019 4:55:03 PM] >start
[10/23/2019 4:55:04 PM] Initializing channels
[10/23/2019 4:55:09 PM] Preparing acquisition . . .
[10/23/2019 4:55:09 PM] Acquisition in progress
[10/23/2019 4:55:10 PM] Input frequency     = 10.1 MHz
[10/23/2019 4:55:10 PM] Input amplitude     = 9.0 dBm
[10/23/2019 4:55:10 PM] Reference frequency = 10 MHz
[10/23/2019 4:55:10 PM] Reference amplitude = 5.0 dBm
[10/23/2019 4:55:10 PM] Sample rate         = 10.0 Hz
[10/23/2019 4:55:10 PM] ENBW                = 5.0 Hz
[10/23/2019 4:55:10 PM] Acquiring data from PhaseStation serial #58526.447544
[10/23/2019 4:55:33 PM] >show state
[10/23/2019 4:55:35 PM] >show inputs
[10/23/2019 4:55:37 PM] >show fcounter
[10/23/2019 4:55:54 PM] >quit
[10/23/2019 4:55:54 PM] Remote client requested disconnection
[10/23/2019 4:55:54 PM] Slot 0: Disconnected (1m 17s, R=8 bps, X=65 bps)
```

FIGURE 8-4: *TSERVE Remote Commands.*

The TSERVE example session shown above was launched from an MS-DOS prompt. Black-on-white characters indicate text entered by the user. The 64-bit version of TSERVE was run by typing `tserve64`, followed by the `/chart=10` command-line option.

Shortly after the server was started, a connection was established from another DOS box on the same PC as shown in Figure 8-5, using the command `telnet 192.168.1.200 1299`:

```
Administrator: C:\WINDOWS\system32\cmd.exe
Welcome to the PhaseStation 53100A

=192.168.1.200 > show tau0
tau0 is: 0.01 seconds

=192.168.1.200 > set tau0 0.1
tau0 is: 0.1 seconds

=192.168.1.200 > start
=192.168.1.200 > show state
Collecting (17 s)
Time Constant: Infinite
=192.168.1.200 > show inputs
Current:
Input: Frequency 10.1 MHz Amplitude 9 dBm
Reference: Frequency 10.0 MHz Amplitude 5 dBm
Last Collection:
Input: Frequency 10.1 MHz Amplitude 9 dBm
Reference: Frequency 10.0 MHz Amplitude 5 dBm

=192.168.1.200 > show fcounter
Reference Frequency: 10 MHz (Auto)

Avg Time (s)     Frequency (MHz)
1                10.1234559900912
10               10.12345599010449
=192.168.1.200 > quit
Exiting command line interface

Connection to host lost.

C:\Program Files\Miles Design\TimeLab>
```

FIGURE 8-5: *Telnet Query Response.*

In this example, several different commands and queries were transmitted to TSERVE from the Telnet client application, including the start command to begin data acquisition. These user-entered commands appear in black-on-white text in the Telnet client window and are displayed in bold white text at the server console. After the user issued the final quit command at 4:55:54 PM, the Telnet session ended. The server (and the measurement acquisition) continued to run, awaiting further connections.

An alphabetical list of supported commands and queries appears below. Except as noted, TSERVE's remote command syntax is compatible with the Microchip/Microsemi/Symmetricom/TSC 5125A and other phase noise test sets in the 51XXA series. Applications and test scripts written for these instruments should run on a 53100A with little or no adaptation.

Note that multiple commands may be entered on one line by separating them with semicolons.

`beep`

Plays a sound on the TSERVE host PC.

`close`

Closes the output stream data file most recently opened with the **open** command or `/file:` command-line option.

`exit`

See **quit**.

`help [<command>]`

Returns a list of commands with brief usage information. If a command name is specified, only the help text for that command is returned.

`history`

Returns a list of previously entered commands.

`logout`

See **quit**.

measurelinear

Computes the slope and intercept coefficients of the current phase-difference chart. After a `measurelinear` command has been issued, a subsequent `removelinear on` command will cause the linear trendline to be removed from the chart data returned by `show phasediff`.

If `measurelinear` is executed while `removelinear on` is in effect, the stored coefficients will be updated for use by subsequent `show phasediff` commands. It is not necessary to use `removelinear off` before issuing a `measurelinear` command.

open <filename>

Opens an ASCII text file to which streaming phase-difference or frequency readings will be written. If the specified file already exists, it will be overwritten. Typically the file is shared with other applications that can access it in read-only mode while it's being written by TSERVE. The data written to the file may be 'followed' from within TimeLab by selecting ***Acquire>Acquire from live ASCII file***. You can also monitor the data written to the file with a command such as `tail -f <filename>` from Cygwin. Finally, pressing the <Scroll Lock> key will cause TSERVE to display the lines written to the file on the stdout device (i.e., the DOS console itself) at a maximum rate of 10 readings per second.

Example: `tserve64 /data_port:0 /cmd_port:0 /start /format:P /file:%HOMEPATH%\Documents\mydata.txt`

The command above writes a continuous stream of phase-difference readings to the file `mydata.txt` in the current user's Documents folder. No TCP/IP ports are opened for either data streaming or command input. You can then use TimeLab or another application to 'follow' the file. Even if the acquisition fails or otherwise encounters problems, you can use the appropriate ***File>Import*** option to bring the data into TimeLab at any time.

The output file may be flushed and closed at any time by issuing a close command or by opening a different file. In addition to the **open** command, a stream output file can also be opened at TSERVE startup time by specifying the `/file: <filename>` command-line option.

pause <chart>

`pause phasediff` and `pause freq` will inhibit updates to the phase difference and frequency difference charts, respectively. Updates may be resumed with `resume phasediff` or `resume freq`. The inconsistent chart nomenclature is required for compatibility with the TSC 51XXA command language.

prompt <on|off>

The `prompt off` and `prompt on` commands will disable and enable the Telnet command prompt, respectively. The prompt is enabled by default. `prompt off` is equivalent to the `/noprompt` command-line option.

quit

Closes the Telnet connection. The TSERVE server will continue running, as will any measurement in progress.

removelinear <on|off>

When `removelinear on` is in effect, the linear trendline most recently measured by the `measurelinear` command will be removed from subsequent phase-difference charts returned by the `show phasediff` command. Use `removelinear off` to disable linear trend subtraction.

reset
resettofactorydefaults

When the Telnet server thread is created by TSERVE at startup time, copies of the default values for the **phaserate**, **tau0**, **referencefreq**, **prompt**, **dateformat**, **timeformat**, and **title** properties are associated with the server instance, taking into account any changes made to the program defaults at the TSERVE command line. These properties subsequently apply to any measurements initiated by either Telnet clients or by a `/start` parameter on the TSERVE command line. Clients may alter these server property values by issuing the appropriate `set` commands. Changes made to the server property values will apply to acquisitions that are subsequently initiated by that client or any others.

Issuing a `reset` or `resettofactorydefaults` command will immediately stop any measurement in progress. TSERVE will continue running and any clients will remain connected, but the server default properties will be restored to the program default or command-line values, just as if TSERVE had been terminated and restarted. The `reset` and `resettofactorydefaults` commands behave identically.

resume <chart>

See `pause`.

save <filename.TIM>

Saves the current phase record and phase noise trace data to the specified `.TIM` file. The saved file may subsequently be loaded for inspection and editing by the TimeLab GUI application.

The length of the phase record in the saved `.TIM` file is determined by the `/timerec` parameter specified on the TSERVE command line, which defaults to 10000 seconds. Note that ADEV results displayed in TimeLab may not necessarily match those reported by the **show adev** command at the time the file is saved. The `.TIM` file contains up to `/timerec` seconds of incoming phase data beginning at the last **start** command, while TSERVE continues to update its existing ADEV bin contents incrementally when new data points beyond the `/timerec` record size cause the phase record to scroll.

selftest

Executes a built-in self test (BIST) routine on the 53100A. As shown in Figure 8-6, the `selftest` command is available only when no measurement is currently in progress.

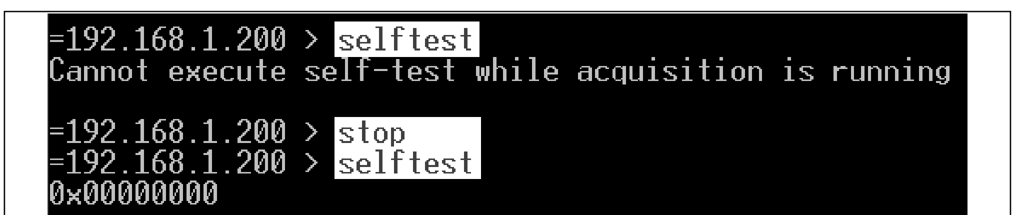


FIGURE 8-6: *Self Test Notification.*

`selftest` returns a 32-bit hexadecimal number whose individual bits represent various fault indications. A result of 0x00000000 indicates that no issues were found. Nonzero bits are interpreted as follows:

```
const U32 BIST_OK              = 0x00000000;  // All bits clear = no faults detected
const U32 BIST_POCXO_COLD       = 0x00000001;  // Clock OCXO not warmed up (< 68C)
const U32 BIST_POCXO_HOT        = 0x00000002;  // Clock OCXO over max temperature
(75C)
const U32 BIST_POCXO_UNLOCKED     = 0x00000004;  // ADC clock PLL unlocked
const U32 BIST_FPGA_HOT         = 0x00000008;  // FPGA over max temperature (100C)
const U32 BIST_FPGA_COLD        = 0x00000010;  // FPGA under min temperature (0C)
```

