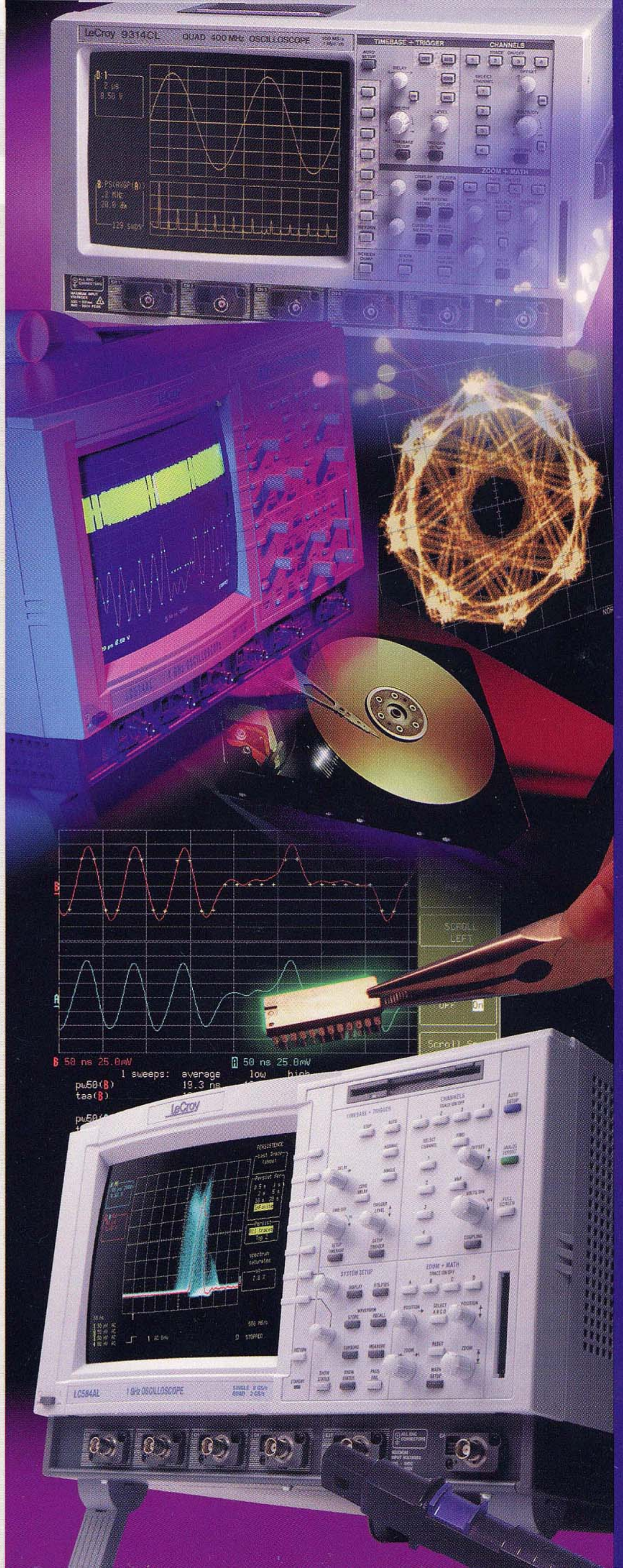
LeCroy
1998

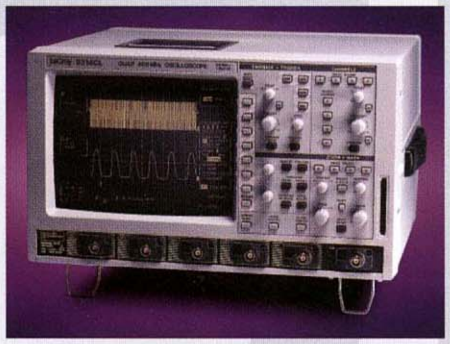
Test & Measurement Products Catalog



Overview

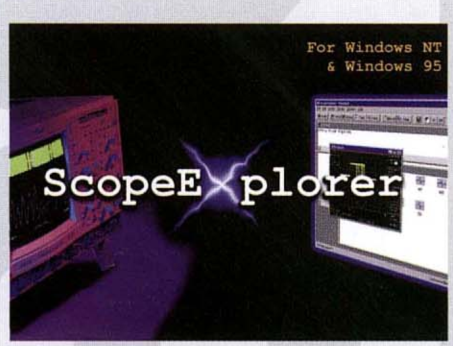
LC Series DSOs

9" Color CRT, 96 MHz PowerPC™ Processor with up to 64 Mbytes of RAM



9300C Series

A wide range of high-value scopes



NEW! ScopeExplorer™

Software and hardware options to make your work easier

LC Series Oscilloscopes

LeCroy's highest performance color digital oscilloscopes

9300C Series Oscilloscopes

A wide range of high-performance and high-value digital oscilloscopes

Options

Software and hardware options make troubleshooting and documentation easier

Probes, Amplifiers and Accessories

A wide range of active, current, differential, high-voltage and passive probes are available. There is also a selection of differential amplifiers and other accessories.

Solutions

Application-specific solution packages for jitter & timing analysis, magnetic and optical data storage products and for telecom testing

Arbitrary Waveform Generators

Easy-to-use tools for creating real-world test signals

Tutorials

"Fundamentals of DSOs," "Creation of Waveforms Made Easy" and a tutorial on "Jitter Measurements"

Applications

A variety of technical application notes on subjects ranging from power supply testing to troubleshooting intermittent problems

Sales and Service Information

A listing of the LeCroy sales and service office locations

LeCroy Technology

Get the Complete Picture

NEW TECHNOLOGY FOR THE WORKPLACE

The primary focus of the technology incorporated in LeCroy products is to provide an instrument that enables engineers to solve problems faster by providing more capability to **CAPTURE, VIEW and ANALYZE** signals.

This time-saving goal is accomplished with an integrated and powerful DSO system, providing the capability to:

CAPTURE

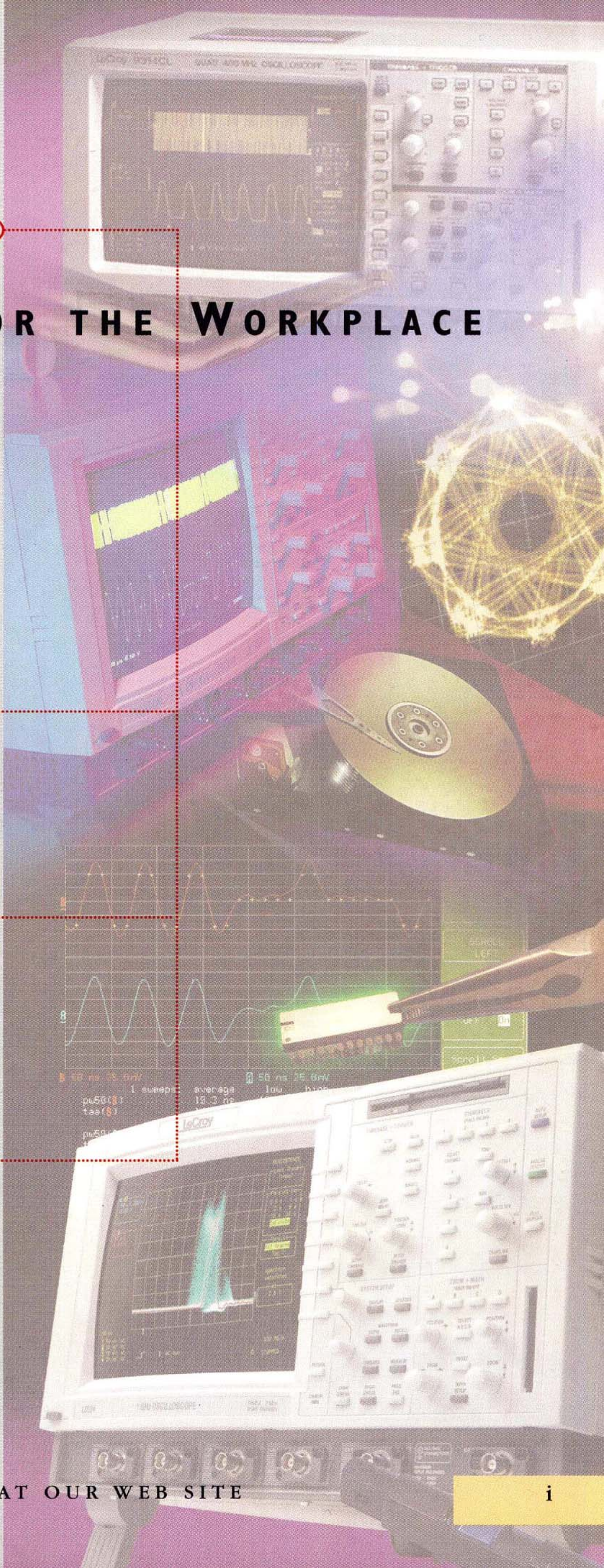
signals with high fidelity using wide-bandwidth amplifiers, fast sampling ADCs and SMARTMemory®.

VIEW

waveforms on a large, bright screen using Analog Persistence, Full Screen Mode and other innovative techniques.

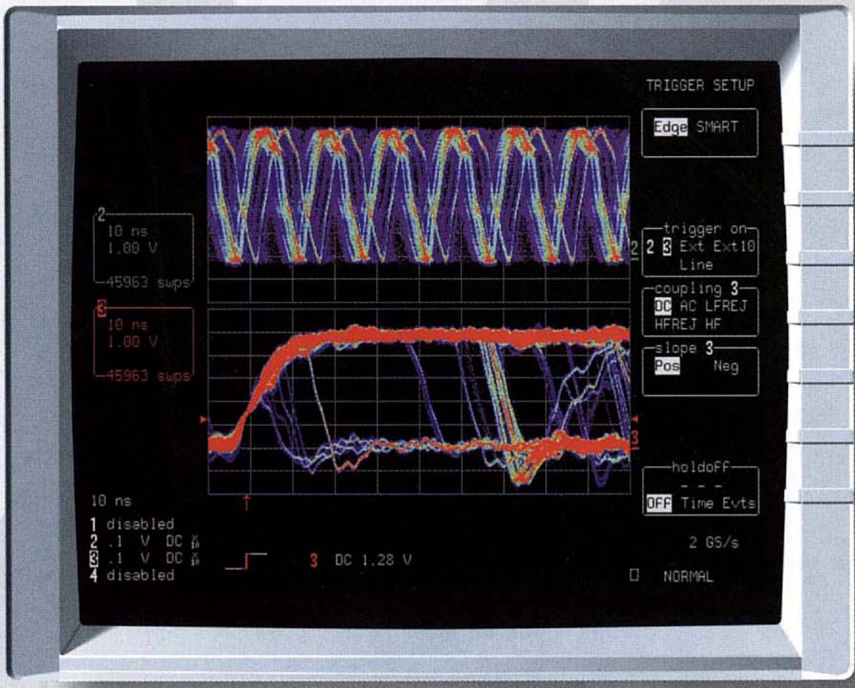
ANALYZE

signals to troubleshoot problems quickly with worst case parameter values, spectrum analysis, trend lines of key signal characteristics, histograms of more than 40 signal parameters and application-oriented solution packages.



The LC584A *Color* Digital Oscilloscope –

Powerhouse Performance at a Knockout Price



- **1 GHz Bandwidth**
- **2 GS/s Single-Shot Sample Rate on 4 channels**
- **8 GS/s Maximum Sampling Rate**
- **Up to 8 Million Points of Acquisition Memory**
- **1 ms Maximum Sample Rate Window**
- **96 MHz PowerPC Microprocessor**
- **8 to 64 Mbytes System RAM**
- **9" Premium Quality Color Display Area**
- **Analog Persistence**
- **Full Screen Grid**
- **Transparent Color Mode**

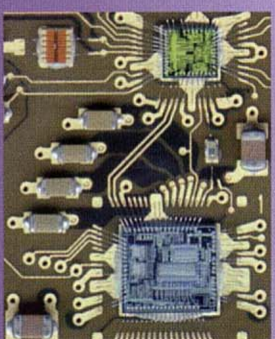
The LC584A family brings more raw horsepower to the task of troubleshooting long, complex signals than was previously available in any digital scope. It captures signals using 1 GHz amplifiers, sampling rates up to 8 GS/s, and 8 Mbytes of acquisition of memory.

The LC platform is powered by a 96 MHz PowerPC microprocessor with up to 64 Mbytes of RAM.

Ten new proprietary ICs designed by LeCroy specifically for the LC584A family bring more power to troubleshoot problems while maintaining an easy-to-use front panel.

A premium quality color display with 9" viewing area accomodates the great variety of information that modern applications demand, with sharp detail, clarity and personal color choice.

LeCroy's new ADC technology captures analog signals and converts them to digital data measurements every 500 picoseconds.



10" CRT with 9" viewing area

Dedicated knobs for Timebase and Trigger Level

Fast graphics printer with landscape mode to view long signals

Auto Setup, Analog Persistence and Full Screen modes at the touch of a Button– no menus

High-bandwidth 1 GHz amplifiers with 2 GS/s ADCs and up to 2 Mbytes of acquisition memory on each channel

Advanced Trigger including capture of glitches down to 600 ps

PCMCIA Options for memory card, portable hard drive or ATA flash allow fast data storage and retrieval

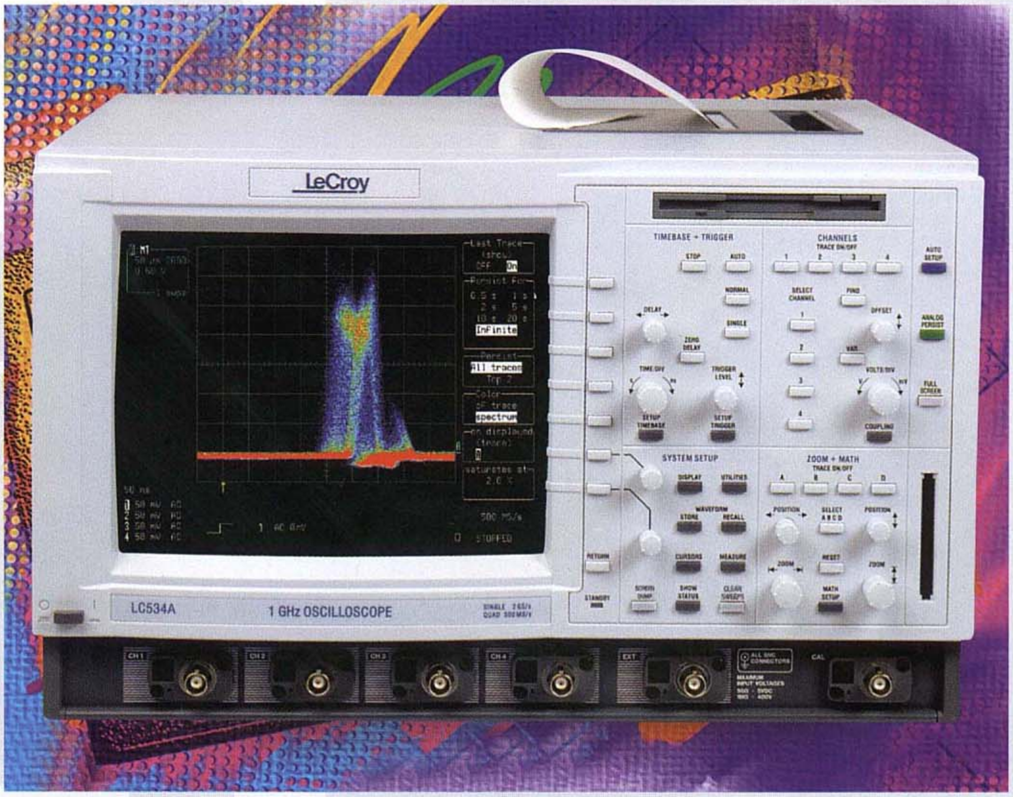
Dedicated knobs for voltage sensitivity and offset

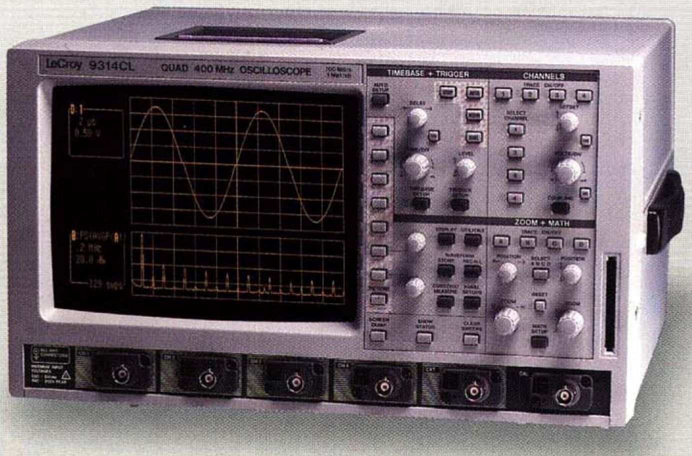
The LC Series of Premium *Color* Digital Oscilloscopes

- **500 MHz and 1 GHz Bandwidth**
- **500 MS/s to 8 GS/s Single-Shot Sample Rate**
- **50 k to 8 Mpoints of Acquisition Memory**
- **8 to 64 Mbytes System RAM**
- **4 ms Maximum Sample Rate Window**
- **96 MHz PowerPC Microprocessor**
- **9" Premium Quality Color Display Area**
- **Analog Persistence**
- **Full Screen Grid**
- **Transparent Color Mode**

The LC series of DSOs is the first to be built on an innovative technology platform that explores new dimensions in signal **capture, viewing and analysis.**

The LC platform is powered by a 96 MHz PowerPC microprocessor supported by copious RAM and cache memory. LC series scopes offer high-performance amplifiers and ADCs, complemented by LeCroy's unique memory management. SMARTMemory is the core of the LC series' integrated analysis system: a system that enables engineers to solve the challenging problems of state-of-the-art applications.





9300C Series – The Complete Package

Want High Performance at a Medium Price?

The 9350, 9370 and 9380 series of scopes offer data acquisition with 500 MHz and 1 GHz amplifiers using high-speed ADCs and long memories.

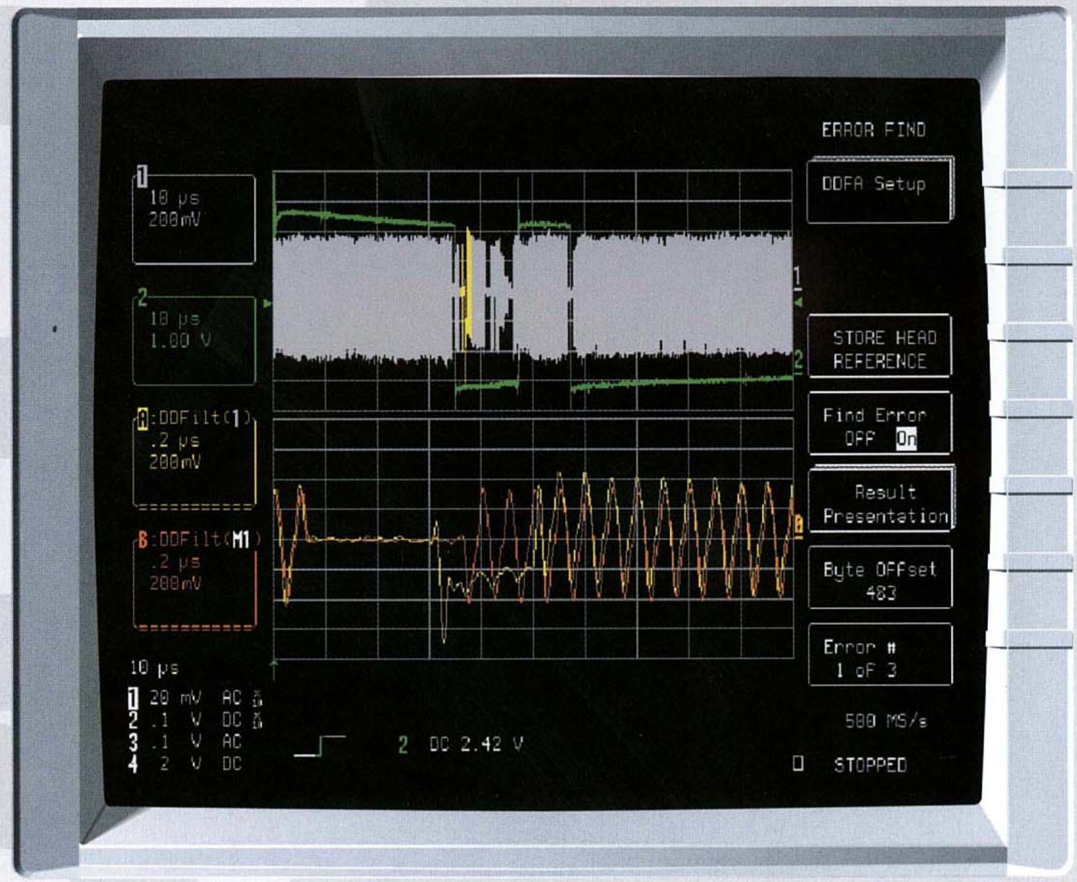
See the New Value Line of Digital Scopes

LeCroy's new and improved "C" version of the 9304, 9310 and 9314 series offers more tools to solve circuit problems in the 200 MHz to 400 MHz range. They offer excellent triggers for troubleshooting, large, high-resolution displays, and more ways to easily locate circuit problems than other scopes at the same price.

- **200 MHz to 1 GHz Bandwidth**
- **100 MS/s to 10 GS/s Single-Shot Sample Rate**
- **500 points to 8 Million Points of Acquisition Memory**
- **8 to 64 Mbytes System RAM**
- **100 ns to 4 ms Sample Rate Window**
- **9" High Resolution Display**

Unique Disk Drive Analyzers

- Drive-Specific Triggers
- PRML Channel Emulation
- Automatic PRML Channel Error Identification
- PRML Data Channel Quality Analysis
- User-Selected or Defined Drive Filtering
- IDEMA Standard Measurements (TAA, PW50, Overwrite and more!)
- Asymmetry Measurements
- Drive Analysis Graphs
- 1 GHz Bandwidth
- 2 GS/s on 4 Ch (8 GS/s interleaved)
- 4 Mpoint/Ch Acquisition Memory



LeCroy Disk Drive Analyzers (DDAs) are designed to meet the specific **capture, viewing and analysis** needs required by engineers and technicians performing disk-drive analysis. The DDA family provides all the capabilities of LeCroy LC family of oscilloscopes with additional disk drive-specific capabilities.

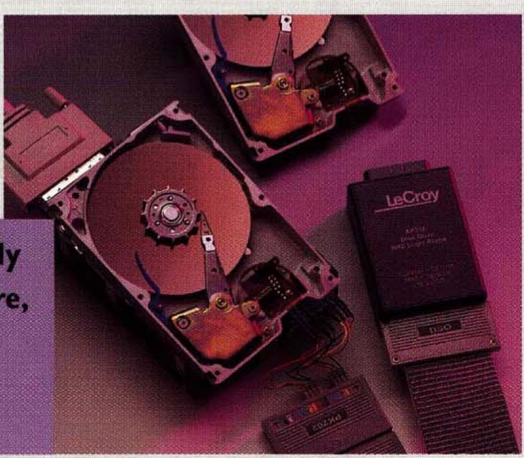
Included with LeCroy Disk Drive Analyzers are PRML data channel emulation, customized triggers for capture of disk drive signals, a rich set of drive-specific signal measurement parameters, and drive analysis graphs. These allow you to rapidly evaluate the quality of your drive signals, find signal errors and determine the causes of errors or of insufficient quality.

An intuitive user interface has been designed for easy access to the DDA disk-drive capabilities. In addition, the instrument still retains nearly identical operation to popular LeCroy LC oscilloscopes for when you are not taking advantage of the DDA family's drive-specific capabilities.

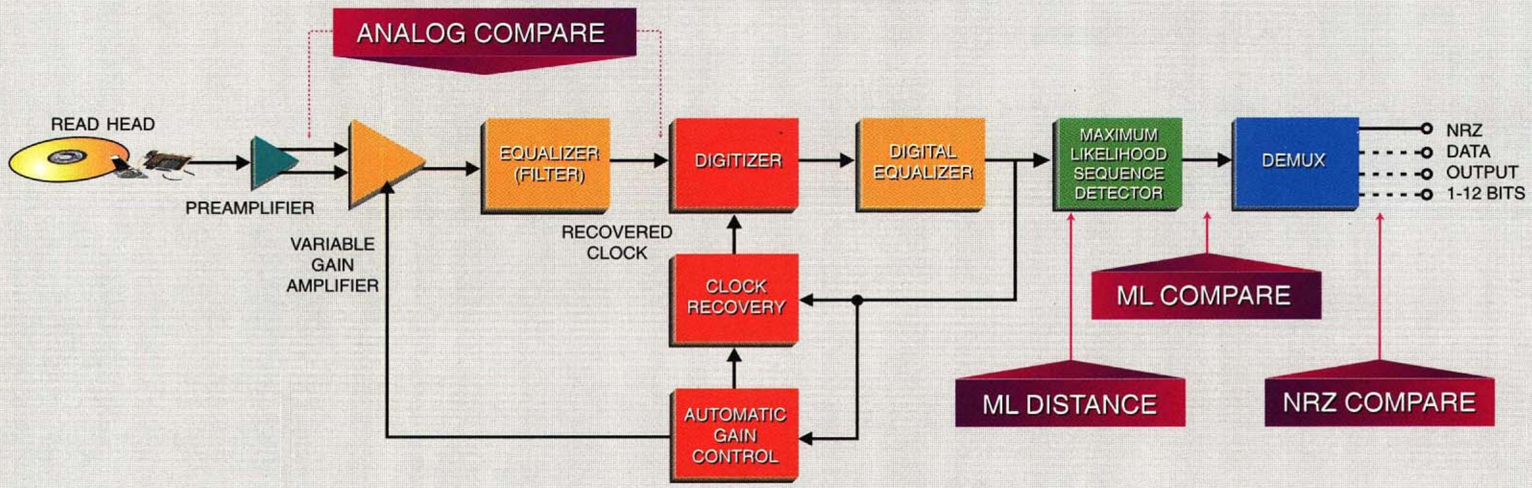
Disk Drive Failure Analysis Package

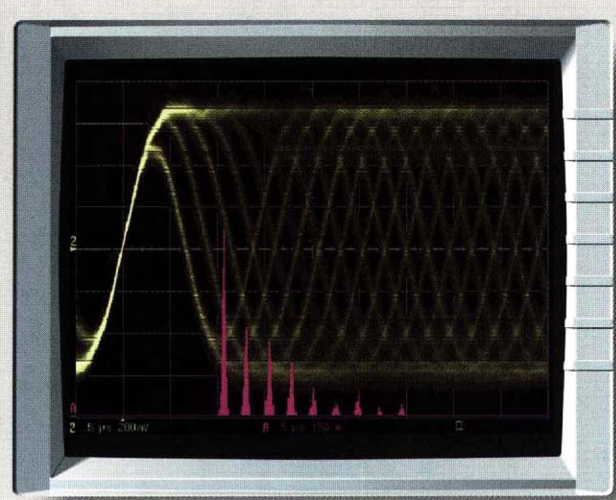
With DDFA you can "View" the head signal through the entire channel from the preamp, after equalization, at the Viterbi detector and, finally, as NRZ data.

- **Locate Drive Errors Automatically**
- **Easily Find and Analyze even Rare, Intermittent Errors**
- **View How Far PRML Signals are from their Ideal Target Points**



LeCroy's new Disk Drive Failure Analysis package can locate errors in heads, read channels or media using five error location methodologies. It can also identify the root causes of errors or insufficient head signal quality.





Optical Recording Measurement Package

The **Optical Recording Measurement package** enables design engineers to quickly view, measure and analyze signals from CD-ROM, Magneto-Optical, and the new Digital Video Disk (DVD) drives. Engineers around the world are now using LeCroy test instruments to develop these exciting new technologies.

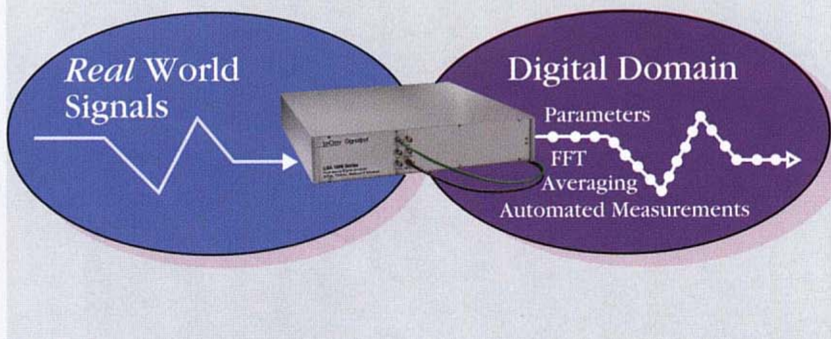
LeCroy *Signalyst*™ LSA1000

Overview

LeCroy's LSA1000 *Signalyst* is a 2 GS/s waveform digitizer which brings the fidelity of LeCroy's digital oscilloscopes to embedded applications. Its onboard PowerPC Processor maximizes measurement throughput and accelerates waveform analysis and computation. Acquired waveforms are transferred to computer via 100 Mbits/s Fast Ethernet. LSA1000 maintains the integrity of your analog signals while digitizing and analyzing them in the shortest possible time.

- **750 MHz Bandwidth**
- **1 GS/s sampling rate on 2 channels simultaneously**
- **2 GS/s on a single channel**
- **Fast throughput with 100 Base-T Ethernet interface**
- **Acquisition memory length up to 4 Mpoints**
- **PowerPC MPC603e processor on board**

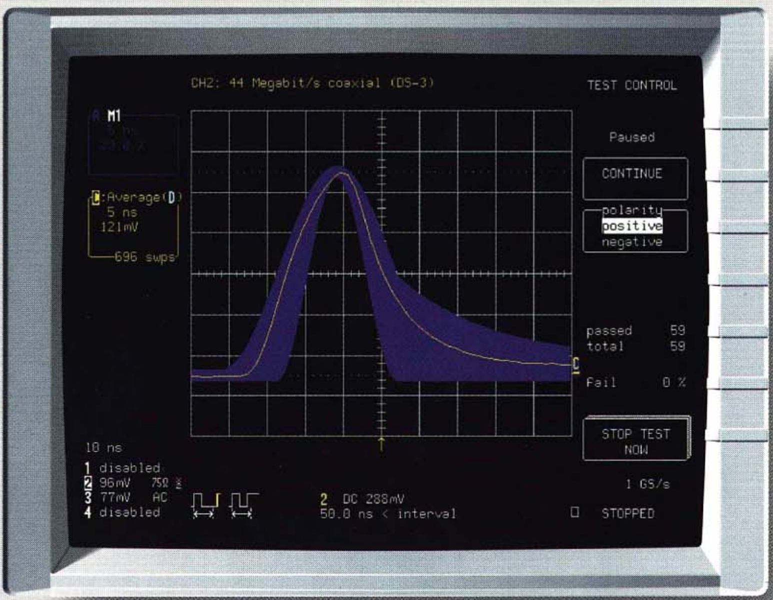
✔ ***100% Computer Controlled***
✔ ***High Throughput***
✔ ***Easy to Use***
✔ ***Powerful Analysis***



The Signalyst transforms analog signals from the device under test into digital data. This allows measurement of key signal parameters, frequency spectra, automated Pass/Fail testing and other operations to be performed.

Solutions for Communications Problems

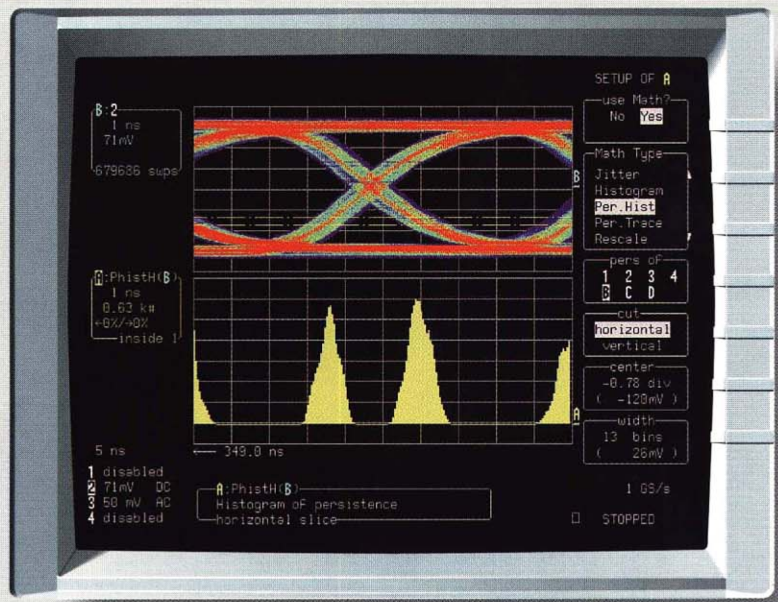
- **EASY TO USE – Fully Automated**
- **Works on Random-Bit Patterns**
- **Tests Positive and Negative Shape Pulses**
- **Self-Aligning**
- **Self-Scaling**
- **Includes all Necessary Balanced and Coax Adapters**
- **Dedicated Menus**
- **Full Remote Control Support for Automated Testing**



Mask Testing

LeCroy's powerful and innovative Mask Tester instantly transforms your digital oscilloscope into a dedicated mask-testing device specifically designed for manufacturing, type approval and field testing.

- **Powerful**: Exclusive Finder function allows pulses or patterns to be easily isolated - even from random-bit streams. Mask alignment is totally automatic, saving valuable testing time.
- **Easy to use**: The scope displays only the Tester's dedicated menus, blocking unneeded control and reducing setup errors.
- **Convenient**: Included in the package are all the twisted-pair and 75 Ω interfaces you'll need for quality cable termination and exact amplitude scaling.



Jitter Analysis

The LeCroy Jitter & Timing Analysis Package (JTA) is dedicated to providing accurate, high-confidence timing measurements on LeCroy oscilloscopes. JTA addresses the ever-growing need to precisely characterize a waveform's timing stability — essential to applications such as synchronous networks or digital systems.

Probes for *Every* Application

LeCroy's high-fidelity digital oscilloscopes are complemented by a wide variety of probes and amplifiers. LeCroy probing solutions help to capture your signal accurately.

High-Voltage Probes to 40 kV

HIGH-VOLTAGE PROBES	
Models	**Bandwidth MHz**
PPE1.2 kV	400
PPE2 kV	400
PPE4 kV	400
PPE5 kV	400
PPE6 kV	400
PPE20 kV (40 kV peak)	100

The PPE20 kV has less than 2 pf capacitance and can measure peak voltages up to 40 kV.

A Full Line of High-Performance Differential Amplifiers and Probes

The AP015 50 MHz/50 Amp Current Probe is well matched to the requirements of power supply design, testing of automotive electronics, and other applications.

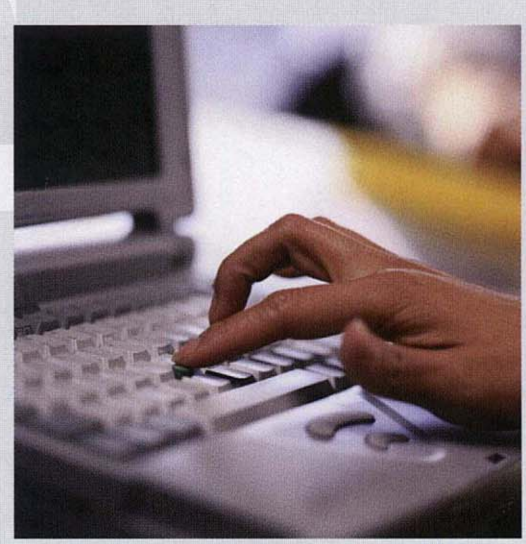
World Class Differential Amplifiers and Accessories

The new 1800 series Differential Amplifiers act as signal conditioning preamplifiers for network and spectrum analyzers, and oscilloscopes, providing unequaled differential measurement capability. Precision offset can be as high as ±155,000 divisions at 5½ digit resolution.

DIFFERENTIAL AMPLIFIERS							
Model	Bandwidth MHz	Input Z MΩ	Common Mode Rejection Ratio DC-100 KHz	1 MHz	Differential* V	Common mode* V	Precision Offset Generator
1820	10	1/100	100,000:1	10,000: 1	±5	±15.5	—
1822	10	1/100	100,000:1	10,000: 1	±5	±15.5	✓
1850	100	1/100	100,000:1	10,000: 1	±0.5	±15.5	—
1855	100	1/100	100,000: 1	10,000: 1	±0.5	±15.5	✓

**Multiplied by probe and attenuator factor*

ScopeExplorer



ScopeExplorer is a PC-based connectivity tool that integrates a LeCroy DSO with the Windows 95 or Windows NT desktop. The scope may be connected to the PC via either GPIB (IEEE 488) or the standard RS-232 serial port that is present on most of today's personal computers.

Once the DSO is connected, data and images can be transferred and stored in the computer. Because it is designed specifically for use with digital oscilloscopes, ScopeExplorer allows these tasks to be completed with only a few keystrokes or clicks of a mouse. Users familiar with the Windows environment will find ScopeExplorer very easy to use.

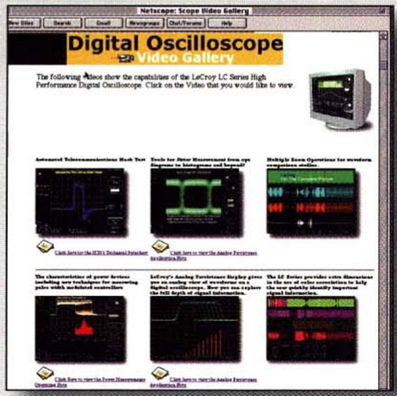
ScopeExplorer provides the following connectivity features:

- **Remote Control Terminal**
- **Image Capture and Storage from DSO**
- **Scope Setup, Capture, Storage and Playback**
- **Trace Capture, Storage, Playback and Conversion to ASCII.**

This shareware application is available to you now by visiting our web site and following the simple download instructions at http://www.LeCroy.com/ScopeExplorer

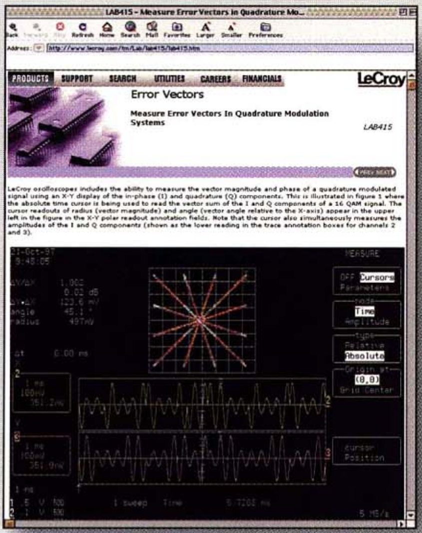
Visit Us on Our Web Site

The LeCroy web site is updated weekly with new product announcements, the latest application notes, newsletters, job opportunities and complete specifications of our products.



Visit the Video Gallery

Software Utilities



Application Notes

- Software Utilities
- Announcement of New Products
- Technical Application Notes
- Videos Show Actual DSO Features in Operation
- Employment Opportunities
- New Sales and Service Offices
- Send Your Suggestions for Future Products

Digital Oscilloscopes

LC Series Premium Color Digital Scopes

LeCroy DSO Model Number	Number of Channels	Bandwidth	Sample Rate per Channel	Memory per Channel	Color Display
LC564A**	4	1 GHz	2 GS/s	100 k	✓
LC584A	4	1 GHz	2 GS/s	100 k	✓
LC584AM	4	1 GHz	2 GS/s	500 k	✓
LC584AL	4	1 GHz	2 GS/s	2 Meg	✓
LC574A	4	1 GHz	1 GS/s	100 k	✓
LC574AM	4	1 GHz	1 GS/s	500 k	✓
LC574AL	4	1 GHz	1 GS/s	2 Meg	✓
LC534A	4	1 GHz	500 MS/s	100 k	✓
LC534AM	4	1 GHz	500 MS/s	500 k	✓
LC534AL	4	1 GHz	500 MS/s	2 Meg	✓
LC374A	4	500 MHz	1 GS/s	100 k	✓
LC334A	4	500 MHz	500 MS/s	100 k	✓
LC334AM	4	500 MHz	500 MS/s	500 k	✓
LC334AL	4	500 MHz	500 MS/s	2 Meg	✓

9300C Series High-Performance Digital Scopes

LeCroy DSO Model Number	Number of Channels	Bandwidth	Sample Rate per Channel	Memory per Channel	Color Display
9384C	4	1 GHz	1 GS/s	100 k	
9384CM	4	1 GHz	1 GS/s	500 k	
9384CL	4	1 GHz	1 GS/s	2 Meg	
9384CTM*	4	1 GHz	1 GS/s	500 k	
9374C	4	1 GHz	500 MS/s	50 k	
9374CM	4	1 GHz	500 MS/s	250 k	
9374CL	4	1 GHz	500 MS/s	2 Meg	
9374CTM*	4	1 GHz	500 MS/s	500 k	
9370C	2	1 GHz	500 MS/s	50 k	
9370CM	2	1 GHz	500 MS/s	250 k	
9370CL	2	1 GHz	500 MS/s	2 Meg	
9354C	4	500 MHz	500 MS/s	50 k	
9354CM	4	500 MHz	500 MS/s	250 k	
9354CL	4	500 MHz	500 MS/s	2 Meg	
9354CTM*	4	500 MHz	500 MS/s	500 k	
9350C	2	500 MHz	500 MS/s	50 k	
9350CM	2	500 MHz	500 MS/s	250 k	
9350CL	2	500 MHz	500 MS/s	2 Meg	
9361C	2	300 MHz	2.5 GS/s	500 to 25 k	
9362C	2	1.5 GHz	5 GS/s	500 to 25 k	

9300C Value Line of Digital Scopes

LeCroy DSO Model Number	Number of Channels	Bandwidth	Sample Rate per Channel	Memory per Channel	Color Display
9344C	4	500 MHz	250 MS/s	50 k	
9344CM	4	500 MHz	250 MS/s	250 k	
9344CL	4	500 MHz	250 MS/s	1 Meg	
9314C	4	400 MHz	100 MS/s	50 k	
9314CM	4	400 MHz	100 MS/s	250 k	
9314CL	4	400 MHz	100 MS/s	1 Meg	
9310C	2	400 MHz	100 MS/s	50 k	
9310CM	2	400 MHz	100 MS/s	250 k	
9310CL	2	400 MHz	100 MS/s	1 Meg	
9304C	4	200 MHz	100 MS/s	50 k	
9304CM	4	200 MHz	100 MS/s	250 k	

*"TM" versions include Advanced Math, Spectrum Analysis and Internal Printer
** LC564A has limited capability to interleave input channels.

Accessories

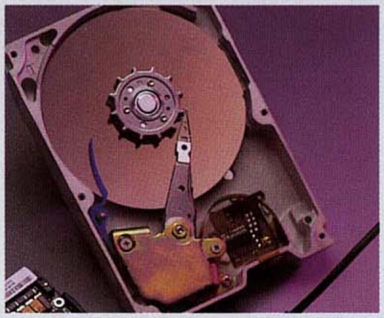
Graphics Printer
PCMCIA Memory Card, ATA Flash, or Portable Hard Drive
Mega Waveform Processing; 8,16 and 64 Mbytes of RAM
CKTRIG for External Clock, Reference Clock and Trigger Out

Advanced Math
Spectrum Analysis
Optical Recording Measurements
Basic Disk Drive Package
PRML Analysis
Disk Drive Failure Analysis
Telecom Mask Testing
NEW! Jitter & Timing Analysis

Differential
High Voltage
Current
Active FET
Scope Cart
Shipping Cases
Soft Carrying Case

LeCroy Solutions Save Time

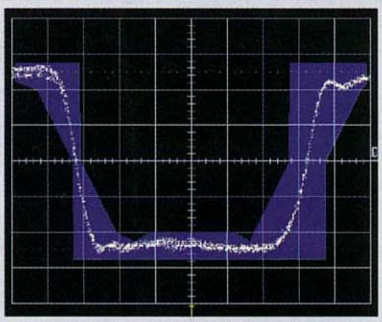
Magnetic and Optical Data Storage



DDM	Basic Disk Drive Measurements
PRML	Characterize PRML Channels
DDFA	Disk Drive Failure Analysis
DDANALYZER	Disk Drive Analyzer Package
ORM	Optical Recording Measurements
DD110/120	Two New Disk Drive Analysis Instruments

www.lecroy.com/datastorage_info

Telecom Testing and Jitter Analysis



MT01	Tests ITU G.703 Signals
MT02	Tests ANSI T1.102 Signals
MT01/02	Combination of ITU G.703 and ANSI T1.102
JTA	NEW! Jitter & Timing Analysis Package

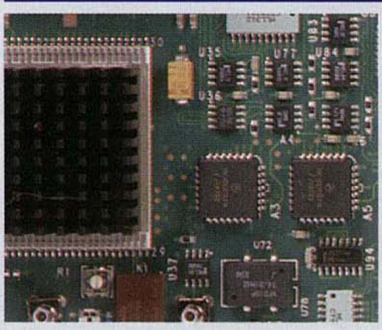
www.lecroy.com/communications_info

Probes for Every Application

- Passive Probes and Accessory Kits
- FET Probes
- Differential Amplifiers and Accessories
- Current Probes
- High-Voltage Probes

www.lecroy.com/probes_info

Embedded Systems Design



- Signalyst
- OEM Kits

www.lecroy.com/signalysis_info

LeCroy Offices Worldwide to Serve You

Corporate Headquarters

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977
USA

- **In the USA, call our 800 number 1-800-5-LECROY (553-2769)**
- **Visit Our Web Site – www.lecroy.com**

or

- **Call a local sales office near you**

LeCroy Sales Offices

Asia South: Australia
Phone (61) 3 9877 9322
Fax (61) 3 9849 0861

Asia North: Hong Kong
Phone (852) 2836 7361
Fax (852) 2836 7007

France: Les Ulis
Phone (33) 1 6918 8320
Fax (33) 1 6907 4042

Germany: Heidelberg
Phone (49) 6221 827 00
Fax (49) 6221 834 655

Italy: Venice
Phone (39) 41 456 97 00
Fax (39) 41 456 95 42

Japan: Osaka
Phone (81) 6 396 0961
Fax (81) 6 396 0962

Japan: Tokyo
Phone (81) 3 3376 9400
Fax (81) 3 3376 9587

Japan: Tsukuba
Phone (81) 2 9841 5810
Fax (81) 2 9841 5830

Switzerland North: Niederlenz
Phone (41) 62 885 8050
Fax (41) 62 885 8055

Switzerland West: Geneva
Phone (41) 22 719 2111
Fax (41) 22 719 2230

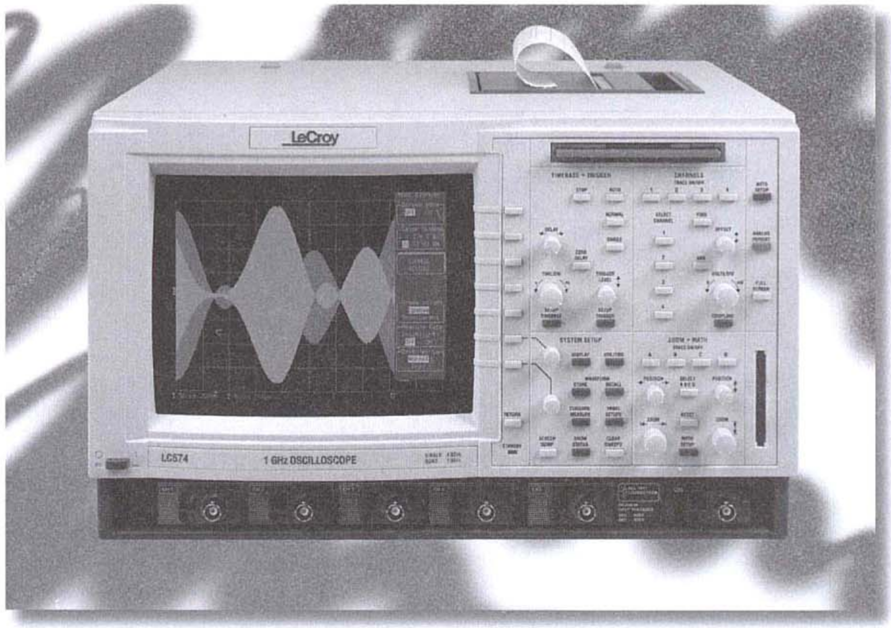
U.K.: Abingdon
Phone (44) 1 235 536973
Fax (44) 1 235 528796

U.S.A.: Chestnut Ridge
Phone (1) 914 578 6020
Fax (1) 914 578 5985

TABLE OF CONTENTS

TABLE OF CONTENTS

The Benefits of Performance Digital Oscilloscopes



Digital scopes are key tools used in the diagnosis, test, and evaluation of electronic circuits and systems. LeCroy performance DSOs provide the ease of use, reliability, and performance required by engineers to quickly solve electronics problems. LeCroy's digital scopes integrate advanced digital signal processing technology and a powerful processor with software solutions to save you valuable time in solving problems. LeCroy's Performance DSOs provide the power needed to capture, view, and analyze signals while keeping the instrument easy to use.

CAPTURE

Capturing signals over a wide range of timebase settings at high sample rates while maintaining fast front panel responsive is made possible by LeCroy's long record lengths and a high-speed RISC microprocessor based system, which includes up to 64 Mbytes of RAM. LeCroy scopes offer the longest record length in the industry – 2 Mbytes of data acquisition memory per channel which can be combined to 8 Mbytes on a single signal. The LeCroy SMARTMemory system provides total memory management which:

- Dynamically assigns maximum acquisition memory to each active trace to keep sampling rate high
- Applies a patented max/min sorting algorithm to data records to quickly create a display which shows the important signal features
- Assigns resources of computational/storage RAM to the tasks selected.

LeCroy technology has been used to achieve the fastest DSO single-shot sampling rate on the market. The model 9362C at 10 GS/s can display the finest details on short, fast signals.

Capturing a signal at the appropriate timebase setting with the best accuracy coupled with rapid data resource assignment and processing enables you to solve problems faster.

VIEW

The bright, nine-inch display provided on all LeCroy DSOs offers you a large viewing area where you can really see the details in a signal. The 9300C series offers a high resolution amber display, while the LC series has both traditional color-graded persistence display and a new "analog persistence" intensity-graded color display mode. Engineers who spend much of their day in front of an oscilloscope appreciate the larger view of the signal, and with a choice of 1, 2, 4 or 8 grids, it is easy to separate waveforms and numerical measurements. Seeing more details in a set of signals on the large viewing area of a LeCroy DSO helps you quickly gain insight into the source of a problem.

ANALYZE

LeCroy DSOs have the most advanced set of signal diagnostic, troubleshooting and documentation tools available, and in many cases, they can eliminate the need to transfer captured signals for analysis off-line. This includes the measurement of over 40 signal parameters, worst case analysis (maximum, minimum, average and standard deviation) on those parameters, an FFT package with capability to resolve 4 million time domain samples into the frequency domain, the ability to daisy chain math functions (such as squaring a waveform and then integrating). LeCroy offers an unmatched advanced math package with integration, differentiation, square root, absolute value, ratio, exponential, log and a set of six selectable digital filters. An optional histogramming and trend capability helps you fully characterize signal instabilities such as timing jitter or amplitude fluctuations. The Pass/Fail test package includes the ability to test each of the four input channels against separate test masks and to combine mask testing with go/nogo testing of key signal parameters. Documentation tools include the ability to save data to floppy disk, GPIB, RS-232-C, internal memory, PC memory card, 170 Mbyte PCMCIA portable hard drive or an internal, high-speed graphics printer.

Power Tools for Engineers

Engineers who use a scope for troubleshooting and have not tried a LeCroy DSO will find substantial benefits in LeCroy's tool set. For example, LeCroy's Performance FFT package differs from those available from other vendors by offering the ability to compute frequency spectra based on up to 4 million time domain sample points. This translates directly into better frequency resolution and more insight into the frequency characteristics of the signal. Worst case parameter tracking offers you the chance to monitor key signal characteristics and display the average, maximum and minimum values of those parameters. This enables you to quickly identify worst case performance of pulse widths, amplitudes, timing jitter, or any other of over 40 signal characteristics. The large display of a LeCroy scope can show single, dual, quad, or octal grids. You can zoom in to see details on any part(s) of the signal, perform a math operation on any segment or the complete waveform, and even perform diagnostics that require "math-on-math" (such as squaring a waveform and then integrating it to find the total power). When searching for intermittents, the Exclusion Trigger allows LeCroy DSOs to avoid the deadtime inherent in other scopes which spend most of their time triggering on the normal signal. Engineers familiar with the aliasing problems caused by short memory will appreciate that all display/triggering modes of LeCroy DSOs take advantage of the full power of the data acquisition memory rather than limiting the acquisition to 500 points as found in the specialized view modes of some digital scopes.

The Power of the LeCroy Scope Architecture

LeCroy's Performance lines (LC564A, LC584A, LC574A, LC534A, LC374A, LC334A, 9384C, 9374C and 9354C) offer four channels of simultaneous sampling with up to 2 Mbytes of memory per channel. This may be combined to provide two channels at twice the sampling rate and 4 Mbytes of acquisition memory or one channel with four times the sample rate and 8 Mbytes record length. Long memories allow the digital storage oscilloscope to operate at the highest sampling rate over a wide range of timebase settings. To complement the long acquisition memories, these scopes can be fitted with up to 64 Mbytes of processing RAM for your most demanding analysis needs. The scope is thus capable of performing extensive waveform math and processing while still maintaining fast screen update rate and lively front panel controls. This capability is achieved through the integrated use of a 96 MHz PowerPC processor in the LC series, or a 32 MHz 68030/68882 combination in all 9300C series DSOs. Competing DSOs that lack LeCroy's integrated processing power and memory capacity are unable to effectively deliver this capability. Another vendor's DSOs might capture 500 kpoints of data but only be able to perform an FFT on 10 kpoints, high resolution computations on 50 kpoints, integrate 130 kpoints or store 250 kpoints to memory. Those types of barriers are eliminated in LeCroy digital scopes.

Mass Storage for DSOs

A PCMCIA Type III Hard Disk capability is optionally available for any LeCroy DSO. A removable hard disk of 170 Mbytes provides great capacity and flexibility for fast storage and retrieval of waveforms and instrument settings. This slot also supports ATA Flash memory cards. This facility is an integral part of a powerful and exceptional combination of available documentation features that include DOS-compatible 3.5" floppy disk and optional IC memory card interface (PCMCIA Type II port) and a built in high-speed graphics printer. These tools permit a gain in productivity by making the data captured by a LeCroy scope easily accessible and transferable. GPIB, Centronics and RS-232-C interfaces are available for programming or printing/plotting. The optional internal graphics printer produces full-resolution screen dumps in under 10 seconds. In landscape mode, the printer can produce fully detailed hard copies of long waveforms by making printouts up to 100 feet long.

Probes

All LeCroy scopes are supplied with LeCroy's ProBus Intelligent Probe Interface. This unique feature permits them to be used with a range of FET probes, controlling the probe from the scope's front panel. The FET probes provide extremely low (1 MΩ, 2 pF) circuit loading and up to 1 GHz bandwidth at the probe tip. Passive probes are provided as standard accessories with most models. FET probes with bandwidths up to 2.5 GHz are available. A wide range of optional probes are available including differential amplifiers with comparators, and differential probes with gain to 1000, CMRR to 100,000:1, and bandwidth to 250 MHz. A new DC-50 MHz current probe is effective for measurement of DC, AC and impulse currents. The PPE series of high-voltage probes provides a selection of models ranging from 100 to 300 MHz and 600 to 20 kV.

Innovative Peak-detect Circuit

Peak-detect is a common feature among many high-end DSOs, because it allows them to show fast phenomena that might otherwise be missed due to undersampling. One undesirable effect of most peak-detect systems, however, is a severe loss of horizontal (time) precision. This happens because detected peaks are known to have occurred during a certain interval, but the specific time at which they occurred is not known. Signals acquired with other manufacturers' peak-detect techniques therefore may not be successfully used for further analysis or processing.

LeCroy solves this problem by maintaining both peak-detected and normally sampled waveforms for each signal. So you get all the benefits of peak-detection without any loss of time precision. LeCroy is the only scope manufacturer to use this innovative technique. This feature is not available in the LC564A/584A series which are designed for troubleshooting of high-speed circuits.

SMART Trigger® and Waveform Processing

Some DSO manufacturers put their best troubleshooting triggers only in their most expensive scopes. But many who use 200–400 MHz DSOs would prefer state-of-the-art triggering tools. All LeCroy DSOs include SMART Trigger capability. In addition to Edge and Window Trigger, the SMART Trigger offers Glitch, Pulse Width, Interval Width, State and Edge Qualified, Dropout, and TV triggers. Time and Events Holdoff are also provided. The scopes include LeCroy's Exclusion Trigger mode which allows you to set the oscilloscope to trigger only when an abnormal signal width or period occurs.

Optional Analysis Packages

An optional Parameter Analysis Package, option WP03, provides extensive statistical analysis capabilities. Detailed measurements can easily be performed on difficult to characterize waveform phenomena such as amplitude fluctuation and timing jitter. Live histogram displays represent the statistical distribution of selected waveform parameter measurements. The trend function draws line graphs to track the value of measured parameters. You can even use math functions such as differentiation to process the trend data.

The DDM and PRML disk drive packages are powerful firmware options that provide a unique integrated tool for engineers developing and testing high-density storage media. The Disk Drive Measurement (DDM) package, developed specifically for those who design and test disk drives and magnetic tape, is based on the IDEMA Standard Measurements for Magnetic Media and includes calculations of Time Average Amplitude (TAA), Pulse Width at 50% (PW50), Resolution, and Overwrite. The Partial Response Maximum Likelihood (PRML) package is also for magnetic media testing and allows the calculation of Auto Correlation, Non-Linear Transition Shifts and Auto Correlation Signal-to-Noise. The advanced analysis can be displayed in histograms and as worst case parameters.

A new disk drive package from LeCroy, DDFA, adds powerful PRML signal failure detection and isolation capabilities to LeCroy oscilloscopes. DDFA provides several tools that can be used to automatically determine when a PRML signal failure occurs. In addition, once failures are detected, the corresponding head signal locations where the errors occur can be directly selected for display and analysis. DDFA also enhances the view of the head signal, through performing PRML drive channel emulation. An emulation of the drive channel noise and equalization filter is performed to display a more easily analyzed head signal. The head signal is annotated with markers that display the ideal PRML target points that the filtered signal should intersect. The difference between the head signal and the ideal target points provides a clear visual indication of PRML signal quality.

The ORM Optical Recording Measurements package allows engineers engaged in the design or test of optical recording media (CD-ROM, magneto-optical or DVD) to make measurements which are specific to that media. Data can be displayed as parametric measurements, histograms or trend lines.

Telecomunications Mask Test packages, with balanced and coax adaptors, are available for ITU G.703 and ANSI T1.102 standards. These telecomunications packages transform LeCroy oscilloscopes into dedicated telecomunications mask testers. The input signal is automatically scaled and aligned within the mask, and our exclusive Finder search engine isolates pulses and patterns even in random-bit streams.

Upgrade Your DSO

Digital scopes are capital equipment with a cost ranging from $5K to $35K. To protect the value of your investment, LeCroy offers an upgrade path to keep up with the latest technology. You can upgrade your DSO's hardware or software, or add analysis packages as your needs change or as new packages are offered. Suppose your next project involves longer, more complex signals. You will need more acquisition memory in your digital scope. Perhaps the application is driven by the need for really fast measurement results. You can add up to 64 Mbytes of RAM and add an analysis package. LeCroy is the only scope vendor that will upgrade DSOs to add more acquisition or processing memory. Maybe you would like to transfer a scope to manufacturing where I/O throughput for ISO9000 documentation is critical. LeCroy can add a PCMCIA portable hard drive, fast internal printer or IC memory card.

Summary

If the ability to use a DSO to solve problems quickly is important to you, then a LeCroy Performance DSO should be on your list. LeCroy scopes offer outstanding abilities to capture, view and diagnose electronic problems. The measurement and documentation tools available for these scopes improve productivity and help companies get new products to market faster.

LC Series Selection Guide

High-Performance Color Digital Oscilloscopes

LeCroy Model Number	Analog BW (Minimum)	Max Transient Sample Rate	Max Repetitive Sample Rate	Number of Channels	Memory per Channel
LC564A	1 GHz	4 GS/s	25 GS/s	4	100k/4 ch 250k/2 ch 250k/1 ch
LC584AL	1 GHz	8 GS/s	25 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
LC584AM	1 GHz	8 GS/s	25 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
LC584A	1 GHz	8 GS/s	25 GS/s	4	100k/4 ch 250k/2 ch 500k/1 ch
LC574AL	1 GHz	4 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
LC574AM	1 GHz	4 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
LC574A	1 GHz	4 GS/s	10 GS/s	4	100k/4 ch 250k/2 ch 500k/1 ch
LC534AL	1 GHz	2 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
LC534AM	1 GHz	2 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
LC534A	1 GHz	2 GS/s	10 GS/s	4	100k/4 ch 250k/2 ch 500k/1 ch
LC334AL	500 MHz	2 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
LC334AM	500 MHz	2 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
LC334A	500 MHz	2 GS/s	10 GS/s	4	100k/4 ch 200k/2 ch 400k/1 ch

LC Series Upgrade Guide

LC334A Series - 500 MHz; 4 Channel DSOs

LC334A	→	LC334AM	→	LC334AL
100k/ch		500k/ch		2M/ch
96 MHz PowerPC processor		96 MHz PowerPC processor		96 MHz PowerPC processor
8M RAM		8M RAM		16M RAM

LC534A Series - 1 GHz; 4 Channel DSOs

LC534A	→	LC534AM	→	LC534AL
100k/ch		500k/ch		2M/ch
96 MHz PowerPC processor		96 MHz PowerPC processor		96 MHz PowerPC processor
8M RAM		8M RAM		16M RAM

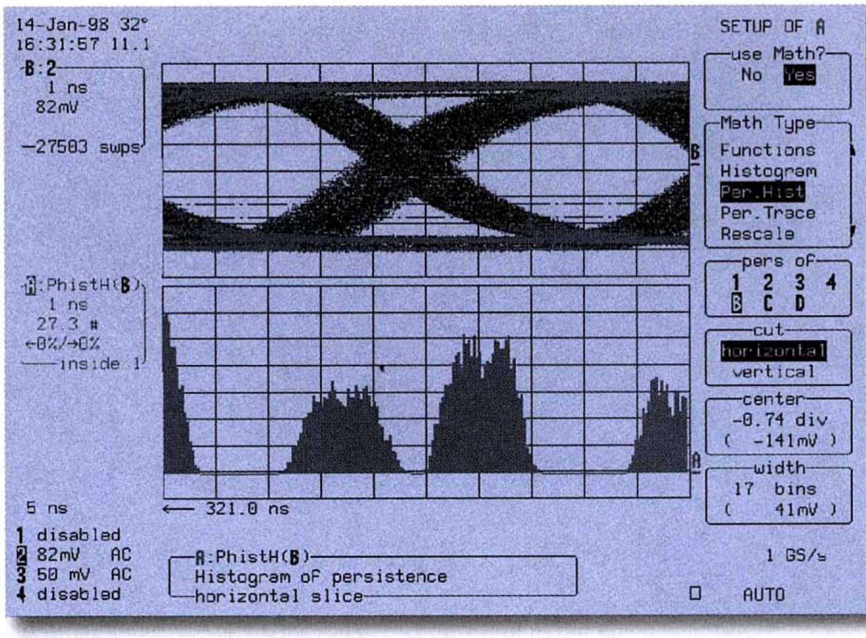
LC574A Series - 1 GHz; 4 Channel DSOs

LC574A	→	LC574AM	→	LC574AL
100k/ch		500k/ch		2M/ch
96 MHz PowerPC processor		96 MHz PowerPC processor		96 MHz PowerPC processor
8M RAM		8M RAM		64M RAM

LC584A Series - 1 GHz; 4 Channel DSOs

LC584A	→	LC584AM	→	LC584AL
100k/ch		500k/ch		2M/ch
96 MHz PowerPC processor		96 MHz PowerPC processor		96 MHz PowerPC processor
16M RAM		16M RAM		64M RAM

LC564A
LC584A
LC584AM
LC584AL



Main Features

- *1 GHz Bandwidth*
- *Up to 8 GS/s Single-Shot Sample Rate*
- *Up to 8 Million Points of Acquisition Memory*
- *600 ps Glitch Trigger*
- *96 MHz PowerPC Microprocessor*
- *Advanced Runt and Slew Rate Trigger*
- *Up to 64 Mbyte System RAM*
- *9" Color Display with 8 Traces*
- *Analog Persistence*
- *Full Screen Grid*
- *Auto Scroll*

Digital oscilloscopes from LeCroy are designed to save engineers valuable time in troubleshooting and problem-solving.

Each oscilloscope is an integrated and powerful system providing the capability to:

- Capture the key events with high resolution for longer time intervals
- View data like never before, giving you more information more quickly, with a large, color CRT and advanced display techniques
- Analyze your signal to get answers quickly and more accurately with a powerful processing system and math packages.

9" Color Display

LeCroy provides a very large, sharp oscilloscope screen that is 50% larger in total viewing area than a 7" screen.

Its powerful features include Analog Persistence, Color-Graded Persistence, Full Screen mode, Opaque or Transparent display, color association and personal color schemes. These provide the user with outstanding benefits that accelerate visual processing and effective communication of on-screen information.

High-Speed Acquisition

The design and debug of fast digital systems and the need to capture fast, transient signals require high speed signal capture. The high 8 GS/s sample rate, 1 GHz bandwidth and long memory of the LC584A series provide a flexible solution for capturing and viewing fast glitches and rise/falltimes.

Large Sample Rate Window

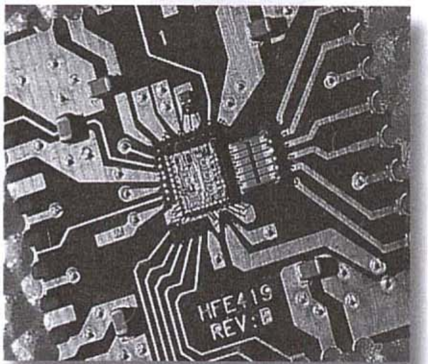
Having a high sample rate in a DSO is only the first step to preserving data integrity. The time window over which this sample rate is available is also of critical importance. Long acquisition memory maintains the oscilloscope's highest sample rate for large time windows allowing the user to sample long signals with high horizontal resolution.

With up to 8 million points of acquisition memory, the maximum 8 GS/s sample rate of these oscilloscopes is maintained for a time window of 1 ms. This sample rate window enables the user to record long signals with high resolution.

Optimum Performance

SMARTMemory is a Total Memory Management system that dynamically allocates resources of microprocessor power, acquisition memory and processing RAM. The intelligent management provided by SMARTMemory guarantees optimal usage of oscilloscope resources.

The 96 MHz PowerPC microprocessor at the heart of these DSOs drives the system to produce results fast, providing rapid waveform update and super panel responsiveness.



High-performance signal conditioning devices preserve signal content.

Quick Diagnoses

Capturing and viewing waveforms is fundamental to an oscilloscope. Productivity improvements are accessible by using built-in math functions to assist troubleshooting and diagnoses of circuit problems.

The signal analysis capability of these DSOs is enhanced by advanced waveform math, spectrum analysis, and waveform parameter analysis. This analysis capability greatly increases the speed with which circuit problems are clearly identified and solved.

Analog Persistence

At a push of the green button, the user can switch between an analog-style view and a digital view of signals on these oscilloscopes.

The depth of signal information can be explored along the third dimension of the waveform display to give the user a complete picture of waveform activity.

Unlike an analog oscilloscope, all signal data is captured and available in memory for analysis and measurements. Analog Persistence gives the user the best of both the analog and digital worlds of oscilloscopes.

Full Screen Grid

These LeCroy DSOs not only have a very large 9" screen but also provide a display mode with an extra-large grid. In Full Screen mode, all of the screen area is used to display signals.

8-Trace Display

An 8-trace display with any combination of math functions, zooms, reference memories or channels is a standard feature in the LC series.

Octal grid display is available in normal and Full Screen display modes, with and without parameters displayed.

Auto Scroll

Auto Scroll displays the captured signal with a zoom expansion and automatically moves it across the screen. Scroll speed, starting point and pausing are freely selectable.

Easy Documentation

All waveform data and results of analysis can be quickly saved to floppy disk or to an optional memory card, ATA flash card, or a removable hard disk. This provides an efficient way to archive information and facilitates easy documentation of results.

An internal graphics printer (standard in LC584AL) outputs screen dumps in seconds providing the user with an immediate and clear record of signal activity.

Signal Capture

Acquisition System

Bandwidth (-3 dB):
@ 50 Ω: DC to 1 GHz
@ 1 MΩ: DC to 500 MHz typ. at PP005 probe tip; DC to 1 GHz at probe tip with optional AP020 1 GHz FET probe

No. of Channels: 4

Sample Rate:
LC584A/M/L: 8 GS/s (1 Ch), 4 GS/s (2 Ch), 2 GS/s (4 Ch)

LC564A: 4 GS/s (2 Ch), 2 GS/s (4 Ch)

Acquisition Memory:
See table below.

Sensitivity:
2 mV/div to 1 V/div, 50 Ω, fully variable.
2 mV/div to 10 V/div, 1 MΩ, fully variable.

Scale factors: Choice of over 12 probe attenuation factors selectable via front panel menus.

Offset Range:
2.00 - 4.99 mV/div: ±400 mV
5.00 - 99 mV/div: ±1 V
0.1 - 0.99 V/div: ±10 V
1.0 - 10 V/div: ± 100 V (1 MΩ only)

±20 V across the whole sensitivity range when using the AP020 FET probe.

DC Accuracy: Typically 2% of Full Scale.

Vertical Resolution: 8 bits

Bandwidth Limiter: 25 MHz and 200 MHz typical.

Input Coupling: AC (>10 Hz typ.), DC, GND

Input Impedance: 10 MΩ//15 pF max (using PP005 probe), or 50 Ω ±1%.

Max Input Voltage:
1 MΩ: 400 V (DC + peak AC @10 kHz)
50 Ω: ± 5 V DC (500 mW) or 5 V RMS

Acquisition Modes

Random Interleaved Sampling (RIS): 25 GS/s. For repetitive signals from 200 ps/div to 1 µs/div.

Single shot: For transient and repetitive signals from 0.5 ns/div (4 ch), 1 ns/div (2 ch), 2ns/div (1 ch).

Sequence: Stores multiple events - each of them time stamped - in segmented acquisition memories.

Number of Segments Available:
LC584A/564A 2 - 1000
LC584AM/L 2 - 2000

Active Channels	Maximum Sampling Rate	Maximum Record Length			
		LC564A	LC584A	LC584AM	LC584AL
4	2 GS/s	100 k	100 k	500 k	2 M
2	4 GS/s	250 k	250 k	1 M	4 M
1	8 GS/s	N/A	500 k	2 M	8 M

Measurements

Cursor Measurements

Relative Time: A pair of arrow cursors measure time differences and voltage differences relative to each other.
Relative Voltage: A pair of line cursors measure voltage differences relative to each other.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

Automated Measurements

The following parametric measurements are available, together with their Average, Highest, Lowest values and Standard Deviation:

amplitude	cycles	fall	mean-	peak to peak	top
area	delay	f 80-20%	median	rise	width
base	Δc2d-, Δc2d+	f@level	minimum	r 20-80%	
cmean	Δdelay	first	overshoot+	r@level	
cmedian	Δ@level	frequency	overshoot-	rms	
crms	duration	last	period	std dev	
csdev	duty	maximum	phase	t@level	

PASS/FAIL: Pass/Fail testing allows any 5 items (parameters and/or masks) to be tested against selectable thresholds. Waveform Limit Testing is performed using masks which may be defined either inside the instrument or, for instance, by downloading templates created with ScopeExplorer. Any failure will cause preprogrammed actions such as Hardcopy, Save to internal memory, Save to mass storage device (card or disk), GPIB SRQ or Pulse Out.

Timebase System

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 500 ps/div (at 8 GS/s), 1 ns/div (at 4 GS/s), 2 ns/div (at 2 GS/s) to 1,000 s/div.

Clock Accuracy: ≤10 ppm

Interpolator resolution: 10 ps

Roll Mode: 500 ms/div to 1,000 s/div

External Clock: Optional DC to 500 MHz rear panel fixed frequency clock input. (<20 ns rise/falltime)

External Reference: Optional 10 MHz rear-panel input.

Additional Information

Interfacing

Remote Control: All front-panel controls as well as all internal functions are possible by GPIB and RS-232-C.

RS-232-C Port (Standard): Asynchronous up to 115.2 kBaud for computer/terminal control or printer/plotter connection.

GPIB Port (Standard): (IEEE-488.2) Configurable as talker/listener for computer control and fast data transfer.

Centronics Port: Hardcopy parallel interface.

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. Supported printers:

B/W: LaserJet, DeskJet, Epson

Color: DeskJet, Epson, Canon BJC 200/400/600

An optional, internal, high-resolution graphics printer is also available for screen dumps; stripchart output formats up to 2 m/div are achievable.

Hardcopy Formats: TIFF b/w, TIFF color, BMP color and BMP compressed.

Output Formats: ASCII waveform output. Compatible with spreadsheets, MATLAB, MathCad. Binary output is also available.

General

Auto-calibration ensures specified DC and timing accuracy.

Calibration Time: <500 ms

Recommended Factory Calibration Interval: 1 year

Temperature: 5° to 40°C rated accuracy (41° to 104°F). 0° to 45°C operating (32° to 113°F).

Humidity: <80% non-condensing.

Altitude: Up to 4600 m (operating), 40°C (104°F) max.

Shock and Vibration: Conforms to selected sections of MIL-PRF-28800F, Class 3.

Power: 90-250 V AC, 45-400 Hz, 500 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions:
(HWD) 10.4" x 15.65" x 17.85", 264 mm x 397 mm x 453 mm.

Weight: typ. 20 kg (44 lbs) net, typ. 28 kg (61.6 lbs) shipping.

Warranty: Three years.

CE Approval
EMC: Conforms to EN50081-1 (Emissions) and EN50082-1 (Immunity)

Signal Analysis

SIGNAL ANALYSIS

RAPID PROCESSING SYSTEM

Microprocessor: 96 MHz PowerPC 603e.
System RAM: 16 to 64 Mbytes.
Video Memory: 1 Mbyte.
Persistence Data Map Memory: 16 bits per displayed pixel (64k levels).

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging, Sine x/x.
Average: Summed averaging up to a million sweeps.
Envelope: Max, Min, or Max and Min values of up to one million sweeps.
Extrema: Roof, Floor, or Envelope values from 1 to 10^6 sweeps.
ERES: Low-Pass digital filters provide up to 11–bit vertical resolution. Sampled data is always available, even when a trace is turned off.
FFT: Spectral Analysis with four windowing functions and FFT averaging.
Statistical Diagnostics*: The Parameter Analysis package permits in-depth diagnostics on waveform parameters. Live histogramming of any waveform parameter measurement is possible, and the histogram can be autoscaled to display the center and width of the distribution.
Any of the above processes can be invoked without losing the data.
**Histogramming and Trending are part of the Parameter Analysis Package.*

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4).
Processing Memory: Up to four 16-bit Waveform Processing Memories (A, B, C, D).
Setup Memory: Four non-volatile memories. The floppy disk or optional cards or portable hard drive may also be used for high-capacity waveform and setup storage.

Safety: The oscilloscope has been designed to comply with EN61010-1 Installation Category (Over-voltage Category) II, 300V, Pollution Degree 2.

UL and cUL approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010. 1-92.

SIGNAL VIEWING

Type: Color 10" Raster Scan CRT, 0.26mm dot pitch with a 9" viewing area.

Resolution: VGA (640 x 480 points)

Controls: Rear-panel presets for position, brightness and contrast. Menu controls for brightness and color selection.

Grid Styles: Single, Dual, Quad, Octal, XY, Single+XY, Dual+XY, and Full Screen - an enlarged view of each grid style.

Graticules: Internally generated; separate intensity control for grids and wave-forms. Selectable blending of grid with displayed traces.

Waveform Style: Dot Join with optional sample point highlight or Dots only.

Persistence Modes: Color-graded persistence and Analog Persistence, infinite or variable with decay over time. In color-graded persistence, a color spectrum from red through violet is used to map signal intensity. With Analog Persistence, the brightness level of a single color denotes signal intensity. Each trace's persistence data is stored in 64k levels.

Trace Display: Opaque or transparent mode, with overlap management.

Number of Traces: 8 (any mix of channels, memories or Math functions).

Real-time Clock: Date, hours, minutes, seconds.

External Monitor: Rear-panel 15-pin socket for VGA compatible monitor.

Vertical Zoom: Up to 5x vertical expansion (50x with averaging, up to 40 µV/div sensitivity).

Horizontal Zoom Factor: Waveforms can be expanded up to 5 points/screen.

Triggering System

Modes: Normal, Auto, Single, and Stop.

Sources: CH1, CH2, CH3, CH4, Line, EXT, EXT/5. Slope, Level and Coupling are unique for each source.

Slope: Positive, Negative, Bi-Slope (Window in & out).

Coupling: DC, AC (>10 Hz), HF (175 MHz - 2 GHz), LFREJ (>50 kHz), HFREJ (<100 MHz)

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div. increments).

Holdoff by time: 2 ns to 20 s

Holdoff by events: 1 to 99,999,999

Internal Trigger Range: ±5 div

Maximum Trigger Frequency: 1 GHz (DC, AC), >1 GHz (HF)

EXT Trigger Max. Input: 10 MΩ// 15 pF at probe tip (PP005): 400 V (DC + peak AC ≤10 kHz).

50 Ω ±1%: ±5 V DC (500 mW) or 5 V RMS.

EXT Trigger Range: ±0.5 V (±2.5 V with EXT/5).

Trigger Output: Optional ECL rear-panel output (option CKTRIG). The calibrator output can provide a trigger status signal or a Pass/Fail test output.

SMART Trigger Types

Pattern: Trigger on the logic combination of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on glitches as short as 600 ps or on pulse widths within/outside two limits selectable from 600 ps to 20 s.

Slew Rate: Trigger on rising, falling edges within/outside two time limits selectable from 600 ps and 20 s.

Signal or Pattern Interval: Trigger on an interval between two limits selectable from 2 ns to 20 s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 2 ns to 20 s.

Runt: Trigger on positive or negative runts within/outside two limits selectable from 600 ps to 20 s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of up to 1500 lines and field synchronization for PAL, SECAM, NTSC or non-standard video.

Autosetup

Automatically sets sensitivity, vertical offset and timebase on all display channels.

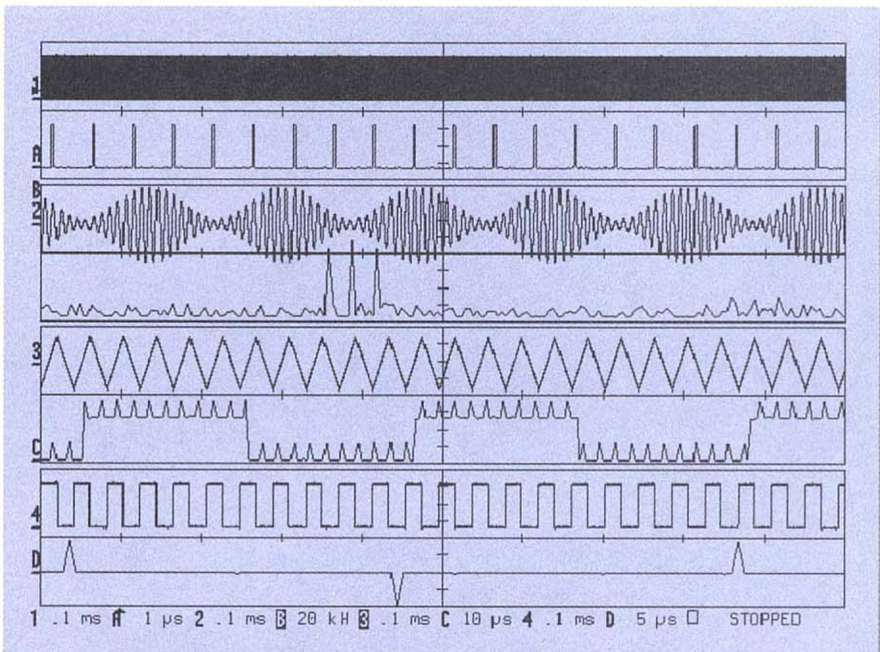
Autosetup Time: Approximately 3 seconds.

Probes

Model: One PP005 probe supplied per channel.

Optional Probe: 1 GHz FET probe (AP020)

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and falltime 1 ns typical. Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

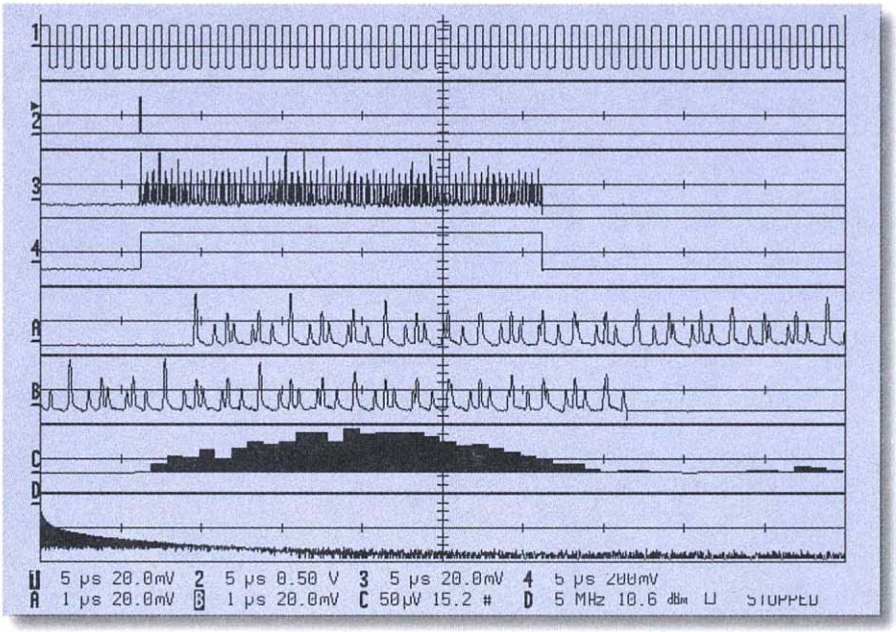


LC564A/584A - Ordering Information

Digital Oscilloscopes:	Product Code	Price
1 GHz, 2 GS/s, 100 kpts./ch, 4 channel Color DSO (4 GS/s; 250k max)	LC564A	$ 19,990
1 GHz, 2 GS/s, 100 kpts./ch, 4 channel Color DSO (8 GS/s; 500k max)	LC584A	24,990
1 GHz, 2 GS/s, 500 kpts./ch, 4 channel Color DSO (8 GS/s; 500k max)	LC584AM	27,990
1 GHz, 2 GS/s, 2 Mpts./ch, 4 channel Color DSO (8 GS/s; 500k max)	LC584AL*	35,990
Included with Standard Configuration:		
10:1 10 MΩ Passive Probe (1 per channel)	PP005	175 (each)
Operator's Manual	LCXXX-OM	85
Remote Control Manual	LCXXX-RCM	85
Hands On Guide	LCXXX-HG	45
Advanced Waveform Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package (Not included in LC564A)	WP03	1,250
Floppy Disk Drive	FD01	
Performance Certificate		
Three-Year Warranty		
Selected Probes & Accessories:		
1 GHz 10:1 FET Probe	AP020	990
DC-15 MHz Differential Probe, 10:1/100:1	AP031	300
DC-15 MHz Differential Probe, 20:1/200:1	AP032	300
2.5 GHz 0.6pF Active Probe	AP54701A**	2,944
Probe Offset and Power Module	AP1143A**	1,568
1 GHz, 10:1, 500 Ω Passive Probe	PP062	95
ProBus 75 to 50 Ω Adapter	PP090	195
Software Options:		
ITU G.703 Fully Automated Mask Tester	MT01	3,000
ANSI T1.102 Fully Automated Mask Tester	MT02	3,000
Jitter and Timing Analysis	JTA	1,875
Disk Drive Failure Analysis	DDFA	4,990
Disk Drive Measurements (includes Parameter Analysis Option WP03)	DDM	3,000
Supplementary Disk Drive Measurements	PRML	1,250
Optical Recording Measurements	ORM	3,000
Hardware Options:		
Memory Card Reader and 512k SRAM Card	MC01/04	500
PCMCIA Type III Slot for Hard Drives and ATA Flash Cards	HD01	590
PCMCIA Hard Disk 170 Mbyte (requires HD01 option)	HD02	499
4MB ATA Flash Card (requires HD01 option)	4MBFC	399
Internal Graphics Printer	GP01	890
DC-500 MHz Ext Clock, 10 MHz Ref Input, Trigger Comparator Output	CKTRIG	490
64 Mbyte System Memory	64MBSM***	2,000
Manuals:		
Service Manual for LC584A Series	LC584A-SM	125
Warranty & Calibration:		
NIST Calibration Certificate	LCXXX-CCNIST	225
MIL STD Calibration	LCXXX-CCMIL	325
Swiss OFMET Standard	LCXXX-CCOFMET	225
5 Year Repair Warranty	LCXXX-W5	545
5 Year NIST Calibration Contract	LCXXX-C5	725
5 Year Warranty & NIST Calibration	LCXXX-T5	975

* *Includes Internal Graphics Printer*
** *Normally ordered together*
*** *Included with LC584AL*

LC334A
LC374A
LC534A
LC574A



Main Features

- ***500 MHz and 1 GHz Bandwidth***
- ***2 GS/s and 4 GS/s Single-Shot Sample Rate***
- ***8 Million Points of Acquisition Memory***
- ***4 ms Maximum Sample Rate Window***
- ***96 MHz PowerPC Microprocessor***
- ***8 to 64 MB System RAM***
- ***9" Color Display with 8 Traces***
- ***Analog Persistence***
- ***Full Screen Grid***

Digital oscilloscopes from LeCroy are designed to save engineers valuable time in troubleshooting and problem-solving.

Each oscilloscope is an integrated and powerful system providing the capability to:

- Capture the key events with high resolution for longer time intervals
- View data like never before, giving you more information more quickly, with a large, color CRT and advanced display techniques
- Analyze your signal to get answers quickly and more accurately with a powerful processing system and math packages.

9" Color Display

LeCroy provides a very large, sharp oscilloscope screen that is 50% larger in total viewing area than a 7" screen.

Its powerful features include Analog Persistence, Color-Graded Persistence, Full Screen mode, Opaque or Transparent display, color association, and personal color schemes. These provide the user with outstanding benefits that accelerate visual processing and effective communication of on-screen information.

High-Speed Acquisition

The design and debug of fast digital systems and the need to capture fast transient signals require high-speed signal capture. The LC574A four-channel, 1 GS/s, 1 GHz bandwidth DSO operates at a 4 GS/s sample rate for single-channel inputs. The high sample rate, bandwidth and the 1 GHz trigger bandwidth provide a flexible solution for capturing and viewing fast risetime signals.

Large Sample Rate Window

Having a high sample rate in a DSO is only the first step to preserving data integrity. The time window over which this sample rate is available is also of critical importance. Long acquisition memory maintains the oscilloscope's highest sample rate for large time windows allowing the user to sample long signals with high horizontal resolution.

With up to 8 million points of acquisition memory, the maximum sample rate of the LC574AL of 4 GS/s (2 GS/s in LC334AL and LC534AL) is maintained for a time window of 2 ms (4 ms in LC334AL and LC534AL). This sample rate window enables the user to record long signals with high resolution.

Optimum Performance

SMARTMemory is a total memory management system that dynamically allocates resources of microprocessor power, acquisition memory and processing RAM. The intelligent management provided by SMARTMemory guarantees optimal usage of oscilloscope resources.

The 96 MHz PowerPC microprocessor at the heart of these DSOs drives the system to produce results fast, providing rapid waveform update and super panel responsiveness.

Quick Diagnoses

Capturing and viewing waveforms are fundamental to an oscilloscope. Productivity improvements are accessible by using built-in math functions to assist troubleshooting and diagnoses of circuit problems.

The signal analysis capability of these DSOs is enhanced by advanced waveform math, spectrum analysis, and waveform parameter analysis. This analysis capability greatly increases the speed with which circuit problems are clearly identified and solved.

Analog Persistence

At a push of the green button, the user can switch between an analog style view and a digital view of signals on these oscilloscopes.

The depth of signal information can be explored along the third dimension of the waveform display to give the user a complete picture of waveform activity.

Unlike an analog oscilloscope, all signal data is captured and available in memory for analysis and measurements. Analog Persistence gives the user the best of both the analog and digital worlds of oscilloscopes.

Full Screen Grid

LeCroy DSOs not only have a very large 9" screen but also provide a display mode with an extra-large grid, up to 150% larger than common grid areas. In Full Screen mode, all of the screen area is used to display signals. This provides a magnificent view of up to 8 waveforms: signal details are seen more clearly and with greater ease.

8-Trace Display

An 8-trace display with any combination of math functions, zooms, reference memories, or channels is a standard feature in the LC series.

Maximum Sample Rate and Acquisition Memories

	Maximum Sample Rate			Memory per Channel			
Channel Use	LC334A LC534A	LC374A*	LC574A	LC334A LC374A* LC534A LC574A	LC334AM LC534AM LC574AM	LC334AL LC534AL LC574AL	Active Channels
All Peak Detect OFF	500 MS/s	1 GS/S	1 GS/s	100 k	500 k	2 M	All
Paired Peak Detect OFF	1 GS/s	2 GS/s	2 GS/s	250 k	1 M	4 M	CH2 & CH3
Paired + Adapter Peak Detect OFF	2 GS/s	2 GS/s**	4 GS/s	500 k	2 M	8 M	One
All Peak Detect ON	100 MS/s data + 400 MS/s peaks			50 k data+ 50 k peaks	250 k data+ 250 k peaks	1 M data+ 1 M peaks	All

** No external adapter*
*** On CH2*

Octal grid display is available in normal and Full Screen display modes, with and without parameters displayed.

Easy Documentation

All waveform data and results of analysis can be quickly saved to floppy disk, memory card, ATA flash card, or a removable hard disk. This provides an efficient way to archive information and facilitates easy documentation of results.

An internal graphics printer (standard in "L" models) outputs screen dumps in seconds providing the user with an immediate and clear record of signal activity.

Signal Capture

Acquisition System

LC334A/LC374A Bandwidth (-3 dB):
@ 50 Ω: DC to 500 MHz

LC534A/LC574A Bandwidth (-3 dB):
@ 50 Ω: DC to 1 GHz

Bandwidth (-3 dB): @ 1 MΩ: DC to 500 MHz typical at probe tip with optional 1 GHz FET probe for LC334A and with PP005 standard with LC374A, LC534A and LC574A.

No. of Channels: 4

No. of Digitizers: 4

Max. Sample Rate Window:
4 ms @ 2 GS/s in single-shot mode; LC334AL, LC534AL.
2 ms @ 4 GS/s; LC574AL.

Sensitivity LC334A:
2 mV/div to 5 V/div, 50 Ω, fully variable.
2 mV/div to 5 V/div, 1 MΩ, fully variable.

Sensitivity LC374A/LC534A/LC574A:
2 mV/div to 1 V/div, 50 Ω, fully variable.
2 mV/div to 10 V/div, 1 MΩ, fully variable.

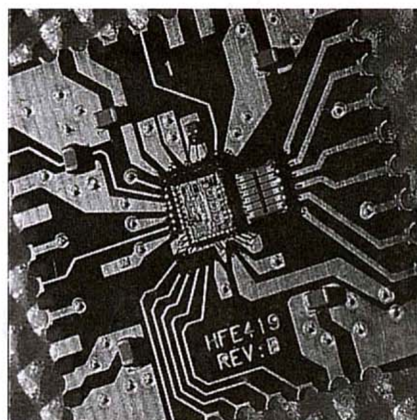
Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range LC334A:

2.00 - 9.99 mV/div:	±120 mV
10.0 - 199 mV/div:	±1.2 V
0.2 - 5.0 V/div:	±24 V

Offset Range LC374A/LC534A/LC574A:

2.00 - 4.99 mV/div:	±400 mV
5.00- 99 mV/div:	±1 V
0.1 - 1.0 V/div:	±10 V
1.0 - 10 V/div:	±100 V (1 MΩ only)



High performance signal conditioning devices preserve signal content.

Measurements

Cursor Measurements

Relative Time: A pair of arrow cursors measure time differences and voltage differences relative to each other.
Relative Voltage: A pair of line cursors measure voltage differences.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

Automated Measurements

A wide range of pulse parameter measurements are available. These are categorized for ease of use. The categories include Pulse, Horizontal, and Vertical parameters. Basic statistical measurements (average, highest, lowest, and standard deviation), can be made on these parameter values in order to understand their distribution. Pass/Fail Testing and Waveform Limit testing using masks can be performed. Test conditions can be expressed as either waveform parameter limits, waveform shape limits (mask) or a combination of both. Any failure can cause preprogrammed actions such as Hardcopy, Save, GPIB service request, logic pulse out, audible beep, or any combination of the above.

DC Accuracy: Typical 1%

Vertical Resolution: 8 bits

Bandwidth Limiter LC334A: 30 MHz

Bandwidth Limiter LC374A/LC534A/LC574A: 25 MHz, 200 MHz

Input Coupling: AC, DC, GND

Input Impedance: 10 MΩ//15 pF for LC334A (system capacitance using PP005), 10 MΩ//11 pF for LC374A/LC534A/LC574A (system capacitance using PP005) or 50 Ω ±1%.

Max Input:
50 Ω: ±5 V DC (500 mW) or 5 V RMS
1 MΩ on LC334A: 250 V
1 MΩ on LC374A/LC534A/LC574A: 400 V (DC + peak AC ≤10 kHz)

SMARTMemory: This total memory management system dynamically manages acquisition memory to guarantee that signals are always sampled at the highest possible sample rate and that system RAM and microprocessor resources are always optimally employed.

Acquisition Modes
Random Interleaved Sampling (RIS): For repetitive signals from 1 ns/div to 5 µs/div (2 µs/div for LC374A and LC574A).

Single shot: For transient and repetitive signals from 10 ns/div (1 ns/div for LC374A and LC574A) with all channels active.

Peak detect: At 400 MS/s, peak detect can capture high-speed events down to 1 ns, while simultaneously capturing normally sampled data.

Sequence: Stores multiple events - each of them time stamped - in segmented acquisition memories.

Dead Time between segments: Typically <30 µs, max. 50 µs

Timebase System

Timebases: Main and up to 4 Zoom Traces

Time/Div Range: 1 ns/div to 1,000 s/div.

Clock Accuracy: ≤10 ppm

Interpolator resolution: 10 ps

Roll Mode: Ranges 500 ms to 1,000 s/div. For >50 kpoints: 10 s to 1,000 s/div.

External Clock: ≤100 MHz (20-100 MHz for LC574A and LC374A) on EXT input with ECL, TTL or zero crossing levels. Optional 50 MHz to 500 MHz rear-panel fixed frequency clock input.

External Reference: Optional 10 MHz rear-panel input.

Additional Information

Interfacing

Remote Control: Possible by GPIB and RS-232-C for all front-panel controls, as well as all internal functions.

RS-232-C Port: Asynchronous up to 115.2 Kb/s for computer/terminal control or printer/plotter connection.

GPIB Port: Configurable as talker/listener for computer control and fast data transfer, up to 300 kbytes/sec. Command Language complies with requirements of IEEE-488.2.

Centronics Port: Hardcopy parallel interface is standard.

PC Card (PCMCIA I/II/III) Ports: For memory cards, ATA compatible flash cards and removable hard disks - optional.

Model			Segments
LC334A/LC374A	LC534A	LC574A	500
LC334AM	LC534AM	LC574AM	2,000
LC334AL	LC534AL	LC574AL	2,000

Number of segments available

Signal Analysis

SIGNAL ANALYSIS

A comprehensive and easy-to-use set of diagnostic tools are available. Calculations are performed rapidly, and results can be presented on-screen or stored to disk.

Rapid Processing System
Microprocessor: 96 MHz PowerPC 603e.
System RAM: 8 to 64 Mbytes.
Video Memory: 1 Mbyte.
Cache Memory: 32 kbyte.
Persistence Data Map Memory: 16 bits per displayed pixel (64 k levels).

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Standard functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging and Sine x/x. The source information for a math function trace can be data from an acquisition channel or from another math function trace. This allows display of traces which "daisy chain" math functions.

Average: Up to 10^6 averages are possible.
Extrema: Roof, Floor, or Envelope values from 1 to 10^6 sweeps.
ERES: Six low-pass digital filters provide up to 11-bit vertical resolution. Sampled data is always available, even when a trace is turned off.
FFT: Spectrum Analysis with five windowing functions and FFT averaging.
Statistical Diagnostics*: The Parameter Analysis package permits in-depth diagnostics on waveform parameters. Live histogramming of any waveform parameter measurement is possible and the histogram can be autoscaled to display the center and width of the distribution.

Any of the above processes can be invoked without losing the data.
*Histogramming and Trending are part of the Parameter Analysis Package.

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4), whose length corresponds to the length of the channel acquisition memory.
Zoom & Math Memory: Up to four 16-bit Waveform Processing Memories (A, B, C, D), whose length corresponds to the length of the channel acquisition memory.
Setup Memory: Four non-volatile memories. The floppy disk or optional memory cards, Flash card or removable hard disks can also be used for high-capacity waveform and setup storage.

Floppy Disk: High-density 3.5" floppy disk drive (DOS format) is standard.

VGA Compatible Display: 15-pin D-type VGA compatible connector for external color display.

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to desktop publishing programs. The following printers and plotters can be used to make hardcopies:

B/W: HP LaserJet, HP DeskJet 500, Epson FX.

Color: HP DeskJet 550C, Epson Stylus, Canon BJC. An optional, internal, high-resolution graphics printer is also available for screen dumps; a stripchart output format with 2 meters per division is also possible.

Output Formats: ASCII waveform output is available in seconds, compatible with spreadsheets, MATLAB, MathCad. Binary output is also available.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.

Temperature: 5° to 40°C (41° to 104°F) rated 0° to 50°C (32° to 122°F) operating.

Humidity: 80% for temperatures up to 31°C decreasing linearly to 50% relative humidity at 40°C.

Altitude: Up to 2000m (operating), 40°C max.

Power: 90-132 V AC, 180-250 V AC, 45-66 Hz, 400 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions: (HWD)10.4" x 15.65" x 17.85" (264 mm x 397 mm x 453 mm)

Weight: 20 kg (44 lbs) net, 28 kg (61.6 lbs) shipping.

Warranty: Three years.

CE Approval: EMC: Conforms to EN50081-1 and EN50082-1.

UL and cUL approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010. 1-92.

Safety: The oscilloscope has been designed to comply with EN61010-1 Installation Category (Over-voltage Category) II, Pollution Degree 2.

Signal Viewing

Type: Color 9" Raster Scan CRT, 0.26 mm dot pitch.

Resolution: 640 x 480 points.

Display Area: 170 mm x 125 mm - 50% greater than that of a 7" display.

Controls: Rear-panel presets for position, brightness and contrast. Menu controls for brightness and color selection.

Grid Styles: Single, Dual, Quad, Octal, XY, Single+XY, Dual+XY, and Full Screen - an enlarged view of each grid style.

Graticules: Internally generated; separate intensity control for grids and waveforms. Selectable blending of grid with displayed traces.

Waveform Style: Dot Join with optional sample point highlight or Dots only.

Persistence Modes: Color-graded persistence and Analog Persistence, infinite or variable with decay over time. In color-graded persistence, a color spectrum from red through violet is used to map signal intensity. With Analog Persistence, the brightness level of a single color denotes signal intensity. Each trace's persistence data is stored in 64 k levels. Analog Persistence is only available in four channel mode on LC334A models.

Trace Display: Opaque or transparent mode, with overlap management.

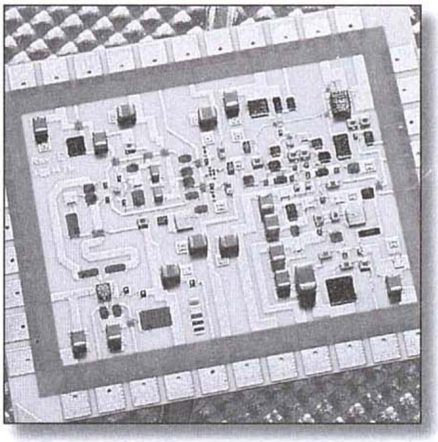
Number of Traces: 8 (any mix of channels, memories or Math functions).

Real-time Clock: Date, hours, minutes, seconds.

External Monitor: Rear-panel 15-pin socket for VGA compatible monitor.

Vertical Zoom: Up to 5x vertical expansion (50x with averaging, up to 40 μV/div sensitivity).

Horizontal Zoom:
LC334A/LC534A: Waveforms can be expanded to give 2-2.5 points/division.



Precision sampling devices maintain signal integrity in the digital world .

This allows zoom factors up to 100,000x for the 'M' models and up to 400,000x for the 'L' models when channels are combined.

LC374A/LC574A: Waveforms can be expanded to give 0.4-0.5 points per division. Zoom factors up to 2,000,000x with all channels combined on the LC574AL.

Triggering System

Modes: Normal, Auto, Single, and Stop.

Sources: CH1, CH2, CH3, CH4, Line, EXT, EXT/10. Slope, Level and Coupling are unique to each source.

Slope: Positive, Negative.

Coupling: AC, DC, HF, LFREJ, HFREJ

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div. increments).

Holdoff by time: 10 ns to 20 s

Holdoff by events: 0 to 99,999,999

Internal Trigger Range: ±5 div

System Memory Configurations

Model			System RAM
LC334A/LC374A	LC534A	LC574A	8 Mbytes
LC334AM	LC534AM	LC574AM	8 Mbytes
LC334AL	LC534AL		16 Mbytes
		LC574AL	64 Mbytes

Maximum Horizontal Zoom Factors

Model			Zoom Factors
LC334A	LC534A		4,000x
LC334AM	LC534AM	LC374A/LC574A	20,000x
LC334AL	LC534AL	LC574AM	100,000x
		LC574AL	400,000x

EXT Trigger Max Input LC334A:
10 MΩ//15 pF
(system capacitance using PP005):
50 V (DC + peak AC ≤10kHz)

50 Ω ±1%: ±5 V DC (500 mW) or 5 V RMS.

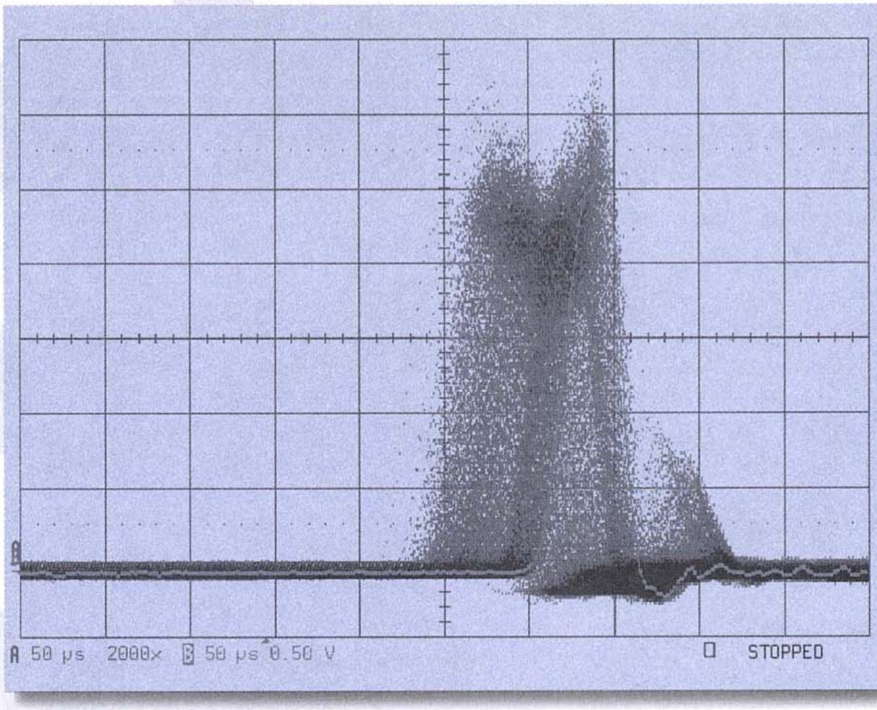
EXT Trigger Max Input LC374A/LC534A/LC574A:
10 MΩ//11pF
(system capacitance using PP005):
400 V (DC + peak AC ≤10 kHz)

50 Ω ±1%: ±5 V DC (500 mW) or 5 V RMS.

EXT Trigger Range: ±0.5 V (±5 V with Ext/10).

Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

Trigger Comparator: Optional ECL rear-panel output. Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.



Analog Persistence gives the user an analog style view of signals on a digital oscilloscope.

SMART TRIGGER TYPES

Pattern: Trigger on the logic combination of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on width between two limits selectable from <2.5 ns to 20 s. Will typically trigger on glitches 1 ns wide.

Signal or Pattern Interval: Trigger on interval between two limits selectable from 10 ns to 20 s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25 ns to 20 s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL (SECAM), NTSC or nonstandard video.

Exclusion Trigger: Trigger on intermittent faults by specifying the normal width or period of a signal. The oscilloscope will trigger only on aberrations which are shorter or longer than normal.

AUTOSETUP

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals, (Frequency above 50 Hz; Duty Cycle greater than 0.1%).

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset for selected channel.