```
const U32 BIST_PREREG_OVERVOLT    = 0x00000020;  // Controller input voltage > 13.9V
const U32 BIST_PREREG_UNDERVOLT   = 0x00000040;  // Controller input voltage < 13.2V
const U32 BIST_POWER_HIGH        = 0x00000080;  // Controller input power > 15W
const U32 BIST_POWER_LOW         = 0x00000100;  // Controller input power < 11W
const U32 BIST_1P0_OVERVOLT       = 0x00000200;  // 1.0V bus > 1.05V
const U32 BIST_1P0_UNDERVOLT      = 0x00000400;  // 1.0V bus < 0.95V
const U32 BIST_1P8_OVERVOLT       = 0x00000800;  // 1.8V bus > 1.89V
const U32 BIST_1P8_UNDERVOLT      = 0x00001000;  // 1.8V bus < 1.71V
const U32 BIST_PSRAM_FAULT      = 0x00002000;  // PSRAM FIFO could not be enabled
const U32 BIST_FPGA_UNCONFIGURED  = 0x00004000;  // FPGA could not be configured
const U32 BIST_BULK_READ_ERROR    = 0x00008000;  // Couldn't stream input data
const U32 BIST_CH0_PRN_FAULT      = 0x00010000;  // Invalid data read from ADC channel 0 (J3)
const U32 BIST_CH1_PRN_FAULT      = 0x00020000;  // Invalid data read from ADC channel 1 (J1)
const U32 BIST_CH2_PRN_FAULT      = 0x00040000;  // Invalid data read from ADC channel 2 (J4)
const U32 BIST_CH3_PRN_FAULT      = 0x00080000;  // Invalid data read from ADC channel 3 (J2)
const U32 BIST_MB_NOT_FOUND       = 0x04000000;  // Main board disconnected
const U32 BIST_FPAN_NOT_FOUND     = 0x08000000;  // Front panel disconnected
const U32 BIST_AUTH_FAILURE       = 0x10000000;  // Authentication failure
const U32 BIST_DEVICE_IN_USE      = 0x20000000;  // Device is currently in use
const U32 BIST_USB_ERROR         = 0x40000000;  // Non-fatal USB communication error(s) occurred
const U32 BIST_CONNECT_FAILURE    = 0x80000000;  // Failed to connect to device
```

It is normal for bit 1 to be set (0x00000001) if the `selftest` command is issued immediately after power-up while the front panel STATUS indicator is still blue.

set <. . .>

When the Telnet server thread is created by TSERVE at startup time, copies of the default values for the **phaserate**, **tau0**, **referencefreq**, **prompt**, **dateformat**, **timeformat**, and **title** properties are associated with the server, taking into account any changes made to the program defaults at the TSERVE command line. These properties subsequently apply to any measurements initiated by either Telnet clients or by a `/start` parameter on the TSERVE command line. Clients may alter these server property values by issuing the appropriate `set` commands. Changes made to the server property values will apply to acquisitions that are subsequently initiated by that client or any others.

The following `set` commands are supported by TSERVE:

set dateformat <1|2|3>

Sets the date format used by the show date command.

1 = dd (abbreviated name of month) yyyy

2 = mm/dd/yyyy

3 = dd/mm/yyyy

The default date format is 1, unless overridden by the `/dateformat` command-line parameter.

set phaserate <rate>

See the description of the `/phaserate` command-line parameter for more information.

set referencefreq <auto|freq>

See the description of the /referencefreq command-line parameter for more information.

set inputfreq <auto|MHz>

See the description of the /inputfreq command-line parameter for more information.

set tau0 <value>

Sets the tau-zero period for the show adev command in seconds. Values of 0.001, 0.01, 0.1, and 1 second are supported.

Note that changing the **tau0** value will recompute the **phaserate** property, and vice versa. See the description of the /phaserate command-line parameter for more information. As with **phaserate**, changes to **tau0** are scaled by the /phasedec parameter if a non-default value is provided on the command line.

set timeformat <24|12>

Sets the time format used by the show date command. The default time format is 24, unless overridden by the /timeformat command-line parameter.

set title <title>

Establishes the title text returned by the show title command. Unless changed by the /title command-line parameter, the default title is the reserved string (Serial #). When show title is issued during a measurement, the reserved string will be replaced by the serial number of the connected instrument. Other title strings will be reported verbatim.

Titles containing spaces must be enclosed in double quotes (" "). See the show title command description below for more information.

show <. . .>

The show command queries the current value of a property or the results of the current measurement in progress. The following show queries are supported by TSERVE:

show adev

Returns the current Allan deviation chart, as shown in Figure 8-7:

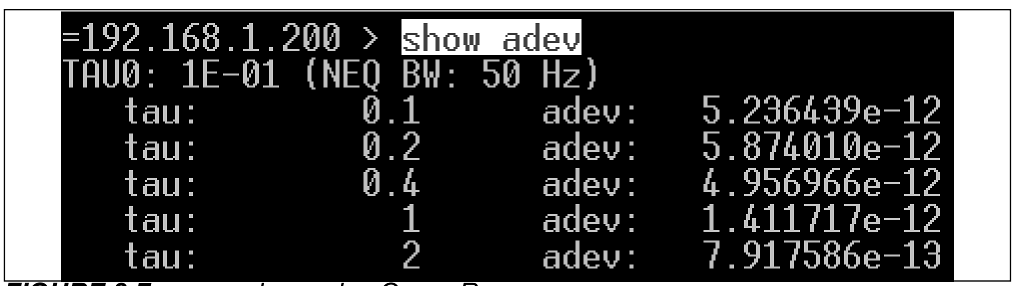


FIGURE 8-7: *show adev Query Response.*

ADEV calculations performed by TSERVE are based on a 1-2-4 distribution of tau bins in each decade, using a minimum threshold of 4 samples per bin. Assuming that the /phasedec parameter is set to its default value of 2, results will be returned for tau intervals ranging from the minimum t0 value given by the reciprocal of the /phaserate parameter (100 seconds by default, yielding t0=0.01 seconds) to a maximum of 1/5 of the /timerec parameter (10000 seconds by default, yielding tmax=2000 seconds).

See the /timerec, /phasedec, and /phaserate parameters for more information.

`show amspectrum`
`show amspurs`

These commands function identically to **show spectrum** and **show spurs**, but for the AM noise rather than phase noise. See **show spectrum** and **show spurs** for more information.

If `/am:false` was specified on the TSERVE command line, these commands will return an error message indicating that no AM measurement data is available.

`show date`

Returns the current date/time information as reported by the TSERVE host OS, as shown in Figure 8-8:

FIGURE 8-8: *show date Query Response.*

The date and time formats are determined by the **dateformat** and **timeformat** properties, respectively.

`show dateformat`
`show timeformat`

Both of these commands return the date and time formats, as established by the **dateformat** and **timeformat** properties:

FIGURE 8-9: *show dateformat Query Response.*

`show fcounter`

Returns the current reference frequency and frequency count chart at all available averaging times up to 1000 seconds:

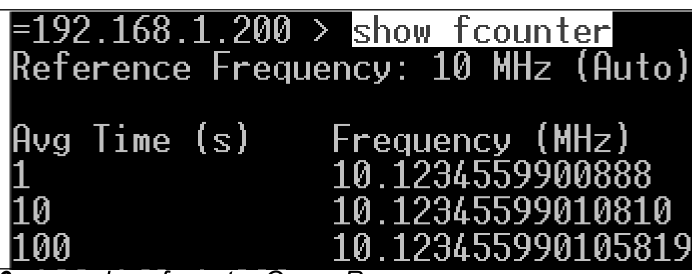


FIGURE 8-10: *show fcounter Query Response.*

The display precision is 13 digits to the right of the decimal point for 1-second averaging times at all DUT input frequencies. At DUT input frequencies of 5 MHz and above, 15 digits are displayed for averaging times longer than 10 seconds. 14 digits are displayed under all other conditions.

As with the TSC 51XXA phase noise test sets, accurate frequency counts with reference frequencies other than multiples of 100 kHz require the actual reference frequency to be specified. This can be done by a Telnet client with the `set referencefreq` command, or by using the `/referencefreq` command-line option on the server.

Unlike the 51XXA instruments, `set referencefreq` must be issued before the measurement begins in order to provide correct frequency counts. Any changes made during the measurement will not take effect until the next measurement begins.

show freqdiff
show freq

Returns the current frequency difference chart (Figure 8-11). Both forms (`freqdiff` and `freq`) are accepted.

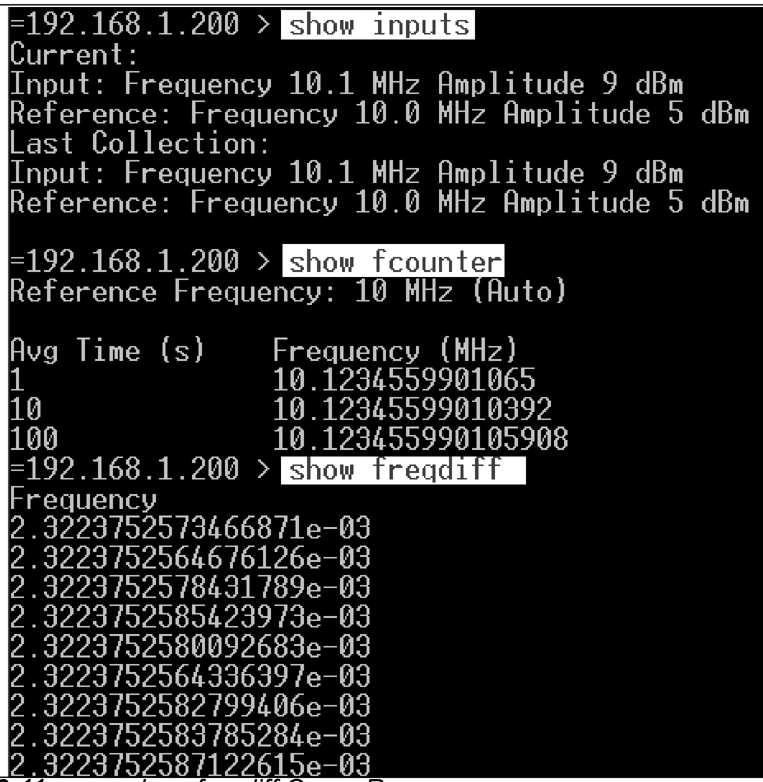


FIGURE 8-11: *show freqdiff Query Response.*

The values reported by this command comprise a historical strip chart record of the frequency of the signal at the DUT input jack, assuming that the reference frequency is either a multiple of 100 kHz or has been set correctly with either `set referencefreq` or `/referencefreq`. These DUT frequency readings are returned in the form of fractional frequency differences relative to the rounded input frequency reported by `show inputs`. Entries for the past n-1 seconds are displayed, ordered by age (oldest to newest), where n defaults to 600 seconds. The value of n can be configured through the use of the `/chart` command-line parameter.

In the example above, the DUT signal was generated by a DDS synthesizer tuned to a nominal frequency of 10.123456 MHz. This value is reported by the `show inputs` query as 10.1 MHz. The readings from `show fcounter` are more accurate as well as more precise, displaying consistent error that reveals the synthesizer’s limited tuning precision. Multiplying 10.1 MHz by one of the reported frequency difference readings near 2.322…E-3 and adding the result back to 10.1 MHz yields a similarly precise absolute frequency count.

show inputs

Returns rounded frequency and amplitude readings for the signals at the 53100A’s REFERENCE and DUT input ports, as shown in Figure 8-11.

Unlike the TSC 51XXA implementation of this command, both the Current and Last Collection values reflect the state of the measurement in progress. If no measurement is running at the time `show inputs` is issued, the message No measurement in progress will be returned.

`show inputfreq`

Returns the nominal DUT input frequency used for phase-difference calculations and the **show inputs** command. See the description of the `/inputfreq` command-line parameter for more information.

`show ipn`

Returns a chart showing integrated phase noise in units of radians over various portions of the Fourier spectrum, with and without the influence of coherent spurs.

```
=192.168.1.200 > show ipn
Time Constant: Infinite
Lower Integration        Integrated Phase         Integrated Phase
Frequency (Hz)           Noise without            Noise with
                         spurs (rad)              spurs (rad)

0.1      7.6e-05                 8.6e-05

1        6.0e-05                 7.3e-05

10       1.6e-05                 4.4e-05

100      1.5e-05                 4.3e-05

1000     1.5e-05                 4.3e-05

10000    1.4e-05                 4.2e-05
```

FIGURE 8-12: *show ipn Query Response.*

Each row in the chart reports the jitter at limits of integration between the given offset shown at left and the maximum offset supported by the 53100A's hardware, normally 1 MHz. Lower integration limits from 0.01 Hz to 10000 Hz are supported. In Figure 8-12, the measurement has been running long enough to provide data at a minimum lower integration limit of 0.1 Hz.

Columns are tab-separated for compatibility with TSC 51XXA applications.

`show message`

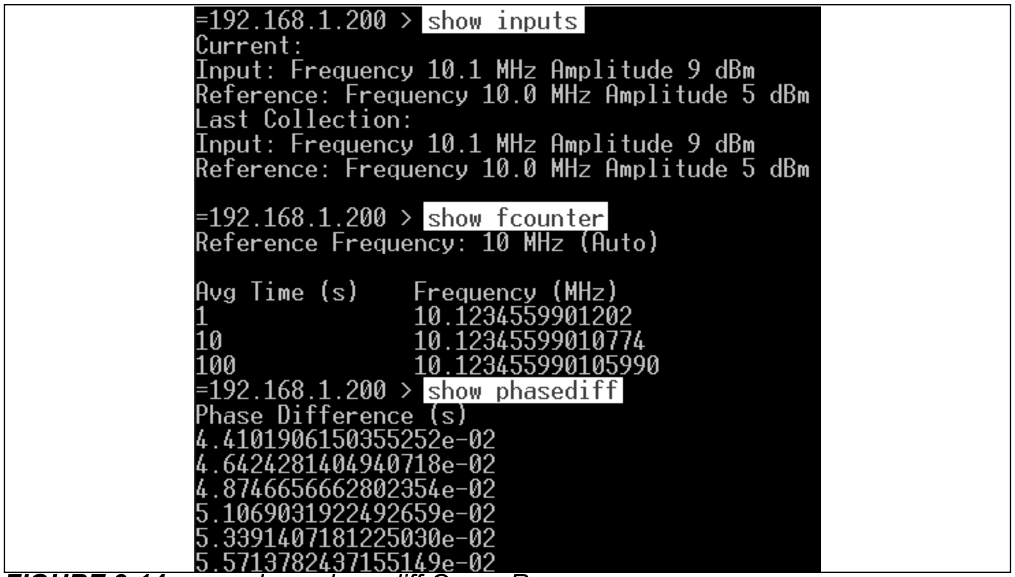
Returns the most recent error or warning message from the 53100A hardware driver (see Figure 8-13).