PROBES

One PP005 probe is supplied per channel. DC to 500 MHz typical (350 MHz typical for LC334A) at probe tip, 500 V max.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and falltime 1 ns typical. Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

LC334A/374A/534A/574A - Ordering Information

Digital Oscilloscopes:	**Product Code**	
500 MHz, 500 MS/s, 100 kpts./ch, 4 channel Color DSO	LC334A	$ 16,490
500 MHz, 500 MS/s, 500 kpts./ch, 4 channel Color DSO	LC334AM	19,490
500 MHz, 500 MS/s, 2 Mpts./ch, 4 channel Color DSO	LC334AL	27,490
500 MHz, 1 GS/s, 100 kpts./ch, 4 channel Color DSO	LC374A	19,990
1 GHz, 500 MS/s, 100 kpts./ch, 4 channel Color DSO	LC534A	19,490
1 GHz, 500 MS/s, 500 kpts./ch, 4 channel Color DSO	LC534AM	22,490
1 GHz, 500 MS/s, 2 Mpts./ch, 4 channel Color DSO	LC534AL	30,490
1 GHz, 1 GS/s, 100 kpts./ch, 4 channel Color DSO	LC574A*	23,490
1 GHz, 1 GS/s, 500 kpts./ch, 4 channel Color DSO	LC574AM*	26,490
1 GHz, 1 GS/s, 2 Mpts./ch, 4 channel Color DSO	LC574AL*	34,490
Included with Standard Configuration:		
10:1 10 MΩ Passive Probe (1 per channel)	PP005	175 (each)
Operator's Manual	LCXXX-OM	85
Remote Control Manual	LCXXX-RCM	85
Hands On Guide	LCXXX-HG	45
Advanced Waveform Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Floppy Disk Drive	FD01	
Performance Certificate		
Three-Year Warranty		
Probes & Accessories:		
Current Probe 150 A	AP011	1,250
1 GHz 10:1 FET Probe	AP020	990
800 MHz 5:1 FET Probe	AP021	990
2.5 GHz 0.6pF Active Probe	AP54701A**	2,944
Probe Offset and Power Module	AP1143A**	1,568
1 GHz, 10:1, 500 Ω Passive Probe	PP062	95
ProBus 75 Ω to 50 Ω Adapter	PP090	195
Software Options:		
Parameter Analysis Package (includes Histogramming and Trending)	WP03	1,250
Disk Drive Measurements	DDM	3,000
Supplementary Disk Drive Measurements	PRML	1,250
Optical Recording Measurements	ORM	3,000
Disk Drive Failure Analysis	DDFA	4,990
Hardware Options:		
Memory Card Reader and 512k SRAM Card	MC01/04	500
PCMCIA Type III Slot for Hard Drives and ATA Flash Cards	HD01	590
PCMCIA Hard Disk 170 Mbyte (requires HD01 option)	HD02	499
4MB ATA Flash Card (requires HD01 option)	4MBFC	2,000
Internal Graphics Printer	GP01***	890
500 MHz Ext Clock, 10 MHz Ref Input, Trigger Comparator Output	CKTRIG	490
64 Mbyte System Memory	64MBSM***	2,000
Manuals:		
Service Manual for LCXXXA	LCXXX-SM	125
Warranty & Calibration:		
US Military Standard	LCXXX-CCMIL	325
US NIST Standard	LCXXX-CCNIST	225

* Includes Internal Graphics Printer and Parameter Analysis Package
** Normally ordered together
*** Included with LC574AL

9300C Series Portable Oscilloscopes Cover the Widest Range of Applications

Main Features

- ***Sampling Rates 100 MS/s to 10 GS/s***
- ***Bandwidths 200 MHz to 1.5 GHz***
- ***Memory Lengths 500 points to 8 million points***
- ***Large High-Resolution Display***
- ***Advanced Triggering***
- ***Powerful Processing up to 64 Mbytes of RAM***
- ***I/O to floppy, PCMCIA portable hard drive, SRAM card, GPIB, RS-232-C or Centronics.***
- ***Internal, High-Speed Graphics Printer***

Overview

Sampling rate, memory depth, and bandwidth. Choose the combination you need. The LeCroy 9300 family has it all! From the low cost 200 MHz 9304C to the high bandwidth and high sample rate 9384C and 9362C, the 9300C series continues to expand with new configurations. They all share an easy-to-use panel layout, programming command set, and memory card, floppy disk storage or PCMCIA portable hard drive. In 1995, LeCroy added the award-winning 9362 which at 10 GS/s is the World's Fastest DSO. The 9384C series offers 1 GHz bandwidth, up to 4 GS/s sampling and as much as 2 Mbytes of memory per channel for applications ranging from disk-drive testing to communications design.

The Easiest DSO to Use

The 9300's knob-per function architecture is the easiest to use. You always know which knob to turn, because their actions never change.

Choose the Memory Depth You Need

Available from 50 k to 2 Mbytes per channel, deep memory avoids aliasing, making the DSO easier to believe. LeCroy's way of managing memory makes DSOs easier to use.

Find Intermittent Signals Fast Without Complex Triggering

Use LeCroy's 2 Mbyte memory and auto-trigger to capture as much data in 1 trigger as in the 4000 triggers that other scopes need in their 500 sample fast view mode. Or use LeCroy's powerful Exclusion-Trigger to look for anomalies. Either way, the resulting data can be saved to hard copy or into histograms that show irregular values for signal width, amplitude, timing and other characteristics. LeCroy gives you real measurements of signal anomalies.

For more information refer, to "Finding Intermittent Faults in Electronic Circuits" (Page 227-230).

A Display You Can Watch All Day

All 9300 scopes have a large 9" display with super sharp 810 x 696 pixel resolution. Multi-zoom provides up to 4 simultaneous views of a waveform.

Make The Measurements You Want

Calculate any of 42 standard measurements on any part of the waveform. Calculate risetime or glitch energy. Pass/Fail tells if a waveform is out of spec. You can measure parameters between two traces such as propagation delays between two different signals. Built-in processing converts waveforms to the most useful format. View power traces or frequency spectra - live!

Advanced Trigger

SMART Trigger® circuitry allows you to lock onto the most complex signal or hard-to-find glitch or dropout.

Statistics

When measuring signal characteristics, most users want to know the stability and worst case values for risetime, propagation delay, etc. The statistics capability which is standard in every 9300 helps troubleshoot problems faster.

Observe average, minimum, maximum and standard deviation values for waveform parameters. The Parameter Analysis option, WP03, allows further diagnosis by displaying bar charts with histograms of parameter values or trend lines showing the time evolution of parameters.

A Complete Instrument

In one mainframe, you can get 4 channels of DSO, floppy, memory card, high-resolution graphics printer, spectrum analyzer, and signal processor.

Features and Benefits

Time Measurement Made Easy and Accurate

Common applications in fields like digital electronics, computers, data communications, etc., require precise time interval measurements. The long memories in the 9384C, 9370C/74C, 9350C/54C, 9310C/14C and 9304C allow for high sampling rate over the whole signal to give excellent time resolution. The 9362C with its 10 GS/s real time sampling rate specializes in precise capture of fast events.

The new JTA Jitter and Timing Analysis package provides a special set of capabilities for timing and jitter measurements.

LeCroy ProBus Intelligent Probe System

The ProBus system provides a complete measurement solution from probe tip to oscilloscope display. ProBus is an intelligent interconnection between LeCroy oscilloscopes and a growing range of innovative probes. ProBus provides automatic sensing of the probe type. For LeCroy's FET probes, it also allows offset at the probe tip and coupling to be controlled from the scope front panel.

A Trigger For Every Application

Two levels of trigger make catching difficult signals an easy task for the 9300 user. The standard trigger functions such as pre- and post-trigger, level, slope, mode and coupling are all accessed with simple and direct controls. The touch of a button accesses further powerful trigger features (SMART Trigger). Icon trigger graphics show the current setup at a glance. SMART Trigger modes allow the acquisition of complex phenomena. Trigger techniques include Fastglitch mode for triggering on glitches down to 1 nsec. The ability to trigger on pulses greater than a particular length catches missing bits, timing shifts and runts. State and Edge qualified modes track timing problems including setup and hold violations. Catch signal interruptions with LeCroy's dropout trigger. Most 9300 scopes also include video trigger and pattern trigger. If you don't know what to trigger on, LeCroy's Exclusion-Trigger will find events that differ from your nominal signal shape.

Automatic Measurements

In addition to cursor measurements, the 9300C series performs fully automatic measurements. Pass/Fail testing allows waveforms to be continually compared with a tolerance mask. (Masks may either be generated inside the instrument, or supplied on memory cards.) In addition, the scope can test any 5 waveform parameters from a list of 42, and compare them with user-defined limits. Any failure will cause preprogrammed actions such as Hardcopy, Save or GPIB SRQ. Basic statistics (low, high, average, and standard deviation) may also be calculated on these parameters.

DOS-Compatible Mass Storage

The 9300C series offers four choices (available together or separately) for built-in mass storage. A 1.44 Mbyte 3.5" floppy disk drive (standard in all 9300C series scopes), ATA FLash card or option HDD which provides a PCMCIA portable hard drive. All three media can store waveforms and setups as DOS files. They may be used as a convenient way of transferring data to a PC. Option MC01 provides high-speed storage to industry-standard IC memory cards, which are also DOS compatible. Up to 4 Mbytes of data (waveforms or setups) may be stored on a single card. Portable hard drives have >170 Mbyte storage capacity.

Mass storage simplifies archiving, and can also be used to ensure that measurements are always made in the same way. Golden waveforms or tolerance masks may also be stored, so that signals are compared with a known reference. Waveform processing is possible on live or stored waveforms.

Built-In Printer

As well as driving most printers and plotters via GPIB, RS-232-C and Centronics interfaces (all standard), the 9300C series also offers an optional internal printer. This high-resolution graphics printer produces full size screen dumps in approximately 10 seconds. It also has a landscape printing mode which allows up to 200x expansion on the printout to see every detail of your signal.

Flexible Interfacing

Both GPIB and RS-232-C interfaces may be used for full remote control of the instrument. All front-panel controls and internal processing functions can be controlled.

Multiple-Waveform Zoom

In addition to showing the complete waveform on the main timebase, the 9300C series has four Zoom/Math traces which may be used for signal processing or zooming waveforms. Up to four traces (e.g. a waveform and three different expansions) may be viewed simultaneously. Alternatively, four different expansions of the same waveform may be viewed. The area to be expanded is selected by moving an intensified portion of the waveform. Cursor measurements may be made from one expanded portion to another, providing the most accurate time measurements possible. Each zoom waveform has independent vertical and horizontal expansion factors for best viewing of each signal's detail.

9300C Series Selection Guide

High-Performance Scopes

LeCroy DSO Model Number	Analog BW (Minimum)	Max Transient Sample Rate	Max Repetitive Sample Rate	Number of Channels	Memory per Channel
9384C	1 GHz	4 GS/s	10 GS/s	4	100k/4 ch 200k/2 ch 400k/1 ch
9384CM	1 GHz	4 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
9384CTM*	1 GHz	4 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
9384CL	1 GHz	4 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
9370C	1 GHz	1 GS/s	10 GS/s	2	50k/2 ch 100k/1 ch
9370CM	1 GHz	1 GS/s	10 GS/s	2	250k/2 ch 500k/1 ch
9370CL	1 GHz	1 GS/s	10 GS/s	2	2M/2 ch 4M/1 ch
9374C	1 GHz	2 GS/s	10 GS/s	4	50k/4 ch 100k/2 ch 200k/1 ch
9374CM	1 GHz	2 GS/s	10 GS/s	4	250k/4 ch 500k/2 ch 1M/1 ch
9374CTM*	1 GHz	2 GS/s	10 GS/s	4	500k/ch 1M/ch 2M/ch
9374CL	1 GHz	2 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch
9350C	500 MHz	1 GS/s	10 GS/s	2	50k/2ch 100k/1ch
9350CM	500 MHz	1 GS/s	10 GS/s	2	250k/2 ch 500k/1 ch
9350CL	500 MHz	1 GS/s	10 GS/s	2	2M/2 ch 4M/1 ch
9354C	500 MHz	2 GS/s	10 GS/s	4	50k/4 ch 100k/2 ch 200k/1 ch
9354CM	500 MHz	2 GS/s	10 GS/s	4	250k/4 ch 500k/2 ch 1M/1 ch
9354CTM*	500 MHz	2 GS/s	10 GS/s	4	500k/4 ch 1M/2 ch 2M/1 ch
9354CL	500 MHz	2 GS/s	10 GS/s	4	2M/4 ch 4M/2 ch 8M/1 ch

** TM Versions include options for Advanced Math, Spectrum Analysis, and Internal Graphics Printer.*

Medium Performance Scopes

LeCroy DSO Model Number	Analog BW (Minimum)	Max Transient Sample Rate	Max Repetitive Sample Rate	Number of Channels	Memory per Channel
9304C	200 MHz	100 MS/s	10 GS/s	4	50k
9304CM	200 MHz	100 MS/s	10 GS/s	4	250k
9310C	400 MHz	100 MS/s	10 GS/s	2	50k
9310CM	400 MHz	100 MS/s	10 GS/s	2	250k
9310CL	400 MHz	100 MS/s	10 GS/s	2	1M
9314C	400 MHz	100 MS/s	10 GS/s	4	50k
9314CM	400 MHz	100 MS/s	10 GS/s	4	250k
9314CL	400 MHz	100 MS/s	10 GS/s	4	1M

9300C Series Upgrade Guide

If you own an older 9300 series scope than the ones shown on the pages of this catalog, you can upgrade it to the newest performance levels. LeCroy is the only scope company that lets you upgrade your scope to keep up with technology.

9304 Series - 4 Channel DSOs

9304C: 200MHz, 50k/ch, 68030 Processor, 4M RAM
→ **9304CM**: 200MHz, 250k/ch, 68030 Processor, 8M RAM

9310 Series - 2 Channel DSOs

9310C: 400 MHz, 50k/ch, 68030 Processor, 4M RAM
→ **9310CM**: 400 MHz, 250k/ch, 68030 Processor, 8M RAM
→ **9310CL**: 400 MHz, 1M/ch, 68030 Processor, 8M RAM

9314 Series - 4 Channel DSOs

9314C: 400 MHz, 50k/ch, 68030 Processor, 4M RAM
→ **9314CM**: 400 MHz, 250k/ch, 68030 Processor, 8M RAM
→ **9314CL**: 400 MHz, 1M/ch, 68030 Processor, 8M RAM

9350 & 9354 Series - 2 & 4 Channel DSOs

9350C → 9350CM → 9350CL

9350C	50k/ch	68030 processor	4M RAM
9350CM	250k/ch	68030 processor	8M RAM
9350CL	2M/ch	68030 processor	16M RAM

9354C → 9354CM → 9354CTM* → 9354CL

9354C	50k/ch	68030 processor	4M RAM
9354CM	250k/ch	68030 processor	8M RAM
9354CTM*	500k/ch	68030 processor	8M RAM
9354CL	2M/ch	68030 processor	16M RAM

9370 & 9374 Series - 2 & 4 Channel DSOs

9370C → 9370CM → 9370CL

9370C	50k/ch	68030 processor	4M RAM
9370CM	250k/ch	68030 processor	8M RAM
9370CL	2M/ch	68030 processor	16M RAM

9374C → 9374CM → 9374CTM* → 9374CL

9374C	50k/ch	68030 processor	4M RAM
9374CM	250k/ch	68030 processor	8M RAM
9374CTM*	500k/ch	68030 processor	8M RAM
9374CL	2M/ch	68030 processor	16M RAM

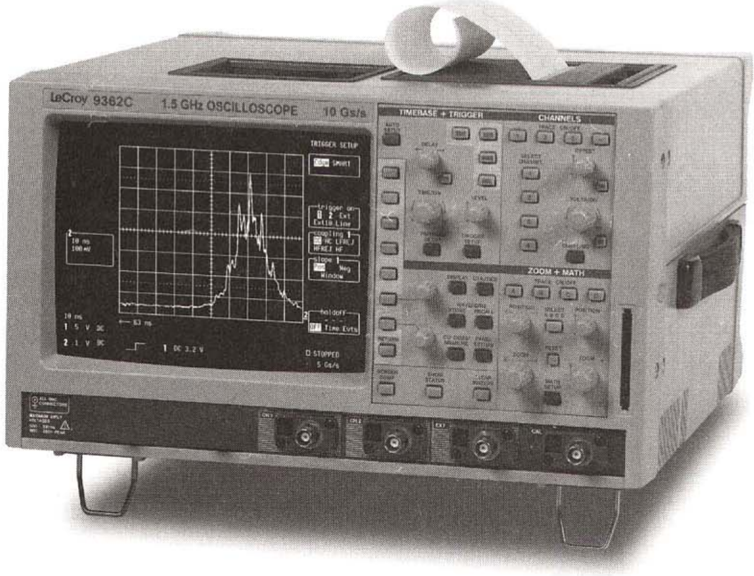
9384 Series

9384C → 9384CM → 9384CTM* → 9384CL

9384C	100k/ch	68030 processor	4M RAM
9384CM	500k/ch	68030 processor	8M RAM
9384CTM*	500k/ch	68030 processor	8M RAM
9384CL	2M/ch	68030 processor	16M RAM

** Includes Internal Graphics Printer, WP01 - Advanced Math Package, WP02 - Spectrum Analysis Package.*

9360C Series Digital Oscilloscopes 300 MHz - 1.5 GHz Bandwidth, 2.5 GS/s - 10 GS/s



Main Features

- *2.5 GS/s (9361C) and 10 GS/s (9362C) Max Sample Rate*
- *300 MHz Single-shot (9361C) and 1.5 GHz Analog Bandwidth (9362C)*
- *Record Length to 25,000 points*
- *42 Automatic Measurements*
- *SMART Trigger®*
- *Automatic Pass/Fail Testing*
- *Advanced Signal Processing*
- *Floppy Disk and Centronics Port Standard*
- *Internal Printer and Hard Disk Options*
- *Fully Programmable via GPIB/RS-232-C*

Digital oscilloscopes from LeCroy are designed to save engineers valuable time in troubleshooting and problem-solving.

Each oscilloscope is an integrated and powerful system providing the capability to:

- Capture fast signal events with high resolution.
- View data like never before, giving you more information more quickly, with a large CRT and advanced zooming techniques.
- Analyze your signal to get answers quickly and more accurately with a powerful processing system and math packages.

High Sampling Rates

The 9361C and 9362C DSOs employ proprietary digitizers that provide these instruments with exceptionally fast single-shot digitizing speeds. The 9361C operates up to 2.5 GS/s. The 9362C maximum single-shot sample rate of 10 GS/s (in single-channel mode) makes it the fastest available digital oscilloscope. In dual channel mode, the two independent digitizers on the 9362C will operate simultaneously at 5 GS/s ensuring high-resolution, channel-to-channel timing measurements.

High Bandwidth

The 300 MHz bandwidth of the 9361C equates to a risetime of about 1 ns, making this instrument the ideal real-time replacement for general purpose analog oscilloscopes. The 1.5 GHz analog bandwidth and the 750 MHz single-shot bandwidth make the 9362C the perfect scope for capturing fast pulses and analyzing fine timing relationships.

Single Shot and Repetitive Capture

At fast timebase settings, most DSOs use repetitive sampling techniques to digitize signals. Repetitive sampling techniques require many recurrences of the signal to complete each acquisition. If the signal is non-repetitive in nature, or if the signal is unstable from one repetition to the next due to glitches or drift, repetitive sampling techniques result in erroneous data. Fast digitizing DSOs such as the 9361C and 9362C resolve this dilemma by capturing infrequent or changing events faithfully every time.

SMART Trigger System

To capture rare or complex conditions, SMART Trigger functions are available. These include Glitch, with 2.5 ns resolution to trigger down to 1 ns, and Dropout mode, which triggers when the signal disappears for a selectable period of time. Other trigger modes include Pattern (9362C), Interval, State- or Edge-Qualified and TV (9361C).

Automatic Parametric Measurements and Statistics

The 9361C and 9362C provide more than 40 parametric measurements and their Average, Highest, Lowest values and Standard Deviation. Pass/Fail Testing allows up to 5 parameters to be tested against selectable thresholds. Waveform Limit Testing can also be performed using masks which may be defined inside the instrument. Any failure can cause pre-programmed actions such as Hardcopy, Save, GPIB Service Request, Pulse Out or Beep.

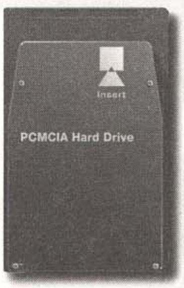
Internal Printer

Most printers and plotters can be driven via GPIB, RS-232-C and Centronics interfaces. The 936xC series offers an optional internal printer which can produce a 126 x 90 mm full resolution screen dump in under 10 seconds at the push of a button.

The unique Strip Chart format expands the horizontal axis of the printer up to 200 cm per division for viewing fine waveform detail within long memory acquisitions.

Mass Storage

All LeCroy scopes offer a 3.5" 1.44 MB floppy disk drive which stores traces, setups, screen graphics and masks. Data are stored as DOS files, which may be read directly by a PC. PCMCIA memory cards and hard disk options are also available.



Data can be saved on an optional PCMCIA portable hard disk drive

Remote Interfacing

GPIB and RS-232-C interfaces may be used for full remote control of the instrument. All front-panel and internal processing functions can be controlled via either interface.

Multiple Display Modes

The high-resolution raster display shows from one to four independent waveform grids. Four Zoom/Math traces may be used for zooming waveforms or for signal processing. Persistence display mode allows easy viewing of signal changes over time and XY mode. Cursors are usable in all display modes.

Advanced Waveform Math Package

Option WP01 provides Summed and Continuous Averaging, Waveform Math Functions, Extrema and Enhanced Resolution Modes. Functions can be chained together, allowing complex computations. Waveform operations can be performed on live, stored, processed or expanded waveforms. The package is fully programmable over GPIB or RS-232-C. WP01 extends the processing capabilities of the 936xC series and eliminates the need for external computers and controllers for processing.

Spectral Analysis Package

Option WP02 provides comprehensive spectral analysis capabilities, permitting the system designer to identify characteristics which may not be apparent in the time domain. WP02 provides a wide selection of windowing functions, as well as averaging in the frequency domain. Spectral analysis can be performed on repetitive and single events. Users can obtain time and frequency values simultaneously and compare phases of the various frequency components with each other.

Automated Parametric Measurements and Statistics

Option WP03 provides extensive analysis capabilities including trending and histogramming of key parameters. Detailed analysis can easily be performed on difficult-to-measure waveform phenomena such as amplitude fluctuation and timing jitter. Live displays include a line graph representing the trend of a parameter or bar chart showing the statistical distribution of selected waveform parameter measurements. Statistical information can be extracted directly from the histograms using automatic statistical measurements including max, min, average, median, standard deviation, etc.

Acquisition System

9361C Bandwidth (-3 dB):
@ 50 Ω: DC to 300 MHz

9362C Bandwidth (-3 dB):
@ 50 Ω: DC to 1.5 GHz (RIS on 2 Ch)
@ 50 Ω: DC to 750 MHz (Single shot on 2 Ch).

No. of Channels: 2
No. of Digitizers: 2

Maximum Sample Rate:
9361C: 2.5 GS/s (Ch 1 & 2)
9362C: 10 GS/s (Ch 1), 5 GS/s (Ch 1 & 2), 10 GS/s (RIS Ch 1 & 2, from 0.2 ns/div to 5 μs/div)

Sensitivity:
9361C: 2 mV/div to 5 V/div, fully variable.
9362C: 2 mV/div to 1 V/div, fully variable; (2 mV vertical scaling factor calculated).

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:

9361C:	2.0 - 9.9 mV/div:	±120 mV
	10.0 - 199 mV/div:	±1.2 V
	0.2 - 5.0 V/div:	±24 V
9362C:	Greater than ±8 div	

DC Accuracy:
9361C: ±3%.
9362C: ±(3% FS + 3% offset)

Vertical Resolution: 8 bits

Input Coupling:
9361C: AC, DC, GND
9362C: DC, GND

Input Impedance:
9361C: 1 MΩ//15 pF or 50 Ω ±1%
9362C: 50 Ω ±2%

Max Input:
9361C @ 1 MΩ: 250 V (DC+peak AC ≤10 kHz); 50 Ω: ±5 V DC (500 mW) or 5 V RMS

9362C: 50 Ω: ±5 V ≥100 mV/div
±2 V <100 mV/div

Bandwidth Limiter (9361C): 30 MHz

Timebase System

Timebases: Main and up to 4 zoom traces.

Time/Div Range:
9361C: 1 ns/div to 1,000 s/div
9362C: 200 ps/div to 1,000 s/div

Clock Accuracy: ≤10 ppm

Timebase Accuracy: ±0.07%

Roll Mode: ranges 500 ms to 1,000 s/div.

Record Length:
9361C: 25 to 25,000 points (500 points for timebase settings from 20 ns/div to 500 ns/div.)

9362C: Up to 25,000 points in RIS mode or at 100 MS/s. (up to 1000 points at 10 GS/s.)

Triggering System

Trigger Modes: Normal, Auto, Single, Stop.

Trigger Sources: CH1, CH2, Line (9361C), EXT, EXT/10.

Slope:
9361C: Positive, Negative, Window (BiSlope).
9362C: Positive, Negative.

Coupling:
9361C: AC, DC, HF, LFREJ, HFREJ
9362C: DC, "DC Auto-level".

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments)
9361C: 0 to 80% at 10 ns/div.
9362C: 0 to 75% at 10 ns/div.

Post-trigger: 0 to 10,000 divisions, adjustable in 0.1 div increments

Holdoff by time: 25 ns to 20 s

Holdoff by events: 0 to 10^9 events.

Internal Trigger Range: ±5 div

EXT Trigger Max Input:
9361C: 1 MΩ//15 pF, 250 V (DC + peak AC)
9362C: 50 Ω: ±5 VDC (500 mW), 5 V RMS

EXT Trigger Range: ±0.5 V (±5 V with EXT/10).

Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART Trigger Types

Pattern (9362C only): Trigger on the logic combination of 3 inputs - CH1, CH2, and EXT Trigger, where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal Width: Trigger on width between two limits selectable from <2.5 ns to 20 s. Will typically trigger on glitches 1 ns wide.

Signal Interval: Trigger on interval between two signal edges selectable from 10 ns to 20 s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25 ns to 20 s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV (9361C only): Allows selection of both line (up to 1500) and field number (up to 8) for PAL (SECAM), NTSC or non-standard video.

Internal Memory

Waveform Memory: Up to four 16-bit memories (M1, M2, M3, M4).

Processing Memory: Up to four 16-bit waveform processing memories (A, B, C, D).

Setup Memory: Four non-volatile memories. The floppy disk or optional cards may also be used for high-capacity waveform and setup storage.

Cursor Measurements

Relative Time: A pair of arrow cursors measure time difference and voltage difference relative to each other.

Relative Voltage: A pair of line cursors measure voltage differences.

Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.

Absolute Voltage: A reference bar measures voltage with respect to ground.

Display

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticule: Internally generated; separate intensity control for grids and waveforms.

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity, only with WP01).

Maximum Horizontal Zoom Factors: 1,000x. Waveforms can be expanded to give 2-2.5 points/division.

Waveform Processing

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging, and Sine x/x.

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 10^6 averages are possible with option WP01.

Extrema: Roof, Floor, or Envelope values from 1 to 10^6 sweeps (with option WP01).

ERES: Low-Pass digital filter provides up to 11 bits vertical resolution.

Sampled data is always available, even when a trace is turned off (with option WP01).

FFT: Spectral Analysis with five windowing functions and FFT averaging (with option WP02).

Histogramming and trending: The Parameter Analysis package permits in-depth diagnostics on waveform parameters (with option WP03).

AUTOSETUP

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals (Amplitude 2 mV to 40 V; frequency above 50 Hz; Duty cycle greater than 0.1%).

Autosetup Time: Approximately 3 seconds.

Vertical Find: Automatically sets sensitivity and offset.

PROBES

Model: 9361C: One PP002 probe is supplied per channel. DC to 250 MHz typical at probe tip, 600 V max. The 9360C series is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical. Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

INTERFACING

Remote Control: Possible by GPIB and RS-232 for all front-panel controls, as well as all internal functions.

RS-232-C Port: Asynchronous up to 115.2 kb/s for computer/terminal control or printer/plotter connection.

GPIB Port: Configurable as talker/listener for computer control and fast data transfer. Command language complies with requirements of IEEE-488.2.

Centronics Port: Hardcopy parallel interface, standard.

Hardcopy: TIFF and BMP formats are available for importing to desktop publishing programs. The following drivers are available: HP DeskJet (color or BW), HP ThinkJet, QuietJet, LaserJet, PaintJet, EPSON; HP 7470 and 7550 plotters, and HPGL compatible plotters. An optional, internal, high-resolution graphics printer is also available.

Output Formats: ASCII waveform output is compatible with spread-sheets, MATLAB and MathCad. Binary output is also available.

PC Card (PCMCIA Type I/II/III) Ports: For memory cards, ATA compatible flash cards and removable hard disks - optional.

Floppy Disk: High density 3.5" floppy disk drive (DOS format) is standard.

GENERAL

Temperature: 10° to 35° C (50° to 95° F) rated 0° to 45° C (32° to 113° F) operating.

Humidity: <80%.

Shock & Vibration: Conforms to selected sections of MIL-PRF-28800F, Class 3.

Power: 90-250 V AC, 45-66 Hz, 150 W (9361C), 200 W (9362C)

Battery Backup: Front-panel settings maintained for two years.

Dimensions: (HWD) 8.5" x 14.5" x 16.25", 210 mm x 370 mm x 410 mm.

Weight: 10 kg (22 lbs) net, 15.5 kg (34 lbs) shipping.

Warranty: Three years.

APPROVALS

EMC: Conforms to EN55022 (Emissions), EN50082-1 and (Immunity).

Safety: The oscilloscope has been designed to comply with EN55022 Installation Category (Over-voltage Category) II, Pollution Degree 2.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

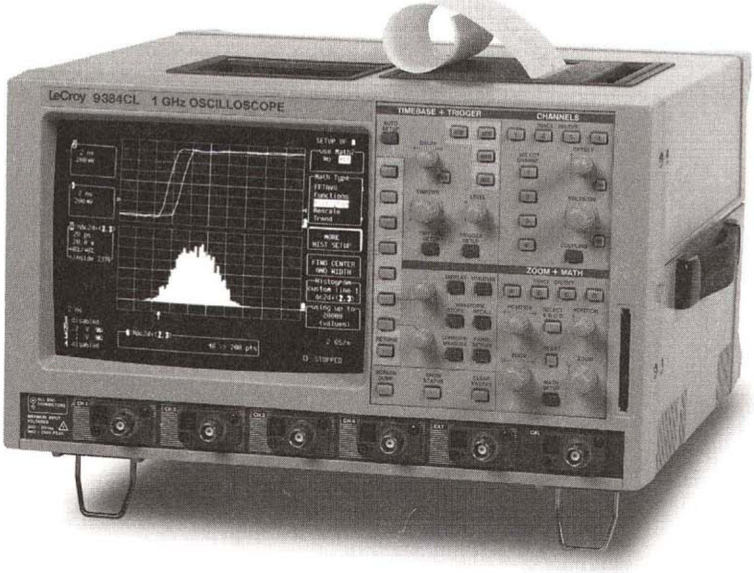
CE

9360C Series - Ordering Information

Digital Oscilloscopes:	Product Code	Price
2 Ch, 300 MHz, 2.5 GS/s, 500 to 25k Memory/Ch DSO	9361C	$ 6,990
2 Ch, 1.5 GHz, 10 GS/s, 500 to 25k Memory/Ch DSO	9362C	14,990
Included with Standard Configuration:		
Two 10:1 10 MΩ Passive Probes (9361C)	PP002	80
Operator's Manual	936XC-OM-E	85
Remote Control Manual	93XX-RCM	85
Floppy Disk Drive	FD01	590
Probes & Accessories:		
1 GHz Active FET Probe (10:1) With ProBus Connector	AP020	990
15 MHz (±700 V) Differential Probe, x10, x100	AP031	300
15 MHz (±1400 V) Differential Probe, x20, x200	AP032	300
A Wide Range of Differential Amplifiers and Probes are available		
50 MHz Current Probe	AP015	1,500
2.5 GHz, 0.6pF Active Probe	AP54701A*	2,944
Probe Offset and Power Module	AP1143A	1,568
10:1, 8 GHz, 500Ω Passive Probe	PP063	750
100:1, 1 GHz, 500Ω Passive Probe	PP064	95
100:1, 400 MHz, 50 MΩ High Voltage Probe, 2 kV Max. DC+Peak AC	PPE2KV	190
1000:1, 100 MHz, 50 MΩ High Voltage Probe, 20 kV(40 kV Peak)	PPE20KV	1,573
Rackmount Adaptor for 9300 Series DSO	RM01	100
Software Options:		
Advanced Waveform Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package	WP03	1,250
Disk Drive Measurements	DDM	3,000
Supplementary Disk Drive Measurements	PRML	1,250
Hardware Options:		
Memory Card Reader with 512K Memory Card	MC01/04	500
Type III PCMCIA Slot & 170 Mbyte Portable Hard Drive (HD01 & HD02)	HDD	990
Type III PCMCIA Slot	HD01	590
PCMCIA Hard Disk 170 MB	HD02	499
4 MB ATA Flash Card (requires HD01 option)	4MBFC	399
Internal Graphics Printer Option	GP01	890
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CC	175
MIL STD Calibration	93XX-CCMIL	275
Swiss Office of Metrology Calibration	93XX-CCOFMET	175
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	650
5 Year Warranty & NIST Calibration	93XX-T5	975

* Requires Model AP1143A Power Supply

9384C Series Digital Oscilloscope 1 GHz Bandwidth, 1 - 4 GS/s



Main Features

- ***Four Full Independent Channels***
- ***Sample Rates to 4 Gigasamples/second***
- ***Memory Lengths to 8 Mpoints***
- ***8-bit Vertical Resolution, 11 with ERES Option***
- ***Vertical Accuracy to 1% Typical***
- ***Peak Detect***
- ***Glitch, Pattern, Qualified, Interval, Dropout, TV, and Exclusion Triggers***
- ***Histogram and FFT Signal Processing Options***
- ***DOS-Compatible Floppy Disk Standard***
- ***PC Card Portable Hard Drive and Memory Card Options***
- ***Internal Printer Option***
- ***Fully Programmable via GPIB and RS-232-C***

1 GHz Bandwidth

The 9384C series digital storage oscilloscope appeals to engineers and scientists at the leading edge of technological developments. The 1 GHz bandwidth and long acquisition memories, reveal previously hidden waveform details. Narrow glitches are more accurately defined; risetime measurements below 1 nanosecond are more precise; and high-frequency content, filtered out in lower bandwidth systems, is retained, thereby preserving signal amplitudes and overall signal integrity. Edge Triggering to 1 GHz and LeCroy's powerful SMART Trigger modes like Glitch, Pattern, Dropout, Interval, Exclusion and TV enable you to capture precisely the events of interest.

4 GS/s Sample Rate

The 9384C samples simultaneously on all channels at 1 GS/s. Thus, it is ideal for demanding, high-speed applications. In addition, two channels can be combined to provide a sample rate of 2 GS/s or 4 GS/s in single-channel mode. Finer horizontal resolution and accuracy are assured by high sample rates. This is especially critical in digital design where unpredictable circuit behavior needs to be identified and analyzed in detail to be fully understood. Together with this excellent single-shot performance, the 9384C series also provides a sample rate equivalent to 10 GS/s for repetitive signals. The innovative peak-detect mode enables glitch capture even at the slowest time settings without loss of precision.

8 Mpoints Acquisition Memory

Channel record lengths of 100k, 500k and 2M are available on the 9384C. The memory power is revealed when the user seeks to sample at the highest speed over many timebase settings. DSOs with less memory may boast a high sample rate for short waveforms, but only LeCroy's long memory oscilloscope can deliver high sample rates for long waveforms. To exploit this capability to its fullest, the LeCroy 9384CL combines its channel acquisition memories to give the user up to 8 million sample points, thereby providing the waveform detail required on long and complex signals.

The combined capabilities of the 9384C place it in the forefront of DSO capability.

PRECISION ACQUISITION
1 GHz bandwidth results in greater accuracy of amplitude and risetime measurements for high-frequency signals and true representation of high-speed digital and analog signals.

HIGH SAMPLE RATE
The 9384C provides maximum sample rates of 1 GS/s, 2 GS/s, and 4 GS/s (when using 4, 2, or 1 input channels respectively) for greater waveform fidelity, excellent zoom detail, protection against aliasing, precision time resolution and wider frequency spectrum.

CHANNEL MEMORY AND CHANNEL INTERLEAVING
Capturing long time windows single-shot requires long memory. LeCroy, the company that invented long memory DSOs, provides three memory selections: 100 kpoints per channel standard, 500 kpoints per channel with the "CM" and "CTM" versions, and 2 Mpoints per channel with the "CL" version.

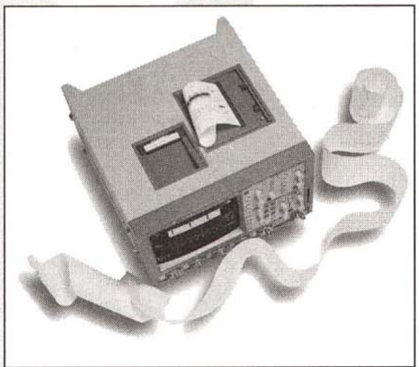
By interleaving the 4 channels of the 9384CL, the acquisition memory and sample rate can be increased 4x to provide up to 4 GS/s and up to 8 Mpoints of memory. The result is that the 9384CL enables you to capture 2 milliseconds of signal duration with 250 ps real time sample resolution. The 8 million data points are available on all timebases from 200 ns/div and up.

ADVANCED PEAK DETECT SYSTEM
The 9384C series offers an innovative peak-detect capture mode. This captures fast glitches by running the ADCs at a high sampling rate even at slow timebase settings, thereby capturing signal details that might have been missed due to under sampling. At the same time, the scope stores the underlying data to ensure no loss of time precision - unlike other peak-detect systems.

SMART TRIGGER SYSTEM
SMART Trigger functions including Glitch, Pattern, Interval, Exclusion, TV, Dropout, and State-or-Edge Qualified triggers are available. Pre- and Post-trigger delay are fully variable. Time and Events Holdoff are also included.

AUTOMATIC PARAMETRIC MEASUREMENTS AND STATISTICS
The 9384C provides more than 40 parametric measurements and their Average, Highest, Lowest values and Standard Deviation. Pass/Fail testing allows up to 5 parameters to be tested against selectable thresholds. Waveform Limit Testing can also be performed using masks which may be defined inside the instrument. Any failure will activate preprogrammed actions such as Hardcopy, Save, Stop, Beep, GPIB SRQ, or Pulse Out.

INTERNAL PRINTER
Most printers and plotters can be driven via GPIB, RS-232-C and a Centronics interface. The 9384C offers an optional internal printer which can produce a 126 x 90 mm full-resolution screen dump in under 10 seconds at the push of a button.



The unique 'Strip-Chart' format expands the horizontal axis of the printer up to 200 cm/div per division for viewing fine waveform detail within long memory acquisitions.

REMOTE INTERFACING
GPIB and RS-232-C interfaces can be used for full remote control of the instrument. All front-panel and internal processing functions can be controlled via either interface.

OPTIONAL ADVANCED MATH PACKAGE - WP01
Option WP01 provides Summed and Continuous Averaging, Waveform Math Functions, Extrema and Enhanced Resolution Modes.

Functions can be chained together, allowing complex computations. Waveform operations can be performed on live, stored, processed or expanded waveforms without altering the original captured data.

OPTIONAL SPECTRAL ANALYSIS PACKAGE - WP02
Option WP02 provides comprehensive spectral analysis capabilities permitting the system designer to identify characteristics which may not be apparent in the time domain. WP02 provides a wide selection of windowing functions as well as averaging in the frequency domain.

Spectral analysis can be performed on repetitive and single-shot waveforms, on any part or zoomed portions of a waveform up to 4 Mpoints, not just the first 10 kpoints of the waveform.

OPTIONAL PARAMETER ANALYSIS PACKAGE
Option WP03 provides extensive parameter analysis capabilities. Detailed statistical analysis can easily be performed on difficult-to-measure waveform phenomena such as amplitude fluctuation and timing jitter. Live histogram displays represent the statistical distribution of the user-selected waveform parameter measurements. Statistical information can be extracted directly from the histograms using automatic statistical measurement including max, min, average, median, and std. deviation. Trend lines can be drawn on the DSO screen showing the time evolution of parameter values.

Acquisition System

Bandwidth (-3 dB):

@ 50 Ω: DC to 1 GHz 10 mV/div and above

@ 1 MΩ DC: DC to 500 MHz typ. at probe tip, with PP005 supplied standard. 1 GHz FET probe optional.

No. of Channels: 4

No. of Digitizers: 4

Maximum Sample Rate: 4 GS/s

Memories: (See table)

Channels Use	Maximum Sample Rate	Memory Per Channel 9384C	9384CM	9384CTM	9384CL	Active Channels
All Peak Detect OFF	1 GS/s	100k	500k	500k	2M	All
Paired Peak Detect OFF	2 GS/s	200k	1M	1M	4M	Ch 2 & Ch 3
Paired + PP094 Peak Detect OFF	4 GS/s	400k	2M	2M	8M	(PP094 input)
All 2.5 ns Peak Detect ON	100 MS/s data+ 400 MS/s peak	50k data+50k peak	250k data+ 250k peak	250k data+ 250k peak	1M data+ 1M peak	All 2.5 ns Detect

Sensitivity: 2 mV/div to 1 V/div, 50 Ω fully variable, 2 mV/div to 10 V/div, 1 MΩ fully variable.

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:

2.00 - 4.99 mV/div:	±400 mV
5.00 - 99 mV/div:	±1 V
0.1 - 1.0 V/div:	±10 V
1.0 - 10 V/div:	±100 V (1 MΩ only)

± 20 V across the whole sensitivity range when using the AP020 FET probe.

DC Accuracy: 10 mV and above, 1% typical.

Vertical Resolution: 8 bits

Bandwidth Limiter: 25 MHz or 200 MHz user selectable.

Input Coupling: AC, DC, GND.

Input Impedance: 1 MΩ // 15 pF typical or 50 Ω ±1%

Max Input:

1 MΩ: 400 V (DC + peak AC ≤10 kHz)
50 Ω: ±5 V DC

External Clock: 10 MHz to 100 MHz using the External Trigger input (standard). The CKTRIG option allows external clock speeds up to 500 MHz.

Timebase System

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 1 ns/div to 1000 s/div.

Clock Accuracy: <10 ppm

Interpolator resolution: 10 ps

Roll Mode: ranges 500 ms to 1,000 s/div. For >50 kpoints: 10 s to 1,000 s/div

Triggering System

Trigger Modes: Normal, Auto, Single.

Trigger Sources: CH1, CH2, CH3 and CH4, External and Line, Slope, Level and Coupling for each source can be set independently.

Slope: Positive, Negative.

Coupling: AC, DC, HF, LFREJ, HFREJ

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).

Holdoff by time: 10 ns to 20 s.

Holdoff by events: 0 to 99,999,999 events.

Width Trigger Sensitivity:
<10% of full scale >1 ns;
<20% of full scale 500 ps to 1 ns

Internal Trigger Sensitivity Range: ±5 div

EXT Trigger Max Input:

1 MΩ // 15 pF: 400 V (DC + peak AC <10 kHz)

50 Ω ±1%:
± 5 V DC (500 mW) or 5 V RMS

EXT Trigger Range: ±0.5 V (±5 V with Ext/10)

Trigger Timing: Trigger Date and Time are listed in the Waveform Status Menu.

Trigger Bandwidth: 1 GHz, use HF coupling for signals above 300 MHz.

SMART Trigger Types

Pattern: Trigger on the logic AND of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, where each source can be defined as High, Low or Don't Care. The trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on glitches <2.5 ns (1 ns typical) or on pulse widths between two limits selectable from <2.5 ns to 20 s exclusive.

Exclusion Trigger: Trigger on a signal or period outside two limits selectable from <2.5 ns to 20 s.

Signal or Pattern Interval: Trigger on an interval between two limits selectable from 10 ns to 20 s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25 ns to 20 s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL, SECAM, NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 2 ms/div.

Random Interleaved Sampling Rate: 10 GS/s

Single shot: for transient and repetitive signals from 2 ns/div (all channels active).

Peak detect: captures and displays 2.5 ns glitches or other high-speed events on slow timebases.

Sequence: Stores multiple events - each of them time stamped - in segmented acquisition memories.

Number of segments available:

9384C	2-500
9384CM	2-2,000
9384CTM	2-2,000
9384CL	2-2,000

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors can be switched off.

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticules: Internally generated; separate intensity control for grids and waveforms.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (25x with averaging, up to 80 µV sensitivity with Advanced Math option WP01).

Horizontal Zoom Factors up to:

9384C	20,000x
9384CM	100,000x
9384CTM	100,000x
9384CL	200,000x

Waveforms can be expanded to give .4-.5 points/division. Zoom factors up to 800,000x for the 9384CL with all channels combined.

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1,M2,M3,M4). The length of each memory is equal to the data acquisition memory.

Processing Memory: Up to four 16-bit waveform processing memories (A,B,C,D).

Setup Memory: Four non-volatile memories. The floppy disk or optional IC memory cards, or PCMCIA hard drives can also be used for high-capacity waveform and setup storage.

CURSOR MEASUREMENTS

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full-scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is displayed.

Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of full-scale in single-grid mode.

Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.

Absolute Voltage: A reference bar measures voltage with respect to ground.

AUTOMATIC MEASUREMENTS

The following Parametric measurements are available, together with their Average, Highest, Lowest values and Standard Deviation:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Pass/Fail testing allows any 5 items (parameters and/or masks) to be tested against selectable thresholds. Waveform Limit Testing is performed using masks which can be defined inside the instrument. Any failure can initiate preprogrammed actions such as Hardcopy, Save to internal memory, Save to mass storage device (card or disk), GPIB SRQ or Pulse Out.

ΔC2D+ and ΔC2D- measure setup and hold times.

WAVEFORM PROCESSING

Up to four processing functions can be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Sine x/x and Summation Averaging.

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to a million sweeps are possible with option WP01.

Envelope*: Max, Min, or Max and Min values of up to one million sweeps.

ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.

Sampled data is always available, even when a trace is turned off. Any of the above modes can be invoked without destroying the data.

FFT*: Spectral Analysis with four windowing functions and FFT averaging.

*Envelope and ERES modes are provided in Advanced Math Package WP01; FFT is in Package WP02.

AutoSetup

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals. (Amplitude 2 mV to 40 V; frequency above 50 Hz; Duty cycle greater than 0.1%)

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset.

Probes

Model: One PP005 (x10, 10 MΩ // 11 pF) probe supplied per channel.

The 9384 family is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and falltime 1 ns typical.

Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

Interfacing

Remote Control: All front-panel controls, as well as all internal functions are possible by GPIB and RS-232-C.

RS-232-C Port (Standard): Asynchronous up to 115.2 kbaud for computer/terminal control or printer/plotter connection.

GPIB Port (Standard): Configurable as talker/listener for computer control and fast data transfer.

Centronics port (standard): Hardcopy parallel interface.

Hardcopy: Screen dumps are activated by a front panel button or via remote control. TIFF format is available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HPThinkJet, QuietJet, LaserJet, PaintJet, and EPSON printers, HP7400 and 7500 series, or HPGL compatible plotters. An optional internal high resolution graphics printer is also available.

General

Auto-calibration ensures specified DC and timing accuracy.

Temperature: 5° to 40°C rated accuracy. 0° to 50°C operating. Derate @ 1°C/1000 ft of altitude to 10,000 ft.

Humidity: <80%

Shock and Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.

Power: 90-250 VAC, 45-66 Hz, 350 W.

Battery Backup: Front panel settings maintained for two years.

Dimensions: (HWD) 8.5" x 14.5" x 16.25" (210mm x 370mm x 410mm).

Weight: 13 kg (28.6 lbs) net, 18.5 kg (40.7 lbs) shipping.

Warranty: Three years

Compliance: Complies with the EU - EMC Directive.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

CE

9384C Series Ordering Information

Digital Oscilloscopes:		
Product Code		**Price**
4 Ch, 1 GHz, 1 GS/s, 100 kpts./Ch	9384C	$ 19,490
4 Ch, 1 GHz, 1 GS/s, 500 kpts./Ch	9384CM	22,490
4 Ch, 1 GHz, 1 GS/s, 500 kpts./Ch - Includes WP01, WP02, GP01	9384CTM	24,990
4 Ch, 1 GHz, 1 GS/S, 2 Mpts./Ch	9384CL	30,490
Included with Standard Configuration:		
Four 10:1 500 MHz 10 MΩ Passive Probe with sense ring	PP005	175 (each)
Operator's Manual	93XXC-OM-E	85
Remote Control Manual	93XX-RCM	85
Hands On Guide	93XX-HG	45
Floppy Drive	FD01	
Probes & Accessories:		
2.5 GHz 0.6pF Active Probe 10:1 - Requires AP1143A Power Supply	AP54701A*	2,944
Probe Offset and Power Module	AP1143A*	1,568
Current Probe 150 Amps, 150 kHz	AP011	1,250
Current Probe 50 Amps, 50 MHz	AP015	1,500
1 GHz Active FET Probe (10:1) with ProBus Connector	AP020	990
15 MHz Differential Probe, x10, x100	AP031	300
15 MHz Differential Probe, x20, x200	AP032	300
A wide variety of differential amplifiers and probes are available		
10:1/100:1, 200/300 MHz, 50Ω High Voltage Probe 600 V/1.2 kV	PPE1.2KV	264
100:1, 400 MHz, 50 Ω High Voltage Probe, 2 kV Max. Voltage	PPE2KV	190
100:1, 400 MHz, 50 Ω High Voltage Probe, 4 kV Max. Voltage	PPE4KV	326
100:1, 400 MHz, 50 Ω High Voltage Probe, 5 kV Max. Voltage	PPE5KV	520
1000:1, 400 MHz, 50 Ω High Voltage Probe, 6 kV Max. Voltage	PPE6KV	647
1000:1, 100 MHz, 50 Ω High Voltage Probe, 20 kV (40 kV Peak) Max	PPE20KV	1,573
Service Manual for 9384C Series	SM9384C	125
Software Options:		
Advanced Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package	WP03	1,250
PRML Analysis Package	PRML	1,250
Any two of the four software options above	C2	1,875
Any three of the four software options above	C3	2,490
Disk Drive Measurements - Includes Parameter Analysis WP03	DDM	3,000
Optical Recording Measurements Package	ORM	3,000
Disk Drive Failure Analysis	DDFA	4,990
Hardware Options:		
Memory Card Reader w/512k Card	MC01/04	500
Type III Slot	HD01	590
170 Mbyte Portable Hard Drive	HD02	499
Type III PCMCIA Slot and 170 Mbyte Portable Drive inc. HD01 & HD02	HDD	990
PC Card Type III External Desktop Adapter for PC (110 V)	DA01-110	360
PC Card Type III External Desktop Adapter for PC (220 V)	DA01-220	360
Internal Graphics Printer	GP01	890
64 Mbyte Memory	64MBSM	2,000
50-500 MHz Ext Clock, 10 MHz Reference Clock	CKTRIG	490
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CC	225
MIL STD Calibration	93XX-CCMIL	325
Swiss OFFMET Calibration	93XX-CCOFFMET	225
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	725
5 Year Warranty & NIST Calibration	93XX-T5	975

* Normally ordered together. The power module can support two AP54701A.

9370C Series Digital Oscilloscopes 1 GHz Bandwidth, 500 MS/s - 2 GS/s

Main Features

- *Two and Four Channel Versions*
- *Up to 8 Mpoint Record Length*
- *DOS Compatible Floppy Drive Standard*
- *Innovative Peak-Detect Mode*
- *Glitch, Exclusion, Pattern, Qualified, Interval, Dropout and Video Triggers*
- *8-bit Vertical Resolution, 11 with ERES option*
- *Fully Programmable via GPIB and RS-232-C*
- *Automatic Pass/Fail Testing*
- *Advanced Signal Processing*
- *Internal Printer Option*
- *PC Card Portable Hard Drive and Memory Card Option*

1 GHz Bandwidth

The 9370C series digital storage oscilloscope opens up new horizons for engineers and scientists at the leading edge of technological developments. With 1 GHz bandwidth and long acquisition memories, it is now possible to reveal previously hidden waveform details. Narrow glitches are more accurately defined; risetime measurements below 1 nanosecond are more precise; and high-frequency content, filtered out in lower bandwidth systems, is retained, thereby preserving signal amplitudes and overall signal integrity.

2 GS/s Sample Rate

The two- and four-channel models of the 9370C series sample simultaneously on all channels at 500 MS/s. Thus, they are ideal for demanding, high-speed applications. In addition, two channels can be combined to provide a sample rate of 1 GS/s. The 9374C provides 2 GS/s in single-channel mode. Finer horizontal resolution and accuracy are guaranteed by high sample rates. This is especially critical in digital design where unpredictable circuit behavior has to be identified and analyzed in detail to be fully understood. Together with this excellent single-shot performance, the 9370C series also provides a sample rate equivalent to 10 GS/s for repetitive signals.

8 Mpoints Acquisition Memory

Channel memory lengths of 50k, 250k and 2M are available on the two and four channel 9370C DSOs. The memory power is revealed when the user seeks to sample at the highest speed over many timebase settings. Short memory DSOs may boast a high sample rate for short waveforms, but only a long memory oscilloscope can deliver high sample rates for long waveforms. To exploit this capability to its fullest, the LeCroy 9370C series combines its channel acquisition memories to give the user up to 8 million sample points, thereby providing the waveform detail required on long and complex signals.

Acquisition System

Bandwidth (-3 dB):
@ 50 Ω: DC to 1 GHz 10 mV/div and above
@ 1 MΩ DC: DC to 500 MHz typ. at probe tip, with PP005 supplied standard. 1 GHz FET probe optional.

No. of Channels:
4 (9374C) or 2 (9370C)

No. of Digitizers:
4 (9374C) or 2 (9370C)

Maximum Sample Rate and Acquisition Memories: See table.

Channels Use	Maximum Sample Rate	Memory Per Channel			
		9374C 9370C	9374CM 9370CM	9374CTM	9374CL 9370CL
All Peak Detect OFF	500 MS/s	50k	250k	500k	2M
Paired Peak Detect OFF	1 GS/s	100k	500k	1M	4M
Paired + PP094 Peak Detect OFF	2 GS/s	200k*	1M*	2M	8M*
All 2.5 ns Peak Detect ON	100 MS/s data+ 400 MS/s peak	25k data+25k peak	100k data+ 100k peak	250k data+ 250k peak	1M data+ 1M peak

** Not applicable in two channel models*

Sensitivity:
2 mV/div to 1 V/div, 50 Ω, fully variable
2 mV/div to 10 V/div, 1 MΩ, fully variable.

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:
2.00 - 4.99 mV/div: ±400 mV
5.00 - 99 mV/div: ±1 V
0.1 - 1.0 V/div: ±10 V
1.0 - 10 V/div: ±100 V (1 MΩ only)

DC Accuracy: Typically 1% for DC gain and offset at 0 V.

Vertical Resolution: 8 bits.

Bandwidth Limiter: 20 MHz/200 MHz

Input Coupling: AC, DC, GND

Input Impedance: 1MΩ//15 pF or 50Ω ±1%

Max Input:
1 MΩ: 400 V (DC + peak AC @10 kHz)
50 Ω: ±5 V DC (500 mW) or 5 V RMS

Timebase System

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 1 ns/div to 1,000 s/div.

Clock Accuracy: ≤10 ppm

Interpolator resolution: 10 ps

Roll Mode: Ranges 500 ms to 1,000 s/div. For >50 kpoints: 10 s to 1,000 s/div.

External Clock: ≤100 MHz on EXT input with ECL, TTL or zero crossing levels. Optional 50 MHz to 500 MHz rear-panel fixed frequency clock input.

External Reference: Optional 10 MHz rear-panel input.

Triggering System

Trigger Modes: Normal, Auto, Single, Stop.

Trigger Sources: CH1, CH2, Line, Ext, Ext/10 (9374: CH3, CH4). Slope, Level and Coupling for each source can be set independently.

Slope: Positive, Negative.

Coupling: AC, DC, HF, LFREJ, HFREJ

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).

Holdoff by time: 10 ns to 20 s.

Holdoff by events: 0 to 99,999,999 events.

Internal Trigger Range: ±5 div.

EXT Trigger Max Input:
1 MΩ//15 pF: 250 V (DC + peak AC ≤10 kHz)
50 Ω ±1%: ±5 V DC (500 mW) or 5 V RMS

EXT Trigger Range: ±0.5 V (±5 V with Ext/10)

Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

Trigger Comparator: Optional ECL rear-panel output.

SMART Trigger Types

Pattern: Trigger on the logic AND of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger (9370C: 3 inputs - CH1, CH2, EXT), where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on width between two limits selectable from <2.5 ns to 20 s. Will typically trigger on glitches 1 ns wide.

Signal or Pattern Interval: Trigger on interval between two limits selectable from 10 ns to 20 s

Dropout: Trigger if the input signal drops out for longer than a time-out from 25 ns to 20 s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL (SECAM), NTSC or nonstandard video.

Acquisition Modes

Random Interleaved Sampling (RIS): For repetitive signals from 1 ns/div to 5 ms/div.

Single shot: For transient and repetitive signals from 10 ns/div (all channels active).

Peak detect: Captures and displays 2.5 ns glitches or other high-speed events.

Sequence: Stores multiple events in segmented acquisition memories.

Number of segments available:

9370C-9374C	2-200
9370CM-9374CM	2-500
9370CL-9374CL	2-2,000

Max. Dead Time between segments: 100 µs

Display

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors can be switched off.

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticules: Internally generated; separate intensity control for grids and waveforms.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity, with Advanced Math Option WP01).

Maximum Horizontal Zoom Factors:

9370C-9374C	2,000x
9370CM-9374CM	10,000x
9370CL-9374CL	80,000x

Waveforms can be expanded to give 2-2.5 points/division. This provides zoom factors up to 400,000x for the 9374CL when channels are combined.

Automatic Measurements

The following Parametric measurements are available, together with statistics of their Average, Highest, Lowest values and Standard Deviation:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Parameters are calculated as defined by ANSI/IEEE Std 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". In addition, rise and falltimes can be measured at 10% and 90% levels, 20% and 80% levels, or any other user-specified levels.

Δdelay provides time between mid-point transition of two sources, for making propagation delay measurements.

Δt at level allows the same measurement to be made at any specified level.

ΔC2D+ and ΔC2D- measure setup and hold times.

Two cursors are used to define the region over which these parameters are calculated.

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is also displayed.

Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of fullscale in single-grid mode.

Absolute Time: A cross hair marker measures time relative to the trigger, and voltage with respect to ground.

Pass/Fail testing allows up to five of the listed parameters to be tested against selectable thresholds. Waveform Limit Testing is performed using templates which can be defined inside the instrument.

Internal Memory

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4) with lengths equal to the acquisition memory length.

Processing Memory: Up to four 16-bit waveform processing memories (A, B, C, D).

Setup Memory: Four non-volatile memories. The floppy disk or optional IC Cards, or PC Card portable hard drive can also be used for high-capacity waveform and setup storage.

Waveform Processing

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging and Sine x/x.

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 10^6 averages are possible with Advanced Math Option WP01.

Extrema*: Roof, Floor, or Envelope values from 1 to 10^6 sweeps.

ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.

Sampled data is always available, even when a trace is turned off.

Any of the above modes can be invoked without destroying the data.

FFT*: Spectral Analysis with five windowing functions and FFT averaging.

*Extrema and ERES modes are provided in Advanced Math Package WP01. FFT is in WP02.

AUTOSETUP

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals (frequency above 50 Hz; Duty cycle greater than 0.1%).

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset.

PROBES

Model:
One PP005 (10:1, 10 MΩ // 10 pF) probe supplied per channel. 500 V max input.

The 9370C series is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and falltime 1 ns typical.

Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

INTERFACING

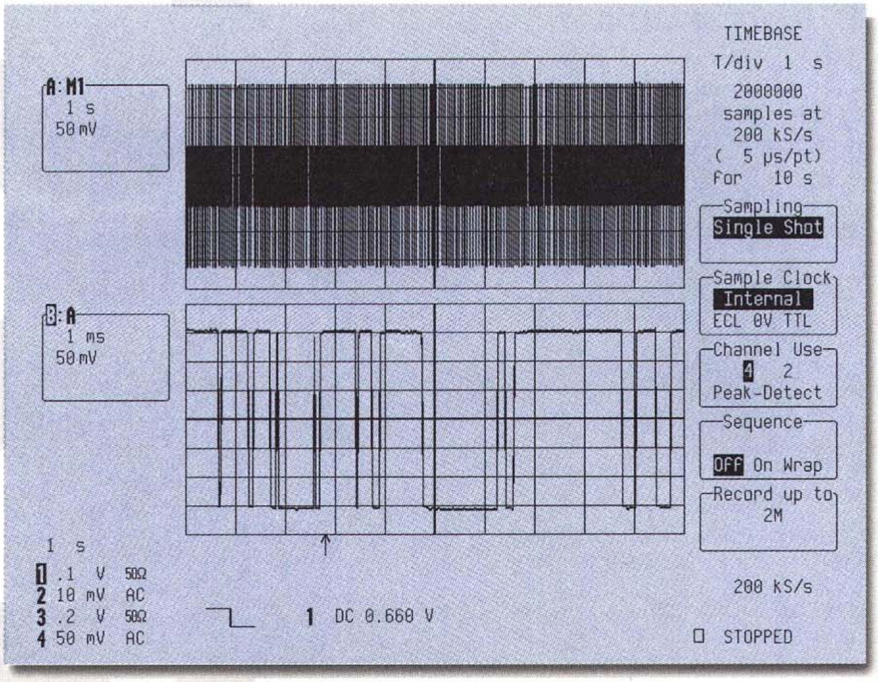
Remote Control: Possible by GPIB and RS-232-C for all front-panel controls, as well as all internal functions.

RS-232-C Port: Asynchronous up to 115.2 kbaud for computer/terminal control or printer/plotter connection.

GPIB Port: Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.

Centronics Port: Hardcopy parallel interface.

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or BW), HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON printers; HP 7470 and 7550 plotters, or similar, and HPGL compatible plotters. An optional, internal, high-resolution graphics printer is also available.



High bandwidth wireless communications signals can be captured best using the triggers, long memory and high bandwidth of the 9370C series. The signal above is 10 seconds (top trace) of data being transmitted to a pager. The zoom detail below shows individual 1's and 0's.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.

Temperature:
5° to 40° C (41° to 104° F) rated 0° to 50° C (32° to 122° F) operating.

Humidity: <80%.

Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.

Power: 90-250 V AC, 45-66 Hz, 230 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions: (HWD) 8.5" x 14.5" x 16.25" (210mm x 370mm x 410mm)

Weight: 13 kg (28.6 lbs) net, 18.5 kg (40.7 lbs) shipping.

Warranty: Three years.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

CE

9370C Series - Ordering Information

Digital Oscilloscopes:	Product Code	Price
2 Ch, 1 GHz, 500 MS/s, 50 kpts./Ch	9370C	$ 11,490
2 Ch, 1 GHz, 500 MS/s, 250 kpts./Ch	9370CM	12,990
2 Ch, 1 GHz, 500 MS/s, 2 Mpts./Ch	9370CL	17,990
4 Ch, 1 GS/s, 500 MS/s, 50 kpts./Ch	9374C	16,490
4 Ch, 1 GS/s, 500 MS/s, 250 kpts./Ch	9374CM	19,490
4 Ch, 1 GS/s, 500 MS/s, 500 kpts./Ch - Includes WP01/02/GP01	9374CTM	22,990
4 Ch, 1 GS/s, 500 MS/s, 2 Mpts./Ch	9374CL	27,490
Included with Standard Configuration:		
Four 10:1, 500 MHz, 10 MΩ Passive Probe with Sense Ring	PP005	175 (each)
Operator's Manual	93XXC-OM-E	85
Remote Control Manual	93XX-RCM	85
Hands On Guide	93XX-HG	45
Floppy Disk Drive	FD01	
Probes & Accessories:		
2.5 GHz 0.6pF Active Probe - Requires AP1143A Power Supply	AP54701A*	2,944
Probe Offset and Power Module	AP1143A*	1,568
Current Probe 150 Amps, 150 kHz	AP011	1,250
Current Probe 50 Amps, 50 MHz	AP015	1,500
1 GHz Active FET Probe (10:1) with ProBus Connector	AP020	990
15 MHz Differential Probe, x10, x100	AP031	300
15 MHz Differential Probe, x20, x200	AP032	300
A wide range of differential amplifiers and probes are available		
10:1/100:1, 200/300 MHz, 50 Ω High-Voltage Probe 600 V/1.2 kV	PPE1.2KV	264
100:1, 400 MHz, 50 Ω High-Voltage Probe, 2 kV Max. Voltage	PPE2KV	190
100:1, 400 MHz, 50 Ω High-Voltage Probe, 4 kV Max. Voltage	PPE4KV	326
100:1, 400 MHz, 50 Ω High-Voltage Probe, 5 kV Max. Voltage	PPE5KV	520
1000:1, 400 MHz, 50 Ω High-Voltage Probe, 6 kV Max. Voltage	PPE6KV	647
1000:1, 100 MHz, 50 Ω High-Voltage Probe, 20 kV (40 kV Peak) Max	PPE20KV	1,573
Service Manual for 9370C/74C	SM9370C/74C	125
Software Options:		
Advanced Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package	WP03	1,250
PRML Analysis Package	PRML	1,250
Any two of the four software options above	C2	1,875
Any three of the four software options above	C3	2,490
Disk Drive Measurements - Includes Parameter Analysis WP03	DDM	3,000
Optical Recording Measurements Package	ORM	3,000
Disk Drive Failure Analysis	DDFA	4,990
Hardware Options:		
Memory Card Reader w/512k Card	MC01/04	500
Type III Slot	HD01	590
170 Mbyte Portable Hard Drive	HD02	499
Type III PCMCIA Slot and 170 Mbyte Portable Drive inc. HD01 & HD02	HDD	990
PC Card Type III External Desktop Adapter for PC (110 V)	DA01-110	360
PC Card Type III External Desktop Adapter for PC (220 V)	DA01-220	360
Internal Graphics Printer	GP01	890
64 Mbyte Memory	64MBSM	2,000
50-500 MHz Ext Clock, 10 Mhz Reference Clock	CKTRIG	490
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CC	225
MIL STD Calibration	93XX-CCMIL	325
Swiss OFFMET Calibration	93XX-CCOFFMET	225
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	725
5 Year Warranty & NIST Calibration	93XX-T5	975

* Normally ordered together. The power module can support two AP54701A.

9350C Series Digital Oscilloscopes 500 MHz Bandwidth, 500 MS/s -2 GS/s

Main Features

- ***Two and Four Channel Versions***
- ***Up to 8 Mpoint Record Length***
- ***DOS Compatible Floppy Drive Standard***
- ***Innovative Peak-Detect Mode***
- ***Glitch, Exclusion, Pattern, Qualified, Interval, Dropout and Video Triggers***
- ***8-bit Vertical Resolution, 11 with ERES Option***
- ***Fully Programmable via GPIB and RS-232-C***
- ***Automatic Pass/Fail Testing***
- ***Advanced Signal Processing***
- ***Internal Printer Option***
- ***PC Card Portable Hard Drive and Memory Card Option***

High speed and long memory make this family the ideal 500 MHz general-purpose Digital Storage Oscilloscopes. Two and four channel simultaneous sampling at 500 MS/s meets demanding high-speed design applications. Even faster sampling may be achieved by combining channels, up to a maximum of 2 GS/s. Acquisition memories may also be combined, providing up to 8 Mpoints of continuous or segmented waveform recording. Repetitive signals are digitized at up to 10 GS/s.

A unique peak detect scheme triggers on glitches down to 1ns and keeps the ADC sampling at 2.5 ns - even at slow time bases - without destroying the underlying data. This provides circuit designers with the benefits of peak detection without any loss of precision.

Live waveforms on the main timebase may be viewed simultaneously with up to 3 expansions, showing all of the signal detail. Expansions are shown as highlights on the main trace. Each zoomed detail may be expanded horizontally and vertically as required.

SMART Trigger modes like Glitch, Pattern, Dropout and TV allow you to capture precisely the events of interest. Pre- and Post-Trigger delay, and Time and Events Holdoff are also standard. The 9350C family features the proven user-interface of LeCroy's portable scopes. A bright 9" CRT allows optimum waveform viewing on a high resolution 810 x 696 pixel screen. Menus and text are arranged around the graticules - they never overwrite the waveforms. Dedicated control knobs keep the scope's performance at your fingertips.

A comprehensive range of signal processing functions including FFT, Math, Histogram and Trending on live or stored waveforms, allows extensive waveform manipulation. Up to 16 Mbytes of RAM are standard allowing advanced processing including FFT's up to 1 Mpoint. For the most powerful processing in the industry, a 64 Mbyte RAM option is available. DOS compatible standard floppy drive, PCMCIA portable hard drive, ATA Flash and IC memory card options store waveforms and test setups, and simplify data transfer to any PC. An optional high resolution graphics printer is also available.

ACQUISITION SYSTEM

Bandwidth (-3 dB): DC to 500 MHz

No. of Channels:
4 (9354C) or 2 (9350C)

No. of Digitizers:
4 (9354C) or 2 (9350C)

Maximum Sample Rate:
2 GS/s (9354C) or 1 GS/s (9350C)

Acquisition Memory:
Up to 8 M (see table).

Sensitivity: 2 mV/div to 5 V/div, fully variable.

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:
2.0 - 9.9 mV/div: ±120 mV
10.0 - 199 mV/div: ±1.2 V
0.2 - 5.0 V/div: ±24 V
±20 V across the whole sensitivity range when using the AP 020 FET probe.

DC Accuracy: 1% typical.

Vertical Resolution: 8 bits.

Bandwidth Limiter: 30 MHz

Input Coupling: AC, DC, GND.

Input Impedance: 1 MΩ//15 pF or 50 Ω ± 1%.

Max Input:
1 MΩ: 250 V (DC + peak AC ≤10 kHz)
50 Ω: ±5 V DC (500 mW) or 5 V RMS

TIME BASE SYSTEM

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 1 ns/div to 1000 s/div.

Clock Accuracy: ≤10 ppm

Interpolator resolution: 10 ps

Roll Mode: Ranges 500 ms to 1,000 s/div. For > 50 kpoints: 10 s to 1,000 s/div.

External Clock: ≤100 MHz on EXT input with ECL, TTL or zero crossing levels; 50 to 500 MHz with option CKTRIG.

Channels Use	Maximum Sample Rate	Memory Per Channel				Active Channels
		9354C 9350C	9354CM 9350CM	9354CTM	9354CL 9350CL	
All Peak Detect OFF	1 GS/s	50k	250k	500k	2M	All
Paired Peak Detect OFF	2 GS/s	100k	500k	1M	4M	Ch 2 & Ch 3
Paired + PP094 Peak Detect OFF	4 GS/s	200k*	1M*	2M	8M*	(PP093 input)
All 2.5 ns Peak Detect ON	100 MS/s data+ 400 MS/s peak	25k data+25k peak	100k data+ 100k peak	250k data+ 250k peak	1M data+ 1M peak	All 2.5 ns Detect

** Not applicable to two channel units*

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single.

Trigger Sources: CH1, CH2, Line, EXT, EXT/10 (9354C: CH3, CH4), Slope, Level and Coupling for each can be set independently.

Slope: Positive, Negative.

Coupling: AC, DC, HF, LFREJ, HFREJ.

Pre-trigger recording: 0 to 100% of full scale (adjustable in 0.1 div increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.01% increments).

Holdoff by time: 10 ns to 20 s.

Holdoff by events: 0 to 99,999,999 events.

Trigger Bandwidth: Up to 500 MHz using HF coupling.

Internal Trigger Sensitivity Range: ±5 div.

EXT Trigger Max Input:

1 MΩ//15 pF: 250 V (DC + peak AC ≤10 kHz)
50 Ω ± 1%: ±5 V DC (500 mW) or 5 V RMS

EXT Trigger Range: ±0.5 V (±5 V with EXT/10)

Trigger Timing: Trigger Date and Time are listed in the memory status menu.

SMART TRIGGER TYPES

Pattern: Trigger on the logic AND of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, (9350C: 3 inputs - CH1, CH2, EXT) where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on glitches as short as 1 nsec or on pulse widths between two limits selectable from < 2.5ns to 20s.

Signal or Pattern Interval: Trigger on an interval between two limits selectable from 10ns to 20s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL (SECAM), NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 2 µs/div (M,L versions: from 1 ns/div to 5 µs/div).

Single shot: for transient and repetitive signals from 10 ns/div (all channels active).

Peak detect: captures and displays 2.5 ns glitches or other high-speed events.

Sequence: Stores multiple events - each of them time stamped - in segmented acquisition memories.

Number of segments available:

9350C-9354C	2-200
9350CM-9354CM-9354CTM	2-500
9350CL-9354CL	2-2,000

Display

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticules: Internally generated; separate intensity control for grids and waveforms.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity).

Horizontal Zoom Factors:

9350C-9354C	2,000x
9350CM-9354CM-9354CTM	10,000x
9350CL-9354CL	100,000x

Internal Memory

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4) with lengths equal to the acquisition memory length.

Processing Memory: Up to four 16-bit Waveform Processing Memories (A, B, C, D).

Setup Memory: Four non-volatile memories. The floppy disk or optional IC Memory Cards, or IC Card hard drives may also be used for high-capacity waveform and setup storage.

Automatic Measurements

The following Parametric measurements are available, together with statistics of their Average, Highest, Lowest values and Standard Deviation:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Parameters are calculated as defined by ANSI/IEEE Std 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". In addition, Rise and Fall times may be measured at 10 % and 90% levels, or 20% and 80% levels, or any other user-specified levels.

Δdelay provides time between midpoint transition of two sources, for making propagation delay measurements.

Δt at level allows the same measurement to be made at any specified level.

ΔC2D+ and ΔC2D- measure setup and hold times.

Two cursors are used to define the region over which these parameters are calculated.

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is also displayed.

Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of fullscale in single-grid mode.

Absolute Time: A cross hair marker measures time relative to the trigger, and voltage with respect to ground.

Pass/Fail testing allows up to five of the listed parameters to be tested against selectable thresholds. Waveform Limit Testing is performed using templates which may be defined inside the instrument.

Waveform Processing

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Sine x/x and Summation Averaging.

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to a million sweeps are possible with Advanced Math Option WP01.

Envelope*: Max, Min, or Max and Min values of up to one million sweeps.

ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.

Sampled data is always available, even when a trace is turned off. Any of the above modes can be invoked without destroying the data.

FFT*: Spectral Analysis with four windowing functions and FFT averaging.

*Envelope and ERES modes are provided in Advanced Math Package WP01, FFT is in WP02.

Autosetup

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals. (Amplitude 2mV to 40V; frequency above 50Hz; Duty cycle greater than 0.1%).

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset.

PROBES

Model: One PP002 (x10, 10 MΩ //15 pF) probe supplied per channel.

The 9350C family is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω , frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical.

Alternatively, the Calibrator output can provide a trigger output or a Pass/Fail test output.

INTERFACING

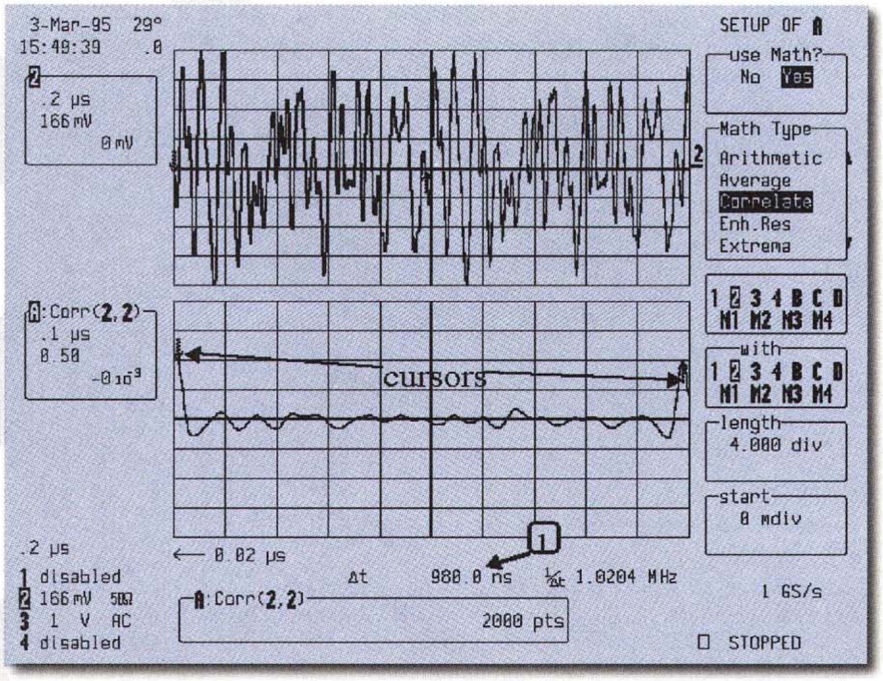
Remote Control: All front-panel controls, as well as all internal functions are possible by GPIB and RS-232-C.

RS-232-C Port (Standard): Asynchronous up to 115.2 kbaud for computer/terminal control or printer/plotter connection.

GPIB Port (Standard): Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.

Centronics Port (Standard): Hardcopy parallel interface.

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF format is available for importing into Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters. An optional internal high resolution graphics printer is also available.



The DDM and PRML packages allow 9350C series scopes to make powerful measurements on magnetic media. Above is an autocorrelation measurement. Refer to the DDM/PRML technical data.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.

Temperature: 5° to 40° C (41° to 104° F) rated, 0° to 50° C (32° to 122° F) operating.

Humidity: <80%.

Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.

Power: 90-250 V AC, 45-66 Hz, 230 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions: (HWD) 8.5" x 14.5" x 16.25", 210mm x 370mm x 410mm.

Weight: 13 kg (28.6 lbs) net, 18.5 kg (40.7 lbs) shipping.

Warranty: 3 years.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

CE

9350C Series - Ordering Information

Digital Oscilloscopes:	Product Code	Price
2 Ch, 500 MHz, 500 MS/s, 50 kpts./Ch	9350C	$ 9,990
2 Ch, 500 MHz, 500 MS/s, 250 kpts./Ch	9350CM	11,490
2 Ch, 500 MHz, 500 MS/s, 2 Mpts./Ch	9350CL	16,490
4 Ch, 500 MHz, 500 MS/s, 50 kpts./Ch	9354C	13,490
4 Ch, 500 MHz, 500 MS/s, 250 kpts./Ch	9354CM	16,490
4 Ch, 500 MHz, 500 MS/s, 500 kpts./Ch - Includes WP01/02/GP01	9354CTM	19,990
4 Ch, 500 MHz, 500 MS/s, 2 Mpts./Ch	9354CL	24,490
Included with Standard Configuration:		
10:1, 10 MΩ Passive Probe With Sense Ring; one per channel	PP002	80 (each)
Operator's Manual	93XXC-OM-E	85
Remote Control Manual	93XX-RCM	85
Hands on Guide	93XX-HG	45
Floppy Disk Drive	FD01	
Probes & Accessories:		
2.5 GHz 0.6pF Active Probe - Requires AP1143A Power Supply	AP54701A*	2,944
Probe Offset and Power Module	AP1143A*	1,568
Current Probe 150 Amps, 150 kHz	AP011	1,250
Current Probe 50 Amps, 50 MHz	AP015	1,500
1 GHz Active FET Probe (10:1) with ProBus Connector	AP020	990
15 MHz Differential Probe, x10, x100	AP031	300
15 MHz Differential probe, x20, x200	AP032	300
A wide range of differential amplifiers and probes are available		
10:1/100:1, 200/300 MHz, 50Ω High Voltage Probe 600V/1.2kV	PPE1.2KV	264
100:1, 400 MHz, 50Ω High Voltage Probe, 2kV Max. Voltage	PPE2KV	190
100:1, 400 MHz, 50Ω High Voltage Probe, 4kV Max. Voltage	PPE4KV	326
100:1, 400 MHz, 50Ω High Voltage Probe, 5kV Max. Voltage	PPE5KV	520
1000:1, 400 MHz, 50Ω High Voltage Probe, 6kV Max. Voltage	PPE6KV	647
1000:1, 100 MHz, 50Ω High Voltage Probe, 20kV (40kV Peak) Max	PPE20KV	1,573
Service Manual for 9350C/54C	SM9350C/54C	125
Software Options:		
Advanced Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package	WP03	1,250
PRML Analysis Package	PRML	1,250
Any two of the four software options above	C2	1,875
Any three of the four software options above	C3	2,490
Disk Drive Measurements - Includes Parameter Analysis WP03	DDM	3,000
Optical Recording Measurements Package	ORM	3,000
Disk Drive Failure Analysis	DDFA	4,990
Hardware Options:		
Memory Card Reader w/512k Card	MC01/04	500
Type III Slot	HD01	590
170 Mbyte Portable Hard Drive	HD02	499
Type III PCMCIA Slot and 170 Mbyte Portable Drive inc. HD01 & HD02	HDD	990
PC Card Type III External Desktop Adapter for PC (110V)	DA01-110	360
PC Card Type III External Desktop Adapter for PC (220V)	DA01-220	360
Internal Graphics Printer	GP01	890
64 Mbyte Memory	64MBSM	2,000
50-500 MHz Ext Clock, 10 Mhz Reference Clock	CKTRIG	490
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CC	225
MIL STD Calibration	93XX-CCMIL	325
Swiss OFFMET Calibration	93XX-CCOFFMET	225
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	725
5 Year Warranty & NIST Calibration	93XX-T5	975

* Normally ordered together. The power module can support two AP54701A.

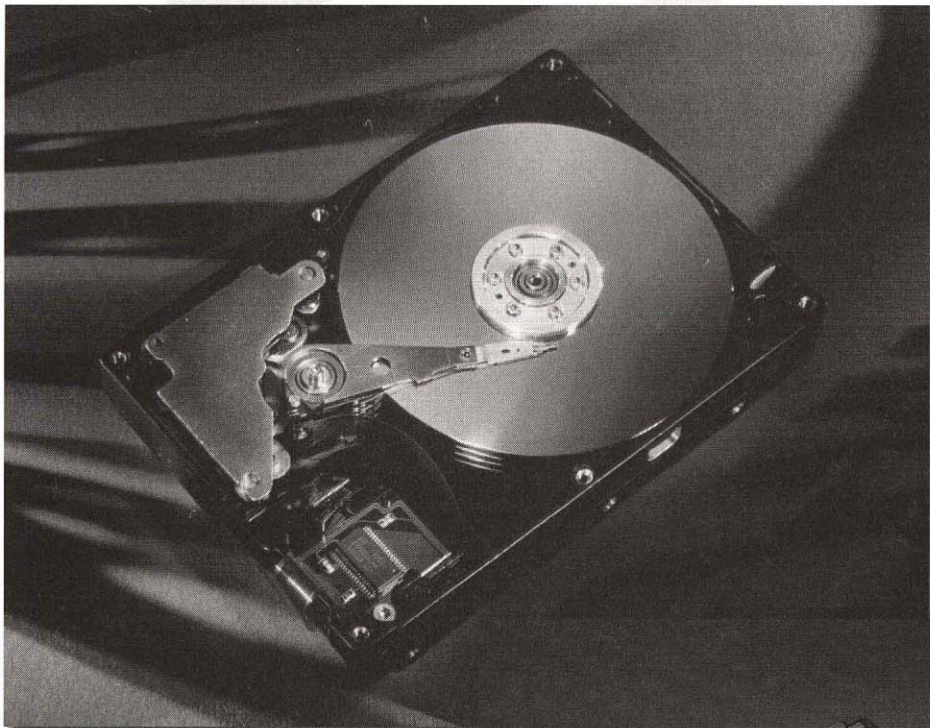
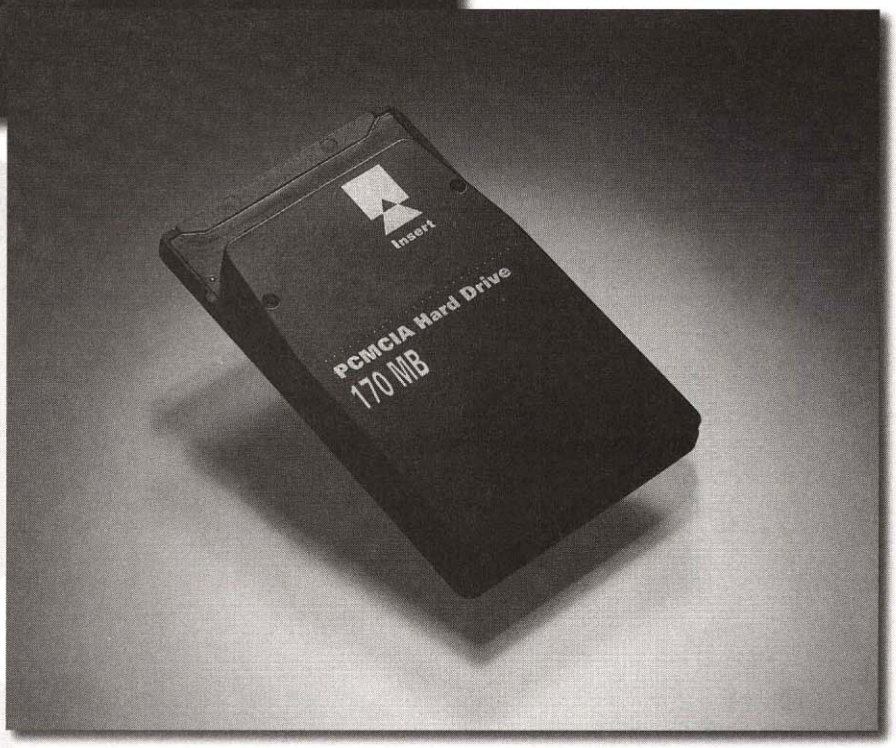
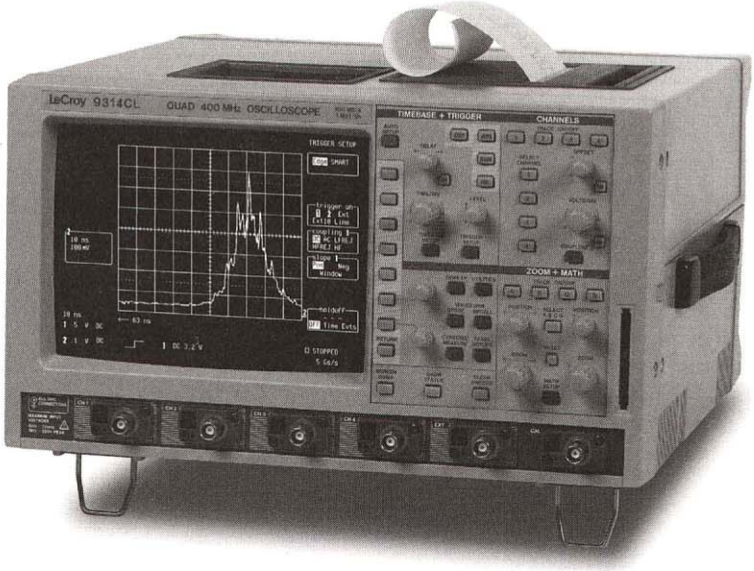


Photo courtesy of Quantum Corporation.



PCMCIA Portable hard drives are a handy way to store data, analysis and documents such as engineering progress reports or ISO 9000 spreadsheets. A type III slot for these DOS devices is available as an option on all LeCroy scopes.

9310C, 9314C Series Digital Oscilloscopes 400 MHz Bandwidth, 100 MS/s



Main Features

- *Two and Four-Channels*
- *50k, 250k and 1Mpoint Records*
- *Glitch, Exclusion, Window, Qualified, Interval, Dropout and Video Triggers*
- *Advanced Signal Processing*
- *External Clock to 100 MHz*
- *8-bit Vertical Resolution—up to 11 with ERES*
- *Over 40 Parametric Measurements*
- *Datalogging and Statistics*
- *Trends and Histograms*
- *Pass/Fail Testing*
- *Persistence, XY and Roll Modes*
- *Floppy Drive*
- *Printer Port*
- *Programmable via GPIB and RS-232-C*
- *Internal High Resolution Graphics Printer Option*
- *PCMCIA Hard Drive, ATA Flash Card and Memory Card Options*

The 9310C and 9314C are two-channel and four-channel general-purpose 400 MHz digital oscilloscopes. They are designed to save engineers valuable time in troubleshooting, problem-solving, test and characterization.

Each scope is an integrated and powerful interactive system providing the capability to:

- Single Shot Capture of signals during key events at up to 100 MS/s, and repetitive signals at 10 GS/s. Record lengths up to 1 Mpoints provide outstanding horizontal resolution, and allow fast digitizing of long-duration events. Memories can be segmented for minimum dead time between acquisitions.
- View signals on a large 9" diagonal CRT, using advanced display technology, enabling you to view more information more rapidly. Live waveforms on the main timebase may be viewed simultaneously with up to 3 expansions, showing all of the signal detail. Expansions are shown as highlights on the main trace.
- Analyze your signal to get answers quickly and more accurately. The powerful processing system enables advanced signal analysis. A comprehensive range of signal processing functions, on live, stored processed, or expanded waveforms, allows waveform manipulation without destroying the underlying data. Perform basic and advanced waveform math as well as advanced statistical and graphical analysis.

The LeCroy ProBus intelligent probe system automatically senses the probe type. For LeCroy's active FET and current probes it also provides variable offset at the probe tip. Offset and coupling are controlled from the scope's front panel.

SMART Trigger modes like Glitch, Interval and Dropout allow you to precisely capture the events of interest.

The 9310C family features the proven user-interface of LeCroy's portable scope family. A bright, high-resolution 9" CRT allows optimum waveform viewing on a high resolution 810 x 696 pixel screen. Menus and text are arranged around the graticules —they never overwrite the waveforms. Each of the main control functions has a dedicated knob keeping control of the scope's performance at your fingertips.

DOS compatible floppy disk, PCMCIA portable hard drive, ATA Flash Card, and memory card options for storing waveforms and test setups make quick transfer of data to a PC easier than ever. Many printers and plotters can be driven via GPIB, RS-232-C, or a Centronics compatible interface. The optional internal, high resolution, strip chart graphics printer, is effective for documenting long waveforms. Data can also be transferred for analysis in programs that accept ASCII data such as MathCad, MatLab, and spreadsheet type programs.

Optional packages provide extensive Waveform Processing capabilities including FFT and Enhanced Resolution to 11 bits.

ACQUISITION SYSTEM

Bandwidth (-3 dB)

@ 50 Ω: Above 200 mV/div: DC to 400 MHz Below 200 mV/div: 350 MHz
At 2mV/div: 300 MHz
@ 1 MΩ DC: DC to 200 MHz typical at the probe tip with 50 ohm source.

No. of Channels: 4 (9314C) or 2 (9310C)

No. of Digitizers: 4 (9314C) or 2 (9310C)

Maximum Sample Rate: 100 MS/s simultaneously on each channel.

Acquisition memories, per channel:

9310C , 9314C	50k
9310CM, 9314CM	250k
9310CL, 9314CL	1M

Sensitivity: 2 mV/div to 5 V/div, fully variable.

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:

2.0 - 9.9 mV/div:	±120 mV
10 - 199 mV/div:	±1.2 V
0.2 - 5.0 V/div:	±24 V

DC Accuracy: ≤±2% full scale (8 divisions) at 0 V offset.

Vertical Resolution: 8 bits

Bandwidth Limiter: 30 MHz

Input Coupling: AC, DC, GND

Max Input:
1 MΩ: 250 V (DC+peak AC@ 10 kHz)
50 Ω: ± 5 V DC (500 mW) or 5 V RMS

TIMEBASE SYSTEM

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 1 ns/div to 1000 s/div.

Clock Accuracy: ≤±0.002 %.

Interpolator Resolution: 10 ps.

Roll Mode: Ranges 500 ms to 1,000 s/div. For > 50k points: 10 s to 1,000 s/div.

External Clock: ≤100 MHz on EXT input with ECL, TTL or zero crossing levels.

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single, Stop.

Trigger Sources: CH1, CH2, Line, Ext, Ext/10 (9314C: CH3, CH4). Slope, Level and Coupling for each can be set independently.

Slope: Positive, Negative, Window (BiSlope).

Coupling: AC, DC, HF (up to 500 MHz), LFREJ, HFREJ.

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% div increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).

Holdoff by time: 10 ns to 20 s.

Holdoff by events: 0 to 99,999,999 events.

Internal Trigger Sensitivity Range: ±5 div.

EXT Trigger Max. Input:
1 MΩ//15 pF: 250 V (DC+peak AC ≤10 KHz)
50 Ω ± 1%: ±5 V DC (500 mW) or 5 V RMS

EXT Trigger Range: ±0.5V (±5V with Ext/10).

Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART TRIGGER TYPES

Signal Width: Trigger on width between two limits selectable from <2.5ns to 20s will typically trigger on 1 ns glitches.

Signal Interval: Trigger on interval between two limits selectable from 10ns to 20s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of line (up to 1500), field number (up to 8), interlace (up to 8:1), and frequency for PAL (SECAM), NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 10 ms/div.

Single shot: For transient and repetitive signals from 50 ns/div.

Sequence: Stores multiple events in segmented acquisition memories.

Number of segments available:

9310C-9314C	2-200
9310CM-9314CM	2-500
9310CL-9314CL	2-2,000

Dead Time between segments: ≤80 µs

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticules: Internally generated; separate intensity control for grids and waveforms.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity).

Maximum Horizontal Zoom Factors:

9310C , 9314C	2,500x
9310CM, 9314CM	10,000x
9310CL, 9314CL	50,000x

Internal Memory

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4) with length equal to acquisition memory.

Processing Memory: Up to four 16-bit Waveform Processing Memories (A, B, C, D).

Setup Memory: Four non-volatile memories. The floppy disk or optional PCMCIA portable hard drive, Memory Cards may also be used for high-capacity waveform and setup storage.

Waveform Processing

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Sine x/x and Summation Averaging.

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 1 million averages are possible with Advanced Math Option WP01.

Extrema: Roof, Floor or Envelope values from 1 to 10^6 sweeps (with option WP01).

ERES: Low-Pass digital filter provides up to 11 bits vertical resolution. Sampled data is always available, even when trace is turned off (with option WP01).

FFT: Spectral Analysis with five windowing functions and FFT averaging (with option WP02).

Histogramming and Trending: The Parameter Analysis package enables graphical and statistical analysis of waveform parameters (with option WP03).

Automatic Measurements

The following Parametric measurements are available including their Average, Highest, Lowest values and Standard Deviation:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Parameters are calculated as defined by ANSI/IEEE Std 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". In addition, Rise and Fall times may be measured at 10% and 90% levels, or 20% and 80% levels, or any other user-specified levels.

Δdelay measures the time between midpoint transition of two sources—measures propagation delay.

Δt at level measures the time between two sources at two independently specified levels.

ΔC2D+ and ΔC2D- enable measurement of setup and hold time (Clock to Data).

Two cursors are used to define the waveform region over which parameters are calculated.

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is also displayed.

Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of fullscale in single-grid mode.

Absolute Time: A cross hair marker measures time relative to the trigger, and voltage with respect to ground.

Pass/Fail Test: Allows up to five parameters to be tested against selectable limits and conditions. Waveform Limit Testing can be performed using Masks which may be defined inside the instrument or imported.

Autosetup

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals. (Amplitude 2mV to 40V; frequency above 50Hz; Duty cycle greater than 0.1%).

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset.

Probes

Model: One PP002 (10:1, 10 MΩ // 15 pF) probe supplied per channel.

The 9310C family is fully compatible with LeCroy's complete line of FET, Current, High Voltage, and Differential Amplifiers and probes.

Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical.

Alternatively, the Calibrator output can provide a trigger output or a Pass/Fail test output.

Interfacing

Remote Control: Of all front-panel controls, as well as all internal functions is possible by GPIB and RS-232-C.

RS-232-C Port: Asynchronous up to 115.2 kb/s for computer/terminal control or printer/plotter connection.

GPIB Port: Configurable as talker/listener for computer control and fast data transfer.

Command Language complies with requirements of IEEE-488.2.

Centronics Port: Hardcopy parallel interface included

3.5" Floppy disk: Standard

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet, and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters. An optional internal high-resolution graphics printer is also available.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.

Temperature: 5° to 40° C (41° to 104° F) rated, 0° to 50° C (32° to 122° F) operating.

Humidity: <80%.

Shock & Vibration:
Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.

Power: 90-250 V AC, 45-66 Hz, 150 W.

Battery Backup: Front-panel settings maintained for two years.

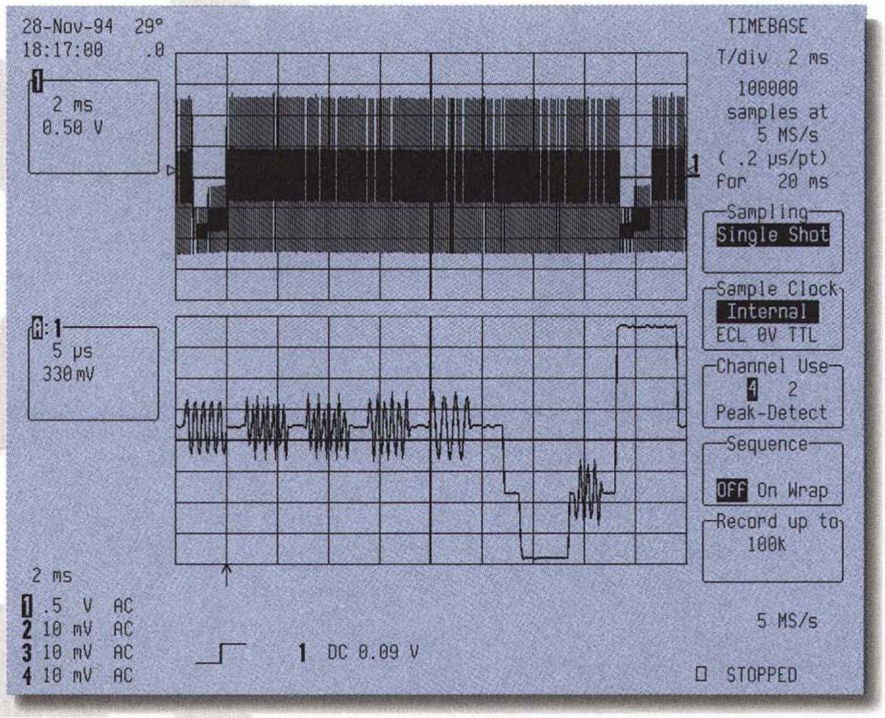
Dimensions: (HWD) 8.5" x 14.5" x 16.25", 210mm x 370mm x 410mm.

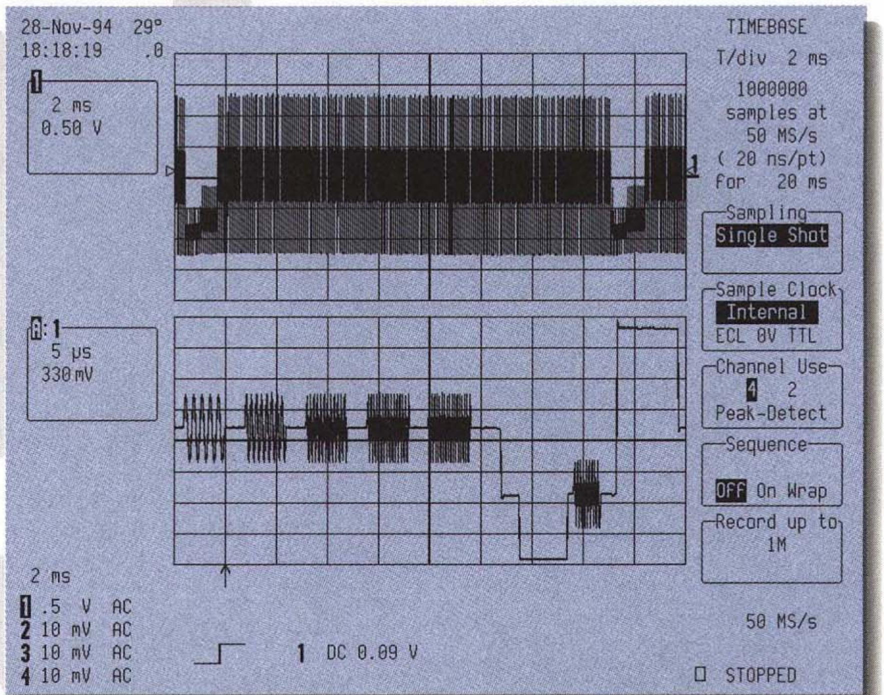
Weight: 12.5 kg (27.5 lbs) net, 18 kg (40 lbs) shipping.

Warranty: Three years.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

CE



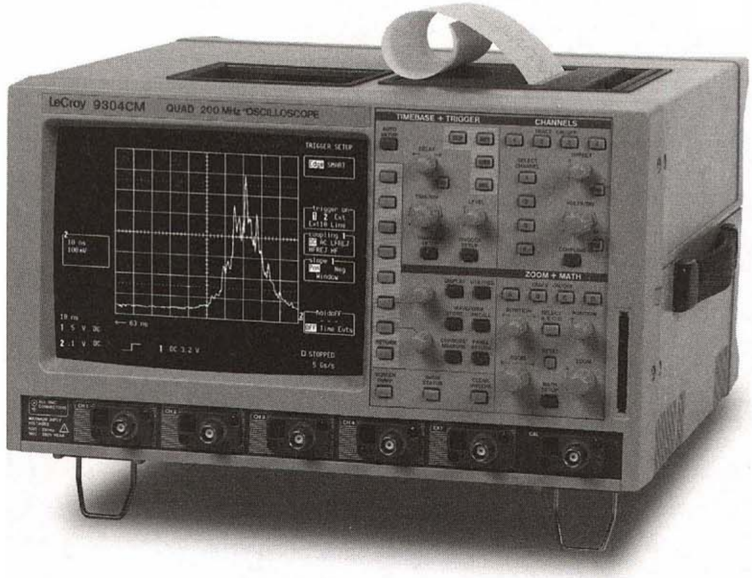


Long Memory allows a scope to capture long duration signals at a high sample rate. Note the difference in detail in the zoom sections shown on the lower traces of the two scope screens above. A 1 megapoint scope puts 10 times more points on the waveform than a 100 kpoint scope.

9310 Series - Ordering Information

Digital Oscilloscopes:	Product Code	Price
400 MHz, 100 MS/s, 50 kpts/ch, 2 channel DSO	9310C	$ 4,990
400 MHz, 100 MS/s, 250 kpts/ch, 2 channel DSO	9310CM	5,990
400 MHz, 100 MS/s, 1 Mpts/ch, 2 channel DSO	9310CL	10,490
400 MHz, 100 MS/s, 50 kpts/ch, 4 channel DSO	9314C	7,860
400 MHz, 100 MS/s, 250 kpts/ch, 4 channel DSO	9314CM	9,440
400 MHz, 100 MS/s, 1 Mpts/ch, 4 channel DSO	9314CL	15,740
Included with Standard Configuration:		
Four 10:1, 10 MΩ Passive Probe with sensing ring	PP002	80 (each)
Operator's Manual	931X-OM	85
Remote Control Manual	93XX-RCM	85
Hands on Guide	93XX-HG	45
Floppy Disk Drive	FD01	
Probes & Accessories:		
15 MHz (±700 V) Differential Probe	AP031	300
15 MHz (±1400 V) Differential Probe	AP032	300
120 KHz Current Probe (±150 A)	AP011	1,250
50 MHz Current Probe(±50 A)	AP015	1,500
ProBus 75 to 50 Ω Adapter	PP090	195
High Voltage Probe 1.2 kV, 300 MHz	PPE1.2KV	264
High Voltage Probe 2 kV, 400 MHz	PPE2KV	190
High Voltage Probe 4 kV, 400 MHz	PPE4KV	326
High Voltage Probe 5 kV, 400 MHz	PPE5KV	520
High Voltage Probe 6 kV, 400 MHz	PPE6KV	647
High Voltage Probe 20 kV (40 kV peak), 100 MHz	PPE20KV	1,573
High Gain 10 MHz Differential Amplifier and Comparator	DA1820	1,995
High Gain 10 MHz Differential Amplifier and Comparator with Precision Voltage Source	DA1822	2,695
100 MHz Differential. Amplifier and Comparator	DA1850	2,695
100 MHz Differential. Amplifier and Comparator with Precision Voltage Source and Selectable Bandwidth	DA1855	3,495
Differential probe,100:1/10:1, 250 MHz, 1MΩ, 500V	DXC100	695
Differential probe, 1:1, 1 MΩ/ 100 MΩ, 50 pf	DXC200	225
Differential Probe,100:1, 250 MHz, 92 MΩ, 4.5 pf, 500V	DXC300	495
Differential Probe,100:1, 250 MHz, 92 MΩ, 2.6 pf, 400V	DXC350	495
Service Manual for 9314C	SM9314C	125
Software Options:		
Advanced Math Package	WP01	1,250
Spectrum Analysis Package	WP02	1,250
Parameter Analysis Package	WP03	1,250
Any two of the three software options above	C2	1,875
All of the three software options above	C3	2,490
Hardware Options:		
Memory Card Reader with 512K Card	MC01/04	500
PCMCIA Type III slot for Hard Drives and ATA Flash Cards	HD01	590
4MB ATA Flash Card (Requires HD01 Option	4MBFC	399
PCMCIA Hard Disk 170 Mbyte (requires HD01 option)	HD02	499
PCMCIA Type III slot and 170 MByte hard drive	HDD	990
PCMCIA Type III External Desktop Adapter for PC (110V)	DA01-110	360
PCMCIA Type III External Desktop Adapter for PC (220V)	DA01-220	360
Internal Graphics Printer	GP01	890
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CCNIST	225
MIL STD Calibration	93XX-CCMIL	325
Swiss OFFMET Standard	93XX-CCOFMET	225
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	725
5 Year Warranty and Calibration	93XX-T5	975

9304C Series Digital Oscilloscopes 200 MHz Bandwidth, 100 MS/s



Main Features

- *Four Channels*
- *50k or 250 kpoints/ch*
- *Glitch, Exclusion, Window, Qualified, Interval, Dropout and Video Triggers*
- *Advanced Signal Processing*
- *External Clock to 100 MHz*
- *8-bit vertical resolution—up to 11 with ERES*
- *Over 40 Parametric Measurements*
- *Datalogging and Statistics*
- *Trends and Histograms*
- *Pass/Fail Testing*
- *Persistence, XY and Roll Modes*
- *Floppy Drive*
- *Printer Port*
- *Programmable via GPIB and RS-232-C*
- *Internal High Resolution Graphics Printer Option*
- *PCMCIA Hard Drive and Memory Card Options*

The 9304C and 9304CM are general purpose 200 MHz four-channel digital oscilloscopes that are designed to save engineers valuable time in troubleshooting, problem-solving, test and characterization.

Each scope is an integrated and powerful interactive system providing the capability to:

- Single Shot Capture of signals during key events at up to 100 MS/s, and repetitive signals at 10 GS/s. Record lengths up to 250 kpoints provide excellent horizontal resolution and allow fast digitizing of long-duration events. Memories can be segmented, for minimum dead time between acquisitions.
- View signals on a large 9" diagonal CRT, using advanced display technology, enabling you to view more information more rapidly. Live waveforms on the main timebase may be viewed simultaneously with up to 3 expansions, showing all of the signal detail. Expansions are shown as highlights on the main trace.
- Analyze your signal to get answers quickly and more accurately. The powerful processing system enables advanced signal analysis. A comprehensive range of signal processing functions, on live, stored processed, or expanded waveforms, allows waveform manipulation without destroying the underlying data. Perform basic and advanced waveform math as well as advanced statistical and graphical analysis.

The LeCroy ProBus™ intelligent probe system automatically senses the probe type. For LeCroy's active FET and current probes it also provides variable offset at the probe tip. Offset and coupling are controlled from the scope's front panel.

SMART Trigger modes like Glitch, Window and Dropout allow you to precisely capture the events of interest.

The 9304C and 9304CM feature the proven user-interface of LeCroy's portable scope family. A bright, high-resolution 9" CRT allows optimum waveform viewing on a high resolution 810 x 696 pixel screen. Menus and text are arranged around the graticules — they never overwrite the waveforms. Each of the main control functions has a dedicated single knob keeping control of the scope's performance at your fingertips.

DOS compatible floppy disk, PCMCIA portable hard drive, ATA Flash Card, and memory card options for storing waveforms and test setups make quick transfer of data to a PC easier than ever. Many printers and plotters can be driven via GPIB, RS-232-C, or a Centronics compatible interface. The optional internal, high resolution, strip chart graphics printer, is effective for documenting long waveforms. Data can also be transferred for analysis in programs that accept ASCII data such as MathCad, MatLab, and spreadsheet type programs.

Optional packages provide extensive Waveform Processing capabilities including FFT and digitally Enhanced Resolution—up to 11 bits.

Acquisition System

Bandwidth (-3 dB)

@ 50 Ω:	DC to 200 MHz
@ 1 MΩ DC:	DC to 200 MHz typical at the probe tip with 50 ohm source.

No. of Channels: 4

No. of Digitizers: 4

Maximum Sample Rate: 100 MS/s simultaneously on each channel. Acquisition memories, per channel:

9304C	50k
9304CM	250k

Sensitivity: 2 mV/div to 5 V/div, fully variable.

Scale factors: A wide choice of probe attenuation factors are selectable.

Offset Range:

2.0 - 9.9 mV/div:	±120 mV
10 - 199 mV/div:	±1.2 V
0.2 - 5.0 V/div:	±24 V

DC Accuracy: ≤±2% full scale (8 divisions) at 0 V offset.

Vertical Resolution: 8 bits.

Bandwidth Limiter: 30 MHz.

Input Coupling: AC, DC, GND.

Input Impedance: 1 MΩ//15 pF (System capacitance using PP02) or 50 Ω ±1%.

Max Input:
1 MΩ: 250 V (DC+peak AC@ 10 kHz)
50 Ω: ±5 V DC (500 mW) or 5 V RMS

Timebase System

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 1 ns/div to 1000 s/div.

Clock Accuracy: ≤ ± 0.002 %.

Interpolator Resolution: 10 ps.

Roll Mode: Ranges 500 ms to 1,000 s/div. For > 50 kpoints: 10 s to 1,000 s/div.

External Clock: ≤ 100 MHz on EXT input with ECL, TTL or zero crossing levels.

Triggering System

Trigger Modes: Normal, Auto, Single, Stop.

Trigger Sources: CH1, CH2, CH3, CH4, Line, EXT, EXT/10. Slope, Level and Coupling for each can be set independently.

Slope: Positive, Negative, Window (BiSlope).

Coupling: AC, DC, HF (up to 500 MHz), LFREJ, HFREJ.

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% div increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).

Holdoff by time: 10 ns to 20 s.

Holdoff by events: 0 to 99,999,999 events.

Internal Trigger Sensitivity Range: ± 5 div.

EXT Trigger: Max. Input:
1 MΩ//15 pF: 250 V (DC + peak AC ≤10 kHz).
50 Ω ± 1%: ±5 V DC (500 mW) or 5 V RMS.

EXT Trigger Range: ±0.5V (±5V with EXT/10).

Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART Trigger Types

Signal Width: Trigger on width between two limits selectable from <2.5ns to 20s will typically trigger on 1 nsec glitches.

Signal Interval: Trigger on interval between two limits selectable from 10ns to 20s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.

State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

TV: Allows selection of (up to 1500), field number (up to 8), interlace (up to 8:1), and frequency for PAL (SECAM), NTSC or non-standard video formats.

Acquisition Modes

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 5 ms/div.

Single shot: for transient and repetitive signals from 50 ns/div.

Sequence: Stores multiple events in segmented acquisition memories. Number of segments available:

9304C	2-200
9304CM	2-500

Dead Time between segments: ≤ 80 µs

Display

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.

CRT: 12.5 x 17.5 cm (9" diagonal) raster.

Resolution: 810 x 696 points.

Modes: Normal, XY, Variable or Infinite Persistence.

Real-time Clock: Date, hours, minutes, seconds.

Graticules: Internally generated; separate intensity control for grids and waveforms.

Grids: 1, 2 or 4 grids.

Formats: YT, XY, and both together.

Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity).

Maximum Horizontal Zoom Factors:

9304C	2,500x
9304CM	10,000x

Internal Memory

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4) with length equal to acquisition memory length.

Processing Memory: Up to four 16-bit Waveform Processing Memories (A,B,C,D).

Setup Memory: Four non-volatile memories. The floppy disk or optional Memory Cards, PCMCIA portable hard drives may also be used for high-capacity waveform and setup storage.

Waveform Processing

Up to four processing functions may be performed simultaneously including: Add, Subtract, Multiply, Divide, Negate, Identity, Sine x/x and Summation Averaging.

Average: Summed averaging of up to 1,000 waveforms is standard. Average up to 10^6 waveforms (with option WP01).

Extrema: Roof, Floor or Envelope values from 1 to 10^6 sweeps (with option WP01).

ERES: Low-Pass digital filter provides up to 11 bits vertical resolution. Sampled data is always available, even when trace is turned off (with option WP01).

FFT: Spectral Analysis with five windowing functions and FFT averaging (with option WP02).

Histogramming and Trending: The Parameter Analysis package enables graphical and statistical analysis of waveform parameters (with option WP03).

Automatic Measurements

The following Parametric measurements are available including their Average, Highest, Lowest values and Standard Deviation:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Parameters are calculated as defined by ANSI/IEEE Std 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". In addition, Rise and Fall times may be measured at 10% and 90% levels, or 20% and 80% levels, or any other user-specified levels.

Δdelay measures the time between midpoint transition of two sources—measures propagation delay.

Δt at level measures the time between two sources at two independently specified levels.

ΔC2D+ and ΔC2D- enable measurement of setup and hold time (Clock to Data).

Two cursors are used to define the waveform region over which parameters are calculated.

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is also displayed.

Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of fullscale in single-grid mode.

Absolute Time: A cross hair marker measures time relative to the trigger, and voltage with respect to ground.

Pass/Fail Test: Allows up to five parameters to be tested against selectable limits and conditions. Waveform Limit Testing can be performed using Masks which may be defined inside the instrument or imported.

Autosetup

Pressing Autosetup sets timebase, trigger and sensitivity to display a wide range of repetitive signals. (Amplitude 2 mV to 40 V; frequency above 50 Hz; Duty cycle greater than 0.1%).

Autosetup Time: Approximately 2 seconds.

Vertical Find: Automatically sets sensitivity and offset.

Probes

Model:

One PP002 (10:1, 10 MΩ // 15 pF) probe supplied per channel.

The 9304C and 9304CM are fully compatible with LeCroy's complete line of FET, Current, High Voltage, and Differential Amplifiers and Probes.

Probe Calibrator: Max 1 V into 1 MΩ, 500 mV into 50 Ω , frequency and amplitude programmable, pulse or square wave selectable, 1 ns typical rise and fall time. The Calibrator can also be configured to provide a trigger output or Pass/Fail test output.

Interfacing

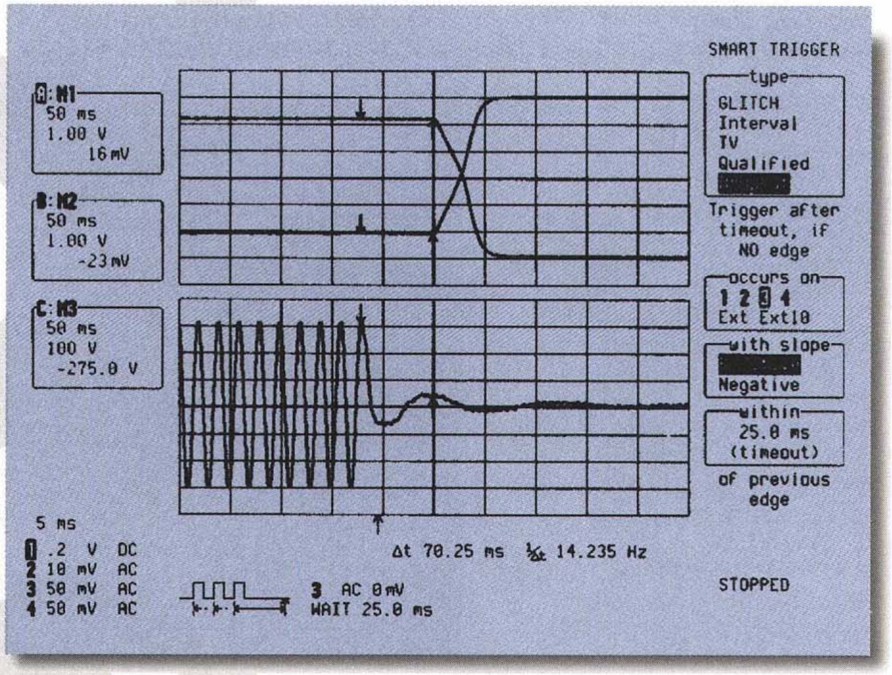
Remote Control of all front-panel controls, as well as all internal functions is possible by GPIB and RS-232-C.

RS-232-C Port: Asynchronous up to 115.2 Kbaud for computer/terminal control or printer/plotter connection.

GPIB Port: Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.

Centronics Port: Centronics parallel printer interface—standard.

Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet, and EPSON printers, HP 7400 and 7500 series, or HPGL compatible plotters. An optional internal high resolution, strip chart graphics printer is also available.



Testing holdup time on a DC power supply is easy using LeCroy's dropout trigger. For more information on power supply testing, refer to the application note on page 241 of this catalog.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.

Temperature:
5° to 40° C (41° to 104° F) rated 0° to 50° C (32° to 122° F) operating.

Humidity: < 80%.

Shock & Vibration:
Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.

Power: 90-250 V AC, 45-66 Hz, 150 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions: (HWD)
8.5"x14.5"x16.25", 210mm x 370mm x 410mm.

Weight: 12.5kg (27.5lbs) net, 18kg (40lbs) shipping.

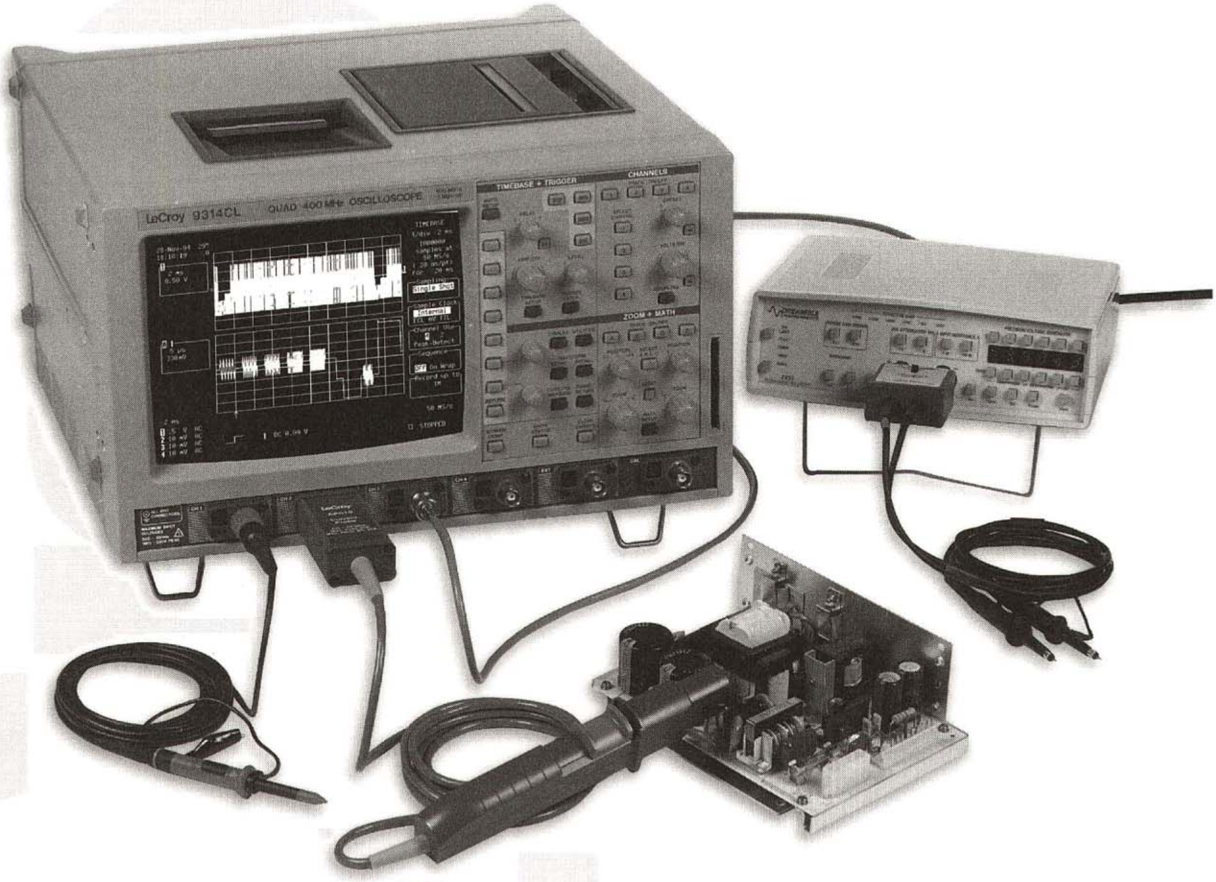
Warranty: Three years.

UL and cUL Approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010.1-92.

CE

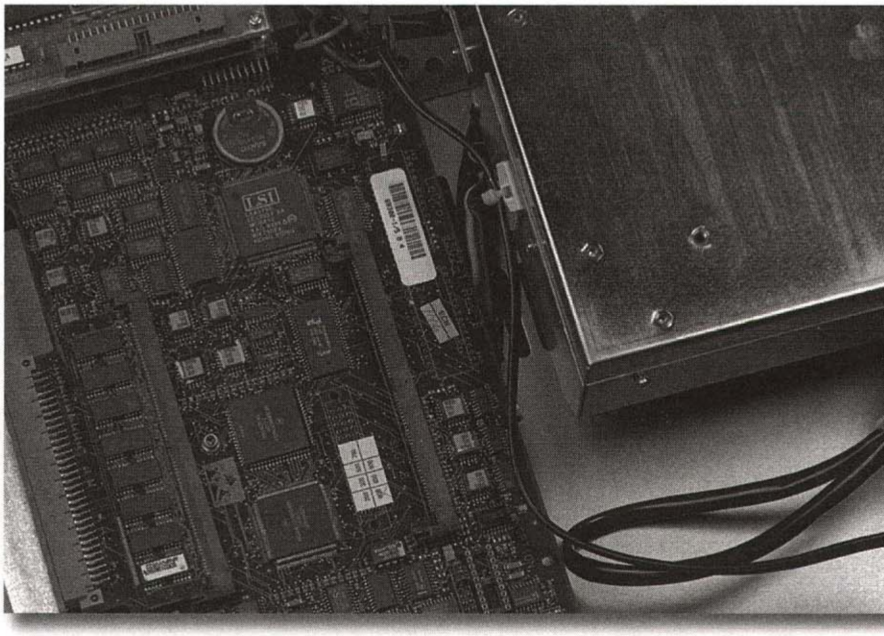
9304 Series Ordering Information

Digital Oscilloscopes:	Product Code	Price
200 MHz, 100 MS/s, 50 kpts/ch, 4 channel DSO	9304C	$ 6,290
200 MHz, 100 MS/s, 250 kpts/ch, 4 channel DSO	9304CM	7,390
Included with Standard Configuration:		
Four 10:1, 10 MΩ Passive Probe with sensing ring	PP002	80 (each)
Operator's Manual	930X-OM	85
Remote Control Manual	93XX-RCM	85
Hands on Guide	93XX-HG	45
Floppy Disk Drive	FD01	
Probes & Accessories:		
15 MHz (±700 V) Differential Probe	AP031	300
15 MHz (±1400 V) Differential Probe	AP032	300
120 KHz Current Probe (±150 A)	AP011	1,250
50 MHz Current Probe(±50 A)	AP015	1,500
ProBus 75 to 50 Ω Adapter	PP090	195
High Voltage Probe 1.2 kV, 300 MHz	PPE1.2KV	264
High Voltage Probe 2 kV, 400 MHz	PPE2KV	190
High Voltage Probe 4 kV, 400 MHz	PPE4KV	326
High Voltage Probe 5 kV, 400 MHz	PPE5KV	520
High Voltage Probe 6 kV, 400 MHz	PPE6KV	647
High Voltage Probe 20 kV (40 kV peak), 100 MHz	PPE20KV	1,573
High Gain 10 MHz Differential Amplifier and Comparator	DA1820	1,995
High Gain 10 MHz Differential Amplifier and Comparator with Precision Voltage Source	DA1822	2,695
100 MHz Differential. Amplifier and Comparator	DA1850	2,695
100 MHz Differential. Amplifier and Comparator with Precision Voltage Source	DA1855	3,495
Differential probe,100:1/10:1, 250 MHz, 1MΩ, 500V	DXC100	695
Differential probe, 1:1, 1 MΩ/ 100 MΩ, 50 pf	DXC200	225
Differential Probe,100:1, 250 MHz, 92 MΩ, 4.5 pf, 500V	DXC300	495
Differential Probe,100:1, 250 MHz, 92 MΩ, 2.6 pf, 400V	DXC350	495
Service Manual for 9304C	SM9304C	125
Software Options:		
Advanced Math Package	93XXWP01	1,250
Spectrum Analysis Package	93XXWP02	1,250
Parameter Analysis Package	93XXWP03	1,250
Any two of the three software options above	93XX-C2	1,875
All of the three software options above	93XX-C3	2,490
Hardware Options:		
Memory Card Reader with 512K Card	93XX-MC01/04	500
PCMCIA Type III slot for Hard Drives and ATA Flash Cards	93XX-HD01	590
4MB ATA Flash Card (Requires HD01Option	93XX-4MBFC	399
PCMCIA Hard Disk 170 Mbyte (requires HD01 option)	93XX-HD02	499
PCMCIA Type III slot and 170 MByte hard drive	93XX-HDD	990
PCMCIA Type III External Desktop Adapter for PC (110V)	93XX-DA01-110	360
PCMCIA Type III External Desktop Adapter for PC (220V)	93XX-DA01-220	360
Internal Graphics Printer	93XX-GP01	890
Warranty & Calibration:		
NIST Calibration Certificate	93XX-CCNIST	225
MIL STD Calibration	93XX-CCMIL	325
Swiss OFFMET Standard	93XX-CCOFMET	225
5 Year Repair Warranty	93XX-W5	545
5 Year NIST Calibration Contract	93XX-C5	725
5 Year Warranty and Calibration	93XX-T5	975



The 9300 series, combined with best in class probes for measuring high voltage, current and differential signals, are well suited for measuring the performance of power devices.

9300 OEM Kits for OEM System Designers



Available for OEM System Designers

- *High-Speed Data Acquisition*
- *First Level Processing/Analysis Tools*
- *Variety of I/O ports*
- *Provides 9300 series performance in a compact package*

9300 series OEM Kits are available for system level designers who need a high-performance front end for a test system or for some other form of signal analysis. A 9300 series digital scope can be made available in kit form which removes the enclosure (including front panel) and display. The advantage of the OEM kit is that it minimizes the space necessary for data acquisition and provides a manufacturer with the parts necessary to capture signals and perform first-level analysis using a set of printed circuit boards and power supply. These can be packaged inside an enclosure under the OEM's brand name.

Designers of integrated test systems frequently require a good front-end stage with amplifier/attenuator, fast analog-to-digital conversion, high-speed memory, and a processor to compute answers or handle data transfer to a higher-level processor. The 9300 series OEM kits provide these features beginning with BNC inputs for the signals through to IEEE-488 or RS-232-C ports. The designer can create his own enclosure to optimize space utilization and air flow for cooling within the system.

When to Consider 9300 Series OEM Kits

Designers of products as diverse as cable testing systems and time-of-flight mass spectrometers use LeCroy 9300 series OEM kits as the front-end data acquisition for their product. Also, test engineers who need to configure test sets used internally for their own manufacturing lines can choose to use OEM kits to save rack space. In both cases, acquiring LeCroy technology for data acquisition and fast, first-level analysis allows the product/test set to come to market much faster than designing it internally, and the customer benefits from LeCroy's experience in fast data acquisition.

The choice of an OEM kit rather than purchase of a 9300 series digital scope should be made in cases where 25 or more systems will be manufactured with the same data acquisition requirement. Other considerations are the cost savings due to reduced space requirements, the ability to prevent the user from changing the test setup through the scope front panel (i.e. forcing the control interface to be through the OEM's computer software), and the ability to have a single brand name on the system. There is also a slight cost savings in the purchase of OEM kits compared to the price of a complete oscilloscope. However, the purchase of an OEM kit commits the customer to integrate the kit within the overall system, which includes designing an enclosure and providing cooling. In cases where a standard digitizer/analyzer is desired in a compact package, LSA1000 *Signalyst* is also available from LeCroy. LSA1000 is a high-speed signal analyzer in a 19" rackmount enclosure. Please see our LSA1000 section for more information.

Specifications

The operating characteristics of a 9300 series OEM kit are the same as those of the oscilloscope from which the kit is made, except that all commands must be via remote control (there is no front panel). For example, the specifications of a 9350C-OEM kit are the same as for the 9350C digital oscilloscope. The designer needs to make sure that appropriate shielding is placed between the data acquisition section of the OEM kit and any other electronics in the system that generate noise and that a fan is supplied to remove heat. Essentially, the electronic operating characteristics of the OEM kits are the same as for the scopes listed in this catalog, but the physical characteristics (size and weight) are reduced.

Power Supply

The power supply provided with the 9300 series OEM kits supplies +/- 5.2 volts and +/- 15.0 volts. There is an output adjustment range of approximately 5%. The output set point tolerance under maximum load is typically +/- 50 mv on the 5.2 volt supplies and 100 mv for the 15 volt supplies. Regulation is to within +/-1% of nominal voltage on all outputs under all conditions of rated load, input voltage or frequency, and operating temperature.

The input of the power supply is a 90-264 VAC universal input. The power supply will configure itself automatically for 115 or 230 VAC. Input frequency can be 45 to 66 Hz.

Environmental Characteristics of OEM Kits

9300 series OEM kits are designed to meet MIL-STD-810D procedures and MIL-T-28000C paragraph 4.5.5.4.2.

High Temperature: non-operating, 48 hours at 40°C (104°F); operating, 2 hours at 50°C (122°F)

Low Temperature: non-operating, 24 hours at -50°C (-58° F); operating, 2 hours at 0°C (32°F).

Humidity: to 75% at 50°C

Vibration: tested for "truck", "aircraft" and "military" test cycles.

Shock: 30 G's peak, duration 12 msec, 3 times non-operating.

Parts Included

93xx motherboard: 2 or 4 input channels with amplifier, sample and hold, ADC and acquisition memory.

93xx processor board: 32 MHz 68030/68882 with 4-16 Mbytes processing RAM (upgradable to 64 Mbytes).

93xx I/O board: Includes IEEE-488 (GPIB) and RS-232-C ports

Power Supply
Each kit contains a power supply suitable for supplying well-regulated DC power to the PC subassemblies for the OEM Kit.

The exact part numbers of the PC boards and power supply vary depending on which OEM kit is desired. A variety of connection hardware is also supplied. Full parts list, mechanical drawings and schematics are available.

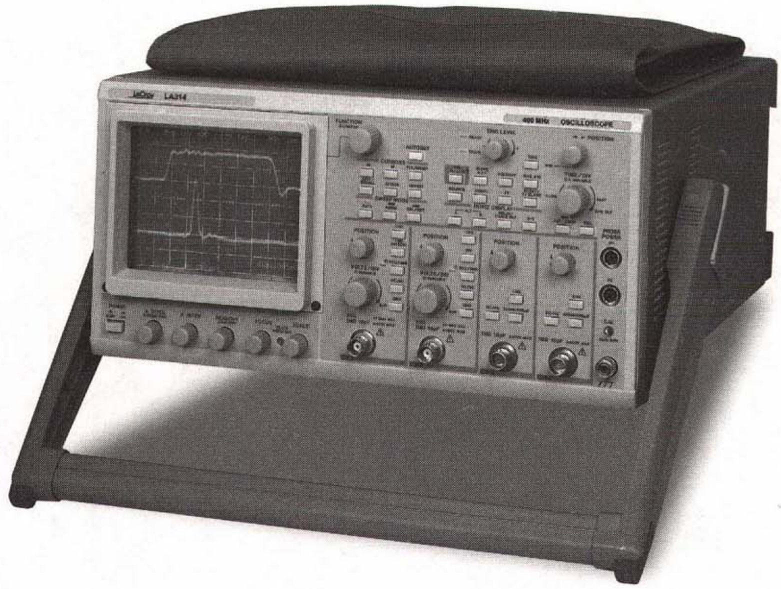
Weight: Approximately 5 kg (11 lbs).

Cooling: The air flow through the main board heat sinks should be at least 49 CFM (84 m^3/h) and through the power supply 45 CFM (76 m^3/h).

Ordering Information

Consult your nearest LeCroy sales office to obtain ordering information on 9300 Series OEM kits. See pages 256-257 for worldwide sales office locations.

LeCroy Analog Oscilloscopes



Some specific measurement problems can be easily solved with analog oscilloscopes, they are:

- ***Viewing of modulation effects***
- ***Viewing low rep-rate events on repetitive signals***
- ***Viewing of relative frequency content in mixed and overlayed signals***
- ***Viewing signals requiring the fastest screen update rate***

To better serve our customers with these unique measurement needs, LeCroy has added 3 high performance analog oscilloscopes to our spectrum of offerings.

Analog Oscilloscopes have measurement and display characteristics that provide specific information, otherwise difficult to obtain.

Grey Scale and Persistence
Analog Displays show faster signals fainter than slower signals. This is referred to as **Grey Scaling**.

Grey scaling gives important information about the relative presence of slow and fast signals when analyzing mixed or overlayed signals as in video waveforms, or disk drive head signals.

Analog displays show slow, non-repetitive events fading until they are dimmer than the rest of the waveform. This is referred to as **Persistence.**

Persistence provides critical information when evaluating and debugging complex analog and mixed signal designs, such as switching power supplies.

Real Time Display
With Analog Oscilloscopes there is minimal dead time between acquisitions.

The analog display responds instantly to changing signal conditions. Therefore analog scopes can trigger on many more waveforms/sec than a digital scope and enables you to see waveform behavior in real time.

Ultra High Writing Speed Analog Scope with Variable Persistence.

Based on a unique scan converter technology, LeCroy offers an analog variable persistence oscilloscope with a visual writing speed of 5 div/ns. This is the fastest analog storage product available in today's market.

The LA354 combines a scan converter tube with a TFT-color LCD screen, providing an update rate of 1 million times per second.

Applications
Analog oscilloscopes and variable persistence scopes are very useful in applications involving real time adjustments, tweaking and glitch hunting, such as:

- Modulated signals in general
- Video, especially VCRs and TVs
- Data Recording for finding servo anomalies, glitches and intermittent phenomena in the disk-drive head
- Eye patterns (for DVD) in optical disk measurements
- Wide-bandwidth noise measurements on magneto-optical disks
- Radar/Lidar burst signals measurements
- Eye pattern measurements on ATM 155 Mbps signals
- Very fast low rep-rate or single shot signals, such as pulsed lasers, particle detectors

LA314H
LA314

Main Features

- *470 & 400 MHz*
- *4 Channels, 10 Traces*
- *Up to 500 ps/div Time Resolution*
- *High-Speed Auto Setup*
- *Cursor Measurements*
- *Event and Burst Trigger Modes*
- *Full TV Trigger with Clamping*
- *Save and Recall Panel settings*
- *Frequency Counter*
- *High-Input Offset Range*
- *High-Intensity CRT*
- *Power for FET Probes*

With four channels and 470 MHz bandwidth, these leading-edge analog oscilloscopes offer the highest level of performance available today.

Analog oscilloscopes offer unique benefits in solving specific measurement problems. The analog display provides important clues on relative frequency content of signals mixed together and the occurrence of low rep-rate events on repetitive signals. The LA314's meshless CRT effectively displays these "grey scaling" and "persistence" effects, and its ultrafast display update rate lets you see how the waveforms behave in real time.

The standard multipurpose trigger, wide-input offset range, comprehensive cursors and counter make the LA314s truly universal oscilloscopes.

Typical Applications

- Video, especially VCRs and TVs
- Data recording, finding servo anomalies, glitches and intermittent phenomena in disk-drive head signals
- Eye patterns (for DVDs) in optical disk measurements
- Wide-bandwidth noise measurements on magneto optical disks
- Radar/Lidar burst measurements
- Eye pattern measurements on ATM 155 Mbps signals

Features

DC - 470 MHz, 4-CH, 10 traces
Four channels up to 470 MHz are available, with CH1 and CH2 boasting the widest frequency range with highest sensitivity (2 mV/div). The fastest sweep speed is 500 ps/div.

Input offset function
Suitable for the observation of small signals superimposed on large signals. The DC input offset function features an offset equivalent to ±500 div. max, which can be applied to CH1 or CH2.

Counter measurement function
Built-in 5-digit counter for frequencies up to 470 MHz.

Save/Recall up to 256 panel settings
Just turn the FUNCTION knob to recall panel setups. Stores up to 256 settings in memory.

Power for FET Probe
Dedicated power supplies for 2 FET probes. Controls DC offset voltage of each probe as well.

TV/HDTV Synchronization
TV triggering is available for NTSC, PAL (SECAM), and HDTV. Field (EVEN, ODD, BOTH) and line select functions are included.

TV Clamp Function
Easy observation of TV video signals with fluctuating average voltage. Back porch level of composite signals is fixed to ground level for display.

Specifications

Display

CRT: 6-inch rectangular, internal graticule (8 x 10 div) meshless CRT.
Accelerating voltage: Approximately 20 kV.

Vertical Deflection System

Mode: CH1, CH2, CH3, CH4, ADD (CH1 + CH2), ALT, CHOP
Channel 1, 2 Sensitivity: 2 mV/div - 5 V/div ±2%, 11 step (1-2-5).
Fine Adjuster: 2 mV/div - 12.5 V/div continuously variable.
Bandwidth (-3dB):
Model LA314H
470 MHz (5 mV/div - 50 mV/div)
440 MHz (2 mV/div, 100 mV/div - 5 V/div)
Model LA314
400 MHz (2 mV/div - 5 V/div)

BW limiter: 20 MHz and 100 MHz selectable.
VSWR: Less than 1.35:1 over DC - 400 MHz (with 50 Ω input)

Risetime:
Model LA314H
Approx. 745 ps @ 20 mV/div.
Model LA314
Approx. 875 ps.

Input coupling: AC, DC, GND
Input RC: Hi-Z input: 1 MΩ ±1.5%//16 pF ±2 pF; Lo-Z input: 50 Ω ±1%.
Maximum input voltage: 1 MΩ input: ±400 V max.; 50 Ω input: 5 V RMS
Polarity switching: CH2 only.
Probe sensors: 1:1, 1:10, 1:100 detection possible.
Offset voltage variable range:
Offset voltage / Vertical axis range
±1 V / 2 mV/div - 50 mV/div
±10 V / 0.1 V/div - 0.5 V/div
±100 V / 1 V/div - 5 V/div

Channel 3, 4 Sensitivity: 100 mV, 500 mV/div
Accuracy: ±3% (+10°C - +35°C)
Bandwidth (-3 dB): 400 MHz
Risetime: Approx. 875 ps (bandwidth x rise time = 0.35).
Input coupling: AC, DC
Input RC: Direct: 1 MΩ ±1.5%// 16 pF + 3 pF.
Maximum input voltage: ±400 V max
Probe sensors: 1:1, 1:10, 1:100 detection possible.

Triggering

A Triggering

Sources: CH1, CH2, CH3, CH4
Coupling: AC, DC, HF-REJ, LF-REJ
Polarity: ±
TV sync - Line selection:
NTSC: 1 - 525H
PAL (SECAM): 1 - 625H
HDTV: 1 - 1125H

B Triggering

Sources: CH1, CH2, CH3, CH4, LINE
Coupling: AC, DC, HF-REJ, LF-REJ
Polarity: ±
Event Delay:
Count: Setting range: 1 - 65535 maximum count freq.: 50 MHz
Burst: Time setting range: 0.15 µs - 9.99 s
Auto setup: Input channels: CH1, CH2, Freq. range: 50 Hz - 100 MHz

Horizontal Deflection System

Horizontal Display A, ALT, B, X-Y

A sweep
Mode: AUTO, NORM, SINGLE
Sweep time: 5 ns/div - 500 ms/div ±2%, 25-step (1-2-5), Fastest sweep time: 500 ps/div, Fine adjuster: 5 ns/div - 1.5 s/div.
B sweep
Delay:
Triggered delay: CH1, CH2, CH3, CH4
Continuous delay: B delayed by A
Sweep time: 5 ns/div - 20 ms/div ±2%, 21 step (1, 2, 5)
Delay time range: 0.2 div - 10.2 div;
Accuracy: + (setting value x 0.005) + (sweeptime x 0.1) -55 ns
Magnifier (MAG): 10 times
Accuracy: ±5% (+10°C - +35°C)
X-Y Operation
X axis: CH1

Y axis: CH1, CH2, CH3, CH4, ADD
Accuracy: ±2% (+10°C - +35°C)

CH2 Out

Output voltage: 20 mV/div ±30%
Frequency output: DC - 200 MHz (50 Ω load)
Output resistance: 50 Ω ±20%

Utilities

Save/Recall Function
Number of panel setups: 256 max

Comments: 12 characters max.

Modulation (Z-axis)

Minimum modulation voltage: 0.5 Vp-p
Polarity: Positive (dark)/negative (bright).
Frequency range: DC - 5 MHz
Max. input voltage: 40 V

Calibrator

Waveform: Square
Repetitive frequency: 1 kHz
Accuracy: ±0.1%
Output voltage: 0.6 V
Accuracy: ±1%

Power for FET probes

Voltage: 2 each +12 V outlets for 2 FET probes, offset control available.

Counter

Display digits: 5 digits shown at all times.
Accuracy: ±0.01%
Frequency measurement range:
2 Hz - 400 MHz on LA314
2 Hz - 470 MHz on LA314H

Cursor Measurement

Voltage axis: 2
Time axis: 2
Time difference: ΔT
Voltage difference: ΔV
ΔT & ΔV can be simultaneously measured.

Power

Voltage range: AC 90 V - 250 V
Frequency range: 48 Hz - 440 Hz
Power consumption: 120 VA max

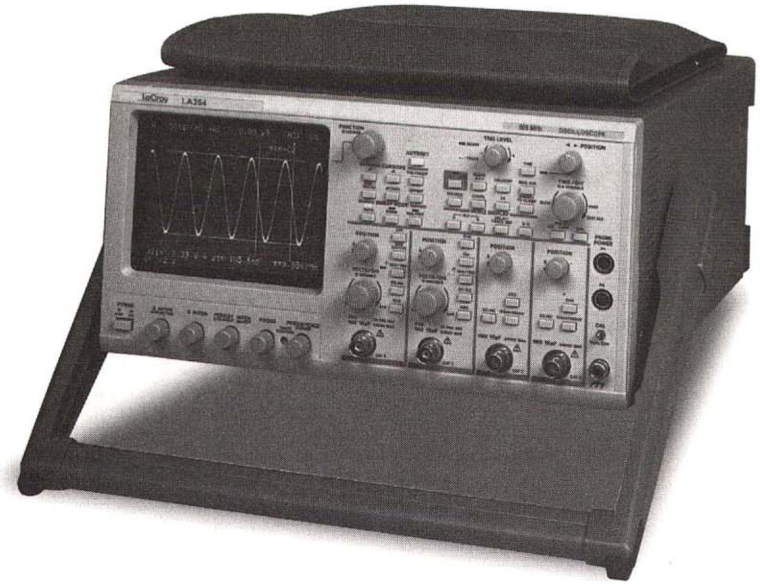
Dimensions and Weight

Approx. (WDH) 320mm x 160mm x 420mm
Weight: approx. 8.5 kg (19.8 lbs)
Warranty: Three years

LA314 SERIES ORDERING INFORMATION

ANALOG OSCILLOSCOPES:	PRODUCT CODE	PRICE
470 MHz, 4-Channel Analog Oscilloscope	LA314H	$ 8,000
400 MHz, 4-Channel Analog Oscilloscope	LA314	7,200
Included with Standard Configuration:		
2 each 10:1 10 MΩ Passive Probes	PP005	175
Operators Manual		
Panel Cover		
Accessory Pouch		
Power Cable		
2 Fuses		
ACCESSORIES		
800 MHz FET Probe	SFP-4A	1,175
1 GHz FET Probe	SFP-5A	1,675
Calibrator for LA314/H Series	IE-1066	225
NIST Calibration for LA314 Series	LAXXX-CCNIST	225
MIL Standard Calibration for LA314 Series	LAXXX-CCMIL	325

LA354 Analog Oscilloscope



Main Features

- *500 MHz Bandwidth*
- *Writing Speed 5 div/ns*
- *Variable Persistence Storage*
- *Timebase Dual Delay*
- *4 Channels*
- *High-Speed Autosetup*
- *Cursor Measurements*
- *Event and Burst Trigger Modes*
- *Full TV Trigger with Clamping*
- *Save and Recall Panel Settings*
- *Frequency Counter*
- *High-Input Offset Range*
- *High Intensity CRT*
- *Power for FET Probes*

With four channels and 500 MHz bandwidth, these leading-edge analog oscilloscopes offer the highest level of performance available today.

Analog oscilloscopes offer unique benefits in solving specific measurement problems. The analog display provides important clues to relative frequency content of signals mixed together or the occurrence of low rep-rate events on repetitive signals. The LA354's scan-converter tube, combined with a TFT-color LCD screen, effectively displays and stores these "grey scaling" and "persistence" effects with up to 5 div/ns writing speed, and it's ultrafast display update rate lets you see how the waveforms behave in real time.

The standard multipurpose trigger, wide input offset range, comprehensive cursors and counter make the LA354 a truly universal oscilloscope.

Typical Applications

- HDTV Applications
- Data recording, finding servo anomalies, glitches and intermittent phenomena in disk-drive head signals
- Pulsed laser related measurements
- Radar/Lidar burst measurements
- Eye pattern measurements

FEATURES

DC - 500 MHz, 4-CH
Four channels up to 500 MHz are available, with CH1 and CH2 boasting the widest frequency range with highest sensitivity (2 mV/div). The fastest sweep speed is 500 ps/div.

Ultra-High Writing Speed
With a visual writing speed of 5 div/ns and a display update of 1 million times per second, the LA354 is the fastest analog storage oscilloscope available, thanks to it's unique scan converter tube technology.

Timebase Dual-Delay Function
Permits simultaneous "zoom" examination of two separate portions of a waveform in real time.

Input offset function
Suitable for the observation of small signals superimposed on large signals. The DC input offset function features an offset equivalent to ±500 div. max, which can be applied to CH1 or CH2.

Counter measurement function
Built-in 5-digit counter for frequencies up to 500 MHz.

Save/Recall up to 256 panel settings
Just turn the FUNCTION knob to recall panel setups. Stores up to 256 settings in memory.

Power for FET Probe
Dedicated power supplies for 2 FET probes. Controls DC offset voltage of each probe as well.

TV/HDTV Synchronization
TV triggering is available for NTSC, PAL (SECAM), and HDTV. Field (EVEN, ODD, BOTH) and line select functions are included.

TV Clamp Function
Easy observation of TV video signals with fluctuating average voltage. Back porch level of composite signals is fixed to ground level for display.

SPECIFICATIONS

DISPLAY

Storage CRT: 5.5-inch TFT LCD rectangular, internal graticule (8 x 10 div).
Accelerating voltage: Approximately 20 kV

VERTICAL DEFLECTION SYSTEM

Mode: CH1, CH2, CH3, CH4, ADD (CH1 + CH2), ALT, CHOP
Channel 1, 2 Sensitivity: 2 mV/div - 5 V/div ±2%, 11 step (1-2-5)
Fine Adjuster: 2 mV/div - 12.5 V/div continuously variable
Bandwidth (-3 dB): 500 MHz (2 mV/div - 5 V/div)
BW limiter: 20 MHz and 100 MHz selectable
VSWR: Less than 1.35:1 over DC - 400 MHz (with 50 Ω input)
Rise time: Approx. 700 ps @ 20 mV/div
Input coupling: AC, DC, GND
Input RC: Hi-Z input: 1 MΩ ±1.5%//16 pf ±2 pf, Lo-Z input: 50 Ω ±1%
Maximum input voltage: 1 MΩ input: ±400 V max., 50 Ω input: 5 V RMS
Polarity switching: CH2 only
Probe sensors: 1:1, 1:10, 1:100 detection possible
Offset voltage variable range: Offset voltage / Vertical axis range
±1 V / 2mV/div - 50 mV/div
±10 V / 0.1 V/div - 0.5 V/div
±100 V / 1 V/div - 5 V/div
Channel 3, 4 Sensitivity: 100 mV, 500 mV/div
Accuracy: ±3% (+10°C - +35°C)
Bandwidth (-3 dB): 500 MHz
Rise time: Approx. 700 ps
Input coupling: AC, DC
Input RC: Direct: 1 MΩ ±1.5%// 16 pF + 2 pF
Maximum input voltage: ±400 V max
Probe sensors: 1:1, 1:10, 1:100 detection possible

TRIGGERING

A Triggering

Sources: CH1, CH2, CH3, CH4, Line
Coupling: AC, DC, HF-REJ, LF-REJ
Polarity: ±
TV sync - Line selection:
NTSC: 1 - 525H
PAL (SECAM): 1 - 625H
HDTV: 1 - 1125H

B Triggering

Sources: CH1, CH2, CH3, CH4
Coupling: AC, DC, HF-REJ, LF-REJ
Polarity: ±
Event Delay: Count: Setting range: 1 - 65535 (maximum count freq.: 50 MHz) Burst: Time setting range: 0.15 μs - 9.99 s
Auto setup: Input channels: CH1, CH2, Freq. range: 50 Hz - 100 MHz

HORIZONTAL DEFLECTION SYSTEM

Horizontal Display A, ALT, B, X-Y

A sweep
Mode: AUTO, NORM, SINGLE
Sweep time: 5 ns/div - 500 ms/div ±2%, 25-step (1-2-5), Fastest sweep time: 500 ps/div, Fine adjuster: 5 ns/div - 1.5 s/div

B sweep
Delay:
Triggered delay: CH1, CH2, CH3, CH4
Continuous delay: B delayed by A
Sweep time: 5 ns/div - 20 ms/div ±2%, 21 step (1-2-5)
Delay time range: 0.2 div - 10.2 div;
Accuracy: + (setting value x 0.005)
+ (sweeptime x 0.1) -55 ns

Magnifier (MAG): 10 times
Accuracy: ±5% (+10°C - +35°C)

X-Y Operation
X axis: CH1
Y axis: CH1, CH2, CH3, CH4, ADD
Accuracy: ±2% (+10°C - +35°C)

CH2 Out

Output voltage: 20 mV/div ±30%
Frequency output: DC - 200 MHz (50 Ω load)
Output resistance: 50 Ω ±20%

Utilities

Save/Recall Function

Number of panel setups: 256 max
Comments: 12 characters max

Modulation (Z-axis)

Minimum modulation voltage: 0.5 Vp-p
Polarity: Positive (dark)/negative (bright)
Frequency range: DC - 5 MHz
Max. input voltage: 40 V

Calibrator

Waveform: Square
Repetitive frequency: 1 kHz
Accuracy: ±0.1%
Output voltage: 0.6 V
Accuracy: ±1%

Power for FET probes

Voltage: 2 each +12 V outlets for 2 FET probes, offset control available

Counter

Display digits: 5 digits shown at all times
Accuracy: ±0.01%
Frequency measurement range: 2 Hz - 500 MHz

Cursor Measurement

Voltage axis: 2
Time axis: 2
Time difference: ΔT
Voltage difference: ΔV
ΔT & ΔV can be simultaneously measured

Power

Voltage range: AC 90 V - 250 V
Frequency range: 48 Hz - 440 Hz
Power consumption: 150 VA max.

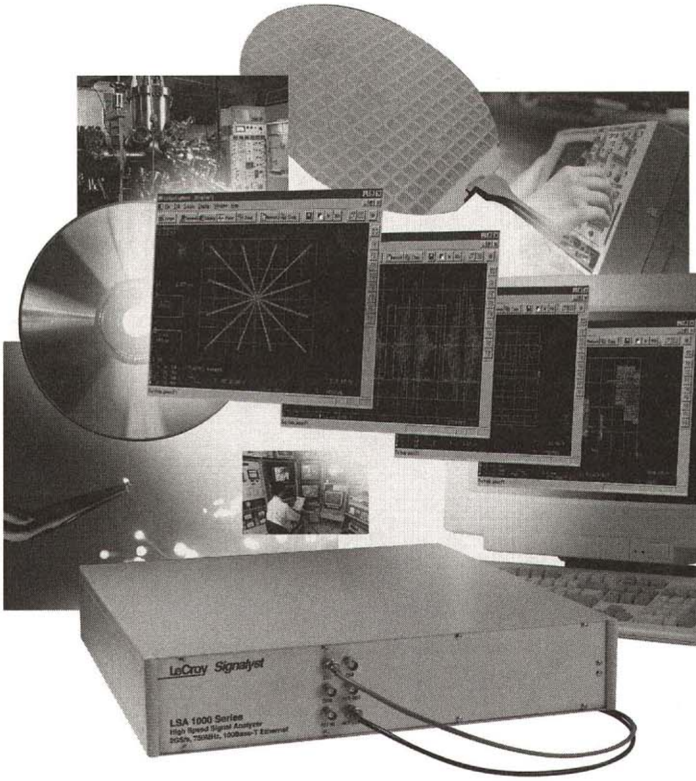
Dimensions and Weight

Approx. (WDH) 320mm x 160mm x 420mm
Weight: approx. 8.5 kg (19.8 lbs)
Warranty: 3 Years

LA354 SERIES ORDERING INFORMATION

ANALOG OSCILLOSCOPES:	PRODUCT CODE		PRICE
500 MHz, 4-Channel Analog Storage Oscilloscope	LA354	$	12,495
Included with Standard Configuration:			
2 each 10:1 10 MΩ Passive Probes	PP005		175
Operators Manual			
Panel Cover			
Accessory Pouch			
Power Cable			
2 Fuses			
ACCESSORIES			
800 MHz FET Probe	SFP-4A		1,175
1 GHz FET Probe	SFP-5A		1,675
NIST Calibration for LA314 Series	LAXXX-CCNIST		225
MIL Standard Calibration for LA314 Series	LAXXX-CCMIL		325

Signalysis: Bringing LeCroy's High-Speed Signal Analysis to Your System



Main Features

- *750 MHz Bandwidth*
- *2 GS/s on One Channel*
- *1 GS/s on Two Channels*
- *100 Base-T Fast Ethernet Interface*
- *Acquisition Memory to 4 Mpoints*
- *More than 50 Built-in Waveform Parameters, Plus Standard and Custom Waveform Analysis Software Packages*

Introducing the Signalysis Business

LeCroy has a long tradition of technical leadership in high-speed, complex electronic signal acquisition and analysis. LeCroy has made many breakthroughs over the years, including the industry's fastest digitizers and longest acquisition memories. The Signalysis Business Unit has been established to provide LeCroy's expertise to system designers and OEM customers.

Designers of integrated test systems or other instrument systems frequently require a good front-end stage with amplifier/attenuator, fast analog-to-digital conversion, high-speed memory, and a processor to compute answers or handle data transfer. By tapping into LeCroy's technologies, system designers can substantially reduce time, cost, and risk of developing new systems for fast data acquisition and analysis.

With *Signalysis*, you will be working with a:

- Technology leader in complex data acquisition and analysis.
- Business partner responsive to your needs.

LSA1000

LeCroy's LSA1000 *Signalyst* is a 2 GS/s waveform digitizer which brings the fidelity of LeCroy's Digital Oscilloscopes to embedded applications. Its onboard PowerPC processor maximizes measurement throughput and accelerates waveform analysis and computation. Acquired waveforms are transferred to computer via 100 Base-T Fast Ethernet. LSA1000 maintains the integrity of your analog signals while digitizing and analyzing them in the shortest possible time.

✓ High Throughput
✓ Easy to Use
✓ Powerful Analysis

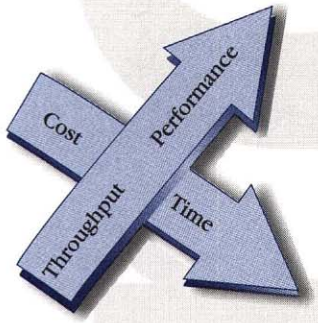
Solutions to Challenging Problems

Today's systems designers and test engineers face major challenges in high-speed signal acquisition and analysis. While real-world signals remain predominantly analog, signal acquisition and analysis must be performed in the digital domain. The process must be fast, accurate, and cost-effective. This challenge requires fast digitizing of complex waveforms, followed by intensive calculations. Results must be communicated to the computer rapidly and must be correlated with design validation or even field-service tests. Meanwhile, test budgets are under constant pressure.

With its design optimized for measurement throughput and its low system overhead, LeCroy's LSA1000 provides a packaged solution at an unmatched price. The onboard 96 MHz PowerPC Processor maximizes throughput, while minimizing loading of your system's computer and busses. LSA 1000's 19" rack-mount form factor integrates easily into most environments and provides a cost-effective solution, even for low channel-count applications.

APPLICATIONS

- High Throughput Automated Test Systems
- Analysis of Fast, Complex Waveforms
- Multi-Channel Data Acquisition Systems
- Signal Analyzers and Processors



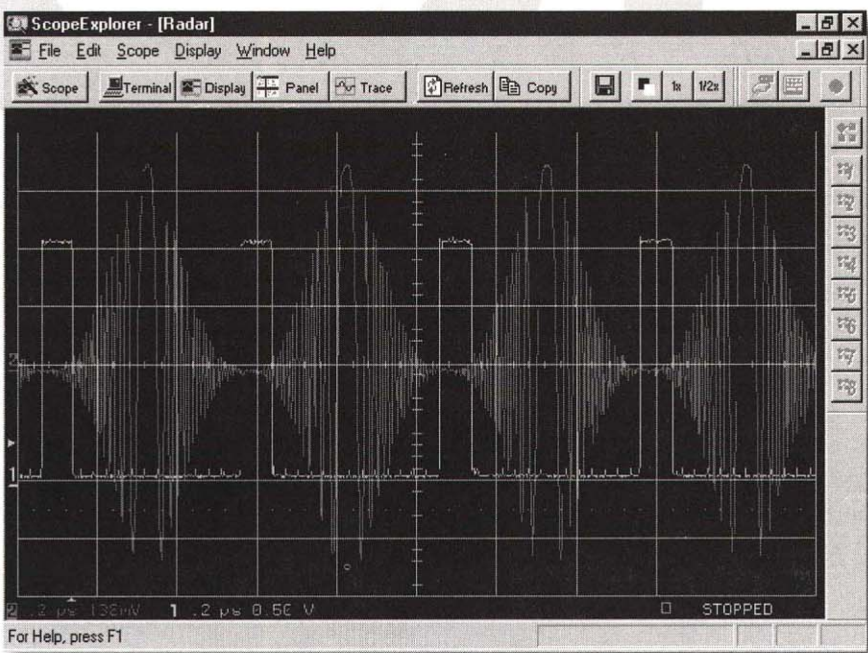
OPTIMIZED FOR HIGH THROUGHPUT

LSA1000 is optimized for high throughput in all phases of signal acquisition and analysis.

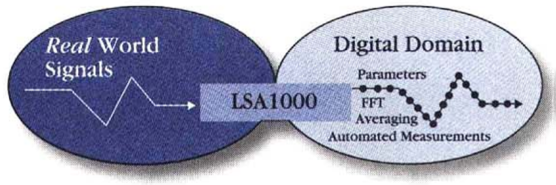
- **Data Acquisition**
  With up to 4 Mbytes on one channel, 1 GS/s sampling can be maintained for up to 4 ms of data. This maximizes waveform capture without costly interruptions.
- **Data Analysis**
  A PowerPC processor performs advanced waveform analysis that otherwise has to be processed by the host computer. This local analysis means faster system throughput as data transfer time is drastically reduced.
- **Data Transfer**
  100 Base-T Fast Ethernet interface ensures easy, standard connectivity to the computer with fast data transfer rate.

EASE OF INTEGRATION

LSA1000 offers the time-to-market advantages of a standard module with the simplicity of a true industry- standard interface. It is as easy to integrate as a network printer. It includes a driver for National Instrument's LabWindows/CVI, industry-standard test development software. LabWindows/CVI provides an integrated software environment where an engineer can easily exercise 100% of LSA1000's functionality. In addition, LeCroy can provide standard and custom software to smooth your integration path.



LeCroy ScopeExplorer is another easy tool to connect with Windows 95 or Windows NT PC.



LeCroy's FASTRACK Program provides qualified OEMs with the assistance they need to get their designs to market quickly. We provide systems integration assistance, data acquisition and analysis advice, and applications engineering to maximize throughput of your measurements.

All LSA1000s come with a 3-year warranty, valid in the specified destination country. Depending on your requirement, LeCroy can provide warranty and calibration support worldwide.

Leverages Familiar Industry Standards

- Fast Ethernet Interface
- Windows NT/95 support
- LabWindows/CVI driver

POWERFUL ANALYSIS TOOL

LSA1000 provides the same powerful waveform analysis capability as LeCroy digital oscilloscopes. Its onboard firmware handles advanced waveform processing locally, using the same high-level commands as LeCroy DSOs. In addition to standard waveform analysis, advanced packages for FFT, histograms, and communications and disk-drive analysis are also available.

Fast Ethernet

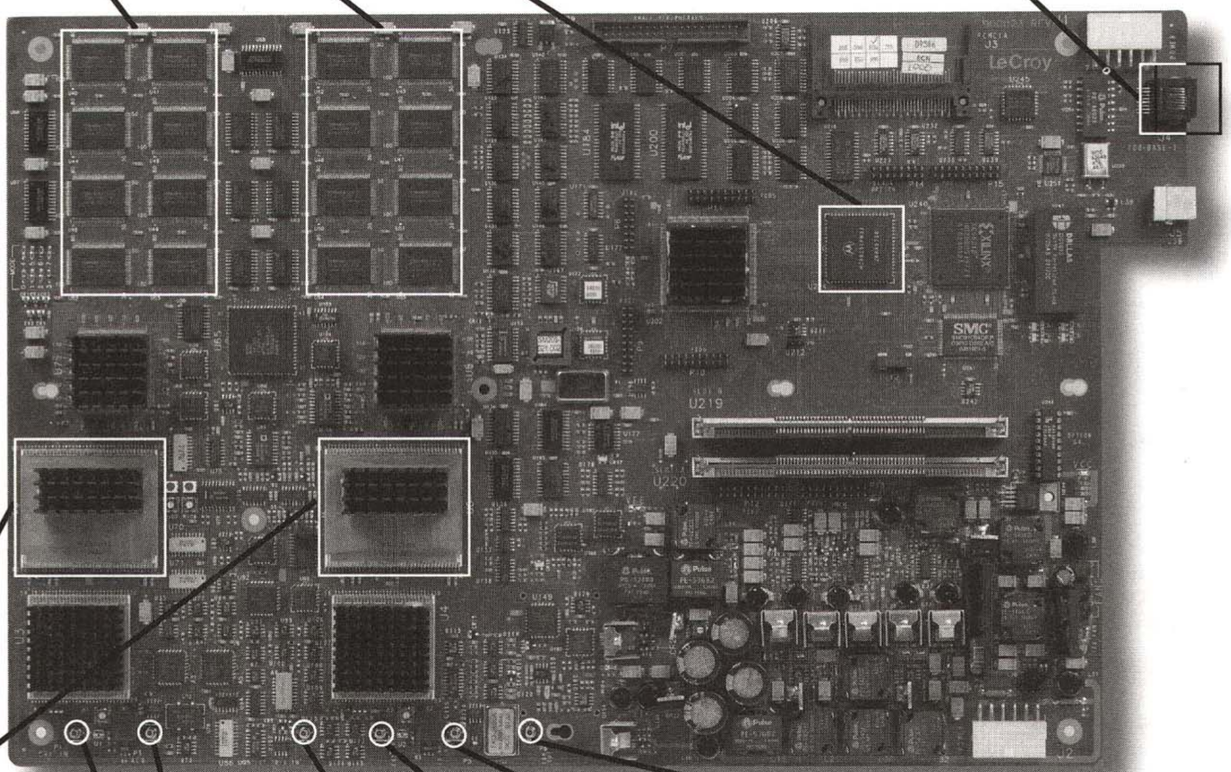
- *100 Base-T Ethernet interface*
- *Maximizes system throughput*
- *Simplifies I/O*

Acquisition Memory

- *Up to 2 Mbytes memory per channel*
- *Interleaved up to 4 MB on 1 channel*

PowerPC

- *96 MHz 603e processor*
- *Provides 25 Mflops of Waveform Calculation power*



Clock Out

Clock In

ADC

- *Two independent 1 GS/s flash ADC*
- *Interleaved for 1 channel at 2 GS/s*

Acquisition Status Out

Ch. 2

Trigger

Ch. 1

LeCroy Custom Solution: From Technology Licensing to Sub-System Development

If your expertise is not in complex waveform acquisition and analysis, LeCroy can help with solutions, ranging from monolithic ICs to full system design. For more information on Custom Solutions Business, please contact LeCroy's Signalysis Business Unit at:
signalysis@lecroy.com

Acquisition System

Bandwidth (-3 dB):
DC to 750 MHz from 100 mV to 7 V Full Scale Range (FSR)
DC to 200 MHz from 20 mV to 80 mV Full Scale Range (FSR)

No. of Channels: 2
No. of Digitizers: 2

Sampling rate:
1 MS/s to 1 GS/s with 2 channels active
2 MS/s to 2 GS/s with 1 channel active.

Sensitivity: 100 mV FSR to 7 V FSR, selectable at time of order. Higher sensitivity achievable with lower bandwidth.

Scale factors: Attenuator selected for proper FSR, adjustable over 10:1 range.

Offset Range: ≥ FSR

DC Accuracy: Typically 1%.

Vertical Resolution: 8 bits (with Option WP01, Enhanced Resolution (ERES) provides up to 11 bits).

Bandwidth Limiters: 200 MHz and 25 MHz*

Input coupling: DC

Input Impedance: 50 Ω ±2%

Max input voltage: 2.5 V rms, and ±5 V peak.

** Bandwidth limit can be customized.*

Acquisition Modes

Single shot: For transient and repetitive signals.

Timebase System

Capture Time Window:

Memory	@1 GS/s	@1 MS/s
100K	0.1 ms	100 ms
500K	0.5 ms	500 ms
1M	1 ms	1 s
2M	2 ms	2 s

Clock Accuracy: ≤10 ppm
External Reference Clock:
10 MHz square wave panel input and output. Input can be used for external clock reference. Output can be used to synchronize multiple units.

Triggering System

Trigger Mode: Single

Trigger Source: Internal (CH1, CH2), External

Slope: Internal: Positive, Negative, Window — External: Positive, Negative

Coupling: DC

Trigger range: Internal: ±100% of Full Scale Range setting.
External: ECL signal swing.

Trigger resolution: ±1 sample or BB ±2 ns whichever is larger.

External trigger max input: 0.0 V to -4.0 V

Pre-trigger recording: 0 to 100% of memory size (adjustable in 1% increments).

Post-trigger delay: 0 to 1,000 times the memory size (adjustable in 1% increments).

Trigger timing: Trigger date and time are available.

Acquisition status output: ECL panel output.

Processing

Microprocessor: 96 MHz PowerPC 603e

System RAM: 16 Mbytes (64 Mbytes optional).

Internal Memory

Waveform memory: Four 16-bit memories .

Processing memory: Four 16-bit waveform processing memories.

Waveform Processing

Up to four processing functions can be simultaneously performed. Standard functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summed Averaging and sine x/x. Optional functions are described below.

Option WP01: Advanced Math:
Average: Summed average of up to 1 million sweeps.

Envelope: Max, Min, or Envelope values of up to 1 million sweeps.

ERES: Low-Pass digital filter effectively provides up to 11 bits of vertical resolution.

Math Functions: Log(e), Log(10), Exp(e), Exp(10), Absolute Value, Reciprocal, Square, Square Root, Integration, Differentiation, Ratio.

Option WP02: Spectrum Analysis
FFT: Spectrum Analysis with five windowing functions and frequency domain averaging (FFT averaging).

Option WP03: Parameter Analysis:
Automatically produce histograms of acquired data or over 40 parameters. Populations of up to 2,000,000 values and up to 2,000 bins are supported. Includes 18 special statistical parameters for analysis of histogram distributions.

Trend: The trend function plots a line graph showing the time sequenced values of a parameter. For example, the propagation delay through a chip could be plotted while varying it's temperature.

Cursor Measurements

Relative time: provides time measurements with resolution of ±0.05% full-scale; resolution to 10% of the sampling interval.

Relative voltage: measures voltage differences up to ±0.2% of full-scale.

Absolute time: measures time relative to the trigger and voltage with respect to ground.

Absolute voltage: measures voltage with respect to ground.

Automated Measurements

The wide range of pulse parameters are available. These include Pulse, Horizontal, and Vertical parameters. Basic statistical measurements of (average, max, min, and standard deviation) can be made on these parameters.

Data Transfer/Remote Control

Remote control: All functions can be controlled remotely through an Ethernet interface.

Ethernet port: 100 Base-T Ethernet.

Ethernet Protocol: TCP/IP

Versatile Instrument Control Protocol (VICP): Protocol that allows communication mediums other than GPIB to emulate much of the behavior of GPIB; Remote command set conforms to the IEEE 488.2 standard to ensure compatibility with existing software.

General

Auto-Calibration: ensures specified DC and timing accuracy; Recommended factory calibration interval: 1 year

Enclosure: 19" rackmount, 2U high

Dimensions: (HWD) 3.5" x 19.5" x 17.5"

Cooling: Internal fans with 200 linear feet per minute airflow.

Temperature: 5° to 40°C (41° to 104°F) rated; 0° to 50°C (32° to 122°F) operating.

Humidity: <80% Non-condensing.

Power: 90-250 V AC, 45-66 Hz, <200 W

MTBF: Calculated 45,000 hrs @35°C per MIL-HDBK-217F.

Warranty: Three years.

FASTRACK: Start-up Assistance Program
The "FASTRACK" program is designed to integrate the *Signalyst* in your system as quickly as possible. The program provides specific assistance with product installation, system setup, configuration. As part of the program, our engineers will visit your site to assist in initial configuration and interfacing and to consult on your specific application. Please contact your local LeCroy representative for help in choosing the appropriate FASTRACK program for your application.

QuickStart Program
This one-day program will ensure correct product installation and interfacing to your controller or network. Data transfer to a correctly configured computer will be demonstrated, and evaluation software installed for your convenience.
Duration: One day

Integration Support Program
This two-day program includes a one-day QuickStart, then integrates the *Signalyst* to your programming environment through the appropriate DLLs or drivers. Communication and control from your software will be established, and programming examples will be reviewed.
Duration: Two days

Ongoing Support Program
In addition to our standard Applications Support (available by phone from 8 am to 8 pm EST), LeCroy will create a custom support program geared to your specific application. Please contact your local LeCroy representative to discuss your requirements.

LSA1000 Ordering Information

Signalysis		Product Code	Price
High-Speed Signal Digitizer/Analyzer		LSA1000-XX	$ 14,950
Standard Configuration			
750 MHz, 1 GS/s, 2 Channel			
100 Base-T Ethernet			
Acquisition Memory	100 K		
Full Scale	1 V*		
Bandwidth Limiters	200 MHz and 25 MHz*		
System Memory	16 Mbytes		
Included with standard configuration			
Operator's Manual		LSA1000-OM	
Remote Control Manual		LSA1000-RCM	
LabWindows/CVI driver		LSA1000-CVI	
LeCroy ScopeExplorer software:		SE01	
NIST Calibration Certificate			
3 Years Warranty			
Mechanical Configuration (-XX)			
Rackmount, Front Panel Connection		LSA1000-01	
Rackmount, Back Panel Connection		LSA1000-02	
Desktop, Front Panel Connection		LSA1000-05	
Desktop, Back Panel Connection		LSA1000-06	

* These specifications can be customized. Please consult the factory for more information.

Instrument Options	Product Code	Price
64 Mbyte System Memory	64MBSM	2,000
Acquisition Memory per Channel		
500 k Memory	LSA1000-M1	1,250
1 Mbyte Memory	LSA1000-M2	2,500
2 Mbyte Memory	LSA1000-M4	5,000
Software Options		
Advanced Waveform Math	WP01	1,250
FFT (Frequency Spectrum Analysis)	WP02	1,250
Parameter Analysis	WP03	1,250
PRML Analysis	PRML	1,250
Basic Disk Drive Measurements (includes WP03)	DDM	3,000
Optical Recording Measurements	ORM	3,000
Disk Drive Failure Analysis	DDFA	4,990
Software Suite		
Choice of any two from (WP01, 02, 03 & PRML)	C2	1,875
Choice of any three from (WP01, 02, 03 & PRML)	C3	2,490
WP01+WP02+DDM	VP1	3,850
WP01+WP02+DDM+PRML	VP2	4,725
DDM+PRML	VP3	3,187
Disk Drive Analyzer Package (DDFA+DDM+PRML)	DDANALYZER	6,990
Optional Power Cords (no charge)		
U.S. power cord	LSA1000-P1 (default)	
European power cord (200 V, 50 Hz)	LSA1000-P2	
UK power cord (240 V, 50 Hz)	LSA1000-P3	
Australian power cord (240 V, 50 Hz)	LSA1000-P4	
North American power cord (240 V, 60 Hz)	LSA1000-P5	
Swiss power cord (220 V, 50 Hz)	LSA1000-P6	
Warranty & Calibration		
MIL STD Calibration	LSA1000-CCMIL	325
Total 5 Year Repair Warranty	LSA1000-W5	545
Total 5 Year NIST Calibration Contract	LSA1000-C5	725
Total 5 Year MIL STD Calibration	LSA1000-CM5	1,125
Total 5 Year Warranty & NIST Calibration	LSA1000-T5	975
Total 5 Year Warranty & MIL STD Calibration	LSA1000-T5/MIL	1,375

Hardware Options-PC Card (PCMCIA) Hard Disk, Internal Printer, ATA Flash & SRAM

Main Features

- ***PC Card Type III Compatible Portable Hard Drive Adapter, DOS Compatible***
- ***High-Resolution Internal Printer, Ideal for Fast, On-the-Spot Documentation***
- ***Ultra-Fast RAM card, DOS Format, Ideal for Pass/Fail testing***
- ***Convenient Hardcopy Storage to Memory Card, Floppy Disk or Portable Hard Drive***

PC Card (PCMCIA) Storage

PC Card Interfaces for IC memory cards, ATA Flash, and portable hard drives allow the use of fast, removable and compact storage media for saving and retrieving waveforms and instrument settings. They comply fully with the PC industry's PC Card and JEIDA standards. With the special Autostore feature, waveforms can be automatically stored after every acquisition and "played back" when desired. When used in combination with the Pass/Fail feature, failure data can be saved automatically for later analysis.

Printer

The internal printer is a valuable tool for instant, on-the-spot documentation. It generates a clear, crisp hardcopy of the screen in just a few seconds. The large size of the printout, combined with its high resolution, provide you with an excellent document that matches the screen's superior quality to show the finest details. Since it frees you from the trouble of carrying and interfacing a bulky printer, it is the ideal solution for field measurements.

The printer also has a landscape mode which allows the printout to be expanded (up to 200 times) for full viewing of all signal details.

A 3.5" Floppy Disk Drive and Centronics printer port are standard on all LeCroy oscilloscopes. They can be added as a field service upgrade to older scopes.

Mass Storage Features and Benefits

LeCroy's mass storage capabilities provide a range of benefits:

- Easy data transfers to PCs
- Waveform data logging
- Waveform archiving for future use
- Faster troubleshooting
- Faster, more reproducible testing
- Shared oscilloscope resources

EASY DATA TRANSFER TO PC

Because LeCroy oscilloscopes use DOS-formatted floppy disks, hard disks and memory cards, transferring waveform data to a PC is simple. The removable storage allows transfers without cables, programming, or any knowledge of GPIB, RS-232, or other interfaces.

In addition, LeCroy provides the facility to convert data from binary to ASCII format. This is very useful for PC-based analysis packages (such as MATLAB, MathCad or other spreadsheets) that require ASCII format.

WAVEFORM LOGGING

By using Glitch or Dropout triggering in combination with the powerful AUTOSTORE mode, LeCroy oscilloscopes can monitor and log intermittent problems automatically. To store a waveform or a function, the oscilloscope opens and names a DOS-compatible file and then stores the waveform data in the file.

This data logging feature requires no operator intervention and retains data and the operational setup in the event of a power line failure. Logged waveforms can be selectively played back either by trigger time/date, by sequence number or can be scrolled through sequentially.

WAVEFORM ARCHIVING FOR FUTURE USE

- Recallable proof of performance
- Additional data analysis as needed
- Accurate trend or drift monitoring
- Calibration procedure verification

When storing waveforms, LeCroy DSOs also archive a header of setup information and the acquisition time/date. After recalling an archived waveform, the several hundred byte header ensures correct time and voltage scaling. When recalled into the oscilloscope, the waveform can be zoom expanded, compared, or analyzed just like a live waveform. The time/date offers proof of measurement authenticity and acquisition sequence.

All LeCroy DSOs store raw waveform data using one byte per sample point. Signal-averaged, Enhanced Resolution (ERES) filtered, and other processed data use two bytes per point to take advantage of the added resolution.

HARDCOPY ARCHIVING

Hardcopies of the screen can also be stored for future use. For instance, a screen saved in TIFF or BMP format can be imported into a word processor to illustrate a report. Additionally, field-measurement screens can be saved in LaserJet format on the memory card or floppy disk and then printed from a PC back in the lab.

FASTER FIELD MEASUREMENTS

Recallable reference waveforms and oscilloscope setups for each test point on a Device Under Test (DUT) can make troubleshooting faster and more accurate. A dedicated memory card or floppy disk will hold all of the correct test point waveforms and associated DSO setups for a particular DUT.

The technician can recall stored setups quickly and consistently, thereby avoiding incorrect measurement conditions. Actual waveforms can then be compared to recalled reference waveforms taken from a known working system, reducing the time spent probing a large number of test points and verifying that the correct waveforms exist.

If a problem is found, the aberrant waveform can be saved. It can later be shown to laboratory-based engineers, for example, for problem-solving guidance or for improvement of DUT design.

IC Memory and ATA Flash cards - rugged and pocket-sized - are ideal for this application.

FASTER, MORE REPRODUCIBLE TESTING

LeCroy oscilloscopes will compare measured waveforms against upper and lower waveshape tolerances or against parameter limits, such as rise-time, overshoot, or peak voltage, and make Pass/Fail decisions. This Pass/Fail testing decreases test times in GPIB-based ATE systems by reducing data transfers. It increases reproducibility and accuracy in manual tests by eliminating human errors.

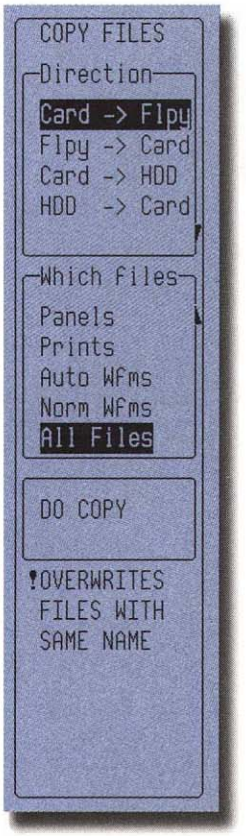
Once defined, these tests may be saved by storing instrument setups which include the specified tolerances and/or reference waveforms. Different test personnel can easily share a common test library via a PC network.

Waveshape test limits can be generated by capturing a "golden" waveform and by then selecting amplitude and timing limits (in fractions of screen graticule divisions). Or a user can create standard waveform limit templates on a computer (e.g. ANSI/CCITT telecommunication templates).

With LeCroy DSOs, specific parameter tolerance test procedures are created by selecting limits for any five out of 20 pulse parameters with Boolean AND/OR conditions between them. During testing, Fail responses can include an audible beep, GPIB SRQ, hardcopy output, or store to memory card.

SHARED OSCILLOSCOPE RESOURCES

By plugging in your personal floppy disk, RAM card, Flash card or PC Card Hard Disk, you can restore your setup in seconds. Individual users can keep preferred setups on separate disks or cards or within separate directories.



A selection of files can be copied between the available mass storage devices

Hardcopy Features and Benefits

The internal printer adds a whole range of benefits to LeCroy 9300C or LC series scopes:

- Ultra-fast printouts
- High-resolution printing
- Easy transportation
- Trouble-free interfacing
- Auto Print on Trigger

Ultra-Fast Printouts

Measurement documentation is made easier and faster, since the internal printer produces a hardcopy in less than 10 seconds. In addition, the document is date- and time-stamped: a real bonus for archiving test results.

High-Resolution Printing

With a resolution of 190 dots-per-inch, the internal printer matches the screen's superior quality. And for even higher resolution, the printout can be stretched to a full 30 meter length so you can see those traces down to their finest details.

Easy Transportation

A printer that is totally integrated in the instrument makes life much easier for field-measurement applications. Imagine carrying a scope, a printer, and a floppy drive, in one hand!

Trouble-Free Interfacing

The internal printer frees you from the struggle with cable schematics, baud rates, gender-changers and dip switches, for more productive tasks. Select the internal printer in the scope's utilities menu, hit the SCREEN DUMP button, and you're in business!

Auto Print on Trigger

The Auto-Print feature is used to print a screen image on each acquisition.

The 9300C and LC series oscilloscopes support a wide range of popular printers. Hardcopies can either be sent directly to the peripheral device or card or hard disk for future use.

Other Hardcopy Solutions

High-quality project reports, presentation materials, technical manuals, and troubleshooting instructions often require integration of text and graphics on the same page.

Advanced PC desktop publishing and word processors such as Microsoft Word or WordPerfect can directly import graphic files, size them, and position them anywhere on the page. Written text can then wrap around or be positioned within the graphics.

LeCroy oscilloscopes will save screens in TIFF or BMP format. After transferring the file to a PC, the desktop publishing software can import and manipulate the document like any other graphic object.

The LeCroy 9300C and LC series DSOs also offer a wide range of interfacing capabilities with external hardcopy devices:

- Printers: HP LaserJet, ThinkJet, PaintJet (including color), DeskJet (including color) and Epson.
- Interfacing: RS-232-C, GPIB, and Centronics ports all standard.

Waveform File

Waveform File size: A channel-trace will use 1 byte per sample plus approximately 360 bytes of waveform descriptor. A processed trace will use 2 bytes per sample.

Template Size:
Approximately 21 kbytes.

Panel Setup Size:
Approximately 3 kbytes.

Printer

Type: Raster printer, thermal.

Resolution: 190 DPI

Printout Size: 126 mm x 90 mm

LCXXX SERIES

	Floppy Disk	RAM Card	Flash Card	Hard Disk
Max. Transfer Rate:	18 kbytes/sec	1.5 Mbytes/sec	300 kbytes/sec	500 kbytes/sec
Typical waveform Transfer Speed (Store/Recall):				
1000 point	1.1 s/0.4 s	20 ms/150 ms	70 ms/60 ms	40 ms/30 ms
10000 point	1.8 s/1.0 s	35 ms/25 ms	120 ms/110 ms	70 ms/50 ms
100000 point	7.5 s/6.5 s	150 ms/150 ms	500 ms/450 ms	400 ms/300 ms
1 Mpoint	57 s/55 s	1 s/1 s	3.5 s/3 s	7.0 s/6.5 s

93XXC SERIES

Max. Transfer Rate:	18 kbytes/sec	500 kbytes/sec	300 kbytes/sec	150 kbytes/sec
Typical Waveform Transfer Speed (Store/Recall):				
1000 point	1.1s/0.4s	40 ms/30 ms	70 ms/60 ms	140 ms/120 ms
10000 point	1.8s/1.0s	70 ms/50 ms	120 ms/110 ms	240 ms/220 ms
100000 point	7.5s/6.5s	300 ms/300 ms	500 ms/450 ms	1.0 s/0.9 s
1 Mpoint	57 s/55 s	2 s/2 s	3.5 s/3 s	7.0 s/6.5 s

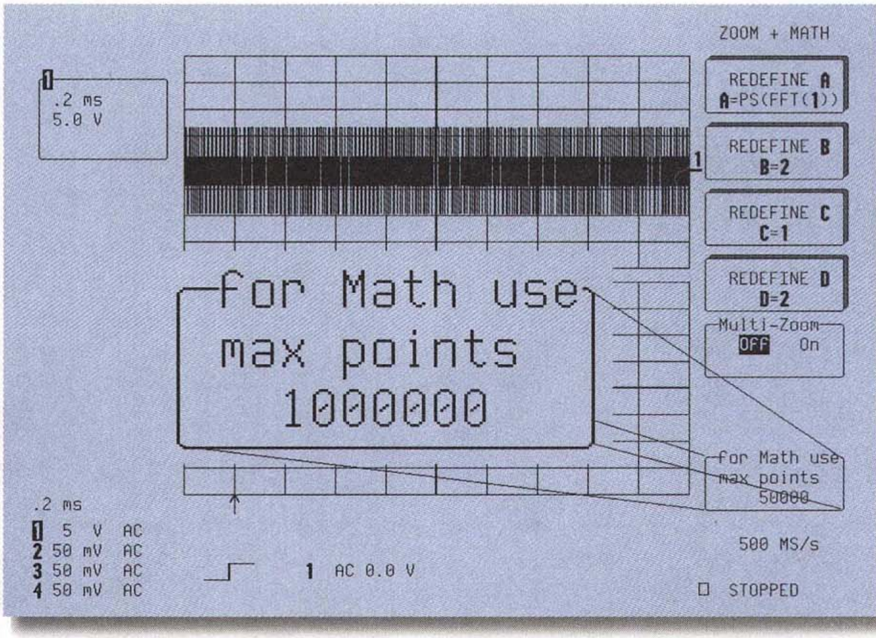
MASS STORAGE SPECIFICATIONS

	Floppy Disk	RAM Card	Flash Card	Portable Hard Disk
Compatibility:	3.5" Floppy Drive	PC Card Type I, II JEIDA 3.0, 4.0	PC Card Type II	PC Card Type III
Supported Formats:	DOS Format	Read/Write: SRAM Read: OTP. ROM. Flash DOS Format	DOS Format	DOS Format
Size:	720 kbyte 1.44 Mbyte	up to 8 Mbytes	up to 175 Mbytes	Supports up to 512 Mbytes

HARDWARE OPTIONS - ORDERING INFORMATION

9300 SERIES HARDWARE OPTIONS:	PRODUCT CODE	PRICE
Graphics Printer Option	GP01	$ 890
Memory Card Reader with 512k card	MC01/04	500
Type III PC Card Slot	HD01	590
Type III PC Card Slot and 170 Mbyte portable hard drive	HDD	990
LC SERIES HARDWARE OPTIONS		
Graphics Printer Option	GP01	890
Memory Card Reader with 512k card	MC01/04	500
Type III PC Card Slot	HD01	590
Type III PC Card Slot and 170 Mbyte portable hard drive	HDD	990
ACCESSORIES		
Type III PC Card External Desktop Adaptor for PC (110 V)	DA01-110	360
Type III PC Card External Desktop Adaptor for PC (220 V)	DA01-220	360

"Mega" Waveform Processing (MWP)



Main Features

- *Up to 64 Mbytes of Processing RAM*
- *High-Speed Processor/Coprocessor*
- *Larger System Memory Extends Math Processing Capacity on Long Waveforms*
- *Waveforms up to 8 Mbytes Can be Read Back into the Oscilloscope*
- *Improved Processing Speed*
- *System Memory is Dynamically Allocated to Traces*
- *Upgrade Older Scopes to New Performance Levels*

Why More Memory?

The example illustrated in the screenshots on the next page clearly demonstrates the advantage of processing memory for the FFT computation. For a given time window and a given acquired record length, more processing memory dramatically expands the frequency spectrum of an FFT.

System Memory

The MWP option increases the standard system memory to 8 MBytes for MWPM and to 16 MBytes for MWPL. Model 930X-64 upgrades memory length to 64 MBytes.

SMARTMemory Allocation

With up to 64MB of system memory, the MWP option dramatically improves the processing power of the machine. And with the SMART Memory allocation, all of this memory can be dynamically dedicated to one demanding task, an FFT for example, freeing up the memory unused by other traces.

Extended Processing

The "No Math on Large Waveforms" message has been consigned to the archives. The MWP option stretches the math processing frontier for digital oscilloscopes. You can now upgrade a 9314AL to average a 1 million point "mega" trace just like a 9314CL, or you can upgrade a 9374CL to perform a 6 Mpoint FFT. MWP also extends the capacity of the oscilloscope's internal memories.

Processor

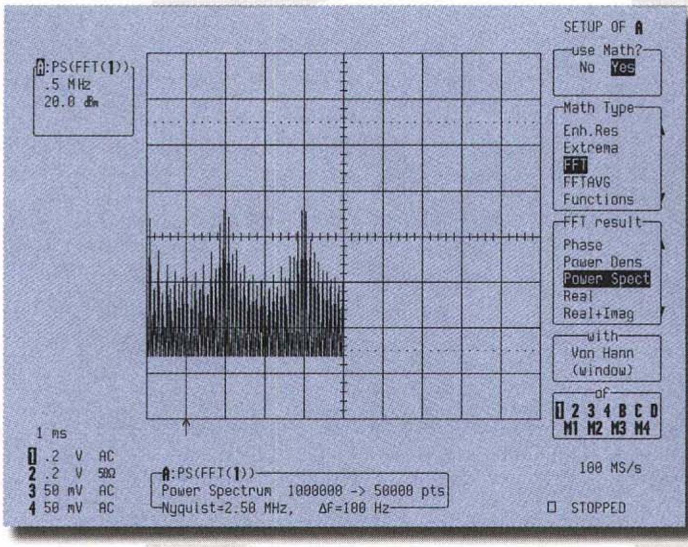
The MWP option also upgrades the 16 MHz 68020/68881 processor system of a 9304A, 9310A, or 9314A, to a 32 MHz 68EC030/68882 system.

Faster Update

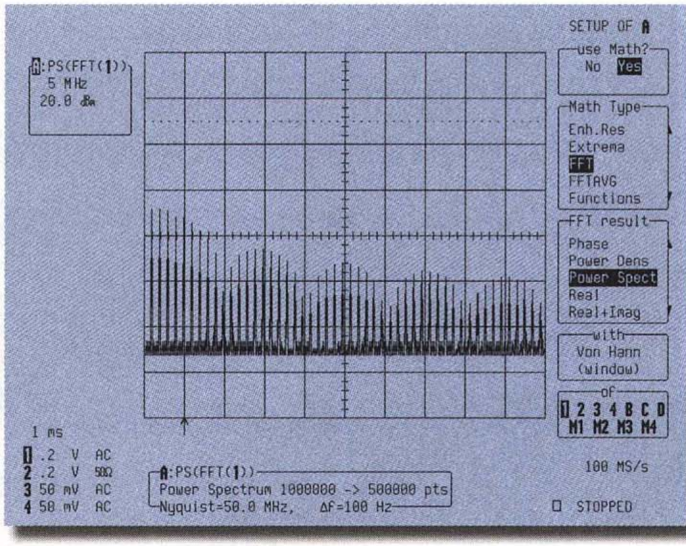
The high-speed processor used in MWP upgrades is the same one installed in the 93XXC Series. It enhances the processing speed of 9304C, 9310C, 9314C and 9320 scopes to yield an essential improvement in the overall DSO response.

New Version Software

The MWP option allows to upgrade 9304A, 9310A or 9314A with new software version 7.2.2



Without MWP option: The FFT processing of a 1 Mpoint record length is limited to 50 k in older scopes; as a result the spectrum is limited to 2.5 MHz.



With MWP option: The same signal processed with a 500 kpoint FFT shows a full spectrum of 50 MHz.

MASS STORAGE SPECIFICATIONS

9304A, 9310A, 9314A

Task Example	Without MWP	With MWP
Retrieve a 1 M waveform saved on a floppy to the scope	Impossible, requires more than 2 Mbyte of memory	Possible
Perform and FFT on a 200k waveform	Possible, by limiting the input points, which also limits the resulting FFT bandwidth	Possible without reducing the input points. The FFT spectrum will cover the full bandwidth
Average 1000-point waveforms at a 100 Hz sweep rate	Impossible for 9304C, 9310C or 9314C scopes, the maximum rate is 80 Hz: some events will be missed	Possible, the maximum rate can actually reach 125 Hz, a 56% improvement

HARDWARE OPTIONS - ORDERING INFORMATION

9300 SERIES - HARDWARE OPTIONS:	**PRODUCT CODE**	**PRICE**
32 MHz 68030/68882 with 8 Mbytes RAM	93XX-MWPM	$ 990
32 MHz 68030/68882 with 16 Mbytes RAM	93XX-MWPL	1,490
64 Mbyte RAM Upgrade	930X-64	3,500
LC SERIES HARDWARE OPTIONS		
64 Mbyte RAM Upgrade for LC Series	LCXXX-64MB	3,500

CKTRIG Hardware Option for the 9350C, 9370C, 9384C & LC Series oscilloscopes

Main Features

- *High-speed 500 MHz External Clock Input*
- *10 MHz External Clock Reference Input*
- *Edge Trigger Comparator Output*
- *BNC, Rear-Panel Mounted Connectors*

External Clock

This feature allows the 9350C, 9370C, 9384C and LC series DSOs to be externally clocked at a fixed rate from 50 MS/s to 500 MS/s, enabling full phase control over the acquired signal. The sample rate can be fine-tuned to the exact speed required by the application.

External Reference

The external reference allows the scope to be phase-synchronized to an external 10 MHz reference, either to match the stability of the external source or to phase lock the acquired signal. Several DSOs can then be synchronized using a simple source as reference.

Trigger Comparator

The trigger comparator outputs a pulse for each valid edge-trigger condition on the trigger signal. This is an invaluable feature for event-counting and throughput applications.

In applications as diverse as capturing radar signals and making advanced measurements on magnetic media using PRML methods, there can be requirements to sample the data at specified frequencies. The 9350C, 9370C, 9384C and LC series scopes have the ability to accept a data sampling clock through the front panel at frequencies up to 100 MS/s. This is applied through the BNC connector that is normally used for the external trigger. The CKTRIG option is for those applications requiring a higher-speed sample clock (up to 500 MS/s) or when the external trigger input is required for triggering the scope.

HARDWARE OPTIONS

External Clock Input

Input signal requirements:

Amplitude: 800 mV p-p

Frequency range: 50 MHz to 500 MHz

Offset: 0 V

Input impedance: 50 Ω

Calibration must be initiated for each external clock change.

The negative pulse width must be less than 5 ns (2 ns recommended).

Swept Clock: Only a fixed-frequency external clock is supported. Swept clocks will cause offset errors (10% worst-case).

External Clock Reference Input

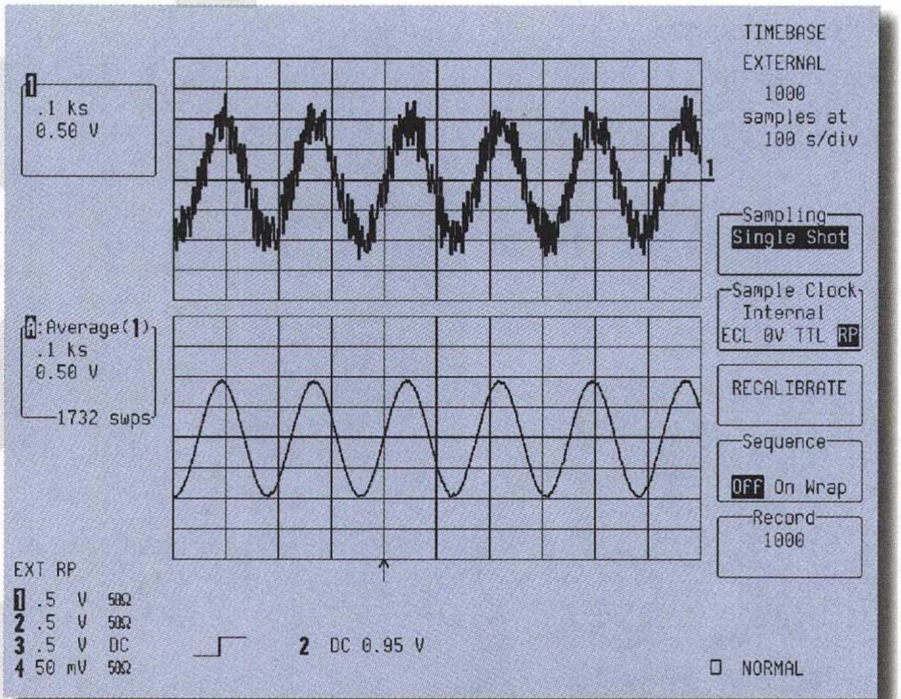
Signal Requirements:

Amplitude: 800 mV p-p

Frequency range: 10 MHz ±5%

Offset: 0 V

Input impedance: 50 Ω



This figure shows how synchronous sampling can eliminate interfering signals. In the picture above, a 455 kHz communications signal with interference and noise is sampled using the Rear Panel ("RP") external sampling clock input available in the CKTRIG option. The top trace shows a single shot of the signal. The interference source has a frequency very near the carrier of the desired signal. The sample clock has been set to be synchronous with the known frequency of the underlying signal. The effects of the noise and interference have been eliminated in the lower trace, which is an average of 1732 acquisitions. The measurement is successful, because the user was able to set the sampling at a frequency where both the noise and interference would average to zero, while the underlying data remained constant.

Trigger Comparator Output

The comparator operates in a 'time-over-threshold' mode and generates a pulse edge of the same polarity as the polarity of the selected triggering edge each time a valid EDGE TRIGGER condition is met on the trigger signal. The duration of the pulse will be equal to the time the trigger signal is above/below the trigger level.

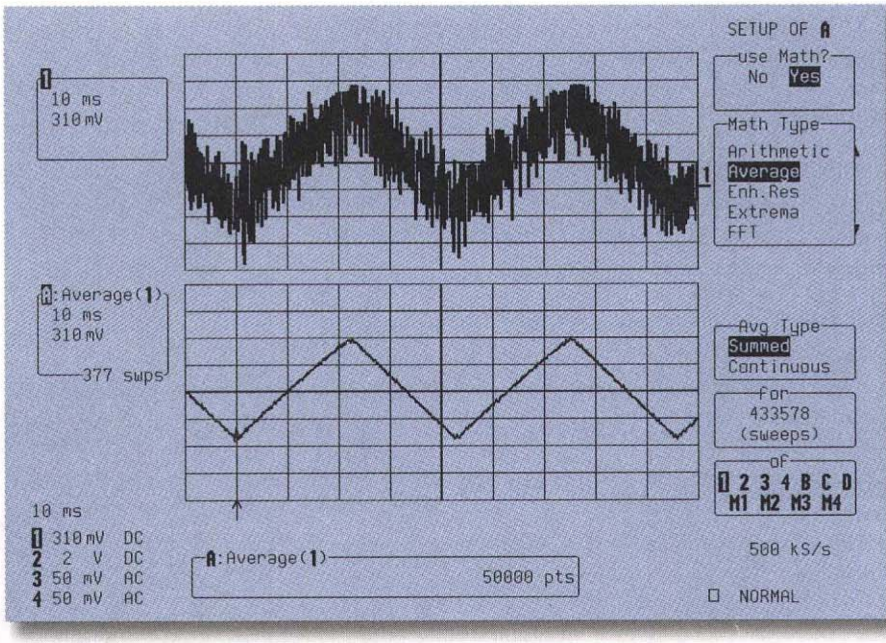
Output signal characteristics: ECL, 50 Ω, series-terminated.

Note: *This feature does not operate in SMART Trigger mode.*

Ordering Information

	Product Code	Price
9300 Series Hardware Options:		
External Clock, Reference Clock	CKTRIG	$ 490
LC Series Hardware Options		
External Clock, Reference Clock	CKTRIG	490

Advanced Waveform Math Package - WP01



Main Features

- ***High-Precision Averaging up to 1 Million Sweeps***
- ***Extended Digital Filtering Capabilities***
- ***Rescale Function, with (ax + b) Correction Factor***
- ***Envelope Mode***
- ***Integration***
- ***Differentiation***
- ***Log(e) and Log(10)***
- ***Exp(e) and Exp(10)***
- ***Absolute Value, Reciprocal***
- ***Square, Square root***
- ***Powerful Function Chaining Feature***

The LeCroy Advanced Math Waveform Processing package features a powerful toolset that extends the processing power inside LeCroy oscilloscopes well beyond the capabilities of a traditional instrument.

In fact, all the processing is built-in to eliminate the need for external computers and controllers. High-speed microprocessors and up to 64 Mbytes of RAM are used to ensure real-time updates of computed waveforms on the screen.

The package is fully programmable over GPIB or RS-232-C interfaces, and hard copies can be made directly on to a wide range of printers (including the optional internal printer), plotters or graphic formats. Data can also be saved to floppy disk (standard) and PCMCIA portable hard drive option.

Extensive Signal Averaging

Advanced Math offers two powerful, high-speed averaging modes that can be used to reduce noise and improve the signal-to-noise ratio. Vertical resolution can be extended by several bits to improve dynamic range and increase the overall input sensitivity to as much as 50 µV/div.

In summed averaging, up to 1,000,000 sweeps are repeatedly summed, with equal weight, in a 32-bit accumulation buffer for improved accuracy. The accumulated result is then divided by the number of sweeps.

With continuous/exponential averaging, a weighted addition of successive waveforms can be performed with weighting factors from 1:1 to 1:1023. The averaging goes on indefinitely with the contribution of "older" sweeps gradually decreasing. The method is particularly appropriate to reduce noise on signals drifting very slowly in time or amplitude.

Enhanced Resolution by Digital Filtering

This allows low-pass finite impulse response filtering of the digitized signals, with 6 different cutoff frequencies per sampling rate setting. As a result, the vertical resolution of the captured signals – single-shot or repetitive – increases from 8 bits to 11 bits in 0.5-bit steps. This feature is ideal for stripping off unwanted high-frequency noise on transient events.

Rescaling

This feature allows an input signal to be rescaled using an (ax + b) correction factor to compensate for gain and offset. This is very useful when dealing with various types of transducers, for reading the correct temperature or pressure value directly from the scope's cursor.

Envelope Mode

This display mode shows the signal envelope by retaining only the highest and lowest amplitudes for every sampling interval, over a user-definable number of sweeps. It is ideal for visualizing the time or amplitude jitter in a signal.

POWERFUL MATH TOOLSET

In addition to the basic arithmetic functions found in the standard models, WP01 adds an impressive set of functions (+,–,÷) such as integration, differentiation, logarithms and exponential – in both bases 10 and e – square, square root, reciprocal, ratio and absolute value. All these functions are updated automatically each time a new waveform is acquired, showing a "live" representation of a computed trace. This would be impossible to achieve on a separate computer.

FUNCTION CHAINING

When more than one math function is needed in the equation, all LeCroy digital scopes support function chaining and allow the user to multiply, for instance, the "Voltage" and the "Current" channels and to integrate the result to get an instantaneous energy curve.

REMOTE CONTROL

All of the waveform processing can be controlled via GPIB or RS-232-C remote control. The function traces do not even need to be called up on screen to be updated, an important feature that speeds up the computation.

GENERAL

Max. number data points: Up to 8 million. Only limited by the available amount of system memory (indicated in the "memory used" status menu).

Min. number data points: Data points can be reduced down to 50 in the processing function to improve update rate.

Vertical Zoom: x50 maximum.

Horizontal Zoom: maximum zooming to a point where 20 - 25 samples of the source trace occupy the full screen.

Maximum Sensitivity: 50 μV/div after vertical expansion.

SUMMATION AVERAGING

Number of Sweeps: 1 to 1,000,000
Speed: up to 200,000 points/s.

CONTINUOUS AVERAGING

Possible Weighting Factors: 1:1, 1:3, 1:7, 1:15, 1:31, 1:63, 1:127, 1:255, 1:511 and 1:1023

ENHANCED RESOLUTION

Choice of six low-pass filters to improve vertical resolution improvement from 8 to 11 bits in 0.5-bit steps.

Resulting bandwidth:

0.5 bit	0.5 ÷ Nyquist BW
1 bit	0.241 ÷ Nyquist BW
1.5 bit	0.058 ÷ Nyquist BW
2 bit	0.029 ÷ Nyquist BW
2.5 bit	0.016 ÷ Nyquist BW

Nyquist BW = 1/2 ÷ sample frequency.
Rescale (ax + b) rescaling with a and b ranging from ±0.00001 E-15 to ±9.99999 E+15.

ARITHMETIC

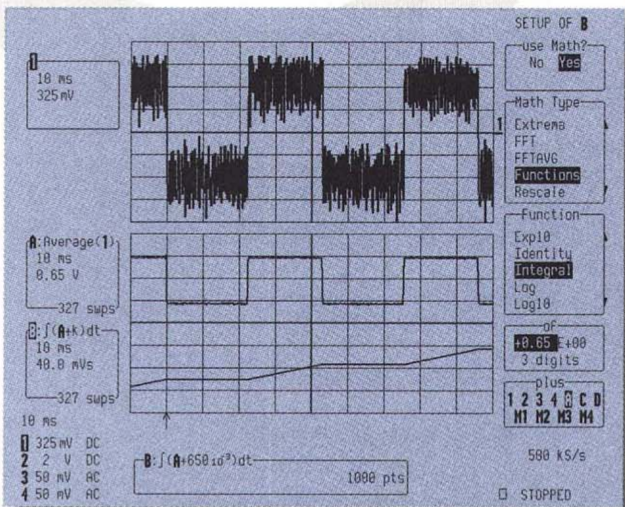
Addition, subtraction, multiplication and ratio on any two waveforms.

FUNCTIONS

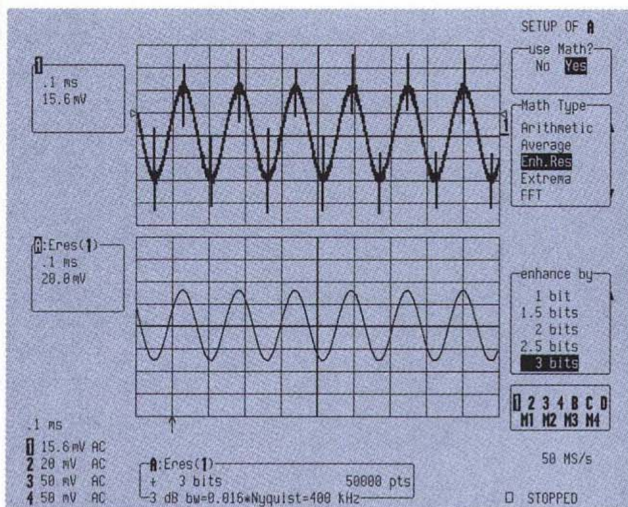
Identity, negation, integration (including additive constant), differentiation, square, square root, logarithm and exponential (base e and 10), sine x/x, reciprocal and absolute value of any waveform.

EXTREMA

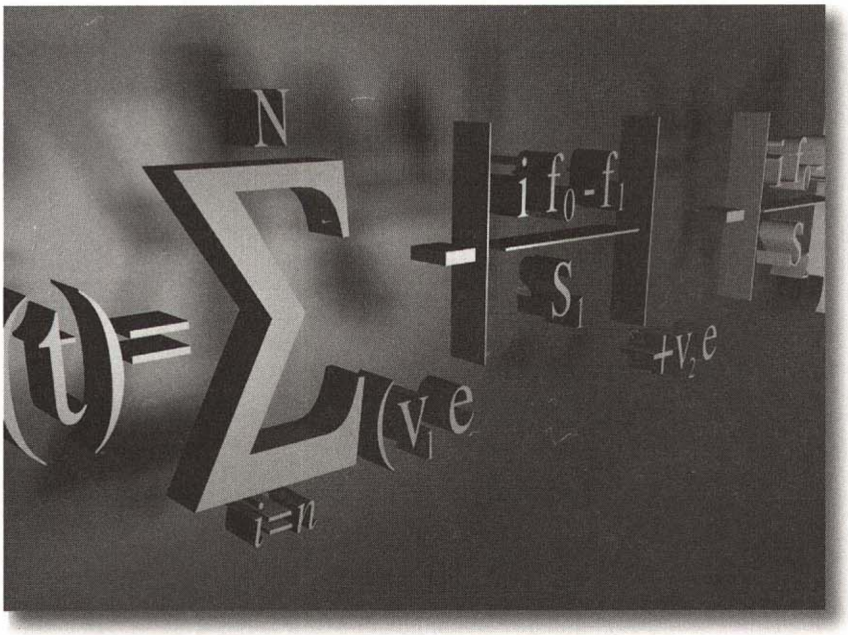
This shows the signal envelope by retaining only the highest and lowest amplitudes for every sampling interval. It logs all extreme values of a waveform over a programmable number of sweeps. Maxima and minima can be displayed together or separately by choosing roof or floor traces.



To illustrate the function chaining ability, the noisy signal in Channel 1 has been averaged in Trace A to remove undesired noise, and the result integrated in Trace B.



High-frequency glitches in Channel 1 have been dramatically reduced in Trace A by using the low-pass filtering properties of the Enhanced Resolution Function.



Number of Sweeps: 1 to 1,000,000.

Function Chaining

Up to four functions can be automatically chained using traces A, B, C and D. Using memories M1 to M4 for intermediate results, any number of operations can be chained manually or via remote control.

Remote Control

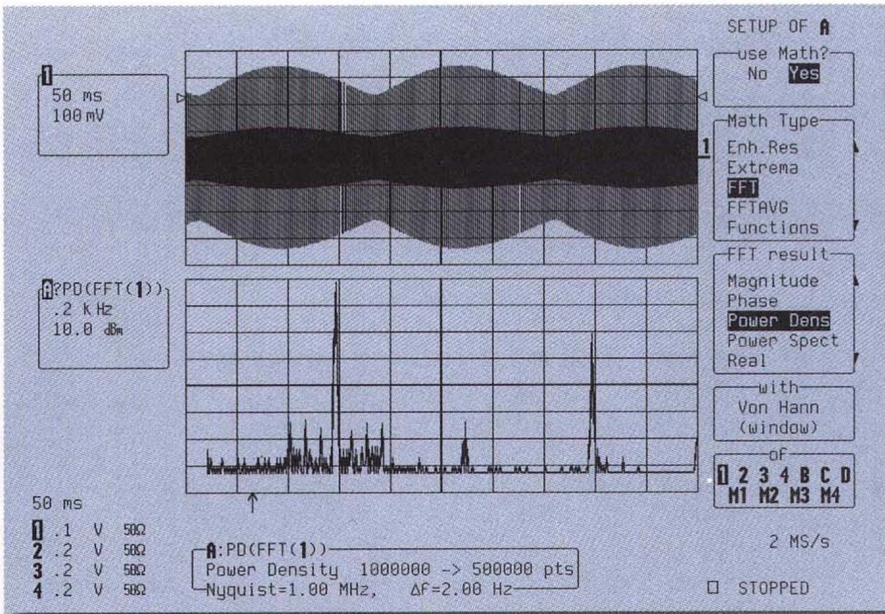
All controls and waveform processing functions are fully programmable using simple commands over the oscilloscope's GPIB or RS-232-C interfaces.

Software Options - Ordering Information

Software Options:	Product Code	Price
Advanced Math Package	WP01	$ 1,250

Included as standard in LC Series Oscilloscopes, and models 9384CTM, 9374CTM and 9354CTM.