```
=192.168.1.200 > show message
USB connection lost
```

FIGURE 8-13: *show message Query Response.*

`show phasediff`

Returns the current phase difference chart (see Figure 8-14).



```
=192.168.1.200 > show inputs
Current:
Input: Frequency 10.1 MHz Amplitude 9 dBm
Reference: Frequency 10.0 MHz Amplitude 5 dBm
Last Collection:
Input: Frequency 10.1 MHz Amplitude 9 dBm
Reference: Frequency 10.0 MHz Amplitude 5 dBm

=192.168.1.200 > show fcounter
Reference Frequency: 10 MHz (Auto)

Avg Time (s)    Frequency (MHz)
1               10.1234559901202
10              10.12345599010774
100             10.123455990105990
=192.168.1.200 > show phasediff
Phase Difference (s)
4.4101906150355252e-02
4.6424281404940718e-02
4.8746656662802354e-02
5.1069031922492659e-02
5.3391407181225030e-02
5.5713782437155149e-02
```

FIGURE 8-14: *show phasediff Query Response.*

The values reported by this command comprise a historical strip chart record of the difference in phase between the nominal DUT input frequency reported by `show inputs` and the actual frequency at the DUT input jack, assuming that the reference frequency is either a multiple of 100 kHz or has been set correctly with either `set referencefreq` or `/referencefreq`. Entries for the past *n* seconds are displayed, ordered by age (oldest to newest), where *n* defaults to 600 seconds. The value of *n* can be configured through the use of the `/chart` command-line parameter.

The phase difference chart’s overall slope is a representation of the fractional difference between the nominal and actual frequencies. In the example above, as in the earlier **show freqdiff** example, the reported DUT input frequency is 10.1 MHz while the actual frequency from the test source is just under 10.123456 MHz. The readings above advance by about 2.322 milliseconds per second, corresponding to the fractional frequency differences returned by the `show freqdiff` command.

See the `measurelinear` and `removelinear` commands for information on calculating and removing the linear trend from the phase-difference chart.

`show phaserate`

Returns the phase data rate set by the `/phaserate` command-line parameter or the most recent `set phaserate` command. See the description of the `/phaserate` command-line parameter for more information.

`show referencefreq`

Returns the reference frequency used for frequency counter and phase/frequency difference calculations. See the description of the `/referencefreq` command-line parameter for more information.

`show spectrum`

Returns a list of offset frequencies and dBc/Hz values corresponding to the phase noise spectrum in the measurement in progress (see Figure 8-15):


```
=192.168.1.200 > show spectrum
Time Constant: Infinite
Frequency (Hz)  Power Spectral Density (dBc/Hz)

19.895                    -130.572329
19.953                    -130.578253
20.010                    -130.588895
20.068                    -130.603304
20.126                    -130.620726
20.184                    -130.640562
```

FIGURE 8-15: *show spectrum Query Response.*

Following the PSD data, the current instrument noise floor estimate will be returned (Figure 8-16):

```
Noise Floor
Frequency (Hz)  PSD
20.000                    -135.240870
37.661                    -137.191687
75.000                    -140.679948
133.872                   -145.450762
```

FIGURE 8-16: *Noise Floor Estimate.*

If no measurement is currently in progress, the `show spectrum` query will have no effect.

`show spurs`

Returns a list of identified coherent spurs in the phase noise spectrum (see Figure 8-17).

```
=192.168.1.200 > show spurs
Spur    Frequency (Hz)  Power (dBc)

0       60              -106.8
1       120             -120.1
2       180             -114.1
3       310             -117.5
4       710             -119.4
5       2630            -115.0
6       10420           -124.4
7       40290           -123.3
8       76020           -126.5
9       171360          -93.3
10      283160          -113.3
11      341500          -96.7
12      511640          -101.8
13      535940          -117.0
14      681780          -107.0
```

FIGURE 8-17: *show spurs Query Response.*

All identified spurs are removed from the PSD plot returned by `show spectrum`. Spurs that are not classified as instrument artifacts will appear in the table returned by `show spurs` at their correct (i.e., non-normalized) amplitudes in dBc.

See the descriptions of the `/spur_Hz` and `/spur_dB` command-line parameters for more information.

`show state`

Returns the current measurement status and elapsed time (see Figure 8-18).

- Ready = No measurement has been started
- Initializing = The measurement has not yet begun to return data

- Collecting = The measurement is currently in progress

```
=192.168.1.200 > show state
Collecting (14m 6s)
Time Constant: Infinite
```

FIGURE 8-18: *show state Query Response.*

Because TSERVE does not support the `timeconstant` property from the TSC 51XXA command language, `show state` will always report **Time Constant: Infinite**.

`show tau0`

Returns the current tau0 property value.

`show timeformat`

See `show dateformat`.

`show title`

Returns the title most recently set by the `set title` command or the `/title` command-line option. As shown in Figure 8-19, the `show title` query response depends on the measurement state as well as the title text itself.

```
=192.168.1.200 > show title
(Serial #)

=192.168.1.200 > start
=192.168.1.200 > show title
58526.447544

=192.168.1.200 > set title "Example title text"
Subtitle has been set to:
Example title text

=192.168.1.200 > show title
Example title text

=192.168.1.200 > set title "(Serial #)"
Subtitle has been set to:
(Serial #)

=192.168.1.200 > show title
58526.447544
```

FIGURE 8-19: *show title Query Response.*

The default title text is the reserved string (Serial #). If a `show title` query is issued during a measurement and the default title has not been changed, the reserved string will be replaced with the serial number of the 53100A that is running the measurement.

`show version`

Returns software and hardware version information (see Figure 8-20).

```
=192.168.1.200 > show version

Model: PhaseStation 53100A
Options: MOD4
FPGA firmware: V1.10
USB firmware: V1.00

Software: Version 1.00
```

FIGURE 8-20: *show version Query Response.*

shutdown

This command can be used to request immediate shutdown of the TSERVE server process, disconnecting all connected clients. To disconnect the current client without exiting TSERVE, use the `quit` command instead.

start
stop

These commands can be used by any connected client to initiate a new measurement or terminate one that is already in progress.

In many applications, it may be more convenient to start a measurement at the time TSERVE is launched and allow it to run until the server itself is stopped. This can be accomplished with the `/start` command-line parameter. Other command-line parameters can be used in lieu of the `set <property>` commands when necessary.

The above approach is analogous to pressing the <START> button on a physical test set. Streaming clients can connect to the data port and acquire data from the 53100A without the need for any Telnet clients or other terminal applications to connect to the command port.

8.4 COMPATIBILITY NOTES

- The following 51XXA commands and queries are not supported by TSERVE:
  - `button <number>`
  - `calinputs`
  - `control <take | yield>`
  - `print [<options>]`
  - `set print <options>`
  - `set timeconstant <value>`
  - `show mac`
  - `show printformats`
  - `show printoptions`
  - `show screens`
- As discussed elsewhere, commands such as `set referencefreq` that affect both current and subsequent measurements on the Microchip/Symmetricom/Microsemi 51XXA phase noise test sets will affect only subsequent measurements in TSERVE.
- The `show inputs` command returns both Current and Last Collection values on the 51XXA test sets. These values are not correctly maintained by the 51XXA test set firmware under certain conditions, such as when the previous input signals are disconnected and different ones reconnected. TSERVE does not attempt to emulate the 51XXA's behavior in this regard. Instead, both the Current and Last Collection values reflect the rounded frequency and amplitude estimates for the measurement currently in progress. If no measurement is currently being performed, the message *No measurement in progress* is returned to the client.
- The streaming phase-difference values returned by TSERVE are based on the rounded input frequency reported by the `show inputs` query. This is also true of the `show phasediff` and `show freqdiff` chart entries. On the 51XXA test sets, however, these values are referred to a more precise internal frequency measurement that is not made available to remote-access clients. Consequently, only the `show fcounter` command can be used to obtain accurate frequency counts on the 51XXA test sets, while TimeLab's own frequency count chart in the *Measurement>Frequency Difference* <f> view can be used with phase data from TSERVE if the correct rounded input frequency is entered in the Acquisition dialog.

- On the 51XXA test sets, the `show adev` command returns separate Allan deviation charts for all supported t_0 intervals. TSERVE returns data only for the t_0 interval corresponding to the most recent `set phaserate` or `set tau0` commands.
- The default phase rate for the 51XXA test sets is 1000 samples per second. TSERVE's default phase rate is 100 samples per second, unless changed with the `/phaserate` command-line option.
- The 51XXA test sets transmit measurement-related error messages to the Telnet client asynchronously, sometimes waiting until the next character arrives from the remote client before sending the message. As a rule, TSERVE transmits text on the Telnet command port only in response to specific commands. The `show message` command is provided to allow the remote user or application to determine if the most recent measurement encountered an error or warning condition. An empty string indicates that no errors or warnings have occurred.

8.5 MEASUREMENT EXAMPLE: PHASE DATA STREAMING

When using software that was originally written to capture phase data from the Microchip/Symmetricom/Microsemi 5115A/5120A/5125A and compatible instruments, you will normally want to allow TSERVE to use its default `/port` value (1298) and default `/format` value (TSC). However, when using TimeLab's *Acquire>Acquire from TCP/IP Streaming Server* option, only the phase-difference data format (`/format:P`) is supported.

Example: `tserve64 /data_port:1234 /phaserate:100 /phasedec:20 /format:P /start`

As an example, the command above will begin capturing phase-difference data at a rate of 100 samples per second as soon as TSERVE is launched. If desired, Telnet commands may be issued via port 1299 as usual, but this isn't required because the `/start` option has been specified on the TSERVE command line.

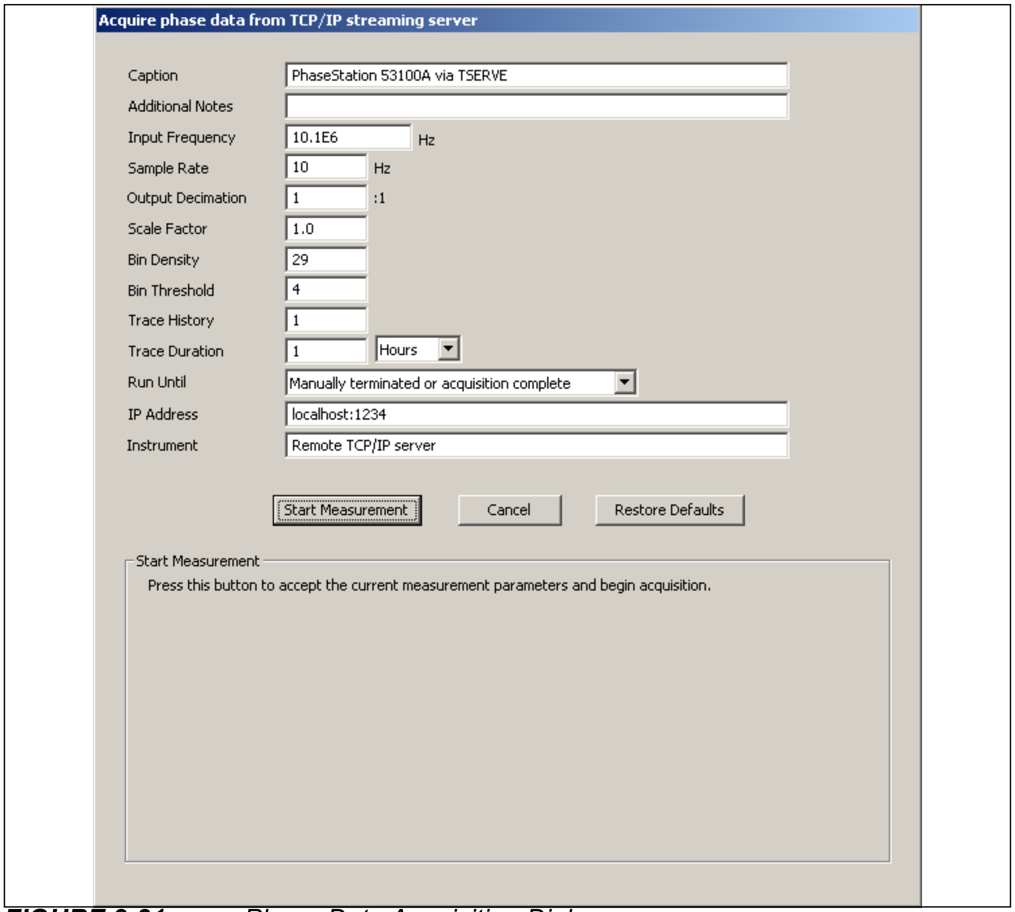


FIGURE 8-21: *Phase Data Acquisition Dialog.*

Internally, the data will be captured at 200 samples per second with a noise-equivalent bandwidth of 50 Hz. Phase data would normally be recorded with 2:1 decimation after detection, for a final data rate of 100 samples per second. However, the use of the `/phasedec:20` option results in a final data rate of only 10 samples per second. This is the rate at which the phase-difference readings associated with `/format:P` will be streamed from port 1234.

You can receive the streaming phase data on any machine that can access the server on your network, including the server PC itself. Either *Acquire>Microchip 5115A /5120A/5125A (Frequency Stability)* or the more general *Acquire>Acquire from TCP/IP Streaming Server* option can be used to retrieve phase data from TSERVE. In Figure 8-21, the latter has been selected. The “Input Frequency” field in the Acquisition dialog has been populated with the 100 kHz rounded value that would be reported by the `show inputs` command, while Sample Rate is set to the final data rate of 10 samples per second. With an Output Decimation value of 1, no additional decimation will be performed by TimeLab.

TimeLab can receive data concurrently from multiple instruments. When the 53100A measurement described above was run alongside a Microchip/Symmetricom 5125A test set connected to the same signal sources, the result shown in Figure 8-22 was obtained:

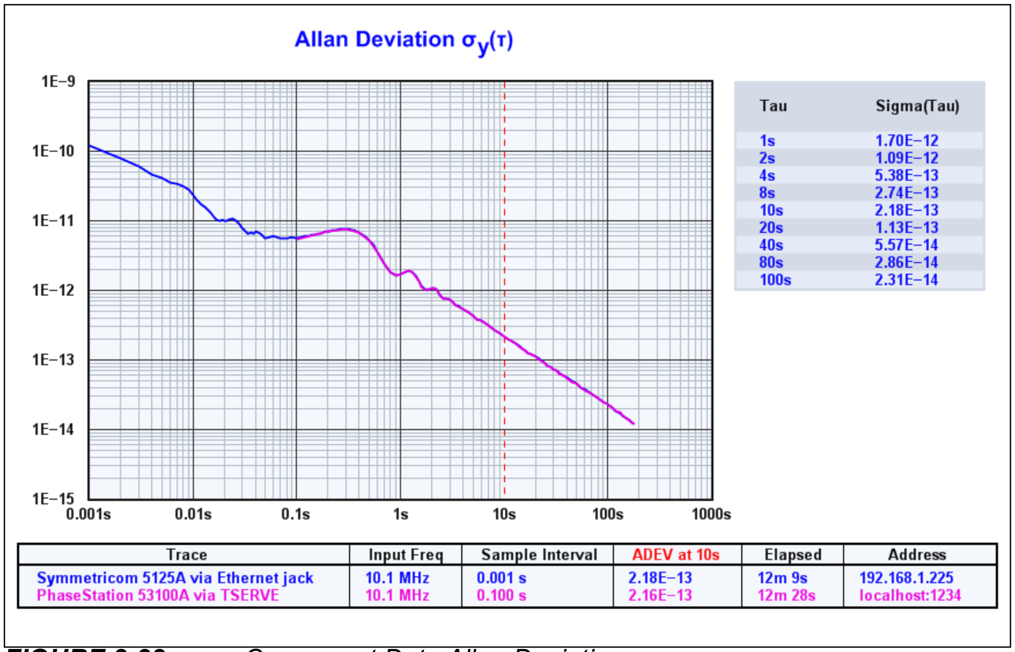


FIGURE 8-22: *Concurrent Data Allan Deviation.*

For this exercise, the Microchip/Symmetricom 5125A's `phaserate` property was left at its default value of 1000 samples per second. Consequently, its Allan deviation trace begins at t_0 = 0.001 second, while the 53100A measurement begins at t_0 = 0.1 second. The results are otherwise virtually identical.

8.6 MEASUREMENT EXAMPLE: PHASE NOISE PLOT ACQUISITION

TimeLab can also retrieve and display phase noise data from both the 53100A and Microchip/Symmetricom 51XXA test sets through the use of the *Acquire>Microchip 5115A /5120A/5125A (Phase Noise)* acquisition option. Unlike the streaming phase data acquisition process, obtaining phase noise data from either TSERVE or an actual 51XXA test set requires the program to connect to the Telnet command port.

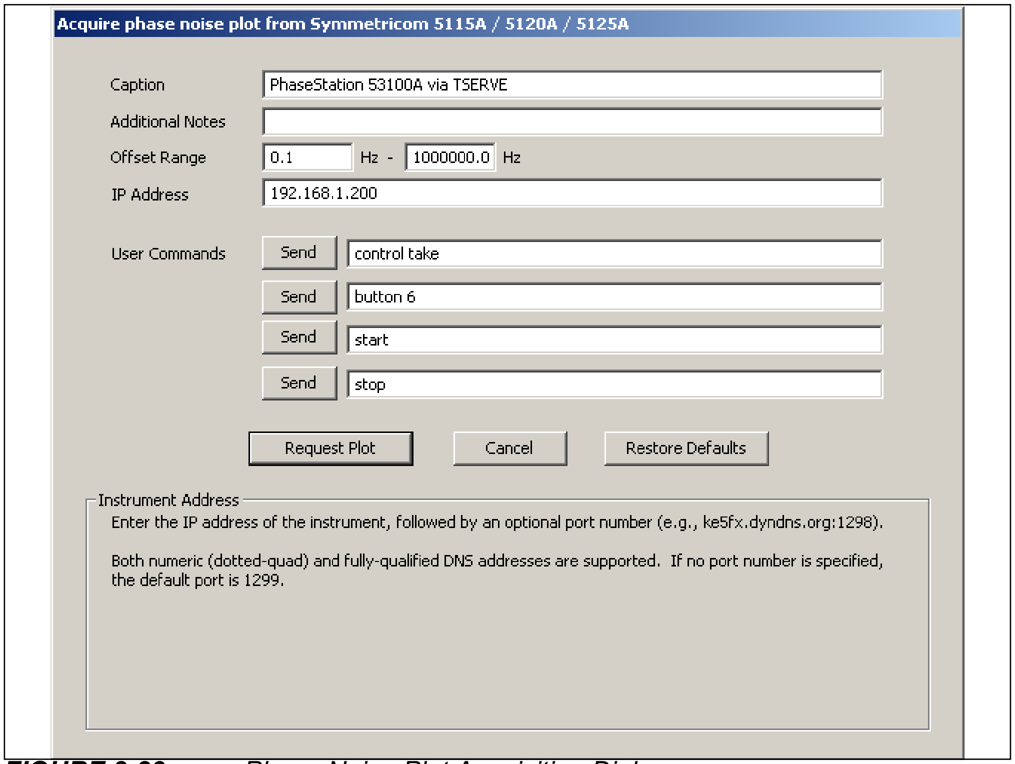


FIGURE 8-23: *Phase Noise Plot Acquisition Dialog.*

Because TimeLab can obtain most of the required measurement parameters and properties directly from the server, relatively few configuration steps are needed in the 51XXA phase noise acquisition dialog. It's necessary only to ensure that the correct IP address and optional port number are specified, in this case either `192.168.1.200` as used in Figure 8-23, or the equivalent `localhost` alias used earlier for phase data capture. No port number is required as long as the default command port assignment (1299) has not been changed with the `/cmd_port` command-line parameter.

For convenience, the phase noise acquisition dialog offers four general-purpose command buttons that are predefined with useful defaults that allow front-panel control commands to be transmitted to an actual TSC 51XXA phase noise test set. Only the <start> and <stop> buttons supported by TSERVE.

Figure 8-24 shows the phase noise plots that were simultaneously measured during the one-hour streaming data acquisition in the previous example.

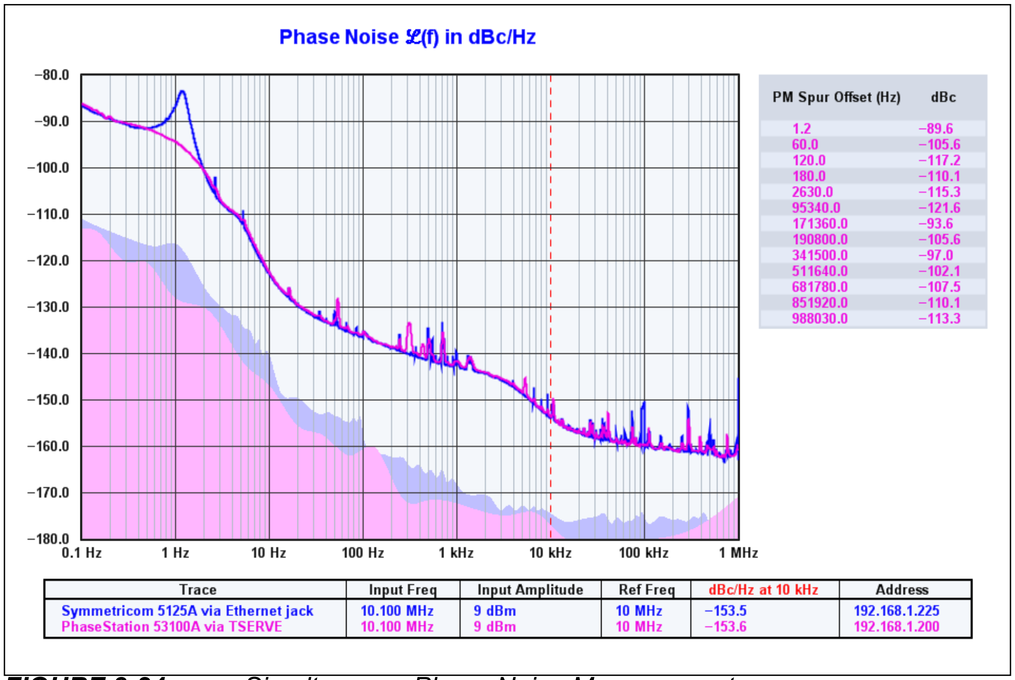


FIGURE 8-24: *Simultaneous Phase Noise Measurements.*

Once again, the results match closely. The most notable difference is that the 53100A has classified the sharp peak near 1.2 Hz as a spur, removing it from the plot and adding it to the spur chart at right. Adding `/spur_Hz=2` to the TSERVE command line would have resulted in an even closer match by forcing the 53100A's spur-detection routine to disregard the peak.

Appendix A. 53100A Dual 100 MHz Reference (Option IR)