Spectrum Analysis Package - WP02



Main Features

- ***Frequency Range From DC up to the Instrument's Full Bandwidth***
- ***Simultaneous FFTs on Up to 4 Channels***
- ***Perform FFT on Up to 4 Million Time Domain Samples***
- ***Frequency Resolution Down to 100 μHz***
- ***Frequency Domain Averaging***
- ***Wide Selection of Scaling Formats and Window Functions***
- ***Full Support of Cursors and Automatic Waveform Parameters***
- ***Full Pass/Fail Testing Support***

The Spectrum Analysis package provides LeCroy oscilloscopes with a powerful frequency-domain toolset that extends its processing capabilities well beyond the realm of a standard instrument. In fact, all the processing is built-in to eliminate the need for external computers and controllers.

High-speed microprocessors and up to 64 Mbytes of RAM are used to perform computations. Fast Fourier Transforms (FFTs) convert time domain waveforms into frequency domain records to reveal valuable spectral information such as phase, magnitude and power. The package is fully programmable over GPIB and RS-232-C interfaces, and hard copies can be made directly to a wide range of printers (including the optional internal printer), plotters or graphic formats. Data can also be saved to optional floppy disk or PCMCIA portable hard drive.

Features and Benefits

Why FFT in a scope?

The FFT package on a LeCroy DSO has at least four clear advantages over common swept spectrum analyzers:

- It can show the spectrum of a transient signal.
- Both time and frequency information can be monitored simultaneously.
- Phase information is available.
- The price is attractive.

It has two definite advantages over FFT analyzers:

- It can show higher-frequency components.
- Both time and frequency information can be monitored simultaneously.

Broad Spectrum Coverage

The frequency spectrum ranges from DC to the full bandwidth of the oscilloscope for repetitive signals and to one half of the maximum sampling frequency for transients.

Multi-Channel Analysis

All input channels can be analyzed simultaneously to look for common frequency-domain characteristics in independent signals.

Versatile Scaling Formats

Frequency-domain data can be presented as magnitude, phase, real, imaginary, complex, log-power and log-PSD (Power Spectral Density).

Standard Window Functions

Use rectangular for transient signals; von Hann (Hanning) and Hamming for continuous waveform data; Flattop for accurate amplitude measurements; Blackman-Harris for maximum frequency resolution.

Frequency Domain Averaging

Up to 50,000 FFT sweeps can be averaged to reduce base-line noise or to enable analysis of phase-incoherent signals or signals which cannot be triggered on.

Frequency Cursors and Waveform Parameters

Cursors can be set on the FFT trace to show up to 0.004% frequency resolution (up to 0.002% for 10,000 point memory) and measure power or voltage differences to 0.2% of full scale. Automatic waveform parameters can also be applied to FFT traces.

Pass/Fail Testing on FFT Traces

Pass/Fail testing is fully supported on FFT traces. The instrument can be setup to test incoming spectra against tolerance masks. In case the signal "fails," the instrument can be programmed to perform a choice of actions (screen dump, waveform storage, pulse out, etc.).

Rescaling

This allows an input signal to be rescaled using an (ax + b) correction factor to compensate for gain and offset. This is very useful, when dealing with various types of transducers, for reading the correct temperature or pressure value directly from the scope's cursor.

Function Chaining

When more than one math function is needed in the equation, all LeCroy digital scopes support function chaining. For example, it would allow the user to perform digital filtering or sine x/x interpolation and then apply FFT analysis.

Remote Control

All of the waveform processing can be controlled via GPIB or RS-232-C remote control. The function traces do not even need to be called up on screen to be updated, an important feature that speeds up the computation.

General

Max. number data points: only limited by the available amount of system memory (indicated in the "memory used" status menu). Up to 6 million data points can be handled in scopes equipped with the 930X-64 RAM option of 64 MBytes of RAM.

Min. number data points: Data points can be reduced down to 50 in the processing function to improve update rate.

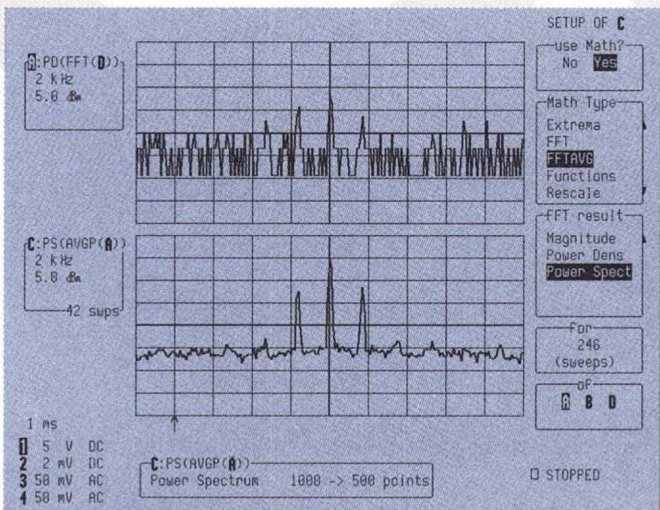
Vertical Zoom: x50 maximum.

Horizontal Zoom: maximum zooming to a point where 20 - 25 samples of the source trace occupy the full screen.

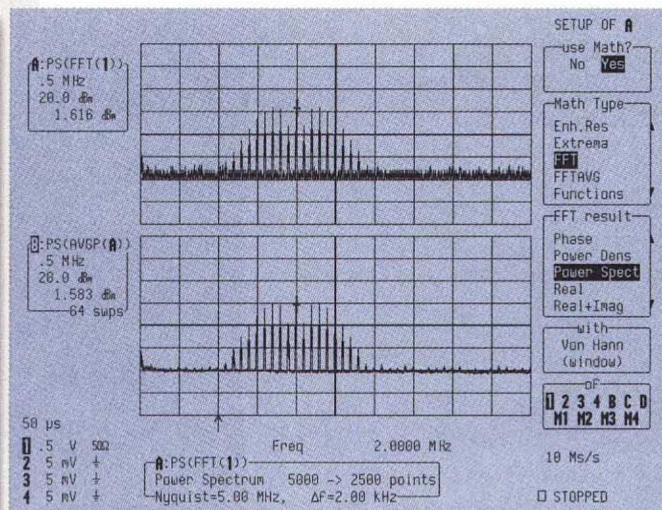
Maximum Sensitivity: 50 µV/div after vertical expansion.

Fourier Processing

Fourier processing is a mathematical technique which enables a time-domain waveform to be described in terms of either frequency-domain magnitude and phase or real and imaginary spectra. It is used, for example, in spectral analysis where a waveform is sampled and digitized, then transformed by a Discrete Fourier Transform (DFT). Fast Fourier Transforms (FFT) are a set of algorithms used to reduce the computation time (by better than a factor of 100 for a 1000 point FFT) needed to evaluate a DFT.



An FFT (top trace) with spectral components buried in noise. By applying the power averaging function (lower trace), all the base-line noise is removed, and the spectral components of an AM signal are clearly visible.



Frequency modulated signal, 2 MHz carrier with 99 kHz modulation frequency, 4:1 frequency deviation. FFT shows modulation sidebands. FFT power average used to improve s/n ratio.

Frequency Range:

Repetitive signals: DC to instrument bandwidth.

Transient signals: DC to 1/2 maximum single-shot sampling frequency.

Frequency Scale Factors: 0.05 Hz/div to 0.2 GHz/div in a 1-2-5 sequence.

Frequency Accuracy: 0.01%

Amplitude and Phase

Amplitude Accuracy: Better than 2%. Amplitude accuracy can be modified by the window function (see the window functions table).

Signal Overflow: A warning is provided at the top of the display when the input signal exceeds the ADC range.

Number of Traces:

Time domain and frequency domain data can be displayed simultaneously (up to 4 waveforms).

Phase Range: -180° to +180°

Phase Accuracy: ±5° (for amplitudes > 1.4 div).

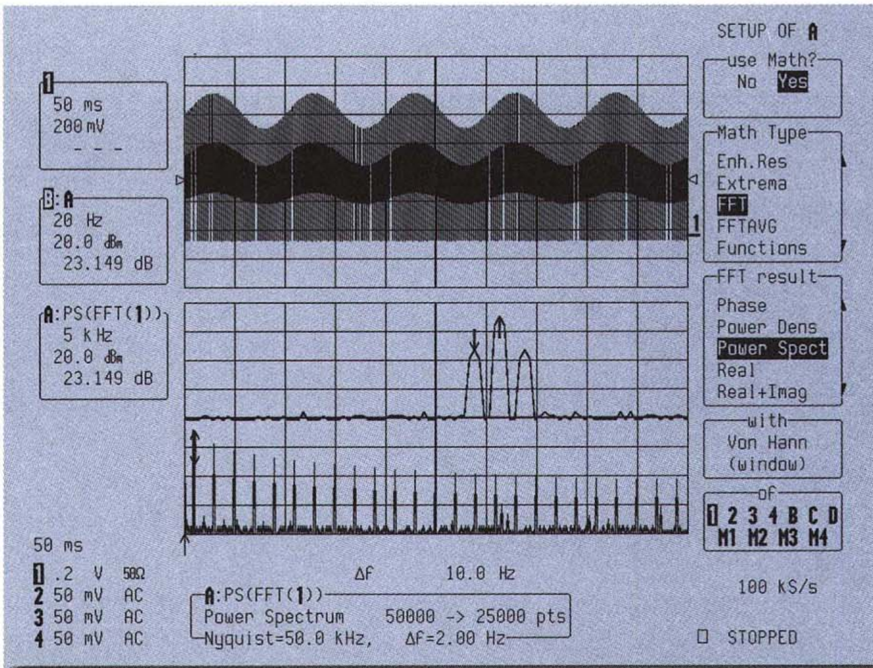
Phase Scale Factor: 50°/division.

Spectrum Scaling Formats

Horizontal Scale: Linear, in Hz.

Vertical Scales: Power Spectrum in dBm (1 mW into 50 W).

Power Spectral Density (PSD) in dBm.



FFT analysis of a 1 kHz square wave with 25% pulse amplitude modulation at 10 Hz. Long memory and 50 kpoint FFT show up to 51st harmonic, while expansion shows 10 Hz modulation sidebands.

Magnitude, Real, Imaginary: Linear, in V/div.

Phase Display: Linear, in degrees.

Window Functions

Rectangular, von Hann (Hanning), Hamming, Flattop and Blackman-Harris (see table below).

FFT Execution Times*

100 points in less than 0.03 s.
1000 points in less than 0.3 s.
10000 points in less than 3 s.

* Valid for 9300C series or for 9350, 9360, 9370, 9384 and 9304/10/14 with MWP option. Other 9300 models, add 50%.

FFT execution in LC series scopes is typically a factor of 15 faster.

Filter Pass Band and Resolution

Window Type:	Filter Bandwidth at 6 dB [freq. bins]	Highest Side Lobe [dB]	Scallop Loss [dB]	Noise Bandwidth [freq. bins]
Rectangular	1.21	-13	3.92	1
von Hann	2	-32	1.42	1.5
Hamming	1.81	-43	1.78	1.36
Flattop	1.78	-44	0.01	2.96
Blackman-Harris	1.81	-67	1.13	1.71

Filter Bandwidth at -6 dB characterizes the frequency resolution of the filter.
Highest Side Lobe indicates the reduction in leakage of signal components into neighboring frequency bins.
Scallop Loss is the loss associated with picket fence effect.

FREQUENCY DOMAIN POWER AVERAGING

Summation averaging of power, PSD or magnitude for up to 50,000 sweeps.

FUNCTION AVERAGING

Up to four functions can be automatically chained using traces A, B, C and D. Using memories M1 to M4 for intermediate results, any number of operations can be chained manually or via remote control.

REMOTE CONTROL

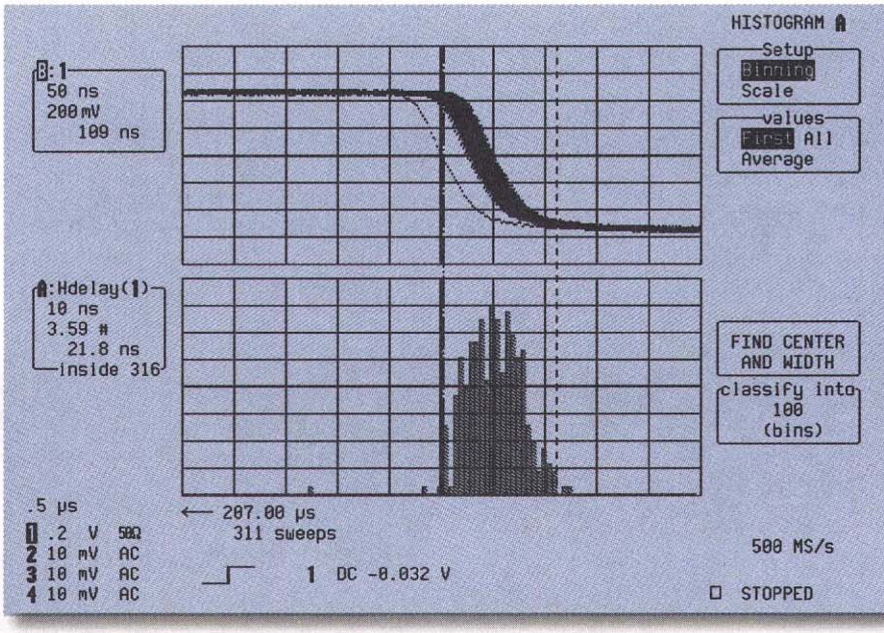
All controls and waveform processing functions are fully programmable using simple commands over the oscilloscope's GPIB or RS-232-C interfaces. Adding the WP02 Spectrum Analysis Package to the 9300 family of digital oscilloscopes provides a fast and economical solution to frequency domain applications.

ORDERING INFORMATION

SOFTWARE OPTIONS:	PRODUCT CODE	PRICE
Spectrum Analysis	WP02	$ 1,250

Included as standard in LC Series Oscilloscopes, 9384CTM, 9374CTM and 9354CTM.

Parameter Analysis Package - WP03



Main Features

- ***Histogram or Trend Functions for Over 40 Different Parameters***
- ***Up to 2000 Bins***
- ***Population of Up to 2,000,000,000***
- ***18 Histogram Parameters***
- ***Autoscale on Histogram***
- ***Histograms of All or Individual Segments in Sequence Waveforms***

The LeCroy Parameter Analysis package extends the measurement capability of the 9300 or LC series oscilloscope by providing new processing functions – built into the oscilloscope – to perform in-depth analysis on waveform parameters, a task that was formerly carried out either manually, with a notepad, or by means of an external computer, in a spreadsheet program.

The new functions provide ***histogramming*** or ***trending*** of any waveform parameter measurement. A histogram is a barchart showing how often each value of a parameter occurred. It can be conveniently ***autoscaled*** to display the center and width of the distribution. In addition, an already wide range of automated measurements are extended to provide a new category of statistical measurements specifically designed to analyze histogram distributions.

The package is fully programmable over GPIB and RS-232-C interfaces, and hard copies can be made directly to a wide range of printers (including the optional internal printer), plotters or graphic formats.

Waveform Parameter Analysis

WP03 adds a powerful dimension to waveform analysis by recording and analyzing the properties of a series of waveform parameter measurements. This is accomplished by a function that records the parameter values and presents the data in a statistical form – the Histogram – or shows the values in time order – the Trend.

The Histogram function produces a bar chart where each bar represents a range of parameter measurement values consisting of one bin. The height of each bar is equal to the number of parameter values which fall into the corresponding bar. Analysis of histogram distributions is supported by a wide range of automated statistical parameters which provide insight into and quantitative analysis for difficult-to-measure phenomena such as jitter and amplitude fluctuation. This function is also invaluable in establishing production test limits.

The Trend function displays the time-sequenced values of selected parameters. Key performance parameters can be tracked during changes in temperature or variation of supply voltage to plot amplitude modulation or other time-ordered dependencies.

A Database in the Oscilloscope

The Histogram function performs calculations on a stored history database of waveform parameters. This allows detailed analysis to be performed on parameter data without the need to reacquire the source waveforms. Having the parameter database available also allows automatic scaling of histogram and graph displays.

Waveform Parameter Measurements

LeCroy DSOs have the capability to perform a wide range of automated waveform parameter measurements which make interpretation of waveform data easy, accurate and repeatable. The distribution of these parameter measurements can be analyzed by histogramming their values.

Some of the waveform parameters available include:

amplitude	duration
minimum	area
duty cycle	overshoot +
base	falltime
overshoot -	cmean
frequency	peak to peak
cmedian	first
period	crms
f80-20%	phase
csdev	f@level (abs)
points	cycles
f@level (%)	risetime
delay	last
r20-80%	Δdelay
maximum	r@level (abs)
Δt@level(abs)	mean
r@level (%)	Δt@level (%)
median	RMS
t@level (t=0,abs)	std dev
t@level (t=0,%)	top
ΔC2D+(hold)	width
ΔC2D-(setup)	

Histogram Features

Provided below are just some of the histogramming capabilities.

Vertical:
Autoscaling, choice of "Linear," "Log" or "Constant maximum" (linear) scales. Up to 50x expansion.

Horizontal:
20 to 2000 bins in a 1-2-5 sequence. User-specified center and width or Autosetup of center and width.

Population:
20 to 2,000,000,000 selectable in a 1–2–5 sequence.

Data Source:
Any waveform parameter.

Value Displayed:
The bin event count/div, the number of events contained within the histogram, and the percent of the captured events lower and greater than the histogram scale are automatically displayed.

Measurements:
18 Statistical parameters operate directly on the histogram. Cursor measurements can also be made directly on histograms.

Histogram Parameters

The standard 9300 and LC series offer basic parameter statistics (maximum, minimum, average and standard deviation). WP03 adds 18 parameters for use directly on the histogram displays. These additional measurements allow detailed analysis of the parameter distributions and can be monitored by the Pass/Fail system to provide go/no-go testing based on parameter statistics.

Trend Features

Up to four graphs of successive values of any waveform parameters can be generated through the Trend function. Output of the function is a line graph whose vertical axis is the value of the parameter and whose horizontal axis is the order in which the values were acquired.

Histogram Parameters

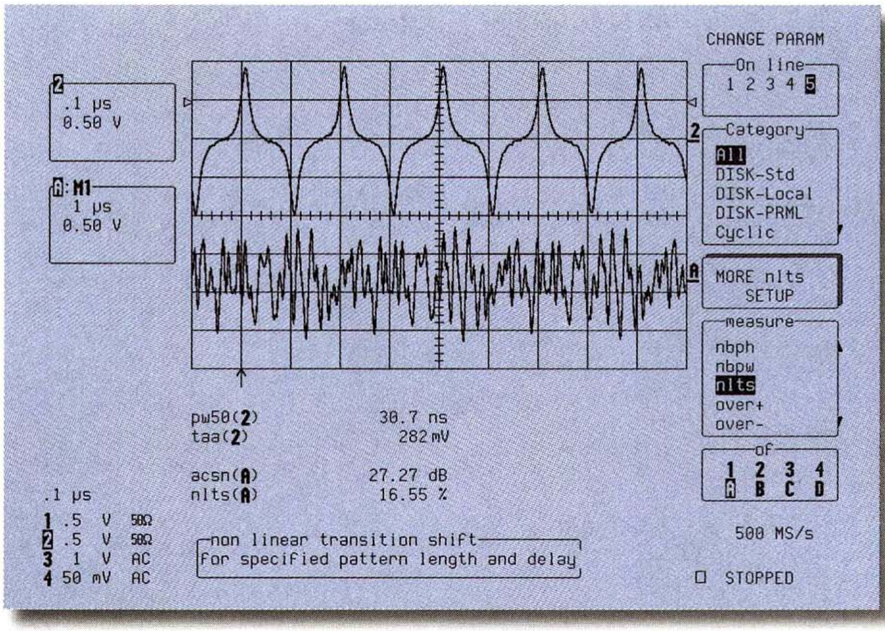
Parameter	Abbreviation	Explanation
histogram base	hbase	Horizontal position of left-most statistically significant bin.
histogram top	htop	Horizontal position of right-most statistically significant bin.
histogram amplitude	hampl	Horizontal difference between the htop and hbase values.
histogram rms value	hrms	Root Mean Square value of histogram distribution.
sigma	sigma	Standard Deviation of histogram distribution.
low	low	Horizontal position of left-most non-zero bin.
high	high	Horizontal position of right-most non-zero bin.
range	range	Horizontal difference between the high and low values.
total population	totp	Total population in the histogram.
maximum population	maxp	Maximum population in any histogram bin (i.e. vertical value at the mode).
peaks	pks	Number of peaks in the distribution.
mode	mode	Horizontal position of the bin with maximum population.
average	avg	Horizontal mean of the distribution.
median	median	Horizontal median of distribution. The value of the mid-point of the distribution.
full width at half max	fwhm	The width of the distribution around the maximum population bin, including bins which contain at least one half of the maximum population.
full width at x% of max	fwxx	The width of the distribution around the maximum population bin, including bins which are at least x% of the maximum population.
x position at peak	xapk	Horizontal position of the nth largest peak by area.
percentile	pctl	Value in histograms for which % of population is smaller.

Software Options - Ordering Information

Software Options:	Product Code	Price
Parameter Analysis Package	WP03	$ 1,250

Disk Drive Analysis Software Packages

- ***Disk Drive Parameters***
  Pulse Width 50
  Track Average Amplitude
  Resolution
  Overwrite
- ***PRML Measurements***
  Non-Linear Transition Shift
  Auto-Correlation Signal-to-Noise
  Auto-Correlation
- ***Feature Analysis Parameters including:***
  Local time between peaks
  Local time between troughs
  Local time over threshold
  And ten others...
- ***Statistical processing Functions***
- ***Bar charts for easy analysis of measurement results over many events***



Disk Drive Measurement Packages

The Disk Drive Measurement and PRML Measurement Packages utilize IDEMA test methods and industry-standard PRML measurements to extend the range of capabilities of the LeCroy 9300C and LC series digital oscilloscopes to provide in-depth analysis of disk drive performance.

Combine the 500 MHz analog bandwidth of the 9354C or LC334A (or the 1 GHz bandwidth of the 9370C, 9384C, LC564A, LC584A or LC534A), 2 GS/s sample rate (4 GS/s for the 9384C or LC564A and up to 8 GS/s for the LC584A series), 2 Mbyte record length per channel (combinable to 8 Mbytes), sequence triggering, and SMART Trigger operation with LeCroy's disk drive measurement packages, and you have the perfect solution to complete disk drive analysis and testing.

Now you can make your standard disk drive measurements and PRML measurements with your LeCroy scope and view the results on screen. Both packages are fully programmable over GPIB or RS-232-C.

Photo courtesy of Quantum Corporation.

Disk Drive Parameters Package

The Disk Drive Measurement package includes processing functions specified in the IDEMA test standards document.* These include:

- Disk Drive Measurements of Pulse Width, Track Amplitude, Resolution and Overwrite
- Feature Analysis Parameters
- Narrow Band Frequency Domain Parameters
- Statistical Parameters
- Statistical Processing Functions

Name	Description
PW50*(1)	Pulse Width 50: Provides an average pulse width, measured at 50% peak amplitude, of all peak/trough pairs in the specified waveform.
PW50(+)	Pulse Width 50 (+): Provides an average pulse width, measured at 50% peak amplitude, of all peaks in the specified waveform.
PW50(-)	Pulse Width 50 (-): Provides an average pulse width, measured at 50% peak amplitude, of all troughs in the specified waveform.
TAA*(2)	Track Average Amplitude: Provides an average peak-to-peak amplitude of all peak/trough pairs in the specified waveform.
TAA(+)	Track Average Amplitude (+): Provides an average peak amplitude of all peaks in the specified waveform.
TAA(-)	Track Average Amplitude (-): Provides an average peak amplitude of all troughs in the specified waveform.
RESOLUTION*(3)	Specified as (TAA(F1)/TAA(F2))*100% Where: F1 = Low Frequency F2 = High Frequency
OW*(4)	Overwrite: Specified as 10 log (V_r/V_o) Where: V_r if the residual V_{rms} of F1 (low frequency) after F2 (high frequency) write V_o is the V_{rms} of F1 (low frequency) after F1 write.

Feature Analysis Parameters

Parameters that provide for analysis of amplitude and timing relationships between features (peak/trough pairs) of a waveform are also included in the Disk Drive Measurement package. Used in conjunction with the Histogram processing function, a statistical description of the waveform can be calculated.

Name	Description
lmax	local maximum
lmin	local minimum
lnum	number of local peak and trough pairs
lpp	local peak-to-peak (lmax - lmin)
ltbe	local time between events (either peak-to-trough or trough-to-peak)
ltbp	local time between peaks
ltbt	local time between troughs
ltmn	local time at minimum
ltmx	local time at maximum
ltot	local time over threshold
ltpt	local time between peak and trough
lttp	local time between trough and peak
ltut	local time under threshold

*As specified in IDEMA Standards.
1994 Revised Edition
(1) Document No. T15-91
(2) Document No. T3-91
(3) Document No. T4-91
(4) Document No. T14-91

Frequency Domain Parameters Description

These parameters provide a rapid technique to extract the amplitude and phase of single frequencies from complex waveforms. These parameters are more efficient than using an FFT if the frequencies of interest are known.

Name	Description
nbph	narrow-band phase in degrees relative to start of waveform
nbpw	narrow-band power in dBv

Statistical Parameters Features Description

These parameters are used in conjunction with histograms to allow for easy interpretation of the results.

Histograms:

Any waveform parameter can be histogrammed. The histogram function produces a waveform with the vertical axis in units of "Events" and the horizontal axis in parameter units (volts, nanoseconds, etc.). The histogram shows the statistical variation of the selected parameter.

Name	Description
low	minimum value
high	maximum value
range	high - low
fwhm	full width half max
maxp	maximum population is the highest population (vertical value) in the histogram
average	mean value
sigma	standard deviation
totp	total population
xapk	provides the horizontal position of the selected peak
pks	provides the total number of peaks
median	provides the horizontal position of the value which divides the histogram into two equal populations
mode	provides the horizontal position of the most frequently occurring value
pctl (Percentile)	provides the horizontal position of the peak which separated the histogram such that the population on its left is a specified percentage of the total

PRML Measurement Package

PRML Parameters
PRML (Partial Response Maximum Likelihood) recording channels provide higher areal densities by allowing magnetic transitions to be written at closer spacing than peak detection channels. The following parameters provide a time domain technique to measure the time shift and s/n ratio created by this magnetic writing process.

PRML Measurement Package
Includes the following functions:

Non-Linear Transition Shift

Auto-Correlation Signal-to-Noise

Auto-Correlation

Name	Description
NLTS (%)	Non-Linear Transition Shift in percent: $NLTS = -200 \times r$ Where: r = auto-correlation coefficient @ time delay
ACSN	Auto-Correlation Signal-to-Noise Ratio: $ACSN = 10 \log (R/1-R)$ Where: R = correlation coefficient
Auto-Correlation	$R_X (u) = \int f_X(t) f_X(t-u) dt$

SOFTWARE OPTIONS

Software Options - Ordering Information

Software Options:	Product Code	Price
Basic Disk Drive Measurements	DDM	$ 3,000
PRML Analysis Package	PRML	1,250

Optical-Recording Measurement Package

Main Features

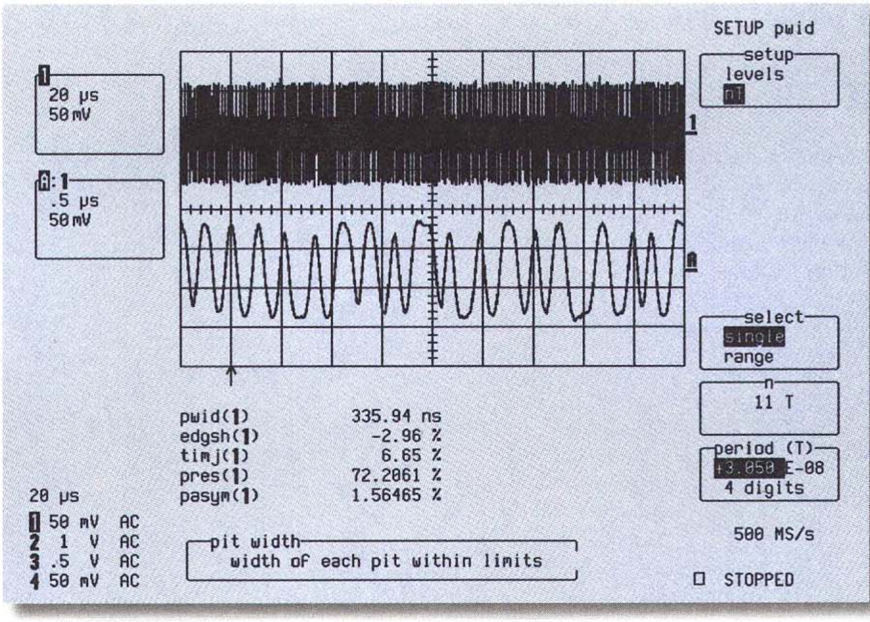
- ***Optical Recording Applications***
  - CD-ROM - PD - DVD
  - Magnetic-Optical
- ***Optical Recording Parameters***

  14 Optical-Recording Specific Measurements, 6 Timing Parameters and 8 Amplitude Parameters, Including Pit Width, Time from Pit Edge to Clock, Resolution...
- ***List by nT Display Mode***

  Display a List of Optical-Recording Measurement Values Indexed by Each (nT) Pulse Width.
- ***Histograms of Measurements***

  Generate Histogram Bar Charts for Analysis of Parameter Value Distributions.
- ***Trend Analysis of Measurements***

  Generate Trend Lines of Parameter Measurement Values to Study Sector Variations, Modulation and Other Time-Ordered Dependencies



Trace 1 is a captured CD waveform. Trace A is a zoom expansion of Trace 1. Measurements performed on Trace 1 are Pit Width (pwid), Edge Shift (edgsh), Timing Jitter (timj), Resolution (pres) and Pit Asymmetry (pasym).

Optical-Recording Measurement Package

LeCroy's Optical-Recording Measurement package provides the ability to perform automated measurements of optically recorded data waveforms. The combination of automated optical-recording measurements, long DSO memory, advanced triggering features and a large-screen waveform display provides previously unavailable optical recording analysis capabilities.

Fourteen optical-recording waveform specific parameter measurements are provided.

Up to five different parameter values can be displayed simultaneously with statistics such as average, maximum, minimum and sigma.

Also provided is a unique List by nT display mode, which simultaneously provides, for each group of 'nT' width pits/spaces, the values of measurements such as edge shift, timing jitter, etc.

Histogram graphs of parameter measurements can be selected to observe statistical anomalies not normally identifiable by calculating, for example, a parameter's average or sigma.

Trend graphs of parameter measurements can also be selected to observe the variation of successive parameter measurements within a sector or even around a track.

These measurements can be made by adding the optical-recording measurements package to either a 9300 or LC series DSO.

Optical-Recording Parameters

Optical-recording measurement package parameters directly support the pit/space width-based, data-encoding mechanism used in optical recording, by pre-screening waveform pits and spaces into width ranges from 1T to 25T, where T is the clock period.

User options include the ability to:

- calculate parameter values for pits, spaces or both.
- calculate parameter values for pits and/or spaces of a specific 'nT' value or range of 'nT' values.
- set the voltage threshold level at which to measure pits/spaces widths.

and much more....

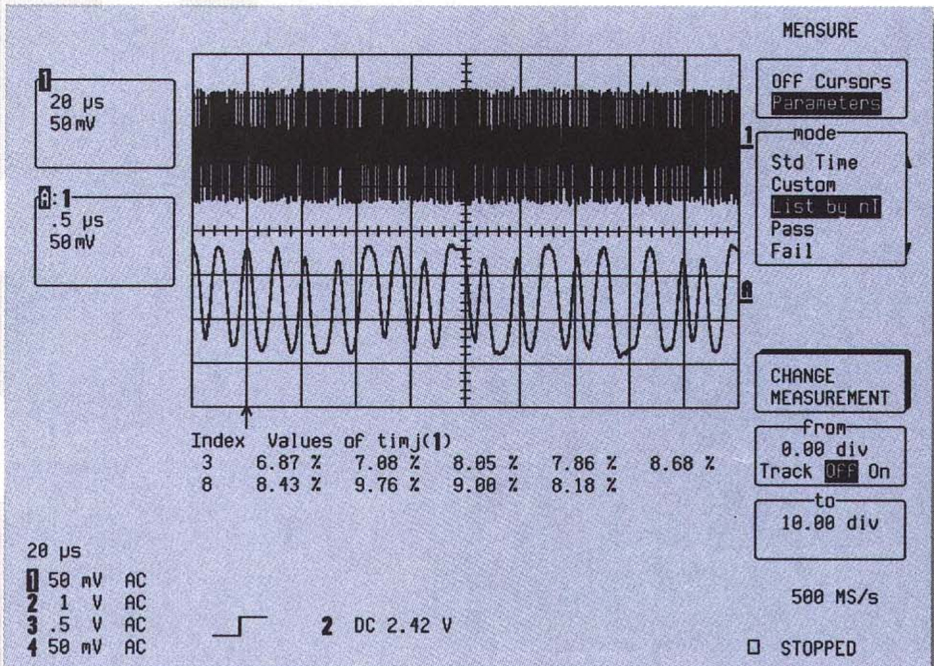
Optical-Recording 'List by nT' Display Mode

Often, it is desirable to view a measurement value for each 'n' value for all possible 'nT' width ranges simultaneously. The List by nT display is provided to accommodate this need. Up to 25 nT values can be displayed simultaneously in this mode. Measurements that can be displayed in the List by nT mode are:

- Time from Pit to Clock
- Pit Width
- Edge Shift
- Timing Jitter
- Pit Top
- Pit Base
- Pit Maximum
- Pit Minimum
- Pit Number
- Pit Average Amplitude

Optical Parameter Description

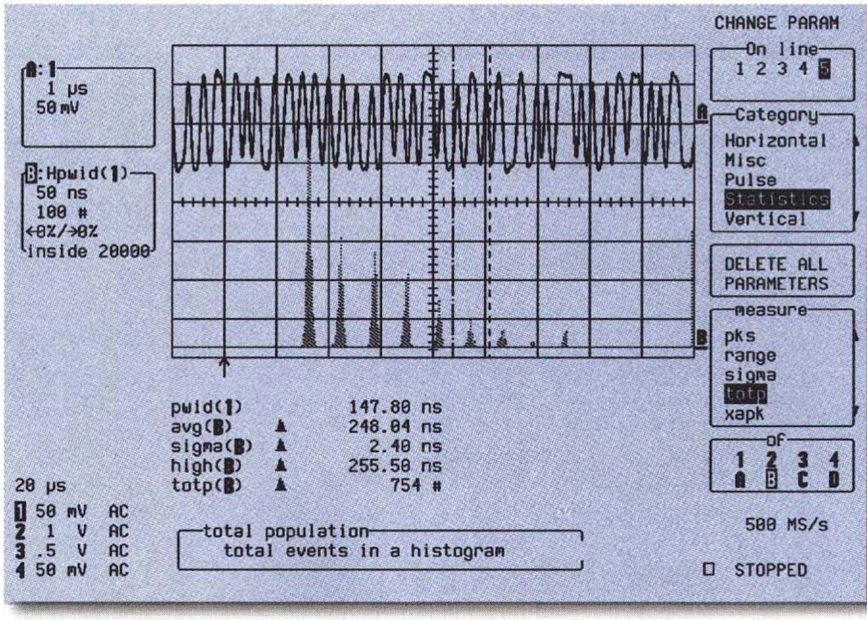
dp2clk	Delta Pit to Clock - time between the pit or space edges and the next clock edge. The measurement is normalized by the period of the clock signal.
edgsh	Edge Shift - the mean value of the difference between pits or space widths and their ideal widths.
paa	Pit Average Amplitude - average amplitude of pits in a waveform.
pasym	Pit Asymmetry - ratio of the difference between the amplitude of the largest 'nT' width pits and the smallest 'nT' width pits to the amplitude of the largest 'nT' width pits.
pbase	Pit Base - the value for the base level of a space.
pmidl	Pit Middle - the midpoint between the top and base of pits.
pmax	Pit Max - the maximum value of a pit.
pmin	Pit Min - the minimum value of a space.
pmoda	Pit Modulation Amplitude - ratio of the amplitude of pits of the smallest 'nT' width to the top of pits of the largest 'nT' width.
pnum	Pit Number - the total number of pits and/or spaces in a waveform.
pres	Pit Resolution - ratio of the amplitude of pits of the smallest 'nT' width to pits of the largest 'nT' width.
ptop	Pit Top - the value for the top level of a pit space.
pwid	Pit Width - the width of pits and/or spaces measured at a user-defined threshold.
timj	Timing Jitter - the standard deviation of the difference between pit and/or space widths and their ideal widths.



List by nT display of Timing Jitter (timj) measurement of CD-ROM Data Waveform with separate values displayed for each 'nT' mark/space width (3T-11T).

Histogram Function

A histogram of any waveform parameter measurement can be displayed. The histogram function produces a bar graph with the vertical axis in units of 'Events' and the horizontal axis in the unit of the parameter being histogrammed (i.e. volts, nanoseconds, etc.). Histograms graphically represent the distribution of parameter measurements, providing insights often not available through standard statistical measurements such as the average and standard deviation.



CD-ROM Data Waveform with Histogram of Pit Width (pwid) parameter. Notice the distinct peaks resulting from pits/spaces all being an integral number of clock periods in width. Statistical analysis of histograms is performed using histogram parameters. For the above figure, the histogram peak representing 8T pits and spaces is selected, and the average (avg) sigma, the highest value (high) and population of the peak (totp) are displayed.

Histogram Parameters

Histogram parameters provide the ability to obtain numeric values for the statistics or other features of a histogram distribution. When combined with the 9300 or LC series parameter cursors, the statistics or other characteristics of a selected section of interest in a histogram, such as a specific histogram peak, can be directly measured.

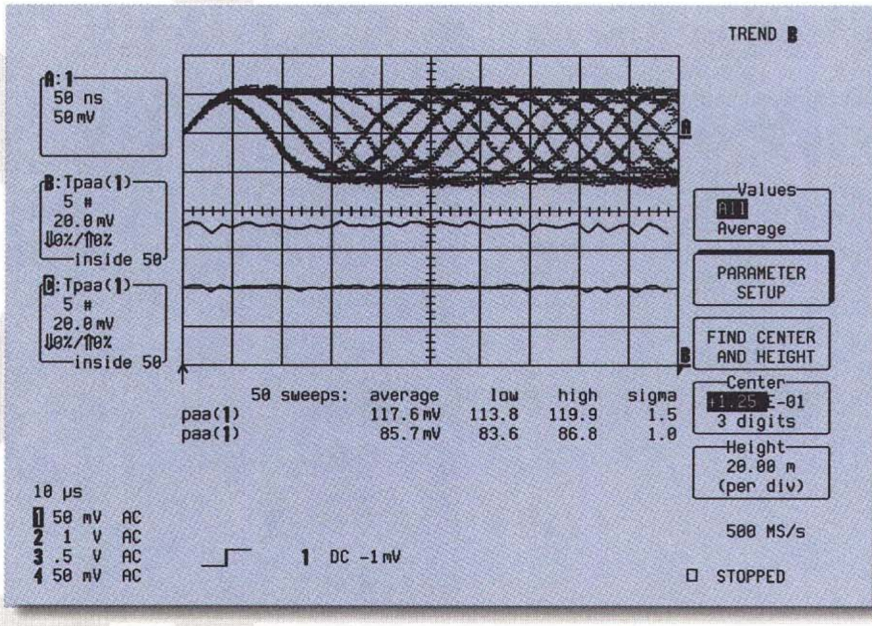
Histogram Parameter Description

low	Minimum horizontal axis value in a histogram.
high	Maximum horizontal axis value in a histogram.
range	High - Low.
fwhm	The width of the largest peak in a histogram at half the peak's amplitude.
maxp	Population of the highest bin in a histogram.
average	The mean value of a histogram.
sigma	The standard deviation of the values in a histogram.
totp	The total number of parameter measurement values displayed in a histogram.
xapk	The horizontal axis value of the selected histogram peak.
Ppks	The number of distinct peaks (modes) in a histogram.
median	The horizontal axis value which divides the histogram population into two equal populations.
mode	The horizontal axis value of the most populated histogram bin.
pctl (percentile)	Horizontal position separating a histogram population such that the population on the left is equal to the selected percentile of the total population.

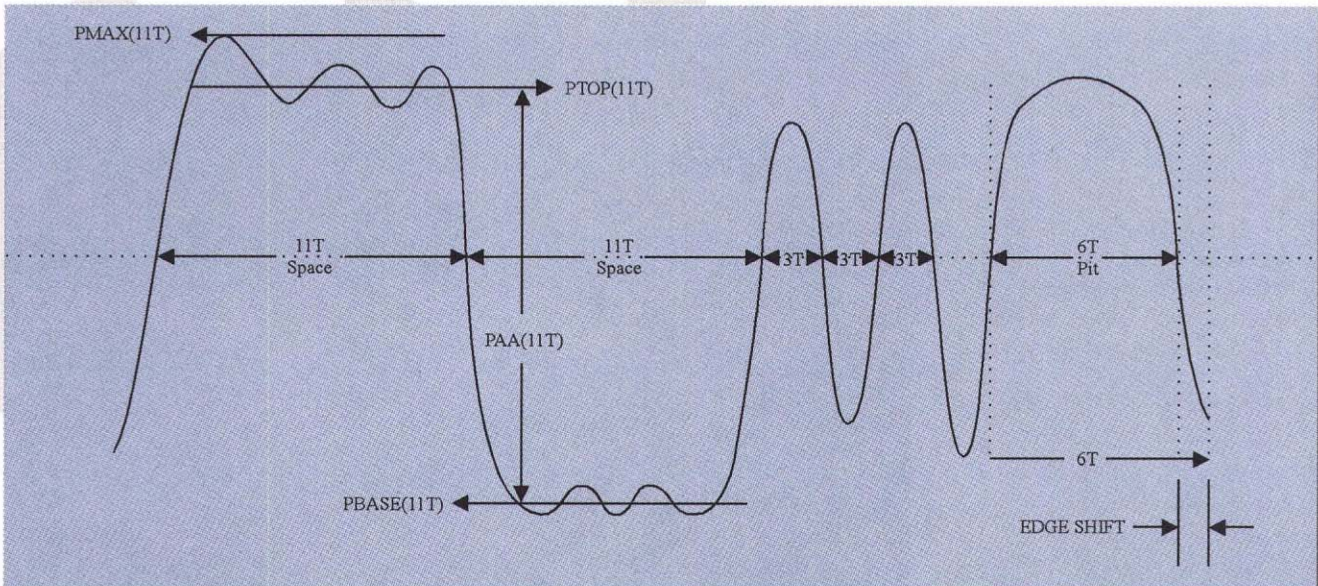
TREND FUNCTION

A graph of successive values of any waveform parameter measurement can be generated through the Trend function. The Trend function produces a line graph with the vertical axis representing the values of parameter measurements and the horizontal axis the rank order number (i.e. first parameter measurement calculated, second parameter...) in which each parameter value displayed was calculated.

The trend function provides instant insight into the variation of a selected waveform attribute for successive parameter measurements calculations. This is particularly useful when trying to determine the modulation of a track or other time- or position-based variations of interest.



Trace A shows an eye diagram of a CD signal. Trace B is a trend of the Pit Amplitude of 11T pits, and Trace C is a trend of the Pit Amplitude of 3T pits. Notice the similarity of the variation in the two trend lines.



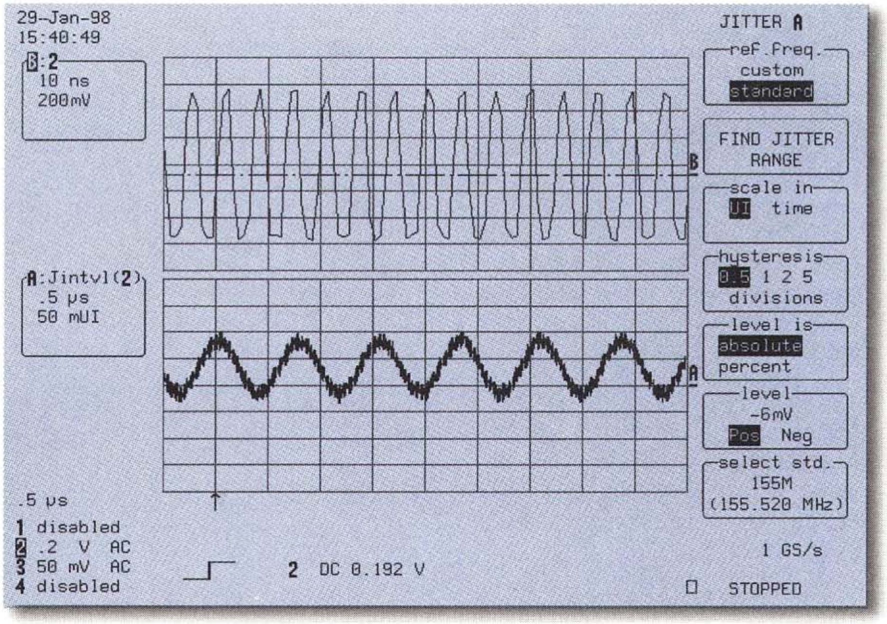
SOFTWARE OPTIONS - ORDERING INFORMATION

SOFTWARE OPTIONS:	PRODUCT CODE	PRICE
Optical Recording Measurements Package	ORM	$ 3,000

Jitter and Timing Analysis Package

Main Features

- *Jitter Measurements*
- *Cycle-to-Cycle Timing Measurements*
- *Histograms on Persistence Waveforms**
- *Full Statistical Analysis*
- *Enhanced Timing Accuracy*
- *Persistence-to-Waveform Tracing**



Cumulative Jitter on a 155 Mb/s clock. Note the sine-shaped jitter.

The Jitter and Timing Analysis Package (JTA) augments the long memory and highly accurate clock of LeCroy oscilloscopes to provide dedicated, precise timing measurements. JTA addresses the growing need to precisely characterize waveform timing stability — essential to applications such as synchronous networks or digital systems. Timing measurements can be represented in standard formats such as UI (Unit Intervals).

JTA offers three basic types of tools: Timing Parameters, Timing functions and Statistical Tools.

JTA can:

- Display the Jitter function of a signal
- Measure Cycle-to-Cycle Jitter
- Measure Duty Cycle or Width (either polarity)
- Show detail in the shape of an edge
- Measure Jitter and Noise on Eye Diagrams
- Measure an unlimited number of cycles on long records
- Count an unlimited number of edges

* On LC series oscilloscopes only

Timing Parameters

Offering maximum flexibility, each timing parameter operates on a **selectable level** of the acquired waveform — in either Volts or percent of signal amplitude.

In addition, each parameter calculation is performed over **all cycles or edges** present in the input signal, without limitation. The acquired set can then be analyzed using **Histograms** or **Trends** (see Statistical Tools).

To optimize measurement **accuracy**, **repeatability and speed**, advanced interpolation filtering is applied to the signal edges in the vicinity of the measurement points.

The Parameters:
P@LV (period at level) calculates the period of each cycle in an acquired waveform.

WID@LV (Width at level) returns the width — positive or negative — of each period in the source trace.

ΔP@LV (Delta period at level) calculates the adjacent cycle deviation (Cycle-to-Cycle Jitter) of each cycle in an acquired record.

EDGE@LV (Edge at Level) counts the number of edges – positive or negative – in the source trace.

DUTY@LV (Duty Cycle at Level) calculates the duty cycle of each period in the source trace.

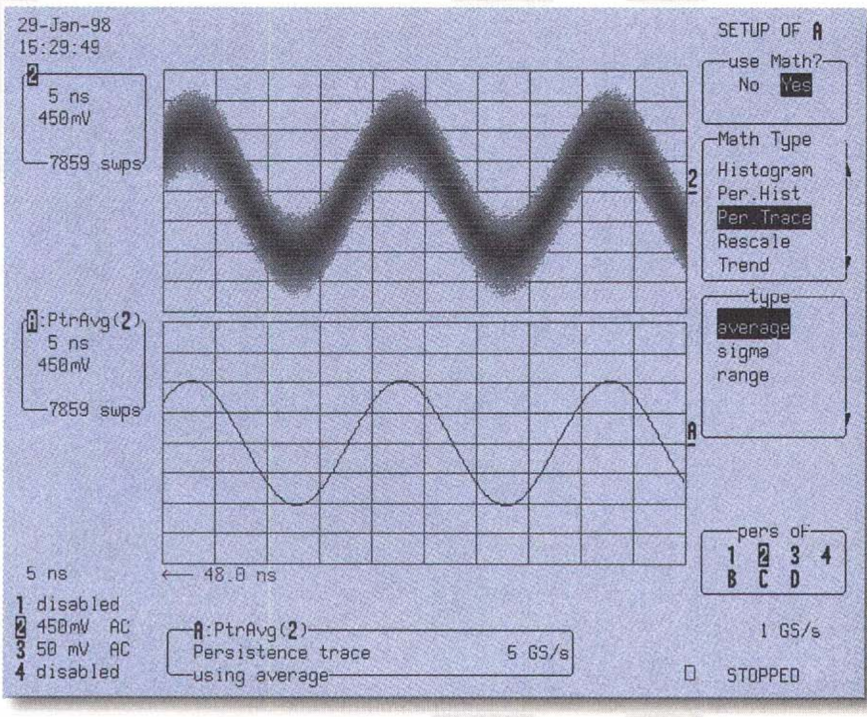
TIE@LV (Time Interval Error at level) calculates the cumulative time interval error in the signal compared to an "ideal" position defined by a user-defined reference.

Timing Functions

The **Jitter** function plots the amplitude of the following waveform attributes, as a function of time:

- Cycle-Cycle variation
- Duty Cycle
- Interval Error
- Period
- Width

The **Interval Error** Jitter function, as defined in Bellcore TR-499, plots "the short-term variations of a digital signal's significant instants, from their ideal positions in time".



Persistence trace (Per.Trace) set to "average"

Persistence Histogram* (Per.Hist) is the ideal "quantitative" companion to persistence display. The function histograms a horizontal or vertical "slice" of the persistence waveform. A pertinent application is jitter and noise analysis on an eye diagram, where the information resides in the persistence map and not the waveform itself. And the Persistence Histogram can in turn be characterized using statistical measurements such as range, sigma, or full width at half max.

Persistence Trace* (Per.Trace) is a totally new concept that involves computing a vector trace from a bit map. Several settings are available:

- *Average:* for each vertical time slice on the persistence map, calculates and plots a trace corresponding to the mean value. Single- shot signals sampled at or above 2 GS/s and accumulated in the persistence map can be traced at a resolution of 10 ps (100 GS/s equivalent sampling).
- *Sigma:* for each vertical time slice on the persistence map, calculates and plots an envelope corresponding to the standard deviation. Multiples of sigma are also supported.
- *Range:* for each vertical time slice on the persistence map, calculates and plots an envelope corresponding to the range. Artifact rejection is also supported.

Statistical Tools

The **Histogram** presents the statistical distribution of any timing parameter's set of values. The most important Histogram capabilities are described here.

Vertical: Autoscaling, choice of "Linear", "Log" or "Constant maximum" scales.

Horizontal: 20 to 2000 bins. User-specified or automatic center-and-width adjustments.

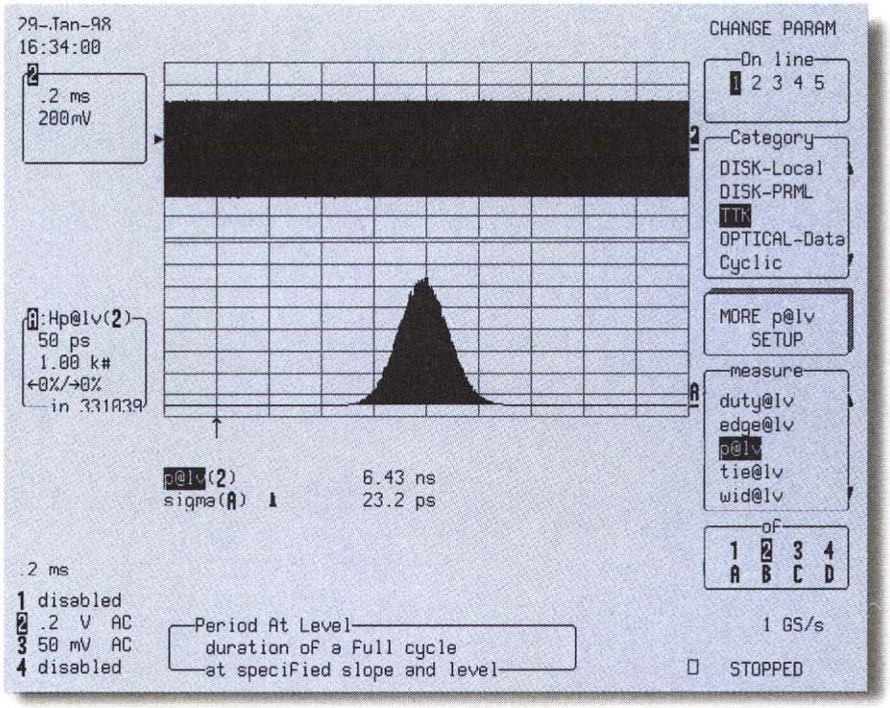
Population: 20 to 2×10^9.

Value Displayed: Automatically displayed are the bin event count/div, the number of events contained within the histogram, and the percentage of the captured events lower and greater than the histogram scale.

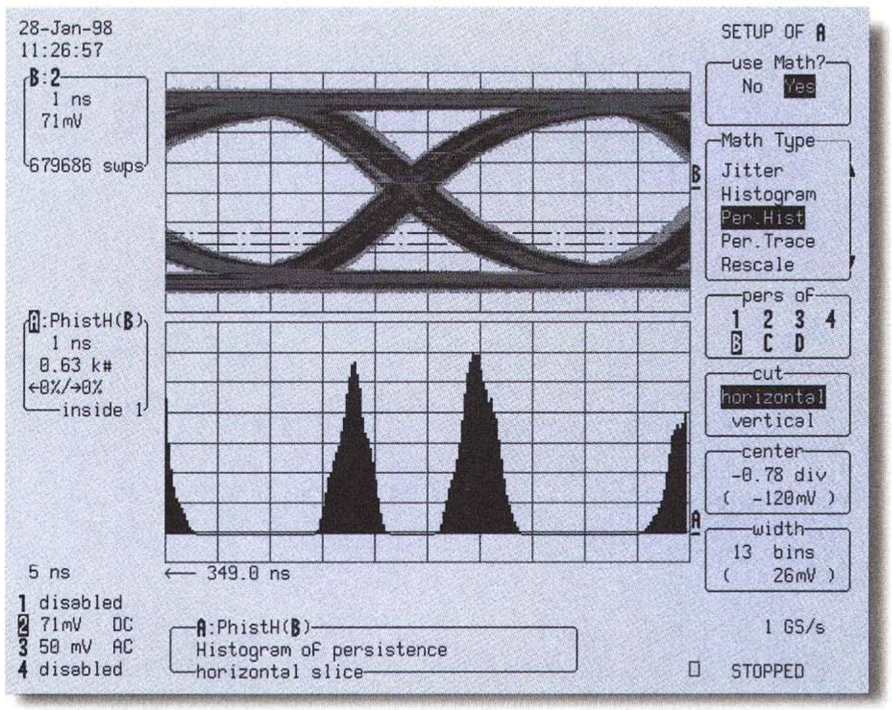
Histogram Measurements: 18 statistical parameters operate directly on the histogram. Cursor measurements can also be made directly on histograms.

The **Trend** function graphically represents the evolution of any given timing parameter. This function outputs a line graph whose vertical axis is the value of the parameter and horizontal axis is the order in which the values were acquired, as in XY or scatter diagrams.

* On LC series oscilloscopes only



Histogram of period at level (p@lv) showing 331039 calculations in one acquisition.

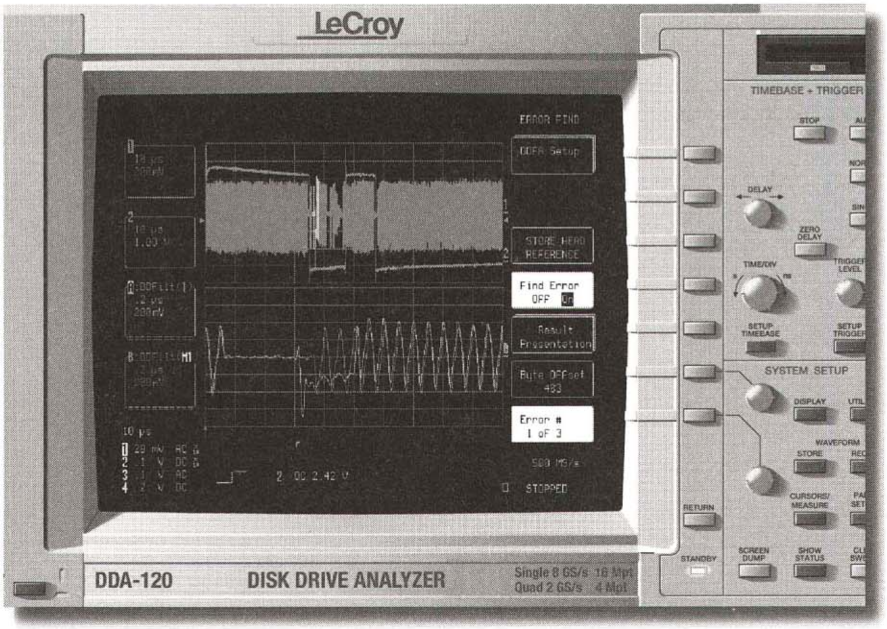


Persistence Histogram (Per.Hist) of a SONET OC-3 eye diagram.

Jitter and Timing Analysis Package - Ordering Information

Software Options	Product Code	Price
Jitter and Timing Analysis Package (includes WP03 statistical analysis)	JTA	$ 1,875
JTA Field Retrofit (includes WP03 statistical analysis)	RK-JTA	Contact Service Office
JTA Upgrade for WP03 Owners	RK-UPG-JTA	Contact Service Office

Disk Drive Analyzers



Main Features

- ***Drive Specific Triggers***
- ***Automatic PRML Channel Error Identification***
- ***PRML Data Channel Quality Analysis***
- ***Servo Bursts Analysis***
- ***User Selected or Defined Drive Filtering***
- ***IDEMA® Standard Measurements (TAA, PW50, Overwrite, etc.)***
- ***Asymmetry Measurements***
- ***Drive Analysis Graphs***
- ***1 GHz Bandwidth***
- ***Up to 8 GS/s Single-Shot Sample Rate***
- ***16 Million Points of Acquisition Memory***
- ***64 Mbyte System RAM***
- ***9" Color Display with 8 Traces***

LeCroy Disk Drive Analyzers (DDA) are designed to meet the specific capture, view and analysis needs required by engineers and technicians performing disk drive analysis. The DDA family provides all the capabilities of LeCroy LC family of oscilloscopes enhanced with a rich set of disk drive specific capabilities defined in the language of drive engineers.

Included with LeCroy Disk Drive Analyzers are PRML data channel analysis tools, servo wedges analysis tools, customized triggers for capture of disk drive signals, a rich set of drive-specific signal measurement parameters, and drive analysis graphs.

These allow you to rapidly evaluate the quality of your drive signals. Find signal errors and determine the causes of errors or of insufficient quality.

An intuitive user interface has been designed for easy access to the DDA disk drive capabilities. In addition, the instrument still retains nearly identical operation to LeCroy's popular LC oscilloscopes for when you are not taking advantage of the DDA family's drive specific capabilities.

LeCroy Disk Drive Analyzers are designed to save engineers valuable time in troubleshooting and problem-solving.

The Disk Drive Analyzers are integrated and powerful systems providing the capability to:

- Capture the key events with high res olution for longer time intervals
- View data like never before, giving you more information more quickly, with a large, color CRT and advanced display techniques
- Analyze your signal to get answers quickly and more accurately with a powerful processing system and math packages.

9" Color Display

The DDA series has a very large, sharp oscilloscope screen that is 50% larger in total viewing area than a 7" screen.

Its powerful features include Analog Persistence, Color-Graded Persistence, Full Screen mode, Opaque or Transparent display, color association and personal color schemes. These provide the user with outstanding benefits that accelerate visual processing and effective communication of on-screen information.

High-Speed Acquisition

The design and debug of fast digital systems and the need to capture fast transient signals require high speed signal capture. The high 8 GS/s sample rate (DDA-120), 1 GHz bandwidth and long memory of the DDA series provide a flexible solution for capturing and viewing fast glitches and rise/fall-times.

Large Sample Rate Window

Having a high sample rate in a data acquisition system is only the first step to preserving data integrity. The time window over which this sample rate is available is also of critical importance. Long acquisition memory maintains the instrument's highest sample rate for large time windows allowing the user to sample long signals with high horizontal resolution.

With 16 million points of acquisition memory, the maximum sample rate of these disk drive analyzers of 8 GS/s is maintained for a time window of 2 ms. This sample rate window enables the user to record long signals with high resolution.

Optimum Performance

SMARTMemory is a Total Memory Management system that dynamically allocates resources of microprocessor power, acquisition memory and processing RAM. The intelligent management provided by SMARTMemory guarantees optimal usage of the disk drive analyzer resources.

The PowerPC microprocessor at the heart of these DSOs drives the system to produce results fast, providing rapid waveform update and super panel responsiveness.

Quick Diagnoses

Capturing and viewing waveforms is fundamental to an oscilloscope. Productivity improvements are accessible by using built-in math functions to assist troubleshooting and diagnoses of circuit problems.

The signal analysis capability of the Disk Drive Analyzer is enhanced by advanced waveform math, spectrum analysis, and waveform parameter analysis. This analysis capability greatly increases the speed with which circuit problems are clearly identified and solved.

Analog Persistence

At a push of the green button the user can switch between an analog view and a digital view of signals on these oscilloscopes.

The depth of signal information can be explored along the third dimension of the waveform display to give the user a complete picture of waveform activity.

Full Screen Grid

These LeCroy disk drive analyzers not only have a very large 9" screen but also provide a display mode with an extra-large grid. In Full Screen mode, all of the screen area is used to display signals.

8-Trace Display

8-trace display with any combination of math functions, zooms, reference memories or channels.

Octal grid display in normal and Full Screen display modes, with and without parameters displayed.

Autoscroll

Autoscroll displays the captured signal with a zoom expansion and automatically moves it across the screen. Scroll speed, starting point and pausing are freely selectable.

Easy Documentation

All waveform data and results of analysis can be quickly saved to floppy disk, memory card, ATA flash card, or a removable hard disk. This provides an efficient way to archive information and facilitates easy documentation of results.

An internal graphics printer outputs screen dumps in seconds providing the user with an immediate and clear record of signal activity.

Signal Capture

Acquisition System

Bandwidth (-3 dB):
@ 50 Ω: DC to 1 GHz
@ 1 MΩ: DC to 500 MHz typ. at PP005 probe tip; DC to 1 GHz at probe tip with optional AP020 1 GHz FET probe

No. of Channels: 4

Sample Rate
DDA-120: 8 GS/s (1 Ch), 4 GS/s (2 Ch), 2 GS/s (4 Ch)
DDA-110: 4 GS/s (1 Ch), 2 GS/s (2 Ch), 1 GS/s (4 Ch)

SOLUTIONS

Acquisition Memory:
See table below.

Sensitivity:
2 mV/div to 1 V/div, 50 Ω, fully variable.
2 mV/div to 10 V/div, 1 MΩ, fully variable.

Scale factors: Choice of over 12 probe attenuation factors selectable via front panel menus.

Offset Range:

2.00 - 4.99 mV/div:	±400 mV
5.00 - 99 mV/div:	±1 V
0.1 - 0.99 V/div:	±10 V
1.0 - 10 V/div:	± 100 V (1 MΩ only)

±20 V across the whole sensitivity range when using the AP020 FET probe.

DC Accuracy: ± (2% FS + 1.6% offset value) for gain setting >10 mV/div.

Vertical Resolution: 8 bits

Bandwidth Limiter: 25 MHz and 200 MHz typical.

Input Coupling: AC (>10 Hz typ.), DC, GND

Input Impedance: 10 MΩ//15 pF max (using PP005 probe) or 50 Ω ±1%.

Max Input Voltage:
1 MΩ: 400V (DC + peak AC @ 10 kHz)

50 Ω: ± 5 V DC (500 mW) or 5 V RMS

Acquisition Modes

For repetitive signals from 200 ps/div to 1 µs/div.

Random Interleaved Sampling (RIS)
DDA-120: 25 GS/s
DDA-110: 10 GS/s
Single shot: For transient and repetitive signals from 0.5 ns/div (4 ch), 1 ns/div (2 ch), 2ns/div (1 ch) for the DDA-120, DDA-110 from 1 ns/div (4 ch), 2 ns/div (2 ch), 5 ns/div (1 ch).

Sequence: Stores multiple events - each of them time stamped - in segmented acquisition memories.

Dead Time Sequence Mode:
60 µs max.

Number of Segments Available:
2 - 1000

Timebase System

Timebases: Main and up to 4 Zoom Traces.

Time/Div Range: 500 ps/div (at 8 GS/s), 1 ns/div (at 4 GS/s), 2 ns/div (at 2 GS/s) to 1,000 s/div

Clock Accuracy: ≤10 ppm

Interpolator resolution: 10 ps

Manual Roll Mode: 500 ms/div to 1,000 s/div

External Clock: 50 to 500 MHz rear panel fixed frequency clock input. (<20 ns rise/falltime).

External Reference: 10 MHz rear-panel input.

Additional Information

Interfacing

Remote Control: All front-panel controls, as well as all internal functions are possible by GPIB and RS-232-C.

RS-232-C Port (Standard):
Asynchronous up to 115.2 kBaud for computer/terminal control or printer/plotter connection.

GPIB Port (Standard): (IEEE-488.2) Configurable as talker/listener for computer control and fast data transfer.

Centronics Port: Hard copy parallel interface.

Hard copy: Screen dumps are activated by a front-panel button or via remote control. Supported external printers:

B/W: LaserJet, DeskJet, Epson

Color: DeskJet, Epson, Canon BJC

Internal, high-resolution graphics printer is included for screen dumps; stripchart output formats up to 2 m/div are achievable.

Hard copy Formats: TIFF b/w, TIFF color, BMP color and BMP compressed.

Output Formats: ASCII waveform output. Compatible with spreadsheets, MATLAB, MathCad. Binary output is also available.

General

Auto-calibration ensures specified DC and timing accuracy.

Calibration Time: <500 ms

Recommended Factory Calibration Interval: 1 year

Temperature: 5° to 40°C rated accuracy (41° to 104°F). 0° to 45°C operating (32° to 113°F).

Humidity: <80% non-condensing.

Altitude: Up to 4600 m (operating), 40°C (104°F) max.

Shock and Vibration: Conforms to selected sections of MIL-PRF-28800F, Class 3.

Power: 90-250V AC, 45-400 Hz, 500 W.

Battery Backup: Front-panel settings maintained for two years.

Dimensions:
(HWD) 10.4" x 15.65" x 17.85",
264 mm x 397 mm x 453 mm.

Weight: typ. 20 kg (44 lbs) net, typ. 28 kg (61.6 lbs) shipping.

Warranty: Three years.

Active Channels	Max. Sampling Rate DDA-120	DDA-110	Maximum Record Length
4	2 GS/s	1 GS/s	4 M
2	4 GS/s	2 GS/s	8 M
1	8 GS/s	4 GS/s	16 M

Measurements

Cursor Measurements

Relative Time: A pair of arrow cursors measure time differences and voltage differences relative to each other.
Relative Voltage: A pair of line cursors measure voltage differences relative to each other.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

Automated Measurements

The following parametric measurements are provided together with their Average, Highest, Lowest values and Standard Deviation:

amplitude	cycles	fall	maximum	peak to peak	t@level
area	delay	f 80-20%	mean-	phase	top
base	Δc2d-, Δc2d+	f@level	median	rise	width
cmean	Δdelay	first	minimum	r 20-80%	
cmedian	Δ@level	frequency	overshoot+	r@level	
crms	duration	last	overshoot-	rms	
csdev	duty	lper	period	std dev	

The following Disk Drive Measurements are provided:

TAA	TAA+	TAA-	PW50	PW50+	PW50-
Resolution	Overwrite	lbase	lbsep	lmax	lmin
lnum	lpp	ltbe	ltbp	ltbt	ltmn
ltmx	ltot	ltpt	lttp	ltut	NLTS
ACSN					

The following histogram parameters are provided:

Low	High	Range	FWHM	maxp	Average
Sigma	totp	XAPK	PKS	Median	mode
Percentile					

PASS/FAIL: Pass/Fail testing allows any 5 items (parameters and/or masks) to be tested against selectable thresholds. Waveform Limit Testing is performed using Masks which may be defined either inside the instrument or by downloading templates created with ScopeExplorer. Any failure will cause preprogrammed actions such as Hardcopy, Save to Internal Memory, Save to mass storage device (card or disk), GPIB SRQ or Pulse Out.

CE Approval
EMC: Conforms to EN50081-1 (Emissions) and EN50082-1 (Immunity)

Safety: The Disk Drive Analyzer has been designed to comply with EN61010-1 Installation Category (Over-voltage Category) II, 300V, Pollution Degree 2.

UL and cUL approved: UL standard: UL 3111-1; cUL Canadian Standard CSA-C22.2 No. 1010. 1-92.

Signal Viewing

Type: Color 10" Raster Scan CRT, 0.26mm dot pitch.

Resolution: VGA (640 x 480 points)

Controls: Rear-Panel presets for position, brightness and contrast. Menu controls for brightness and color selection.

Grid Styles: Single, Dual, Quad, Octal, XY, Single+XY, Dual+XY, and Full Screen - an enlarged view of each grid style.

Graticules: Internally generated; separate intensity control for grids and waveforms. Selectable blending of grid with displayed traces.

Waveform Style: Dot Join with optional sample point highlight or Dots only.

Persistence Modes: Color-graded persistence and Analog Persistence, infinite or variable with decay over time. In color graded persistence a color spectrum from red through violet is used to map signal intensity. With Analog Persistence the brightness level of a single color denotes signal intensity. Each trace's persistence data is stored in 64 k levels.

Trace Display: Opaque or transparent mode, with overlap management.

Number of Traces: 8 (any mix of channels, memories or Math functions).

Real-time Clock: Date, hours, minutes, seconds.

External Monitor: Rear-panel 15-pin socket for VGA compatible monitor.

Signal Analysis

Rapid Processing System

Microprocessor: 96 MHz PowerPC 603e.
System RAM: 64 Mbytes.
Video Memory: 1 Mbyte.
Persistence Data Map Memory: 16 bits per displayed pixel (64k levels).

Waveform Processing

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging.
Average: Summed averaging up to a million sweeps.
Envelope: Max, Min, or Max and Min values of up to one million sweeps.
Extrema: Roof, Floor, or Envelope values from 1 to 10^6 sweeps.
ERES: Low-Pass digital filters provide up to 11–bit vertical resolution. Sampled data is always available, even when a trace is turned off. Any of the above modes can be invoked without destroying the data.
Histogramming: Generate histogram of waveform parameter calculations.
Trending: Generate trend sequence of waveform parameter calculations.
Correlation: Calculate the normalized correlation coefficient between two signals.
FFT: Spectral Analysis with four windowing functions and FFT averaging.
Statistical Diagnostics: The Parameter Analysis package permits in-depth diagnostics on waveform parameters. Live histogramming of any waveform parameter measurement is possible and the histogram can be autoscaled to display the center and width of the distribution.
Any of the above processes can be invoked without losing the data.

Internal Memory

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4).
Processing Memory: Up to four 16-bit Waveform Processing Memories (A,B,C,D).
Setup Memory: Four non-volatile memories. Optional Cards or Disks may also be used for high-capacity waveform and setup storage.

Vertical Zoom: Up to 5x vertical expansion (50x with averaging, up to 40 µV/div sensitivity).

Horizontal Zoom Factor: Waveforms can be expanded up to 5 points/screen..

Triggering System

Modes: Normal, Auto, Single, and Stop.

Sources: CH1, CH2, CH3, CH4, Line, Ext, Ext/5. Slope, Level and Coupling are unique for each source.

Slope: Positive, Negative, Bi-Slope (Window in & out).

Coupling: DC, AC (>10 Hz), HF (175 MHz - 2 GHz), LFREJ (>50 kHz), HFREJ (<100 MHz)

Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% increments).

Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div. increments).

Holdoff by time: 2 ns to 20 s.

Holdoff by events: 1 to 99,999,999.

Internal Trigger Range: ±5 div.

Maximum Trigger Frequency: 1 GHz (DC, AC), >1 GHz (HF).

Trigger Sensitivity:

DC to 500 MHz: 0.5 div
500 to 750 MHz: 1 div
750 MHz to 1 GHz: 2 div.

Trigger Accuracy:
500 ps to 10 ns: ±10% ±200 ps
10 ns to 100 ns: ±2% ±200 ps
100 ns to 20 s: ±1 ns.

EXT Trigger Max. Input: 10 MΩ// 15 pF at probe tip (PP005): 400 V (DC+ peak AC <= 10 kHz).

50Ω ±1%: ± 5 V DC (500 mW) or 5 V RMS

EXT Trigger Range: ±0.5 V (±2.5 V with Ext/5)

Trigger Output: ECL rear panel output. The calibrator output can provide a trigger status signal or a Pass/Fail test output.

SMART Trigger Types

Pattern: Trigger on the logic combination of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.

Signal or Pattern Width: Trigger on glitches as short as 600 ps or on pulse widths within/outside two limits selectable from 600 ps to 20 s.

Slew Rate: Trigger on rising, falling edges within/outside two time limits selectable from 600 ps and 20 s.

Signal or Pattern Interval: Trigger on an interval between two limits selectable from 2 ns to 20 s.

Dropout: Trigger if the input signal drops out for longer than a time-out from 2 ns to 20 s.

State/Edge-Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.

Disk Drive Triggers: A variety of specialized triggers for disk drive signals are available.

TV: Allows selection of up to 1500 lines and field synchronization for PAL, SECAM, NTSC or non-standard video.

AUTOSETUP

Automatically sets sensitivity, vertical offset and timebase on all display channels.

Autosetup Time: Approximately 3 seconds.

PROBES

Model: AP215 Disk Drive NRZ Logic Probe.
Model: One PP005 probe supplied per channel.

Optional Probe: 1 GHz FET probe (AP020). 500 MHz Active Differential Probe (AP033).

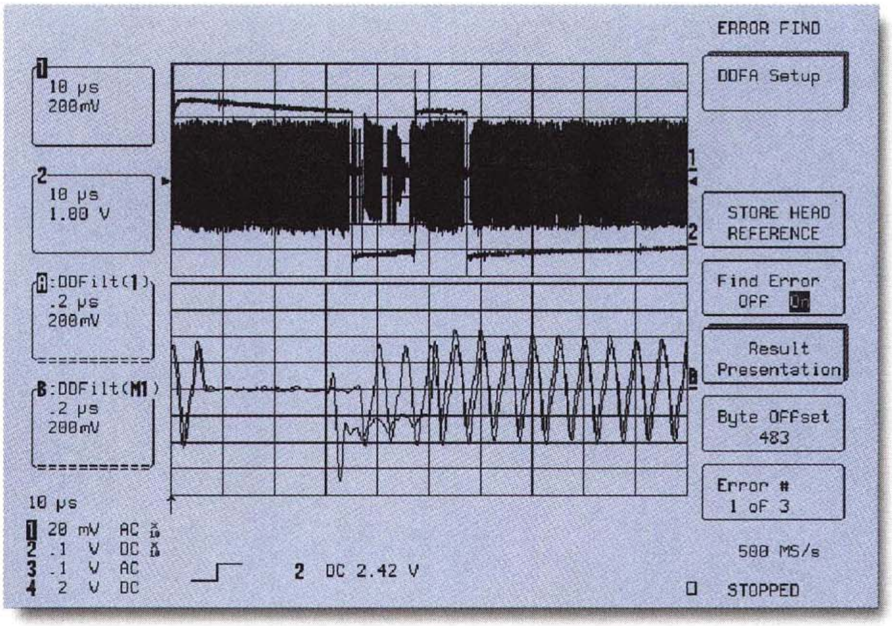
Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and falltime 1 ns typical. Alternatively, the calibrator output can provide a trigger output or a Pass/Fail test output.

Disk Drive Analyzer - Ordering Information

Disk Drive Analyzers	Product Code	Price
1 GHz, 2 GS/s, 4 Mpts./ch, 4 channel Disk Drive Analyzer/DSO	DDA-120	$ 41,990
1 GHz, 1 GS/s, 4 Mpts./ch, 4 channel Disk Drive Analyzer/DSO	DDA-110	37,990
Included with Standard Configuration:		
10:1 10 MΩ Passive Probe (1 per channel)	PP005	175
Disk Drive Analyzer User's Guide	DDA-UG-MAN	85
Disk Drive Analyzer Reference	DDA-REF-MAN	85
Performance Certificate		
Three Year Warranty		
Selected Probes & Accessories:		
1 GHz 10:1 FET Probe	AP020	990
DC-15 MHz Differential Probe, 10:1/100:1	AP031	300
DC-15 MHz Differential Probe, 20:1/200:1	AP032	300
500 MHz Differential Probe	AP033	2,495
2.5 GHz 0.6pF Active Probe	AP54701A**	2,944
Probe Offset and Power Module	AP1143A**	1,568
1 GHz, 10:1, 500 Ω Passive Probe	PP062	95
ProBus 75 to 50 Ω Adapter	PP090	195
SMD Kit for PP005 Probe	PK106	150
SMD Kit for AP020 Probe	PK006	120
Software Options:		
Jitter & Timing Analysis Package	JTA	1,875
Optical Recording Measurements	ORM	3,000
Hardware Options:		
Memory Card Reader	MC01	500
PCMCIA Type III Slot for Hard Drives and ATA Flash Cards	HD01	590
PCMCIA Hard Disk 170 Mbyte (requires HD01 option)	HD02	499
4MB ATA Flash Card (requires HD01 option)	4MBFC	399
PCMCIA type III External Desktop Adaptor for PC (110 V)	DA01-110	360
PCMCIA type III External Desktop Adaptor for PC (210 V)	DA01-220	360
Manuals:		
Service Manual for DDA-1X0	DDA-SM	125
Warranty & Calibration:		
NIST Calibration Certificate	DDA-CCNIST	225
MIL STD Calibration	DDA-CCMIL	325
Swiss OFMET Standard	DDA-CCOFMET	225
5 Year Repair Warranty	DDA-W5	545
5 Year NIST Calibration Contract	DDA-C5	725
5 Year Warranty & NIST Calibration	DDA-T5	975

** *Normally ordered together*

LeCroy DSO Disk Drive Options



LEADING SPECIFICATIONS

- ***PRML Head Signal Analysis***
- ***PRML Failure Find and View***
- ***Positioning Head Signal Display by Byte Number***
- ***Real Time NRZ Error Probe***
- ***IDEMA® Test Standard Measurements-PW50, TAA, Resolution, Overwrite***
- ***PRML Non-Linear Distortion and Noise Measurements***
- ***Histograms and Trends for Statistical Analysis***

LeCroy digital oscilloscopes combined with LeCroy's Disk Drive Options are designed to save engineers valuable time in characterizing and troubleshooting hard disk drives and their components. They provide an integrated hardware and software toolset for engineers and technicians working in research, design, test and failure analysis.

- Capture head and control signals from a track or a group of sectors at sampling speeds up to 8 GS/s using memories as long as 8 million sample points.
- View the whole captured signal, or use zooms to see finer detail in multiple sectors of data. The display can show the head digital signals, frequency spectra and histograms of the parameters.
- Analyze with flexible and integrated tools. LeCroy's Disk Drive Analysis Solution combines three individual packages that incorporate time-saving methods for solving problems found in PRML and peak-detect drive technologies.

Disk Drive Failure Analysis Package (DDFA)

This package provides advanced error-finding techniques for understanding the performance of PRML (Partial Response Maximum Likelihood) and peak-detect disk drive products. Using a common setup on either LeCroy color or 9300 series oscilloscopes, the DDFA package provides five techniques to help you find marginal errors.

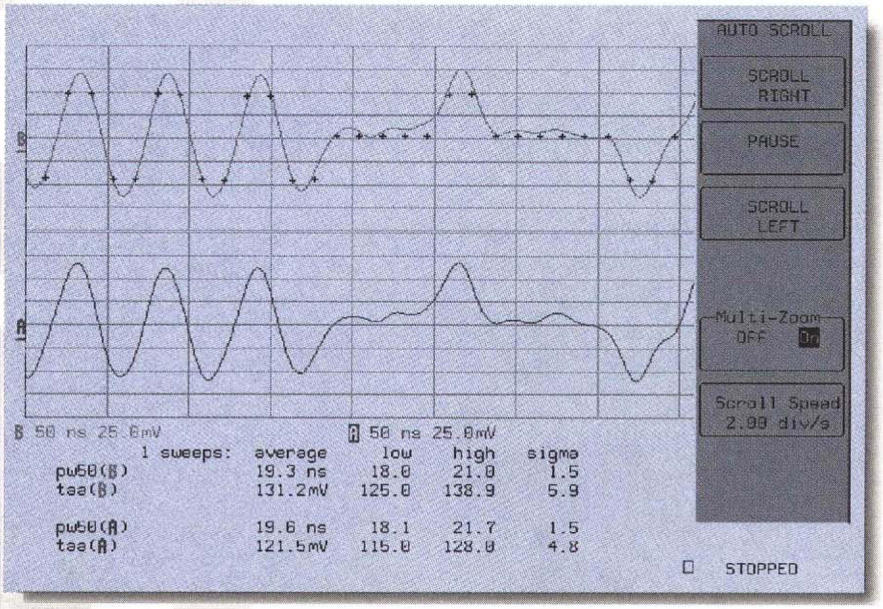
LeCroy has innovated in several areas to make the oscilloscope and analysis features easy to use:

- Helper menus guide the user to select the necessary drive characteristics such as PR4, EPR4 or E^2PR4 and the encoding method. For example, by selecting the oscilloscope input channels for the analog data, optional read gate, and read clock, the DDFA package will automatically calculate the VCO sync bit cell time and identify the first data byte.

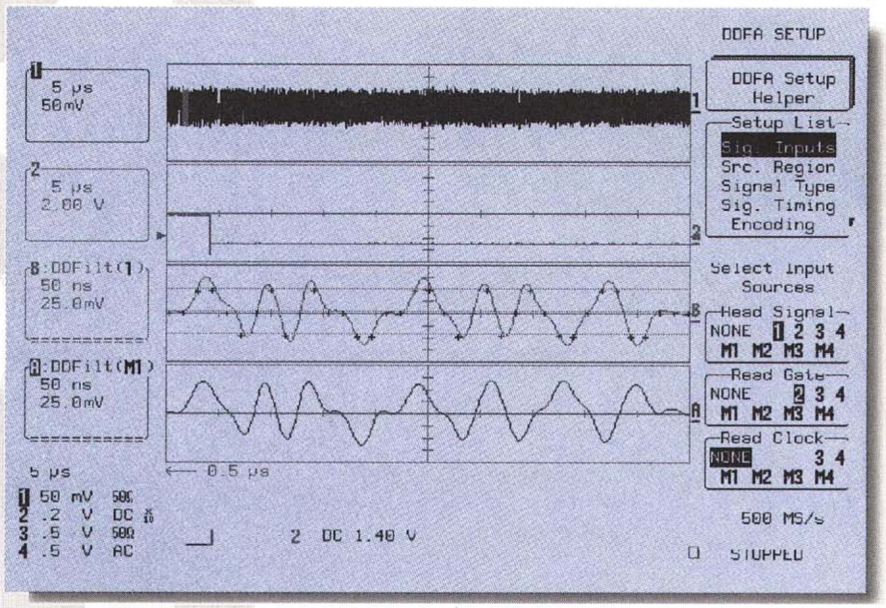
  For repeated testing of a specific drive model, use the Setup Helper only once, and store the settings as a panel setup to the floppy disk, optional hard drive or memory card. Panel and GPIB Remote Command can be used for the standardization of testing procedures.

- Auto Scroll zooming displays the captured signal with an accurate zoom expansion that moves across the screen. Select where to start scrolling through the zoomed data, and pause on any feature.
- A self-training filter adjusts the cutoff and boost components to optimize the filter applied to the analog head signal. All the error-finding methods, parameter and math functions of the oscilloscope operate transparently on the filtered signal data.

Photo courtesy of Quantum Corporation

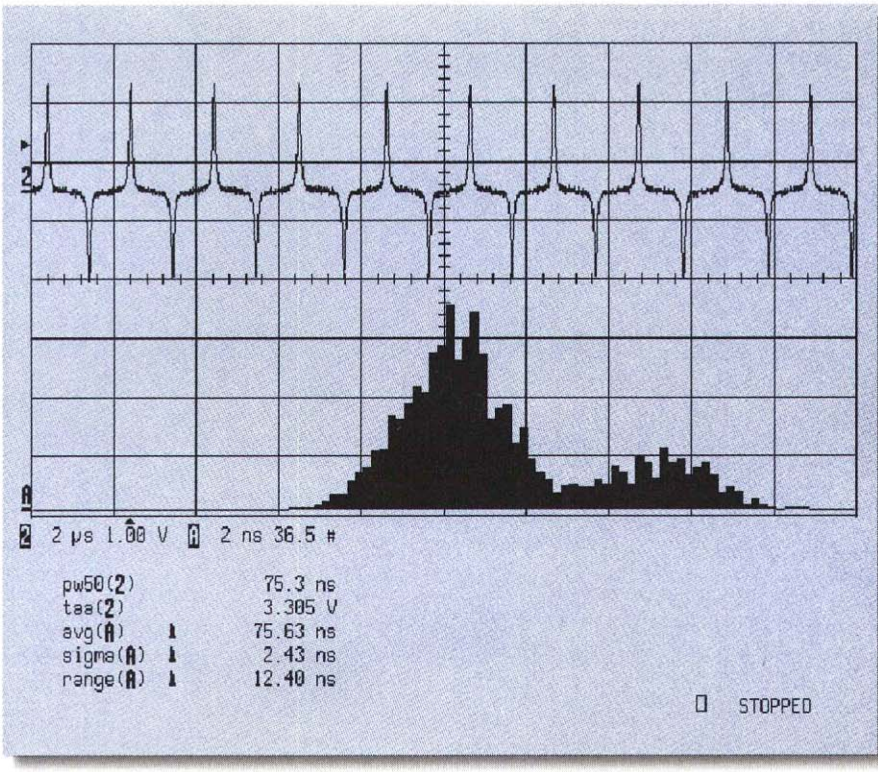


Auto Scroll automatically looks through the analog head data .



Helper menus lead you through the setting up of any of five different error-finding methods.

Histogram shows the variation in pw50.



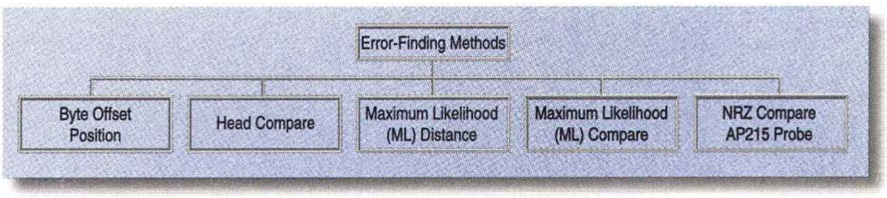
New Approach to Finding Errors

There are five different error-finding methods used in the DDFA package. Each helps find the errors in a different part of a drive, while following a common step-by-step approach.

- Connect input signals to scope (head, read gate, etc.)
- Input drive characteristics (PRML type, filter characteristics, encoding ratio)
- Select and start Error-Finding Method (automatically stops triggering when acquisition contains errors).

All methods count the number of errors found and let you dial into the exact byte offset position to locate and view the detected errors. The number of errors and byte offset of each is displayed on the screen.

Errors are ranked either from largest to smallest or from left to right of the display and can be individually viewed, allowing an engineer to see the range of each measured on a drive. Now there is no need to manually find a problem in a sector ... it's automatic.



Error-Finding Methods

Byte Offset Position

The DDFA package uses the setup information about the drive type, VCO sync bytes and encoding to automatically identify the byte in which the error is located. If you already know the error position, you can repeatedly go back and find the byte as an offset from the beginning of the read gate.

Maximum Likelihood Distance

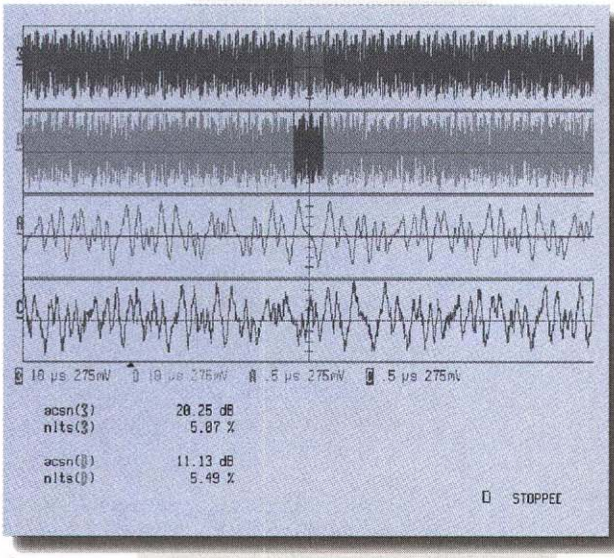
ML Distance, using a full disk drive channel emulation, helps understand how the signal should appear when a good reference signal is not available. The DDFA package includes the algorithms for measuring the margin of a channel using any pattern.

ML Distance looks at the signal on a drive and uses the self-training filter to minimize errors. It calculates the data-point extracted from the ML (Viterbi) detector and provides a Sequence Amplitude Margin (SAM) for the measurement.

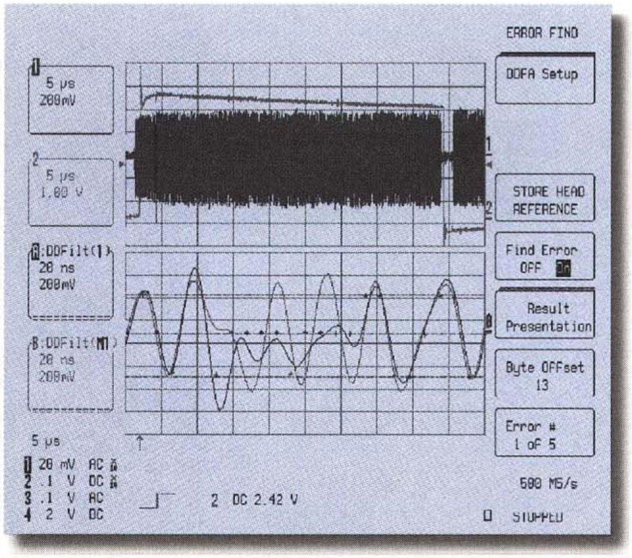
Maximum Likelihood Compare

While the ML Distance mode acquires a single trace and predicts in which bit the drive is most likely to create an error, the ML Compare error mode calculates the Viterbi output for both a reference signal and a new acquisition of a drive signal. The algorithm compares the two and finds the mismatch. ML Compare differs from the other comparison methods in that it stores only those points at the clock location (as defined by the emulated PRML channel inside the scope).

SOLUTIONS



Non-linear distortion and signal to noise measured on raw and filtered head signal .



Error found between reference memory and filtered drive signal. Blue markers indicate the PRML sample points.

Head/Analog Compare

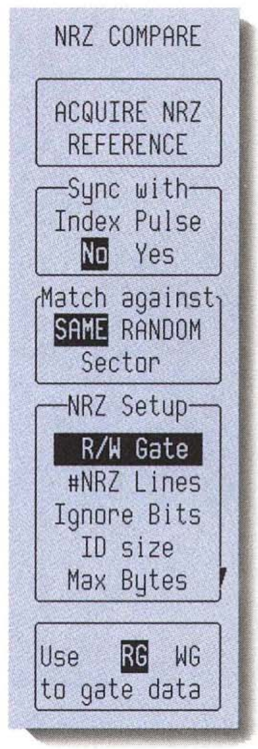
Before the introduction of LeCroy's DDFA package, looking for small differences or soft errors on a drive was difficult and time consuming. Now the Head/Analog Compare feature simplifies and speeds up the process. When the Head/Analog Compare mode is selected, a "known good" signal is stored in memory. The software automatically aligns and compares the reference and live signals. An error is detected when the difference between live and reference exceeds a user-defined threshold. Up to 100 errors can be found and are stored from the largest to the smallest. Select the error you want to view, and the byte offset position automatically shows you the reference, the error byte, and adjacent bits on the screen.

NRZ Data Digital Compare

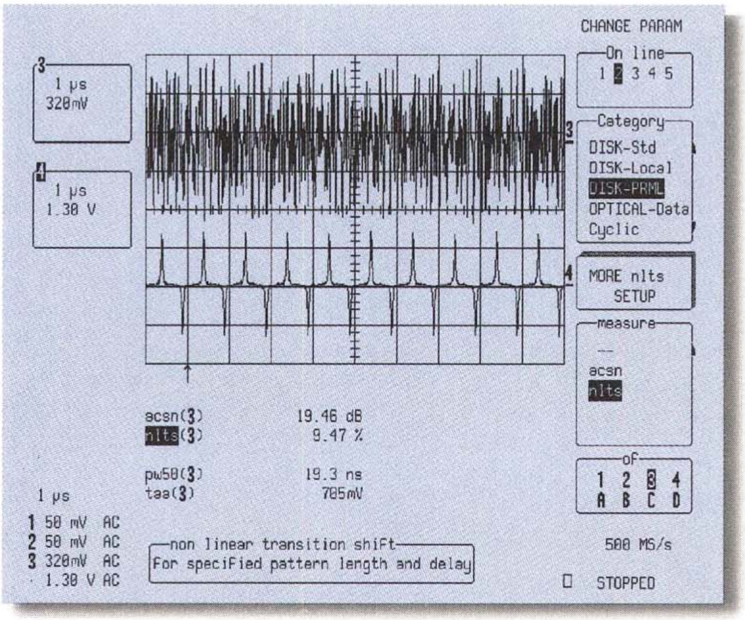
Intermittent data errors on a drive can be found in real time using the new AP215 Disk Drive NRZ Logic Probe. The probe connects up to 12 NRZ data lines, read clock and control signals to the oscilloscope. After loading a reference pattern into the probe's 32 K word memory, a real-time compare is done between live NRZ signals and the digital reference pattern. Setup is simplified through the oscilloscope's NRZ Compare Setup Menu. In drive failure analysis, an engineer might hesitate to rewrite customer data on a known bad drive. By loading the known bad sector into the reference, the probe then looks for errors between the live NRZ signal and the NRZ reference during successive reads. When an error occurs, the analog signal can automatically be viewed along with the byte offset position.

The AP215 probe connects to the external trigger input of the oscilloscope, which keeps the four input channels of the scope accessible for the head signal and digital signals on the drive.

AP215 Disk Drive NRZ Logic Probe	
Inputs	AP215
Channel NRZ data lines	Up to 12
Read Gate / Write Gate	Y
Index	Y
Read Clock / Write Clock	Y
Synchronize probe to index	Standard
Input Signal Levels	TTL
Maximum Clock Speed	Number of NRZ Lines x 50 MHz
Setup / Control	Menu Selection on Scope
Compatibility	LC Series / 9300 Series Oscilloscopes



The head signal and the parametric measurements are updated simultaneously on the large inch color display.



Histograms are especially helpful in finding how the variation of a drive metric, e.g. pw50, might effect the performance of a head disk assembly. By looking at the statistics of a parameter, an engineer can begin to correlate key parametric measurements with error rate performance.

IDEMA Test Methods Parameters

The DDM package includes processing functions specified in the IDEMA test standards document.*

*As specified in IDEMA Standards, 1994 Revised Edition
(1) Document No. T15-91
(2) Document No. T3-91
(3) Document No. T4-91
(4) Document No. T14-91

Disk Drive Measurement Package (DDM)

LeCroy's Disk Drive Measurement package provides the ability to perform automated drive waveform measurements. The combination of automated measurements, long memory, and large waveform display creates previously unavailable drive analysis capabilities.

The DDM package provides IDEMA test methods measurements and many other measurements for analysis of Lorentzian signals.

Built-in parameter and histogram measurements in the DDM package help characterize the drive, head or media on several sectors or a whole track. The algorithms are innovative and robust to measure asymmetric MR signals and to provide accurate results even when viewing noisy drive signals.

Also provided with the DDM package are two powerful math functions (histogram and trend) that allow any parameter to be histogrammed and statistically analyzed.

Name	Description
PW50*(1)	Pulse Width 50: Provides an average pulse width, measured at 50% peak amplitude, of all peak/trough pairs in the specified waveform.
PW50(+)	Pulse Width 50 (+): Provides an average pulse width, measured at 50% peak amplitude, of all peaks in the specified waveform.
PW50(-)	Pulse Width 50 (-): Provides an average pulse width, measured at 50% peak amplitude, of all troughs in the specified waveform.
TAA*(2)	Track Average Amplitude: Provides an average peak-to-peak amplitude of all peak/trough pairs in the specified waveform.
TAA(+)	Track Average Amplitude (+): Provides an average peak amplitude of all peaks in the specified waveform.
TAA(-)	Track Average Amplitude (-): Provides an average peak amplitude of all troughs in the specified waveform.
RESOLUTION*(3)	Specified as (TAA(F1)/TAA(F2))*100% Where: F1 = Low Frequency F2 = High Frequency
OWRT*(4)	Overwrite: Specified as 10 log (V_r/V_o) Where: V_r if the residual V_{rms} of F1 (low frequency) after F2 (high frequency) write V_o is the V_{rms} of F1 (low frequency) after F1 write.

Peak/Trough Pair Parameters

Parameters that measure amplitude and timing relationships between positive peaks and negative peaks (troughs) of a waveform are also included in the DDM package. Used in conjunction with the histogram processing function, a statistical description of the waveform can be calculated.

Frequency Domain Parameters

These parameters provide a rapid technique to extract amplitude and phase of single frequencies from complex waveforms. These parameters are more efficient than using an FFT for specific frequencies of interest.

Name	Description
nbph	narrow-band phase in degrees relative to start of waveform
nbpw	narrow-band power in dBv

The nbpw frequency domain parameters provide an easy method for measuring non-linear distortion using Fifth Harmonic Elimination.

Histograms

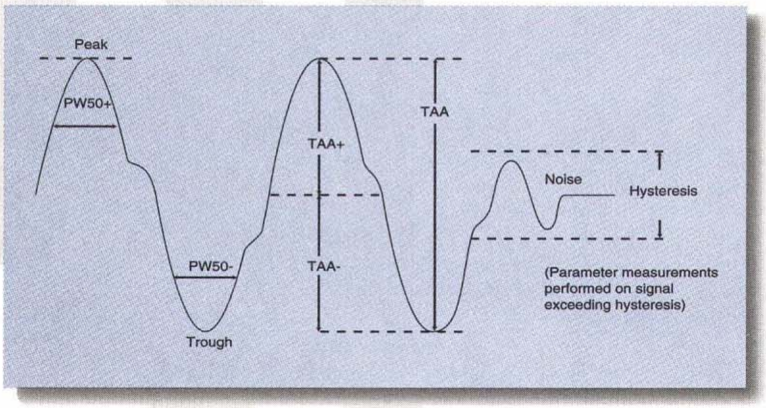
Any waveform parameter may be histogrammed. The histogram function produces a waveform with the vertical axis in units of 'Events' and the horizontal axis in parameter units (volts, nanoseconds, etc.). The histogram shows the statistical variation of the selected parameter and is an extremely valuable analysis tool.

Using scope measurement cursors, the value and population of any bin can be exactly determined.

Trends

Any waveform parameter may be used to generate a sequence trend of calculated values. The trend function shows variation of a parameter measurement as the head moves through a sector or multiple sectors.

Name	Description
lmax	local maximum
lmin	local minimum
lnum	number of local peak and trough pairs
lpp	local peak-to-peak (lmax - lmin)
ltbe	local time between events (either peak-to-trough or trough-to-peak)
ltbp	local time between peaks
ltbt	local time between troughs
ltmn	local time at minimum
ltmx	local time at maximum
ltot	local time over threshold
ltpt	local time between peak and trough
lttp	local time between trough and peak
lbase	baseline voltage of peak trough pair
lbsep	baseline voltage difference of a peak vs. trough
ltut	local time under threshold



Solutions

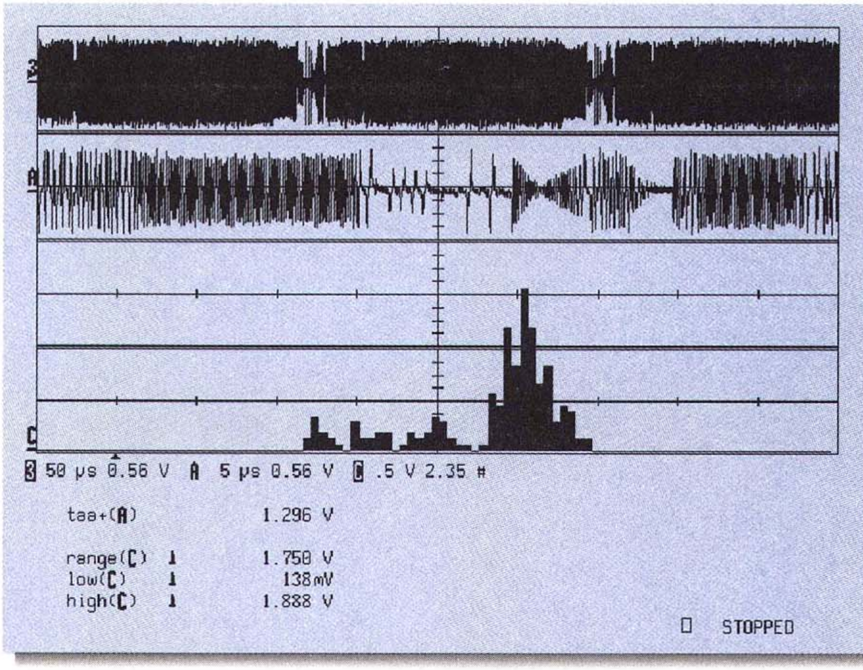
Histogram Parameters

Histogram parameters provide the ability to obtain numeric values for statistics or other features of a histogram. When combined with the LC series or 9300 family parameter cursors, the statistics or other characteristics of a selected section of interest in a histogram can be measured.

PRML Measurement Package

The PRML package provides parameter measurements specifically for PRML signals including PR4, EPR4 and E^2PR4.

PRML (Partial Response Maximum Likelihood) recording channels provide higher area densities by allowing magnetic transitions to be written at closer spacing than peak detection channels. The following parameters provide a time domain technique to measure the time shift and s/n ratio created by this magnetic writing process.



A histogram of TAA shows the amplitude variation on the complete signal or on the zoomed area.

Name	Description
NLTS (%)	Non-Linear Transition Shift in percent: NLTS = -200 x r Where: r = auto-correlation coefficient @ time delay
ACSN	Auto-Correlation Signal-to-Noise Ratio: ACSN = 10 log (R/1-R) Where: R = correlation coefficient
Auto-Correlation	$R_X(u) = \int f_X(t) f_X(t-u) dt$

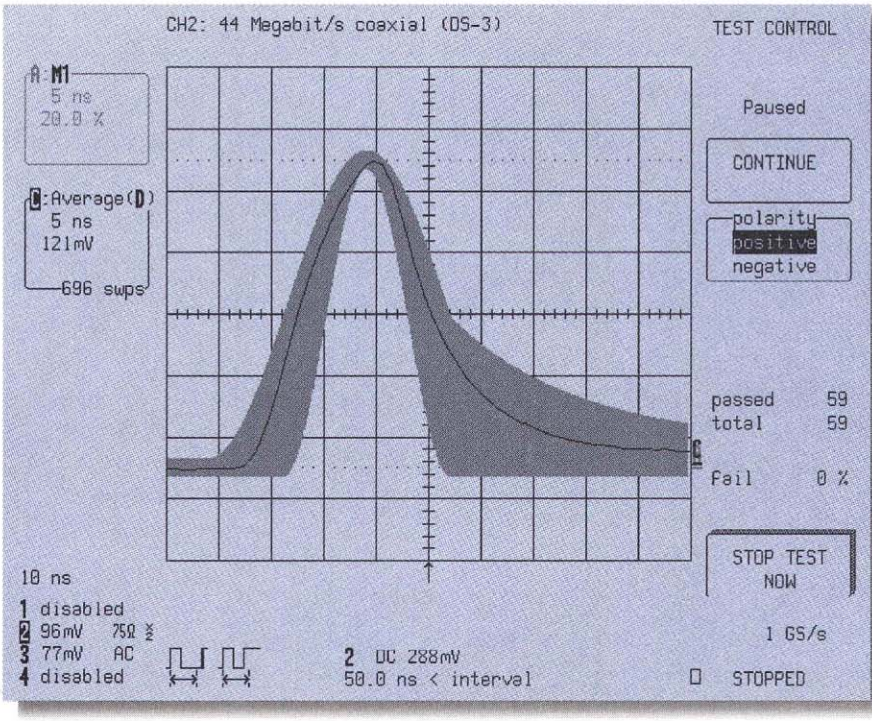
Name	Description
low	minimum value
high	maximum value
range	high - low
fwhm	full width half max
maxp	maximum population is the highest population (vertical value) in the histogram
average	mean value
sigma	standard deviation
totp	total population
xapk	provides the horizontal position of the selected peak
pks	provides the total number of peaks
median	provides the horizontal position of the value which divides the histogram into two equal populations
mode	provides the horizontal position of the most frequently occurring value
pctl (Percentile)	provides the horizontal position of the peak which separated the histogram such that the population on its left is a specified percentage of the total

Solutions - Ordering Information

Datastorage Software Options:	Product Code	Price
Disk Drive Analysis Package	DDANALYZER*	$ 6,990
Disk Drive Failure Analysis Package	DDFA	4,990
Disk Drive Measurement Package	DDM	3,000
PRML Measurement Package	PRML	1,250
Disk Drive NRZ Logic Probe	AP215	1,850

* Includes all three Disk Drive Solution Packages

Telecom Testing



Main Features

- ***Easy to Use***
- ***Exclusive: Works on Random Bit Streams***
- ***Self-Aligning***
- ***Self-Scaling***
- ***Includes all Necessary Balanced and Coax Adapters***
- ***Dedicated Menus***
- ***Full Remote Control Support for Production Test***

LeCroy's powerful and innovative Mask Tester instantly transforms your digital oscilloscope into a dedicated mask-testing device, specifically designed for manufacturing, type approval and field testing.