Option IR adds two independent 100 MHz reference outputs to the Microchip 53100A. These reference sources support fully self-contained noise and stability measurements at a higher level of performance than virtually any single-channel references can provide, and can also serve as spectrally pure 100 MHz signal sources in other applications. The reference outputs are directly accessible at the front-panel INT REF 1 and INT REF 2 jacks.

A.1 FRONT AND REAR PANEL LAYOUTS

Test sets equipped with Option IR are delivered with the channel-1 and channel-2 input jacks strapped to INT REF 1 and INT REF 2 by default, rather than to the built-in reference splitter outputs (Figure A-1). In this configuration, the N-F front-panel REFERENCE input jack may be driven by an external 10 MHz "house clock" to discipline one or both of the internal references, or simply left unconnected for true standalone operation.

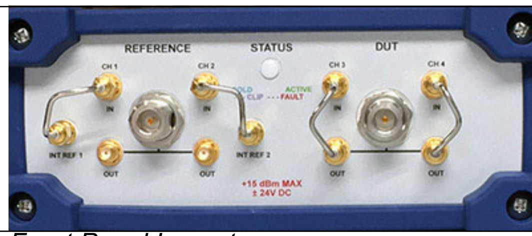


FIGURE A-1: *Front Panel Layout.*

The rear panel includes the additional TTL/5V CMOS level 1 PPS IN jack shown in Figure A-2. Like the front-panel REFERENCE jack, an external disciplining source may be connected to the 1 PPS IN jack. More information on selection and connection of external reference sources appears later in this section.

FIGURE A-2: *Rear Panel Layout.*

The INT REF 1 and INT REF 2 outputs provide reference signals at 100 MHz as long as power is connected to the 53100A, regardless of whether external 10 MHz or 1PPS sources are present. At the same time, all four of the 53100A's input channels remain user-accessible in both Option IR and standard units, to support applications that require direct connection of multichannel sources or external references.

A.2 OPTIONAL INTERNAL ATOMIC STANDARD (STD)

The Option IR reference module may itself be equipped with an optional board-level atomic frequency standard, which can serve as an additional disciplining source in measurement applications that require long-term frequency stability but that do not have access to high quality external standards. Reference frequency stability at intervals longer than approximately 1000 seconds is improved up to 10x in units equipped with the IR/STD option.

A.3 BLOCK DIAGRAM

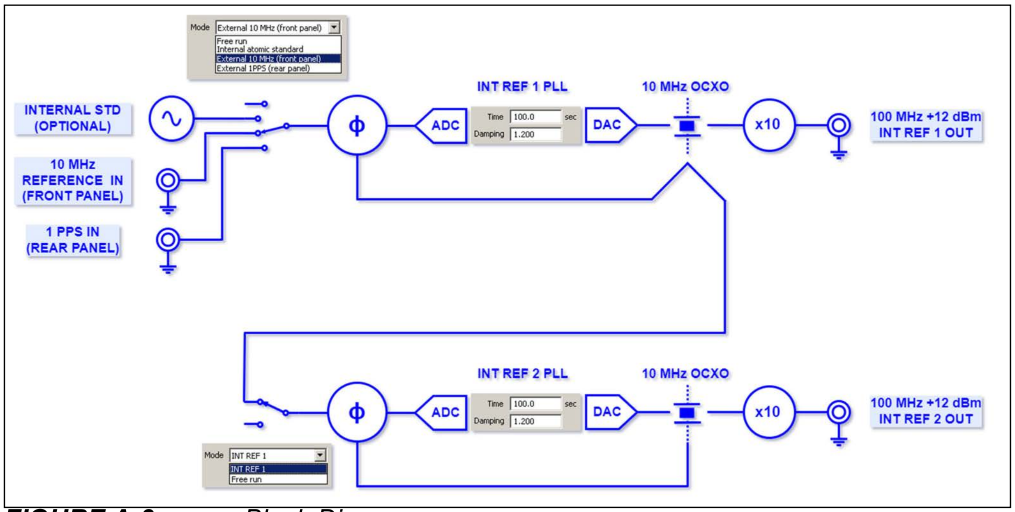


FIGURE A-3: *Block Diagram.*

Figure A-3 illustrates the basic architecture of the Option IR internal reference module. Each of the two independent channels has its own 10 MHz oven-controlled crystal oscillator (OCXO) which is followed by a low-noise frequency multiplier that generates the 100 MHz output for that channel.

While capable of free-running operation, the 10 MHz OCXO that drives the INT REF 1 output is most often phase-locked to an external or internal 10 MHz standard to maintain frequency accuracy and long term stability, with its PLL acting as a "cleanup" loop for any short-term noise that may be present. Similarly, the INT REF 2 OCXO can either be phase-locked to the INT REF 1 OCXO or allowed to free-run. By default, INT REF 2 is locked to INT REF 1 with a 100-second time constant, allowing the two channels' short-term noise to remain uncorrelated while maintaining overall frequency accuracy at longer intervals.

With this approach, for example, the 53100A can measure the 1 Hz phase noise of ultrastable 5 MHz OCXOs at levels near –130 dBc/Hz even though the 1 Hz phase noise at the INT REF 1 and INT REF 2 outputs is closer to –120 dBc/Hz. At the same time, Allan deviation measurements near 2E-13 @ t=1s are practical. In areas of the graph where the INT REF 1 and INT REF 2 sources are uncorrelated, the real-world measurement floor for a 53100A equipped with Option IR is often determined more by acquisition time than by the reference sources' own specifications.

A.4 WHY 100 MHz?

Compared to traditional 5 MHz or 10 MHz references, the use of 100 MHz reference sources offers substantial reductions in PN measurement time when working with high-quality VHF crystal oscillators. Especially at offsets above 1 kHz, lower-frequency references require many more FFT averages to achieve the necessary noise floor improvement. Unfortunately, even the best 100 MHz OCXOs lack the stability to make good reference sources for measurements of high-quality HF oscillators.

Option IR is designed to overcome both limitations. As noted above, the two INT REF output signals originate with independent 10 MHz oven-controlled crystal oscillators (OCXOs) with excellent short-term stability and phase noise characteristics. These oscillators are followed by 100 MHz analog PLLs that are based on JFET frequency multipliers rather than traditional dividers. As a result, the OCXOs' superior phase stability is maintained at offsets below 1 kHz without compromising the broadband noise floor. Integrated jitter at the 100 MHz outputs is typically better than 40 fs in the critical 1 Hz to 1 kHz range and below 10 fs from 1 kHz to 1 MHz.

A.5 SOFTWARE SUPPORT

The TimeLab acquisition dialog for the Microchip 53100A includes a separate page of settings and controls for units equipped with Option IR. This page is accessed by pressing the **Internal Reference** button seen at right (Figure A-4) after selecting _Acquire>Microchip 53100A_ in the TimeLab main menu.

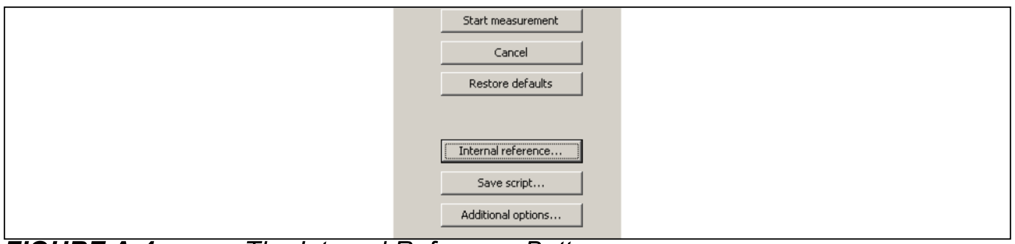


FIGURE A-4: *The Internal Reference Button.*

As shown in Figure A-5, this dialog page includes controls to adjust PLL properties, configure lock source preferences, and calibrate the two OCXOs and the optional internal atomic standard.

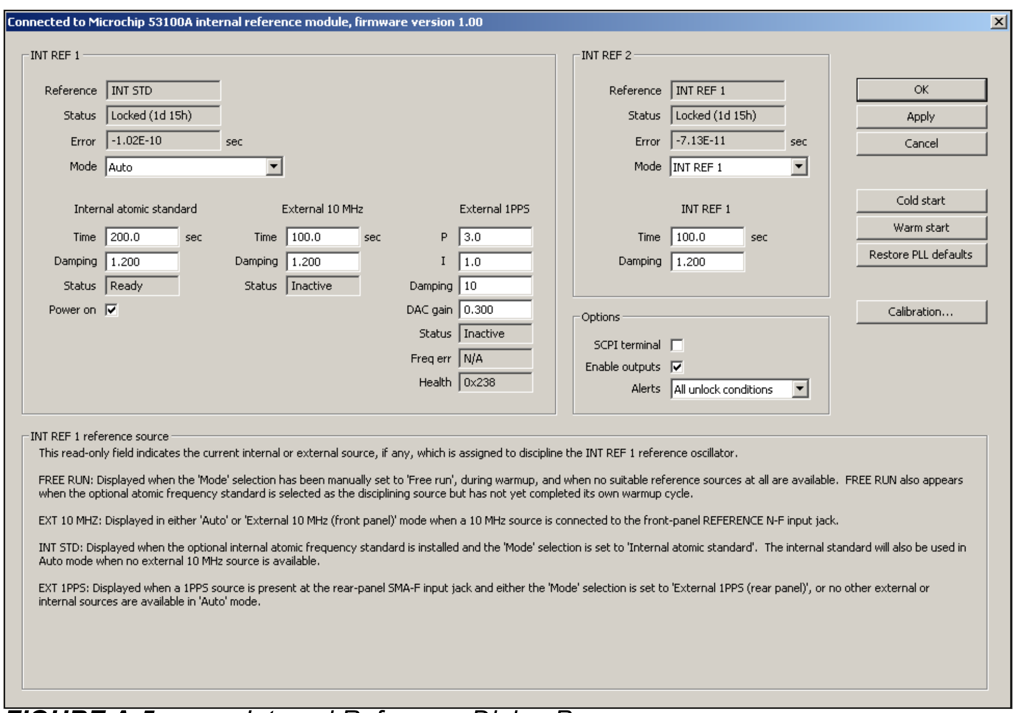


FIGURE A-5: *Internal Reference Dialog Page.*

The Option IR configuration dialog is divided into two separate sections governing the INT REF 1 and INT 2 references and a third section containing controls common to both. The two INT REF sections are similar, except that INT REF 1 can be locked to the optional internal atomic standard or to an external 10 MHz or 1 PPS source, while INT REF 2 can be disciplined only by INT REF 1. Buttons are also provided at right to reset the internal reference module's onboard CPU (**Cold start**), force immediate relocking in both channels (**Warm start**), and restore the values that determine the PLL properties in both channels to their factory default settings (**Restore PLL defaults**).

A.6 USER AND FACTORY CALIBRATION CONTROLS

Note: Only models equipped with an Internal Reference option may be calibrated with the procedure shown in this section. The base unit, on the other hand, inherits the calibration of the externally applied reference.

The **Calibration** button opens an additional dialog page containing user calibration options for the internal OCXO sources and optional atomic standard (Figure A-6).

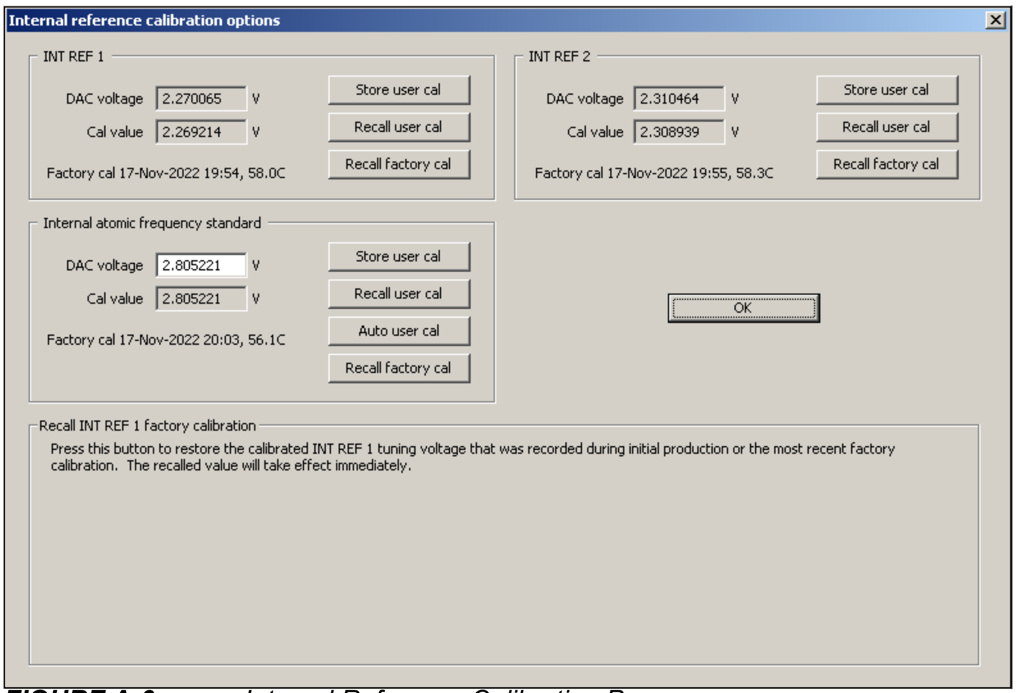


FIGURE A-6: *Internal Reference Calibration Page.*

This dialog box provides access to the calibration constant parameters that apply when a given OCXO is in free-running operation, unlocked to any internal or external source. These calibration constants represent tuning voltages applied via microvolt-resolution DACs to the OCXO frequency-control inputs during unlocked operation. When an OCXO is in free-running (unlocked) operation, its calibration constant can be edited manually if desired and updated by pressing **Store user cal**. The oscillator's tuning range and sensitivity in hertz per volt appears in the mouseover help text for that channel's "DAC voltage" field. In units equipped with the optional internal atomic frequency standard, a third calibration constant determines its tuning voltage as well.

A key point is that the OCXO calibration constant is not used at all when its corresponding oscillator is locked to an internal or external standard. The OCXO's tuning DAC is driven by its respective software PLL during closed-loop operation, with the DAC voltage displayed as a read-only value. At any time, the tuning DAC voltage for a given channel can be saved to nonvolatile memory with the channel's **Store user cal** button.

This will establish a new “user calibration” value for the channel. Assuming the OCXO was locked to a given calibration source at the time **Store user cal** was pressed, its frequency during subsequent free-running operation will be very close to that of the source.