- **Powerful:** the Tester's exclusive Finder function allows pulses or patterns to be easily isolated - even from random-bit streams. Mask alignment is totally automatic, saving valuable testing time.
- **Easy to use:** the Mask Tester takes over control of the oscilloscope. The scope displays only the Tester's dedicated menus, blocking unneeded control and reducing setup errors.
- **Convenient:** included in the package are all the twisted-pair and 75 Ω interfaces you'll need for quality cable termination and exact amplitude scaling.

Dedicated Mask Tester

With the MT01 or MT02 Mask Tester, your LeCroy digital oscilloscope becomes a powerful, dedicated mask-testing instrument.

Power & Innovation

Do you ever wish your oscilloscope could isolate a pulse in that scrambled STS-1 signal? Your wish is granted using the Mask Tester's exclusive Finder search engine.

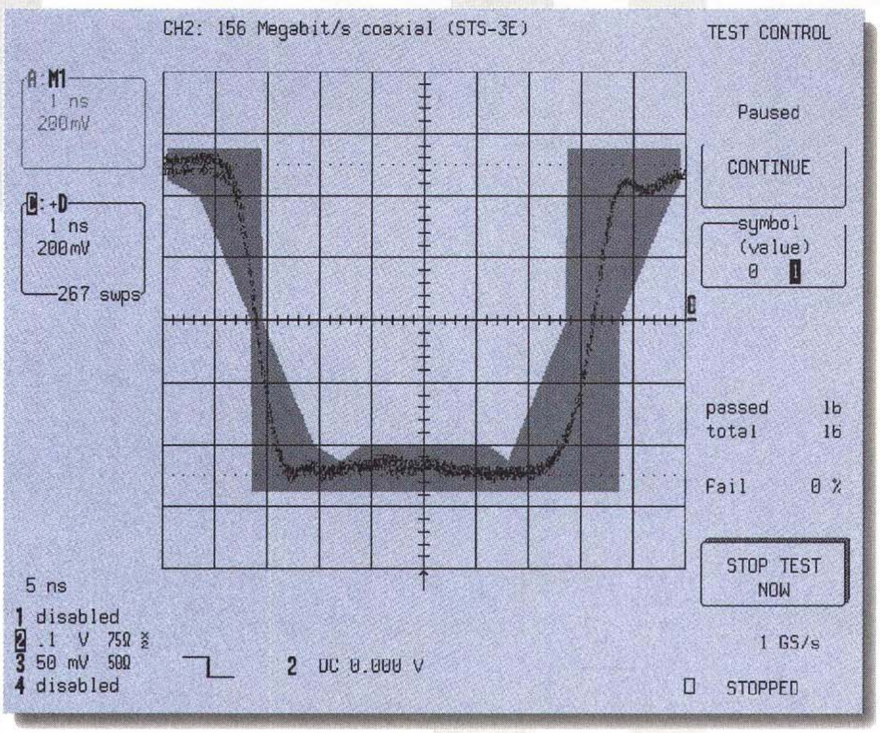
Capturing and aligning certain telecom signals can be tricky. But Finder uses pattern recognition. Pulse isolation can be performed at all bit rates, on any random-bit stream, eliminating the need for sophisticated pattern generators. Some CMI encoded signals (STS-3E, STM-1E, 140 Mb/s) tolerate a limited amount of offset (±0.05 V) when the signal is adjusted to the mask. The Mask Tester does this automatically, prompting the user if the offset goes beyond limits. And as required by the standard, the resulting offset adjustment is propagated to both masks ("1" and "0").

Ease of Use

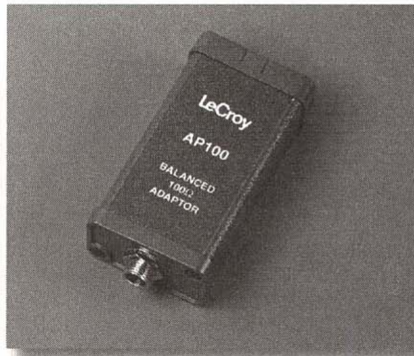
The Mask Tester's powerful features are even easier to use thanks to another innovation: the tester takes over complete control of the scope. It shows only those on-screen menus dedicated to the application, blocking unneeded front-panel controls. This simplifies operation and reduces operator error. The general-purpose DSO is made to "think and act" exactly like a dedicated mask tester.

Maximum Convenience

Twisted-pair and 75 Ω lines can easily be interfaced to the oscilloscope via intelligent ProBus adapters. These adapters provide the scope with both correct line termination and accurate amplitude scaling. The balanced adapters are Op-Amp based, providing ultra-wide bandwidth, flat-frequency response, and overall low distortion. Signal fidelity is assured.



Testing the 155 Mb/s SONET/SDH electrical signal. Notice how the "1" pattern is cleanly isolated in this PRBS stream.



The AP100 ProBus adapter provides adequate interfacing and scaling for ANSI/DS-1 signals.

Full Remote Control Support

All mask tester functions are available using high-level remote-control commands. And because the functions are specially designed and tailored to the tester, it takes fewer than 10 commands to control all of them. This makes ATE integration fast and painless. The AP100 ProBus adapter provides adequate interfacing and scaling for ANSI/DS-1 signals.

Specifications

Supported Mask Tests (All Electrical Pulse Masks)

MT01: E1 (2 Mb/s), E2 (8 Mb/s), E3 (34 Mb/s), E4 (140 Mb/s "0" and "1"), and STM-1E (156 Mb/s "0" and "1")

MT02: DS-1, DS-3, STS-1, STS-3 ("0" and "1")

Signal Adaptors

MT01: 120 Ω balanced adapter with Siemens-type banana connector, 75 Ω coax adapter.

MT02: 100 Ω balanced adapters with Bantam-type connector, 75Ω coax adapter.

Features

MT01:

- Automatic signal to mask alignment.
- Cable attenuation compensation.
- 4 selectable Pass/Fail actions: "Stop," "Hardcopy," "Store," "Beep."

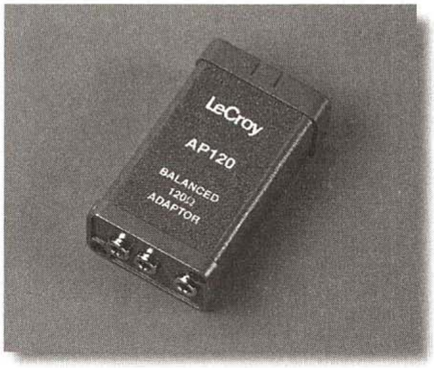
- "1" and "0" CMI pulse extraction for 140 and 156 Mb/s.
- Convenient offset management for 140 and 156 Mb/s.
- 120 Ω balanced and 75 Ω coax ProBus adapters: automatic scale compensation for accurate amplitude readout.

MT02:

- Exclusive, "Isolated pulse" extraction on random-bit stream following ANSI T1.102 requirements.
- 4 selectable Pass/Fail actions: "Stop," "Hardcopy," "Store," "Beep."
- "1" and "0" CMI pulse extraction for 140 and 156 Mb/s.
- Convenient offset management for 140 and 156 Mb/s.
- 100 Ω balanced, and 75 Ω coax ProBus adapters: automatic scale compensation for accurate amplitude readout.

Warranty:
Three years.

The AP120 ProBus adapter, the twisted pair G.703 2 Mb/s signals correctly terminated and scaled.



Name	Bit Rate (Mb/s)	Pulse	Impedance	Coding	Isolation Required	Isolation Pattern
MT01 - ITU G.703						
2 M TP	2.048	pos neg	120 Ω	HDB3	NO	
2 M Coax	2.048	pos neg	75 Ω	HDB3	NO	
8 M Coax	8.448	pos/neg	75 Ω	HDB3	NO	
34 M	34.368	pos/neg	75 Ω	HDB3	NO	
139 M	139.264	pos neg	75 Ω	CMI	YES	1010 1001
STM-1E	155.520	pos neg	75 Ω	CMI	YES	1010 1001
MT02 - ANSI T1.103						
DS-1	1.544	pos neg	100 Ω	AMI or B8ZS	YES	000010 0000-10
DS-3	44.736	pos neg	75 Ω	B3ZS	YES	0010 00-10
STS-1	51.840	pos neg	75 Ω	B3ZS	YES	0010 00-10
STS-3	155.520	pos neg	75 Ω	CMI	YES	1010 1001

Software Options - Ordering Information

Software Options:	Product Code	Price
ITU G.703 electrical pulse mask includes 120 Ω balanced and 75 Ω coax adapters	MT01	$ 3,000
ANSI T1.102 electrical pulse mask includes 100 Ω balanced and 75 Ω coax adapters	MT02	3,000
Bundled MT01 + MT02 package	MT01/02	4,000
Field upgrade for MT01	RK-MT01	Contact Service Office
Field upgrade for MT02	RK-MT02	Contact Service Office
Field upgrade for MT01 + MT02	RK-MT01 + MT02	Contact Service Office

Digital Oscilloscope Probes & Accessories

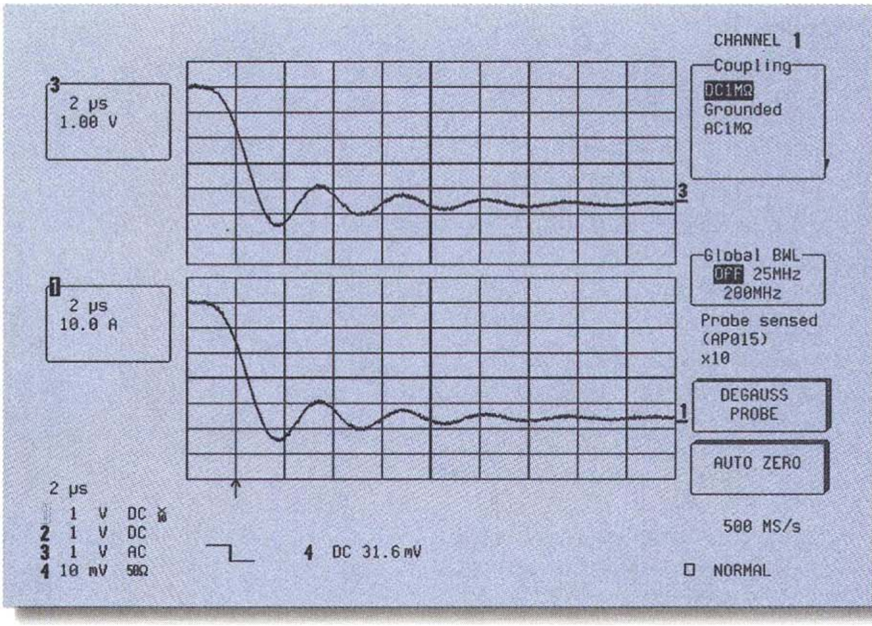
Main Features

- ***Bandwidths from 10 MHz to 8 GHz***
- ***Attenuation from 1x to 100x***
- ***Input rise times as low as 58 ps***
- ***Differential Probes***
- ***High Voltage Probes***
- ***Passive Probes***
- ***Active Probes***
- ***50 MHz Current Probes***
- ***Differential Amplifiers***

LeCroy has recently added a wide variety of world class probes and amplifiers to it's product line. The 1800 series of differential amplifiers and probes, the 500 MHz AP033 differential probe (check www.lecroy.com for more information on this brand new product), PPE series of six high voltage probes, AP015 (50 MHz, 50 Amp), AP011 (120 kHz, 150 Amp) current probes and a wide selection of active and passive probes with bandwidths to 8 GHz are available.

Choosing a Passive or Active Probe

The scope/probe system bandwidth is dependent on the scope's bandwidth, probe impedance, and the circuit's source impedance.



$$BW = \frac{1}{2 \pi R_S C}$$

Where R_S = resistance of source circuit and C is total capacitance of probe and circuit.

The most commonly quoted specifications of passive probes are their bandwidth, impedance and capacitance. In fact, all three characteristics are related. The capacitive reactance (impedance in ohms) of a passive probe is related to the input frequency and probe capacitance by :

$$X_C = \frac{1}{2 \pi F C}$$

Where X_C is the capacitive reactance (in ohms) at an input frequency F for a probe with capacitance C. As an example, a 10 MΩ passive probe with 11 pF capacitance is supplied by a scope manufacturer who rates its performance as 500 MHz at the probe tip. But in a separate document, the manufacturer also correctly points out that the capacitive reactance of this probe is only 290 Ω at 50 MHz. For signals of 50 MHz and above, this probe is not the best tool.

LeCroy offers three types of probes to address this problem. The PP005 10 MΩ probe supplied standard with the 9370C and 9384C series scopes has the typical 11 pF capacitance of high-impedance probes. But if your circuit can drive 500 Ω, the PP063 has <0.5 pF capacitance and 8 GHz bandwidth. The most common tool for high-speed designers is the active (FET) probe. LeCroy offers 1 GHz and 2.5 GHz active probes which present the circuit under test with a low-capacitance, constant high-impedance load. The 1 GHz (model AP020) probe is very reasonably priced and acquires its power from the oscilloscope via the ProBus connection which is integral to the scope. The 2.5 GHz probe (model AP54701A supplied to LeCroy from Hewlett Packard) is a very powerful tool with wide dynamic range and offset control. It requires a separate power supply (model AP1143A). The 500 MHz bandwidth AP033 is a high-impedance differential probe.

Passive Probes

LeCroy digital oscilloscopes are provided with a set of passive probes, one per channel. In order to provide the best possible pulse and frequency response, each passive probe is adjusted to match a specific oscilloscope.

Adjustments

Frequency compensation on the high-impedance probes is accomplished through the use of adjustment screws on the probe heads. All LeCroy digital oscilloscopes provide a calibration output on their front panel for this adjustment. The LeCroy 9300C and LC series scopes provide internal capability of adjusting both the amplitude and frequency of the calibration output to suit user preferences. The output is applied to a front panel BNC, and a BNC-to-probe tip adapter is supplied in each probe kit.

Passive Probes Selection Guide

Types	Bandwidth	Input Z Ω	Input C pF	Attenuation	Maximum Voltage	Probe Ring	Compatibility
PP002	350	10 M	14.0	10:1	500	YES	1; 2
PP005[1]	500	10 M	11.0	10:1	500	YES	3
PP062	1000	500	1.5	10:1	22	YES	1; 2; 3; 4
PP063[2]	8000	500	<0.5	10:1	10	NO	1; 2; 3; 4
PP064	1000	5 K	1.3	100:1	30	YES	1; 2; 3; 4

[1] Mini Probe: The ideal probing tool for fine pitch integrated circuits.

[2] Equipped with SMA conductor

Compatibility:

1= 9304C/9310C/9314C
9350C/54C

2= 9361C

3= 9370C/74C
9384C
LCs

4= 9362C

PROBES & ACCESSORIES

LeCroy ProBus System

The ProBus system provides a complete measurement solution from probe tip to oscilloscope display. This intelligent interconnection between LeCroy oscilloscopes and a growing range of accessories is achieved via a 6-wire bus following Philips' I2C protocol. It provides major benefits over standard BNC or even probe-ring connections:

- **Autosensing of the probe type**, eliminating all the guesswork – and the errors – from manually setting attenuation or amplification factors and proper input coupling.
- **Transparent gain and offset control** right from the front panel. Particularly useful for FET and current probes.
- **Gain and offset correction factors** are uploaded from the ProBus EPROMS on FET probes and **automatically compensated** to achieve fully calibrated measurements.

Active Probes

FET probes extend the measurement capabilities of any oscilloscope. They provide higher resistance, lower capacitance and a flatter system bandwidth than passive probes. The reduced load on the circuit being probed results in more accurate measurements. FET probes are the ideal tool for working on sensitive or high-speed electronics.

FET Probes

Model Number	Bandwidth MHz	Input Z MΩ	Input C pF	Attenuation	Dynamic Range (V)	DC Offset Range (V)	ProBus
AP020	DC to 1000 MHz	1	1.8	10:1 ±2%	10	±20	YES
AP54701A*	DC to 2.5 GHz	0.1	0.6	10:1	10	±50	NO

* Needs external power supply AP1143A

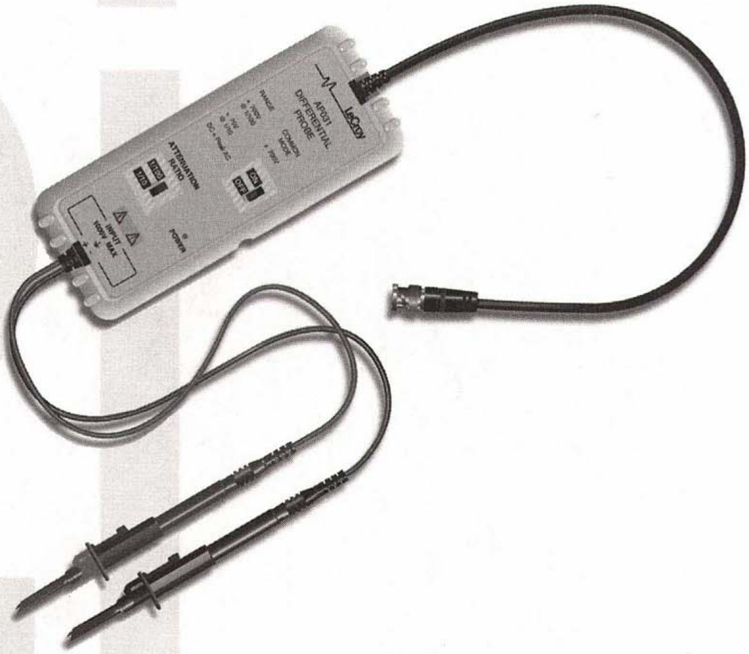
PROBES & ACCESSORIES

Differential Probes

The AP031, AP032, and AP033 are active differential probes compatible with all 1 MΩ input oscilloscopes. The differential techniques employed permit measurements to be taken at two points in a circuit without reference to ground.

This allows the oscilloscopes to be safety grounded without the use of opto-isolators or isolating transformers.

The two signals are processed in the probe, and the resultant output is fed into a single channel of the oscilloscope. The output from the probe is a coaxial cable equipped with a standard BNC connector.



Differential probes are key tools for measuring signals in power supplies, power devices, automotive electronics, high-speed analog/digital circuits and data storage devices.

Differential Probes

Model	Bandwidth MHz	Input Z MΩ	Common Mode Rejection Ratio 50 Hz	Common Mode Rejection Ratio 200 kHz	Attenuation	Maximum Input Voltage DC + Peak A Diff. V	Com. mode V	Abs. max. V
AP031	DC to 15	4	-86	-56	10:1 100:1	±70 ±700	±700 ±700	1400 1400
AP032	DC to 15	4	-80	-50	20:1 200:1	±140 ±1400	±1400 ±1400	1400 1400
AP033	DC to 500	1			x10 1:1 10:1 100:1	See the LeCroy website for more details		

HIGH-VOLTAGE PROBES

The PPE series of probes are suitable for a wide range of applications where high-voltage measurements must be made safely and accurately. There are five fixed-attenuation probes covering a range from 2 kV to 20 kV, and one switchable probe providing ÷10/÷100 attenuation for voltage inputs up to 1.2 kV.

New technology which utilizes hybrid circuitry (and switch reading for probes with switchable gain/attenuation) minimizes ringing and overshoot to provide a precise response.

All fixed-attenuation, standard probes automatically re-scale any LeCroy 9300C or LC series oscilloscope for the appropriate attenuation factor of the probe.

HIGH-VOLTAGE PROBES SELECTION GUIDE

Types	Bandwidth MHz	Input R Ω	Input C pF	Attenuation	Maximum Voltage	Probe Ring	Cable Length
PPE1.2kV[1]	400	50 M	<6	10:1 / 100:1	600 V/1.2 kV	No	2 m
PPE2kV[1]	400	50 M	<6	100:1	2 kV	Yes	2 m
PPE4kV[1]	400	50 M	<6	100:1	4 kV	Yes	2 m
PPE5kV[1]	400	50 M	<6	100:1	5 kV	Yes	2 m
PPE6kV[1]	400	50 M	<6	1000:1	6 kV	Yes	2 m
PPE20kV[2]	100	50 M	<2	1000:1	20 kV (40 kV peak)	Yes	3 m

Supplied with the probe:

[1] Probe Kit: trimming tool, ground lead, rigid tip, IC insulator, BNC adaptor, tip insulator, spring hook, red crocodile clip, 4 mm safety adaptor, safety ground lead, green/yellow crocodile clip.

[2] Probe Kit: trimming tool, ground lead with a crocodile clip.

The PPE series is compatible with all LeCroy 9300C and LC series oscilloscopes.

Probe Accessories

General Purpose

D9013: 10:1 High-Impedance Divider

The D9013 plugs directly onto the input BNC of the scope in 1 MΩ configuration and is compatible with the models listed below.

Model	Oscilloscope Model Compatibility
D9013	930xC, 931xC, 935xC 9361C, 937xC 9384C, LCs

SG9001: Overvoltage Input Protector

Assembled in a BNC feedthrough housing, model SG9001 protects the high-impedance scope input circuitry from voltage signals exceeding 230 V. It is a spark gap protection device, which adds negligible capacitance to the input, thus ensuring clean signal measurement.

It is compatible with all LeCroy oscilloscopes.

PB001: ProBus Kit

For users requiring their own custom circuit, the ProBus kit offers a ProBus case, input and output BNC connectors, ProBus connector for ±12 V and ground connections, a breadboarding PCB, and a set of screws.

Mechanical drawings and pin assignments are provided in the kit.

PP090: 75 to 50 Ω ProBus Adaptor

Used with the ProBus-compatible scope input, the adaptor provides 75 Ω input impedance. Gain compensation is performed automatically by the oscilloscope. Primary applications include telecommunications and video.

Probe Kits

Probe accessories are supplied as kits for the various probe models and can be purchased separately.

The table below lists the contents of each kit and the probes with which it is compatible.

SMT Kits

LeCroy introduces two new SMT probe kits PK006 and PK106 to allow the user to connect the probes to standard IC test clips (QFP or SOIC) or directly on chip pins using clips included.

Probe Kits

LeCroy Ordering No.	PK001	PK003	PK004	PK006	PK101	PK102	PK103	PK106
Probe Compatibility	PP002	PP062 PP063 PP064	AP020	AP020 PP002	PP005	PP005	PPE1.2KV PPE2KV PPE4KV PPE6KV	PP005
Spring Hook	1	1	1			1	1	
Ground Lead	1	1	1			2	3	
BNC Adapter	1	1	1			1	1	
Ground Bayonet	3	3	3			1		
IC Insulating Tip	1	1	1			1	1	
Insulating Tip								
Single Lead Adaptor		1	1	1	1			1
Mini Clip 0.8mm pitch (red)			1	1				
Mini Clip 0.8mm pitch (black)				1				
QFPIC Clip 1300mm 0.5mm pitch					1			
QFPIC Clip 0.5mm pitch				4	1			4
Dual Lead Adaptor			1	1				1
Male/Female Lead 4"			2	2				2
Male/Female Lead 2"			2	2				2
Mini Clip 0.5mm (black)			1					
Mini Clip 0.5mm (red)			1					
Color Tag Orange	2	2						
Color Tag White	2	2						
Screw Driver	1				1	1	1	
Straight Tip						1	5	
Spring Tip 0.8mm						5	5	
Spring Tip 0.38mm						5		
Crocodile Clip							4	
Hook								
Probe Tip to PCB Adaptor								1

Software Utilities for PCs

LeCroy 9300C and LC series oscilloscopes are compatible with National Instruments LabWindows, LabView and Hewlett Packard HPVEE software. Drivers are available on the LeCroy's Web site.

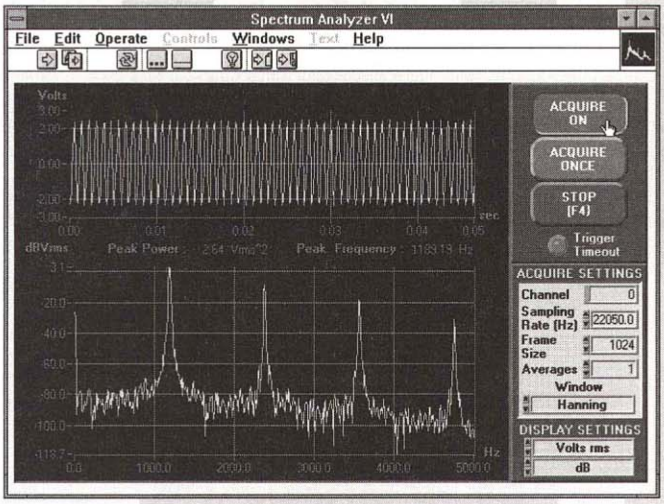


Photo courtesy of National Instruments Corp.

Scope Explorer

ScopeExplorer is a PC software connectivity tool between a LeCroy oscilloscope and Windows 95 or NT desktop. ScopeExplorer can be used for remote control and transfer of waveforms. Scope Explorer is available on the LeCroy Web site at http://www.lecroy.com/ScopeExplorer

Transit Cases

LeCroy transit cases are made of a heavy-duty reinforced aluminum. Light-weight and measuring approximately 30 x 50 x 60 cm (size given for 9300C series), these cases are ideal for transporting oscilloscopes by air, road or sea.

Instrument Carts

Oscilloscopes and Signal Sources can be easily transported around the laboratory on instrument carts which roll on large locking casters.

OC9003A

For 9300C and LC series digital oscilloscopes. Includes printer shelf. Also compatible with LW400 series arbitrary waveform generators..

Carrying Case

These soft cloth carry bags have an internal pouch for the instruction manuals and accessories. Designed for customers who use their oscilloscope in several different locations; the carry bag also acts as a protective cover.

High-Impedance, 2.5 GHz AP54701A Active Probe

Faithful Reproduction

- ***2.5 GHz bandwidth***
- ***140 ps risetime***
- ***1% long-term flatness***
- ***0.5% DC gain accuracy***

The AP54701A active probe from Hewlett Packard is available through LeCroy. It offers digital designers 2.5 GHz of bandwidth for extending measurement response, along with 140 ps risetime for accurate measurement of fast signals. Adding 1% long-term flatness and ±0.5 DC gain accuracy results in a clearer representation of the input signal than ever before possible.

Reliable Performance

- ***200 V AC max input tolerance***
- ***±12 kV ESD tolerance***
- ***Pliable, replaceable probe tips***
- ***±5 V peak AC ±50 V DC***

The AP54701A's microcircuits are protected by their ability to withstand damage from high-input voltage, ESD pulses, and shock to the probe tips. You'll appreciate the reliability and ruggedness of the AP54701A.

Versatile, Powerful Probing

- ***AP1143A independently powers the AP54701A***
- ***Programmable offset***
- ***±50 V offset***

The AP54701A, with the AP1143A probe offset control and power module, is versatile enough to be used with any test and measurement equipment with a 50 Ω input.

The AP1143A provides power and independent offset control for two AP54701A probes. The probe's offset can be controlled via a 9-pin, D-subminiature connector on the rear panel of the AP1143A. Additionally, the ±50 V offset capability extends the dynamic range of the probe measurement system beyond that of many test and measurement instruments.

AP54701A Specifications

Bandwidth (-3dB)*: >2.5 GHz

Risetime (10% to 90%): <140 ps calculated from tr = (0.35/bandwidth)

Attenuation Factor*: 10:1

DC Input Resistance*: 100 kΩ ±1%

DC Gain Accuracy*: ±0.5%

Input Capacitance: 0.6 pF (typical)

Flatness: input edge: ≥170 ps
<3 ns from rising edge: ±6%
≥3 ns from rising edge: ±1%

Dynamic Range (<1.5% gain compression):
±5 V peak AC ±50 V DC

DC Offset Accuracy: ±1% of offset ±1 mV

Offset Adjustment Range: ±50 V at the probe tip

Offset Gain: 11.5 V/mA

RMS Output Noise:
(DC to 2.5 Ghz with input loaded in 50 Ω): <300 µV

Propagation Delay:
7.5 ns (approximately)

Maximum Input Voltage: ±200 V (DC + peak AC (<20 MHz))

ESD Tolerance (150 Ω/150 pF): ±12 kV

Operating Temperature: 0°C to 55°C

Operating Humidity: 95% relative humidity at 40°C

Power Supply:
±17 V DC at 110 mA
±16.25 V DC minimum

Net Weight: 0.6 kg (1.3 lbs.)

Shipping Weight: 1.0 kg (2.3 lbs.)

AP1143A Specifications

Number of probes that can be operated independently: 2

Front Panel Controls (for each probe):
Remote/Local Pushbutton
Zero/Variable Control
Fine and Coarse Offset Control Knobs

Positive Power Output*: +17.3 V ±150 mV

Negative Power Output*: ±17.3 V ±150 mV

Max Current Capability:
(both +17.3 V and -17.3 V supply): 300 mA

Offset Current: Variable from zero to ±5 mA

Rear Panel Control:
A 9-pin, D-subminiature connector provides remote control of the offsets. The voltage contained on this interface is converted to a voltage offset at the probe tip via the probe's offset gain. The conversion gain is 500 µA/V.

Operating Temperature: 0°C to 55°C

Operating Humidity: 95% relative humidity at 40°C

Net Weight: 1.5 kg (3.4 lbs.)

Shipping Weight: 2.4 kg (5.4 lbs.)

Power Requirements:
90 to 132/198 to 264 V AC, 47 to 440 Hz, 40 VA max

Dimensions:
Offset Control and Power Module:

211mm (8.3") W x 173 mm (6.8") D x 78 mm (3.1") H

* These are specified parameters. All others are characteristics.

AP011 Current Probe

Main Features

- *DC, AC or Impulse Currents*
- *150A Maximum Current*
- *DC - 120 kHz Bandwidth*
- *Probe Accuracy 1% ±2 mA*
- *Measurement Units in Amperes*
- *ProBus Compatible, Sensed Automatically by the 9300C Family of Oscilloscopes.*
- *Rugged Mechanical Design*

Current Measuring

The AP011 allows the oscilloscope to measure current flowing through a conductor. The AP011 is based on a combination of Hall effect and transformer technology which allows measurements to be made on DC, AC and impulse currents. It is rugged in design and uses a split-core transformer to allow the probe head to be clamped around a conductor that remains in circuit.

Fully Integrated

With the ProBus interface, the AP011 probe becomes an integral part of the oscilloscope. The probe is automatically detected with full calibration and control achieved from the on-screen menu system. No external power supplies or amplifiers are required.

Full Remote control is possible over GPIB or RS-232-C interfaces.

Scaled Measurements

Waveform scaling factors and unit conversions are automatically applied.

The existing wide range of oscilloscope software analysis functions and parameter measurements is compatible and handles mixed-unit conversion.

Fully Integrated System

ProBus compatibility ensures full integration of the AP011 features into the oscilloscope. The probe is fully operational whenever it is attached to the instrument. There is no need for external amplifiers or power supplies. All controls are menu-driven from the oscilloscope screen, avoiding the need for accessing probe-mounted controls which can be particularly difficult and dangerous in some applications.

Auto-Zero Adjustment

Optimal calibration of the probe is achieved by using the auto-zero feature. This should be done whenever the probe is first connected, subjected to wide temperature variations, re-oriented with respect to the earth's magnetic field, or subjected to overload conditions. The auto-zero operation on the AP011 is performed automatically by pressing the 'AUTO ZERO' menu button in the associated channel menu (see Figure 1).

Automatic Measurement Unit Conversion

Automatic unit conversion and calibration ensure correct interpretation of data and avoid the painstaking task of recording and applying conversion and scaling factors.

All waveforms acquired from the AP011 are automatically calibrated and adjusted to be scaled in ampere units. A wide range of functions can be applied to current waveforms. Advanced functions such as FFTs and statistical analysis are available as optional firmware packages.

All functions and measurements recognize ampere vertical scales and adjust the resulting waveform or calculation units, including mixed unit conversions (e.g. current multiplied by voltage is shown as watts in Figure 1).

Electrical Characteristics

System Bandwidth: DC to 120 kHz

Measuring Range: 0 to ±150 A

Max. Overload Current: 1500 A

Offset Range: ±150 A

Output sensitivity: 50 mV/A

DC Accuracy (@ 25°C): 1% of reading ±2 mA.*

AC Accuracy (@ 25°C): 1% of reading DC to 2 kHz decreasing to 5% @ 120 kHz.

Delay Time: <1 µs

dI/dT Tracking: >35 A/µs

Dielectric Strength: 2.3 kV, 50 Hz, 1 min

External field rejection: 500:1 @ DC 100:1 @ 10 kHz

General Characteristics

Operating Temperature: 0°C to 50°C

Max Conductor Size: 19 mm

Cable Length: 2 m

Interface: ProBus, 1 MΩ only

Weight: 300 g

Usage Environment: Indoor

Max. Altitude: 2000 m

Max. relative humidity: 80% (max. 31°C)

** Note: Accuracy is specified for probe operating in fixed orientation with respect to earth's magnetic field following an auto-zero operation.*

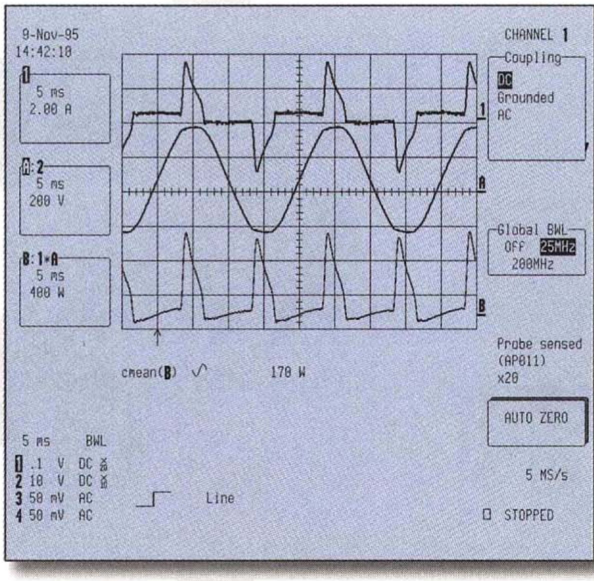


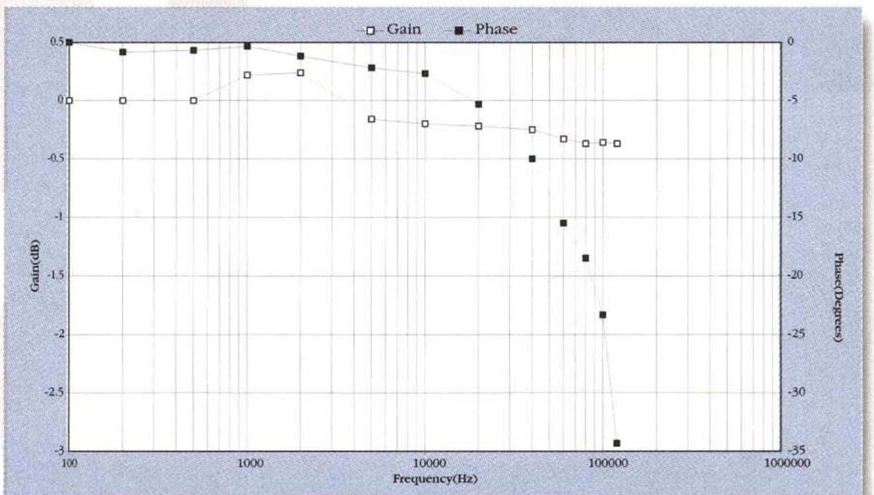
Figure 1: This example shows a power supply input current (top trace in amps) vs. voltage (middle trace in volts). These are multiplied to provide the input power waveform (lower trace with 400 watts per division). A parameter measurement is then made to calculate the mean input power.

Note that the input coupling menu is automatically configured to control the AP011 attached to that channel.

Safety

The probe has been designed to comply with IEC1010-2-032 Installation Category (Overvoltage Category) II, 300 V, Pollution Degree 1.

Performance Data



AP015 Current Probe

Main Features

- *DC - 50 MHz Bandwidth*
- *±30 A Max DC Current*
- *±50 A Peak Pulse Current*
- *External Field Rejection: 6000:1 @ DC*
- *Measurement Units in Amperes*
- *Overheating Detection and Degauss Function*
- *ProBus™ Sensed Automatically by LeCroy Oscilloscopes*
- *Full Remote Control*

The AP015 current probe allows the oscilloscope to measure current flowing through a conductor. The AP015 is based on a combination of Hall effect and transformer technology which allows measurements to be made on DC, AC and impulse currents.

Fully Integrated System

ProBus compatibility ensures full integration of the AP015 features into the oscilloscope. The probe is fully operational whenever it is attached to the instrument. There is no need for external amplifiers or power supplies. All controls are menu-driven from the oscilloscope screen, avoiding the need for accessing probe-mounted controls, which can be particularly difficult and dangerous in some applications. Full remote control is possible over GPIB or RS-232-C interfaces.

Auto-Zero Adjustment

Optimal calibration of the probe is achieved by using the auto-zero feature. This should be done whenever the probe is first connected, subjected to wide temperature variations, or subjected to overload conditions. The auto-zero operation on the AP015 is performed automatically by pressing the "AUTO ZERO" menu button in the associated channel menu (see Figure 1).

Automatic Measurement Unit Conversion

Automatic unit conversion and calibration ensures correct interpretation of data and avoids the painstaking task of recording and applying conversion and scaling factors.

All waveforms acquired from the AP015 are automatically calibrated and adjusted to be scaled in ampere units. A wide range of functions can be applied to current waveforms. Advanced functions such as FFT and statistical analysis are available as optional firmware packages.

All functions and measurements recognize ampere vertical scales and adjust the resulting waveform or calculation units, including mixed-unit conversions.

Degauss Function

Optimal use of a current probe implies the utilization of a backing current to eliminate core saturation by applying an alternating field that is reduced in amplitude over time from an initial high value (i.e., AC powered). This function is automatically performed by pressing the "DEGAUSS" menu button in the associated channel menu (see Figure 1).

Overheating Detection

The AP015 is equipped with an automatic overheating detection circuit that generates a warning message, displayed on the oscilloscope screen, to avoid damaging the probe.

Probe Unlock Detection

The Probe Unlock Detection feature prevents bad probe head ground connections and ensures correct measurements. If the probe head is not properly locked, the probe sends an interrupt to the scope, which then displays a warning message.

Specifications

Electrical Characteristics

System Bandwidth: DC to 50 MHz
Max. DC Current: ±30 A
Max Peak Pulse Current: ±50 A with pulse width < 10 s
Offset Range: ±100 A maximum*
Output Sensitivity:
10 mA/div to 20 A/div
Coupling: AC, DC, GND
DC Accuracy (at 25° C):
±1% of reading to 15 A
±2% of reading to 30 A
Rise Time: < 7 ns
di/dt Tracking: > 1.6 A/ns
External Field Rejection: 75 dB at DC
Insertion Impedance: < 0.06 Ω at 5 MHz

** Note: depends on the oscilloscope used.*

General Characteristics

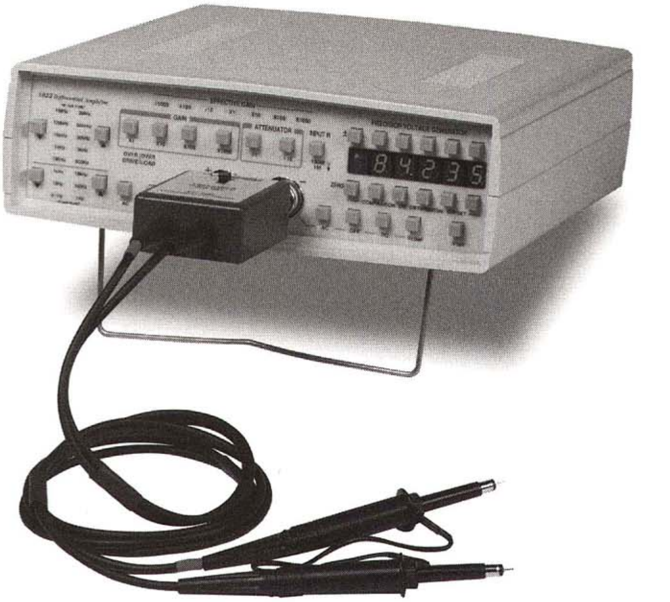
Operating Temperature: 0° C to 40° C
Max. Conductor size: 5 mm
Cable Length: 2 m
Interface: ProBus, 1 MΩ only
Weight: 300 gr
Usage Environment: Indoor
Maximum Altitude: 2000 m
Maximum Relative Humidity: 80% (maximum 31° C)
Warranty: 3 years
Calibration: Certificate supplied

Safety

The probe has been designed to comply with IEC1010 Installation Category (Overvoltage Category) I, 300 V, Installation category (Overvoltage Category) II, 150 V, pollution Degree 1.

Conforms to Low Voltage Directive 73/23 EEC for product safety.

Differential Amplifier Model DA1820 and DA1822



Main Features

- *DC to 10 MHz Bandwidth*
- *100,000 to 1 CMRR*
- *Gain of 1, 10, 100 & 1000*
- *Full Upper & Lower Bandwidth Limits*

The DA1820/1822 is a stand-alone, high-performance 10 MHz differential amplifier. They are intended to act as a signal conditioning preamplifier for oscilloscopes and network and spectrum analyzers, providing differential measurement capability to instruments having only a single-ended input.

Amplifier gain can be set to 1, 10, 100 or 1000. The high gain of the DA1822 can extend the sensitivity of a scope with 1 mV/div to a very usable 1 µV/div. A built-in input attenuator can be separately set to attenuate signals by a factor of 10, allowing gains of 1000, 100, 10, 1, or 0.1 and common mode dynamic range of ±15.5 V (÷1) or ±155 V (÷10). Optional probes further increase the maximum input signal and common mode ranges in proportion to their attenuation ratio, but not exceeding the probe's maximum input voltage rating. Effective gain of the DA1822, including probe attenuation, amplifier gain and attenuator settings, is automatically displayed.

The DA1820/1822 have a bandwidth of DC to 10 MHz, but the operator can select from a full complement of high- and low-frequency -3 dB points. In critical measurements, the signal-to-noise ratio can be greatly improved by restricting the amplifier bandwidth to the frequency range of interest.

The DA1822 features a built-in Precision Voltage Generator (PVG) that can be set to any voltage between ±15.5 volts (±10 volts in Differential Offset) with 5½ digit resolution. Each digit of the voltage generator output can be individually incremented or decremented and the sign changed between + and -. The PVG's output can be selected as an input to the inverting (-) input of the amplifier for operation as a differential comparator or applied internally as a true differential offset voltage. The voltage is also available to be used externally through a rear panel connector. The PVG is not included in the model 1820.

The DA1820/1822 operate from 100 to 250 V AC line without line switching. A wide range of high-performance differential probes are available for use with the DA1820/1822.
These include the DXC100 selectable (÷10/÷100) attenuation probes, the DXC350 ÷100 high-impedance (92 meg/2.4 pF) probe and the ÷1 DXC200 probes. Differential probes with higher voltage ratings are also available.

Comparator Mode (DA1822 only)

The DA1822 becomes a differential comparator when the internal Precision Voltage Generator (PVG) output is selected as the amplifier's inverting (-) input. In this mode, the DA1822 can be used to very accurately measure relatively small signals that are riding on large AC or DC components. Due to the precision and 5½ digit resolution of the voltage generator, an oscilloscope, when used with the DA1822, can make voltage measurements that are much more accurate than the oscilloscope is capable of by itself. The output of the PVG is available for external use via a rear-panel connector. When used in the comparison mode, the DA1822's "-" Input is connected to the output of the PVG, and the DA1822's "-" Input probe is no longer used. The operator can then use the PVG as a very accurate position or offset control to compare to the PVG's value with any point on the "+" Input signal. The decimal point in the PVG readout is automatically positioned to account for the DA1822's attenuator and any probe attenuation.

True Differential Offset Mode

The built-in PVG can be used to generate a true differential offset while still allowing both inputs to be used as differential inputs. Operation in the differential offset mode is very similar to that of the comparison mode, except the "-" Input of the DA1820/1822 is still functional. In this mode, the output of the PVG is used to generate an offset within the DA1822's amplifier (an external voltage can be supplied to the DA1820). The PVG now functions as if a zero impedance adjustable voltage source were placed in series with the "-" Input. The decimal point in the PVG readout is automatically placed to account for DA1822 attenuator and probe attenuation factors as well as the DA1822's gain setting.

This mode facilitates making measurements such as changes to a transistor's base to emitter voltage caused by variations in temperature and/or current. Used in this mode, the voltage generator can be set to a value that will zero out the static value of the junction's on voltage. The DA1822's differential measurement capability will reject any dynamic signal common to both sides of the junction, and the oscilloscope is left to measure only the changes in the junction voltage.

Precision Voltage Generator (DA1822 only)

The Precision Voltage Generator is controlled from the DA1822 front panel. Each digit can be individually incremented or decremented and rollover automatically carries to the next digit. The display is treated as an absolute number and the sign can be changed without altering the value. The decimal point placement is calculated to take into account the DA1822 mode (Comparator or Differential offset), gain, and attenuator settings, along with any probe attenuation. Thus the display accurately reflects the proper effective value of the Comparison or Differential Offset voltage. The range of the generator is ±15.5 V for the comparator mode and ±10.0 V for differential offset mode. The generator's temperature-controlled oven allows for a DC accuracy specification of 0.05% +500 µV.

The DA1820/1822 input is protected to ±250 V and will automatically disconnect large signals.

Upper & Lower Bandwidth Limits

The DA1820/1822 allows the user to select both the upper and lower frequency -3 dB points. Selections for the high frequency -3 dB points are 3 MHz, 1 MHz, 300 kHz, 100 kHz, 30 kHz, 10 kHz, 3 kHz, 1 kHz, 300 Hz, and 100 Hz. Selections for the lower frequency -3 dB points are 0.1 Hz, 1 Hz, 10 Hz, 100 Hz, and 1 kHz. These filters make it possible to improve the signal-to-noise ratio when making measurements on microvolt magnitude signals.

Autobalance

Each time any of the gain buttons is pressed, the DA1820/1822 adjusts the amplifiers DC balance.

Specifications

General

Amplifier gain: 1, 10, 100 or 1000

Gain accuracy: ±1%

Bandwidth:
(x1 or x10 GAIN) DC to 10 MHz
(x100 GAIN) DC to 3 MHz
(x1000 GAIN) DC to 1 MHz

Risetime: (x1 or x10 GAIN) <35 ns

Output impedance: 50 Ω

Intended output load: 50 Ω

Maximum output: limited at ±5 V into 50 Ω

Input attenuation: ÷1 or ÷10

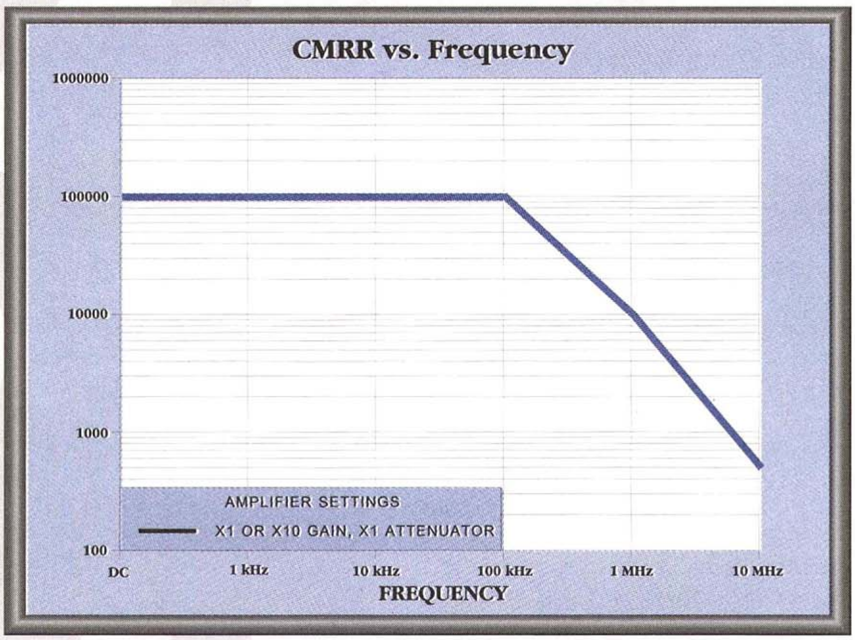
÷10 ATTENUATOR accuracy: ±0.05%

Max differential linear input: see equation

Input noise (x10 GAIN): <7 nV/sqrt Hz, broadband

DC drift (x10 GAIN): 50 µV/°C

$$\text{Max Differential Linear Input} = \frac{5\text{ Volts}}{\text{GAIN}} \times \text{Attenuation Factor (Probes plus internal attenuator)}$$



Common mode rejection ratio: See graph on previous page.

Max common mode input range:
(÷1 ATTENUATOR): ±15.5 V
(÷10 ATTENUATOR): ±155 V
(÷10 ATTENUATOR and x10 probe): ±1.55 kV

Input resistance
(÷1 ATTENUATOR): 1 MΩ or 100 MΩ
(÷10 ATTENUATOR and/or with attenuating probe attached): 1 MΩ
Input capacitance (÷1 or ÷10 ATTENUATOR): 20 pF

Bandwidth limit filters
Upper: 3 MHz, 1 MHz, 300 kHz, 100 kHz, 30 kHz, 10 kHz, 3 kHz, 1 kHz, 300 Hz and 100 Hz

Lower: 0.1 Hz, 1 Hz, 10 Hz, 100 Hz and 1 kHz

Filter characteristics: 6 dB/octave

+ Input selections: AC, OFF (precharge), DC

- Input selections: AC, OFF (precharge), DC, VCOMP

Input coupling capacitor: 0.1 μF, 400 V DC

Input gate current (x1 and x10 GAIN, ÷1 ATTENUATOR): <10 pA, 0-45°C

Input protection: protected to ± 250 V, automatic input disconnect with manual reset.

Differential Offset (VDIFF) Mode

Differential offset range (referred to input):
(x10 GAIN or higher, ÷1 ATTENUATOR): ±1 V

(x1 GAIN, ÷1 ATTENUATOR): ±10 V

(x10 GAIN or higher, ÷10 ATTENUATOR): ±10 V

(x1 GAIN, ÷10 ATTENUATOR): ±100 V

(x1 GAIN, ÷10 ATTENUATOR, x10 probe): ±1.0 kV

Differential offset accuracy

(x10 GAIN or higher, ÷1 ATTENUATOR): 0.1% + 50 μV

(x1 GAIN, ÷1 ATTENUATOR): 0.1% + 500 μV

(x10 GAIN or higher, ÷10 ATTENUATOR): 0.15% + 500 μV

(x1 GAIN, ÷10 ATTENUATOR): 0.15% + 5 mV

Comparison Offset (VCOMP) Mode

Effective comparison voltage range (not effected by gain setting):
(÷1 ATTENUATOR): ±15.5 V
(÷10 ATTENUATOR): ±155 V
(x10 probe and ÷10 ATTENUATOR): 1.55 kV

Precision Voltage Source

Output range: ±15.5 V
DC accuracy: 0.05% of reading +500 μV (15° to 45°C)
Resolution: 100 μV (5½ digit)
Control: All digits are addressable. Digit carries to next decade.
Temperature coefficient: typically <5 ppm/°C of full scale
Type: Oven stabilized buried zener.
Output: Applied to inverting input and available at rear panel.
Autozero: Sets output to zero when 0.0 volts selected and periodically thereafter.

Power Requirements

Line voltage requirement: 100 to 250 V AC
Line frequency range: 48 - 66 Hz
Power requirement: 35 W maximum

Environmental Characteristics

Operating Range: 0° to 50°C
Non-Operating: -4° to 75°C

Physical Characteristics

Height: 7.29 cm (2.87")
Width: 21.2 cm (8.36")
Depth: 23.2 cm (9.12")
Weight: 2.15 kg (4.75 lb)
Shipping Weight: 3.12 kg (6.88 lb)
Warranty: 3 years

Differential Amplifier Model DA1850 DA1855

MAIN FEATURES

- ***DC to 100 MHz Bandwidth***
- ***100000 to 1 CMRR***
- ***Gain 1 or 10***
- ***State-of-the-Art Overdrive Recovery***
- ***Very Low Noise***

The DA1850/1855 is a stand-alone, high-performance 100 MHz differential amplifier. It is intended to act as a signal conditioning preamplifier for oscilloscopes, digitizers and spectrum analyzers, providing differential measurement capability to instruments having only a single-ended input. When used with a DA1850/1855, most good-quality oscilloscopes can obtain Common Mode Rejection Ratio (CMRR) and overdrive recovery performance levels previously unobtainable.

Amplifier gain can be set to 1 or 10. A built-in input attenuator can be separately set to attenuate signals by a factor of 10, providing gains of 10, 1, or 0.1 and common mode dynamic range of ±15.5 V (÷1) or ±155 V (÷10). Optional probes increase the maximum input signal and common mode ranges in proportion to their attenuation ratio but do not exceed their maximum input voltage rating. Effective gain of the DA1855, including probe attenuation, amplifier gain and attenuator settings, is automatically displayed.

The DA1855 has a bandwidth of 100 MHz, but any one of the three 3-pole bandwidth limit filters can be selected to reduce bandwidth to 10 MHz, 1 MHz or 100 kHz to limit noise above the frequency of interest.

The DA1850/1855 output is carefully limited to ±500 mV, so that the oscilloscope is not overdriven by large inputs. This allows many oscilloscopes to directly measure the settling of D/A converters with 14-bit (60 ppm) precision, better than any other differential comparator.

The DA1855 features a built-in Precision Voltage Generator (PVG) that can be set to any voltage between ±15.5 volts (±10 volts in Differential Offset) with 100 µV resolution. Each digit of the voltage generator output can be individually incremented or decremented and the sign changed between + and -. The PVG's output can be selected as an input to the inverting (-) input of the amplifier for operation as a differential comparator or applied internally as a true differential offset voltage. The PVG is also available for external use through a rear panel connector.

The DA1850/1855 operates from 100 to 250 VAC line without line switching.

High-performance differential probes such as the DXC100 10x/100x high CMRR probes are recommended.

OVERDRIVE RECOVERY

The DA1850/1855, by limiting the signal applied to the input of an oscilloscope, will greatly improve the oscilloscope's effective overdrive recovery. For example, an oscilloscope with very good overdrive recovery will tolerate input signals of about ±2 V when its attenuator is in the straight through position (input signal not attenuated). The scope will recover within 0.2% (2000 ppm) in 50 ns, producing an error signal of 4 mV. Such an error signal is better than most oscilloscopes specify.

Using the same oscilloscope and the DA1850/1855 set at x10 gain, the oscilloscope error will be reduced to about 1 mV by the amplifier's limiting. At the same time, the amplifier increases the gain by 10 resulting in an equivalent error of 0.1 mV referred to the DA1850/1855 input 100 ppm of the 2 V input signal.

Unlike the oscilloscope, the DA1850/1855 handles input signals up to 15.5 V with no increase in error. For a 10 V input signal, the same 0.1 mV error represents just 10 ppm of the signal. This improves on the raw oscilloscope performance by a factor of about 200.

COMPARATOR MODE

The DA1855 becomes a differential comparator when the internal Precision Voltage Generator (PVG) output is selected as the amplifier's inverting (-) input. In this mode, the

DA1855 can be used to very accurately measure relatively small signals that are riding on large AC or DC components. Due to the precision of the voltage generator, an oscilloscope, when used with the DA1855, can make voltage measurements that are much more accurate than the oscilloscope is capable of by itself. The output of the PVG is available for external use via a rear panel connector. The DA1850 also functions as a differential comparator when an optional voltage source is supplied.

True Differential Offset Mode

The DA1855's built-in Precision Voltage Generator can be used to generate a true differential offset while still allowing both inputs to be used as differential inputs. The offset range can be as high as ±100,000 divisions and the generator has 5 1/2 digit resolution. This mode facilitates making measurements such as changes to a transistor's base to emitter voltage caused by variations in temperature and/or current. Used in this mode, the voltage generator can be set to a value that will zero out the static value of the junction's on voltage. The DA1855's differential measurement capability will reject any dynamic signal common to both sides of the junction, and the oscilloscope is left to measure only the changes in the junction voltage.

Precision Voltage Generator (DA1855 only)

The Precision Voltage Generator is controlled from the DA1855 front panel. Each digit can be individually incremented or decremented and rollover automatically carries to the next digit. The display is treated as an absolute number, and the sign can be changed without altering the value. The decimal point placement is calculated to take into account the DA1855 mode (Comparator or Differential Offset), gain, and attenuator settings, along with any probe attenuation. Thus the display accurately reflects the proper effective value of the Comparison or Differential Offset Voltage. The range of the generator is ±15.5 V for the comparator mode and ±10.0 V for differential offset mode. The generator's temperature-controlled oven allows for a DC accuracy specification of 0.05% +500 µV.

The DA1850/1855 input is protected to ±250 V, and will automatically disconnect large signals and will require a manual reset.

Autobalance

Each time either gain setting button is pressed, the DA1850/1855 automatically adjusts the amplifier's DC Balance.

Specifications

General
Amplifier gain: 1 or 10
Gain accuracy: ±1%
Bandwidth: >100 MHz
Risetime: <3.5 ns
Output impedance: 50 Ω
Intended output load: 50 Ω
Maximum output: limited at ±0.50 V into 50 Ω.
Input attenuation: ÷1 or ÷10
÷10 ATTENUATOR accuracy: ±0.05%

Max differential linear input:
(x10 GAIN, ÷1 ATTENUATOR): ±0.05 or ±0.5 V with x10 probe
(x1 GAIN, ÷1 ATTENUATOR): ±0.5 or ±5.0 V with x10 probe
(x10 GAIN, ÷10 ATTENUATOR): ±0.5 or ±5.0 V with x10 probe
(x1 GAIN, ÷10 ATTENUATOR): ±5.0 or ±50 V with x10 probe

Maximum input slew rate:
(÷1 ATTENUATOR, x1 probe): 0.5 V/ns
(÷10 ATTENUATOR or x10 probe): 5.0 V/ns
(÷10 ATTENUATOR and x10 probe): 50 V/ns
(÷1 ATTENUATOR and x100 probe): 50 V/ns
(÷10 ATTENUATOR and x100 probe): 500 V/ns
Input noise (x10 GAIN): <4 nV/sqrt Hz, broadband.
DC drift (x10 GAIN): 50 µV/°C

Common mode rejection ratio: See graph on the next page.

Max common mode input:
(÷1 ATTENUATOR): ±15.5 V (x1 or x10 GAIN)
(÷10 ATTENUATOR): ±155 V (x1 or x10 GAIN)
(÷10 ATTENUATOR and x10 probe): ±1.55 kV (x1 or x10 GAIN)

Input resistance:
(÷1 ATTENUATOR, x1 or x10 GAIN): 1 MΩ or 100 MΩ
(÷10 ATTENUATOR, x1 or x10 GAIN): 1 MΩ
Input capacitance (÷1 or ÷10 ATTENUATOR): 20 pF
Bandwidth limit filters: (DA1855 only) 10 MHz, 1.0 MHz and 100 kHz
Filter characteristics: (DA1855 only)18 dB/octave (3-pole Bessel)
+ Input selections: AC, OFF (precharge), DC
- Input selections: AC, OFF (precharge), DC, VCOMP
Input coupling capacitor: 0.1 µF, 400 V DC

Input gate current (x1 and x10 GAIN,÷1 ATTENUATOR): <10 pA, 0-45°C

Input protection: protected to ±250 V, automatic input disconnect with manual reset.

Differential Offset (VDIFF) Mode

Differential offset range (referred to input):
(x10 GAIN, ÷1 ATTENUATOR): ±1 V
(x1 GAIN, ÷1 ATTENUATOR): ±10 V
(x10 GAIN, ÷10 ATTENUATOR): ±10 V
(x1 GAIN, ÷10 ATTENUATOR): ±100 V
(x1 GAIN, ÷10 ATTENUATOR, x10 probe): ±1.0 kV

DA1855 Differential offset accuracy:
(x10 GAIN, ÷1 ATTENUATOR): 0.1% + 50 µV
(x1 GAIN,÷1 ATTENUATOR): 0.1% + 500 µV
(x10 GAIN, ÷10 ATTENUATOR): 0.15% + 500 µV
(x1 GAIN, ÷10 ATTENUATOR): 0.15% + 5 mV

Comparison Offset (VCOMP) Mode

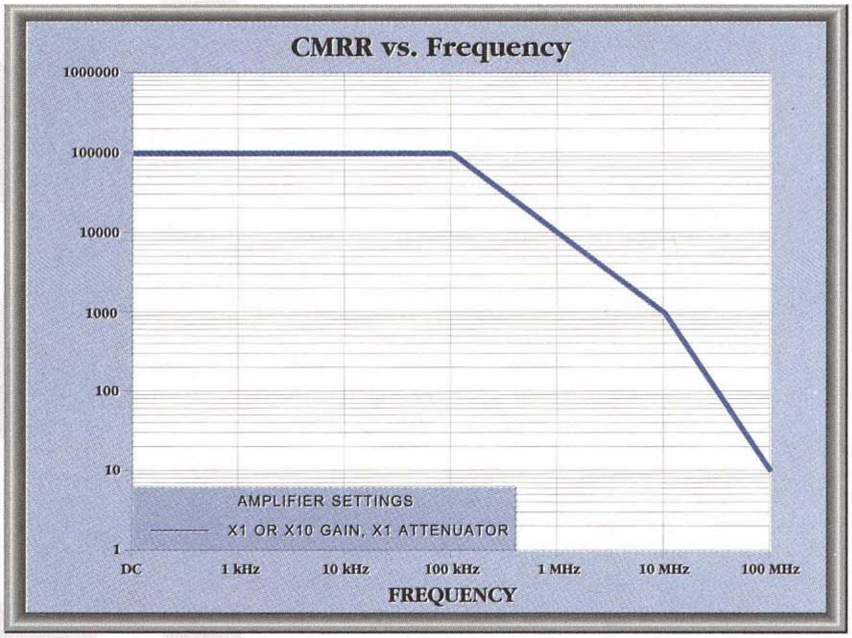
Effective comparison voltage range:
(÷1 ATTENUATOR): ±15.5 V (x1 or x10 GAIN)
(÷10 ATTENUATOR): ±155 V (x1 or x10 GAIN)
(x10 probe and ÷10 ATTENUATOR): 1.55 kV (x1 or x10 GAIN)

Precision Voltage Source

Output range: ±15.5 V
DC accuracy: 0.05% of reading +500 µV (15° to 45°C)
Resolution: 100 µV (5 1/2 digit)
Control: All digits are addressable. Digit carries to next decade.
Temperature coefficient: typically <5 ppm/°C of full scale.
Type: Oven stabilized buried zener.
Output: Applied to inverting input and available at rear panel.
Auto-zero: Sets output to zero when 0.0 volts selected and periodically thereafter.

Power Requirements

Line voltage requirement: 100 to 250 V AC
Line frequency range: 48 - 66 Hz
Power requirement: 35 W maximum

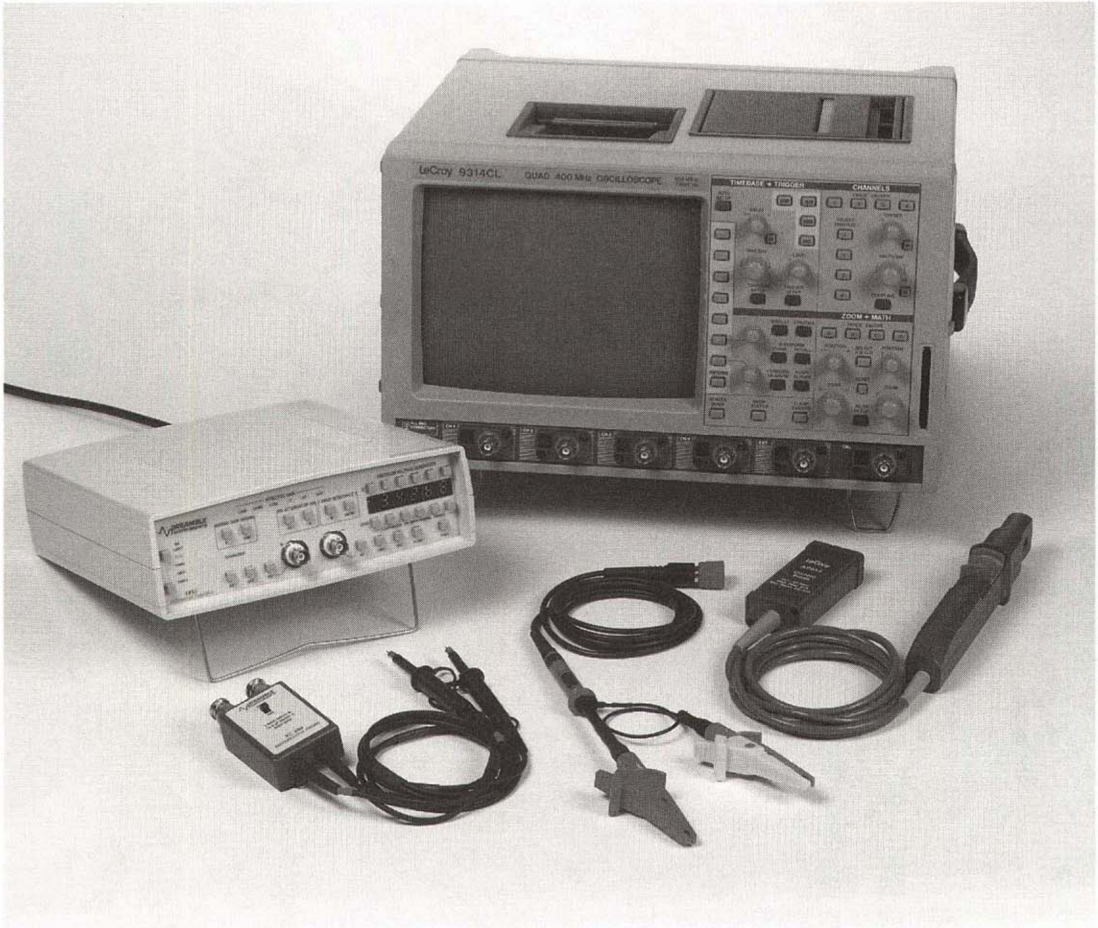


Environmental Characteristics

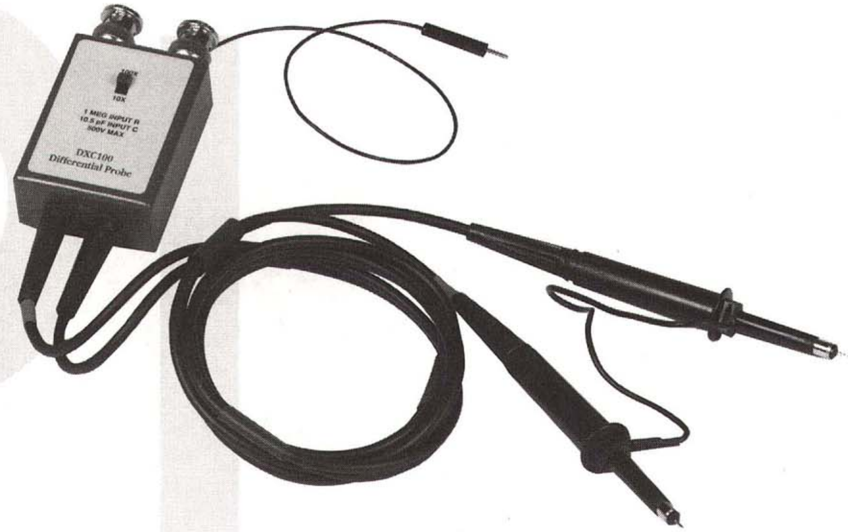
Operating Range: 0° to 50°C
Non-Operating: -4° to 75°C

Physical Characteristics

Height: 7.29 cm (2.87")
Width: 21.2 cm (8.36")
Depth: 23.2 cm (9.12")
Weight: 2.15 kg (4.75 lb)
Shipping Weight: 3.12 kg (6.88 lb)
Warranty: 3 years


LeCroy 9314CL
QUAD 400 MHz OSCILLOSCOPE
TIMEBASE + TRIGGER
CHANNELS
ZOOM + MATH

Model DXC100



Main Features

- *DC to 100 MHz Bandwidth with DA1850/DA1855*
- *Max Input Voltage 500 V*
- *Selectable 10 or 100 Attenuation Factor*
- *1.2 Meter Cable Length*

The DXC100 is a high-performance, passive, matched, differential probe pair designed for use with DA1800 series differential amplifiers. The probe pair consists of two highly matched individual probes that share a common compensation box to allow the attenuation factor on both probes to be simultaneously switched between 10x and 100x. When used with the DA1850/1855 differential amplifier, the probe's attenuation factor is automatically incorporated into the effective gain display, and the location of the decimal into the voltage generator display. Although primarily designed for use with the amplifiers, the DXC100 differential probe pair can be used with any oscilloscope or plug-in unit with an input impedance of 1 MΩ/15-26 pF and one inch (25.4 mm) spacing between connectors. When used on a differential amplifier, the DXC100 compensation box allows for precise adjustment and matching of the transient response and optimization of the system Common Mode Rejection Ratio (CMRR).

Specifications

Attenuation factor: 10 or 100
Bandwidth (-3 dB): 250 MHz
System Bandwidth (-3 dB) (with DA1850/DA1855): 100 MHz
System Risetime (with DA1850/DA1855): 3.5 ns
Input Resistance: 1 MΩ ±1%
Input Capacitance: 10.5 pF ±0.5 pF
Compensation Range: 15 to 26 pF
Maximum non-destructive Input Voltage: 500 V DC + peak AC
Length: 1.2 meter

Environmental Characteristics:
Operating Range: 0° to 50°C
Non-Operating: -4° to 75°C

Physical Characteristics:
Weight: 0.21 kg (0.47 lb)
Shipping Weight: 0.45 kg (1 lb)
Warranty: 1 year

Model DXC200

Main Features

- *DC to 50 MHz with DA1850/DA1855*
- *Max Input Voltage 500 V*
- *x1 Differential Probe Pair*
- *0.7 Meter Cable Length*

The DXC200 is a pair of x1 probes matched for differential measurement applications. The DXC200 is designed to minimize capacitance loading (compared to coaxial cable) while still maintaining practical probe-to-circuit attachment. Full DA1850/DA1855 gain and Common Mode Rejection Ratio (CMRR) are maintained. The x10 gain setting of the DA1850/DA1855 yields a usable 100 µV/div sensitivity at the probe tip for scopes with a 1 mV/div setting. The DXC200 allows the user to take advantage of the DA1850/DA1855's 100 MΩ input resistance setting.

Specifications

Attenuation factor: 1
Capacitance: 30 pF
Maximum Non-destructive Input Voltage: 500 V DC + peak AC
Length: 0.7 meter

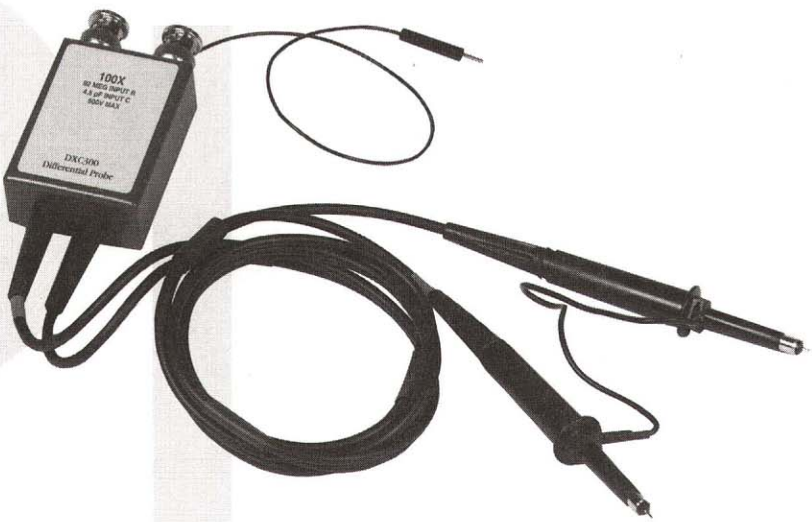
DXC200 & DA1850/DA1855 System Specifications
Risetime: 7 ns
Bandwidth (-3 dB): 50 MHz
Input Resistance (selectable): 1 or 100 MΩ
Input Capacitance: 50 pF
Maximum Input Voltage:
1 attenuator 15.5 volts
10 attenuator 155 volts

Environmental Characteristics:
Operating Range: 0° to 50°C
Non-Operating: -4° to 75°C

Physical Characteristics:
Weight: 0.21 kg (0.47 lb)
Shipping Weight: 0.45 kg (1 lb)

Warranty: 1 year

Model DXC300 & DXC350



Main Features

- *DC to 100 MHz with DA1850/DA1855*
- *Max Input Voltage 500 V (DXC300), 400 V (DXC350)*
- *100 Attenuation Factor*
- *1.2 Meter Cable Length*

The DXC300 and DXC350 are high-impedance probes matched for differential measurement applications. They are designed to minimize circuit loading to a level similar to that of an FET probe, while still retaining all the versatility and ruggedness of a passive differential probe. They are ideal for probing in sensitive circuits where probe loading is a problem. They extend the DA1800 series amplifier's signal range (both differential and common mode) to ±500 or ±400 volts.

Models DA1855 and DA1822 differential amplifiers automatically account for the probe's attenuation factor in their effective gain displays and the location of the decimal in the precision voltage generator display.

Specifications

		DXC300	DXC350
Attenuation factor:		100	100
Bandwidth (-3 dB):	w/DA1850/DA1855	100 MHz	100 MHz
	w/DA1820/DA1822	10 MHz	10 MHz
Risetime:	w/DA1850/DA1855	3.5 ns	3.5 ns
	w/DA1820/DA1822	35 ns	35 ns
Input Resistance:		92 MΩ	92 MΩ
Input Capacitance:		4.5 pF	2.4 pF
Maximum non-destructive Input Voltage:		±500 V	±400 V
Length:		1.2 meter	1.2 meter

Environmental Characteristics:
Operating Range: 0° to 50°C
Non-Operating: -4° to 75°C

Physical Characteristics:
Weight: 0.21 kg (0.47 lb)
Shipping Weight: 0.45 kg (1 lb)
Warranty: 1 year

Probes & Accessories - Ordering Information

Probes:	Product Code		Price
Current Probe - 150 Amps, 150 kHz	AP011	$	1,250
Current Probe, 50 Amps, 50 MHz	AP015		1,500
1 GHz Active FET Probe (10:1), With ProBus connector	AP020		990
15 MHz Differential Probe, x10, x100	AP031		300
15 MHz Differential Probe, x20, x200	AP032		300
Disk Drive NRZ Logic Probe	AP215		1,850
Probe Offset and Power Module	AP1143A		1,568
2.5 GHz 0.6pF Active Probe, Requires AP1143A Power Supply	AP54701A		2,944
Divider 1:10 1 MΩ	D9013		165
10:1 350 MHz 10 MΩ Passive Probe, With sense ring	PP002		80
10:1 500 MHz 10 MΩ Passive Probe, With sense ring	PP005		175
10:1 1 GHz 500 Ω Passive Probe	PP062		95
10:1 8 GHz 500 Ω Passive Probe	PP063		750
100:1 1 GHz 500 Ω Passive Probe	PP064		95
2 GS/s Adapter for 9354/M/L or LC334 Series	PP092		295
2 GS/s Adapter for 9374/M/L or LC534 Series	PP093		295
4 GS/s Adapter for 9384/M/L, Included with 9384/M/L	PP094		295
10:1/100:1 200/300 MHz 50 MΩ High-Voltage Probe, 600 V/1.2 kV Max	PPE1.2KV		264
100:1 400 MHz 50 MΩ High-Voltage Probe, 2kV Max	PPE2KV		190
100:1 400 MHz 50 MΩ High-Voltage Probe, 4kV Max	PPE4KV		326
100:1 400 MHz 50 MΩ High-Voltage Probe, 5kV Max	PPE5KV		520
1000:1 400 MHz 50 MΩ High-Voltage Probe, 6kV Max	PPE6KV		647
1000:1 100 MHz 50 MΩ High-Voltage Probe, 20kV (40kV Peak) Max	PPE20KV		1,573
Probe Accessories Kit for PP001/2	PK001		40
Probe Accessories Kit for PP011/12	PK002		40
Probe Accessories Kit for PP061/62/64	PK003		40
Probe Accessories Kit for AP020/21	PK004		70
SMT Probe Kit for AP020	PK006		120
Microclip Accessories for PP005	PK101		172
Standard Accessories for PP005	PK102		135
SMT Probe Kit for PP005	PK106		155
Protective Front Cover 9300 Series	93XX-FC		50
Telecom Templates, On 512k SRAM card	MC-TC1		700
Telecom Templates, On 3.5" Floppy Disk	FD-TC1		350
Graphic Printer Paper/10 Rolls	GPR10		100
128k Memory Card for 9300 Series	MC02		175
512k Memory Card for 9300 Series	MC04		330
Rackmount Adaptor for 9300 Series DSO	93XX-RM01		100
Hard Carrying Case for 9300 Series DSO	93XX-TC1		570
Soft Carrying Case for 9300 Series DSO	93XX-TC2		225
2 Meter GPIB Cable (IEEE488)	DC/GPIB		140
Instapulser	IP-2		250
Oscilloscope Cart with Drawer and Printer Shelf for 9300 or LC Series	OC9003A		795
Overload Protector for High Voltage	SG9001		120
Differential Amplifiers & Accessories			
10 MHz Differential Amplifier	DA1820	$	1,995
10 MHz Differential Amplifier with Precision Source; Probe Sensing	DA1822		2,695
100 MHz Differential Amplifier	DA1850		2,695
100 MHz Differential Amplifier with Precision Source; Probe Sensing	DA1855		3,495
100:1 or 10:1 Selectable 250 MHz Passive Differential Probe Pair	DXC100		695
1:1 50 MHz Passive Differential Probe Pair	DXC200		225
100:1 250 MHz 92 MΩ 4.5 pF Differential Probe Pair	DXC300		495
100:1 250 MHz 92 MΩ 2.6 pF Differential Probe Pair	DXC350		495
10:1 1 MΩ Passive Attenuator	DA101		175

The Benefits of LeCroy Arbitrary Waveform Generators

- ***Create Real-World Waveforms with One of LeCroy's Many Tools, Capture on a DSO and Import, or Import From a Simulation Output File.***
- ***Two Precise Phase Synchronized Channels, Two Clock/Marker Channels, External Trigger, Internal Noise Generator, and Digital Outputs Available.***
- ***Move Signal Edges in Increments as Small as 100 ps to Simulate Signal Jitter.***
- ***Easily Vary the Amplitude, Risetime, Phase, or S/N of a Signal by Simply Turning a Knob. Observe "Live" How These Changes Affect Circuit Performance.***

What is an Arbitrary Waveform Generator?

The Arbitrary Waveform Generator (AWG) is a signal source that uses digital techniques to produce user-specified custom analog waveforms. You might think of it as a digital oscilloscope operating in reverse. The shape, pattern, and harmonic content of the waveform to be generated is defined by a sequence of numeric values loaded into a high-speed waveform memory. Each successive memory location contains a value proportional to the amplitude of the waveform point to be generated. A high-precision programmable time base is used to clock the memory address counter which loads the next value to be output into a digital-to-analog converter (DAC). This produces an analog equivalent to the numeric waveform description. Like other digitally synthesized signal sources, it is characterized by high accuracy, stability, repeatability, and ease of control. The distinctive benefit of an arbitrary waveform generator is the ability to produce structurally complex waveforms as well as standard sine, square, and triangle waves.

Generates Multiple Periodic Waveforms

A common requirement in industries such as communications and medical electronics is to generate waveforms which use multiple periodic waveforms with accurately controlled harmonic amplitude and phasing. These complex waveforms are readily generated using the AWG. Very long waveforms can be created and generated using the sequence modes and external triggering can be used for control.

Simulates Random or Infrequent Signals

Another class of applications involves duplicating signals upon demand that are the results of random or infrequent events. Electromagnetic pulse (EMP) susceptibility testing and power line transient testing are common examples. Such transient events can be specified by equation or captured using a digital oscilloscope. Once the waveform file describing the transient waveform is generated, it can be used when and where needed.

Precisely Controls Amplitude and Phase

Many applications make use of the AWG's precise control of amplitude or phase. Communications, radar, sonar, and radio navigation test signals are all phase sensitive. AWGs with dual outputs are especially well suited for producing outputs with controllable phase differences. AWGs with synchronous digital outputs provide phased digital inputs directly to your product's signal processing circuits at high, operational data rates. Magnetic peripherals like disk and tape drive testing require selective control of signal amplitude or timing a specific point within the waveform. Dual channel outputs can be added or subtracted to produce amplitude or timing variations at the desired points within the waveform for tolerance and margin testing.

Should You Be Using An AWG?

The examples cited are samples of a broader range of applications which would benefit from the use of an AWG as a signal source. You should consider an AWG if your signal requirements fall into any of the following categories:

- ***You're using "hot mock-ups," "golden reference" assemblies, or custom designed generators to supply real signals.***
- ***It would help if you could capture an existing signal from a system and regenerate it for use in other work.***
- ***You need to generate signals based on computer simulations for input to your system.***
- ***You must test with signals that occur rarely or unpredictably.***
- ***You have to supply signals that originate in parts of a system that are unavailable or are hard to control.***
- ***You have to supply multiple waveform types that would require many different signal sources.***
- ***You need mixed analog and digital test signals.***

When Choosing an AWG, Be Sure to Consider the Following:

Ease of Waveform Creation

AWGs are extremely versatile, so to obtain maximum benefit, convenient user interaction is of great importance. The LW400 series allows you to create and control waveforms "live" at the turn of a knob on the front panel while viewing the signal on a built-in 9" CRT. It provides easy-to-use waveform creation methods, file management, including waveform transfer from digital scopes from LeCroy and other manufacturers. You can also download data files from P-Spice, MATLAB, MathCad and other programs directly into the LW400 series.

Sufficient and Non-volatile Waveform Storage Memory

Recalling stored waveforms from memory is faster than recreating them from equations or externally downloading them when you want to change output waveforms. LeCroy uses non-volatile memory to store waveform data, setup files, and macro-command sequence files, which are all used for quick, automated AWG operations. The LW400A AWGs support 256 kpoint waveforms standard with up to 1 Mpoint waveforms optional.

DC Accuracy

DC accuracy is a measure of how precisely an AWG can provide the fundamental output voltage upon which all other smaller dynamic inaccuracies piggyback. It is important to focus on this attribute and then analyze the overshoot, ringing, risetime, settling time, and harmonic distortions that can adversely affect the fidelity of your waveforms. LeCroy AWGs emphasize this specification, offering <-50 dB typical total harmonic distortion. The LW400A always uses eight bits in representing your signal, so the full dynamic range is maintained. This is automatic, so you can focus on your work without concerning yourself with details of the signal generator.

Precise Signal Control & Conditioning

One of the most important characteristics of an AWG is the ability to make precise, controlled shifts in waveform timing and amplitude. An outstanding benefit of the LW400 series design is the EASY way in which the user can control signal edge and feature placement in 100 ps increments. Output signal conditioning is optimized through an amplifier/attenuator/filter section that provides the signal you need without complex programming. Some competitive instruments force the user to set waveform lengths in multi-point increments, but with the LW400A, you get what you need - single-point resolution for optimum signal control.

Phase Synchronized Dual Channel Operation

In the LW420A, two independent channels operate from a common timebase, providing precise phase synchronization as well as simultaneous, dual-function operation. You can use the two channels to generate different but time-related signals, or you can sum the signals from both channels into one output.

LeCroy WaveStation LW410A/LW420A Arbitrary Waveform Generator

Main Features

- *100 ps Feature Placement and Single Point Resolution*
- *1 and 2 Channels Versions*
- *Generate Complex, Phase Synchronized Signals on Two Channels.*
- *Continuously Variable Sample Clock From 6 MHz to 400 MHz with 1 Hz Resolution*
- *Independent Pseudorandom White Noise Generator*
- *Live Control of Edge Timing and Pulse Amplitude While Viewing Output Wave*
- *Stand Alone Design, no PC Required*
- *8 Bits of Vertical Resolution*
- *Up to 1 Mbyte of Playback Waveform Memory per Channel*
- *FastSwitch Group Sequence Test Mode Provides Random Access to Sequences With an Access Time of Under 11 ms*
- *Internal Disk Drives for Project, Sequence, and Waveform Storage*
- *Digital Output Option Provides 8-Bit TTL and ECL Digital Outputs Corresponding to the Wave on the Analog Output. Special Digital Editing Mode Useful in Creating Data Patterns.*
- *CE, UL and cUL Certified*

Features & Benefits

LeCroy's LW420A WaveStation™ is a dual-channel, 400 MS/s arbitrary waveform generator (AWG) that brings together high performance with the flexibility and capability needed to quickly generate long, complex waveforms. WaveStation offers more than just great technical specifications. It provides a high level of functionality and ease of use while eliminating many of the traditional obstacles of AWGs.

Building on over 11 years of experience in the design and manufacture of high-performance digital storage oscilloscopes and signal sources, LeCroy's WaveStation combines innovative signal processing, high-performance design, and human factors engineering to provide a truly intuitive and highly interactive arbitrary waveform generator.

The Choice is Yours: Specify The Waveform, and Let The LW420A Handle the Details or Take Control Yourself

With the WaveStation, you need no awareness of the sample clock period or the particular reconstruction filter being used. All the LW420A needs is your waveform's time and voltage relationships. No matter which of the many available tools you use to specify the waveform, the LW420A will generate the output using the optimum combination of sample clock rate and filter bandwidth. The filters automatically selected will assure that aliasing does not take place and that all the timing relationships within the waveform will be precisely maintained. Full control of the clock and bandwidth filters is there for those who need it.

Real-time Waveform Manipulation Lets You Quickly Control The Waveshape—Easily and Interactively—While Viewing on the Internal CRT Display

Select a section of the waveform using the time cursors, then select one of a set of waveform manipulation operations (e.g. move feature, delay, amplitude) and turn the knob! That is how easy it is to continuously modify all or part of a waveform. Time shifts, as small as 100 ps, amplitude variations on a peak, or changes in signal duration are instantly reflected in the output signal. Margin testing or characterization, with the most complex waveforms, has never been so easy.

Waveform Creation Has Never Been Easier

Waveforms can be selected from libraries of traditional functions or application specific waveforms. They can also be created using equations or imported from external sources such as oscilloscopes, or from computer programs and simulator output files. Once waveforms are created or captured, they can be further modified using internal waveform (array) math processing. The waveform math functions include basic arithmetic operations, smoothing, integration, differentiation, and convolution.

The highly developed waveform editing capability uses advanced signal processing to provide bandlimited cut, paste, insert and offset operations with minimal editing artifacts. Single sample resolution, further simplifying waveform creation, is allowed since waveforms are not constrained to 8 sample multiples as with most other AWGs.

To simulate real-world signals, the internal, asynchronous, wide-band noise generator is easily used to add controlled amounts of noise to your signals—simply dial in the noise level as a percentage of your signal's amplitude. A real timesaver is that if you vary the signal's amplitude, the signal-to-noise ratio is maintained.

Flexible Waveform Import And Transfer

Pull waveforms directly from most digital scopes; Connect a GPIB cable between the LW420A and your digital oscilloscope. Select your scope from a list of commonly available models and begin importing waveforms.

Waveforms of up to 1 Mpoints in ASCII or from programs such as MathCad, MATLAB, PSPICE, IQSIM, TOPSIM and others can be imported from the floppy drive. You can also use a shareware program from LeCroy to convert your files to DIF format and transfer directly over the GPIB to the LW420A.

When importing or transferring files, you have the choice of over sampling or importing the points exactly as they are. Once in the WaveStation, all the modification, editing and math tools can be used to put the waveform in the shape you need for your task.

Fast Switch Group Sequence Increases Test Flexibility and Minimizes Test Time

LeCroy's Fast Switch Group Sequence capability enables you to switch between many different pre-loaded waveforms in less then 11 ms. Waveforms will continually play until a sequence advance is received from the front panel or a remote command. Choose to auto advance from sequence to sequence or choose to jump to the nth sequence in the group. Generate a continuous output of a sequence selected from the group, or use the external trigger input to initiate a burst or single shot of the selected sequence.

Digital Output Option

The Digital Output option provides 8-bit TTL and ECL digital outputs corresponding to the current value of the Channel–1 analog output. The latched digital data is held for the duration of the sample clock. The digital data, including the sample clock and its complement, are available via rear-panel connectors. The special digital editing mode is useful for creating and editing byte wide data patterns or selected bits and the standard "cut and paste" tools available for analog waveforms can also be used.

400 MS/s Maximum Clock Rate, 1 Mpoint Waveforms, and Synthesizer Timebase With Two Phase-Synchronized Channels

A maximum sample rate of 400 MS/s, up to 1 Mbyte of waveform memory, a precise timebase, and single point resolution gives you the power you need to generate the most demanding, complex stimuli. The timebase combining 3 ppm accuracy and 1 ppm/year stability assures that the waveforms you test your systems with next year will be the same as the ones you use today. Low single sideband phase noise and a 1 Hz frequency resolution over a continuous 6 kHz–400 MHz range provide the flexibility and capability needed to generate even the most complex and demanding waveforms.

Fully Integrated AWG Includes High Performance Processor, Internal Hard Disk Drive, And Built-in 9 Inch CRT

WaveStation provides all the power needed to work with long and complex waveforms. A built-in hard disk drive, a 486 processor, up to 24 Mbytes of RAM, and a large internal monochrome VGA display make the LW420A a fast, responsive instrument ideally suited for the interactive graphical operations required in a high-performance AWG.

Generator Mode

Standard Function Waveforms

Sine, 1 Hz–100 MHz
Square, 1 Hz–50 MHz
Triangle, 1 Hz–25 MHz
Ramp, 1 Hz–25 MHz
Pulse, (period) 20 ns - max. memory
DC
Frequency Sweep, Linear / Log
Multitone, 1–10 tones,
1 Hz–100 MHz

Special Waveform Generation Mode
IMD - Intermodulation distortion test waveform: Select center frequency, 1-15 tone pairs, tone spacing, resolution, offset from center frequency.

Arbitrary Functions

Waveform Creation
Interactive Graphical editor on internal 9" diagonal CRT—8.5" viewable.

Standard Functions
Sine, Square, Triangle, Ramp, Pulse, DC

Equation Editor
Waveform (array) Math
Waveform Import From
Digital Oscilloscope
Floppy Disk

Feature Time Resolution:
100 ps @ 400 MHz

Available memory:
256 k/ch standard
1 Mpoint optional

Segmented Waveforms

Minimum segment length: 64 points
Maximum segment length:
Up to available memory (1 Mpoint with memory option installed).
Segment length resolution: 1 point

Number of links:
512 for 256k memory
2048 for 1M memory

Noise Generator

Independent pseudorandom white noise generator with a Gaussian distribution and 2^{22} states. The noise is asynchronous, generated and summed internally into the output channels.

Waveform Output Characteristics

Output channels:
LW410A – 1 Channel
LW420A – 2 Channel

Output Impedance: 50 Ω, ±5%

DC Accuracy:
2% ±40 mV > 500 mV
2% ±15 mV < 500 mV

Vertical resolution: 8 bits

Minimum output voltage:
10 mV p-p into 50 Ω

Maximum output voltage:
10 V p-p into 50 Ω

Offset voltage range: ±5 V into 50 Ω. The output voltage (signal + offset) must be in the range ±5 V into 50Ω.

Offset voltage resolution: 0.05% of full scale

Output bandwidth: 100 MHz (-3dB) (widest bandwidth)

Total harmonic distortion:
For sinusoidal output of <5 V p-p;

< -45 dBc (-50 dBc typical) for frequencies: <1MHz

< -35dbc (< -45 dBc typical) for frequencies: 1 MHz–20 MHz

< -25 dBc (< -40 dBc typical) for frequencies: >20MHz–50 MHz, predominantly 2nd harmonic

Spurious & non-harmonic distortion:
< -60 dBc for frequencies <1 MHz

Signal-to-noise ratio: >40 dB (-45 typical) for output amplitudes >100 mV @ 0 offset

Transition times: 5.0 ns, 10%–90% at widest bandwidth.

Overshoot and ringing: <8% of step size max. 3% typical

Settling time: <50 ns to within 2% of step size at widest bandwidth.

Inter-channel crosstalk: <1%

Ch 1 to Ch 2 skew: <1 ns for identical waveforms in each channel (widest bandwidth).

Output protection: ±20 V

Output filtering: Gaussian filters with the following cutoff frequencies can be selected; 100 MHz , 10 MHz, 1 MHz , 100 kHz , 10 kHz

Sample Clock Characteristics

(with internal 10 MHz reference)
Sample Clock: 6 kHz–400 MHz
Resolution: 1 Hz
Accuracy: <3 ppm over operating temperature range.
Stability: aging <1 ppm/year
SSB Phase Noise: < -90 dBc/Hz @ 10 KHz offset for a 10 MHz sine wave at the output

Triggering Characteristics

Trigger slope: Positive or Negative
Trigger input impedance: 50 Ω ± 5%
Threshold range: ±2.5V
Threshold resolution: 20 mV
Threshold accuracy: 100 mV
Threshold sensitivity: 50 mV p-p
Minimum pulse width: 5 ns
Protection: ±5 V

Trigger Modes

Continuous: Runs continuously

Single: Outputs 1 repetition of the waveform for each trigger received. Triggers received while the waveform is still running are ignored.

Burst: Outputs the selected waveform a programmable number of times in response to a trigger. The maximum number of repetitions for a burst is 4,095. Triggers received while the burst is running are ignored.

Gated: The waveform starts on the leading edge of the gate signal and stops on completion of the waveform cycle occurring at the trailing edge of the gate signal.

Trigger Delay

Minimum delay time: 35 ns ±3.5 ns +5 sample clocks (fixed)

Maximum delay time: 10 s at highest clock rate to 100k s at lowest clock rate.

Delay resolution: 1 sample clock. Delay is in units of seconds. When operating from the front panel, the resolution is set in increments of the sample clock period.

Delay accuracy: Same as sample clock + minimum delay time.

Delay jitter: 1 sample clock.

Trigger Sources

Manual: Front panel push-button.
External: Front panel BNC connector.
GPIB: A trigger command may be issued over the GPIB bus.

Mass Storage

3.5" 1.44 MB DOS format floppy drive
400 MB internal hard disk drive.

Auxiliary Inputs

External 10 MHz reference: Rear panel BNC connector for input of an external reference clock. 400 mV p-p to 5 V p-p into 50 Ω.

Auxiliary Outputs

10 MHz reference: ± 3 ppm accuracy
Amplitude (high): 1.6 V into 50 Ω.
Amplitude (low): 0.2 V into 50 Ω.

Markers: Select Edge or Clock
Edge: 1 bit memory—set up to 128 edge transitions—ECL or TTL levels
Clock: Frequency up to one half the sample clock rate.

Protection: Outputs protected to ±5 V.

Channel 1 Digital Output Optional: 8 bits and clock with TTL and ECL logic levels available simultaneously.

Noise In/Out: From rear panel BNC connectors.

Hard Copy Outputs

Supported Printers include:
Epson MX/FX
Epson LQ
HP LaserJet II
HP ThinkJet

Programmability

GPIB IEEE 488.2 compatible. Compliant with SCPI programming language. Capable of initiating and controlling waveform transfer from digital oscilloscopes by simply connecting a GPIB cable (no computer required).

Mechanical

Dimensions:
14.92"W x 7.67"H x 19.58"D
(37.9 cm x 19.5 cm x 49.7 cm)

Weight: 27.6 lbs (12.5 kilograms)

Environmental

Temperature: 5° to 35° full specifications; 0° to 40°C operating; -20° to 70°C non-operating.

Humidity: 10% to 90% relative, non-condensing

Power:

Autosensing
90-132/180-250 V AC
47-63 Hz

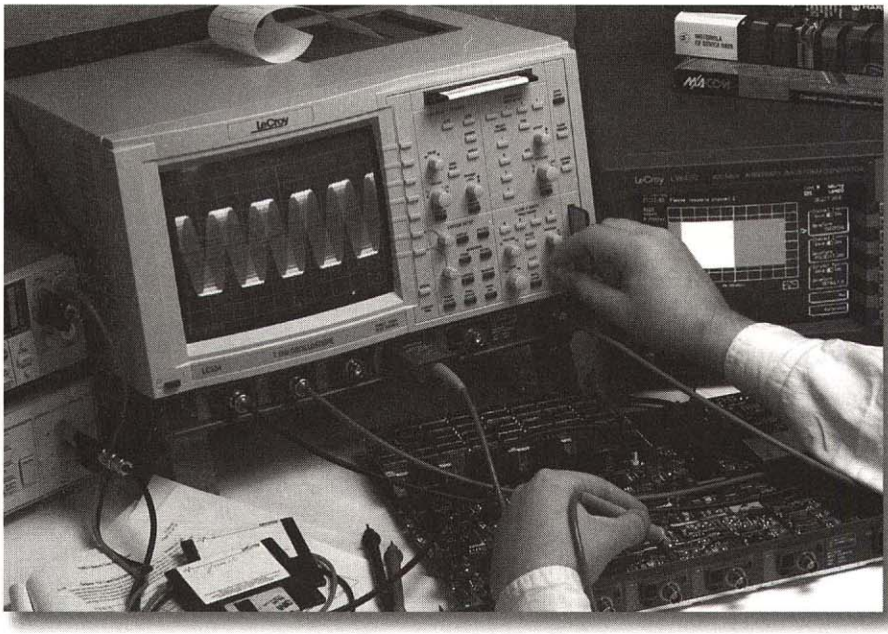
4 amps @ 115 V AC
(20 amps cold start surge)

2 amps @ 230 V AC
(40 amps cold start surge)

LW400 Series - Ordering Information

Waveform Generators:	Product Code	Price
Single Channel 400 MS/s Arbitrary Waveform Generator	LW410A	$ 13,945
1 Megasample memory - 1 channel	LW410-ME2	3,495
Dual Channel 400 MS/s Arbitrary Waveform Generator	LW420A	18,950
1 Megasample memory - 2 channels	LW420-ME2	4,995
Rackmount Adapter for LW410/420	LS-RM	340
Transit Case for LW410/420	LS-TRANS	570
Soft Carrying Case for LW410/420	LS-SOFT	199
Operators Manual for LW410/420 - Included with LW410/420	LW400-OM	85
Remote Programming Manual for LW410/420 - Incl. with LW410/420	LW400-RPG	85
Service Manual for LW410/420	LW400-SM	125
Digital Output - Channel 1 Only	LW400-09A	1,995
5 NIST Calibrations on any LW400 Series AWG	LW4XX-C5	800
NIST Calibration on LW400 Series	LW4XX-CC	250
MIL-STD Calibration on LW400 Series	LW400-CCMIL	450
5 Year Warranty and NIST Calibration on LW400 Series	LW4XX-T5	950
5 Year Warranty on LW400 Series AWG	LW4XX-W5	500
5 Year Warranty and MIL-STD 45662A Calibration on LW400 Series	LW4XX-R5/MIL	1,350

Fundamentals of Digital Oscilloscopes and Waveform Digitizing



This technical note discusses how electronic signals are measured by data acquisition instruments and stored as numbers in fast memory. Concepts discussed include data sampling, triggering, recording pre-trigger data, how sampling rate affects usable bandwidth and how long memory improves sampling rate. There is also a brief discussion of diagnostic capabilities including standard parameters, frequency analysis (FFT) and statistical analysis (histograms).

Introduction

Digital oscilloscopes and waveform digitizers sample signals using a fast analog-to-digital converter (ADC). At evenly spaced intervals, the ADC measures the voltage level and stores the digitized value in high-speed dedicated memory. The shorter the intervals, the faster the digitizing rate, and the higher the signal frequency which can be recorded. The greater the resolution of the ADC, the better the sensitivity to small voltage changes. The more memory, the longer the recording time.

What are the benefits of this digital technology? Multiple signals associated with intermittent and infrequent events can be captured and analyzed instantly. Complex problems can be quickly identified by viewing waveform data which precedes a failure condition (pre-trigger data). Captured waveforms can be expanded to reveal minute details such as fast glitches, overshoot on pulses, and noise. These captured waveforms can be analyzed in either the time or frequency domains.

Most digital oscilloscopes provide:

- Capture of transient events
- Internally adjustable pre-trigger viewing
- Superior measurement accuracy
- Fast measurements with cursors and automatic parametric readouts
- Quick hardcopies on printers and plotters
- Archives for later comparison or analysis
- Waveform mathematics and spectral analysis
- Complete programmability and automatic setups

Some oscilloscopes will:

- Monitor parameters such as amplitude fluctuations, timing jitter, risetime, etc., and display worst-case values
- Provide histograms or trend lines to accurately characterize important signal parameters
- Allow the user to use the full screen as signal viewing area
- Allow signals to be saved or recalled from PCMCIA portable hard drives, ATA Flash Cards, or IC memory cards

Getting to an Instrument Solution

The instrument purchaser needs to understand basic digitizer specifications and architectures to get the right digitizer for the application. For analog oscilloscopes, the primary specifications are simply bandwidth, voltage sensitivity, and accuracy. For digital oscilloscopes, the basic specifications also include sample rate, vertical resolution, waveform memory length and diagnostic capabilities for troubleshooting. Some architectures are optimized for transient signal capture, while others only record repetitive signals. A general-purpose instrument can capture both single-shot and repetitive waveforms.

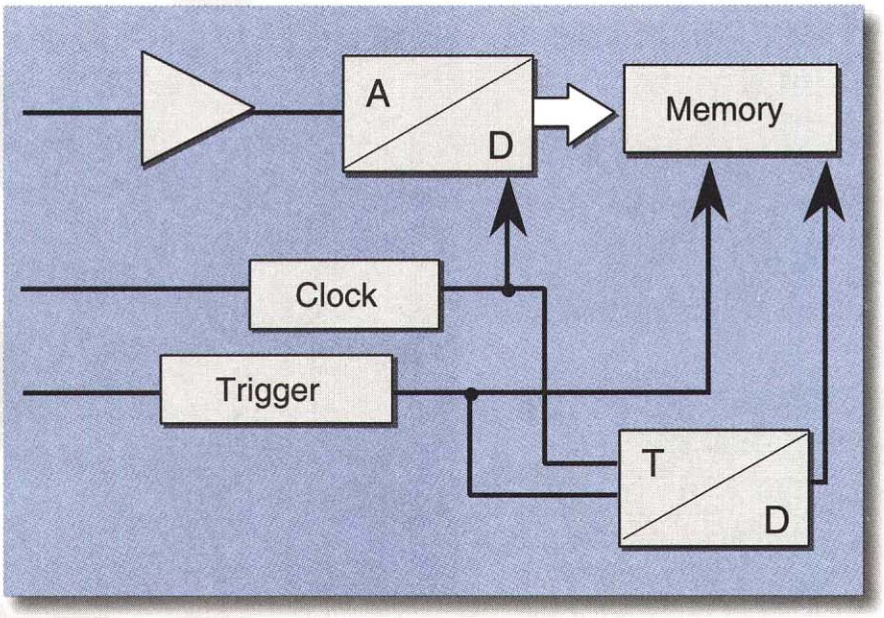
Know Your Waveform

Before you evaluate digitizers, evaluate your signals. Answering these questions regarding your signal and the types of measurements needed will help you choose the right instrument. This preparation will save time and money in the long run.

1. Are the signals ever transient in nature (intermittent, single-shot, random, modulating, drifting quickly, or occurring slower than 100 times per second)?
2. What is the signal bandwidth?
3. How small are the details you need to resolve relative to the peak-to-peak voltage?
4. How accurately do you want to measure voltages and times on the waveforms?
5. How long a waveform portion do you want to capture?
6. What conditions do you need to trigger on?
7. How often should the display update with new waveforms and analyzed results?
8. What kinds of diagnostic tools do you want?
9. How often will you change setups?
10. Do you want to automate tests?
11. Do you want to store and recall waveforms?

Transient Capture

Most analog scopes have a difficult time displaying transient events. In contrast, many digital oscilloscopes are designed for transient capture. Three basic digitizer architectures exist. Transient digitizers and Random Interleaved Sampling (RIS) digitizers can capture transient signals; sampling digitizers cannot. All three types can record repetitive signals. Only transient and RIS digitizers record pre-trigger waveform information; sampling digitizers cannot.



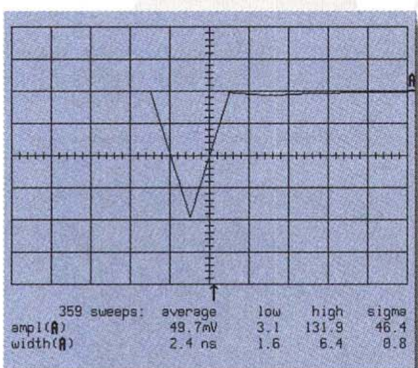
RIS digitizer block diagram

Transient digitizers contain an analog-to-digital converter (ADC) and waveform memory. Once "armed," the ADC digitizes the signal continuously and feeds the samples into the memory using circular addressing. After the last memory location is filled, the system overwrites the stored data, starting at the beginning of memory. After a trigger is generated, memory continues to fill with a user-selected number of post-trigger samples. Then the ADC stops feeding the memory. If the user had selected 100% pre-trigger data, then the ADC would stop sending data as soon as the trigger arrived. If the user selected 100% post-trigger, then the system would fill every memory location one more time and stop. Memory would contain waveform data which occurred after the trigger.

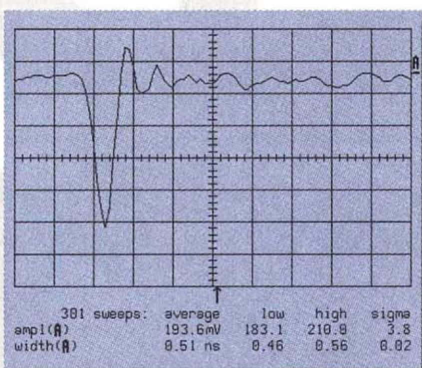
RIS digitizers consist of a transient digitizer with the addition of an interleaved mode. For each trigger, the RIS digitizer records a set of waveform sample points. The digitizer interleaves sample point sets from additional triggered acquisitions to construct a detailed representation of the original waveshape.

Since the digitizer has no way of knowing when the trigger will arrive, the sample clock and the trigger point are asynchronous. Therefore, the time between the trigger and the very next sample clock randomly varies from waveform acquisition to acquisition. The RIS architecture uses a time-to-digital converter (TDC) to measure this relationship and accurately interleave successive waveform acquisitions. The TDC has much better timing resolution than the sample interval, so RIS reconstructions can reveal details that the transient digitizer alone misses. Yet the RIS digitizer provides user-selectable pre-trigger recording, just like the transient digitizer.

Sampling digitizers effectively consist of a sampling head, an ADC, waveform memory, and some timing circuitry. The sampling head stores the voltage



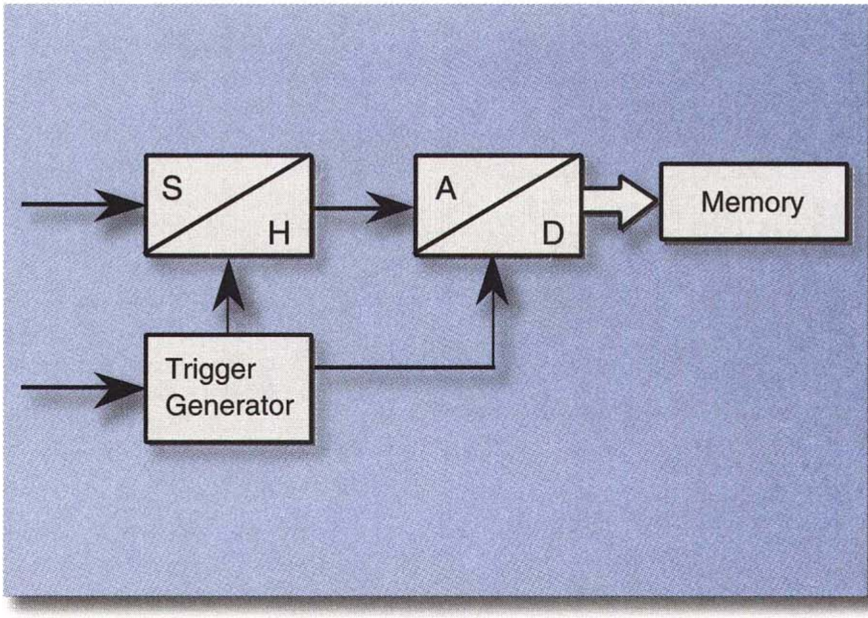
1 ns glitch digitized at 500 MS/s. It is impossible to accurately determine amplitude or width.



The same glitch sampled at 10 GS/s. Both pulse width and peak amplitude may be measured accurately.

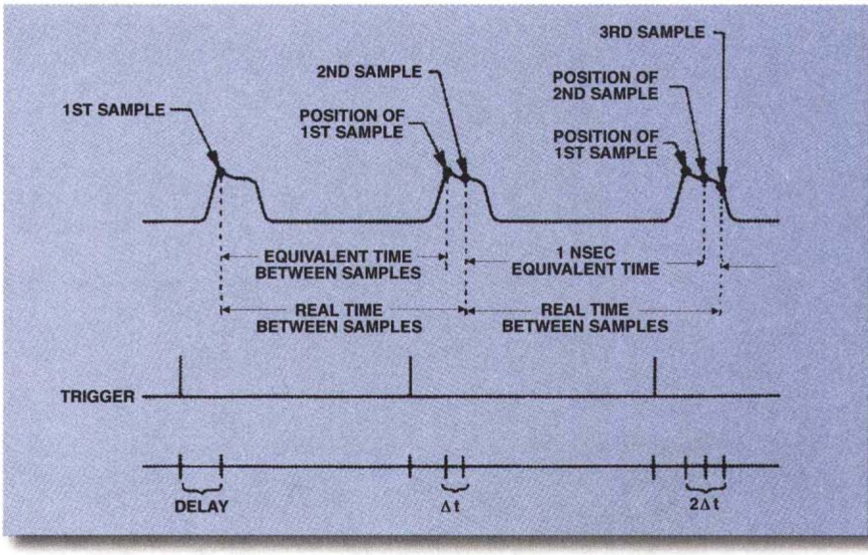
and then holds it while the ADC digitizes it. Sampling digitizers acquire just one sample per trigger. For each successive trigger, the timing circuitry delays the time from the trigger to the sample point. For example, for an equivalent sample rate of 1 GS/s, the first sample point would be at the trigger point, the second delayed by 1 ns, the third delayed by 2 ns, and so on. Since the sample points are delayed from the trigger point, sampling digitizers cannot record pre-trigger information.

With one sample per trigger, sampling digitizers can take a long time to construct long waveform records. For example, for a 1,000 point long record, they require 1,000 waveforms to occur, and for a 50,000 point record, 50,000 waveforms.



Sampling digitizer block diagram

Sampling digitizer operation



Bandwidth and Sample Rate

Bandwidth is an important specification for digitizers, just like for analog scopes. The digitizer's input amplifiers and its filters determine the bandwidth. Fast pulse edges and sharp waveform peaks contain high-frequency signal components. To accurately record these edges and peaks, the digitizer must have adequate bandwidth to pass these high-frequency signal components with minimal attenuation.

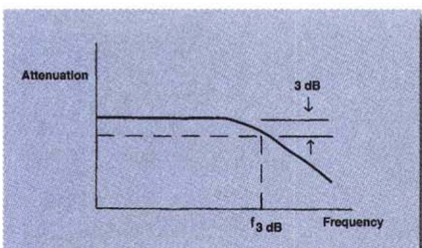
But how much bandwidth is enough? To accurately indicate signal peak amplitudes, the digitizer bandwidth should exceed the signal bandwidth. So first determine the signal bandwidth by estimating the fastest pulse risetime in your signal. Assuming a single pole system response, the signal bandwidth is as follows:

Signal Bandwidth ≈ 0.35/(10%-90% risetime)

For example, a signal with 1 ns risetime (1 x 10^{-9} s) has a bandwidth of 350 MHz (350 x 10^6 per second).

The digitizer bandwidth indicates the frequency at which the signal is attenuated by 3 dB (29%). This attenuation occurs gradually, starting at a much lower frequency. Therefore, choose a digitizer with higher bandwidth than the signal.

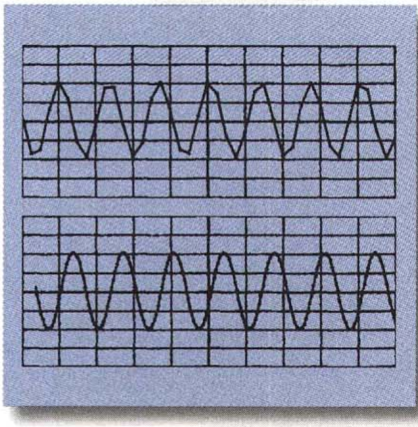
Attenuation occurs within the passband, not just at the cutoff (-3 dB) frequency.



Input Frequency (Relative to -3dB Frequency (F_o))	Attenuation dB	Attenuation %
1.0 F_o	-3 dB	-29%
0.5 F_o	-1 dB	-11%
0.1 F_o	0.1 dB	-1%

Sample Rate Effects on Usable Bandwidth

The digitizer sample rate can degrade the usable bandwidth. To ensure adequate sampling, obtain at least 2.5 samples per cycle with sine x/x interpolation, or 10 samples per cycle with



straight line interpolation. In all cases, more samples will result in a better measurement. If your signal is transient, then look at the single-shot sample rate specification; if repetitive, then the faster equivalent time sample rate can be used.

Given an ideal, the digitizer with no noise, and given a bandwidth-limited signal, Nyquist criterion holds true. Nyquist states that at least two samples must be taken for each cycle of the highest measurable input frequency. In other words, the highest input frequency cannot exceed one half the sample rate. Given this scenario, a sine x/x interpolation algorithm can reproduce the digitized input signal fairly accurately. The sine x/x algorithm fits curve segments between sample points to create a smooth waveform representation. Unfortunately, sine x/x interpolation can amplify noise. Since noise exists in real signals and digitizers, sine x/x should be used cautiously, especially with only 2 samples per cycle.

Sine x/x algorithms can also create undesirable overshoot and preshoot on fast edges. At least 2 data samples are required on the fastest edge in a signal. It is important that the user be able to examine the number of raw data points acquired in any scope using sine x/x display.

For more accurate waveform representations, the digitizer should record at least four sample points per cycle of the highest frequency sine component. The additional sample points effectively enhance the signal-to-noise ratio for sine x/x interpolation. For example, a 1 GS/s (gigasample per second) sample rate could capture the waveshape of signals up to 250 MHz.

Straight line interpolation can deliver accurate waveform representations without the noise amplification caused by curve fitting. For best results, it requires 10 or more samples per cycle.

Maintaining Usable Bandwidth

Long memory allows the scope to maintain the fastest specified sample rate on more timebase settings than a shorter memory scope. Memory determines the maximum possible sample rate at a particular timebase setting as follows:

$$\text{Sample Rate} = \frac{\text{Waveform Memory}}{(\text{Timebase Setting}) \times (\text{\# CRT Divisions})}$$

For example, if the digitizer contained 50,000 points of memory and 10 CRT display divisions and the timebase was set to 5 µsec/division, then the sample rate could be as high as 1 GS/sec and still fill the screen.

As the timebase is lengthened (more time per division), the digitizer must reduce its sample rate to record enough signal to fill the display screen. By reducing the sample rate, it also degrades the usable bandwidth. Long memory digitizers maintain their usable bandwidth at more timebase settings than short memory digitizers. This allows the user to see more detail in the signal and make more accurate measurements.

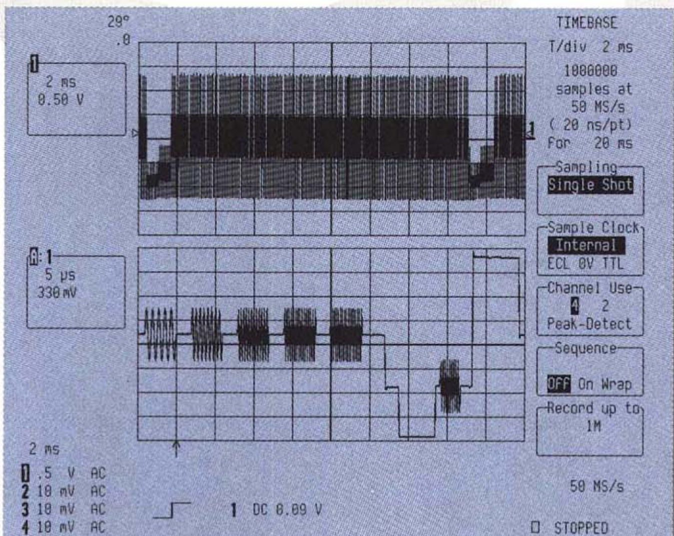


Figure 1. Capturing a frame of video using 1 million points of acquisition memory allows 20 msec of data to be sampled at 50 MS/s. Note that the original trace and its expansion can be displayed simultaneously.

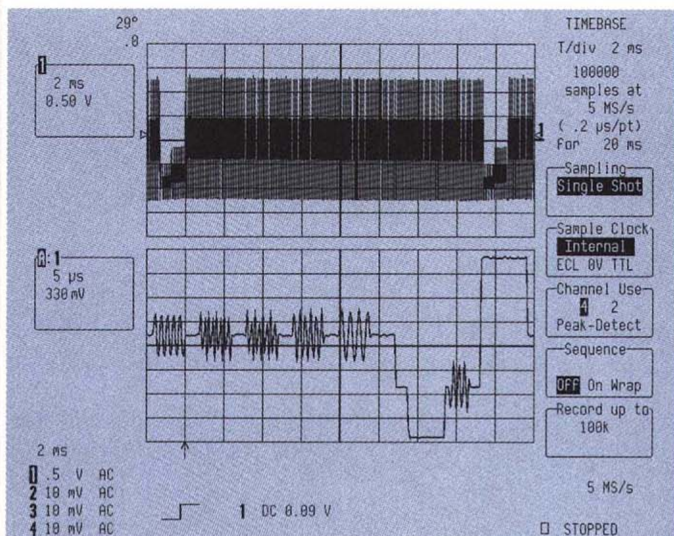


Figure 2. The same signal captured by a 100k memory scope. The trace is undersampled as shown in the expansion below the main trace. The same 20 msec of data causes the sampling rate to become 5 MS/s due to shorter memory.

Benefits of Long Memories in Digital Oscilloscopes

Increasing the memory length of digital storage oscilloscopes brings many advantages, not all of them obvious. Among these are:

- No missed details on waveforms, thanks to higher effective sampling rate.
- Permanent glitch capture, without waveform distortion.
- Better time and frequency resolution.
- Reliable capture of events which are unpredictable in time.
- No dead time between acquired events.

No Missed Details

Figures 1 and 2 show the same waveform (a 20 ms video signal) acquired by two different oscilloscopes configured with memory lengths of 1 million and one hundred thousand points respectively. The superior resolution of the longer memory scope is best seen by comparing the expanded portion of its waveform in Figure 1 (lower trace) with the expansion in Figure 2 from the shorter memory scope. The longer memory scope shows the waveform undistorted by the undersampling evident in the shorter memory scope.

This example illustrates the effect of record length upon sampling rate. Both scopes are displaying 20 ms of data (10 divisions at 2 msec/div). Thus the 100k point scope is digitizing at:

20 ms/100,000 = 0.2 µs per point
= 5 MS/s

while the 1,000,000 point scope is digitizing at:

20 ms/1,000,000 = 20 ns per point
= 50 MS/s

Hence the sample rate is a direct function of memory length. (This is true up to the limit of the scope's maximum sample rate.) As a result, the scope with the longer memory will maintain its bandwidth over more time per division settings without compromising it with a much lower sampling rate. Even if two scopes have the same basic sampling rate capability for short waveforms, the DSO with the longer memory can "put more points on the waveform" and thereby give greater usable bandwidth for longer signals.

A word about default setups: In LeCroy oscilloscopes, the easiest to use default setup automatically digitizes the signal at a memory length and sampling rate optimized to yield the highest sampling rate possible for each time base setting. Scopes from other vendors may have a default setting that results in a 500 point digitization and 500 point display. This optimizes the display update rate but can cause poor sampling. If the waveform is not accurately captured using 500 points, a different setup will need to be made. The defaults represent a difference in philosophy, but the result is a difference in convenience and often performance.

Permanent Glitch Capture

Not all long memory scopes display data in the same way. Some display only a small portion of their long memory on screen and must window or scroll the display to show the rest of the data. LeCroy scopes represent all measured points on-screen in such a way that a live waveform can be displayed together with up to three expanded views. This is done using a proprietary compaction algorithm, and it ensures that any glitch, representing as little as 1/8,000,000th of the displayed waveform, will always be captured accurately and displayed.

Compare this with scopes that rely on peak detection to capture glitches. While peak-detected data acquired may be useful to look at, it will no longer

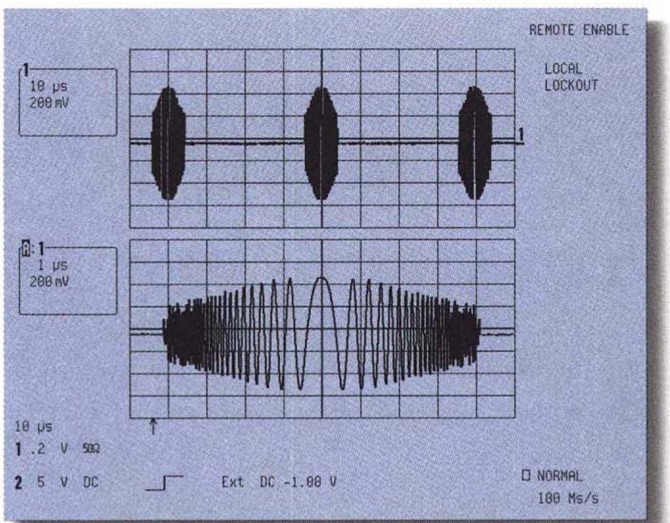


Figure 3. Example of radar signal. Each burst of data can be captured and zoomed to examine the details.

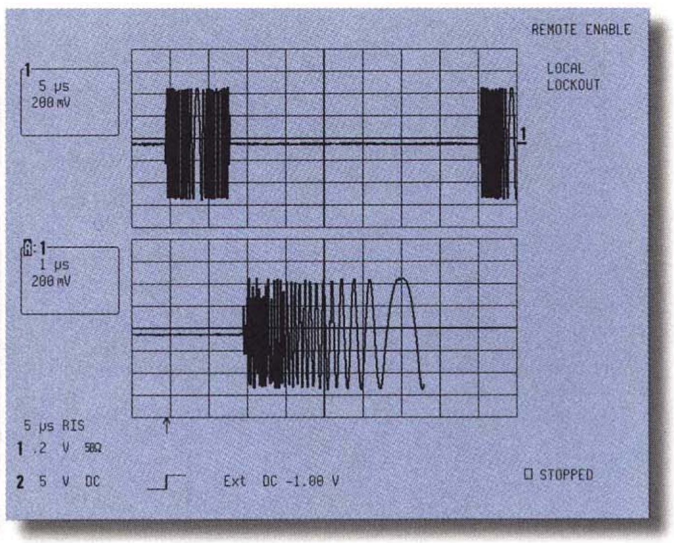


Figure 4. Signals that have long periods of inactivity are well suited to sequence mode. It triggers each time the signal occurs and avoids recording the baseline.

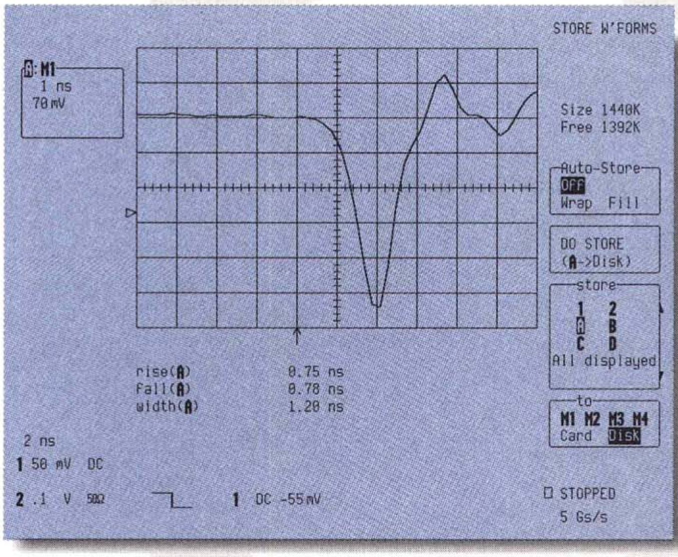


Figure 5. A typical 9354 display. Note the trigger level and source identified below the grid. The left-side and bottom arrows give a visual indicator of trigger level and time.

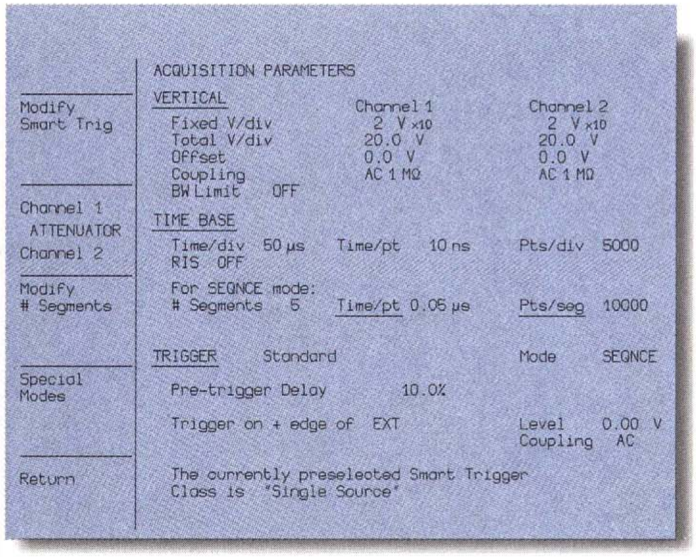


Figure 6. The acquisition parameter menu of the 9354 shows a summary of both the data acquisition and trigger conditions.

yield accurate parametric or cursor measurements, since all the time information has been randomly skewed.

Some DSOs have a special "Peak Detect" mode in which the ADC runs at its fastest sampling rate, but only the maximum and minimum signal values are stored in memory. The time at which these peaks occur is not well known. An advantage of LeCroy's long memory is that half the memory can be used to store peak-detected values while the other half can store a normally digitized picture of the signal.

Better Time & Frequency Resolution

Comparing the different scopes in Figures 1 and 2, the first scope offers 10 times more horizontal points and thus has better horizontal resolution by a factor of 10:1. Better horizontal resolution will improve the accuracy of any time-related measurement. It will also result in improved frequency domain (i.e. Fourier transformed) displays, since the number of points displayed in an FFT is equal to the number of points in the original record (only half are displayed; the other half represent negative frequency).

Reliable Capture of Unpredictable Events

The occurrence of some events may be so unpredictable that they are difficult to trigger on reliably. The easiest way to acquire this type of event is with a long memory oscilloscope. The entire pulse train can be captured and expanded for examination. Once the nature of the failure is understood, LeCroy's SMART Trigger can be used to trigger on this particular type of event.

No Dead Time Between Acquired Events

There is a finite period of time after an acquisition has been made before any scope is ready to make another acquisition. During this period, the scope performs various processing and display routines. This dead time, typically several milliseconds, creates problems when sequential events are being acquired. An example is the sequence of bursts shown in Figure 3. Displaying this accurately requires a high sampling rate over a relatively long period of time.

Figure 4 shows a similar signal, with longer "quiet time" between bursts. One way to acquire such bursts is to segment the scope's acquisition memory into many shorter memories. Using this technique will reduce the measurement dead time from milliseconds to less than 100 microseconds. Thus the bursts in our illustration could be stored into 50 separate, time-stamped memories of 1k each. The time stamp for each trigger is important, since users often want to know the time when each event occurred. Scopes from some manufacturers will store multiple events without any time stamp information.

Triggering

The power of a digital oscilloscope in any given application depends on a combination of several features, including the ability to trigger on the event of interest.

An important criterion when choosing a digital oscilloscope is the flexibility and sophistication of the trigger. To capture rare phenomena such as glitches or spikes, logic states, missing bits, timing jitter, microprocessor crashes, network hang-ups or bus contention problems, the user needs a much more sophisticated trigger system than is found in conventional oscilloscopes.

Some companies put their "good" trigger design into their more expensive scopes and use a less adequate trigger in lower-bandwidth, lower-price scopes. LeCroy believes all scope users at every bandwidth want both a simple standard trigger and the power of a SMART Trigger to use in troubleshooting difficult problems.

The Standard Trigger Mode

The standard mode resembles that of a conventional analog oscilloscope and is directly controlled using the front-panel controls. The following controls and modes are available:

Trigger source: Channel 1, Channel 2, (Channel 3, Channel 4), Line, EXT, EXT/10

Trigger coupling: AC, LF Reject, HF Reject, DC, HF

Trigger slope: Positive, negative.

Trigger level: Channel 1, 2, 3 or 4

Ext: Adjustable to ±2 V.

Ext/10: Adjustable to ±20 V.

Line: Not adjustable.

Trigger mode: Single event, normal, automatic, sequence.

The trigger delay can be adjusted between 1,000 screen widths after the trigger and one screen width before the trigger. Together with large memories, this enables the user to see events which occur much later or much earlier than the trigger itself.

A very distinctive feature of the LeCroy triggers is that coupling, slope and level can be adjusted separately for each trigger source, allowing ultimate trigger flexibility.

Figure 5 shows a typical LeCroy scope display. The trigger level is indicated by the small arrows at the left edge of the grid and the trigger timing position by the arrow under the grid. At the bottom of the screen, a trigger summary, including LeCroy's trigger graphics, gives an overview of the trigger conditions. Figure 6 shows the data acquisition menu which is available at the touch of a button. The trigger conditions, as well as the acquisition conditions, are fully specified here.

Another important feature of the LeCroy triggers is Sequence Mode, which divides the long acquisition memories into as many as 2,000 segments. The instrument can then acquire as many events as the defined number of segments, and record each new event in successive segments.

Sequence Mode

Acquisition is explained in detail in the previous section (Figures 3 & 4). A substantial benefit found in LeCroy scopes that is not available in some competitive instruments is the ability to timestamp each trigger, so the user knows the time of occurrence for each event.

The SMART Trigger

A push-button control switches between standard and SMART Trigger. With the SMART Trigger, the user has access to a variety of sophisticated trigger modes based on two important facilities.

1. The ability to preset the logic state of the trigger sources, CH1, CH2, CH3, CH4, Ext, and Ext/10.
2. A presettable counter, which can be used to count a number of events between 1 and 10^9 or to measure time intervals from <2.5 n up to 20 s in steps of 1% of the time scale.

Combining these two facilities opens the door to such a large variety of trigger conditions that the oscilloscope could potentially become cumbersome and difficult to use. However, great care has been taken to make the SMART Trigger mode user-friendly without loss of versatility. On the screen, special trigger graphics illustrate the trigger conditions for every trigger mode. Examples of these graphics can be found below the grid in all the screen figures. The SMART Trigger has several principal modes of operation:

- Single source trigger with hold-off
- Width triggers (+ glitch) including Exclusion Trigger
- Pattern Trigger
- Dropout Trigger
- State-qualified Trigger
- Edge-qualified Trigger
- TV Trigger

Single Source Trigger - Hold-off

Using this trigger mode, the user can select the desired source and its coupling, level and slope. A hold-off can be set when the waveform contains bursts or patterns and can be specified as a hold-off by time or number of events.

Hold-off by time: Many oscilloscope measurements require the ability to acquire a complex waveform which lacks any unique features to trigger on. Examples of these types of waveforms include data packets from local area networks, disk-drive data streams, and outputs from charge coupled devices. These signals, which are clocked and generally of fixed length, are easily synchronized by using trigger hold-off by time or event.

Hold-off by events: Consider the need to synchronize the acquisition of a pseudorandom noise generator output. The data offers no distinctive trigger points and the only available timing signal is the generator's clock signal. If the user knows the length of the pseudorandom sequence is 4095 states, then the clock signal, with a hold-off by 4094 events, can be used as the trigger source.

Single Source Trigger - Width

The width-based trigger has been a major innovation in oscilloscopes. Two possibilities exist:

1. Pulse Width (i.e. the time from the trigger source transition of a given slope to the next transition of opposite slope).
2. Interval Width (i.e. the time from the trigger source transition of a

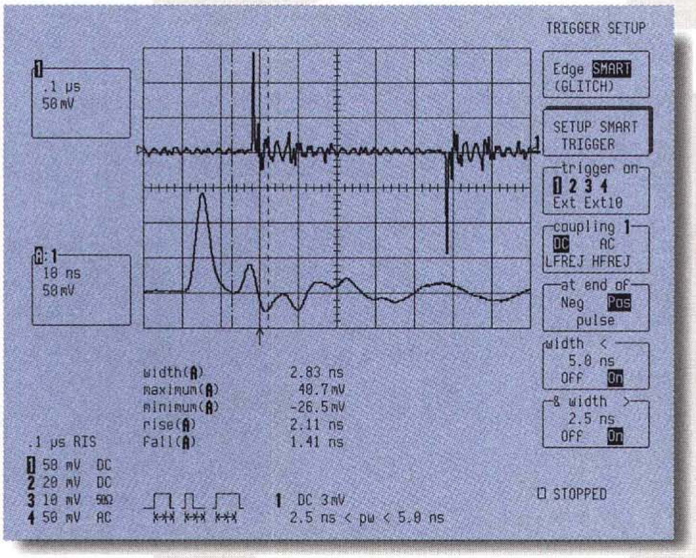


Figure 7. Selective trigger on a 2.83 ns glitch. The DSO has been set to trigger on any pulse narrower than 5.0 ns and wider than 2.5 ns. Pulse parameters are used to characterize this phenomenon after expansion in the bottom trace.

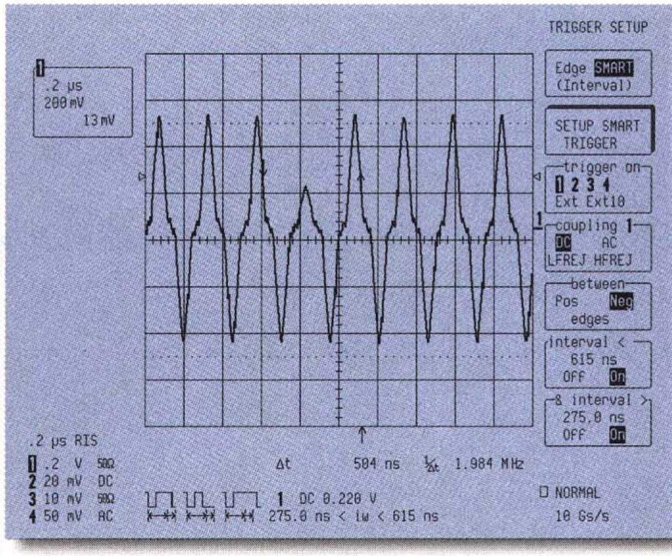


Figure 8. Triggering on a missing bit when reading a magnetic disk. A missing bit can be interpreted as a pulse wider than the period of the pulses or a pulse separation greater than the pulse period. The "interval width >" is used to trigger on this condition.

given slope to the next transition of the same slope).

After selecting a pulse or an interval width, the user can choose to trigger on widths smaller or greater than the given value. This feature offers a wide range of capabilities for application fields as diverse as digital and analog electronic development, ATE, EMI, telecommunications, and magnetic media studies. Catching elusive glitches becomes very easy. In digital electronics, where the circuit under test normally uses an internal clock, a glitch can be theoretically defined as any pulse narrower than the clock period (or half period). The oscilloscope can selectively trigger only on those events, as shown in Figure 7.

In a broader sense, a glitch can be defined as a pulse much faster than the waveform under observation. As glitches are a source of problems in many applications, the possibility of triggering on a glitch, investigating what generated it, and measuring the damage caused by it represents a fundamental research tool. The width-based trigger provides this capability.

Besides triggering on short widths (glitches), there is another substantial benefit of the "width" trigger. In cases where jitter or other timing problems cause a pulse to be too wide, the user can trigger on long widths (trigger condition width > XX). Triggering on a wide pulse is also useful in many communications protocols where a wide pulse occurs at the beginning of a datastream. In some cases, the user wants to trigger the scope based on the time elapsed between two rising or falling edges. An example of this "interval width" trigger is shown in Figure 8.

Dropout Trigger

The dropout trigger allows the user to trigger when a signal stops occurring. Common applications are microprocessor crashes, network hangups and bus contention problems. The user connects the signals of interest to the oscilloscope and specifies a time period for one of them. If that signal becomes quiescent, the scope triggers and data is displayed from all input channels. An example of dropout trigger used in power supply testing is shown on Page 248.

Multi-Source Triggers - Pattern

The pattern trigger is based on the logic state of the several input channels, CH1, CH2 (CH3, CH4) and EXT. Here the user can set the coupling and trigger level of each channel. He then chooses the required logic state for each input and decides whether the scope should trigger at the beginning of the defined pattern or at the end, i.e., when the pattern is "entered" or "exited."

The width and time-separation trigger capabilities described above can be combined with pattern trigger, enabling the user to compare the duration of the pattern, or the interval between patterns, with a reference time. This type of trigger will be greatly appreciated whenever complex logic has to be tested. Examples are: setup and hold times on ICs, computer or microprocessor debugging; high-energy physics where a physical event is identified by several events occurring simultaneously; and debugging of data transmission buses in telecommunications. Figure 9 shows an example of a pattern trigger. The pattern trigger is the logic AND of two to five defined input logic states. However, applying de Morgan's laws, the pattern trigger becomes much more general. To demonstrate this, let's look at an example which is of particular importance, that is a bi-level trigger (see Figure 10). Bi-level trigger means that the user wants the scope to trigger on a single-shot signal of unknown polarity and of roughly known amplitude.

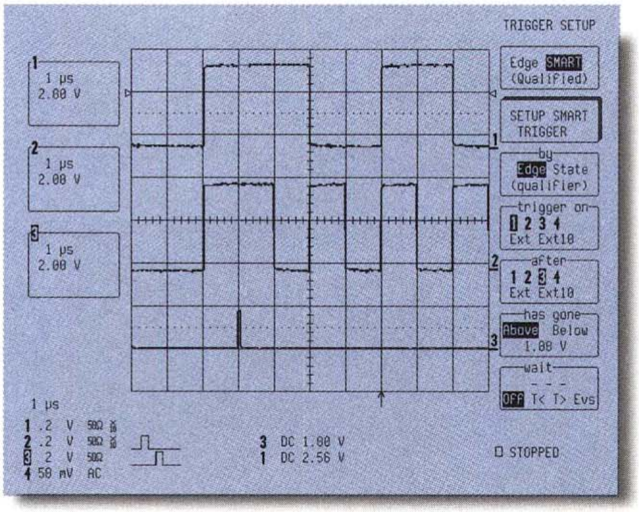


Figure 9. Logic Qualified (Pattern) Trigger: In this figure, acquisition is triggered on Channel 1's trigger conditions only after the signal on Channel 3 meets its own, independent set of trigger conditions. The trigger setup menu shows setup options, including delay (wait) by user-entered time or number of trigger events.

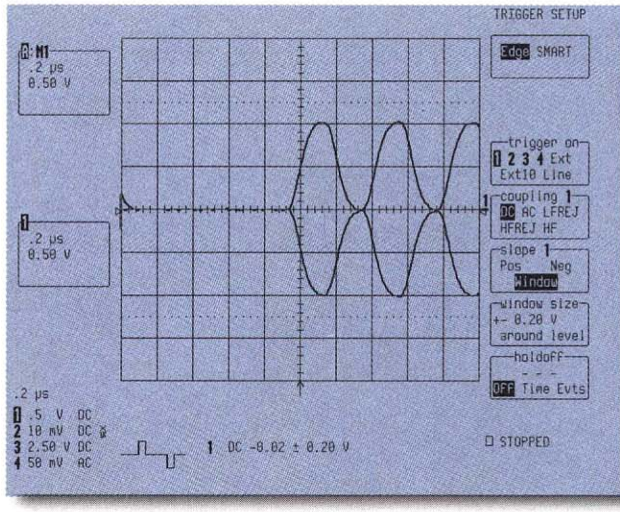


Figure 10. Example of bi-level trigger. The pattern trigger is set so that the scope can trigger on both the upper as well as the lower trace. While the lower trace shows Channel 1, the upper trace shows a previous event stored in memory M1. The arrow at the bottom of the screen shows the trigger time in both cases.

This can be done by connecting the signal source to two inputs, for instance CH1 and CH2. Let's imagine setting the threshold of CH1 to +100 mV and the threshold of CH2 to -100 mV. Bi-level triggering occurs if the scope triggers on CH1 for any pulse greater than +100 mV OR on CH2 for any pulse more negative than -100 mV.

In Boolean notation we can write:

Trigger = CH1 + CH2 (when entering the pattern).

By de Morgan's law this is equivalent to:

Trigger = CH1 • CH2

Triggering on Channel 1 or Channel 2 becoming high is the same as triggering on exiting the pattern CH1=Low and CH2=Low. This last configuration can easily be programmed.

The possibility of setting the threshold individually for each channel extends this method to a more general window trigger. In this case, to trigger the DSO the input pulse amplitude must lie within or outside a given window. Another important aspect of the pattern trigger is that all the features of the single-source trigger mode can also be applied. That is, the user again has the choice of imposing a hold-off by time or by number of events or, alternatively, of detecting durations or intervals which are greater or smaller than a time fixed by the user.

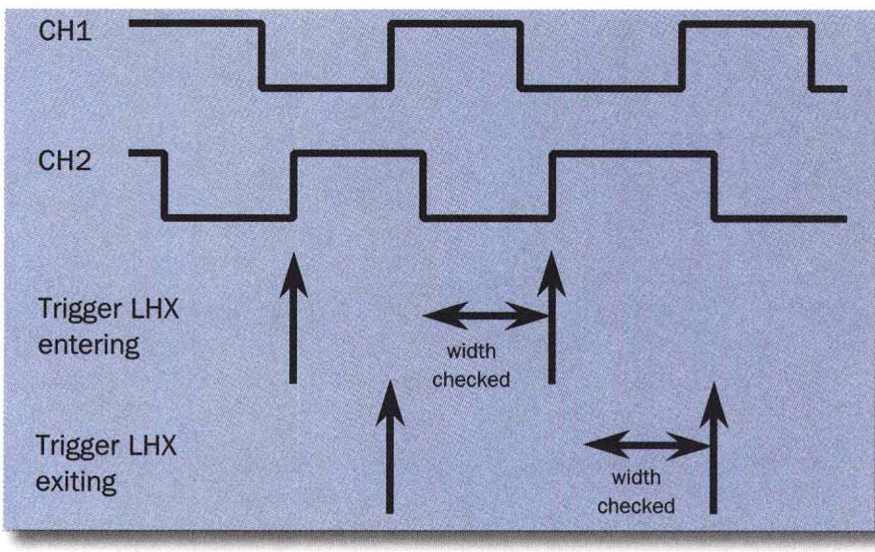


Figure 11. Timing diagram of the pattern trigger.

A warning should be given here about which time interval is compared to the reference time. The pattern trigger is designed to let the user always choose the trigger point. So if, for instance, LHX-entering is chosen, the trigger will occur as soon as the pattern LHX becomes true. If we now add the condition "pattern width < reference time," the width which is compared to the reference time is the width of the pattern LHX complement preceding the trigger point. Therefore, this trigger mode checks the repetition time of the pattern.

On the contrary, if LHX-exiting, "pattern width < reference time" is chosen, then the duration of the LHX state will be compared to the reference time, and the scope will trigger when LHX becomes false. (A timing diagram is shown in Figure 11 and an example in Figure 12.)

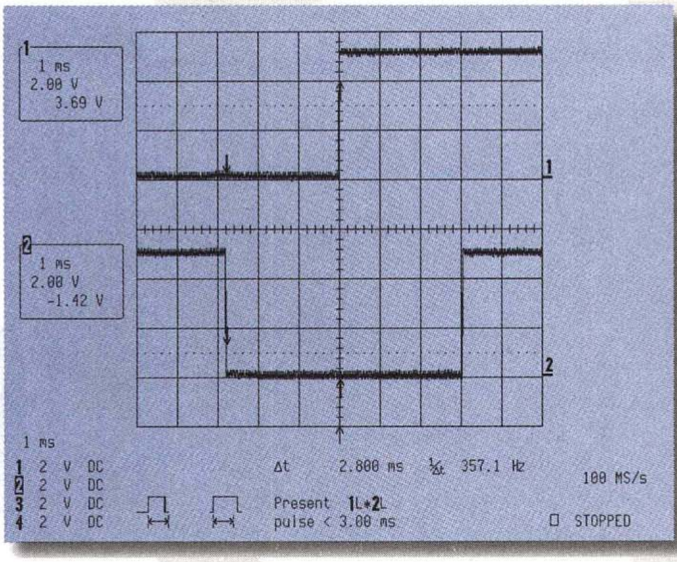


Figure 12. Example of triggering on the delay between two waveforms using pattern trigger. The DSO is triggered on a delay of less than 3 ms between Channel 1 and Channel 2. Pattern trigger has been set for triggering when CH 1 and CH 2 are both more negative than the trigger threshold levels for an elapsed time narrower than 3 ms. Triggering will occur on exiting the pattern.

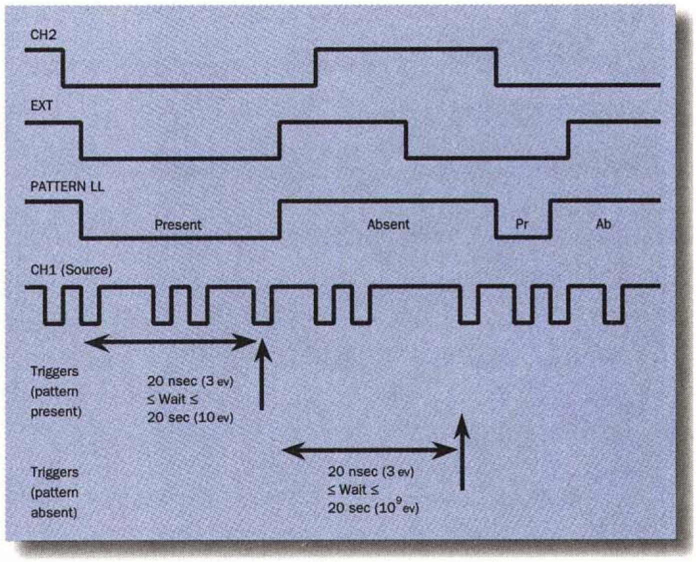


Figure 13. Timing diagram of the state-qualified trigger.

Multi-Source Trigger - State-Qualified

This trigger enables the oscilloscope to trigger on one source, CH1, CH2 or EXT, as soon as a selected logic condition of the other two sources exists. The qualifying state must be held until the oscilloscope triggers. The user sets the required logic pattern on two sources and uses this condition as an enable or a disable for the third source. Different coupling, slope and trigger level settings can be chosen for each channel.

It is also possible to choose a delay by time or number of events which starts as soon as the logic pattern is valid, as illustrated in the timing diagram shown in Figure 13. Typical applications for this trigger can be found wherever time violations occur, for instance in microprocessor debugging or in telecommunications.

Multi-Source Trigger - Time/Event (or Edge) Qualified

This is another conditional trigger requiring a trigger source, CH1, CH2 or EXT, and a given logic state to occur on the three inputs. This trigger, unlike the state-qualified trigger, does not require that the qualifying logic state be maintained until the trigger occurs. From the moment that this logic state is present or absent, a delay can be defined in terms of time or number of events. When the delay has elapsed, triggering is enabled as shown in Figure 14. This feature provides a solution to applications which involve systems with long firing jitter time, e.g. lasers and magnetic discs. Other applications can be found in telecommunications or microprocessors for debugging of asynchronous data buses.

As an example of an edge-qualified trigger application, a DSO is set up to trigger off of the 5th pulse out of an optical shaft encoder. This pulse represents a 1.75° rotation of the shaft, where 1024 pulses represent a full rotation. The index pulse, the 0° reference, is applied to the DSO's CH2 input and the output pulses are applied to CH1. The edge-qualified SMART Trigger is used with the positive-going edge of the index pulse, enabling the trigger on the positive-going edge of the signal on CH1. Hold-off by event is set to trigger after four trigger events. Thus, the oscilloscope triggers on the desired fifth positive-going edge (Figure 15).

TV Trigger

The user can decide whether he wants to trigger on every field, on either odd or even fields, or, when working with color TV signals, he can trigger on one of the four or eight color fields. This can be done for TV standards such as NTSC, PAL-M, PAL and SECAM-625.

Once the field has been selected, the user can selectively trigger on any line within the field.

When it comes to TV applications, LeCroy digital oscilloscopes offer many advantages over traditional test equipment. By combining pre- and post-trigger viewing capabilities, long acquisition memories (up to 2 Mword per channel) and very high sampling rates, the oscilloscopes enable measurements with improved timing accuracy and provide better analytical capabilities. For example, waveforms are easily stored and overlaid allowing rapid comparisons for measurements such as K ratings. Expansion (up to 100,000 times) can be used to reveal glitches and discontinuities that affect picture quality and stability. Timing measurements on sync width, burst width, front-porch and horizontal blanking width can all be made with greater precision even on single-shot acquisitions. An FFT (Fast Fourier Transform) spectral analysis package is available so that frequency, power and phase information can be revealed at the touch of a button.

LeCroy DSOs offer a very comprehensive trigger system. Versatility has been combined with user friendliness to provide instruments with exceptionally powerful triggers.

Display

Analog oscilloscopes update 10 to 100 thousand times per second. Digitizers update much less frequently. Fast update rates give digitizers a "live response", or an analog feel. If the response is too slow, the digitizer can miss changing or infrequent events, can be irritating to operate because of the lack of feedback, and can even provide erroneous results. Digitizer architecture, processor type(s) and speed(s), analysis algorithm efficiency, and display algorithm are determining factors in the display update rate. Some manufacturers offer fast acquisition modes but compromise performance by capturing only 500 points into a persistence display mode.

The "analog persistence" display mode found in LC series DSOs offers the same type of brightness-graded intensity as analog scopes without comprising signal fidelity as is done in the special display modes of other digital scopes. This is done using 16 bits of information for each screen pixel and 1 Mbyte of VRAM.

Processor Speed

Microprocessors are used in most DSOs. They handle data transfers between memory, the display, any communication ports, and internal storage devices. They accept setting changes from the front panel controls or from the ports. In some cases, they control the waveform acquisition and configure advanced trigger settings. Their efficiency at manipulating data tremendously effects display update rates.

Use of multiple, fast-clocked, 32-bit processors plus dedicated digital signal processors can cause a digitizer to approach real-time update rates, even when extensive signal processing, such as FFT, is applied to the signal. Digitizer designs using a single, slow-clocked, 8-bit processor are less expensive but can also make the instrument slow to operate.

Display Algorithm

Use of dedicated display processors and simple long-memory compression techniques increase the display update rate. For example, if the CRT can display 2000 waveform points horizontally and memory holds 50,000 points, then only one out of each 25 points can be displayed. A simple display data reduction algorithm is to take every 25th point and display it. Although fast, this technique can miss important signal peaks and glitches. LeCroy's proprietary "compaction" algorithm shows all the details and takes only slightly longer to run. High-speed 32-bit processors minimize the effect of the additional calculations. Other display algorithms, such as smoothing or sine x/x interpolation, require many calculations and, therefore, processing time.

Dynamic Accuracy

Accuracy consists of resolution, precision, and repeatability. Resolution indicates uncertainty associated with any reading. Precision indicates how well the reading matches the actual voltage. Repeatability indicates how often the same reading occurs for the same input.

All digitizers contain numerous measurement error sources which limit precision and repeatability. These errors include:

- Harmonic distortion
- Spurious response
- Differential non-linearity
- Noise (both amplitude and aperture jitter)

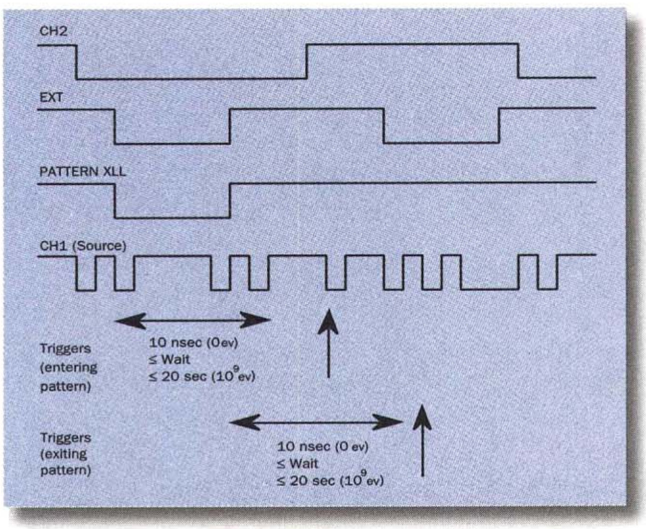


Figure 14. Timing diagram of the edge-qualified trigger.

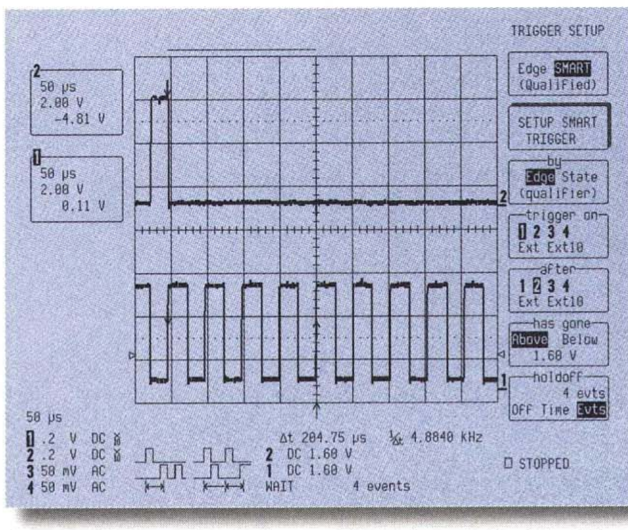


Figure 15. Example of edge-qualified trigger to find the 5th pulse after occurrence of fiducial event.

- Phase shift with frequency
- Amplitude and offset response with frequency

DC errors indicate how accurately the digitizer will measure static or slow moving signals. The input amplifier, not the ADC, determines DC accuracy. Analog oscilloscopes typically have 3% DC accuracy which matches the display errors. Digitizers can deliver better measurement accuracy and thus should have better DC accuracy (typically 1-2%).

Dynamic accuracy represents DC accuracy plus numerous other error sources. Amplitude non-linearities result in harmonic distortion. These include static (DC) non-linearity, sometimes called integral non-linearity. Dynamic non-linearities, as can be induced by slew-limiting, contribute to harmonic distortion. All of these factors introduce spectral components into the digitized waveform data, at integral multiples of the input frequency. For example, for a 5 MHz sine input, 2nd and 3rd harmonic distortion adds 10 MHz and 15 MHz components to the original signal. Typically, dynamic non-linearities become larger for higher input signal frequencies and levels.

Differential non-linearity is a measure of the uniformity in the spacing of adjacent quantizing levels for a digitizer. For an N-bit digitizer, 2 to Nth power minus one quantizing levels exist. For example, an 8-bit digitizer has 255 quantizing levels. For each digitizer code, the bin-width is defined as the difference between its upper and lower quantizing levels. An ideal digitizer has perfectly uniform, nominal spacing between all quantizing levels. The differential non-linearity is defined as the worst-case variation, expressed as a percentage, from this nominal bin-width. For example, if the LSB voltage is 2 mV and the worst case bin is 3 mV, then the differential non-linearity is 50%. A "missing code" has equal adjacent quantizing levels, or zero bin-width, precluding the possibility of the correct code being output at that input level. Differential non-linearity typically causes significant errors only for small signals since the error is usually only one count of the ADC.

Phase distortion means the digitizing system phase shifts the input signal different amounts at different input frequencies. Square pulse edges are composed of a spectrum of frequencies. The pulse waveshape is maintained only if the phase of all the sine components remains constant. Therefore, phase distortion induces erroneous overshoots and risetimes on edges.

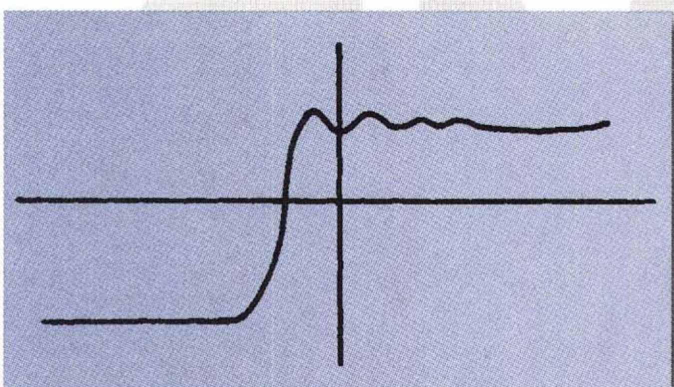
Amplitude noise is random or uncorrelated to the input signal. The amplifier associated with the digitizer generates noise into the digitizing process. Noise can mask subtle input signal variations on transient events. For repetitive signals, noise can be reduced by averaging several waveform acquisitions. A high-resolution FFT plot of a digitized sine input indicates noise distribution, but it also indicates quantization noise. Even an ideal digitizer will have an FFT noise floor because of the quantization noise caused by the finite resolution (e.g. an ideal 8-bit digitizer has a -75 dB noise floor).

Aperture uncertainty represents sampling time noise or jitter on the clock. The amplitude noise induced by clock jitter equals the time error multiplied by the slope of the input signal. The amplitude error increases for fast signal transitions, such as pulse edges or high-frequency sine waves. Thus, aperture uncertainty affects timing measurements such as risetime, falltime, and pulse width. Aperture uncertainty has little effect on low frequency signals.

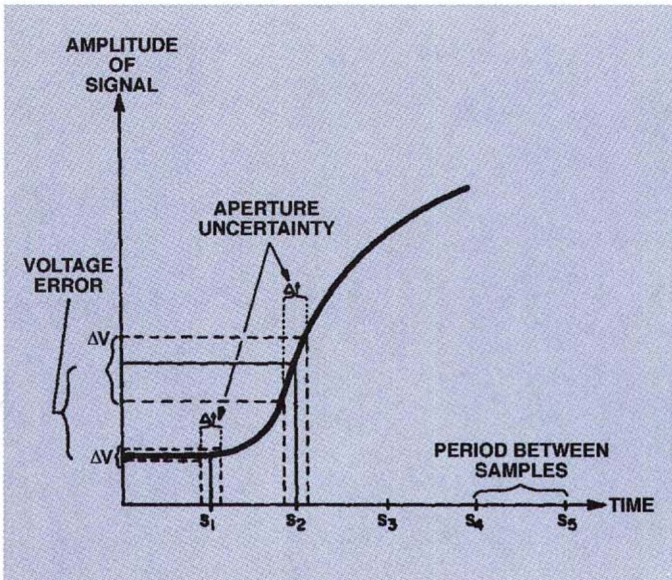
Effective Bits

A figure of merit called "effective bits" provides a simple means of comparing the accuracy of two digitizers. It indicates dynamic performance. The effective bits measurement includes errors from harmonic distortion, differential non-linearity, aperture uncertainty, amplitude noise, and slewing. The effective bits measurement compares the digitizer under test to an ideal digitizer of identical range and resolution.

Effective bits as a performance indicator has many drawbacks. Effective bits measurements change with input frequency and amplitude. Since the effects of harmonic distortion, aperture uncertainty, and slewing increase at higher signal frequencies and amplitudes, the effective bit values decrease.



Phase distortion can cause pulse overshoot.



Aperture uncertainty causes errors on fast edges.

TUTORIALS

To represent overall performance under a wide variety of conditions, effective bits should be plotted for various frequencies and amplitudes.

The effective bits indicator is calculated using sine wave inputs. Therefore, it does not include phase, gain, or offset errors which vary with frequency. It poorly represents worst-case errors and does not indicate which error source contributed most.

Analysis

One of the greatest advantages of digitizing is the ability to analyze the data. Since the digitizer has converted the analog signal into digital data, either an external computer or the internal digitizer processor can analyze the data. Most digitizers now have a wide spectrum of analysis built in. For additional analysis, PC software packages simplify custom array processing. Let's consider some of the available analysis.

Pulse Parameters

Cursor readouts allow the use of the full resolution of the ADC to measure absolute and relative times and amplitudes on a waveform. However, most users commonly measure the same parameters on a waveform. These parameters include risetime, falltime, pulse width, overshoot, undershoot, peak voltage, peak-to-peak voltage, maximum, minimum, standard deviation, rms value, frequency, and period. The IEEE-194-1977 Standard defines how to make these pulse parameter measurements.

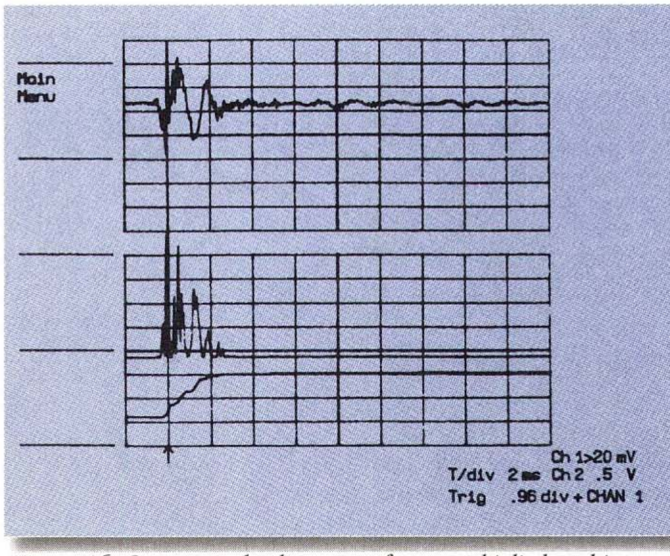


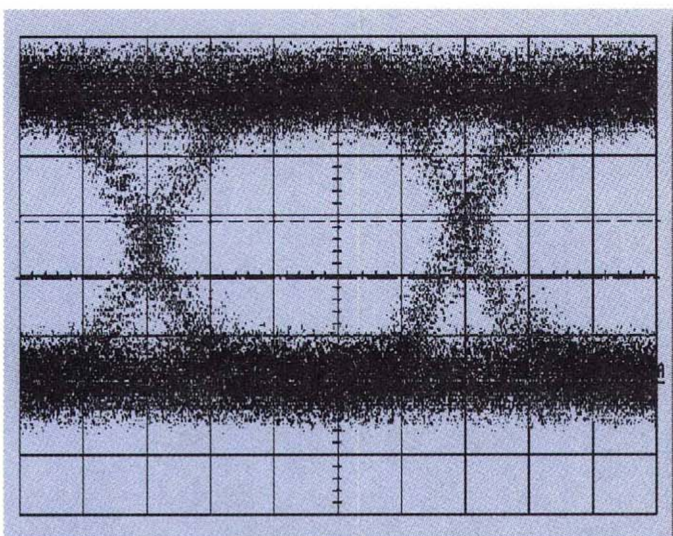
Figure 16: Current and voltage waveforms multiplied and integrated to display total energy.

Waveform Math and Engineering Units

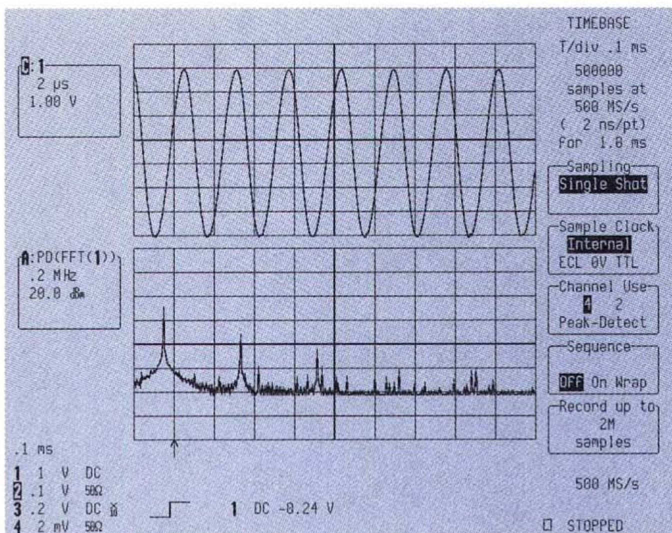
Waveform math allows the user to display final answers rather than raw data. For example, inputs from voltage and current transformers can be multiplied together to display power. LeCroy scopes have a very important feature: the ability to daisy chain math functions. For example, the power trace can be integrated to display energy (Figure 16).

Signal Variation

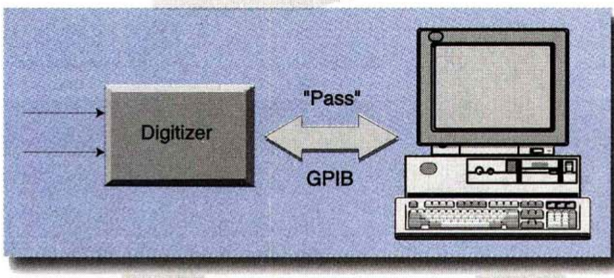
Digitizers can accurately indicate subtle changes in a repetitive signal via either a roof/floor envelope ("extrema") or a persistence mode (e.g. "eye diagrams"). The roof/floor envelope records and displays the max and min values for each point. Persistence mode displays the last N waveforms acquired, where N is a user-selectable number. The persistence mode indicates the density of occurrences; extrema does not.



Persistence mode displays a user-selected number of sequential measurements.



FFT of sine wave shows harmonics not visible in time domain.



Local analysis reduces data transfer time.

Frequency Domain

The Fourier transform converts sampled waveform information into a unique set of sine wave components. The data is usually plotted as frequency vs. amplitude. Two algorithms are common: the Discrete Fourier Transform (DFT) and the Fast Fourier Transform (FFT). Practical implementations use the FFT, since it is many times faster to calculate and can expose information not easily visible in the time domain (time vs. amplitude). Ideal uses for FFT analysis include measuring frequency components of communication signals, monitoring drift in an oscillation, etc. The frequency resolution of an FFT is directly proportional to the number of time domain points the FFT algorithm can handle. Some companies make scopes with 500 kpoints, but their FFT algorithm can accept only 10 k. Those scopes have 1% as much resolution as a LeCroy scope which can perform 1 million point FFTs.

Statistical Domain

The existence of measured waveforms in digital representations permits convenient utilization of the data inherent in those measurements. Besides analysis of signals in the frequency domain and the ability to perform mathematical operations and signal averaging upon the data, one can also determine trends and analyze histograms of the data.

Histograms: A histogram is a bar chart of the number of occurrences of a measured parameter. For instance, one might want to measure the risetime of a repetitive signal. If all the measurements were exactly equal, a resultant histogram would be a straight vertical line with no breadth. However, variations in the risetimes create a plot with some horizontal structure, implying variations in the measurements. LeCroy oscilloscopes can create such histograms and also allow measurement of their own characteristics.

Trend: A Trend function will show the time sequenced values of a parameter. For example the propagation delay through an IC could be tracked while varying it's supply voltage.

Automating Tests

Almost all digitizers can be controlled from a host computer across the GPIB (IEEE-488 Standard Interface bus). The IEEE-488.2 Standard specifies command structure for common digitizers settings, such as voltage range, sample rate, etc. Therefore, digitizers which conform to IEEE-488.2 have easily understood, English-like, mnemonic commands.

One of the problems associated with high-accuracy digitizers in a GPIB-based automated test system is the transfer time and storage requirements of long waveform data blocks. Local data analysis within the digitizer allows for transfer of answers, not extensive data blocks. This analysis can be as simple as calculating pulse parameters, or it could actually consist of Pass/Fail testing.

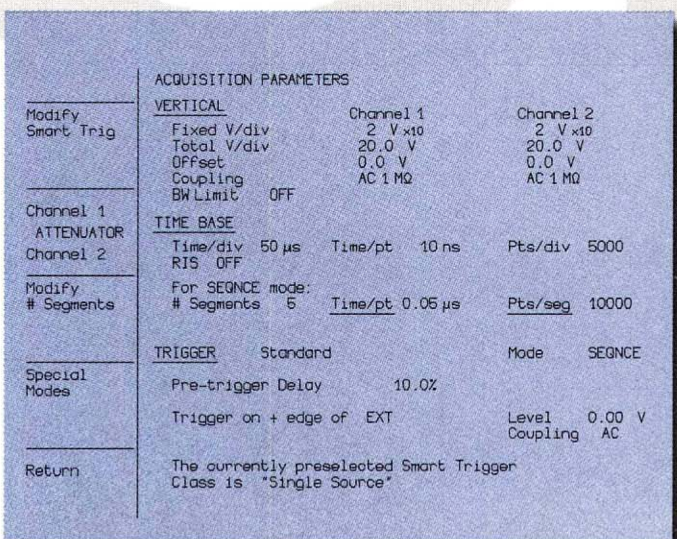


Figure 17. Non-volatile storage and recall of complete configurations simplify setup changes.

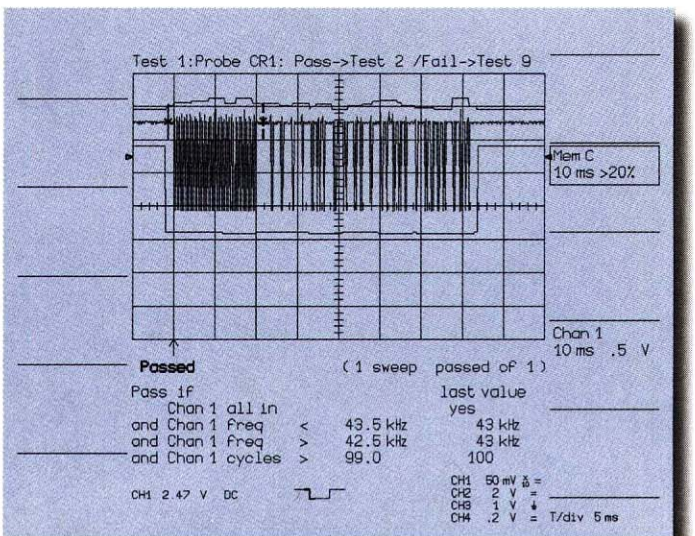


Figure 18. Testing an infrared remote control unit. Note the simultaneous use of both parameters, such as frequency and number of cycles, and tolerance mask testing. Pass/Fail tests can incorporate up to 5 user-defined test conditions.

A "save-on-delta" type of test compares the actual waveform against a high and low limit. The limits are set as tolerances compared to a reference waveform. If the acquired data passes outside the limits, the digitizer can take an action (beep, GPIB SRQ, etc.).

Some digital oscilloscopes may contain a more flexible and powerful test than envelope limits check. The different pulse parameters can be measured on the acquired data. Each parameter can have its own tolerance. For example, the digitizer could act if risetime exceeds a 5% tolerance AND overshoot exceeds 2% OR frequency varies by 0.5% OR the third harmonic is larger than -42 dB.

In Figure 18, both a tolerance mask and waveform parameters are established to test the drive signal from an infrared remote TV control unit. In this case, frequency and number of cycles as well as the upper and lower amplitude versus time limits are used to pass or fail the device under test.

The test conditions are completely programmable and therefore completely flexible. The actions taken can include printing the data, printing a report, saving the waveform to disk, polling the GPIB-SRQ line, modifying its own setup and taking a different measurement, beeping, turning on an external device, etc.

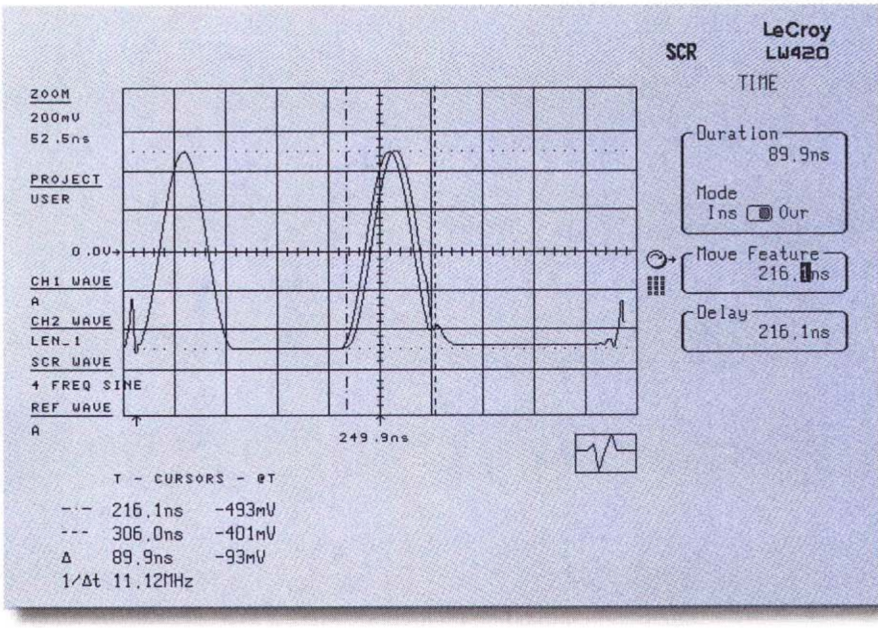
Storing & Recalling Waveforms & Parameters

A few digital oscilloscopes have built-in mass storage for storing large numbers of waveforms. The capability is powerful and time saving. An internal floppy drive or hard disk can store and recall waveforms, setups, measured parameters, and test programs, or they can continuously record every waveform displayed. In the latter case, this "record" mode can be exited and the stored waveforms scrolled back onto the screen one at a time.

Many DSOs now offer built-in floppy disks, RAM memory cards, ATA Flash, and portable hard drives, all in DOS-compatible format. After storing waveforms, the memory card, diskette or hard drive can be removed from the oscilloscope and transferred to a PC for further storage, manipulation, or network transfer, or it can be carried over to or copied for other test, field service, or R&D stations. Absolute consistency can be maintained in testing via this method, as all locations share the same waveform files.

All LeCroy digital oscilloscopes have a floppy disk and GPIB, Centronics and RS-232 ports as standard. Besides storage and transfer to memory devices, LeCroy digital scopes offer push-button transfer of waveforms and settings to LW400 series arbitrary waveform generators. This facility enables a reference waveform, for instance, to be captured from a known good device and then to be used as a test stimulus applied to other devices.

Waveform Creation Made Easy



This technical note discusses how an Arbitrary Waveform Generator (AWG) can be used to perform common types of tests used in engineering and product test. Emphasis is placed on the software and hardware technology that simplifies and speeds up the job of generating test waveforms.

After an introduction which discusses how waveform features can be moved and how to avoid signal discontinuities, there are specific examples of waveform creation for quadrature signal generation, pulse strings, bit jitter tolerance testing, creating jitter to specification and a variety of standard waveform elements that can be used to create signals.

Introduction

Moving Waveform Features in Small Increments

One of the most valuable capabilities of arbitrary waveform generators (AWGs) is the ability to time shift or scale waveform features such as edges and peaks by time increments significantly less than the sample clock period. Many engineers using high-performance AWGs have applied a calculation-intensive version of this technique for years to simulate sub-nanosecond shifts in disk drive and data communications waveforms. WaveStation LW420A, the latest and most advanced AWG from LeCroy, brings this capability to new levels of accessibility and usability. Tedious off-line computations have been replaced by a single, interactive control on the front panel.

The LW420A, using a maximum sample clock rate of 400 MS/s (2.5 ns sample period), is capable of moving waveform features by an increment as small as 100 ps with a simple, single knob control. The figure above, from the LW420's front panel display, shows a pulse being moved within a waveform. Time cursors bracket the segment to be moved. Move Feature is chosen from the Time Edit menu and the segment is moved by varying the main control knob or by entering the desired time shift using the numeric keypad. Note that the Time Edit menu also includes the ability to modify the duration (time scale) and to delay (time shift) the waveform. Each edit action features a minimum time increment of 100 ps.

While the technique is implemented using some very sophisticated signal processing, the basic concept of sub-sampling interval waveform modification is very simple. Consider the two waveforms shown in Figure 1 on the next page. There are two ways to add a time delay to a waveform. Samples can be delayed in time by multiples of the sample clock period. This technique works well for large delays and is very simple.

The LW420A uses this technique for coarse movement of waveform features. Finer delay increments are achieved by changing the amplitude of the samples to correspond with the amplitudes of the desired sample points on the delayed waveform.

For example, if the amplitude at each sample point in the figure is moved to the amplitude of the delayed waveform, then the resultant waveform is moved later in time by "t" seconds. This is indicated, in the figure, by the arrows which show the amplitude changes necessary to move from the original to the delayed waveform. The vertical resolution, one part in 256 for an 8 bit system, offers significantly finer placement of each point on the waveform than shifting by the sample clock period. The correct amplitude value corresponding to a desired time delay is determined by numerical interpolation using advanced signal processing techniques.

Other processing methods are used to optimize the transition points to minimize signal discontinuities. All of this processing occurs so fast that the changes, controlled by a front panel knob, appear at the output as the knob is turned.

The oscilloscope display shown in Figure 2 illustrates the results of the waveform time shift operation. It shows overlayed pulses, from the LW 420A, being shifted by increments of 2, 3, 3.5, and 3.7 ns. Note that the effect is to translate the waveform in time without changing or distorting the waveform in any way.

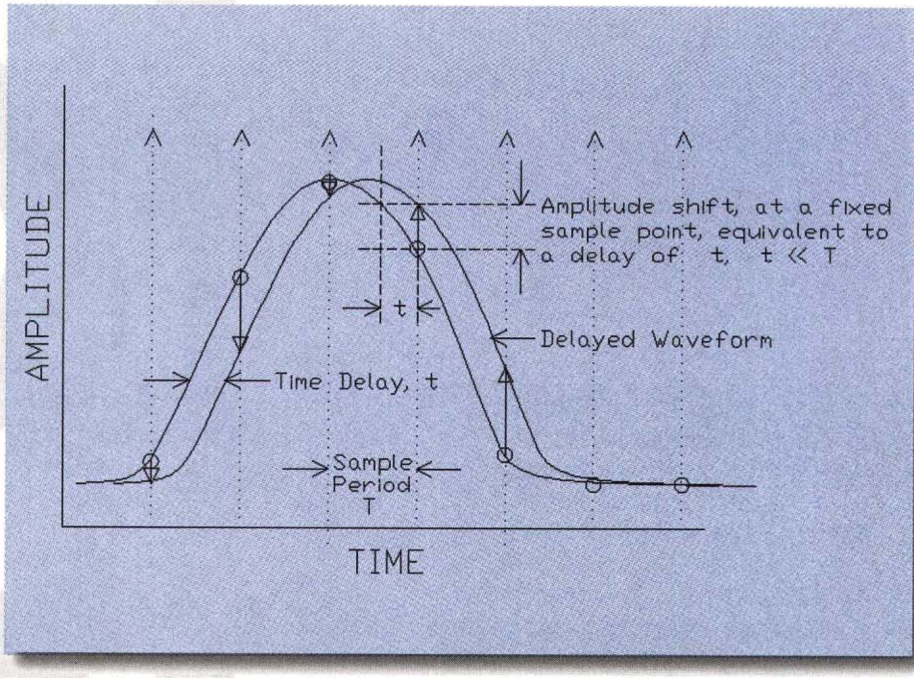


Figure 1. Creating precise waveform time shifts

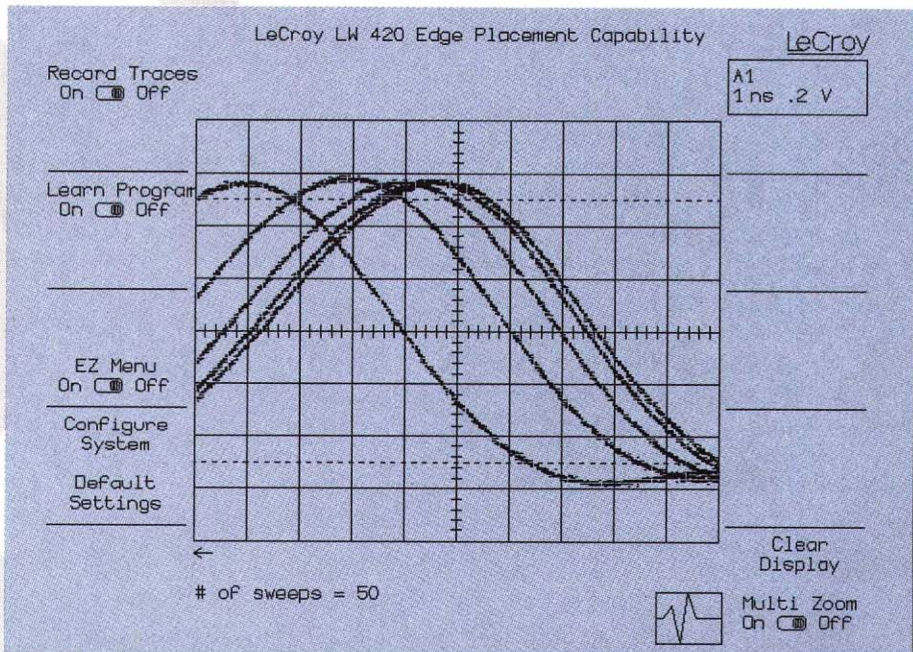


Figure 2. A waveform shifted in increments of 2, 3, 3.5 and 3.7 ns. Note the horizontal scale is 1 ns/division.

Preventing Signal Discontinuities (Nyquist Violations)

The LeCroy WaveStation LW400 series arbitrary waveform generators use advanced signal processing techniques to perform live waveform manipulations, such as duration change, move, and delay with 100 ps time resolution. The interpolation and resampling processes used to perform this task require properly bandlimited data to produce clean, aberration-free output waveforms. Waveform editing, a process common to all AWGs, can be the source of signal discontinuities which violate the Nyquist criteria resulting in undersampled data. The LW400 includes an automatic bandlimiting algorithm which locates and eliminates such discontinuities arising from editing, waveform mathematics, or other sources.

Waveform editing operations such as deletions (cut) and insertions (paste) can produce step changes that occur in less than one sample period. For example, a step waveform within the 2.5 ns sample period of the LW400 has a bandwidth in excess of 1 GHz. This type of discontinuity would generally cause little problem if it were simply output as an analog waveform. The bandwidth would be limited by the output circuits. However, to achieve the benefits of live waveform manipulation, the waveform must be processed further. For example, to move the edge in 100 ps increments, the data must be passed through a sine x/x, finite impulse response (FIR), digital filter. The sine x/x interpolation filter is used because of its flat frequency response out to the Nyquist frequency limit. It also has the property of passing input sample points through to the output if they occur at the identical time. The only drawback of this type of filter is a step response that exhibits overshoot and ringing. If a step discontinuity is applied to the filter input, then the output is shown by the adjacent figure. The filter produces an output where all the output sample values match the desired input sample amplitudes. Two such points are identified by the time cursors on the display. Between the samples, the waveform will exhibit the aberrations shown in Figure 3. This is the step response of the digital filter. These values will be seen at the output as the waveform is moved in time by less than a sample period. The result would be an output level that varied in amplitude as a function of the time displacement. Automatic bandlimiting eliminates this response and produces a clean transition with minimum overshoot and ringing.

When a discontinuity is detected, the data samples are passed through an FIR smoothing filter shown in the block diagram of Figure 4 on the next page. The three coefficient filter converts the input discontinuity, such as a step waveform, into a ramp function.

The smoothed output data can be used in the sine x/x interpolator without the aberrations described earlier. The entire process is totally automatic and transparent from the user's point of view. The response of the LW400 interpolator to both the smoothed and unsmoothed data is shown in Figure 5. The smoothed data exhibits almost no overshoot. This response minimizes changes in the waveform shape when sub-sample delay, move and duration changes are evoked.

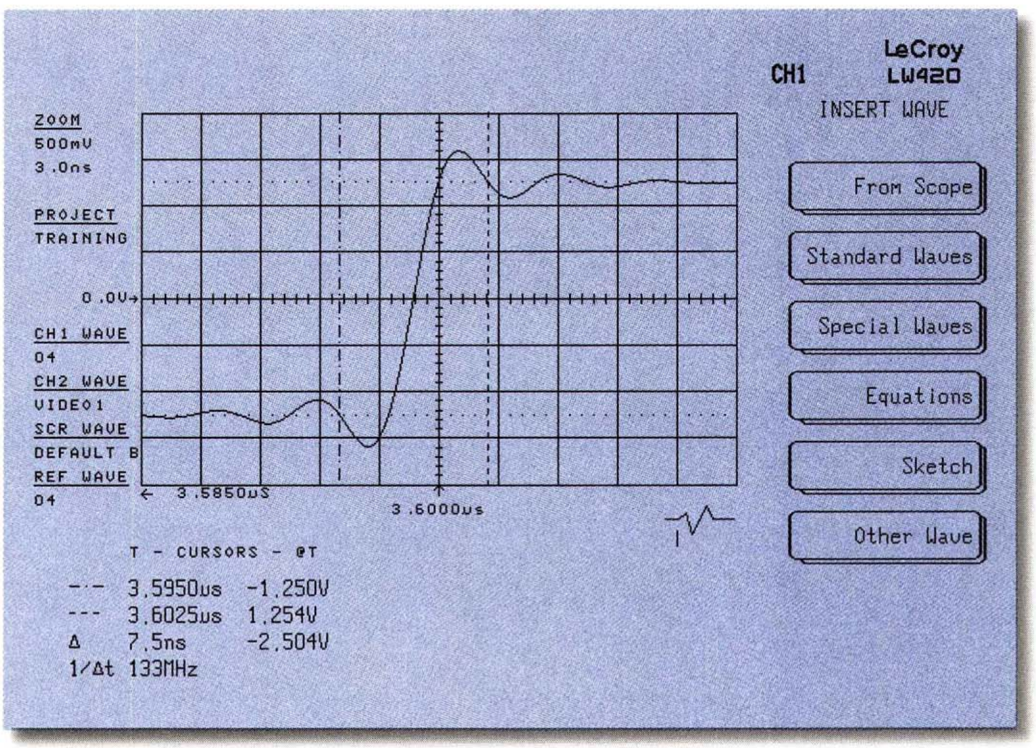


Figure 3.

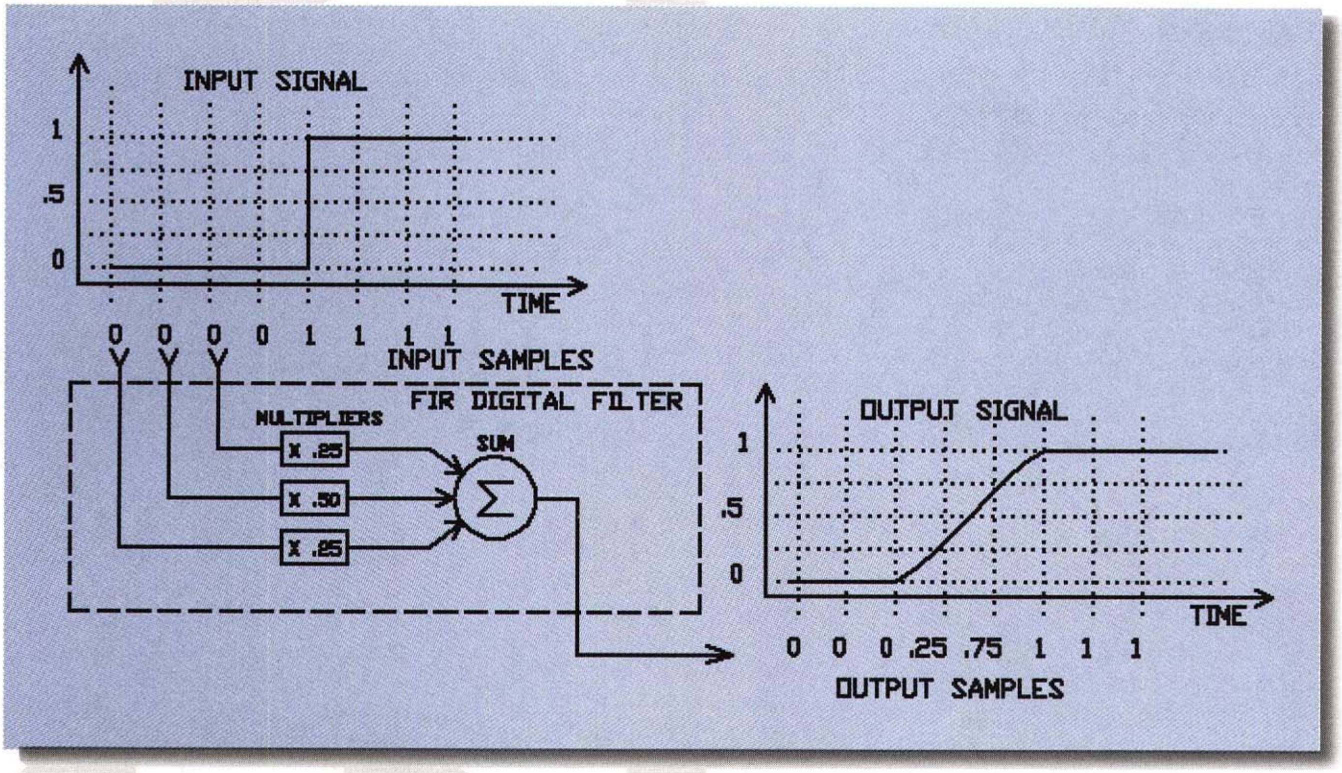


Figure 4.

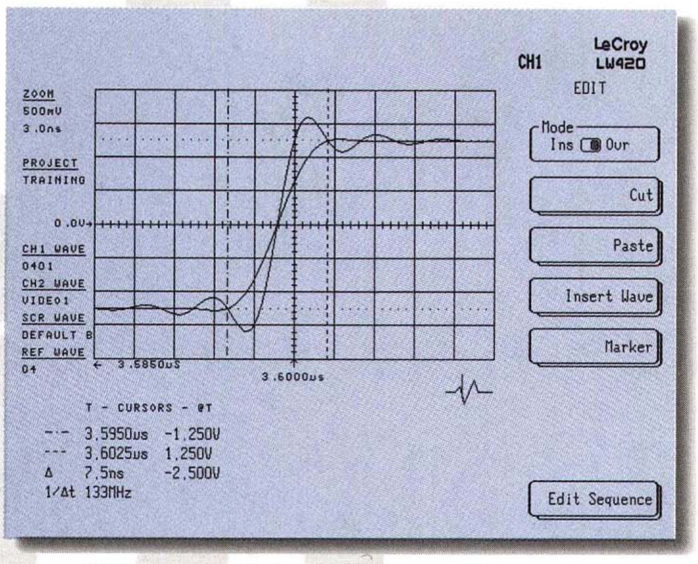


Figure 5. Signal output before and after smoothing

Quadrature Signal Generation - Simulating Phase Encoded Data

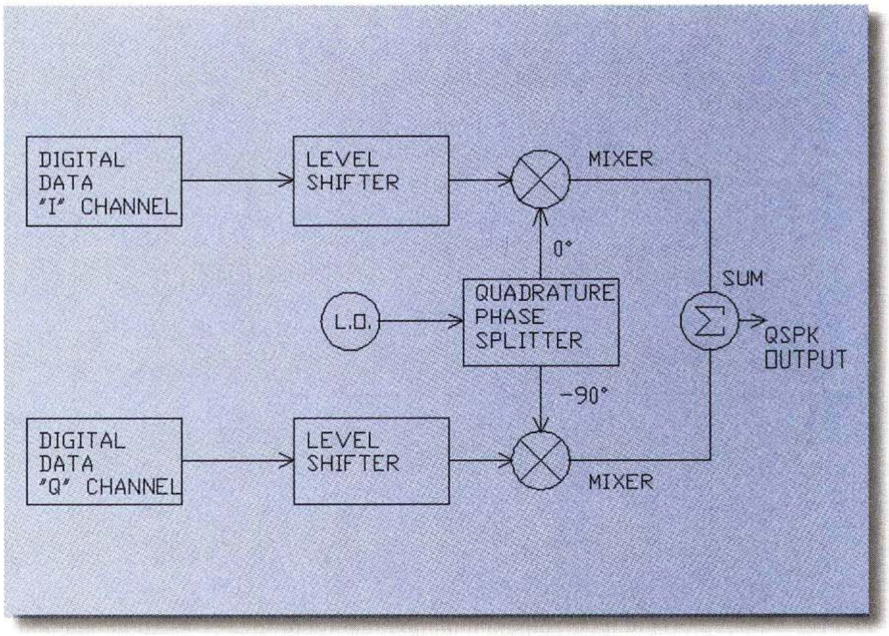


Figure 6.

Dual-channel AWGs are ideal for simulating quadrature signal generation processes. Mixed analog/digital waveform creation coupled with waveform math and precise time, phase, and amplitude modification capabilities offer a full range of functional and margin test opportunities.

Consider the quadrature phase shift keyed (QPSK) system shown in the block diagram of Figure 6. The QPSK output is the sum of dual binary phase shift keyed (BPSK) generators using quadrature local oscillator (LO) signals. LeCroy WaveStation LW420A can be used to replace any, or all, of the system blocks to provide signals with a full range of variability to simulate worst case changes in amplitude, phase, frequency, or signal-to-noise ratio.

Figure 7 shows the I and Q data signals as they would appear at the output of the level shifters in the block diagram. These waveforms were created in the LW420A using the dual channel outputs. Signals can be created from standard wave shapes, equations, or imported from digital oscilloscopes. Independent waveshapes, sharing a common output clock, guarantee correct synchronization. 100 ps edge time resolution in varying edges' positions and durations make it easy to simulate jitter and variations in edge rate.

The local oscillator outputs are created using the standard sine function. In addition to the amplitude, frequency, and number of cycles parameters, the standard sine includes the start phase, settable to 0.01 precision (see Figure 8). This parameter was used to create the - 90° phase shift for the quadrature local oscillator output. These waveforms can also be created using equations. Waveforms created using equations can be phase shifted by adding the phase offset in the function argument. For example, LW420 equations, SIN(2*PI*T*1M)and SIN(2*PI*T*1M+PI/2) are 90° out of phase as are SIN(2*PI*T*1M) and COS(2*PI*T*1M).

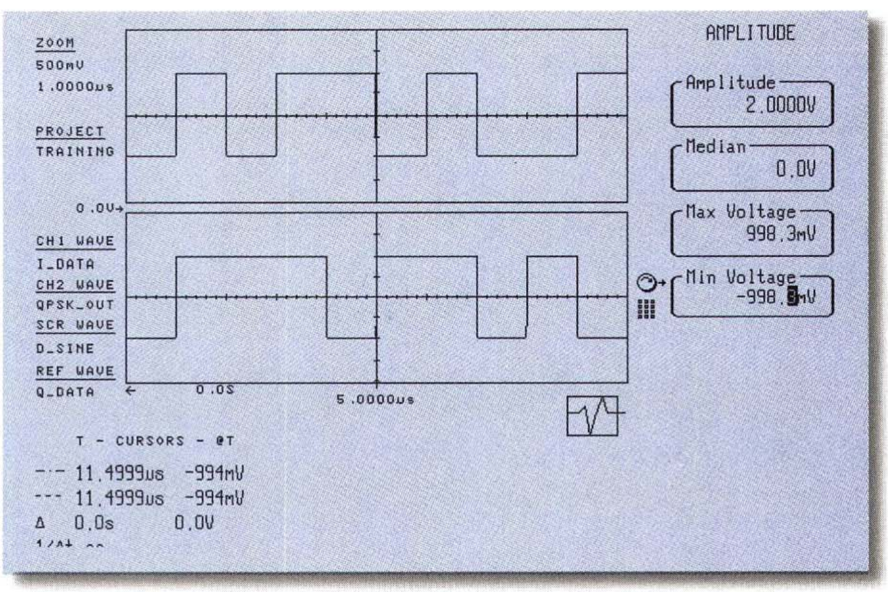


Figure 7.

The outputs of the I and Q mixers are obtained by using the LW420 waveform mathematics (Wave Math) to multiply the data and corresponding local oscillator signals. The resultant I and Q BPSK waveforms, shown in Figure 9, are then added to produce the QPSK output waveform. Wave Math operates on entire waveforms and includes standard arithmetic functions, integration, differentiation, and convolution.

Figure 10 shows the QPSK output signal. In addition to the waveform manipulation, operations which were mentioned previously, uncorrelated Gaussian noise at user-specified relative amplitude, can be added to the output. This permits testing the effect of signal-to-noise ratio on detector performance.

The LW420A has 5 linear phase low-phase filters with bandwidths of 100 MHz to 10 kHz in decade steps. It automatically selects a filter appropriate for the sample rate. If necessary, a lower bandwidth can be selected.

The WaveStation includes XY display capability for characterizing signals created using quadrature generation techniques as shown in Figure 11.

The QPSK output, plotted against the in-phase local oscillator output, shows the output phase trajectory for a selected section of the waveform. The LW420A's X-Y display can also be used to plot I-Q diagrams for visually determining output phase angle and signal magnitude.

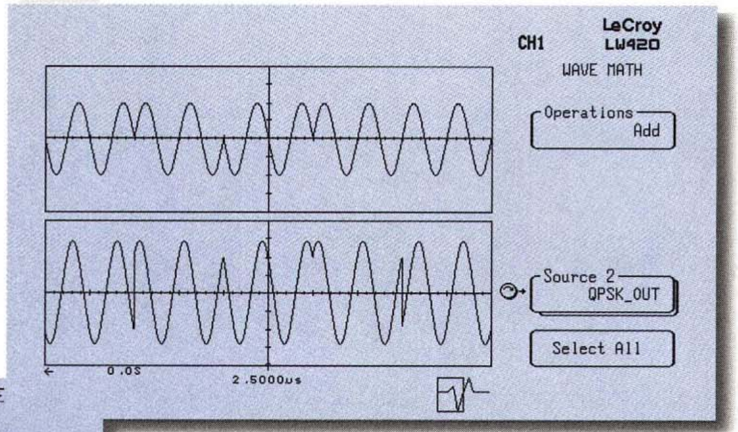


Figure 9.

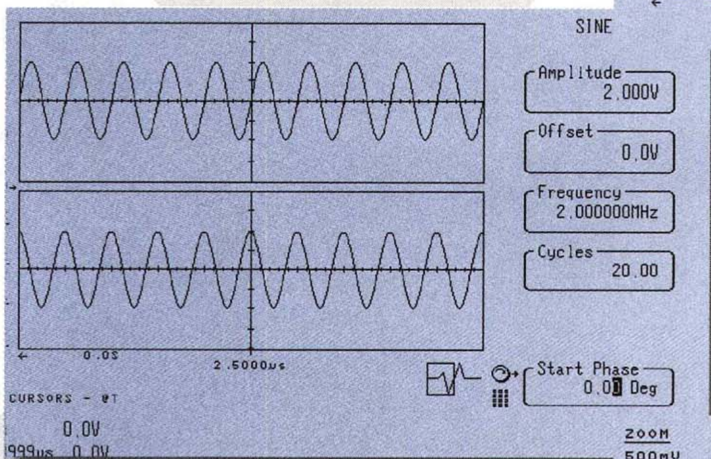


Figure 8.

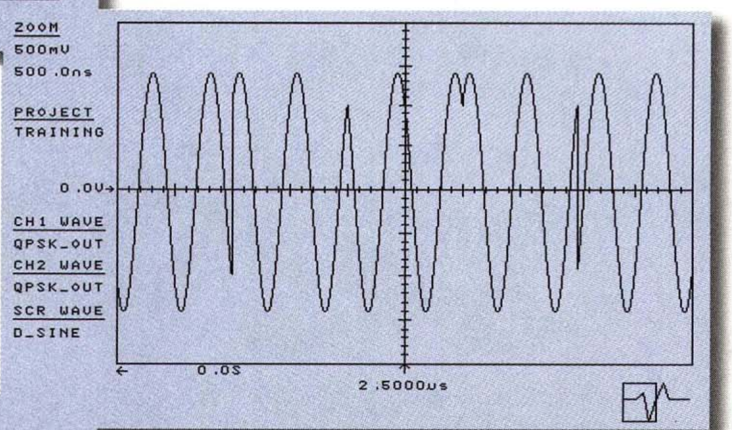


Figure 10.

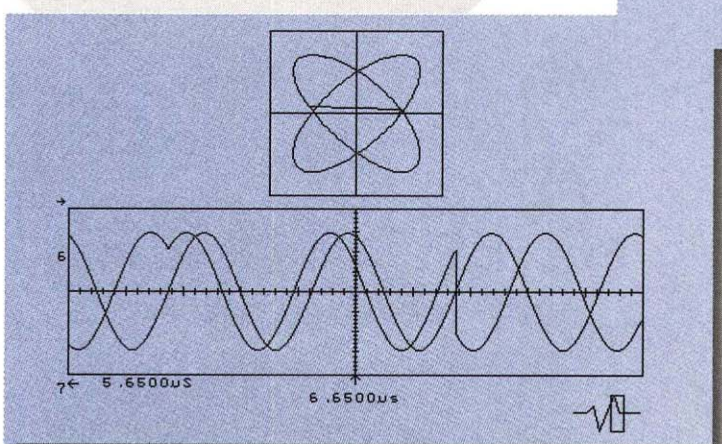


Figure 11.

GENERATING PULSE TRAINS WITH AN AWG

Many electronic applications require non-standard pulse waveforms. Periodic pulses, with multiple levels, controlled amounts of noise, and added or missing pulses are difficult to obtain from conventional pulse generators. The WaveStation LW400 series of AWGs are ideal sources of both special and standard pulse waveforms. Non-standard pulses can be created by combining standard waveforms or by describing them by equations. The following examples illustrate several approaches used to create special pulses using equations.

The basic pulse waveshape (Figure 12) can be described by combining two, time-delayed, unit step pulses. Each step function describes an edge of the pulse. In the LW400 AWG, this is expressed as:

STEP(T-3.5µ) * STEP(6.5µ-T)

where: STEP [f(t)] = 0 for f(t)<0
and STEP[f(t)]=1 for f(t) ≈0

Or its equivalent PULSE function in the form:

PULSE (3.5µ , 6.5µ)

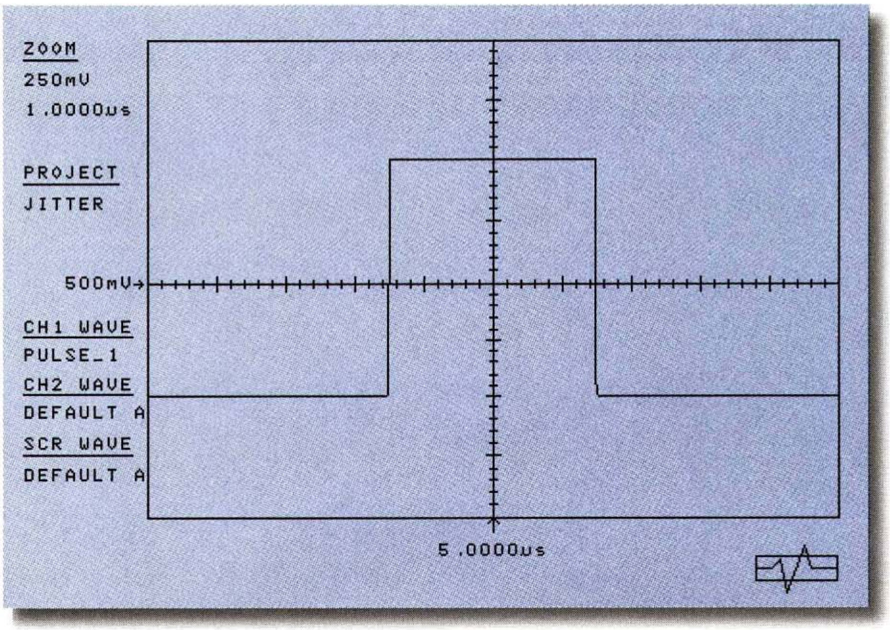


Figure 12. PULSE (3.5µ, 6/5µ)

A repetitive pulse is created by using a periodic function as an argument in the step or pulse functions as is shown in Figure 13.

The upper trace is a square wave created by using a 1 MHz sine wave as an argument of a step function:

STEP(SIN(2*PI*T*1M))

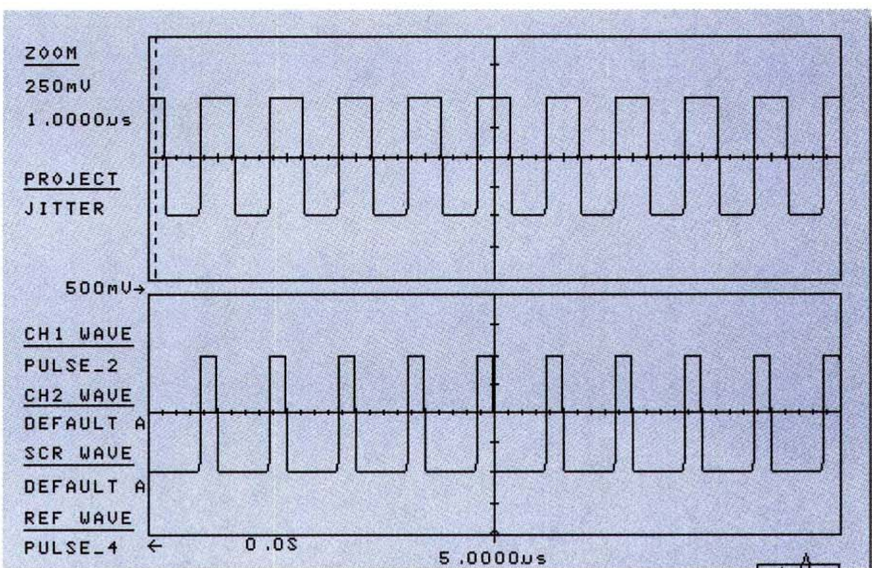


Figure 13. Upper: STEP(SIN(2*PI*T*1M))
Lower: PULSE(SIN(2*PI*T*1M),COS(2*PI*T*1M))

In the lower trace, 2 periodic arguments were used in the pulse function to create an asymmetric pulse:

PULSE(SIN(2*PI*T*1M),COS(2*PI*T*1M))

The duty cycle of the pulse train is determined by the phase relationship of the functions chosen for the arguments.

The duty cycle of a pulse described by,

PULSE
(SIN(2*PI*T*1M),SIN(2*PI*T*1M+f))

will vary from 50% to 0% as the phase offset, f, changes from 0 to p radians. Duty cycles in the range of 50% to 100% are created by taking the complement of this pulse using the equation:

1-PULSE
(SIN(2*PI*T*1M),SIN(2*PI*T*1M+f))

The duty cycle now varies from 50% to 100% as the phase offset is changed from 0 to p radians (Figure 14 lower trace).

Multi-level pulses can be created in many ways. A simple method of creating a bipolar, tri-level pulse analytically is to use the following equation:

STEP(SIN(2*PI*T*1M)) -
STEP(SIN(2*PI*T*1M+PI/2))

An alternative technique is to use the integer floor function with an amplitude offset sine wave (Figure 15):

FLOOR (SIN(2*PI*T*1M)+0.5)

The width of the positive and negative pulses will depend on the value of the offset.

It is possible to modify selected pulses within a pulse train.

Two examples of this are shown in Figure 16. In the upper trace, every third pulse has had noise added to it. The pulse train in the lower trace had every third pulse removed. Both conditions were created by multiplying the original pulse train by a gating signal:

X1=2*PI*T*1M

X2=PULSE(SIN(X1),COS(X1))

X3=PULSE(SIN(X1/3),COS(X1/3))

X4=X2*(1-K*X3)

where: Upper: K=NOISE,

and Lower: K=1

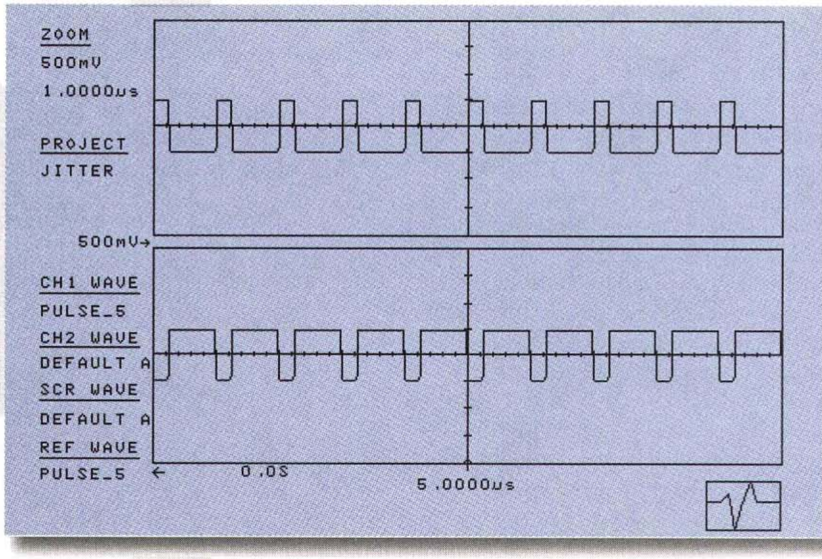


Figure 14. Upper: PULSE(SIN(2*PI*T*1M),SIN(2*PI*T*1M+PI/2))
Lower: 1-PULSE(SIN(2*PI*T*1M),SIN(2*PI*T*1M+PI/2))

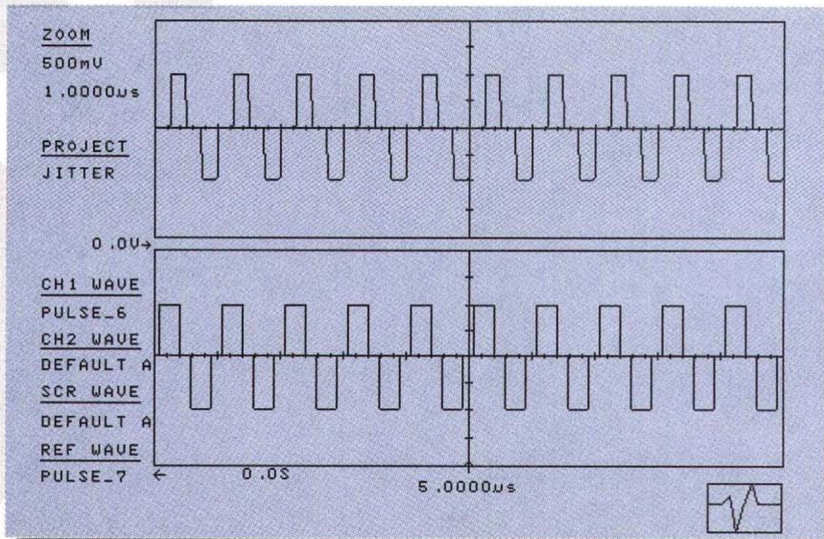


Figure 15. Upper: STEP(SIN(2*PI*T*1M)) STEP(SIN(2*PI*T*1M+PI/2))
Lower: FLOOR (SIN(2*PI*T*1M)+0.5))

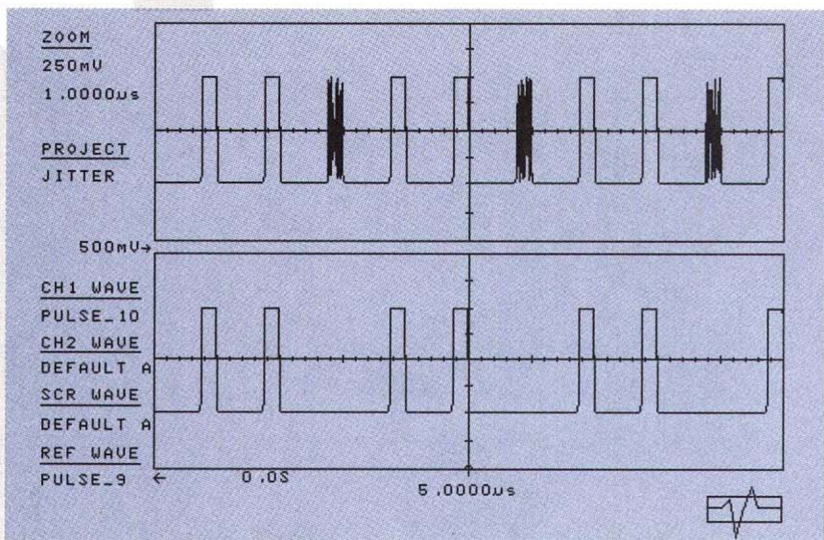


Figure 16. Modifying selected pulses within a pulse train

Generating Bit Jitter Tolerance Tests

Arbitrary waveform generators are ideal sources of pulse waveforms for testing self-clocked data communications and magnetic media storage systems. Unlike conventional pulse generators, selected pulses within a long pulse train can be modified to simulate a variety of conditions. Pulse amplitude, duration, transition time, or placement can be changed with great precision. The LW400 series AWGs, which include the ability to change waveform timing with 100 ps precision, are ideally suited for simulating bit jitter for testing clock recovery and data synchronizing circuits.