It’s also important to note that the optional internal atomic frequency standard is not automatically steered by an external source. (In fact, an external 10 MHz source connected to the front-panel REFERENCE jack will take precedence over the internal atomic standard in locking the INT REF 1 OCXO when the channel’s **Mode** selection is set to the default “Auto” value). Instead, the internal standard can be calibrated by connecting an external 10 MHz or 1PPS signal temporarily and pressing the **Auto user cal** button once the INT REF 1 OCXO has successfully phase-locked to the external source. This will start an auto-calibration routine that typically takes 3-5 minutes to match the frequency of the external signal to a fractional accuracy of less than 1E-10. If successful, the resulting DAC voltage will be stored as the internal atomic standard’s user calibration constant. The external standard may then be disconnected, if desired.

Finally, the most recent factory calibration constant for INT REF 1, INT REF 2, or the internal atomic standard may be recalled at any time by pressing the appropriate **Recall factory cal** button. The factory calibration constant will replace the user calibration constant (if any) for that channel. It will remain in effect until a new user calibration constant is stored with **Store user cal** or a previously-stored one is recalled with **Recall user cal**. The factory calibration constants are always available for selection and cannot be overwritten in normal operation.

A 12 month re-calibration cycle is recommended. Initial calibration due date is 12 months from the end-user receipt date. It is recommended that the end-user complete the **date due** on both the calibration certificate as well as the calibration sticker found on the unit.

A.7 USER CALIBRATION INSTRUCTIONS

1. Ensure that power has been connected for at least 2 hours prior to calibration, and that no measurement is currently in progress
2. Connect a calibrated frequency source, such as the Microchip 5071B primary frequency standard, to the front-panel REFERENCE jack
3. Click *Acquire>Microchip 53100A*, then select the Internal reference control page.
4. Ensure that INT REF 1’s Mode control is set to either Auto or External 10 MHz (front panel), and that the INT REF 2 Mode is set to INT REF 1. (These are the same defaults established by the Restore PLL defaults button.) Wait for the Status fields in both channels to reach the Locked state.
5. Ensure that the Time fields for both INT REF 1 and INT REF 2 are set to at least 10 seconds for best results. (Restore PLL defaults will set both fields to 100 seconds.)
6. Press the Calibration button and observe the DAC voltage fields for the INT REF 1 and INT REF 2 channels. If the external 10 MHz source was recently connected or if any loop parameters have recently been changed, these readings can be expected to fluctuate significantly as the control loops settle. For best results, wait until the DAC voltages remain within ±10 microvolts for several seconds before proceeding.
7. After the DAC voltages have stabilized, press the Store user cal buttons for both the INT REF 1 and INT REF 2 references. Observe that the Cal value fields capture the current DAC voltages, and that the calibration status line changes to “User cal <date> <time> <temperature>.” Calibration of the channel-1 and channel-2 OCXOs is now complete.

(Option IR/STD only) To calibrate the internal atomic standard, simply connect the external 10 MHz standard as described above and press the Store user cal button in the control area for the internal atomic frequency standard. This procedure will take approximately 3-5 minutes. OCXO calibration does not need to be performed prior to atomic standard calibration.

A.8 FIRMWARE UPDATES

The Option IR module runs continuously under the control of its own microprocessor, even when the 53100A's rear-panel power switch is turned off. The latest firmware for the option module accompanies each TimeLab software release alongside the firmware for the 53100A itself. To install new firmware, open the **Additional options** dialog box from the **53100A acquisition** dialog and click the **Update firmware** button, then select the appropriate Intel `.hex` file with the file-selection dialog box that appears.

It is not necessary to power-cycle or otherwise reboot the 53100A manually after installing new firmware, although phase lock will be lost during the cold-start cycle that is automatically initiated. As with any other cold-start cycle, please wait at least 30-60 minutes before attempting to make high-performance measurements after updating.

A.9 ONLINE HELP

As with other acquisition dialog pages in TimeLab, individual controls and features in the **Internal reference** and **Calibration** dialogs may vary from one software release to the next. Detailed context-sensitive mouseover help text is provided for all dialog fields and serves as the primary documentation for these controls. Please refer to the help text for the latest user information and operating tips.

A.10 APPLICATION EXAMPLES

The following measurements share one aspect in common: they were carried out with no external equipment or reference sources other than a Microchip 53100A equipped with Option IR.

A.10.1 Phase Noise of 100 MHz VCXO (1-minute and 30-minute runs)

In the first example, the 53100A was used to evaluate a high-performance VHF crystal oscillator module for compliance with its phase noise specifications. A one-minute test returned the following result (Figure A-7):

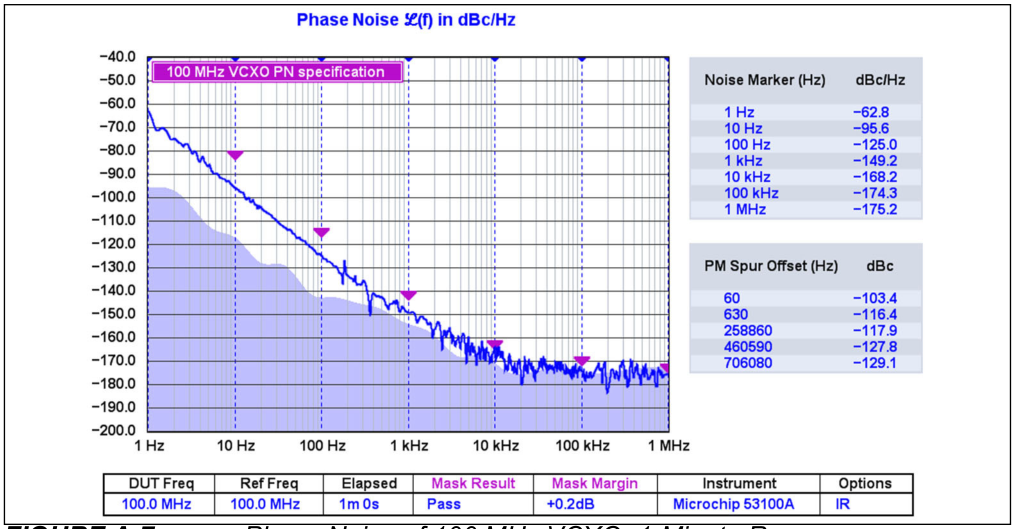


FIGURE A-7: *Phase Noise of 100 MHz VCXO, 1-Minute Run.*

The observed close-in noise is excellent for this class of device, with substantial head-room available at offsets below 10 kHz. Specifications at the higher-frequency offsets are met as well, but only barely. Along with the high instrument floor estimate, signifi-cant trace variance at offsets beyond a few kHz suggests that the cross-correlation measurement hasn't had enough time to converge fully. Running for 30 minutes instead of only one minute gives us a better clue to the oscillator's true performance, as well as that of the 53100A.

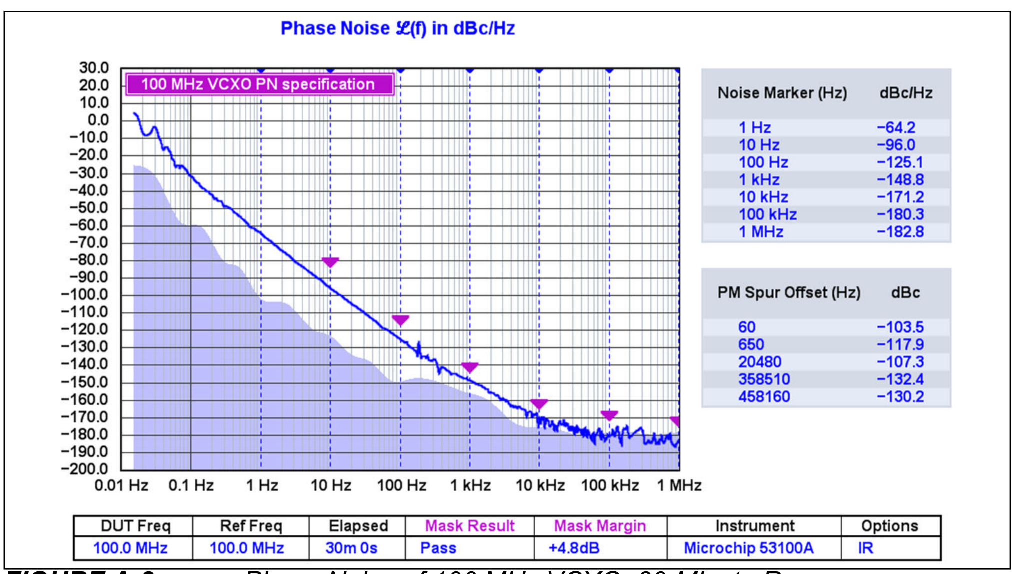


FIGURE A-8: *Phase Noise of 100 MHz VCXO, 30-Minute Run.*

In Figure A-8, the trace still hasn't converged fully beyond 10 kHz after 30 minutes and likely will not do so regardless of measurement duration, given that it is already well below the –175 dBc/Hz typical performance figures noted in the 53100A's own documentation. However, it is safe to conclude that the DUT's broadband noise floor is in the vicinity of –180 dBc/Hz[1].

Most of the 53100A's acquisition parameters, and all of the Option IR loop parameters, were left at their default values for this measurement, apart from specifying the 1-minute and 30-minute measurement durations. Parameter changes made for this demonstration are listed below.

A.10.1.1 SET APPROPRIATE SPUR AMPLITUDE AND OFFSET THRESHOLDS

These options can be found on the **Additional options** page of the 53100A acquisition dialog (Figure A-9). Especially if you use continuous limit-line masks for PN pass/fail evaluation, it's helpful to reduce the **Spur threshold** from 6 dB to 3 dB to keep small unrecognized spurs from artificially failing the PN test.

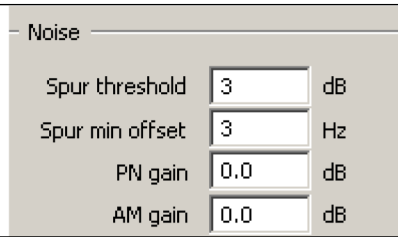


FIGURE A-9: *Spur Amplitude and Offset Thresholds.*

False spur identification at close-in offsets can be avoided by setting a minimum offset for spur detection. This effect is more likely to occur when testing sources with very low close-in noise, rather than the VCXO in this example.

A.10.1.2 ENABLE OVERLAPPED ACQUISITION

This will help low-level phase noise tests pass sooner, often within less than a minute (Figure A-10). Try disabling AM noise measurements if USB overruns occur. Also, use the **System power** option to ensure that high performance power plan is in effect during acquisition.

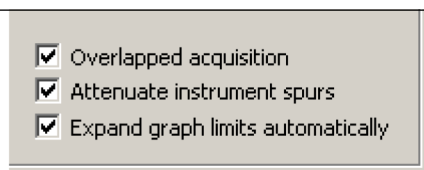


FIGURE A-10: *Overlapped Acquisition Option.*

Both of these fields are on the **Additional options** page of the main 53100A acquisition dialog.

1: Specifically, the oscillator has a carrier output power of +12 dBm and source impedance near 50Ω. At this power level, a theoretically ideal instrument could measure the PN noise at levels down to –177 dBm/Hz – 12 dBm + 3 dB = –186 dBc/Hz, allowing 3 dB of additional noise for the analyzer's own load impedance. Some caution is warranted as cross-correlating analyzers are subject to artifacts that can underestimate the true noise level when sources are operating near the thermal limit. However, measurement time constraints and very low-level instrument spurs usually determine the 53100A's performance floor before these effects become apparent.

A.10.1.3 USE THE ABS(I) CROSS SPECTRUM ESTIMATOR