A static window truncation test for disk drives, which determines the limits of the timing synchronization window, is a typical test of this type. The test uses a simulated encoded read data stream consisting of a long synchronization field of about 200 bits, with a single, moveable bit at its end. The bit is initially located well outside the synchronization window and is gradually moved toward the nominal window center until it is reliably detected. The process is then repeated with the moveable bit starting on the opposite side of the window. Figure 17 shows part of the synchronization field, made up of 20 15-ns wide pulses with a 100 ns period, created using the standard pulse function in an LW420A dual channel AWG. This waveform, repeated 9 times, will have another waveform, with the moveable bit, linked to it.

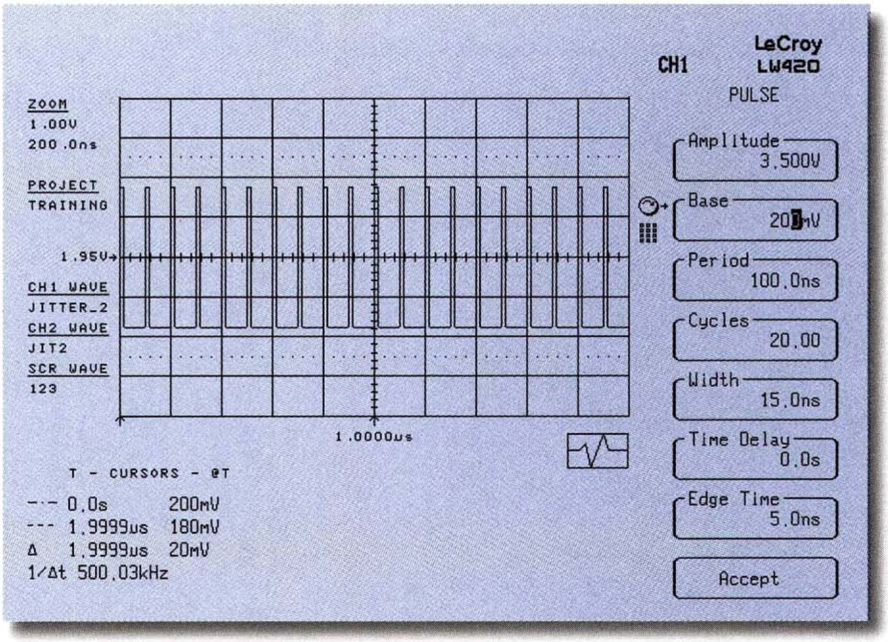


Figure 17.

The moveable bit is created at the end of a separate waveform which also contains 20 bits. The final bit in the waveform is moved in time by using the LW420's Move Feature capability which has 100 ps time placement resolution (see Figure 18). This pulse was advanced in time by 300 ps so that it is easier to see the displacement relative to the overlayed reference waveform. For this test, a series of these final waveforms, each containing a final bit with the displacement varied in 1ns steps, is created.

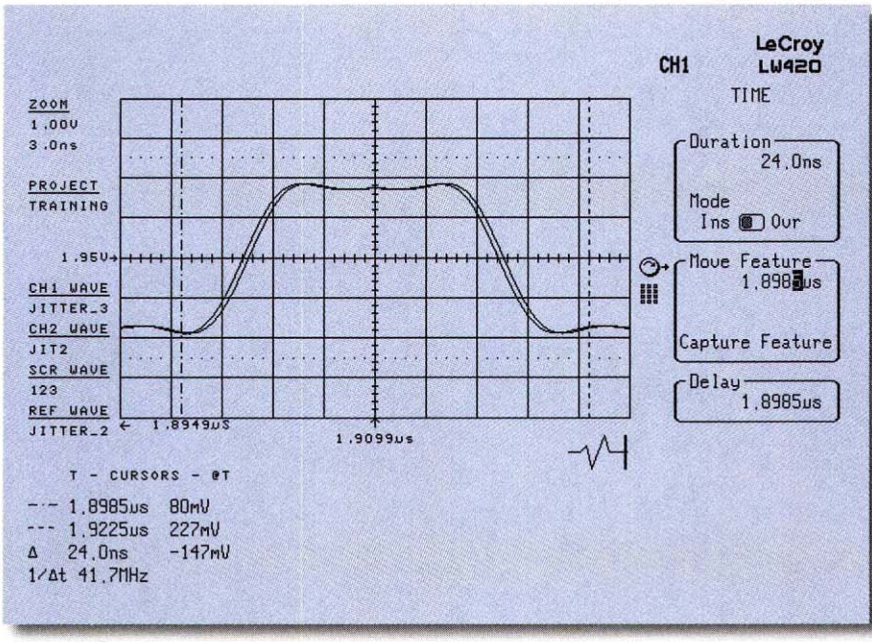


Figure 18.

All the waveforms are joined, or linked, into a sequence using the LW420's sequence editor shown in Figure 19. The compound waveform which is generated will have 199 uniformly spaced data pulses to allow for synchronization. 180 of these pulses are generated by repeating the waveform, JITTER_2, 9 times. The resulting waveform shown in Figure 20 contains 19 evenly spaced pulses plus the displaced pulse. Initially, the moveable bit, in the waveform JITTER_25, is advanced 25 ns. The cycle is repeated, with the advance decreased to 24 ns, and continues, with the moveable bit shifted in 1 ns steps, until the pulse is detected. At this point, an external GPIB controller, or a human operator, selects a second sequence which repeats the test for a delayed bit.

The oscilloscope display in Figure 20 shows a history of pulse positions for the early pulse displacements from 25 to 0 ns. The upper trace shows the moveable pulse relative to the neighboring fixed pulses. The lower trace is a horizontal expansion of the upper trace showing the uniformity of the time displacements over the 25 ns range.

The test described above used a 1 ns time displacement increment. The LW420A is capable of 100 ps displacements, as shown in the oscilloscope display of Figure 21. The lower trace, a highly expanded view of the moveable pulse, shows the pulse with 0.5, 1, 1.3, 1.4, and 1.5 ns displacements from the initial rightmost trace.

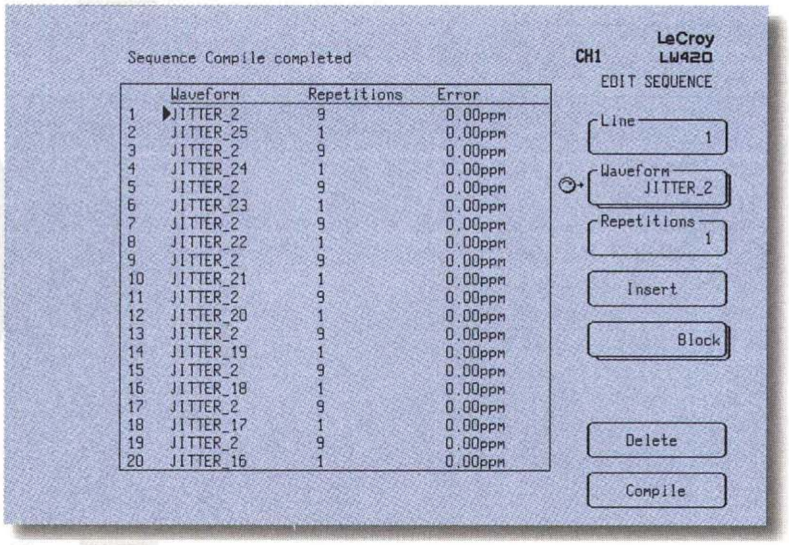


Figure 19.

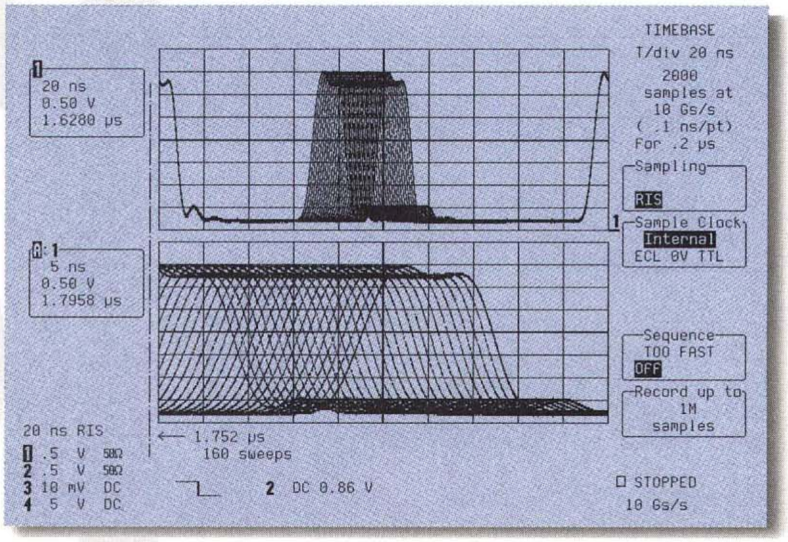


Figure 20.

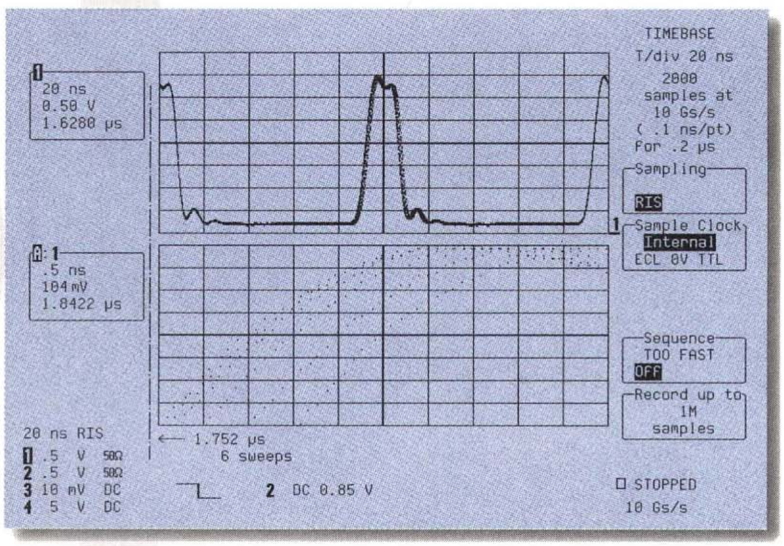


Figure 21.

Creating Jitter to Specification

The LeCroy LW400 series AWGs are ideal signal sources for worst case timing tests in digital communications and magnetic data storage systems. Data and timing signals can be generated with precisely controlled amounts of jitter. Signal timing can be controlled, with 100 ps timing resolution, using the LW400's waveform modification feature. Figure 22 shows a single pulse being moved within a pulse train. Individual control of waveform duration and delay are also available; each can be applied to entire waveforms or to selected portions of a waveform as shown here.

Jitter can also be described analytically using equations. Creating jitter in this way allows the user to specify jitter as a function of time. Figure 23 shows the equations which describe a 10 MHz pulse train in which each pulse is displaced linearly with time. Both the leading and trailing edges move synchronously with a maximum time shift of 1/6 of a cycle (16.6 ns).

The equations in Figure 23 show the basic technique for creating a pulse train with jitter. Phase-modulated sine and cosine waves are squared off using the step function and then multiplied to create periodic rectangular pulses. The phase modulation waveform, on line X1, controls the jitter waveform and magnitude. In this example, the waveform is a simple ramp which produces a linear phase shift of p/3 radian over a period of 10 msec.

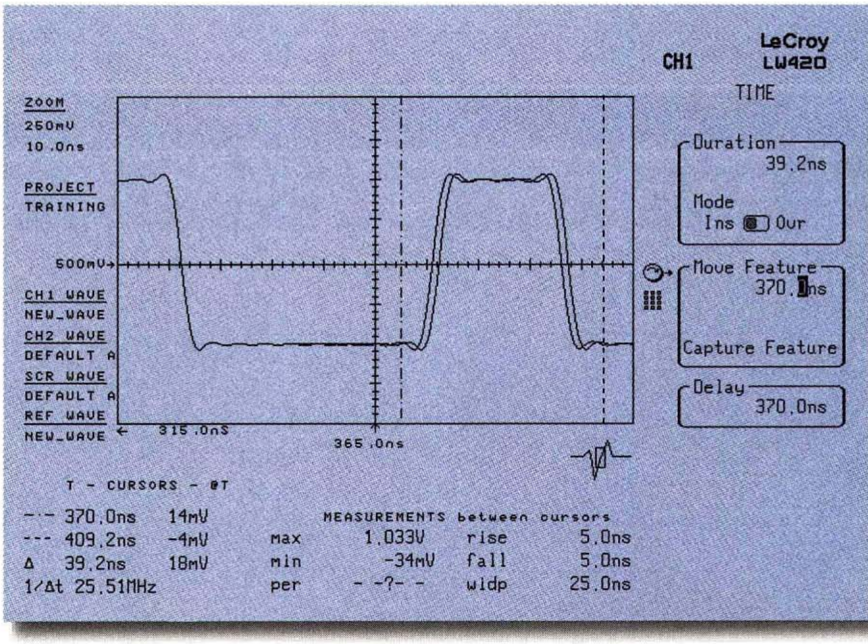


Figure 22. Modifying waveform timing using "Move Feature"

Figure 24 shows the measured output from the AWG as displayed on a LeCroy 9354 DSO. The persistence mode display shows a time history of several seconds, revealing the total range of pulse jitter.

Figure 25 shows an example of trailing edge jitter which is described by the equations in Figure 26.

Note that only the cosine controls the position of the trailing edge.

Edge placement for waveforms created using equations is limited to the AWG's minimum clock period of 2.5 ns.

Leading edge jitter is created in a similar fashion. As the equations in Figure 27 show, the sine wave, which determines where the leading edge occurs, is phase modulated. Figure 28 shows the measured leading edge jitter.

Creating pulses using this set of equations allows the jitter waveform and magnitude of the leading and trailing edges to be defined and controlled independently.

Figure 29 shows a simple version of this. By inverting the phase modulation of the cosine wave, edges move in opposing directions. The resultant pulse width jitter is shown in Figure 30.

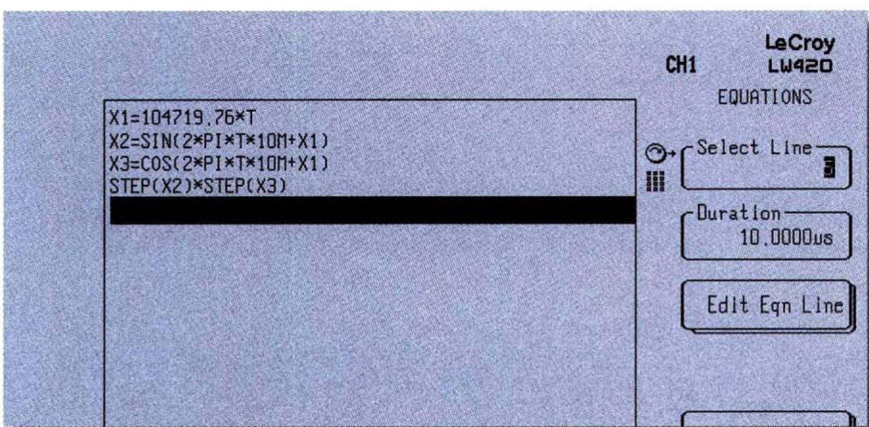


Figure 23. Equations for creating jitter

Any of the LW400's waveform functions can be used to control the jitter waveform. In this example, a simple linear ramp was used, but sinusoidal, exponential, logarithmic and random (NOISE or GNOISE) functions can be used to describe the variation of pulse edge position as a function of time. Using the LW400 series AWGs, jitter creation is under the total control of the user, from live, interactive waveform manipulation to precise analytic descriptions.

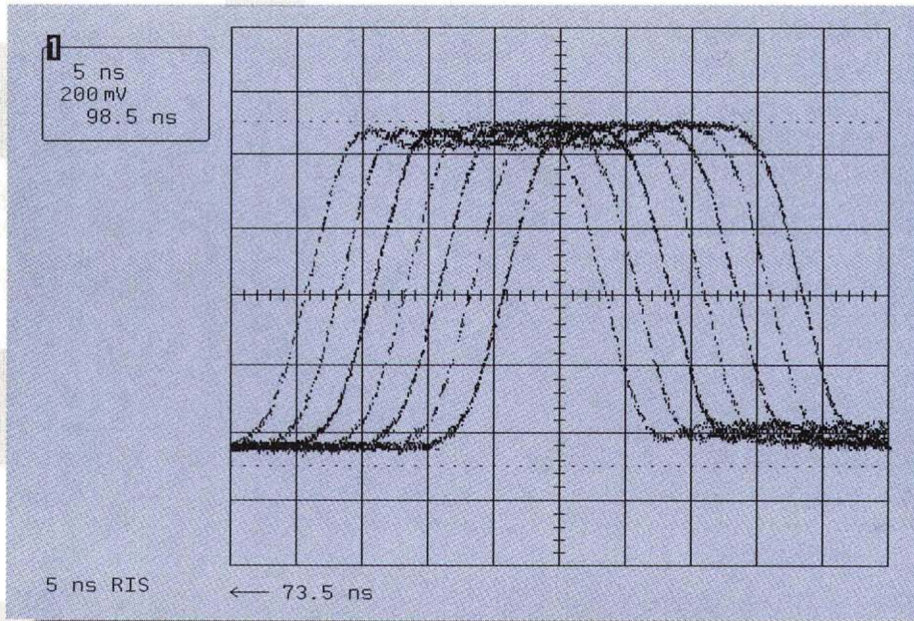


Figure 24. Persistence display showing jitter range

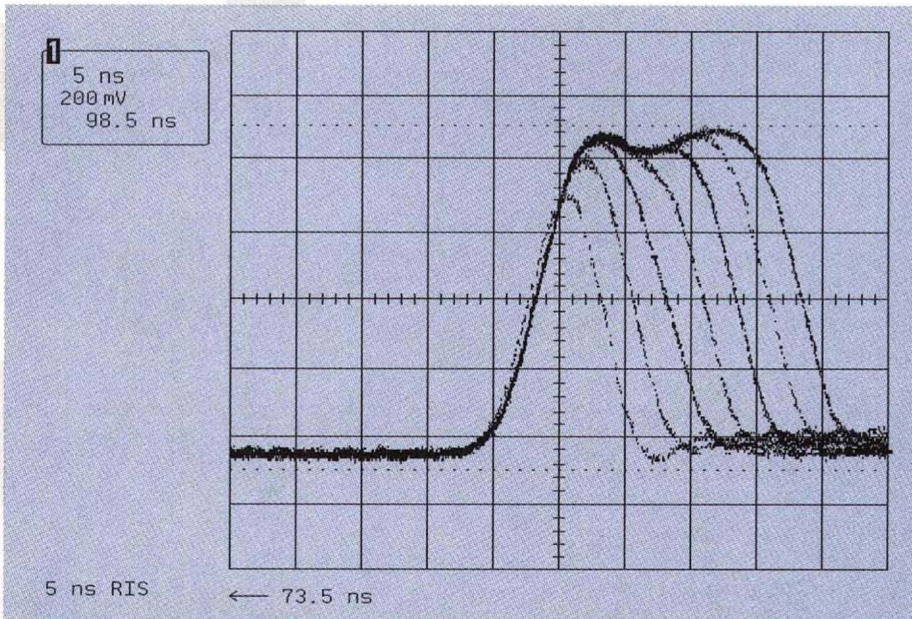


Figure 25. Trailing edge jitter

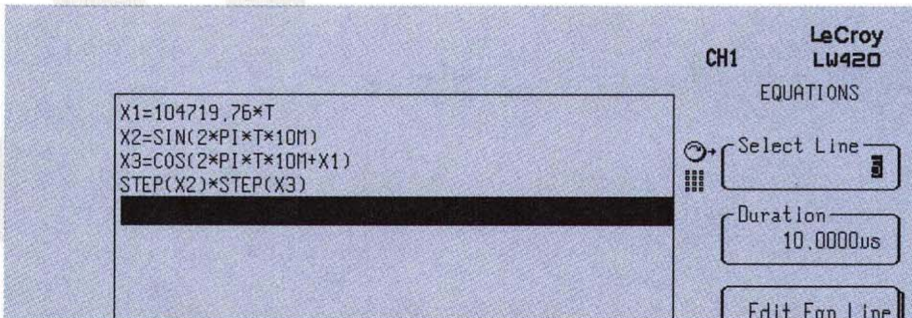


Figure 26. Equations for trailing edge jitter

TUTORIALS

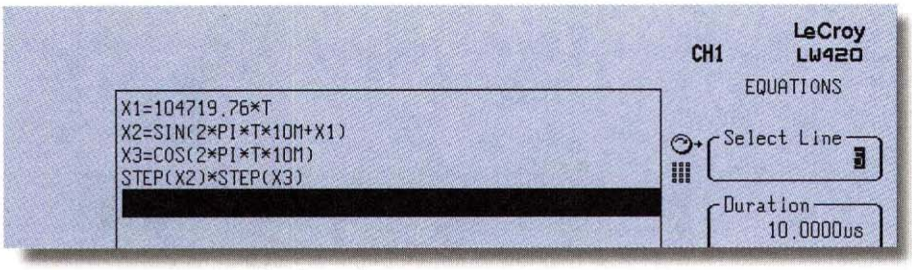


Figure 27. Equations for leading edge jitter

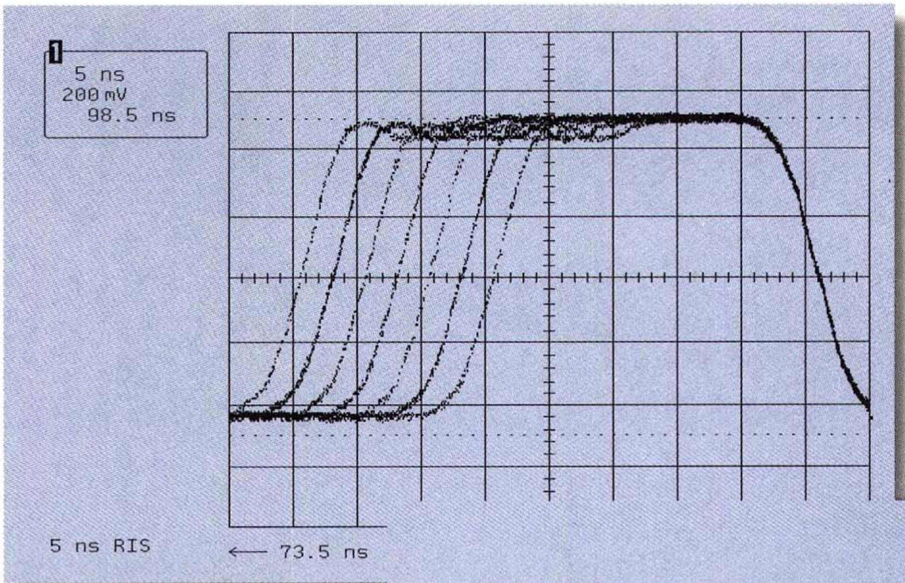


Figure 28. Leading edge jitter

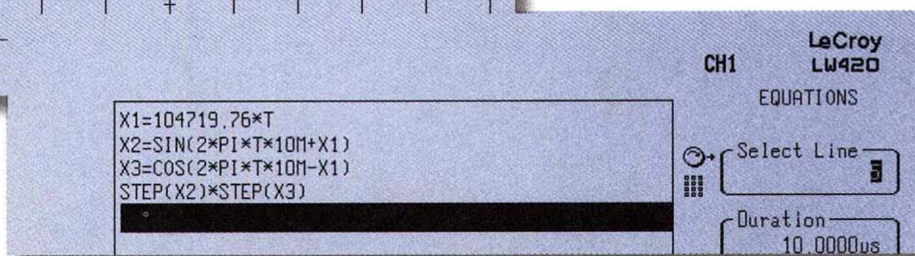


Figure 29. Equations for opposing edge jitter

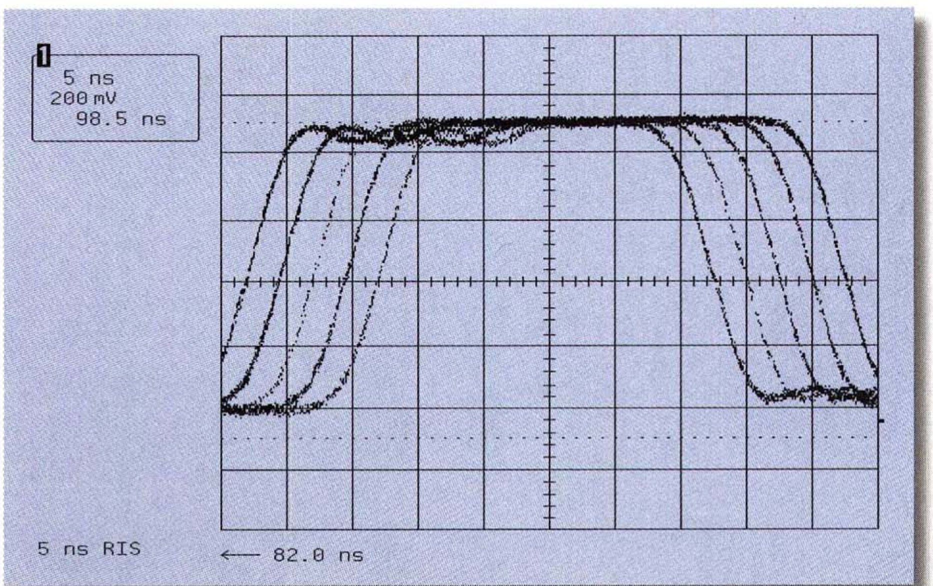
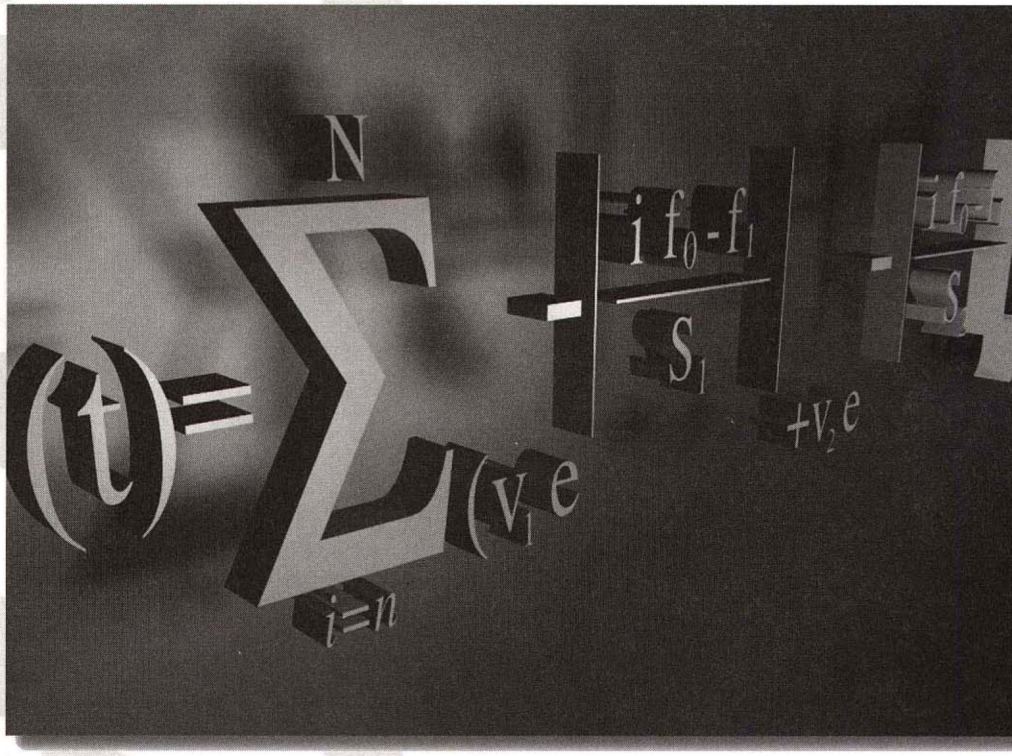


Figure 30. Edges moving in opposite directions

LW400 Equation Notebook

Equations offer the most precise method of creating a waveform in the LW400 series AWGs. This notebook is intended to provide examples of commonly used waveforms and the equations which describe them. It also provides examples of waveform creation techniques which can be applied more generally.



The WaveStation equation editor includes 11 mathematical functions and 9 operators, which are described briefly below. A more thorough discussion of each can be found in the LW400 operator's manual:

FUNCTIONS

ABS ( )	-Absolute Value: calculates the absolute value, unipolar magnitude, of a function or argument
COS ( )	-Cosine: calculates the cosine of the argument
EXP ( )	-Exponential: calculates an exponential, using the base of natural logarithms, e, raised to the power specified in the argument
FLOOR ( )	-Floor: calculates the integer floor of a function
LN ( )	-Natural Logarithm: calculates the natural logarithm, base e, of the argument or function
LOG ( )	-Common Logarithm: calculates the common logarithm, base 10, of the argument or function
PULSE ( )	-Pulse: creates a pulse using edge locations, or functions, specified in the argument
SIN ( )	-Sine: calculates the sine of the argument
SQRT ( )	-Square Root: calculates the square root of the argument or function
STEP ( )	-Step Function: creates a unit step at the location specified by the argument or function
TAN ( )	-Tangent: calculates the tangent of the argument

OPERATORS

+	- Addition
-	- Subtraction
*	- Multiplication
/	- Division
(	- Mathematical grouping
)	- Mathematical grouping
'	- comment
=	- equality
^	- Raise to a power (exponentiation)

VARIABLES

The variables X1 - X16 can be used to label the contents of any line on the equation editor. The variable can then be used to replace the contents in another equation.

Example:
X1 = SIN(2*PI*10E6*T)
X2 = (1+ 0.75 * COS(2*PI*1E3*T))
X1*X2

The product X1*X2 will be computed as follows:
X1*X2 = SIN(2*PI*10E6*T) * (1+ 0.75 * COS(2*PI*1E3*T))

ARGUMENTS

There are five functional arguments available for use in equations:

2*PI*T	Phase variable for trigonometric functions, in radian seconds
T	Time variable, in seconds
PI	Numerical Constant 3.14159265358979
NOISE	Uniformly distributed random numbers 0-1, mean = 0.5 standard deviation = 0.288
GNOISE	Gaussian distributed random numbers 0-1, mean = 0.5 standard deviation = 0.1667

CONSTANTS

Numerical constants can be entered from the keypad on the front panel. Use the units multiplier entry keys, p(pico, 1E-12), n (nano, 1E-9), u (micro, 1E-6), m (milli, 1E-3), ENTER (units, 1), k (kilo, 1E3), M (Mega, 1E6) to specify the correct multiplier. For example 7.5 M = 7.5 E6 and 2n = 2 E-9

EQUATION FILES

Equations can be created offline in a text editor and imported as equation files, specified by the file extension, .EQN. Consult the operators manual for specific information on the format of equation files.

WAVE MATH

Equations are used in the creation of waveforms from an analytical description. Wave Math is a waveform array processor which operates on entire waveforms, regardless of their source. The operations available in wave math include:

- Smoothing
- Waveform Addition
- Waveform Subtraction
- Waveform Multiplication
- Waveform Division
- Integration
- Differentiation
- Convolution

These operations are available in addition to equation entry but are unique in that they operate on entire waveform. Wave Math operations are covered in a separate publication.

LeCroy WaveStation LW420A

Importing and Transferring Software Generated Communications Waveforms.

Introduction

Waveforms used in communications are often generated with software programs such as Mathcad and Mathlab or with specialized simulation software such as PSPICE, IQSIM, and TOPSIM. Importing waveforms for generation with LeCroy's LW420A High Speed two channel AWG is easy, and the LW420A provides high quality, phase synchronized signals for evaluating communications systems. With a sample clock range of 6 kHz to 400 MHz, precise phase control and single point resolution the LW420A is highly effective in generating communications signals. The internal, asynchronous, wide band noise generator with 2^{22} states is summed into the output and is useful in providing controlled signal to noise ratio.

DCS1800 Cellular Standard Simulation Example

Create a simulated signal with your favorite software and save the I signal to a file and the Q signal to a second file as ASCII text (example: DCS1800.I and DCS1800.Q).

DCS1800 File Contents

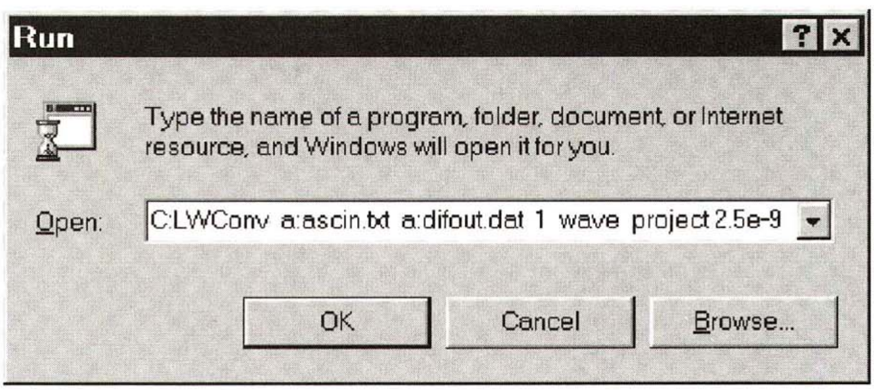
Two ASCII files—one for the I signal and one for the Q signal—must contain the values corresponding to the amplitude of the signal at increments of the sample interval. These files are imported into the LW420 or can be converted to the standard Data Interchange Format (DIF) for transfer over the GPIB.

File Contents

-.5413376
-.5946198
-.6737949
-.7661268
-.8571002
-.9330237
-.9830337
-.9999856
-.9803423
-.9235429
:
etc.

Convert to DIF for Transfer over GPIB with LeCroy's Shareware converter

LeCroy's shareware program converts text files to DIF format so you can quickly get your waveforms into the LW420A. You can then transfer the waveform over the GPIB direct to the LW420A. Run the program LWConv with the options: input file, output file, # of header lines to skip, LW wavename, LW project name, and sample interval. Then select okay and the DIF file is created.



Once the DIF file is created you can transfer your waveform directly over the GPIB to the LW420A.

Import the simulated signal into the LW420A from a floppy disk

1) Insert the floppy disk that contains the I and Q signals into the floppy drive.
2) Select Clock Control menu by pressing the **red 2nd** key and the Time key (**Clock in red** over key).
3) Set the following conditions on the Clock control menu—see Figure 1;
   a) **Optimize Clock** to **No**
   b) **Auto Clock** Set to **No**
   c) **Limit Clock** to **Internal Filter Ranges** to **No**
4) Set **Clock Rate** to the Bit Rate x Over sampling used in your simulation.
5) In this example the clock rate is set to the Bit Rate 270.833kH x 8 over sampling = 2.166664 MHz.
6) Press **Project** key then **Import** soft key.
7) Press **What** soft key and select **Spreadsheet** as the format.
8) Press the **Import As** soft key and name the waveform.
9) Example: When importing the "I signal" name it DCS1800I.
10) Press **Import** soft key. A message will appear requesting time base information. Press the **Use Current** soft key since the clock rate that determines the sample rate was set in step 3—see figure 2.
11) The LW420 will prompt you to insert another disk. If the complete waveform fits on one floppy as it does in this example then press the no soft key and the waveform is imported and available for use.
12) Repeat 1-11 for the Q signal.
13) The internal noise generator can be used to add wide band noise into the output of each channel for control of the signal-to-noise ratio.

Figure 1

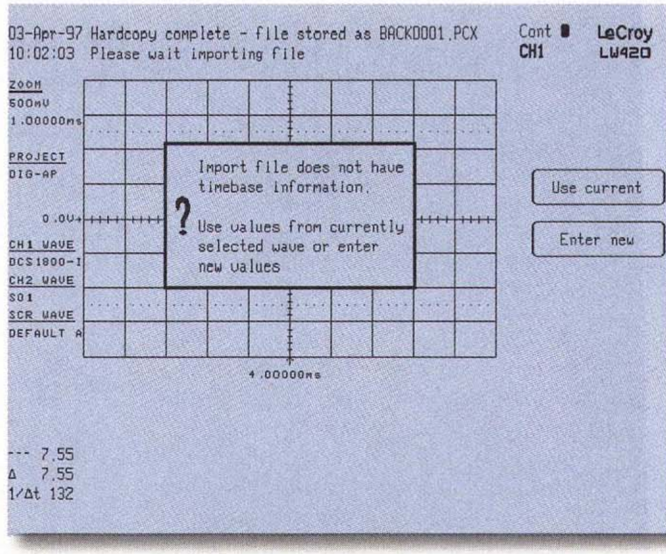


Figure 2

LeCroy LW420A Waveform Displayed on LeCroy LC Series DSO

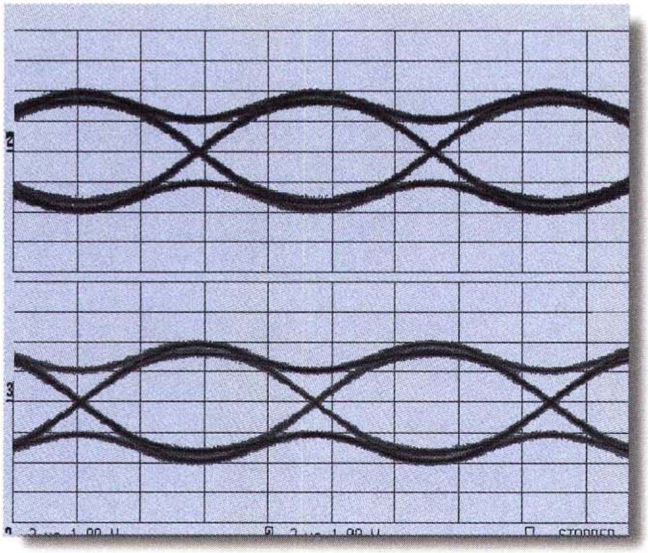


Figure 3—Eye Diagram of I and Q with triggering on the 270.833 kHz bit clock. The clock is obtained from the LW420A marker clock output.

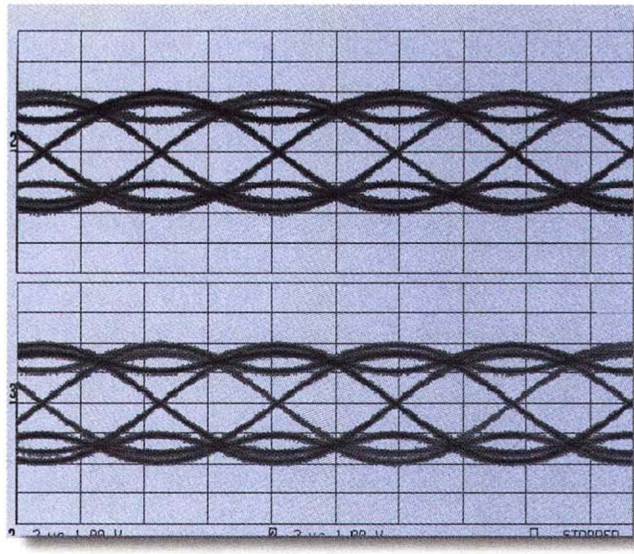


Figure 4—Eye Diagrams of I & Q Signals using Analog Persistence and triggering on the I signal. This shows the proper phase relationship.

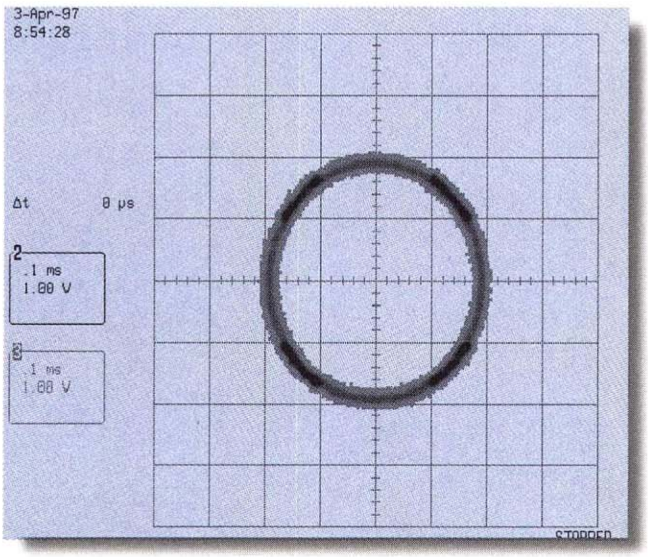


Figure 5— Phase trajectory displayed in X-Y mode with analog persistence on. The brightest points indicate the most frequently occurring events.

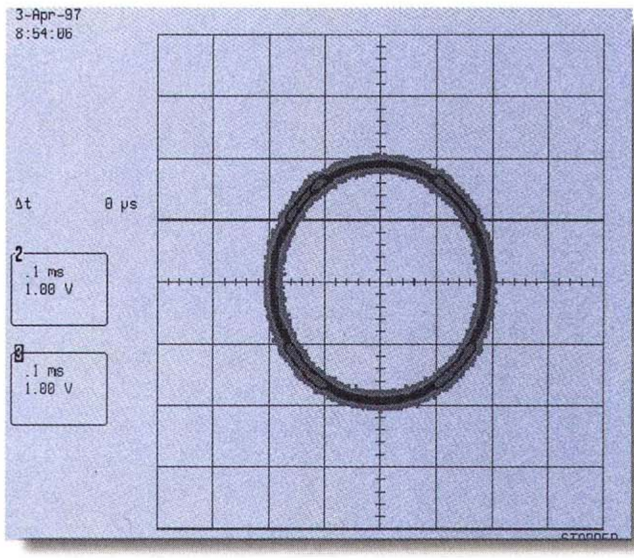


Figure 6—Same as Figure 7 using color graded persistence. The hottest color, red, indicates the most frequently occurring events.

Making More Accurate Jitter Measurements

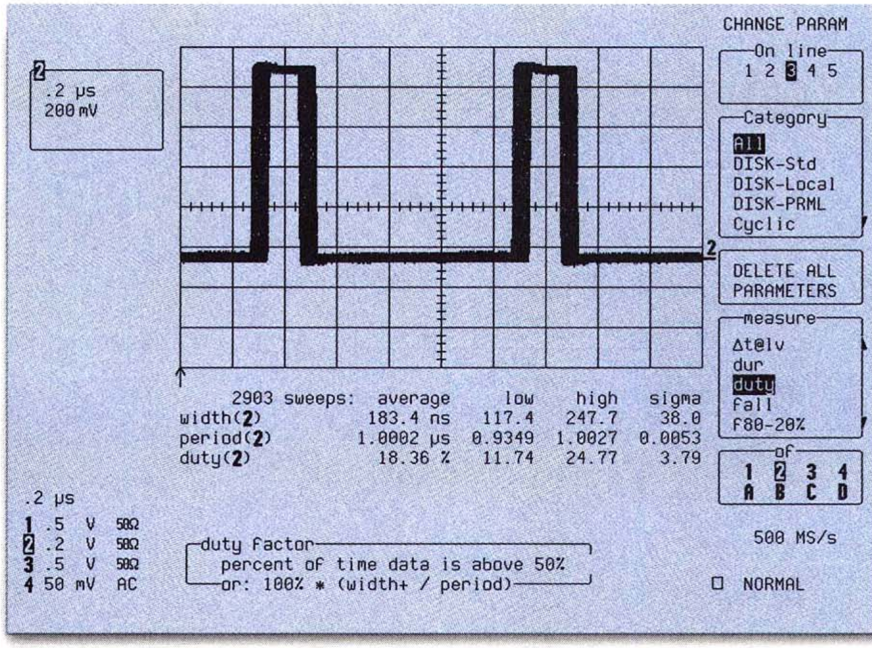


Figure 1. Direct readout of mean, low/high range, and standard deviation of width, period, and duty cycle measured over 2900 sweeps as shown in a persistence display.

A variety of new techniques are available to make more accurate timing measurements. Applications include analyzing the timing characteristics of a single signal (such as locating clock jitter anomalies) or characterizing the timing jitter between multiple signals (such as I and Q in wireless data transmissions). This paper will discuss the use of wide-bandwidth digital oscilloscopes incorporating histograms and trending plots in making precise timing measurements, their application to specific design problems, the use of statistical analysis to determine product specifications and sources of error in jitter measurements. Using advanced techniques, timing changes as small as one picosecond can be observed.

Direct Readout of Jitter Using Histograms or Parameters

Jitter measurements are among the most common applications for digital oscilloscopes. With an extensive range of automatic measurement parameters, it is easy to measure the key timing parameters such as width, period, and duty cycle. Some digital oscilloscopes offer statistical analysis of these parameters over multiple acquisitions, providing direct readout of the mean, lowest and highest value, and standard deviation (sigma) of up to 5 measurement parameters as shown in Figure 1.

The standard deviation provides direct readout of the rms jitter for that parameter. The difference between the lowest and highest value is the peak-to-peak jitter. For example, in Figure 1, the width has an rms jitter of 38 ns and a peak to peak jitter of 130 ns.

Some digital oscilloscopes offer the ability to read out the maximum and minimum values of parameters but only use data from the first pulse captured each time the scope triggers. This can cause the loss of important data and even lead to incorrect conclusions. Oscilloscopes with sufficient processing capability can measure an unlimited number of values of a parameter on each single-shot trigger. Parameter measurement statistics provide direct reading jitter characterization. A parameter analysis package extends this capability, providing histogramming, trending and statistical parameters to automatically interpret the histogram data. Histograms provide a visual display of the statistical distribution of the measured parameters. The trending function draws a line graph that shows the time evolution of parameter values. Using the four traces available in a DSO, it is possible to display up to 4 histograms or trend lines.

Knowledge of the distribution of random processes like jitter is often of critical importance in understanding the source. An example is shown in Figure 2 where the width jitter of a waveform is histogrammed.

Note that in addition to the histogram display, the sigma and range of the distribution are being readout as parameters. In this case, the jitter is uniformly distrib-

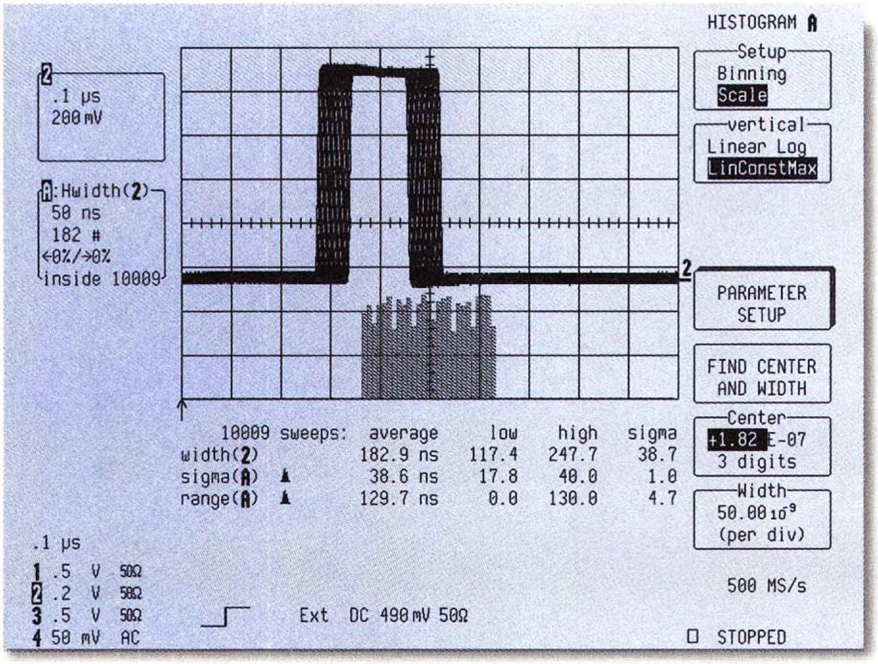


Figure 2. The histogram of the width parameter for 10,000 sweeps and direct readout of rms jitter, sigma (A), and peak-to-peak jitter, range (A).

uted (i.e. any of the width deviations within the range are equally probable). Figure 3 shows the analysis of width jitter in which the jitter has a Gaussian distribution.

The uniform distribution is often associated with synchronization operations. The input waveform to a synchronizer selects the next available internal clock pulse. If the input and internal clocks are independent, then the delay between the input and the clock is distributed uniformly over a clock period.

The Gaussian distribution is associated with random noise which, in Figure 3, is associated with the phase noise in a reference oscillator.

When making a precision jitter measurement, it is useful to know the sources of jitter inherent in the oscilloscope. These include trigger jitter, timebase stability, and delay jitter. In high-performance digital oscilloscopes, jitter due to the DSO is in the range of tens of ps. This number can be minimized by using 0 delay, using a trigger signal with a high signal-to-noise ratio, and maximizing the measured waveform dynamic range by operating close to the full scale range of the selected Volt/Div setting. Since the jitter internal to the DSO (or other measuring instrument) is generally uncorrelated with the device under test, the instrument jitter can be subtracted from the total jitter using quadrature subtraction:

$$t_{DUT} = (t_{meas}^{2} - t_{instr}^{2})^{1/2}$$

Where:

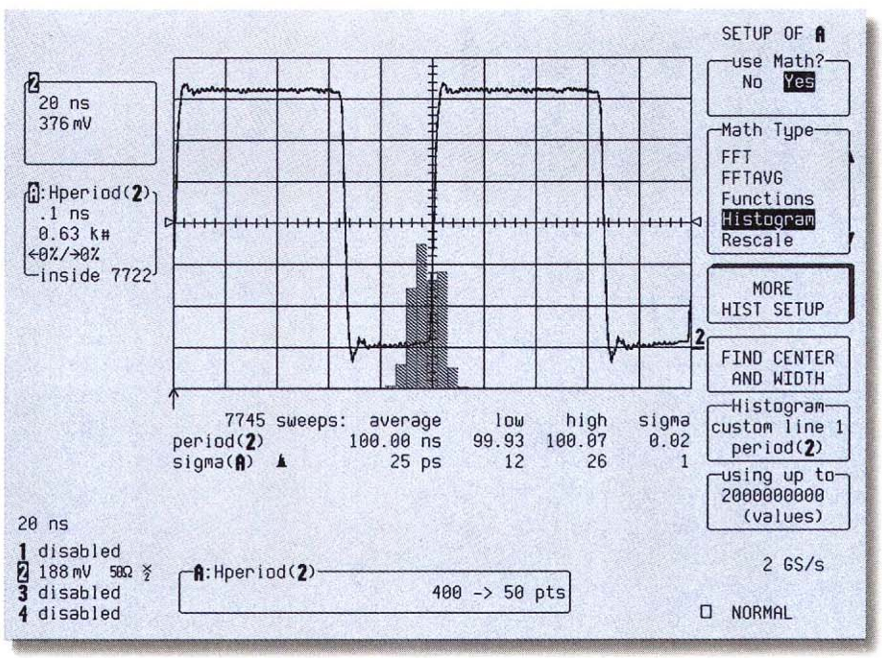
t_{DUT} - jitter of device under test

t_{meas} - total measured jitter

t_{instr} - jitter due to instrument

The jitter due to instrumentation should be measured under the specific conditions of the test being performed. This will be discussed in the next section.

Figure 3. The histogram of width and direct readout of rms width jitter, sigma (A) and peak-to-peak jitter, range (A).



Setup - Verifying the Accuracy of Timing Jitter Tests

Demonstrating the Accuracy of Time Parameter Histograms

Oscilloscopes equipped with parameter analysis capabilities can characterize time interval measurements with picosecond resolution in histogram displays. This usually brings up questions concerning the accuracy of these measurements. The following experiment demonstrates the inherent accuracy of measuring short (<1 us) time intervals using the random interleaved sampling (RIS) acquisition mode. It also serves as a model to setup real world measurements.

In this demonstration, the propagation delay of a length of coaxial cable is measured using a fast (32 ps) edge as the driving source. The oscilloscope is triggered externally using the trigger output of the edge generator. The cable delay, for a 2-meter RG 58C/U cable, is approximately 9 ns. The oscilloscope is set to a sweep speed of 5 ns/div with a RIS sampling rate of 10 GS/s. The time delay between the Channel 1 and Channel 2 waveforms was measured using the delta delay (Δdly) (1,2) parameter. The cable delay is constant and any variation in the delay is due to the oscilloscope. This experiment allows testing of the accuracy of the measurement system. In a real example, two signals of interest would be connected to the inputs of the DSO, and the timing jitter between them could then be analyzed.

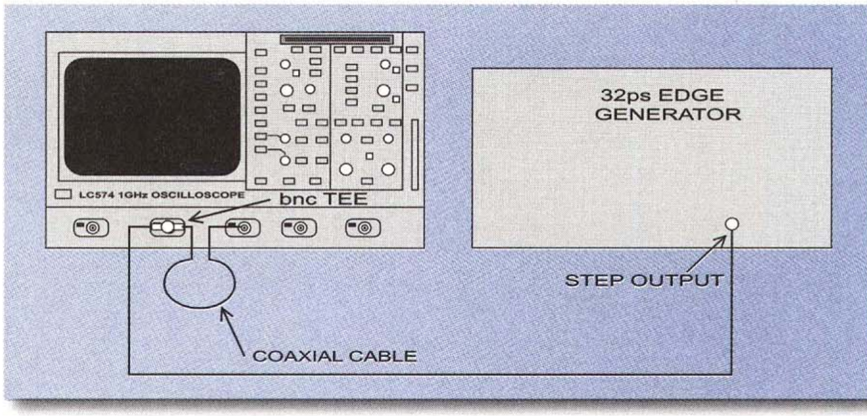


Figure 4. A test setup for measuring propagation delay through a coaxial cable. Since the delay of the passive cable is fixed, the variations in measured value are primarily due to the oscilloscope.

In RIS mode, many acquisitions are made, and the time between the trigger and the first sample is measured using a time-to-digital converter (TDC) which has a 10 ps resolution. Since the trigger and sampling clock are generally not synchronous, there is a random distribution of time offsets. The oscilloscope places selected samples into appropriate 100 ps wide bins to achieve the 10 GS/s effective sampling rate (20 times the single-shot rate of 500 MS/s). The accuracy of this process is dominated by the TDC interpolator accuracy. Other error sources, such as slew rate error in the delay measurement, are minimized by using a signal with a fast transition time. Similarly, the acquisitions are triggered simultaneously using the common, external trigger source to eliminate trigger jitter as an error source. And finally, the timebase accuracy, 10 ppm, has little or no effect contributing much less than 1 ps of error.

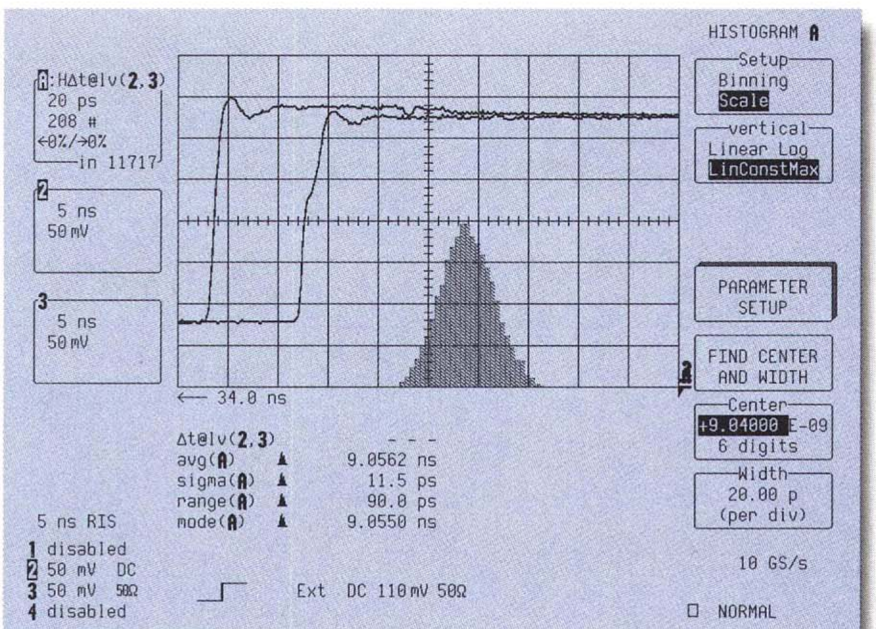


Figure 5. Histogram of the delay between Ch 2 and Ch 3 with the statistical analysis displaying the average value, standard deviation (sigma), and range.

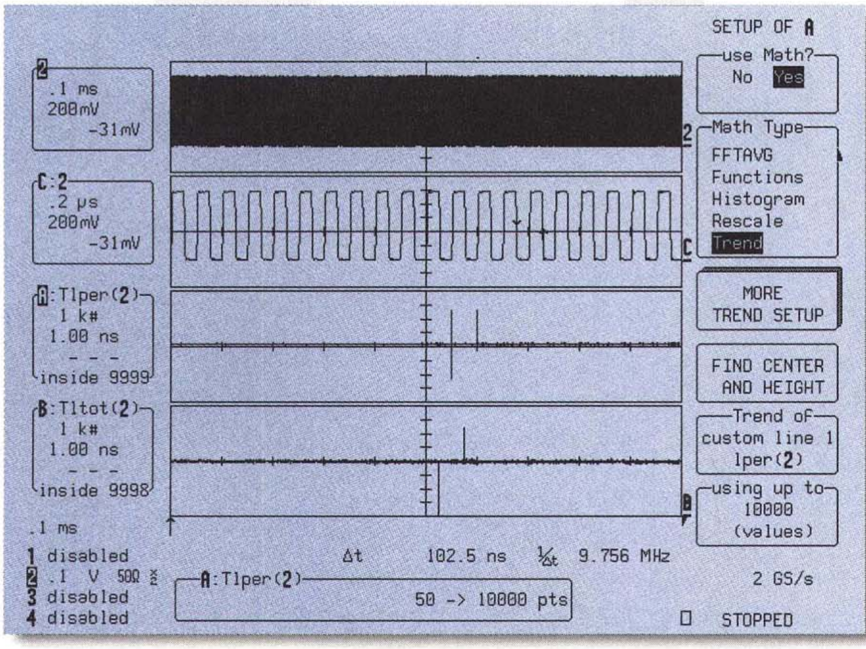


Figure 6. Trend graphs of local (cycle-to-cycle) period and local time over threshold (cycle-by-cycle width) locate variations in clock signal timing over 10,000 clock cycles.

Figure 5 shows the result of the measurement. The upper trace shows the input to Channel 2; the middle trace shows the delayed signal as seen in Channel 3; and the lower trace contains the histogram of over 10,000 acquisitions and delay measurements. The basic delay parameter and three additional statistical parameters appear in the table below the trace display. The statistical parameters read the mean (average), standard deviation (sigma), and range of the histogrammed delay measurements. Note that the standard deviation, which corresponds to the rms error, is 11.5 ps. This is less than the specification limit of the interpolator (TDC) rms accuracy of 20 ps. Keep in mind that this is the accuracy of any single measurement made with this oscilloscope. If n measurements are made and averaged, then the accuracy improves by $\sqrt{n}$, which is why measurement parameter readouts are better than 1 ps resolution.

Using this method an oscilloscope, with parameter analysis capabilities can provide timing accuracy of 11.5 ps for each individual measurement of the time between two signal edges. However use of statistical analysis allows a change in average timing between the two signals to be measured to 1 ps or better.

Locating Clock Jitter Anomalies

Using Histogram and Trend Plots in a Single Signal to Locate Period and Width Violations

Trend graphs plot a series of up to 20,000 measured parameter values and display them on the oscilloscope screen. When combined with the local (cycle-to-cycle) parameters, these plots are ideal for locating timing anomalies in large blocks of acquired clock signals.

The upper trace in Figure 6 contains 10,000 cycles of a 10 MHz clock waveform. Trend graphs of local period (lper) and local time over threshold (ltot) are shown in Trace A and Trace B. Trace A, the third trace from the top, shows a

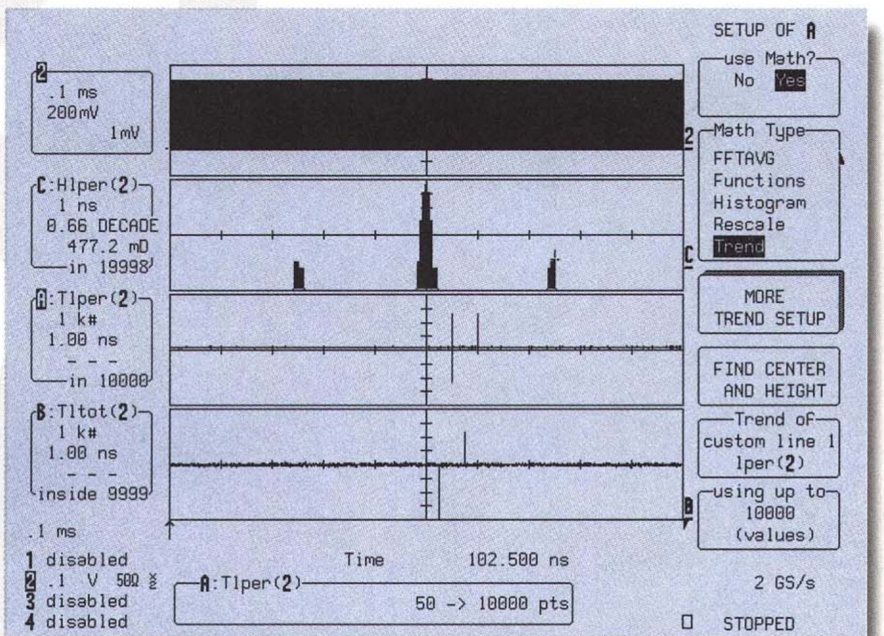


Figure 7. Histogram of local period shows the distribution of cycle-by-cycle period measurements.

flat trend with the exception of several spikes. Each spike represents a variation in the period of a single cycle of the clock waveform. The deviation can be read using the vertical axis scaling of 1 ns/div. The horizontal (event) axis of the trend plot has a one-to-one correspondence with each cycle in the acquired trace. By using a zoom expansion of the acquired trace centered around the region corresponding to a spike in the trend plot, we can view the period anomaly. This is shown in Trace C where the long period (102.5 ns instead of the nominal 100 ns) is marked by the relative time cursors arrows. Similarly, the bottom trace (Trace B) shows the location of each cycle which has a width which differs from the nominal value.

In Figure 7, Trace C has been redefined as the histogram of local period. The histogram displays the distribution of up to 2,000,000,000

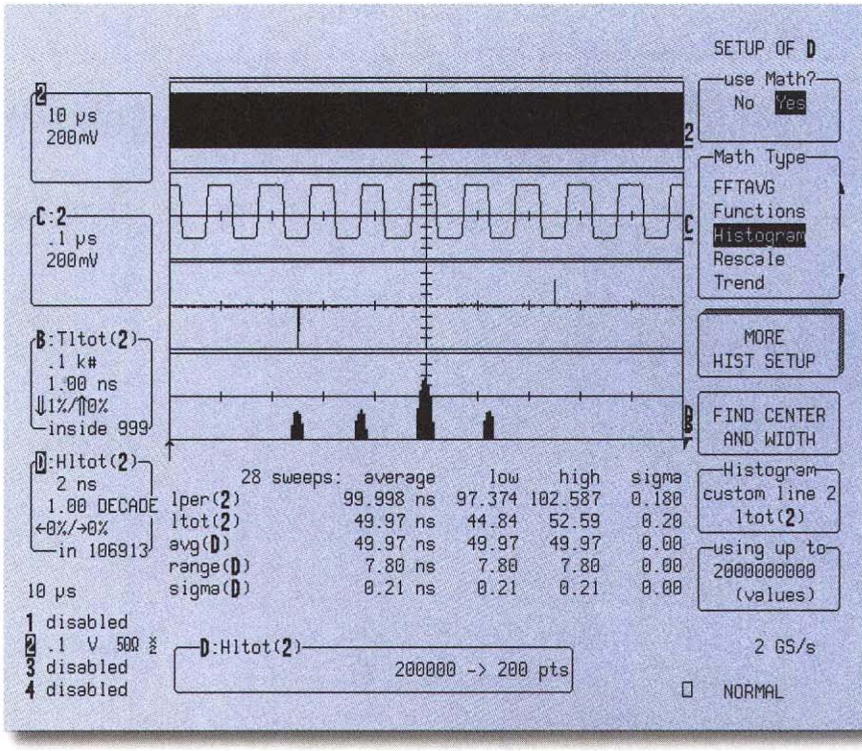
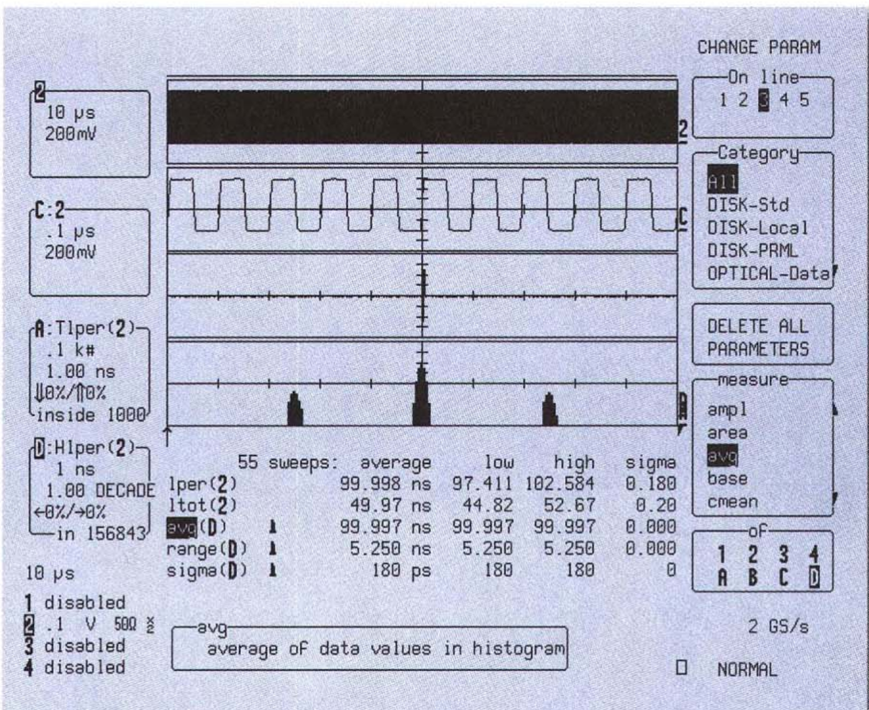


Figure 8. Parameter statistics and statistical parameters completely characterize waveforms and histograms.

Figure 9. Analysis of the trend and histogram of local period.



measured parameter values. In this example, it is showing the distribution of cycle-to-cycle period. The vertical scale is a logarithmic display of the number of measurements of each value. The center of the horizontal axis represents a period of 100 ns. The horizontal scaling is 1 ns/div. The small distribution to the right occurs about 102.5 ns.

The histogram and the trend displays are complementary. The histogram shows the number and distribution of parameter values, while the trend shows its location in the acquired data.

The interpretation of waveforms and histograms is aided by the use of measurement parameters.
In Figure 8, the parameter readouts show the average, low, high, and standard deviation of the local period and local time over thresh-

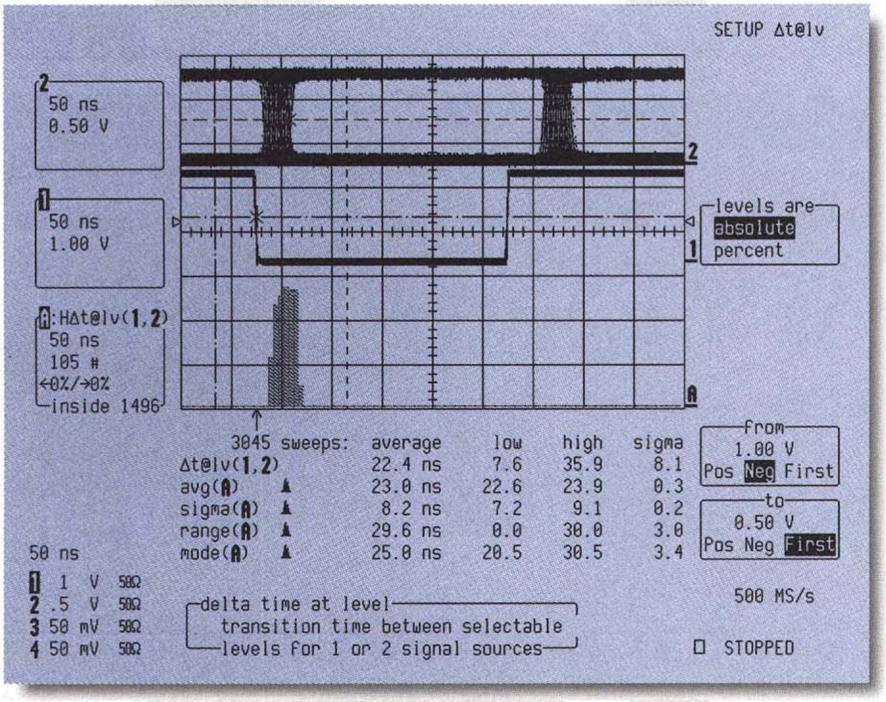


Figure 10. Histogram of relative timing jitter between clock and data waveforms. Data waveform is shown in traditional "Eye" diagram format. The histogram shows the distribution of jitter across the leading edge of the eye.

old measurements. This is an example of parameter statistics. The lower three parameters read the average, range, and standard deviation of the histogram of local time over threshold (width). These values correspond to the mean width, the peak-to-peak width jitter, and the rms width jitter in the acquired waveform. Figure 9 shows the same type of analysis applied to the local period measurement.

Trends and histogramming analysis of any of the 40 standard or 60+ application-specific measurement parameters are available in high-performance oscilloscopes.

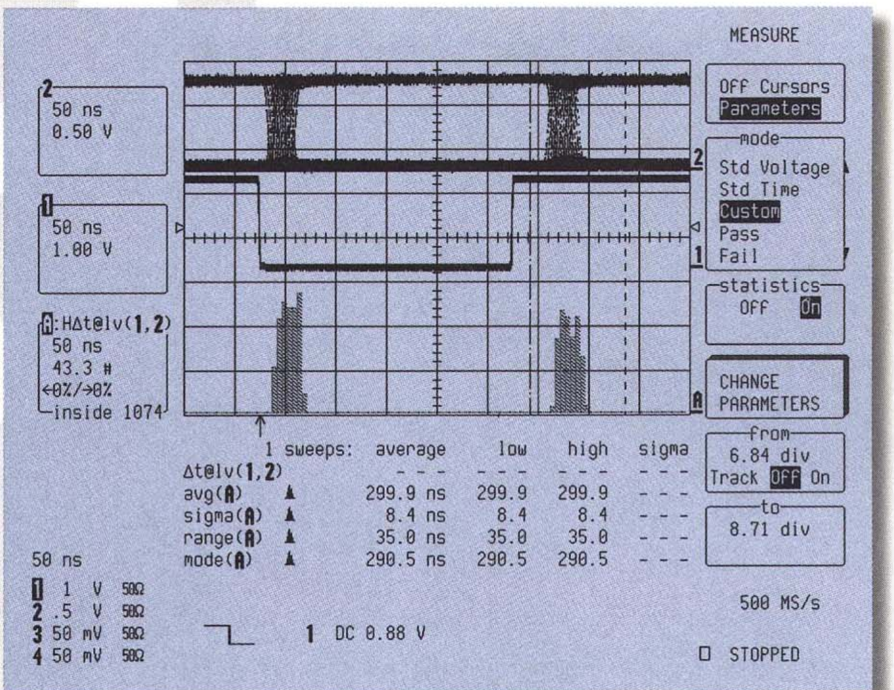
Relative Jitter Measurements

Using Histograms to Characterize Relative Timing Jitter between Multiple Signals such as Clock and Data

Relative timing jitter between multiple signals, such as clock and data waveforms, has traditionally been measured using "Eye" diagrams. These persistence displays provide good qualitative information about both timing and signal-to-noise ratio.

High-performance oscilloscopes augment the eye diagram with statistical analysis of waveform parameters. Histogramming delay, Δ delay, or Δ time @ level provide a quantitative analysis of relative timing between two waveforms. In Figure 10, the leading edge jitter of the data waveform (Trace 2), shown in a traditional eye diagram, is measured relative to the clock (Trace 1) using the Δ

Figure 11. Measuring the trailing edge jitter. After acquiring the histogram, use the parameter cursors to limit analysis to the trailing edge.



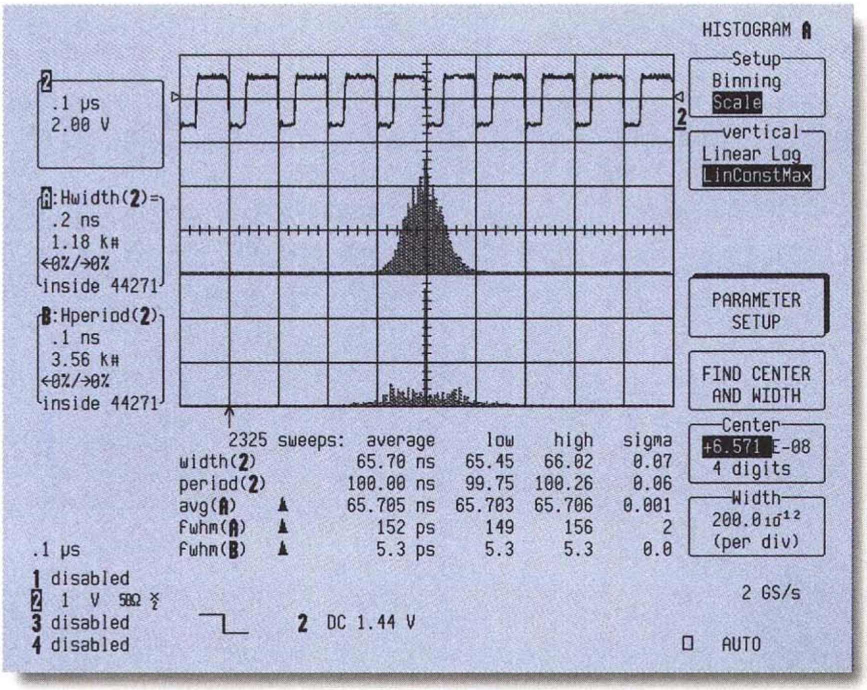


Figure 12. Histogram of the width and period of a clock waveform show different distributions of time jitter.

time @ level parameter. This parameter provides independent settings of the threshold level, shown as dashed horizontal lines, for each waveform as well as user selection of the desired edge slope. The top line of the parameter readout field shows the average, low, high, and sigma of this parameter for 3045 sweeps.

The lower trace is a histogram of the Δ time @ level parameter. The horizontal range has been selected to match the Time/Div setting for the data waveform. This allows a visual analysis of the number of occurrences of each edge delay value. Additional statistical parameters, including average, sigma, range, and mode, provide a quantitative readout of the distribution of the delay values shown in the histogram.

Note that parameter cursors (the dashed vertical lines in Figure 10) select the region being analyzed in all displays. In this example, the analysis is confined to the leading edge of the eye diagram. Since the histogram parameters are also being computed, the histogram must also be within the parameter cursors.

The trailing edge of the data waveform can also be analyzed in a similar manner, as shown in Figure 11.

In Figure 11, the histogram was generated using the entire width of the "eye." The acquisition was stopped, and the parameter cursors used to select only the trailing edge. The statistical parameters analyze only the region within the cursor limits, providing a detailed analysis of the trailing edge.

Histograms accept up to 2,000,000,000 measured values with a resolution of up to 2000 bins. There are a total 18 statistical parameters available to help analyze histograms. In this example, the standard deviation of the histogram yields the rms jitter, while the range provides the peak-to-peak jitter. Average value and mode (most commonly occurring value) are also displayed.

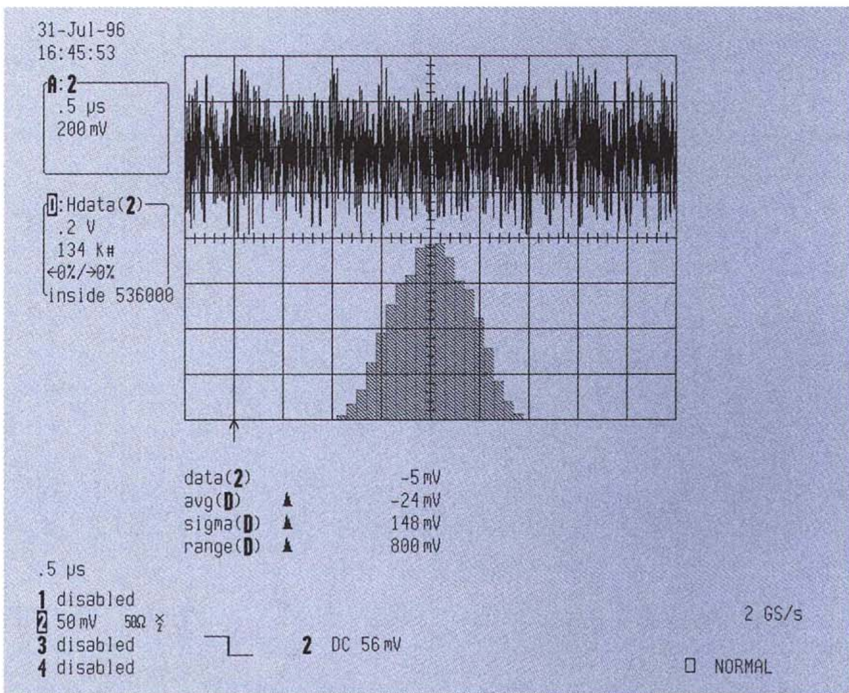


Figure 13. The Gaussian distribution found in the amplitude values of a random noise generator.

Jitter Measurements

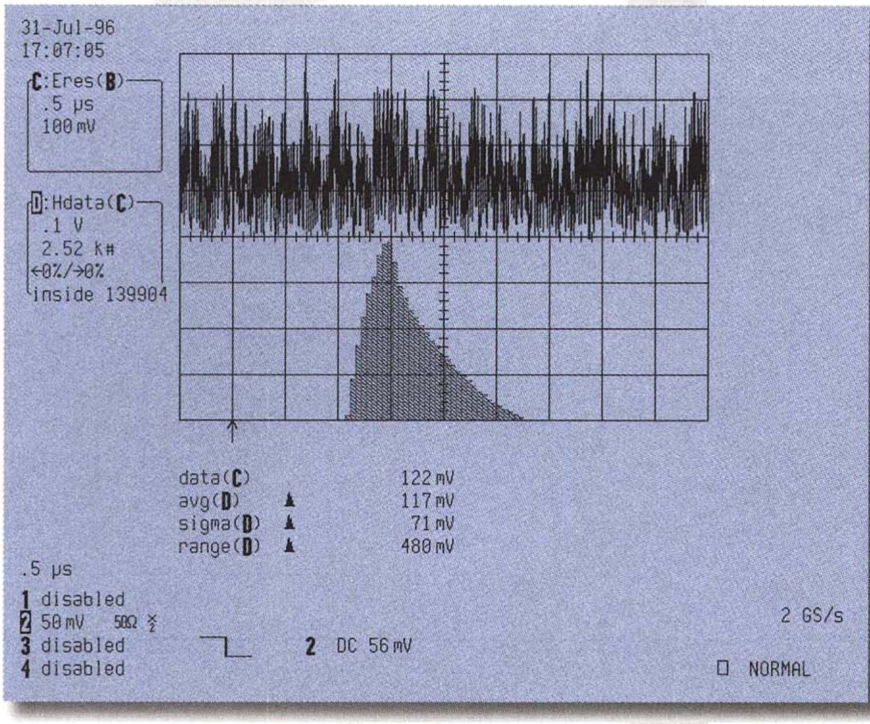


Figure 14. The effect of passing Gaussian noise through an envelope detector.

Using Statistical Analysis to Characterize Random Events

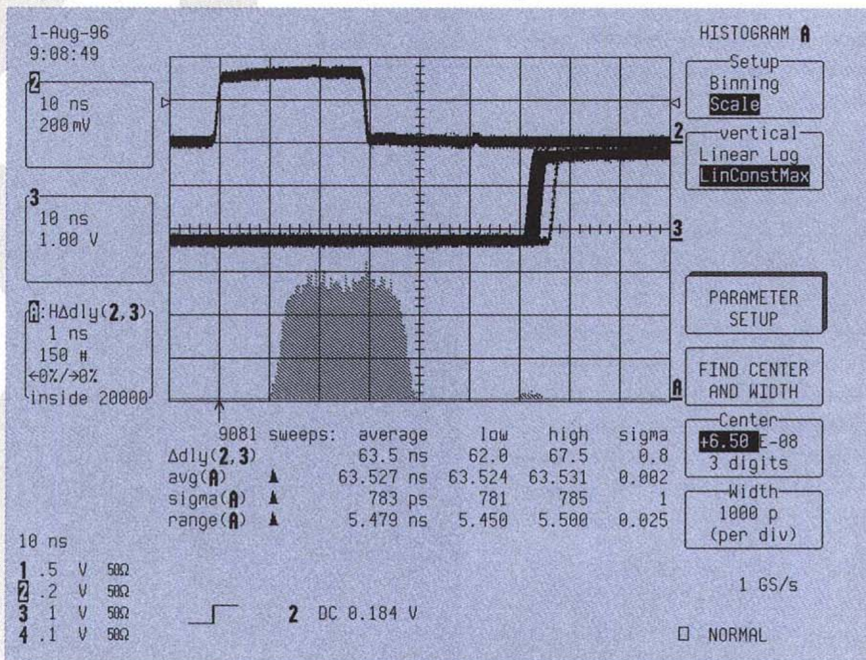
Electronic measurements produce data that contains both systematic and random variations. For example, the width and period of a clock pulse can be viewed as having a nominal value accompanied by a random variation which we call jitter. Statistical analysis allows engineers to study and characterize these random processes thereby gaining insight as to their causes. A parameter analysis option in a digital oscilloscope offers engineers an ideal tool for visualizing and quantifying random processes as shown in Figure 12. The histogram display shows the shape of the distribution of parameter values and statistical parameters provide accurate and concise measurements of that distribution.

The distribution of measurement values is related to the underlying process which generates the distribution. Figure 13 is an example of a random process than produces a Gaussian or normal distribution of amplitude values. The Gaussian distribution is a good indication that a random process is shaping variations in the measurement.

Consider what happens when a Gaussian distributed noise signal is applied to an envelope detector as shown in Figure 14. Here the process involves half-wave rectification and filtering (simulated in the scope using waveform math), and the distribution of amplitude values changes to a Rayleigh distribution. The amplitude values are no longer symmetric about the mean value (the effect of rectification). Knowledge of these effects allows calculation of expected noise power related to the input noise levels. Conversely, if the process were unknown, measurement of the input and output distributions would help identify it.

Let's look at another distribution. The uniform distribution of delay shown in Figure 15 is characteristic of normal operation in a timing synchronizer. This circuit synchro-

Figure 15. The uniform distribution of delay in timing synchronizer.



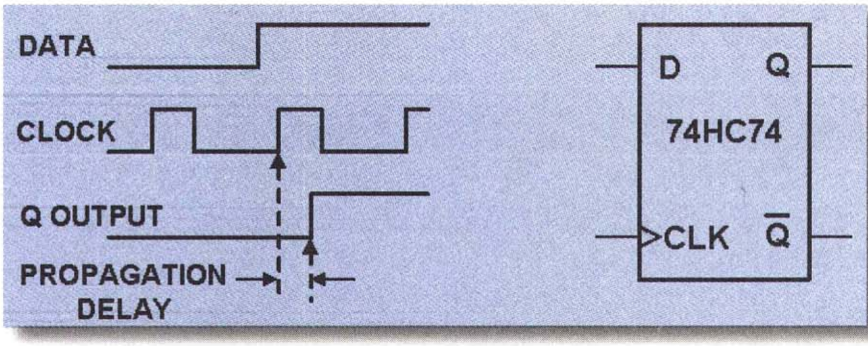


Figure 16. The propagation delay of a flip-flop is a typical specification that can be characterized by statistical analysis.

nizes a random trigger event with an internal 400 MHz clock (2.5 ns period). If the input signal is independent of the system clock then there is an equal probability of having any value of delay between the input and output over the range of 1 clock period. In this example, observe that the primary distribution of the measured delay varies uniformly over a range of 2.5 ns as expected, but occasionally a longer delay occurs. This highlights an advantage of the statistical study of measured data in that it quantifies rarely occurring events which might be otherwise missed.

The upper trace (A) in Figure 17 is the clock. The middle trace (D) is the Q output, and the lower trace (B) is the histogram of the delay between positive going edges of the clock and the Q output. The histogram shows the distribution of over 1100 individual measurements. The statistical parameters average (avg[C]) and range (range[C]), listed in the parameter readout field below the display, provide a quantitative measure of the histogram. This data can now be stored into memory M1 for later comparison and the experiment repeated at 0°C.

The results of the next set of measurements is shown in Figure 18. Trace C, to the right in the lower trace, contains the data taken previously at 25°C which was stored in memory M1. Trace B, overlaid on Trace C and to the left in the lower trace, shows that the propagation delay has shifted to a lower value. The average value (mean) has shifted from 41.448 ns to 40.417 ns as indicated in the statistical parameter readings. In addition, the shape of the distribution has narrowed indicating a reduction in the spread of the measurements as shown in the

Using Statistical Analysis to Determine Product Specifications

Oscilloscopes are ideal instruments for measuring the electrical characteristics, such as risetimes, setup/hold time, and propagation delay of electronic devices. Oscilloscopes with a parameter analysis option can perform statistical analysis on up to 2,000,000,000 measurements and display this data as a histogram.

Statistical parameters, extend the analysis capability, offering accurate readouts of up to 18 key statistical measurements such as mean, standard deviation, range, and many others.

Figure 17. A histogram showing the distribution of over 1100 measurements of the propagation delay of a 74HC74 at 25 0C.

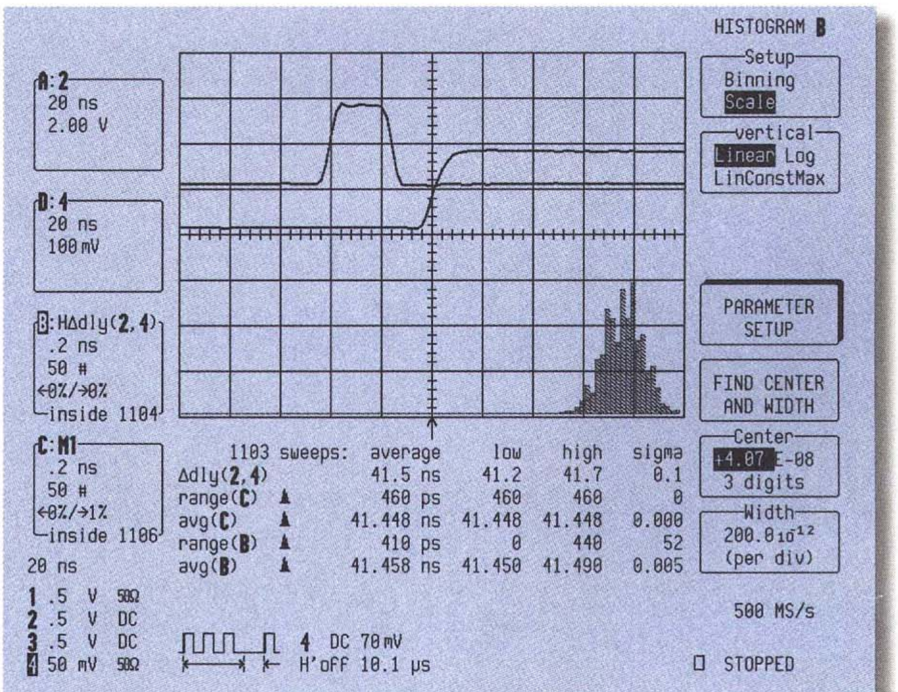
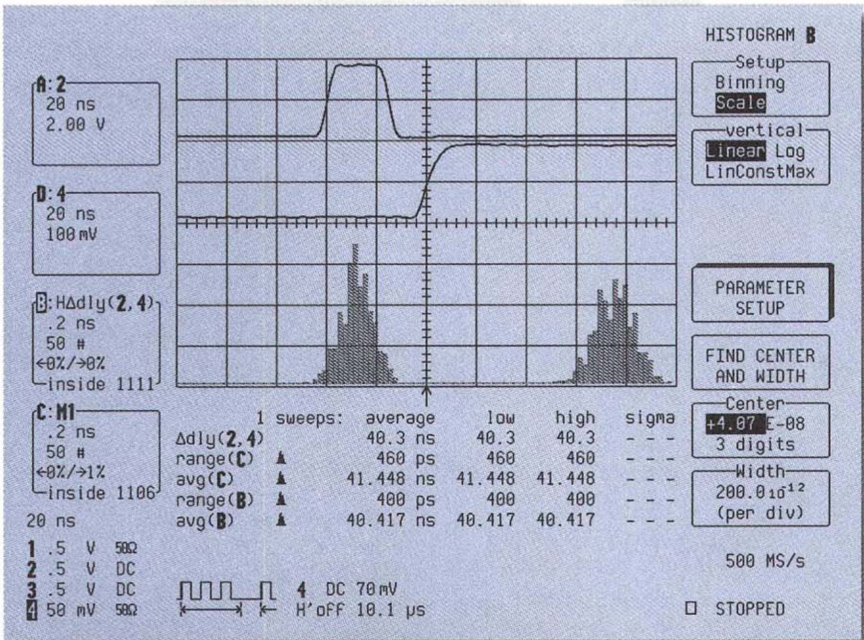


Figure 18. Comparing the propagation delay at 0˚C (at the left in lower trace) and at 25˚C (to the right in the lower trace).



Statistical Parameters for Characterization of Product Specifications	
avg	average of data values in histogram
fwhm	full width (of largest peak) @ half of maximum bin
fwxx	full width (of largest peak) @ xx% of maximum bin
hampl	histogram amplitude between two largest peaks
hbase	histogram base or leftmost of two largest peaks
high	highest data value in histogram
hmedian	median data value in histogram
hrms	rms value of data in histogram
htop	histogram top or rightmost of two largest peaks
low	lowest data value in histogram
maxp	population of most populated bin in histogram
mode	data value of most populated bin in histogram
pctl	value where specified % of population is smaller
pks	number of peaks in histogram
range	difference between highest and lowest data values
sigma	standard deviation of the data values in histogram
totp	total population in histogram
xapk	x -axis position of specified largest peak

range parameter change from 460 ns to 400 ns. These represent only two of the possible choices for analysis parameter readout. The complete list of available statistical parameters is shown in the accompanying table below.

This is a simple example of how histograms can be used to characterize component or unit specifications under selected conditions. It is extremely useful in applications where the manufacturer has not characterized the device in exactly the way required by your application. Note also the ability to display and compare data taken at different times and under different conditions. This total integration of measurement, display, and analysis is a hallmark of LeCroy oscilloscopes.

Statistical Analysis as a Diagnostic Tool

Diagnosing circuit problems requires a fair amount of skill and good measurement tools. In most cases, the more ways you can look at a problem, the easier it is to solve. Parameter analysis provides an alternative view of the data and gives the diagnostician additional perspective. Consider the problem of detecting and diagnosing crossover distortion in a push-pull amplifier stage shown in Figure 19.

Distortion, especially at low levels, is difficult to see in a conventional oscilloscope time display. Figure 20 is an example of a waveform with crossover distortion. The distortion, although significant, is barely visible and could easily be missed.

Modern oscilloscopes offer additional processing such as the Fast Fourier Transform (FFT) to help detect problems like distortion. The FFT is a great asset in determining the existence of distortion, as shown in Figure 21, but it cannot differentiate between the various sources of distortion.

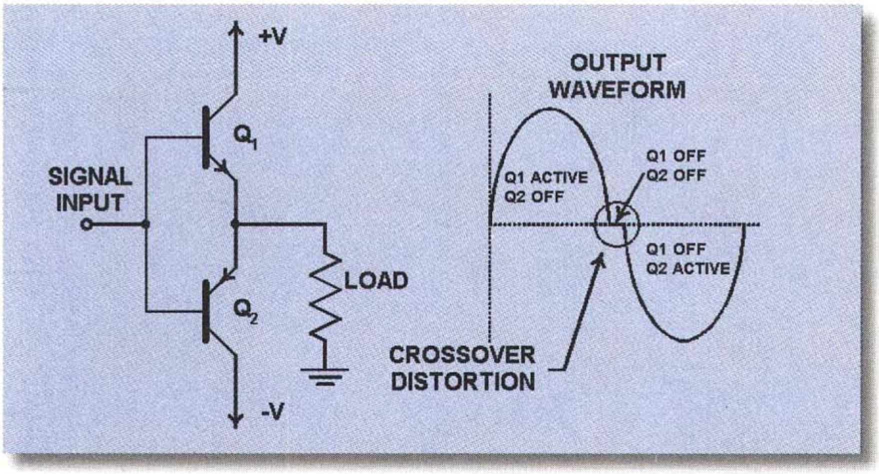


Figure 19.A simplified view of a push-pull amplifier showing the source of crossover distortion.

Clipping, asymmetries, limiting, and crossover all produce similar frequency domain spectra. The high harmonic content, in this case approximately -40 dB below the fundamental, is the key indication of the distortion that is present in the waveform.

The histogram of the amplitude data values, added to the waveform and FFT in Figure 22, provides the missing information about the nature of the distortion. The histogram is calculated by dividing the amplitude range of the oscilloscope into from 20 to 2000 bins (100 bins are used in this example). The number of samples which fall into each of these bins is plotted on the vertical axis, against the nominal voltage value of the bin on the horizontal axis. The histogram of data values shows the number of samples in the waveform within each small voltage range. Note that instead of the usual "saddle shaped" histogram of a sine wave, we observe a higher than normal population of sample values at the center which represents zero volts. The waveform is hesitating at the zero crossing, a sure sign of crossover distortion. Clipping and limiting would be manifested as a higher population at the maximum and/or minimum peaks. Distortion due to asymmetry would be visible as an asymmetric histogram.

The ability to view the signal in three different domains (time, frequency, and statistical) provides a powerful tool for anyone having to diagnose complex circuit problems.

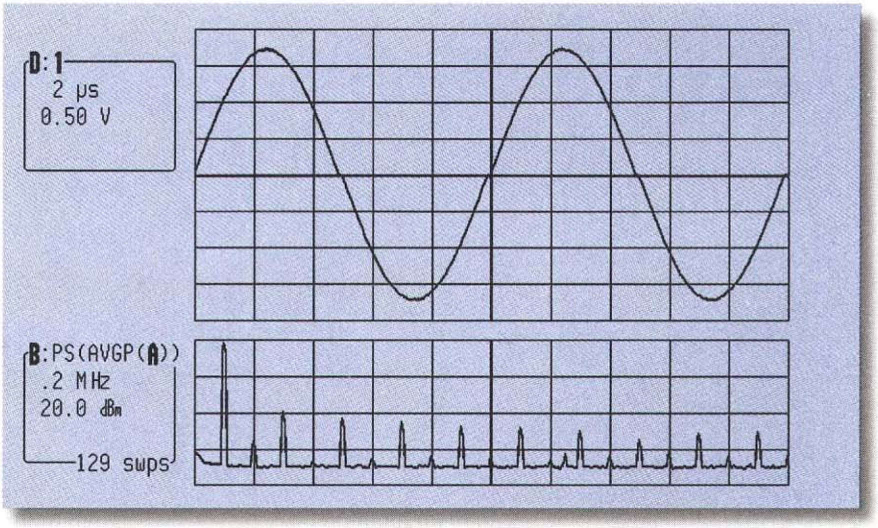


Figure 21. The FFT shows high harmonic content due to distortion but provides no clues to its source.

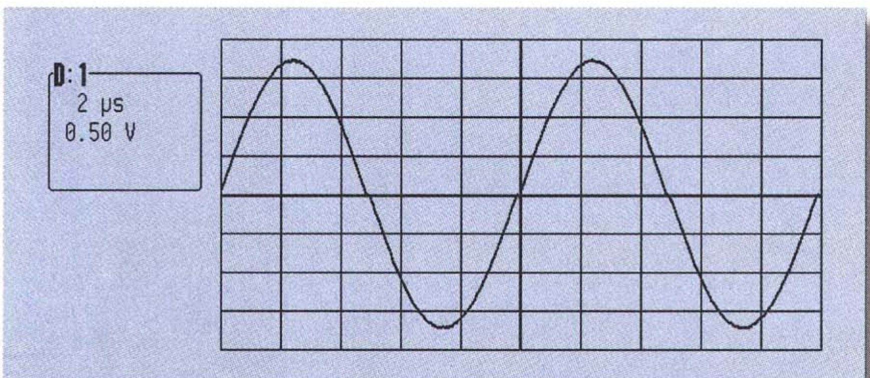


Figure 20.A time domain waveform with crossover distortion.

Viewing Waveforms Related to Specific Histogram Data

Statistical analysis using histograms is a powerful technique for looking at and processing large amounts of data. For more detailed analysis, it is sometimes necessary to try to recover the source waveforms corresponding to an individual measurement appearing in the histogram.

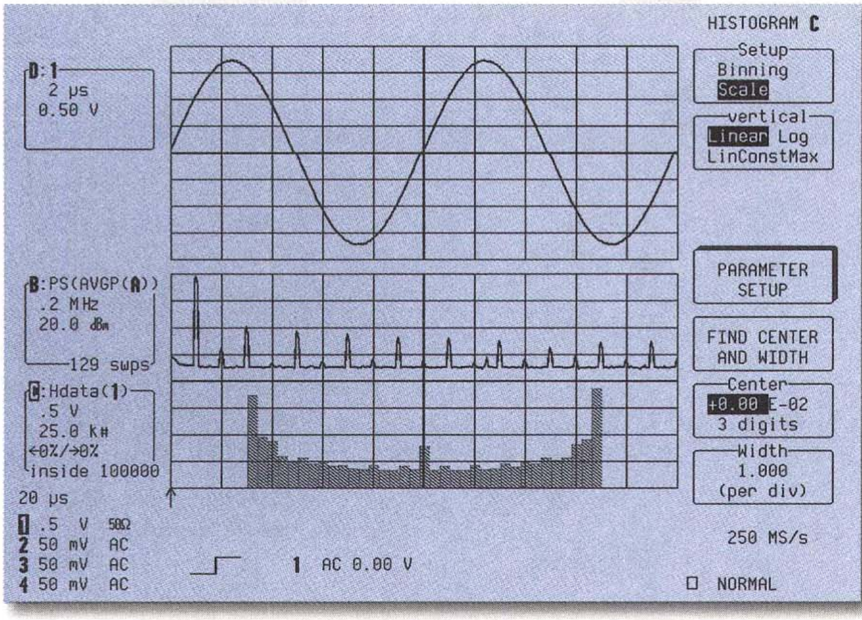
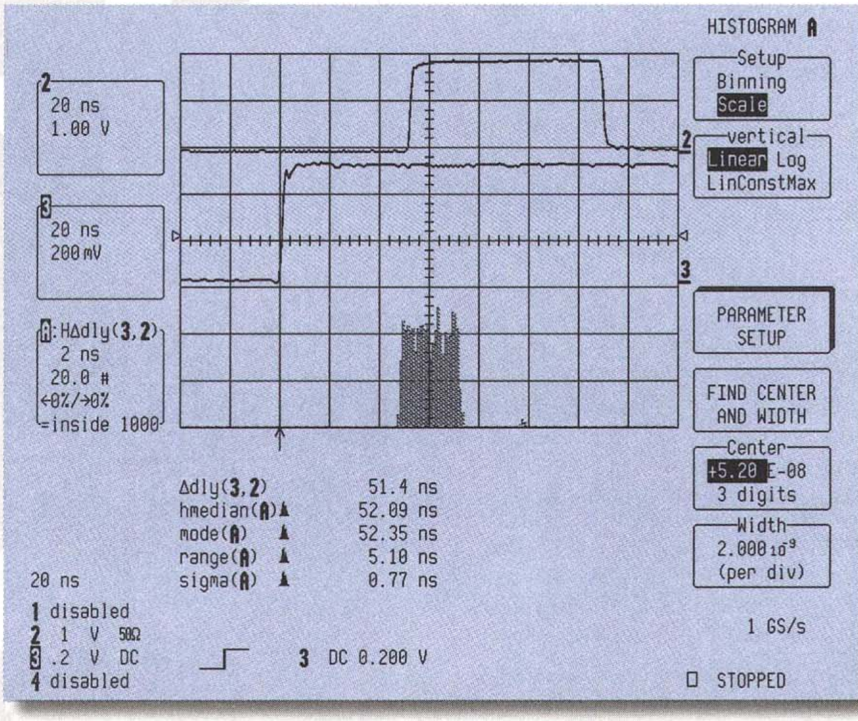


Figure 22. The histogram of data amplitude shows a higher than normal number of sample values at the zero crossing at the center of the distribution. This indicates that the high harmonic levels are due to crossover distortion.

Figure 23. A histogram of delay between traces 3 and 2 with an unknown event occurring 2.5 ns outside the expected range.



Oscilloscopes with advanced memory management make such recovery possible due to the high level of functional integration designed into them.

Consider the histogram of delay measurements shown in the bottom trace of Figure 23. This histogram shows the uniform distribution of the delay between the two source waveforms shown in the Traces 2 and 3. These waveforms are from a trigger circuit which synchronizes an external event (Trace 3) with an internal 400 MHz clock to produce a synchronous pulse output (Trace 2).

The expected delay between the input and output is uniformly distributed over a range of 2.5 ns. Note, however, that a small number of output pulses are delayed by an additional 2.5 ns clock period. This behavior was not expected. Of the 1000 waveforms that were used to create the histogram, only the last one is still available in the scope.

We can take advantage of the long memories and the memory segmentation (sequence mode) available in some digital oscilloscopes to retain from 20 up to 2000 measured waveforms in the scope's acquisition memory. The maximum number of segments varies with the total amount of memory available in any given model. Each of the segments has an individual time stamp which provides a real-time readout with 1/10 second precision and a relative time stamp with 1 ns resolution.

Memory segments pose no problem for the analysis, because the analysis functions operate correctly on data in the segmented memory.

Another advantage of oscilloscopes with advanced memory management is that the segmented traces can be displayed individually while retaining exact horizontal synchronization. This allows both the input and output waveforms for any selected segment to be displayed individually. Not only can they be displayed but parametric measurements of the delay for each segment can be displayed to help identify the data we're looking for.

Figure 24 shows the same histogram setup using sequence mode with 1000 memory segments. Sequence is an acquisition mode controlled using the timebase menu. Note that the histogram data appears the same and can be confirmed by comparing the parameter readouts.
The individual traces are viewed by expanding the upper traces using zoom mode. The oscilloscope is setup to lock the horizontal axes of both traces together using multi-zoom. The result is shown in Figure 25. Using multizoom, we can quickly scan through all the segments until the desired measurements are found. Note that the bottom line of the parameter readout is reading the delay for only the segment currently being viewed. In Figure 25, segment 228 is being displayed. Note that the delay measurement for this segment is 55.8 ns, making it one of the three measurements of interest.

This is a great example of how LeCroy oscilloscopes allow users to combine functions easily and seamlessly to solve tough measurement problems. In this example, statistical analysis, sequence mode, automatic parameter measurements, and multizoom were combined to acquire, store, analyze, and document the desired waveforms.

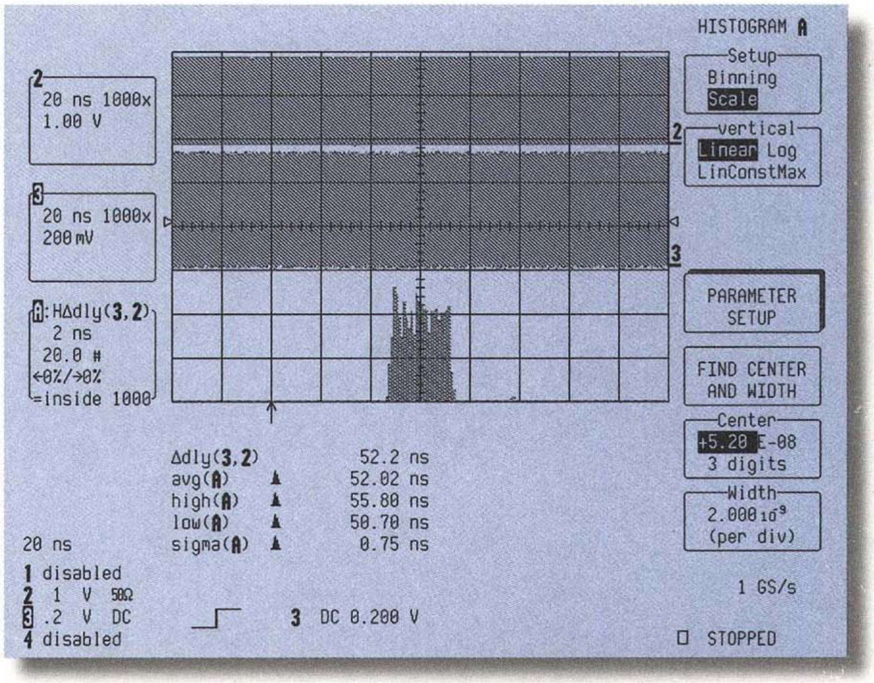


Figure 24. Histogram of 1000 measurements acquired and stored in sequence (segmented memory) mode.