This improves test time in challenging measurements where the DUT noise floor is close to the instrument floor (Figure A-11, also on the **Additional options** page). The trace may appear 'uglier' at first with numerous false spurs that may take a minute or two to resolve. However, the instrument noise contribution will be 3 dB lower and there will be a corresponding improvement in measurement convergence time.

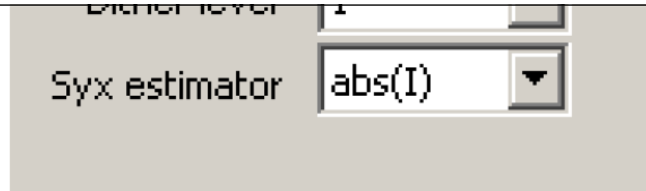


FIGURE A-11: *Syx Estimator Option.*

A.10.2 Short-Term Stability of Ultrastable 5 MHz DOCXO

In the second scenario, the goal is to verify that a double-oven OCXO meets its short-term Allan deviation specifications of 2E-13 @ t=0.1s, 2E-13 @ t=1s, and 8E-13 @ t=10s. Figure A-12 reveals that the 53100A's internal reference module can make this measurement, given that its own absolute ADEV specifications are several times higher, as long as a few prerequisites are understood.

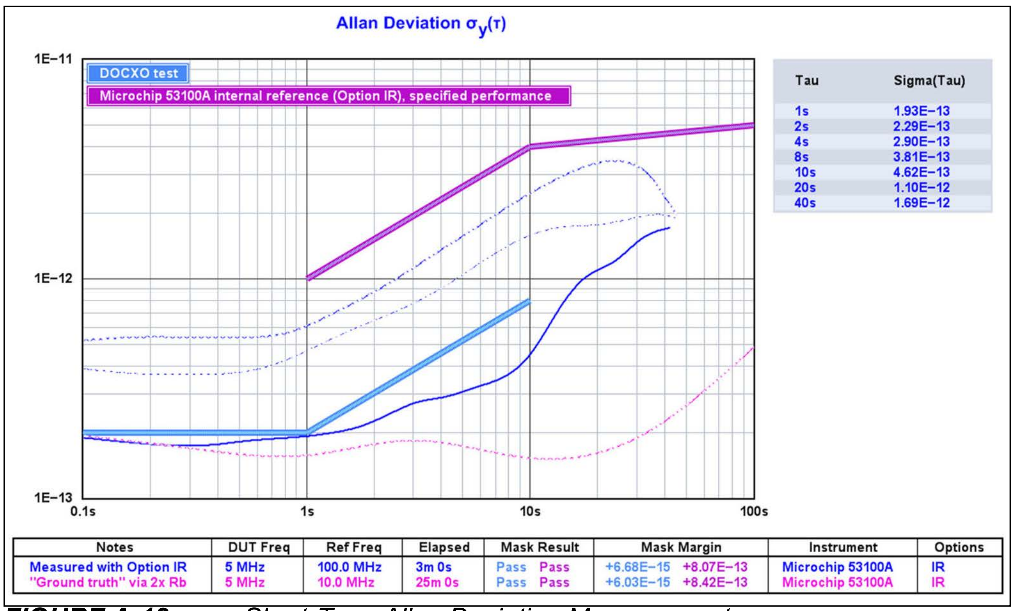


FIGURE A-12: *Short-Term Allan Deviation Measurement.*

A.10.2.1 SELECT A MEASUREMENT ROLE WITH CROSS ADEV SUPPORT

Cross Allan deviation is not a unique measurement type in itself, but rather a way to perform traditional Allan deviation measurements using multiple channels and/or reference sources in a manner reminiscent of more familiar cross-correlated phase noise measurement techniques. Just as with cross-correlated PN measurements, both reference stability and instrument ADC noise performance undergo progressive improvement over time by averaging the results of two identical measurements carried out simultaneously. While the Microchip 53100A can make cross ADEV measurements using a pair of external or internal references, the technique is an especially-good fit for Option IR instruments.

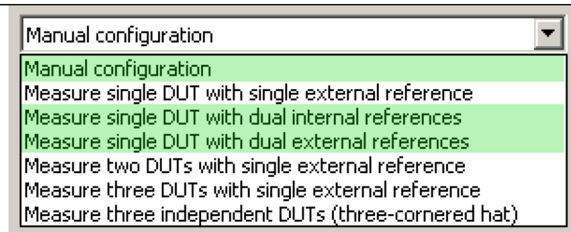


FIGURE A-13: *Manual Configuration Menu.*

Referring to the main page of the 53100A’s acquisition dialog, any of the predefined measurement role options highlighted in Figure A-13 can be used to perform cross ADEV measurements. The required secondary phase data record is automatically created whenever channels 3 and 4 have separate **Stability reference** channels assigned to them. This will be the case whenever one of the predefined dual-reference roles is chosen, as well as when **Manual configuration** is used to set up a measurement that meets the same conditions. Note that **Always use cross ADEV when possible** must also be checked on the **Additional options** page of the acquisition dialog. This checkbox is selected by default.

In TimeLab itself, make sure that *Trace>Show cross ADEV traces when available* <Ctrl-j> is enabled. For the screenshot example in Figure A-12, we’ve also selected *Trace>Show original traces in computed xDEV displays* <F6> to highlight the improvement in the stability measurement floor achieved with cross ADEV. The heavy and light dotted traces in blue represent the measurements that would have been obtained by measuring the DUT against either the INT REF 1 or INT REF 2 reference source by itself. Also, for the sake of comparison, the magenta trace shows the actual performance of the DOCXO under test as measured with a pair of lab-grade rubidium frequency standards serving as reference sources.

A.10.2.2 CONSIDER USING DEFERRED ACQUISITION IF NECESSARY

Given adequate warmup time and an appropriate PLL time constant, drift is negligible when INT REF 1 is locked to an internal or external 10 MHz standard. When one or both OCXOs is allowed to free-run, however, temperature variations associated with the onset of USB data acquisition can induce a small amount of frequency drift in the early part of the measurement. Challenging ADEV measurements such as the one in this example may take longer than expected to settle as a result.

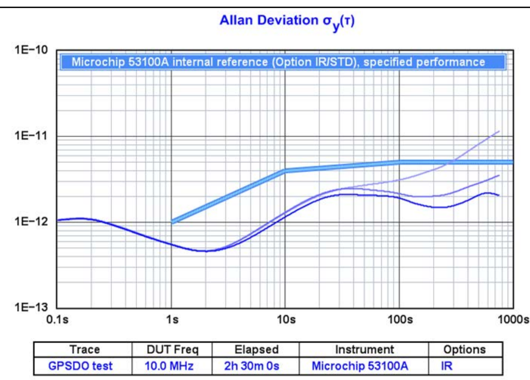


FIGURE A-14: *Diagnosing Initial Drift.*

As with other temperature-related effects, initial drift can often be diagnosed by using *Edit>Trace properties* <e> to set the “Trace history” parameter to 2 or 3 (Figure A-14). Here, the darker ADEV traces correspond to later segments of the measurement’s phase record.

One way to avoid this issue is to tell TimeLab to discard the initial subset of measurement data by using *Acquire>Acquisition options* to specify a delay as shown in Figure A-15. Subsequently, select the *Acquire>Enable deferred acquisition* option to enable the delay. The measurement will begin as usual, but by selecting an appropriate "Acquisition delay" parameter, no data will actually be recorded until temperature equilibrium has been established.

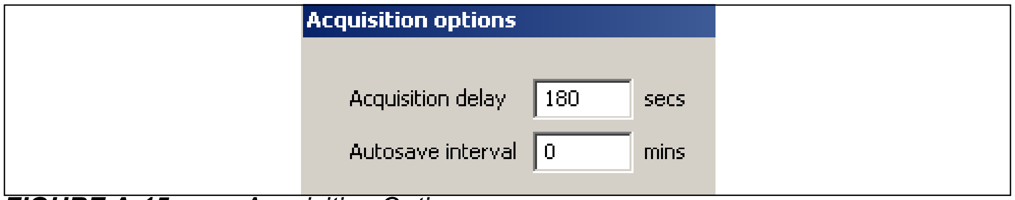


FIGURE A-15: *Acquisition Options.*

A.10.2.3 REDUCE THE MEASUREMENT BANDWIDTH

The DOCXO that we measured in this example would not have passed its ADEV test at the default 50 Hz (100 points/sec) measurement bandwidth due to the unusually tight performance requirement at t=0.1s. It was necessary to select 5 Hz instead (Figure A-16).

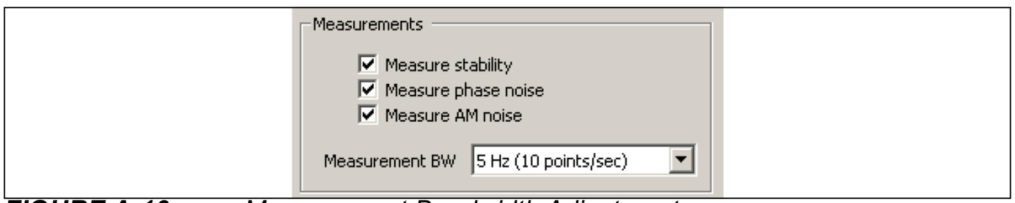


FIGURE A-16: *Measurement Bandwidth Adjustment.*

Note that the choice of measurement bandwidth does not affect noise measurements, only stability measurements.

A.10.2.4 ENSURE REFERENCES ARE DISCIPLINED APPROPRIATELY

To achieve the lowest ADEV measurement floor near t=1s, it may be tempting to configure INT REF 1 and/or INT REF 2 in free-running mode. Doing so can keep the external or internal standard from contributing to short-term reference instability, but the resulting drift may give rise to artifacts that take a very long time to resolve, such as the large divot in Figure A-17 that's caused by leaving both references unlocked.

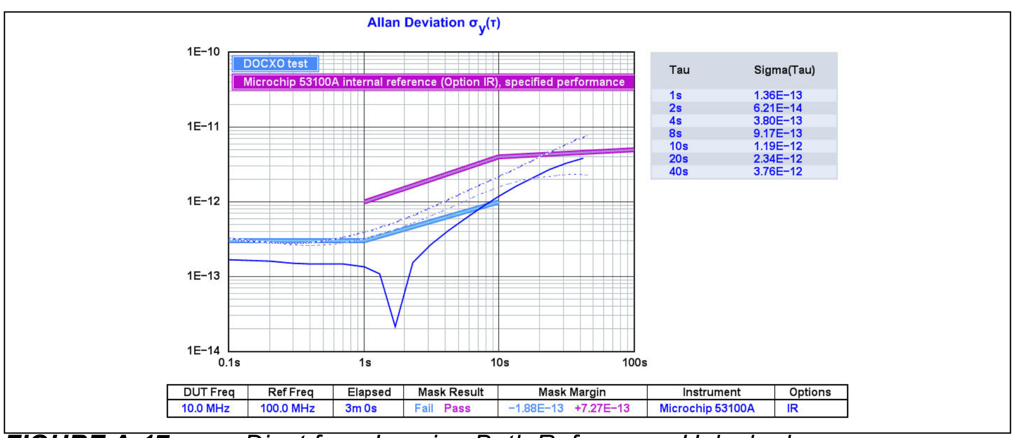


FIGURE A-17: *Divot from Leaving Both References Unlocked.*

While both cross ADEV and phase noise measurements rely on statistical independence of INT REF 1 and INT REF 2 at the taus and offset frequencies of interest, the choice of lock bandwidth is more likely to be dictated by the maximum ADEV tau of interest than by the minimum PN offset requirement. INT REF 2’s lock bandwidth will have a noticeable impact on the cross ADEV measurement floor at taus exceeding 5% to 10% of the lock time constant in seconds.

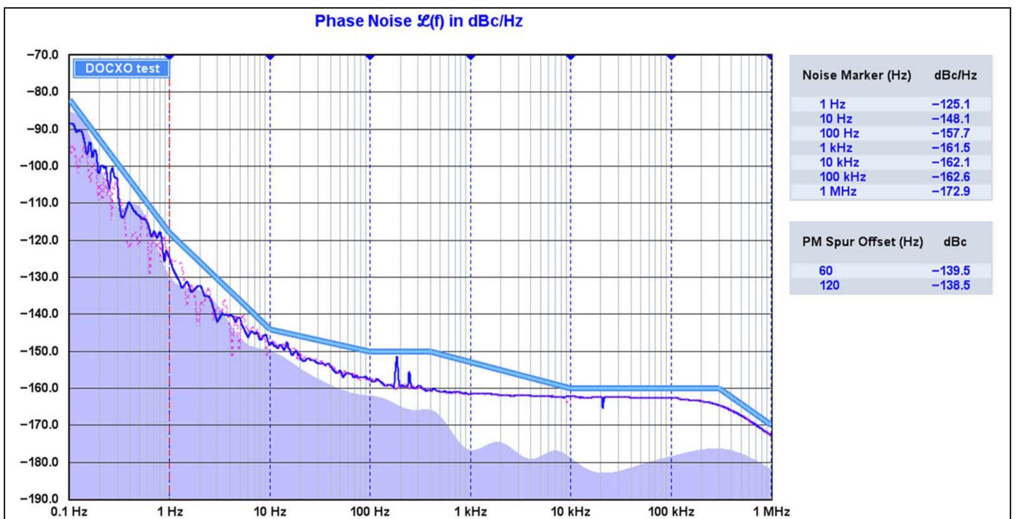
Consequently, in the absence of an external 10 MHz reference with excellent short-term stability that can be used as a disciplining source for INT REF 1, a better strategy for measuring low ADEV levels at taus exceeding a few seconds can be to operate INT REF 1 with a longer-than-usual time constant (e.g., 200 seconds or more, particularly if locking to the internal atomic standard) while locking INT REF 2 to INT REF 1 with a similar time constant. INT REF 1 can also be allowed to free-run while INT REF 2 is locked to it. All of that being said, the result in Figure A-12 was obtained with the factory-default lock parameters.

On the other hand, when a high-quality 10 MHz reference such as a maser or ultrastable OCXO is available, consider using short time constants on the order of 1 second for both INT REF 1 and INT REF 2. Stability measurements will inherit both the short-term and long-term characteristics of your external reference in this case, while phase noise measurements at offsets beyond a few hertz will benefit from the independent low-noise internal OCXOs as usual.

As a further note, external 1PPS references should be avoided in demanding applications such as this example. Residual ADEV from the 1PPS source is approximately 1E-11 at t=30s with the default 1PPS disciplining parameters. The 10 MHz loops have significantly better residual performance, are much easier to tune, and lock much more rapidly.

A.10.3 Close-In Phase Noise of Ultrastable 5 MHz DOCXO

The phase noise of the DOCXO was also measured during the previous test and is now evaluated for compliance with specified limits (Figure A-18):



Notes	DUT Freq	Ref Freq	dBc/Hz at 1 Hz	Elapsed	Mask Result	Mask Margin	Instrument	Options
Measured with Option IR	5 MHz	100.0 MHz	−125.1	3m 0s	Pass	+1.5dB	Microchip 53100A	IR
"Ground truth" via 2x Rb	5 MHz	10.0 MHz	−125.0	25m 0s	Pass	+2.1dB	Microchip 53100A	IR

FIGURE A-18: *Close-In Phase Noise View.*

As before, the blue trace represents the measurement made by the standalone 53100A equipped with Option IR in 3 minutes, while the magenta trace represents the same DUT measured against a pair of high performance rubidium standards over 25 minutes. Both measurements are sufficient to confer a passing grade on the DUT. In particular, the self-contained Option IR references were able to measure the oscillator's 1 Hz phase noise at –125 dBc/Hz (a figure achieved by a relatively small fraction of devices on the market) while additionally confirming performance below –170 dBc/Hz at 1 MHz.

A.11 ADDITIONAL TIPS FOR HIGH-PERFORMANCE MEASUREMENTS WITH OPTION IR

A.11.1 Allow Sufficient Stabilization Time After Applying Power or Changing Loop Parameters

As noted earlier, the Option IR module is active whenever the 53100A is connected to its power supply, regardless of the power switch setting. The firmware enforces a 3-minute warmup period after power application before any lock attempts are made. This represents a minimum requirement. It is strongly recommended that the reference module be allowed to warm up for at least 30-60 minutes before making measurements with a 53100A that has just been connected to its power supply. When freshly powered up, the INT REF 1 OCXO may require multiple attempts to lock to an external 10 MHz source or to the optional internal atomic standard. If INT REF 2 is locked to INT REF 1, it may need some extra time as well.

A.11.2 Observe Lock Status Before and During the Measurement

Prior to starting a measurement, you can monitor the lock status for both INT REF 1 and INT REF 2 by clicking on the **Internal reference** button in the 53100A acquisition dialog to bring up the Option IR configuration dialog box shown in Figure A-19. The read-only "Reference", "Status", and "Error" fields in the configuration dialog will be updated periodically to reflect the current INT REF 1 and INT REF 2 lock states. Lock status messages may be observed in the SCPI terminal, which can be toggled on and off with the corresponding checkbox in the **Options** area.

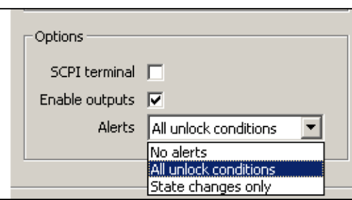


FIGURE A-19: *Option IR Configuration Dialog Box.*

Additionally, the tuning voltages for any OCXOs undergoing phase locking are also updated in real time on the **Calibration** page. Stable lock conditions exist when the least significant digits of the tuning voltages are no longer changing rapidly.

During the measurement itself, there are two ways to keep an eye on the reference's lock status. First, whenever operating conditions such as loss-of-lock, OCXO and atomic standard warmup, and 1PPS holdover are detected by the reference module's onboard controller, they will be reported by default in the status line at the bottom of the main TimeLab window. Refer to the help text for the **Alerts** control in the **Options** area of the Option IR configuration dialog box (Figure A-5) for more information about the conditions that generate these messages. The most common alerts from the internal reference module will resemble Figure A-20, indicating that the reference module is attempting to return to a phase-locked condition after excessive drift, external signal loss, or other hardware or environmental issue has interrupted the disciplining process. Timestamps help determine when the most recent interruption or other event occurred in the course of a long (and possibly unattended) measurement.

FIGURE A-20: *Internal Reference Alerts.*

For more specific information about the operating status of the Option IR module while a measurement is in progress, you can access the **Internal reference** and **Calibration** dialogs in much the same way as you would when the 53100A is idle. Select *Acquire>Microchip 53100A* in TimeLab, just as if you were preparing to initiate a new measurement. The device selection menu entry for the 53100A that's currently performing the measurement will be marked "In use", with all of the other controls in the acquisition dialog box except for the **Cancel** and **Internal reference** buttons disabled. Selecting **Internal reference** will close the acquisition dialog and bring up the **Option IR configuration** dialog in its place. All options and controls in this dialog box, as well as those on the **Calibration** page, are available for use while the 53100A is collecting data. Note, however, that any Option IR dialog boxes will automatically be closed when the measurement ends, canceling any operations such as user calibration of the optional atomic frequency standard that may be in progress at the time.

Access to the Option IR dialog boxes at measurement time can be invaluable for monitoring and diagnostic purposes. Of course, any attempt to change disciplining sources, make significant adjustments to the PLL parameters, or select different calibration states may have adverse effects on the measurement in progress. These operations are best performed before initiating the measurement.

A.11.3 Use High-Grade Cables to Connect the DUT

The use of cables with low shield resistance, as measured with an ohmmeter from shell to shell, is especially important for PN measurements that are expected to reach –170 dBc/Hz and below.

A.11.4 Shield DUT from Environmental Effects

Devices that are exposed to the open air on a PCB or breadboard will be vulnerable to effects such as HVAC circulation and local convection currents that make it difficult to pass demanding ADEV tests. They can also exhibit higher-than-necessary levels of close-in phase noise. Both environmental and RF isolation can be improved by enclosing the DUT in an insulated housing for test purposes (Figure A-21). This was necessary in order to achieve the results obtained here for both the 10 MHz DOCXO and the 100 MHz VCXO.

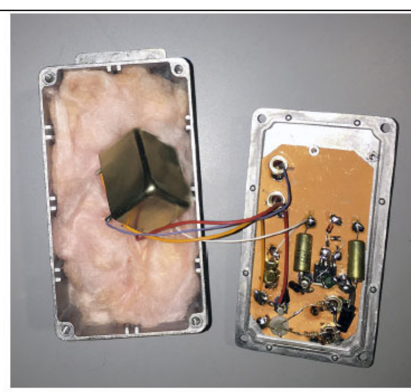


FIGURE A-21: *Insulated Housing for the DUT.*

Appendix B. Legal and Regulatory Notices

B.1 SOFTWARE LICENSE: TIMELAB

http://www.miles.io/timelab/readme.htm

B.2 SOFTWARE LICENSE: FFTSS

http://www.ssisc.org/fftss/index.html.en

The Scalable Infrastructure Project, supported by "Development of Software Infrastructure for Large Scale Scientific Simulation" Team, CREST, JST.

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Version 2.1, February 1999

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[This is the first released version of the Lesser GPL. It also counts as the successor of the GNU Library Public License, version 2, hence the version number 2.1.]

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Most GNU software, including some libraries, is covered by the ordinary GNU General Public License. This license, the GNU Lesser General Public License, applies to certain designated libraries, and is quite different from the ordinary General Public License. We use this license for certain libraries in order to permit linking those libraries into non-free programs.

When a program is linked with a library, whether statically or using a shared library, the combination of the two is legally speaking a combined work, a derivative of the original library. The ordinary General Public License therefore permits such linking only if the entire combination fits its criteria of freedom. The Lesser General Public License permits more lax criteria for linking other code with the library.

We call this license the "Lesser" General Public License because it does Less to protect the user's freedom than the ordinary General Public License. It also provides other free software developers Less of an advantage over competing non-free programs. These disadvantages are the reason we use the ordinary General Public License for many libraries. However, the Lesser license provides advantages in certain special circumstances.

For example, on rare occasions, there may be a special need to encourage the widest possible use of a certain library, so that it becomes a de-facto standard. To achieve this, non-free programs must be allowed to use the library. A more frequent case is that a free library does the same job as widely used non-free libraries. In this case, there is little to gain by limiting the free library to free software only, so we use the Lesser General Public License.

In other cases, permission to use a particular library in non-free programs enables a greater number of people to use a large body of free software. For example, permission to use the GNU C Library in non-free programs enables many more people to use the whole GNU operating system, as well as its variant, the GNU/Linux operating system.

Although the Lesser General Public License is Less protective of the users' freedom, it does ensure that the user of a program that is linked with the Library has the freedom and the wherewithal to run that program using a modified version of the Library.

The precise terms and conditions for copying, distribution and modification follow. Pay close attention to the difference between a "work based on the library" and a "work that uses the library". The former contains code derived from the library, whereas the latter must be combined with the library in order to run.

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This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

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