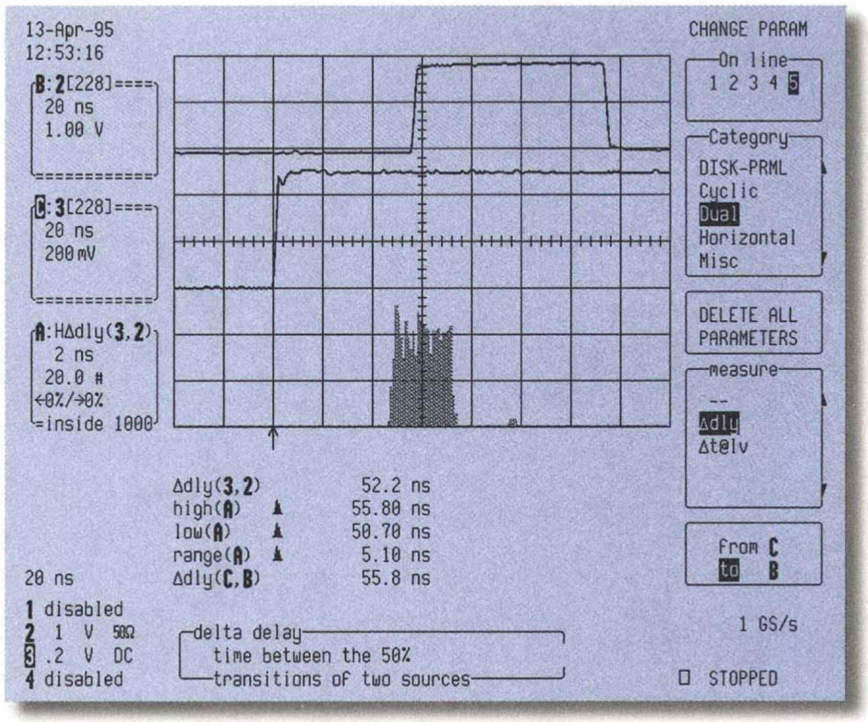
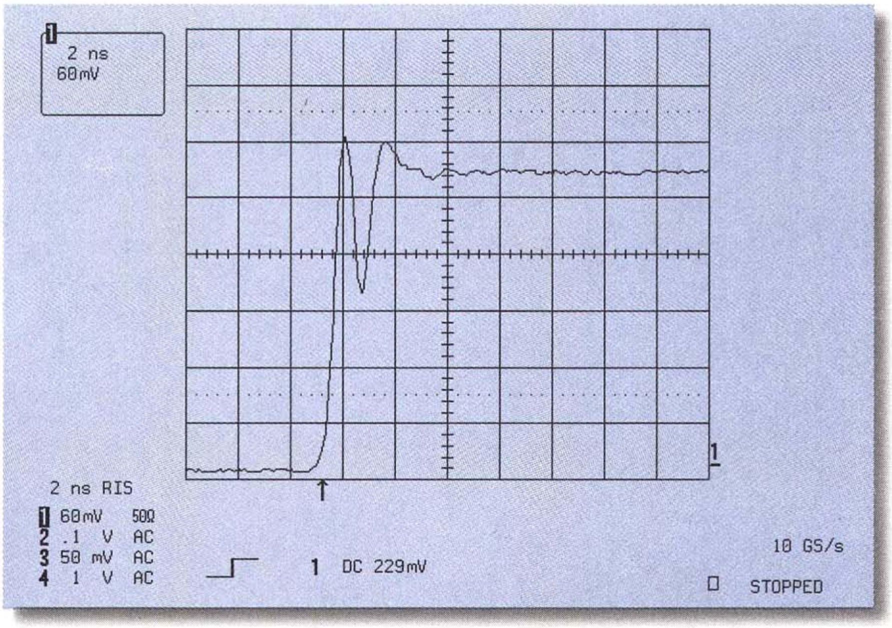


Figure 25 - Using Zoom to review individual waveform segments reveals one of the 3 long delays, 55.8 ns in segment 228

DSO Applications in High-Speed Electronics



Introduction

Analog designers have long battled against high-frequency effects including reflections, noise, capacitive loading, and power supply transients. They address these problems with tools such as Transmission Line theory and Network Analysis.

Until recently, digital designers have been unaffected by these "analog" phenomena. But today's hardware designer, analog or digital, ignores them at his or her peril.

With microprocessor clock speeds now routinely exceeding 100 MHz, and the corresponding reduction in transition times and propagation delays, digital circuits are exhibiting increasingly non-digital behavior. The old simplifying assumptions (perfectly square pulses, clean edges, all signals either High or Low) are no longer valid. At the same time, fewer systems are 100% analog or digital; many are "mixed signal", imposing analog and digital design disciplines.

Fortunately, help is at hand. New design tools are better able to theoretically model such effects. At the same time, DSOs provide the capability to investigate high-speed signal performance.

This Application Note introduces the different types of DSOs available for high-speed work and discusses their relative merits and applications.

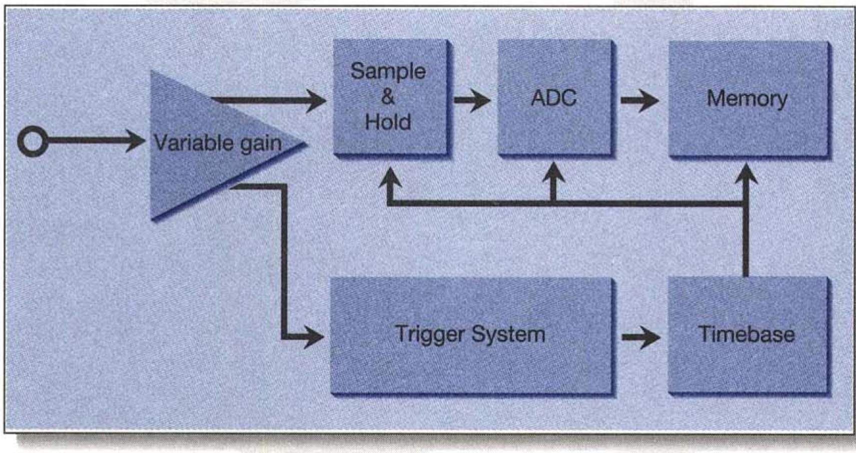
Choosing the Right Scope

Single-shot signals

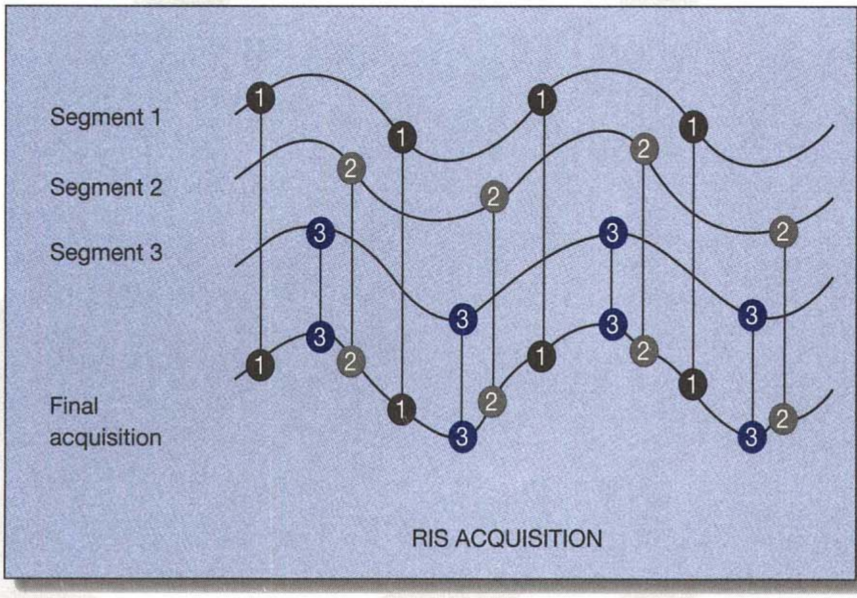
Single-shot signals are those that occur only once. Examples include glitches, intermittent problems and communication signals. Many bus signals occur so infrequently that they must also be considered single-shot.

Faithful capture of single-shot signals requires fast analog-to-digital conversion. The critical specification for a single-shot DSO is, therefore, its sample rate. Analog bandwidth is also important but is not usually the limiting factor, since a single-shot DSO's sample rate should be approximately ten times its bandwidth.

The schematic of a typical single-shot DSO is shown on the next page. The front-end amplifiers provide signal conditioning and buffering. A Sample-and-Hold circuit is used to sample the input waveform. An analog-to-digital converter then digitizes these samples, and they are stored in memory. A separate trigger circuit determines where the displayed acquisition starts and stops, and the time period acquired is determined by the timebase.



Single-shot DSO simplified schematic.



Build-up of an RIS waveform.

Repetitive Signals

The majority of high-speed electronic signals are repetitive. (This explains the enduring popularity of analog oscilloscopes, which are not suitable for fast single-shot events.) However, DSOs now provide superior bandwidth and price/performance even for repetitive signals.

Repetitive signals do not require fast single-shot acquisition. A waveform that occurs many times per second can be digitized at moderate speed, with a few samples taken each time the signal occurs. As long as the samples are taken on different parts of the waveform, a composite picture can be built up. This technique is known as repetitive sampling.

In Random Interleaved Sampling (RIS) – the most flexible form of repetitive sampling – the samples are taken at random times, and the waveform is then reconstructed. The small number of "duplicate" samples are ignored.

The key specification of repetitive DSOs is their analog bandwidth, as this will determine the fastest signals that can be acquired.

Bandwidth Requirements

Bandwidth determines the ability of an oscilloscope to capture a fast signal without filtering it. An oscilloscope without sufficient bandwidth will reduce the signal's high-frequency content: amplitudes will be reduced and pulse edges slowed down.

But how much bandwidth is enough? In the case of fast pulses, errors on risetime and falltime measurements are particularly worrying. When measuring a signal risetime, error is introduced by the oscilloscope's intrinsic risetime.

This risetime is generally determined by the equation:

$$\text{Risetime (in nanoseconds)} = \frac{350}{\text{bandwidth (MHz)}}$$

Thus, a 350 MHz oscilloscope has a rise time of 1 nanosecond.

When making a risetime measurement, the measured value is determined by the equation:

$$\text{Measured risetime (tr)} = \sqrt{(\text{tr signal})^2 + (\text{tr scope})^2}$$

Using a 350 MHz scope to measure a 1 ns risetime will yield a result of 1.4 ns, a 40% measurement error!

The graph in Figure 4 shows measurement error versus signal risetime for a range of DSOs with bandwidths from 100 MHz to 1 GHz. For signal risetimes of 2 or 3 ns, the 100 and 300 MHz oscilloscopes introduce significant (>10%) errors, and the 500 MHz scope introduces errors of about 4%. The 1 GHz scope makes more accurate measurements.

Bandwidth Effects on an Edge Measurement

To illustrate the bandwidth problem, the same signal was acquired using DSOs of 200 MHz, 500 MHz and 1 GHz bandwidth. The signal is the output of an ECLinPS part, whose rising edge contains a fast glitch. The glitch is caused by stray capacitance in the PCB layout, resulting in mistermination and a reflection.

When viewed with the 200 MHz oscilloscope (Figure 1), the signal appears clean and relatively noisefree. The edge has a risetime of 3 ns and appears smooth and free of noise and distortion.

When acquired with a 500 MHz oscillo-

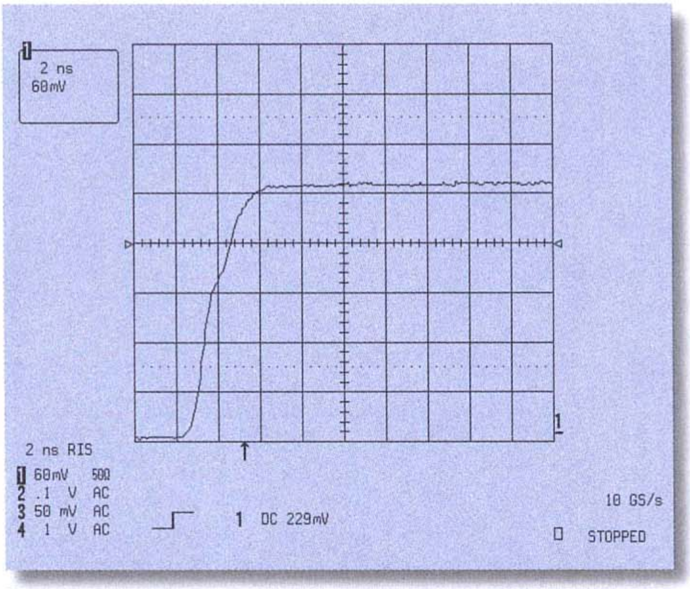


Figure 1:

Fast edge acquired with 200 MHz band-width.

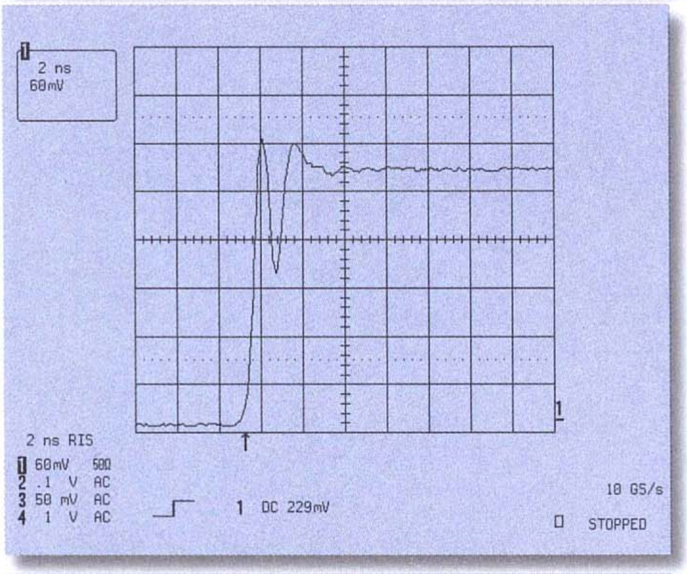


Figure 2:

Same edge acquired with 500 MHz band-width.

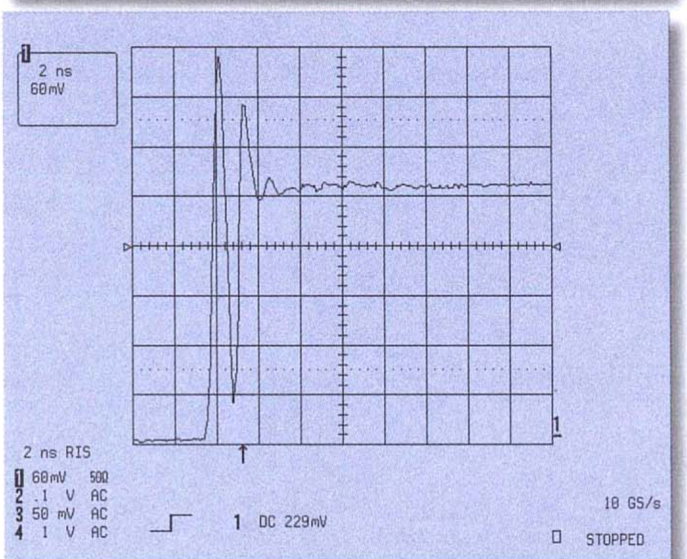


Figure 3:

Same edge acquired with 1 GHz band-width.

scope, the pulse looks a little different. The rising edge is much faster with a significant kink in the edge. A small amount of noise is also apparent.

Viewed with a 1 GHz oscilloscope, the signal looks dramatically different. The kink in the edge is actually a full-amplitude glitch. It alters the signal's risetime and will affect the switching time of the following stage. It could even cause misfiring or metastability.

The reflection was very hard to see with the 500 MHz scope and completely hidden on the 200 MHz instrument.

Sample Rate Considerations

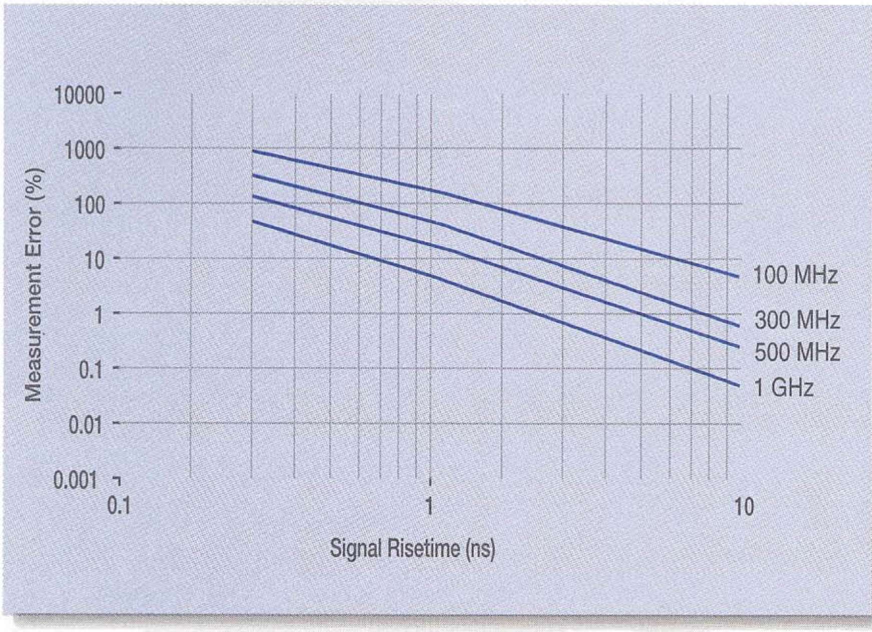
A DSO's sample rate also limits the fastest signal that it can capture. To avoid aliasing (which completely distorts displayed waveforms), the sample rate must be at least twice as fast as the highest frequencies present in the signal (Nyquist criterion). However, in order to make precise measurements, the sample rate should be approximately 10 times faster than the frequencies measured. Sampling at a lower rate will yield poor horizontal resolution and other inaccuracies.

Sample rate is especially critical in digital design and debug applications, where unpredictable circuit behavior is often caused by fast glitches. Determining the cause of such glitches may require detailed analysis of their form and timing. This, in turn, needs the high resolution provided by fast sampling. Figures 5, 6 and 7 show the effect of sampling a 1 ns glitch at 500 MS/s, 2 and 10 GS/s.

We have seen that DSO bandwidth and sample rate affect the measured signal in different ways. Therefore, the two main DSO categories to consider are single-shot (i.e. high sample rate) and repetitive (i.e. high bandwidth).

Single-shot capture is particularly important when looking for intermittent faults. Thus a single-shot DSO should be used for debugging and troubleshooting new designs.

Figure 4: Error Introduced in a risetime by DSOs of different bandwidths.



Repetitive scopes may be used to troubleshoot an already characterized circuit, where the board under test will be compared with a known good board. The parameters measured (for example, phase margins and timing values) are typically repetitive.

A third category is the "general-purpose" DSO, which offers both high bandwidth and fast single-shot sampling. A good example is LeCroy's LC534A, a four-channel color DSO with 1 GHz bandwidth and 2 GS/s single-shot digitizing. Available for less demanding applications is the LeCroy model 9354C, a 500 MHz DSO with 2 GS/s single-shot digitizing. The same series of instruments includes DSOs with the longest memory of any scopes available, up to 8 million points of acquisition memory.

Longer Memory Means Higher Effective Bandwidth

A DSO's maximum sample rate is the fastest it can possibly sample. But at most timebases, the instrument will sample at far slower than maximum speed. This is because it must fill its acquisition memory in precisely the time specified by the timebase. When the time per division is set, so is the sample rate. However, the more memory a scope has, the faster it can sample during that time. The longer the memory, the faster the sampling.

This is particularly important in debugging microprocessor-based systems. Circuits having asynchronous events are easier to debug with fast digitizing over long time windows.

Figure 8 illustrates a typical example of this. The top trace is a burst of communication pulses between a microprocessor and a peripheral device. Acquired at a relatively slow timebase, it shows a complete 2 millisecond burst. The waveform has also been expanded (lower trace), in order to make measurements on the individual pulses. The 2 million point memory available for the LC584A, LC574A, LC334A, LC534A, or the 9354CL, 9374CL and 9384CL, models allow the signal to be acquired at 500 MS/s (1 GS/s with 9384CL, LC574A or 2 GS/s with the LC534A), even over the required long time-window.

Typical Measurement Problems

Measuring In The Presence of Noise

It is sometimes necessary to characterize a circuit in noisy conditions. This can occur in the early stages of product design, before shielding and layout are finalized.

Alternatively, circuit layout may make effective probe grounding difficult. In either case, noise can dramatically mask measurement, as illustrated in Figure 9.

A common approach to the noise problem is to filter the signal. However, this compromises measurement accuracy by reducing bandwidth. A better solution is to average the waveform over time. The noise, which is random, is averaged to zero. For example, LeCroy's Continuous Averaging function provides noise rejection without reducing the bandwidth.

A further benefit of averaging is that the resulting averaged waveform has a greater dynamic range than the original waveform. This can be very useful when measuring small effects such as over-shoot on large signals. Figure 10 shows the effect of averaging the noisy waveform shown in Figure 9.

Inter-Channel Measurements

Most timing measurements are made between two or more different signals. For example, it may be necessary to test a BiCMOS buffer.

The propagation delay (time from input to output) for this part is nominally 4.5 ns. The DSO is used to measure the time from CH1 (input) to CH2 (output). This delay is shown by the Δ delay parameter. In addition, statistics show the highest, lowest and average values, and the standard deviation.

Alternatively, Pass/Fail testing can be used to verify that all acquisitions fall within the specified limits.

In the example show in Figure 11, timing is measured from the 50% point of the input edge to the same point of the output edge. This is typical for propagation delay measurements, although LeCroy DSOs enable the user to specify other signal levels, either in percentages or in volts.

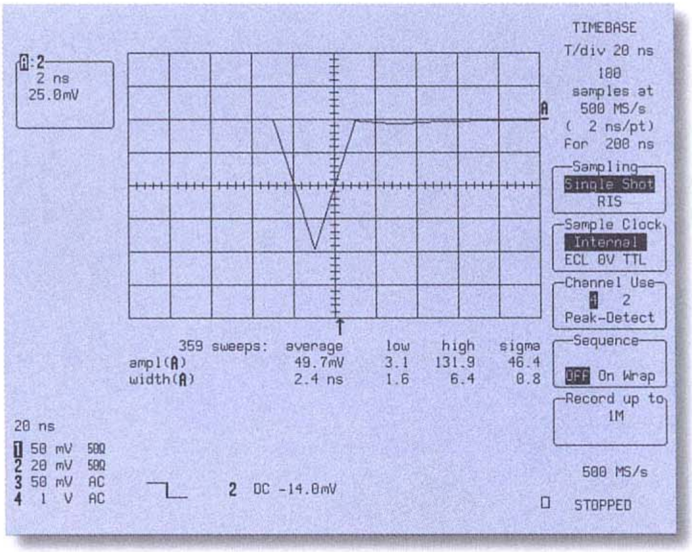


Figure 5:

1 ns glitch digitized at 500 MS/s. It is impossible to accurately determine amplitude or width.

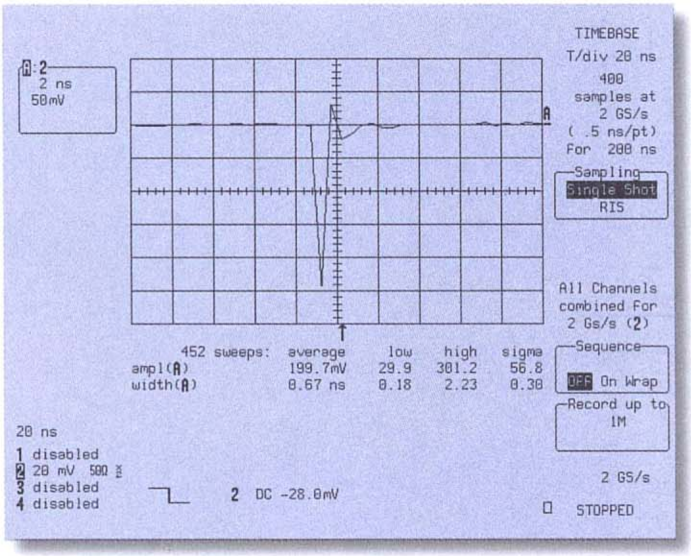


Figure 6:

The glitch of Figure 5 sampled at 2 GS/s. Width is measurable, but peak amplitude information is missing.

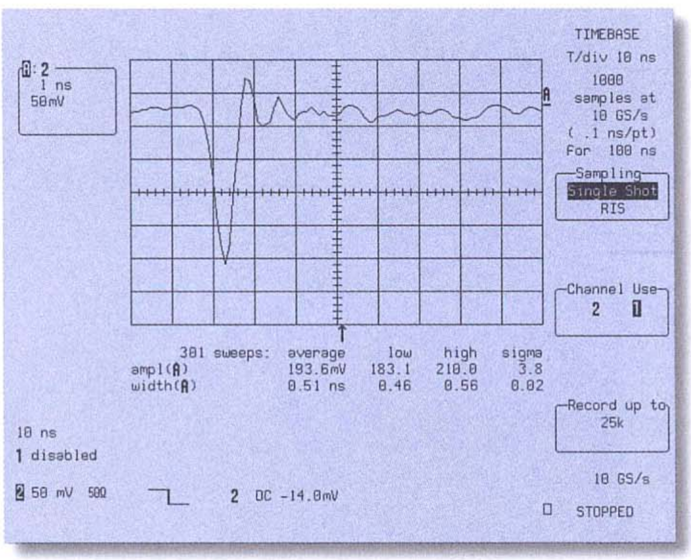


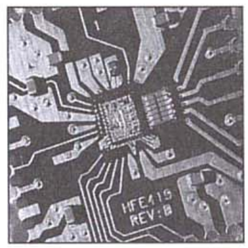
Figure 7:

The same glitch sampled at 10 GS/s. Both pulse width and peak amplitude may be measured accurately.

An engineer using this buffer in a circuit will probably test it using a general-purpose DSO. The IC manufacturer is more likely to use a high-bandwidth (repetitive) scope, with a test circuit set up to cycle the chip repetitively.

Choice of Level for Edge Measurements

As we have shown, the risetime of a signal will be accurately measured as long as the DSO has sufficient bandwidth. Risetimes are often measured from the 10% to the 90% point on the waveform in order to include the signal's full voltage swing. However, for very fast circuits, it is more common to measure the 20% to 80% risetime. This makes the risetime specification insensitive to inflections near the top or the bottom of the pulse. LeCroy DSOs allow the user to measure risetime at these or any other levels.



Crosstalk

A previous example showed a bus reflection – one of the unwanted effects of stray capacitance. Parasitic capacitance between PCB tracks can also cause the fast edges of high-speed logic to propagate from one signal line to another.

This crosstalk can have catastrophic effects, producing glitches large enough to cross logic thresholds: glitches that can cause unpredictable failures such as unwanted logic pulses in a data path or even timing errors that result in device misfiring. Figure 12 shows how crosstalk can distort a signal and corrupt data.

Detection of glitches, and accurate measurements of their amplitudes and widths, is therefore of major importance in identifying sources of crosstalk. A DSO with glitch trigger

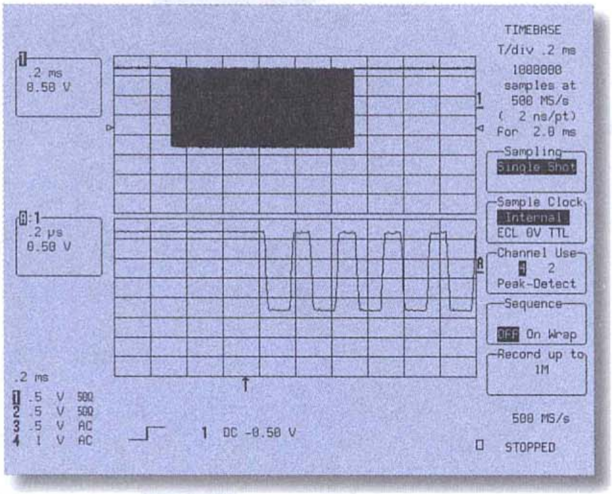


Figure 8: A burst of microprocessor communications activity. The expansion (lower trace) shows individual pulses in the train.

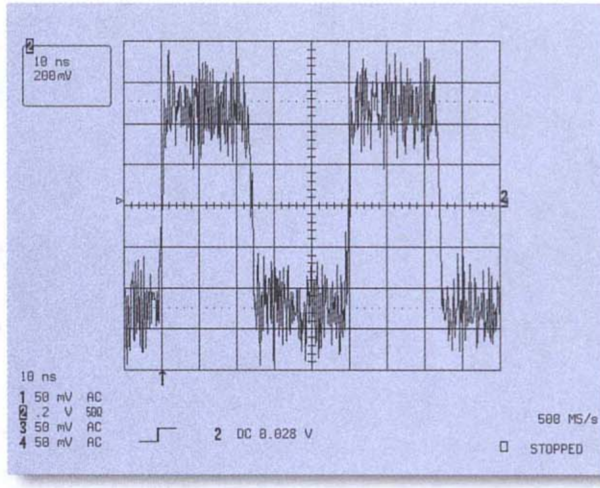


Figure 9: Pulses masked by noise.

capability is extremely useful for such applications.

Microprocessor Crashes

During the final phase of many designs, microprocessor crashes or lockups are common. These may be due to hardware problems, software bugs, or unpredicted interaction between hardware and software.

In investigating such crashes, the designer is interested in the sequence of events leading up to the failure. Therefore, it is particularly helpful to have a DSO that can trigger on the crash itself, with a large amount of pre-trigger data stored in memory. If the system successfully restarts, it is also useful to trigger on the restart condition.

A convenient way to trigger on micro-processor lockup is to use LeCroy's Dropout trigger mode. Any busy processor line can be monitored, and a timeout period specified. Whenever the processor is quiet for longer than the timeout, the DSO will trigger. Using a four-channel scope with long pretrigger memory will allow observation of several signals for milliseconds or even seconds before the crash.

Triggering on a successful restart is possible with LeCroy's unique Edge Qualified trigger. Typically, the DSO monitors a reset line and a data signal. The trigger conditions can be set so that the first event on the data line will cause a trigger, but only if a reset has first been asserted for a specified period of time. (The signal monitored could in fact be a dedicated Watchdog Timer output.)

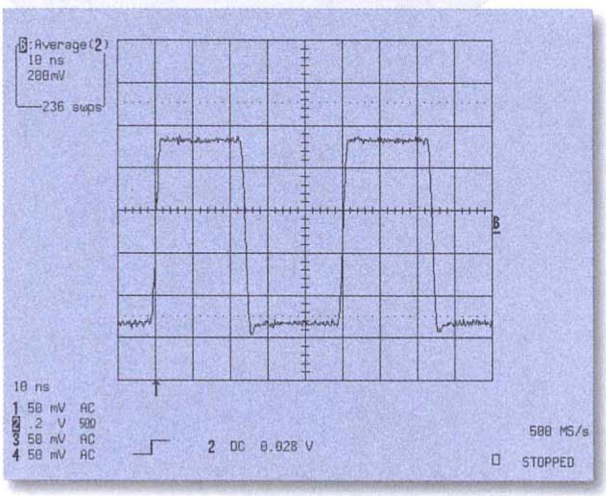


Figure 10: Noise removed by averaging.

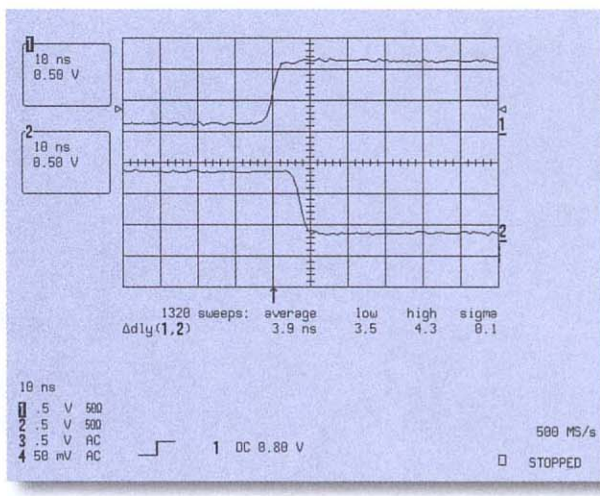


Figure 11: Propagation delay measurement.

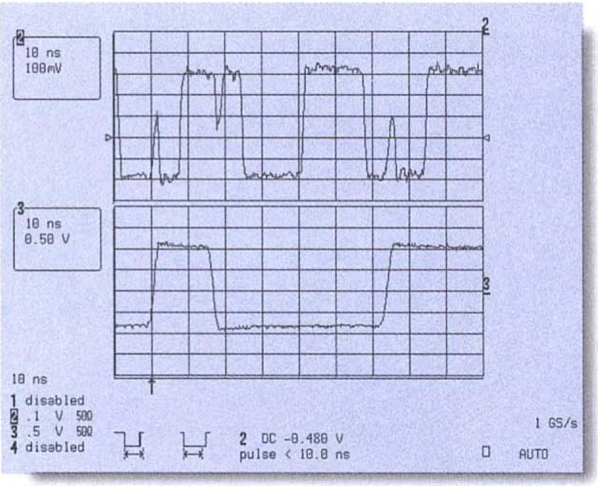


Figure 12: Crosstalk effects on a pulse train.

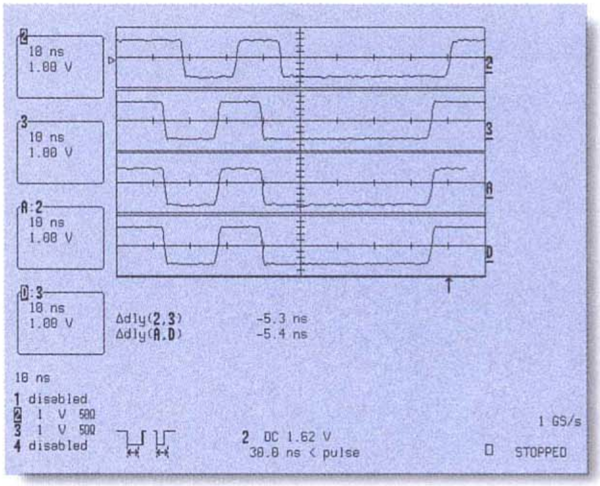


Figure 13: De-skewing clock signals.

Clock Skew

Timing problems can be caused by skew between clock signals delivered to different parts of the circuit. It is therefore important to identify any skew or jitter present on clock edges. In order to measure accurately, the user must first eliminate any skew attributable to the DSO and probes used, particularly if the probes are not identical. To do this using a LeCroy DSO, both probes are connected to the same test point and the DSO is set to its fastest timebase.

If any inter-channel skew is seen, the zoom function is used to create copies of the main traces, and the zoom position control to eliminate the skew, as shown in Figure 13.

Jitter measurements can be made using the DSO's Infinite Persistence display mode. Any changes in the signal's performance will be "painted" onto the display, and the total jitter on a clock edge can then be viewed. Alternatively, LeCroy's Jitter and Timing Analysis package performs a variety of timing measurements, including jitter, very precisely.

Metastability

The data input to a flip-flop should be stable for a given period of time before and after the clock pulse. This period is known as the device's setup and hold time.

If the data changes during the setup and hold time, the flip-flop's output may not change cleanly but go to an intermediate level between high and low.

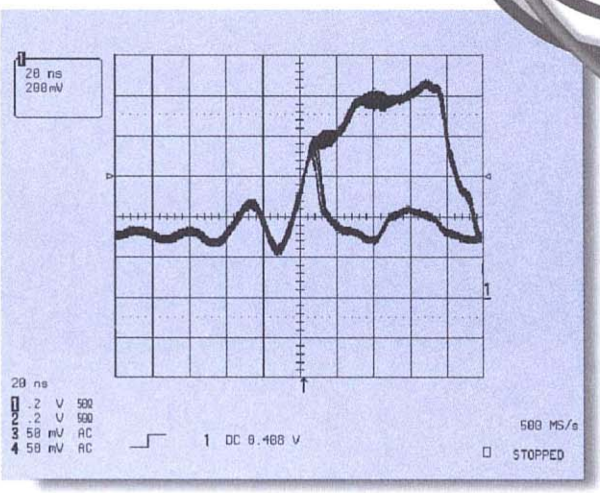


Figure 14: Flip-flop output exhibiting metastability.

While it remains in this indeterminate state, the signal is said to be metastable.

Figure 14 shows the output of such a flip-flop, with many successive acquisitions overlaid in Infinite Persistence display mode. A region of metastability is clearly visible during the 5 ns following the low-to-high transition.

Probes And Probing

The simple act of probing a high-frequency circuit can significantly alter its performance. The proper use of probes is therefore crucial, including choice of the right probe for each measurement and good grounding technique.

Ground leads should be kept as short as possible, and, whenever possible, a spring-clip ground pin should be used.

The three main factors to consider when selecting a probe are bandwidth, resistance and capacitance. The effects of low probe bandwidth are obvious: the composite oscilloscope/probe bandwidth is degraded.

Low-impedance passive probes offer very high bandwidth (typically several GHz). They also feature very low capacitance. However, owing to their low impedance (typically 500 Ω), they present a significant load to the circuit under test. Such resistive loading results in loss of signal amplitude. This may be problematic when using TTL with 1 kΩ pull-up resistors or CMOS, incapable of sourcing the current required. It is usually not a problem when ECL is used.

High-impedance passive probes present much lower resistive loading but add significant capacitance. This can be a major bandwidth degrading factor, resulting in signal distortion. For example, the capacitance of a 10 MΩ probe is typically around 15 pF. This means that with a 1 kΩ source impedance, bandwidth degradation will limit rise-time measurements to the order of 33 ns. HiZ probes are generally restricted to applications where signal frequency is less than 50 MHz.

A better approach is to use an active probe. These have bipolar or field effect transistors in the probe tip, which act as the input stage of a buffer amplifier. These active probes provide high bandwidth, high impedance and low capacitance, but are more expensive and may be sensitive to damage owing to over-voltage abuse.

For more details on probes and probing, see the Probes section of this catalog.

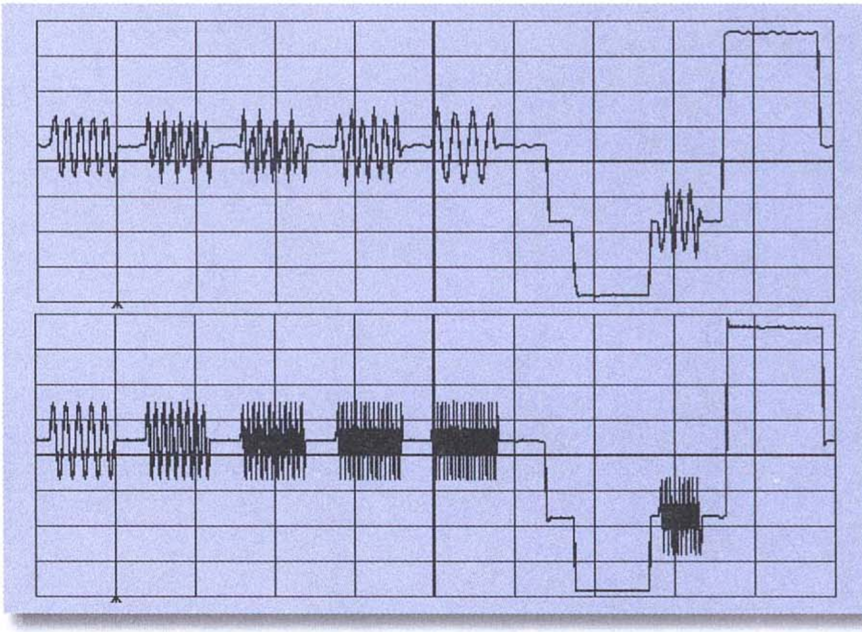
How to Use the Benefits of Long Memory in Digital Oscilloscopes

This technical note discusses how the user of a digital oscilloscope with long memory can apply that memory toward achieving higher sampling rate, spotting abnormalities in a signal and improving frequency domain measurements. In spotting signal irregularities, comparison is made to scopes which have a more limited ability to acquire 500 point waveforms in a fast view mode. Long memory allows a user not only to spot the signal irregularities with fewer triggers, but it also provides the basis for making real measurements to troubleshoot the problem.

A portion of this article was originally printed in EE Magazine

Introduction

Two of the most important parameters to specify for a digital storage oscilloscope (DSO) are the length of its acquisition memory and the amount of RAM memory that can be applied to calculating answers from the raw data. The amount of acquisition memory in many cases determines the fidelity with which the scope can record a signal. But recording the signal is only the first step. The key to finding signal aberrations, characterizing circuit performance and making the wide variety of measurements that have made digital scopes popular is in the processing horsepower of the oscilloscope.



Capturing a Signal

The maximum time window that can be captured by a DSO using a sampling period Δt is :

Time Window = Δt x Acquisition Memory Length

where "Acquisition Memory Length" is the number of samples that can be captured in the data acquisition memory. Since the acquisition memory length is a fixed amount, the only way to capture longer time windows is to make the period between samples longer (Figure 1). For example, a scope with 100 k of memory and a sampling period of 2 ns (500 MS/s) can capture a total time window of 0.2 ms at that sampling rate. If the user wanted to see a 4 ms signal using 100 k samples, the points would have to be stretched farther apart to 40 ns per sample (25 MS/s). This means the accuracy of timing measurements is degraded by a factor of 20, and many signal details are lost. Any frequency above 12.5 MHz (one half the sample rate) will be aliased. Many DSO users believe the ADC in a scope determines its sampling rate. They don't realize the acquisition memory length also plays a vital role. The current state-of-the-art for acquisition memory is 8 million sample points per channel. In the example just given, a full 16 ms can be captured at 2 ns per sample using 8 million points. The bottom line is that a scope putting 2 Mpoints on a signal will give you 20 times better timing accuracy, a much better view of your signal, and more usable bandwidth than one which uses 100 kpoints on the same signal.

How to Use Long Memory to Spot Signal Irregularities

One of the prime purposes of an oscilloscope is to troubleshoot problems. The toughest problems are ones which occur infrequently. Scope manufacturers have been working hard to help the engineer with this task. One recently introduced scope has a chip set that can quickly acquire many triggers and display a view of them in color persistence mode. Less frequent events come out in a different color than common events but few analysis tools are available. There is a further limitation that only 500 points can be acquired. This means the signal must have a short, simple shape or that the sampling rate must be reduced to record long events (with the danger that signal details and glitches will be missed between samples). Long memory can be used in a different way to attack this problem. Suppose the symptom is occasional misbehavior of a clock and the available memory record length in 2 Mbyte.

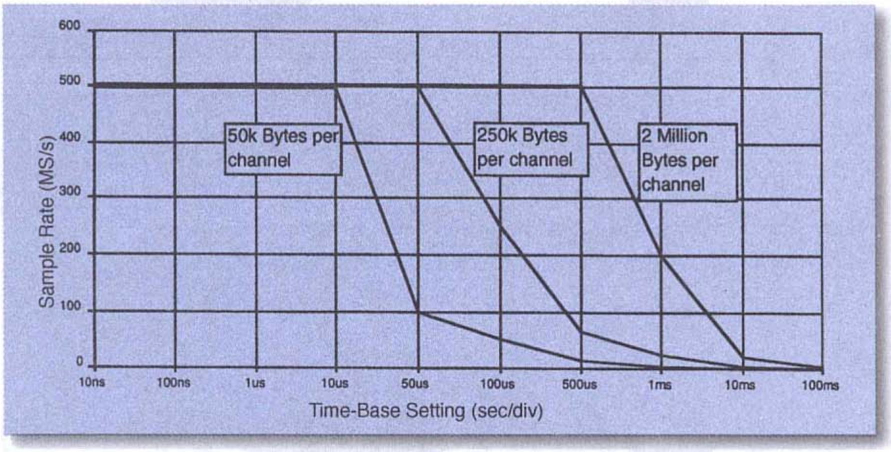


Figure 1. Maintaining the maximum sample rate over more timebase settings is possible with long memory.

The nature of the problem is unknown, so there is no prior knowledge that would allow the engineer to set up a special trigger (based on amplitude, risetime, width, etc.). The user can simply use auto trigger, acquire 2 million samples of continuous clock data (per trigger) and then histogram the pulse amplitudes, widths, risetimes, areas or other parameters of interest. A single trigger with 2 million data points will have as much information as 4,000 triggers of 500 points each. In just a few triggers, the user gets enough data to see the nature of the irregularities.

With this method, there is measurable information as to the number of occurrences of each type of wrongly shaped clock pulse. Figure 3 shows what the results might look like if the clock synchronizer occasionally chopped a clock pulse. There are rare pulses which are very short followed by a second pulse with a glitch. The histogram of 993 sweeps quickly acquires 7046 pulses. The lowest width is 7.4 ns, the average is 50 ns, and the high is 56.2. Note that the vertical scale is logarithmic. There are 12 bad clocks with 7.4 ns width, 12 with 56.2 ns width and 7012 with the normal 50 ns width. The user can measure the ratio of good to bad pulses, make an adjustment and see if it has a measurable effect or use the data in the histogram to set up a special trigger based on width in order to troubleshoot the problem.

Another way to solve the problem is to request the DSO to trigger only when a poorly shaped signal occurs. This can be done using Exclusion trigger as discussed in the following application note (page 169).

The Effects of Long Memory on Frequency Domain Measurements

One of the most common options in DSOs is FFT (Fast Fourier Transform) capability. Since the FFT comes from a set of discrete points (with sampling period Δt), the information in the frequency domain is also a discrete set of points (whose spacing is Δf). The resolution in the frequency domain is determined by two factors, the frequency span being measured and the number of points within that span.

Nyquist's theorem determines the range of frequencies that can be measured. They range from DC to one half the sampling rate at which the data was captured. An FFT of an array of N time domain data points produces N/2 frequency domain points within the range of frequencies between DC and the Nyquist frequency. So the frequency

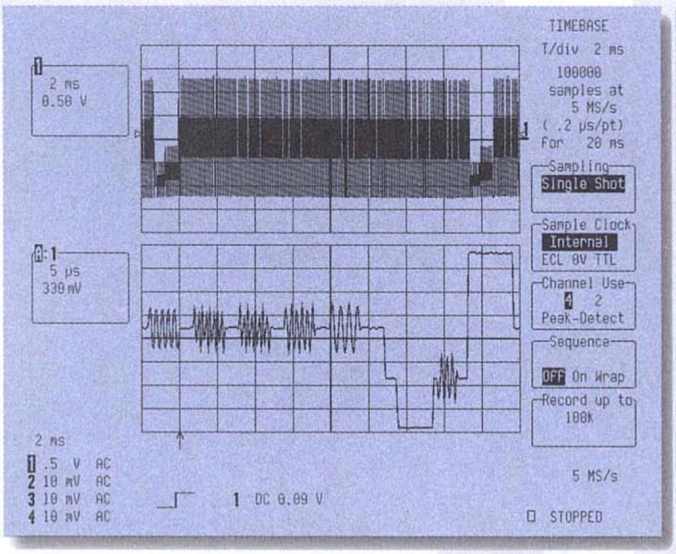


Figure 2a. Undersampled video waveform: 100,000 samples captured. The zoom trace reveals inaccurate aliased data.

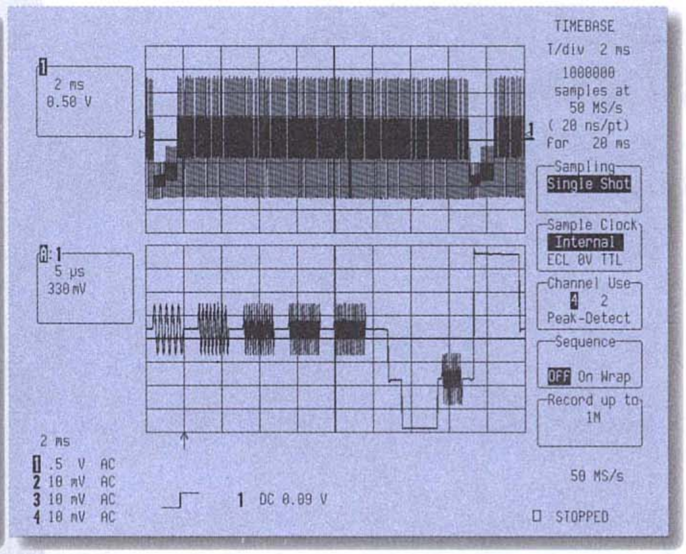


Figure 2b. Long memory enables a higher sampling rate: 1,000,000 samples captured. The zoom trace shows accurate details of the signal.

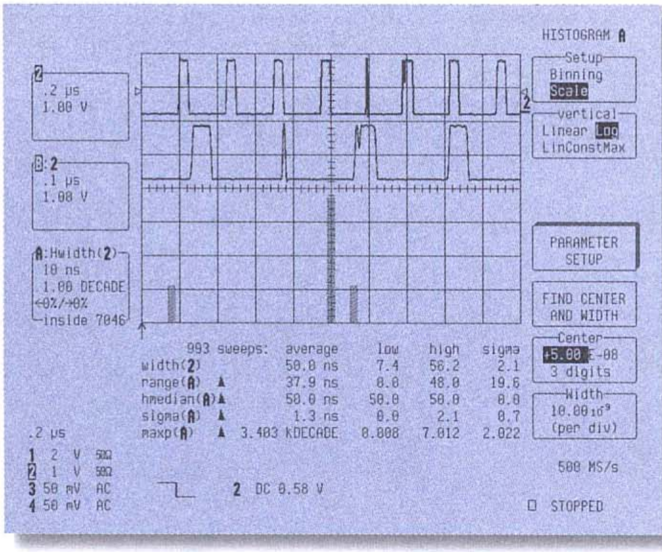


Figure 3. The top trace shows a clock signal with occasional problems. The zoom below shows one occurrence of the problem. On the bottom four divisions of the screen is a logarithmic scale with a histogram of pulse widths.

resolution of the FFT is:

$$\Delta f = \frac{(1/2)\ \text{Sampling Rate}}{(1/2)\ \text{Number of Points input to the FFT algorithm}}$$

The two factors of 1/2 cancel, giving a resolution equal to the Sampling Rate divided by the number of points input to the FFT. Obviously, it is important to capture the data at a high sampling rate. Long data acquisition memory plays an important role here, since it allows the scope to have a fast sampling rate for a longer period of time. It is also clear that we can put more data points into the FFT algorithm if we capture more points in a long memory scope. But just capturing the points isn't enough. The DSO needs to have the processing horsepower to actually compute the FFT on a long data array. As an example, some digital scopes can capture up to 500,000 points of data on a signal, but the FFT processing in the scope are limited to the first 10,000 points captured. This loses a factor of 50 in the resolution of the FFT compared to a scope which can process the complete 500,000 points. This is a tremendous loss in frequency information. Why would a vendor do this? The answer lies in the next important facet of memory in a DSO. An FFT calculation is complex and may require ten times as much RAM in the processing memory as the number of points input to the FFT algorithm. To perform an FFT on a 500,000 point waveform may require 5 Mbytes of RAM. You also need a fast powerful processor and numerical coprocessor to handle long data arrays. Both the RAM and the processor/coprocessor add considerable cost to a scope. Figure 4 shows the difference made by this trade off between price and performance. On the left, an FFT is performed on the first 10,000 points of a waveform. On the right 1,000,000 samples are captured on the same waveform and an FFT is performed on the entire record. Both sets of data are captured at 500 MS/s sampling rate (so the highest frequency component measured is 250 MHz). The difference in frequency resolution is a factor of 100 (50 kHz vs 500 Hz). The frequency peaks on the bottom of the left screen image are very broad. In fact, there is only a single point on each of them. On the right, the peaks are seen more accu-

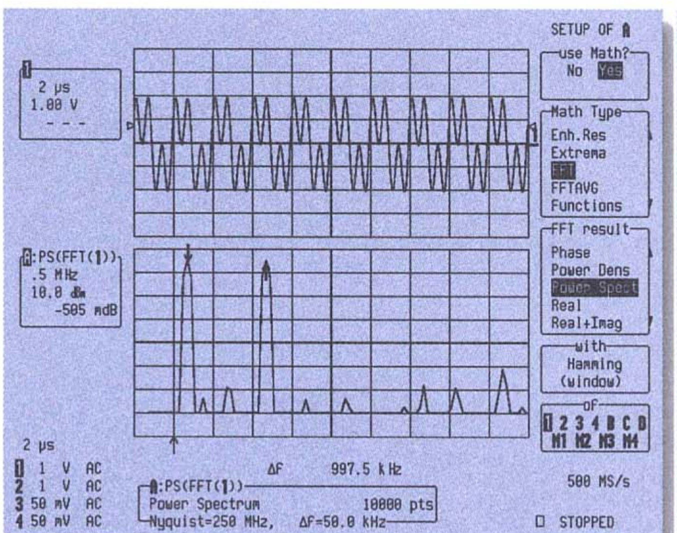


Figure 4a. An FFT of 10,000 points captured at 500 MS/s. Δf is 50kHz

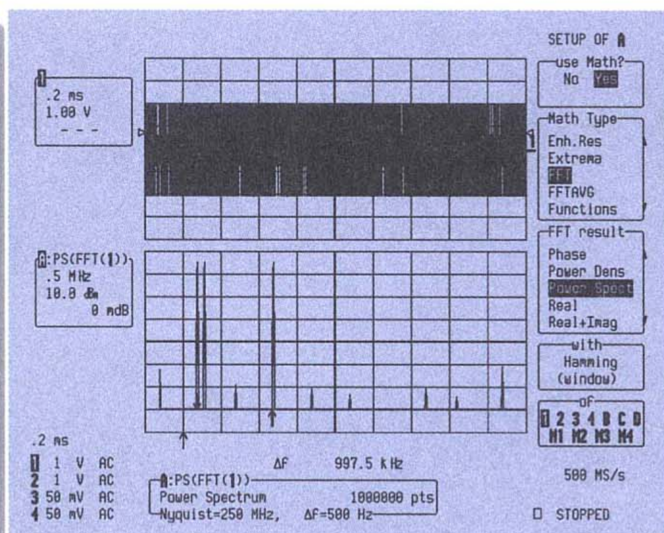


Figure 4b. An FFT of the same signal from Figure 4a with 1,000,000 points captured and analyzed. Now Δf is 500 Hz and the initial peak of Figure 4a is resolved into 2 peaks.

rately as being very narrow. In fact, the first peak is really two peaks at closely spaced frequencies. Those two peaks could not be resolved by the 10 kpoint FFT.

Capturing a Sequence of Signals with Minimum Dead Time

Many digital scopes have a mode which allows the user to segment the data acquisition memory into separate pieces. Each time the scope triggers, data is written into one of the segments of the memory. Then the scope quickly rearms itself for the next trigger. This process is useful in capturing signals where the dead time between events can use up the memory of the scope in recording uninteresting information. An example would be 5 ns width laser pulses happening 200 times per second. If a scientist is examining a sample with a short lifetime, he would want to capture every laser pulse but not the dead time between pulses. This mode is also useful for recording short, irregularly spaced events such as intermittent failures in a circuit set to run an overnight test or for capturing the effects of lightning bursts on communications lines. The user cannot predict when the event will occur, and it is important not to miss any occurrences.

It is easy to see how the benefits of long memory can be applied to using a fast capture-and-store mode as described above. The power of this triggering mode comes from dividing the acquisition memory into separate blocks, which will each record one event. A longer memory allows the user to have more blocks and gives the flexibility to put a larger amount of memory into each block (thereby getting more points on each event of interest). A LeCroy 9300 or LC series scope can record as many as 2,000 separate triggers in Sequence mode and use a total memory length up to 8,000,000 points. Also, each trigger has its own time stamp to mark when the event occurred. In contrast, competitors with 2,000,000 data acquisition points only have the capability to capture 910 events with a smaller amount of memory for each event and do not save the time of occurrence.

How Long Memory Affects Peak Detection

In Peak-Detect mode, a digital scope will keep its ADC running at the full sampling rate even on slow timebases. In the first part of this article, it was shown that this type of operating mode would require more memory than was available. Let's suppose the timebase is 2 ms/div (20 ms for the full screen), and the sampling rate of the ADC is 500 MS/s (2 ns per sample). In order to store the entire 20 ms of data, the scope would require 10,000,000 memory points. In Peak-Detect mode, a scope with 100,000 memory points would have its ADC sample and measure all 10,000,000 points but only store 100,000 of them. The 100,000 that are stored are chosen by looking at smaller bins of data and choosing the maximum and minimum (peak) values to be saved. In this example, the ratio between the number of measurements by the ADC and the number of memory points that can be stored is 100/1. So the scope could examine each group of 200 points as they are acquired and save only 2 points (the maximum and minimum values). In peak-detect mode, the timing resolution of the scope is severely compromised even though the ADC is running at its full rate, because the user does not know whether the peaks occurred at the beginning, middle or end of the group from which they were saved. Normally, it is not possible to perform math operations on peak-detect waveforms because of the uncertainty of the time at which the samples were taken.

A long memory scope brings three benefits to peak-detect mode. The first is that the longer memory can record normal data at full sampling rate for a longer period of time, so the user isn't forced to resort to peak-detect mode. Secondly, when in peak-detect mode, the longer memory scope can save a larger proportion of the data (perhaps it can save 1,000,000 out of 10,000,000 samples rather than only 100,000). A third benefit is found only in LeCroy scopes. In peak-detect mode, a 9300 or LC series scope will allocate half of its memory to storing the data peaks as described above and the other half to sampling data in normal fashion. This allows the customer to view all the peaks and still be able to perform math. An example might be an engineer who is recording voltage on Channel 1 and current on Channel 2. On a third trace, he displays power (Channel 1 x Channel 2) which is the real waveform of interest. But it is also important for him to know if there are any spikes in the current or voltage waveforms. With a LeCroy scope, he can do the whole job.

In buying $5,000 computers, we have become expert at getting to know the amount of RAM, how much cache memory there is for the processor and the amount of local RAM on the video board. Those memories are very important to the power of the computer. The same is true with digital scopes. There is data acquisition memory, processing RAM, display memory and storage memory for both waveforms and front-panel setups. The power of the scope is in its ability to capture, view, measure, analyze and archive signals—all of which are tied to its memory.

Using Exclusion Trigger to Find Intermittent Faults in Electronic Signals

This technical note discusses how digital oscilloscopes can be used to capture, view, analyze and document intermittent faults in electronic circuits. After discussing the older technique, color-graded persistence, the article moves to newer tools including Exclusion Trigger, statistics on parameters, and histograms.

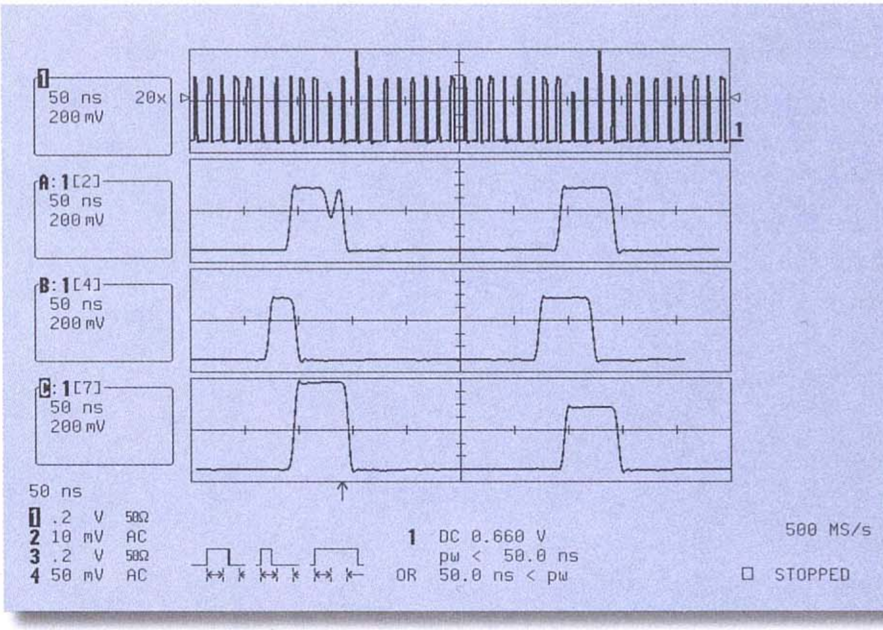


Figure A. An intermittent fault in a clock circuit is captured 20 times. A compacted display of all 20 faults is shown in the top trace. The next three traces show the full detail of the 2nd, 4th and 7th events. For more details, refer to the discussion of Figure 6.

The most difficult problems to troubleshoot are those which are intermittent. This is especially true if the shape of the failing signal changes characteristics each time the failure occurs. The engineer does not know when to trigger the scope (because the failure is irregularly spaced in time) and does not know what shape of signal to trigger on (because the failure does not always have the same characteristic). Since the digital oscilloscope has become the tool of choice for troubleshooting the easier problems in circuits, it would be helpful if their power could be applied in these cases also.

The power of a DSO is in its ability to capture, view, measure, analyze and document electronic signals. For the application described here, the challenge is to capture a signal when the trigger conditions are unknown, view those signals which are aberrant, measure the aberrations, analyze the cause of the signal irregularities and document them. Let's suppose that the signal of interest is the master clock. Each clock pulse is about 1 volt in amplitude, 50 ns wide and the clock period is 250 ns. Looking at this signal on a digital scope gives a picture as shown in Figure 1 (on the next page). Unfortunately, something goes wrong with this signal occasionally. How do we track down the problem ?

The first generation product-offering by digital scope manufacturers to capture and view signal irregularities was standard edge triggering coupled with color-graded persistence display. This was offered by LeCroy's 7200A series and by other manufacturers. Under this mode, the scope triggers many times on the signal of interest and displays the most commonly captured signal shape in red and least common in blue. Spectral shades between red and blue measure the frequency of occurrence of signals shapes which have "medium" or "rare" probability. This mode provides some useful information for the engineer, but not a lot. There is a bright red trace that shows the normal signal shape, and, if you were lucky enough to capture some of the failure modes, there are additional traces in other colors laid on top of the red one. There is no quantitative information concerning how often each failure type occurred. In fact, if two failure modes happen with equal frequency, they come up in the same color, and the display is confusing.

One of the major scope companies announced in 1994 a new version of color-graded persistence mode to find signal irregularities. The new version works in exactly the same fashion as previous scopes (described above), but there is an improvement in the trigger rate. The new mode has a shorter "dead time" between triggers. Under typical operating conditions, the scope is active 23% of the time (77% dead time). One catch is that the user has no control over the number of data sample points used to capture the signal—it is always 500 points. Many real-world signals are complex and cannot be described using only 500 points. The color-graded persistence mode has a maximum time constant of 10 seconds. The scope reverts to monochrome for infinite persistence. So in order to use the qualitative information in the color grading, it is necessary that the failure mode occur at least once per 10 second interval. Also, when your failure occurs, there is a 77% chance you will miss it. Suppose your circuit fails once

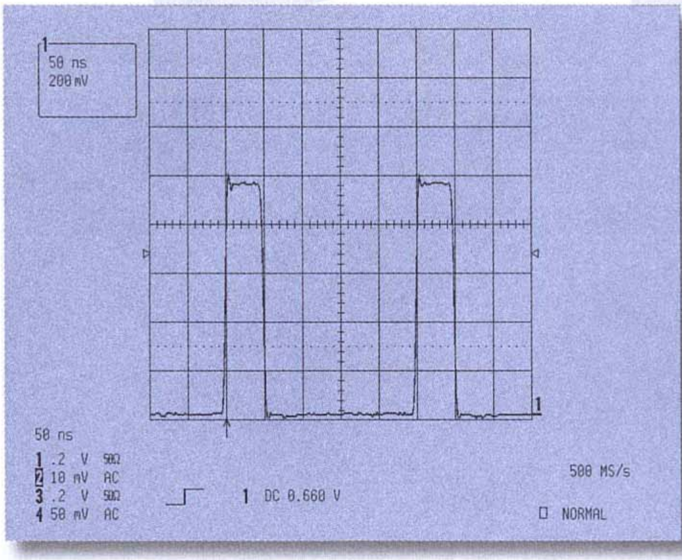


Figure 1. The normal signal shape

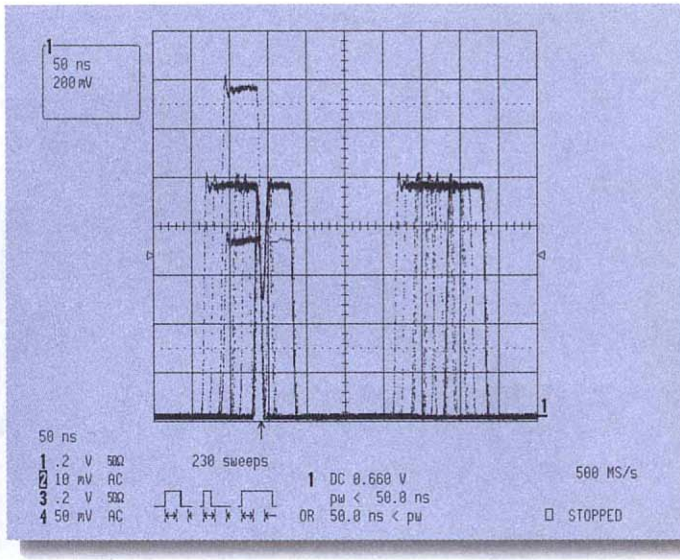


Figure 2. Exclusion trigger has been used to capture 230 events with pulse width pulse width other than 50.0 ns

per hour, the probability is that during a period of 4 hours the failure will occur 4 times, you will miss triggering on it 3 times and trigger on it once – and if you are in color mode you will have less than 10 seconds to hit the stop button to keep the picture on the screen when that one interesting trigger occurs. A significant annoyance that is often overlooked is that the engineer must be present when the glitch occurs and act in less than 10 seconds to stop the scope, otherwise, the glitch appears and then disappears.

Clearly, there are some drawbacks to the use of persistence mode in looking for signal instabilities. Fortunately, a much improved troubleshooting technique is now available. The new method improves the ratio of active time/dead time in capturing the signal and also greatly improves the ability to view, measure, analyze and document the signal aberrations.

Let's return to the problem of the 50 ns clock pulses. The engineer suspects there are rare problems but does not know the nature of the fault(s). What the scope should really show to him is any pulse that is not 50 ns wide (or any that are 50 ns wide but have a glitch somewhere during that time) or any clocks that are not the proper amplitude. He wants the scope to monitor the signal, ignore all the normally shaped pulses, keep the trigger circuit active by not triggering on the normal pulses, and only trigger when the aberration occurs. In this manner, the scope would be active nearly 100% of the time, and the engineer would see only the signals of interest. This type of performance is available in LeCroy 9300C and LC series digital scopes. Furthermore, there are excellent analysis tools that can be applied to the data.

One of the trigger features for LeCroy digital scopes is called "Exclusion Trigger." Under this trigger mode, the user tells the scope to ignore signals with a certain width or period (the "normal" signal). The scope triggers only on irregularities. A typical setup is shown in Figure 2. The scope is set to trigger on any pulses which are longer than 50 ns ("50 ns < pw") or on any which are shorter than 50 ns ("pw < 50 ns"). A customer could watch the type of display shown in Figure 1 a long time on any manufacturer's scope without seeing the signal irregularities, but by activating the Exclusion trigger, the display in Figure 2 quickly shows the type of signal irregularities that are present. In this case, the problem is unusually bad. There are a dozen different types of wrongly shaped clock pulses. Some have amplitudes too high or too low, others have wrong widths while others have glitches near the leading or trailing edges.

If there was only one type of oddly shaped pulse, the data in Figure 2 would be much easier to interpret. But real-world failures are not so convenient. The persistence display is revealing a variety of oddly shaped clocks. In order to begin making measurements of the problem, the user can touch a single button that requests "Statistics on Parameters." Figure 3 shows the result.

We now know the maximum clock width is 75 ns, while the minimum is 6.5 ns. The period ranges from 14.3 to 251.5 ns, and we know the amplitude range is .726 volts to 1.375 volts. This is a good start in making a measurement of the problem, but we can do much better.

The next step is to request the scope to capture a certain number of our "problem signals," so that we can get a better view and better analysis of the problem. This is done by choosing a number between 1 and 2000 and asking the scope to capture that number of triggers. Each trigger goes into a particular "segment" of the data acquisition memory. In Figure 4, the scope is capturing 20 individual triggers (note the number "20x" in the rectangle at the upper left of the display).

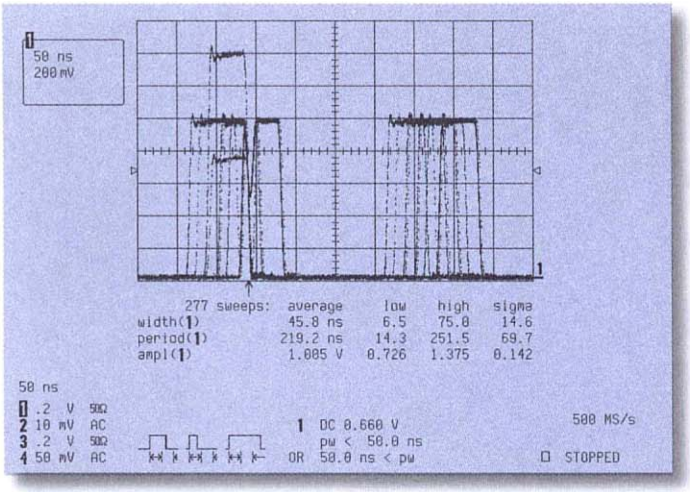


Figure 3. Using statistics on pulse parameters shows the worst case values of pulse width, amplitude and period for signals captured by the exclusion trigger.

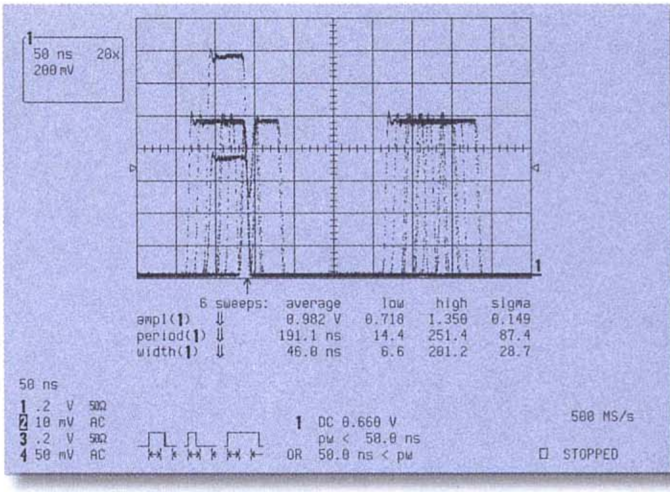


Figure 4. The oscilloscope is now capturing sequences of 20 abberant signals. The 20 signals are displayed in persistence mode along with pulse parameter statistics.

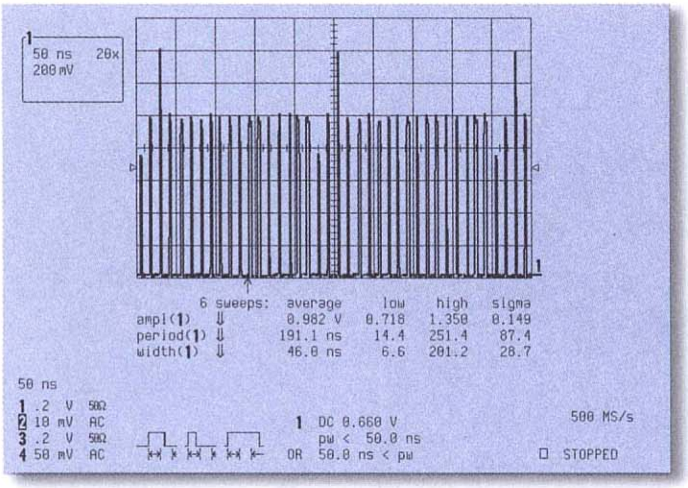


Figure 5. The same 20 pulses from Figure 4 shown in a compacted display of the 20 events.

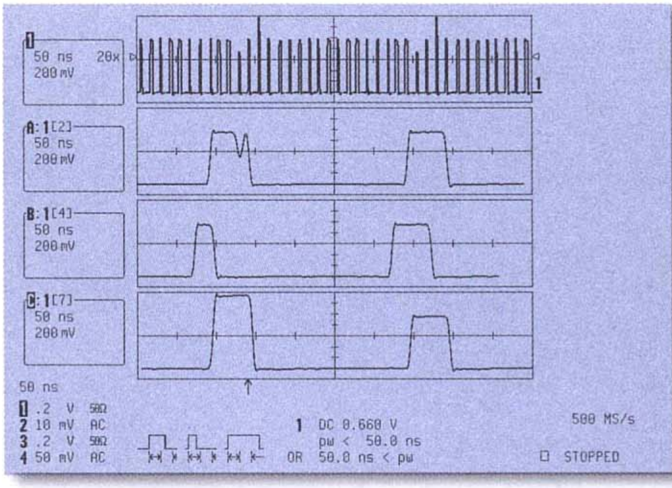


Figure 6. The compacted display of 20 events is on the top trace, and on the other traces, the zoomed detail of the 2nd, 4th and 7th event are shown.

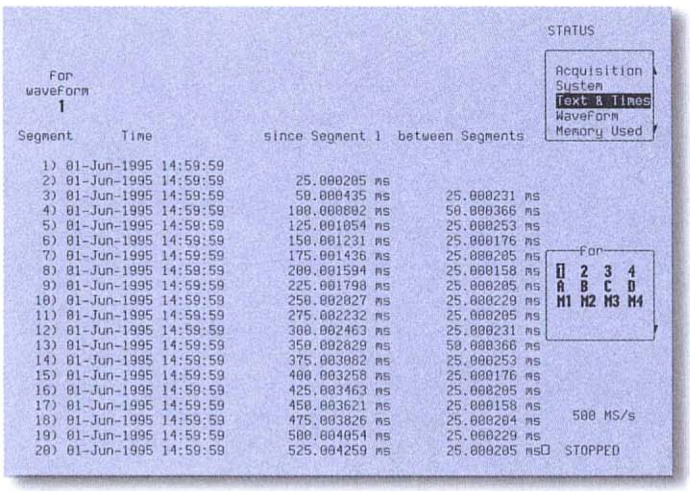


Figure 7. The date and time of each event that was caught by the exclusion trigger. The time between triggers is in the right hand column.

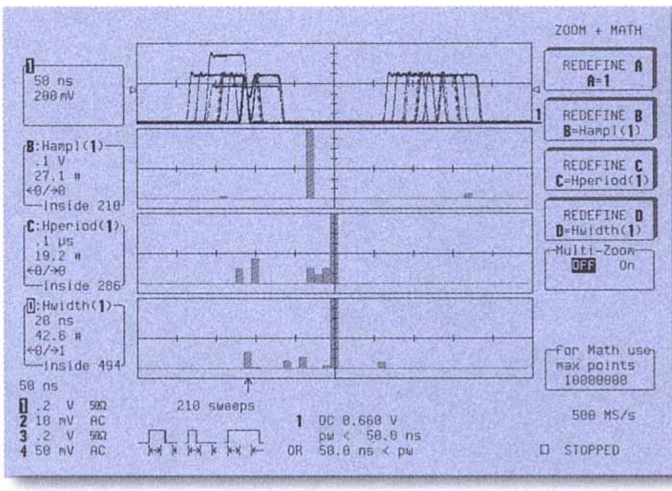


Figure 8. Histograms showing the amplitude, period and width of events caught by the exclusion trigger.

FINDING INTERMITTENT SIGNALS

In fact, the scope has acquired 6 sweeps, and in each sweep there are 20 events. The pulse parameter statistics at the bottom of the screen are based on the total of 120 abnormal signals that were captured. By touching only one button, we can change from the display of Figure 4 to that of Figure 5. In Figure 4, all 20 of the irregular pulses are laid on top of each other in the traditional persistence mode display. In Figure 5, the 20 individual signals are shown going from left to right. All 20 events are compactly shown (2 per division). For example, the events with large amplitude pulses can be clearly seen in the first, sixth and last divisions of the display.

The user can now zoom in on the details of each individual failure. Figure 6 shows all 20 failures in the compacted view mode on the top trace and shows three of the individual events on the next three traces. The engineer can now REALLY SEE the failures. Trace A shows a glitch near the trailing edge of the pulse. In Trace B, the clock has been chopped off short. In the third trace, the amplitude is too large.

A further analysis tool is shown in Figure 7, which shows the time of the first of the 20 triggers, the difference in time between the first trigger, and each of the other 19 events and the time elapsed between each trigger and the one just prior to it. By looking at the final column (labeled "between Segments"), the engineer can notice that the aberrant pulses are usually occurring 25 ms apart. His basic clock period is 250 ns. The conclusion is that there is some problem which occurs regularly after each 100,000 pulses (100,000 x 250 ns = 25 ms).

Now the engineer is ready for the final level of analysis. He knows the high and low ranges for the parameters that describe the failure has seen what the individual failing signals look like. He also knows the timing between the failures. But it would very nice to know how often each type of failure occurs. Can we quantify the relative frequency of each failure type? It would also be extremely helpful to have some type of scope display that could be observed while making adjustments to the circuit to see whether one or more of the failure modes becomes more common or less common while making the adjustment.

Figure 8 shows the persistence display of the failure modes on the top trace. The next three traces are bar charts (which are also called histograms) quantifying each of the failure types.

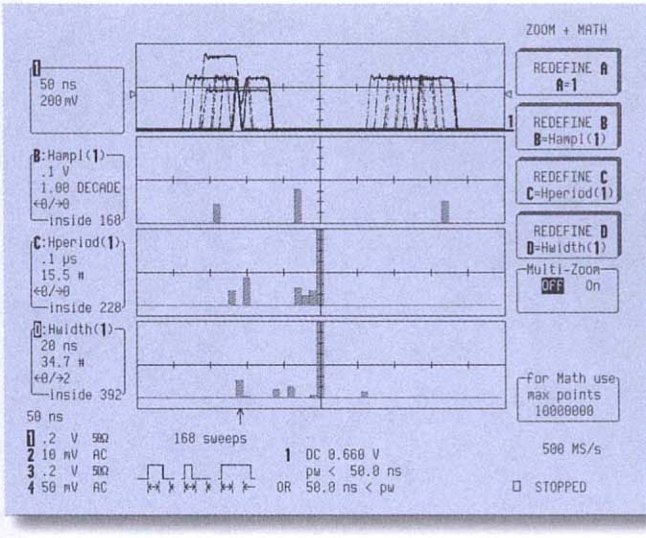


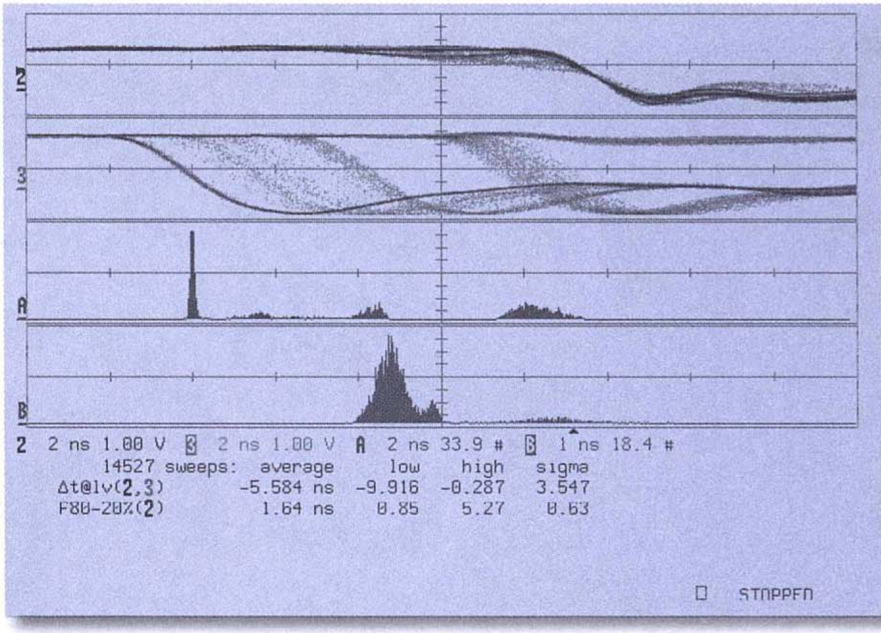
Figure 9. Trace B has been changed to log scale, for easier viewing of the shorter bars on the left and right of the screen.

Trace B shows amplitudes. The oscilloscope can be requested to automatically set the scale of the histogram so that the data is displayed clearly, or the user can set the scale to specific values. In this case, the engineer has set the center of each scale near the nominal values expected for clock amplitude, period and width. The amplitude histogram is centered about the value of 1 V, and each division is 100 mV. Similarly, the period is centered at 250 ns, and the width is centered at 50 ns. The most common amplitude of the aberrant pulses is the tallest bar at .96 V (just to the left of the center of the screen). There are small peaks at .718 V and 1.35 V corresponding to failure modes with these amplitudes. The next trace is a bar chart of periods, and the final trace shows pulse widths. In each of these traces, the nominal value is at the center of the screen (250 ns for the period and 50 ns for the width). The bar chart of periods has a scale of .1 µs per horizontal division, while the width is on a finer scale of 20 ns per division. The bar farthest to the right in Trace D is the failure mode with 75 ns width, while the bar toward the left side corresponds to the smallest pulse widths (6.6 ns). The engineer can quickly see which failure modes are most common from the heights of the bars. Quantitative measurements can also be made. The engineer can put cursors on each bar chart to determine how many pulses out of the total 210 irregular clocks had a certain amplitude, period or width. These histograms can be saved onto floppy or as hard copy outputs. They can also be saved internally in the scope. The engineer can adjust his circuit and compare a new histogram against one he saved from before the adjustment.

Some failure rates may be much rarer than others. For example, in looking closely at the top bar chart in Figure 8, there are very short bars in the left half and right half of the screen in addition to the large bar near the center. The scope can present the data in a format which allows the rare events to be seen more clearly by going to a log display for this trace while keeping all the other traces in their normal (linear) format. In Figure 9, a log display of the bar chart for amplitudes shows the very rare events more clearly.

Finding intermittent faults in electronic circuits is one of the most difficult and important problems a design or test engineer faces. It can often be very time-consuming. In the past, persistence displays were used to spot signal irregularities, because there were no better tools. By providing the user new technology that is much more powerful, LeCroy offers superior capability to capture, view, measure, analyze and document these signals. For a company and its engineers, it means the chance to get a product to market more quickly by solving problems faster.

Debug and Characterization of High Speed Digital Electronics



Developers of digital systems rely on advanced design tools such as logic synthesizers, simulators, timing analyzers, and PCB layout tools to ensure the proper operation of complex integrated circuits and printed circuit boards. Nevertheless, system characterization and debug are normally required and remain two of the most time consuming aspects of the product development process. Development schedules often slip due to unpredictable system integration problems. More than ever there is a need for the test and measurement tools available with today's digital storage oscilloscopes (DSOs) and logic analyzers.

The DSO's powerful signal-capture, display, and analysis capabilities can effectively be used to debug, characterize, and assess signal quality, simplifying the process and reducing time to market.

Debug and Characterization

When selecting a scope for debugging digital systems, it is important to consider the scope's ability to capture and faithfully display the signals of interest as well as analysis capabilities that aid in solving problems, speeding up the debug and characterization process. Oscilloscopes from LeCroy provide a broad range of capture, display, and analysis capabilities. These include a broad variety of trigger types, color graded and Analog Persistance displays, automated parameter measurements, histograms, trending, pass/fail testing, sequential capture with time stamps, as well as the processing speed and memory required for effective signal analysis. Two cases that demonstrate the use of DSOs to debug and characterize digital systems are presented. Traditional as well as new techniques that are now possible as a result of advancements in the capture, display and analysis of digital signals using digital oscilloscopes are described.

Case #1: A Simple Timing Violation

The test results of an early production run of an Intel 386 DX based controller

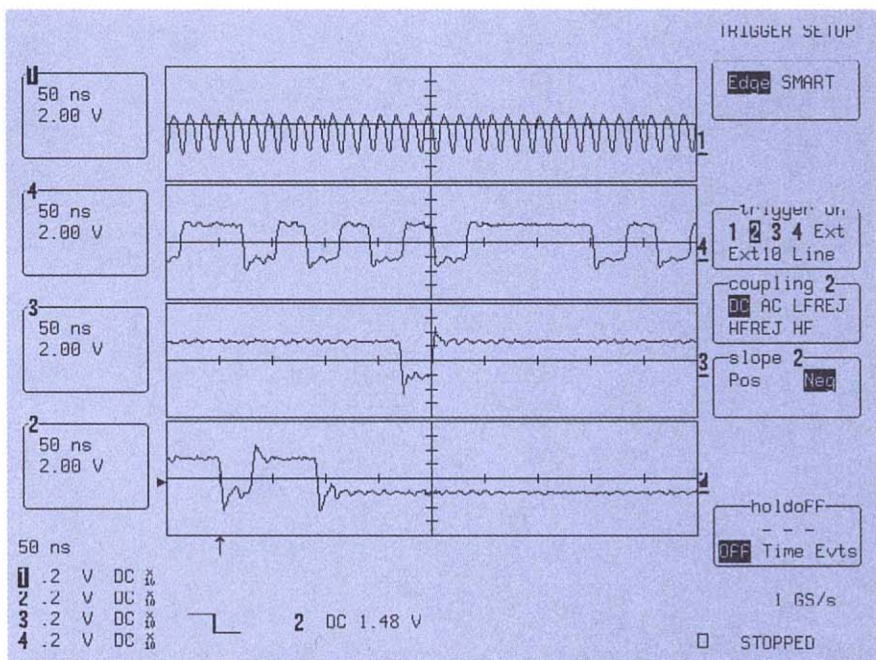


Figure 1. Cache timing signals including the 66.7 MHz CPU clock, address/data stable, output enable, and cache chip enable.

board indicates many instruction cache diagnostic failures. Some boards that successfully pass the cache diagnostic test subsequently fail when running the application program, while some always fail. All boards run properly when their caches are disabled. Due to limitations of the diagnostic program and the nature of the failures, it is not possible to determine the reason for the failures.

A simple debug program that exercises the bus is run on a defective board. The debug program successfully loops, and intermittent failures do not occur. An analog or digital scope may be used to to observe the cache control signals: Write Enable (WE-), Chip Enable (CE-), and the Output Enable (OE-). Observations of the control signals—on all nine cache chips—appear to be of normal shape, duration, and level.

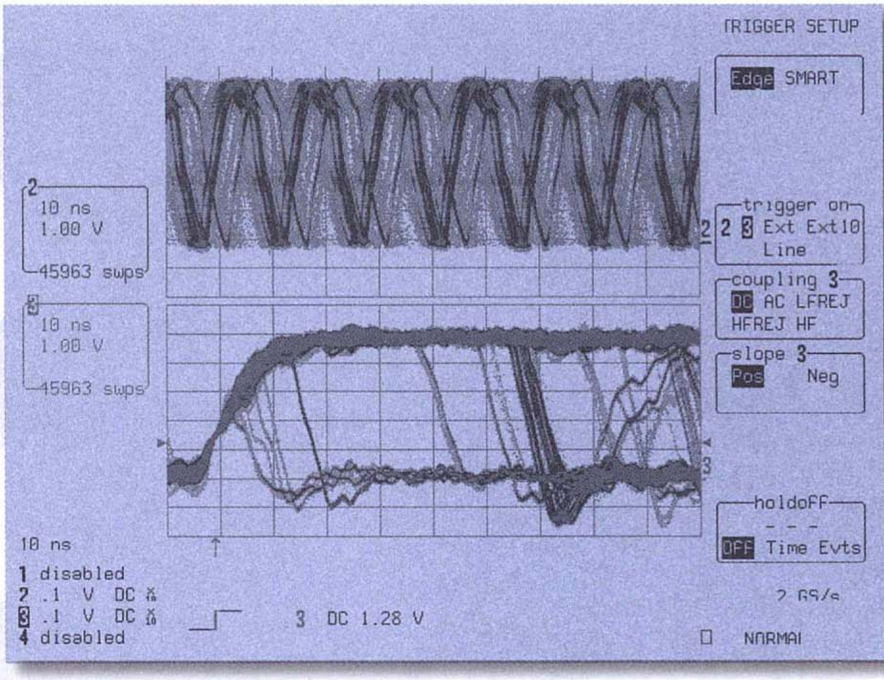


Figure 3. LeCroy's Color-Graded Persistence display of the 33.3 MHz bus clock and a cache data line.

The basic bus cycle is then confirmed and found to be operating normally using a DSO or a logic analyzer.

Figure 1 shows the 66.7 MHz CPU clock, the address/data bus stable flag (ADS-), OE-, and CE-. A DSO is used, since it can be more effective in viewing non-repetitive signals then an analog oscilloscope.

The bus logic appears to behave normally, leading us to suspect an address or data problem. The block diagram of the cache configuration for the system under test is shown in Figure 2. Two critical timing paths are associated with the cache controller: one for the cache address latch enable and the other for the SRAM output enable.

For simplicity, a persistence display is used to look for anomalies. Figure 3 shows the bus clock and one of the cache data lines displayed using a LeCroy LC574 DSO in color-graded persistence mode. In this display mode, the most common events are indicated by the hottest color—i.e. red. As the figure demonstrates, persistence displays can be difficult to interpret when viewing bus signals. The data bit displays complex behavior including undershoot, runts, and edges with different risetimes (which makes the clock appear to jitter in the display).

At first glance, it would appear that there are variety of timing problems. However, closer examination reveals that the display actually shows normal system behavior! The "runts" appearing near the rising edge of the data line are approximately one CPU clock in duration, a perfectly legal condition since a complete bus cycle requires two CPU clocks. The undershoot, while undesirable, is well within expected values. The CPU data bus is multiplexed, making it impossible to tell which device is driving it at any given time. Variations in propagation time from one device driver to another can easily explain the observed 2 ns to 3 ns variation in falltime. The larger risetime variations are most likely caused by timing differences between cache and CPU cycles.

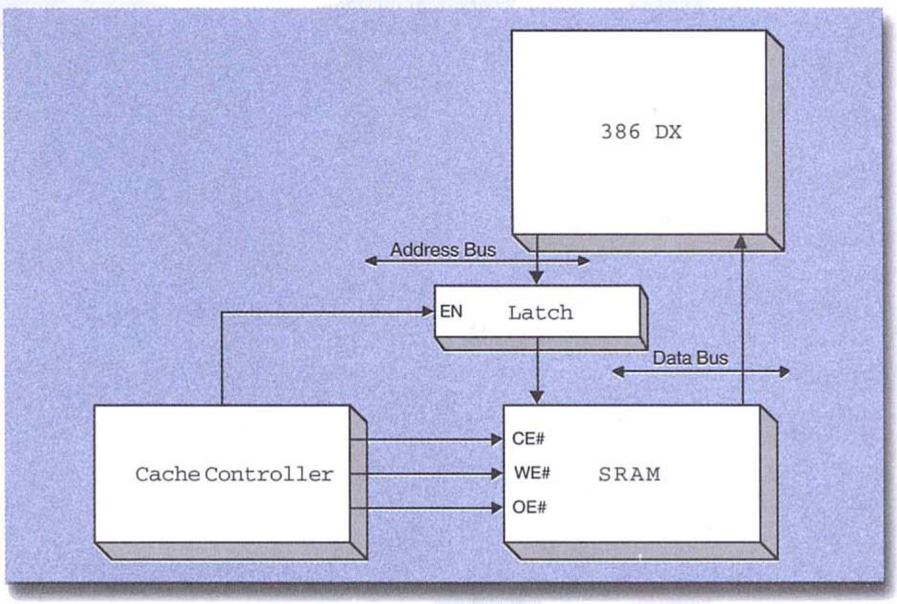


Figure 2. System cache configuration.

SELECTED APPLICATIONS

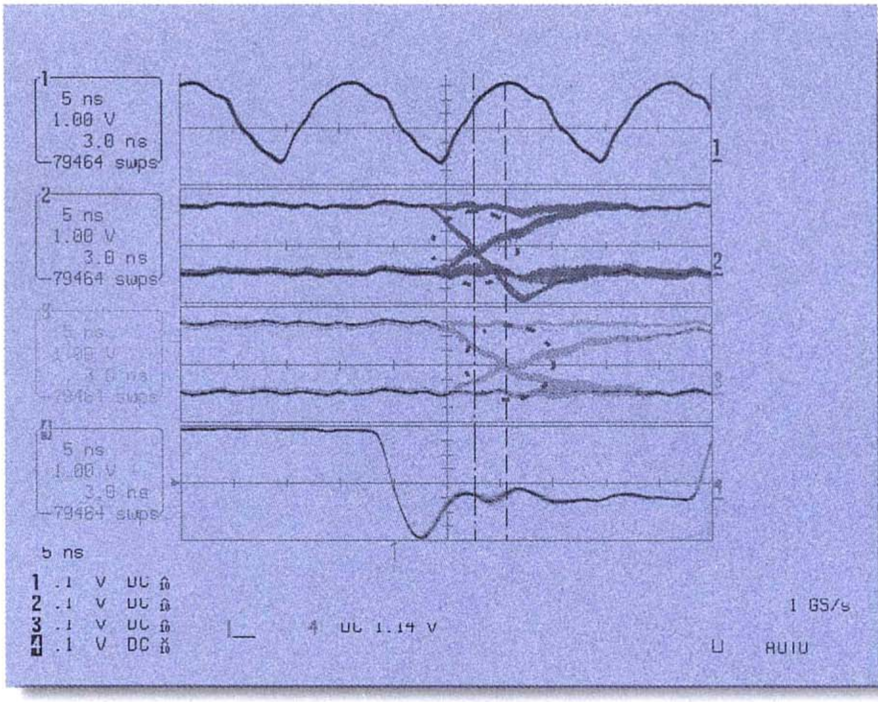


Figure 4. Comparing cache data lines on a read cycle. A 3 ns delay is measured between the crossing of the two data lines.

In general, viewing digital signals using a persistence display without the benefit of a qualifying trigger provides little useful information. In this case, observing the cache data and address lines— using a persistence display— while triggering on the cache output enable proves to be more effective.

Figure 4 shows the clock, data line D6, data line D4, and OE-. Using the scope's relative time cursors, a 3 ns delay is measured between the crossings of the two data lines.

Additional measurements indicate that the falling edge of data line D4, is slower than all other cache data lines. The slow edge may be the cause of the failure since the cache's SRAM chip requires a minimum OE- to data delay of 10 ns to meet the microprocessor's setup time specification.

The accumulated analysis results, leads to the conclusion that there is a cache read problem due to a defective SRAM. The SRAM is replaced; unfortunately, this does not solve the problem, which is as expected, since more than one board is failing in the same way! In the next steps, the signals are viewed using single shot acquisition, and the timing analyzed using the scope's automated measurement parameters.

Figures 5 and 6 show the Δt@lev parameter used to measure the delay from the falling edge of the cache output enable to both the rising and falling edges of D4 and D6. The Δt@lev parameter has the capability needed to accurately measure time delays between two signals with the flexibility of independently selecting for each signal: the reference level, the edge (positive, negative, or first edge), and a hysteresis setting.

Automated parameter measurements are performed on the signal region lying between the cursors. This provides the capability of measuring the timing on selected cycles.

By moving cursors from one cache read cycle to the next, the measurements show a small difference in risetime between two data bits. The falling edges of the data bits are of more interest since they exhibit a significant difference of more than 3 ns. Oddly enough, it is also apparent that there is no undershoot on D4 during cache reads.

It often proves helpful to quantify and develop an understanding of the repetitive nature of a problem. LeCroy scopes provide powerful statistical analysis capacities and the processing

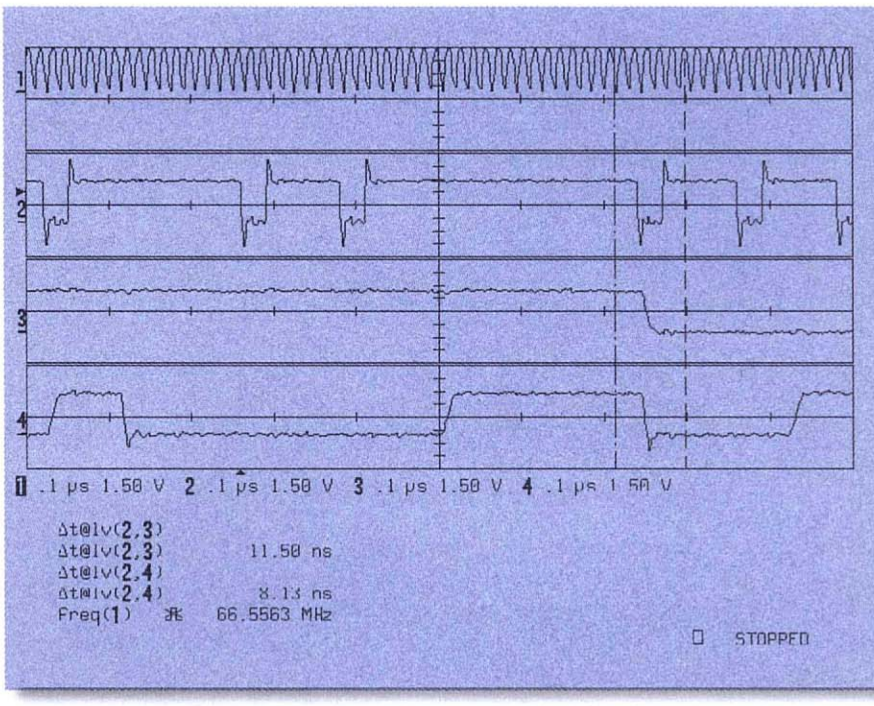


Figure 5. The Δt@lev parameter is used to measure the delay from OE- to the rising edge of the cache data lines. The parameters show measurements for the portion of the signal lying between the time cursors.

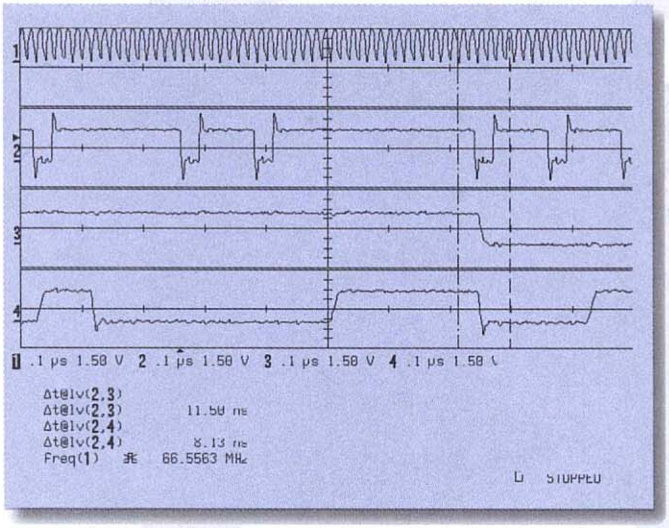


Figure 6, The Δt@lev parameter is used to measure the delay from OE- to the falling edge of the cache data lines.

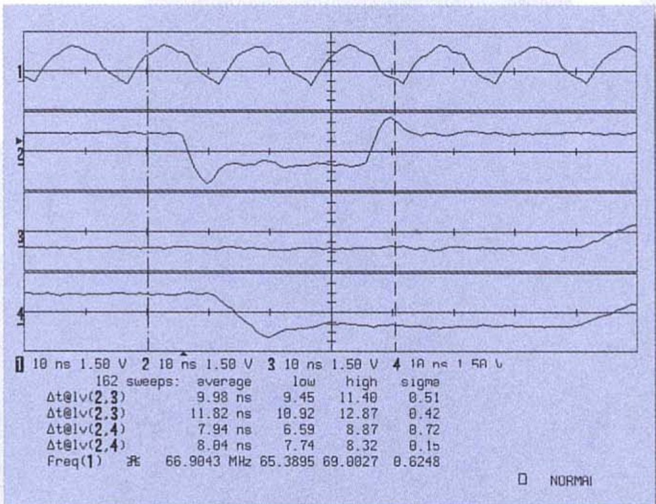


Figure 7. Parameter statistics are used to accumulate delay measurements over many sweeps. The top four parameter lines show the delay from OE- to the rising edge of D4, the falling edge of D4, the rising edge of D6, and the falling edge of D6, respectively.

power needed to collect automated parameter measurement statistics on selected parameters over many sweeps as shown in Figure 7.

The results show that over time, the average difference in falltime between the two data bits is approximately 3.8 ns (11.82 - 8.04). The standard deviation of the measured delay is relatively low, indicating that whatever the cause of the problem, it is very stable.

Based on the visual, parametric, and statistical results collected, it is reasoned that the problem is due to the PCB itself. Sure enough, a check of the trace for D4 between the SRAM and the CPU indicates that its impedance is greater then 200Ω! Such a high value would explain the extended falltime and the reduced undershoot. A jumper wire is used to bypass the suspected trace, and the failure is eliminated.

Case #2: Intermittent Failures

A microprocessor-based system, similar to that in Case #1, fails intermittently and generates sporadic DRAM parity errors. The failures appear to be unrelated to the operating mode and the memory diagnostic indicates seemingly random single and multiple bit errors.

The DRAM data and address buses are examined at the various failure points indicated by the diagnostic. A logic analyzer is used to verify important control signals while observing the buses; however, there is no indication of any logic related problems. Repetitive reading and writing to the failing locations does not provide additional insight.

The evidence thus far leads to the conclusion that the failure may be noise related. To gain additional insight, the multiplexed address bus is examined using a DSO, which can better measure the characteristics of the non-repetitive bus signals.

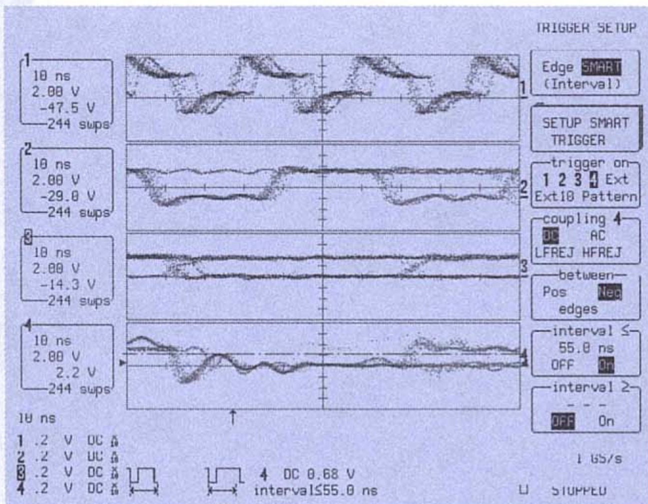


Figure 8. Using LeCroy's Interval Trigger and Analog Persistence to capture glitches on a DRAM address line (Trace

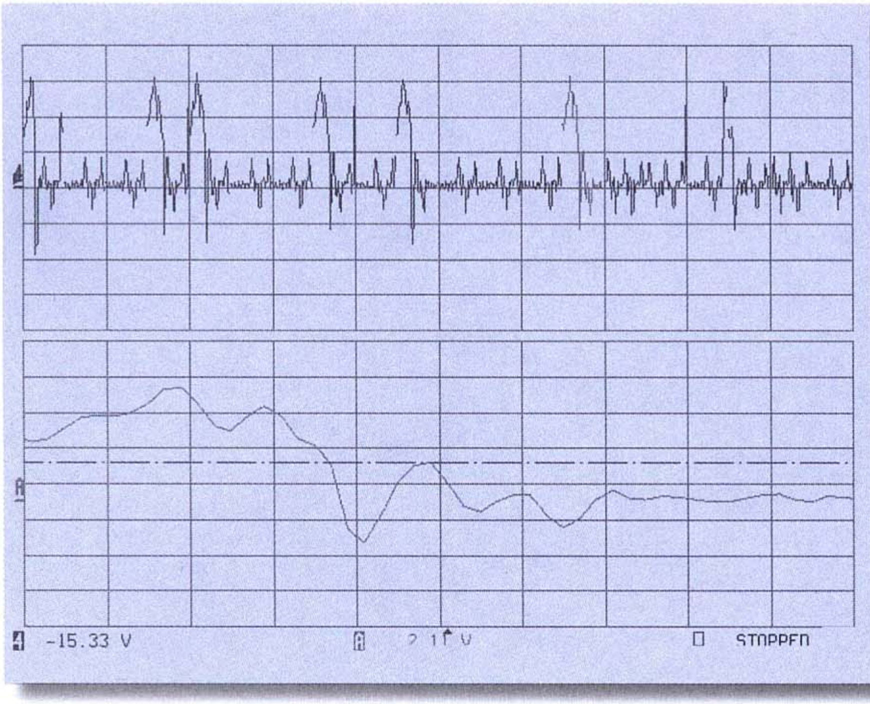


Figure 9. Sequence mode is used to examine a series of possible glitches. The Zoom trace A shows the details of a "bump" following a valid high-to-low transition.

A LeCroy LC574 scope, with SMART Trigger capability is used for further investigation. The interval trigger mode is selected to trigger the DSO when the interval between negative edges on the address bus is * 55 ns—slightly less than two bus clocks. Addresses will normally not change in less than two clock cycles unless there is a problem, which will result in triggering the scope. With this trigger setup we probe each address line until we find one that triggers the scope—indicating a potentially problematic address line.

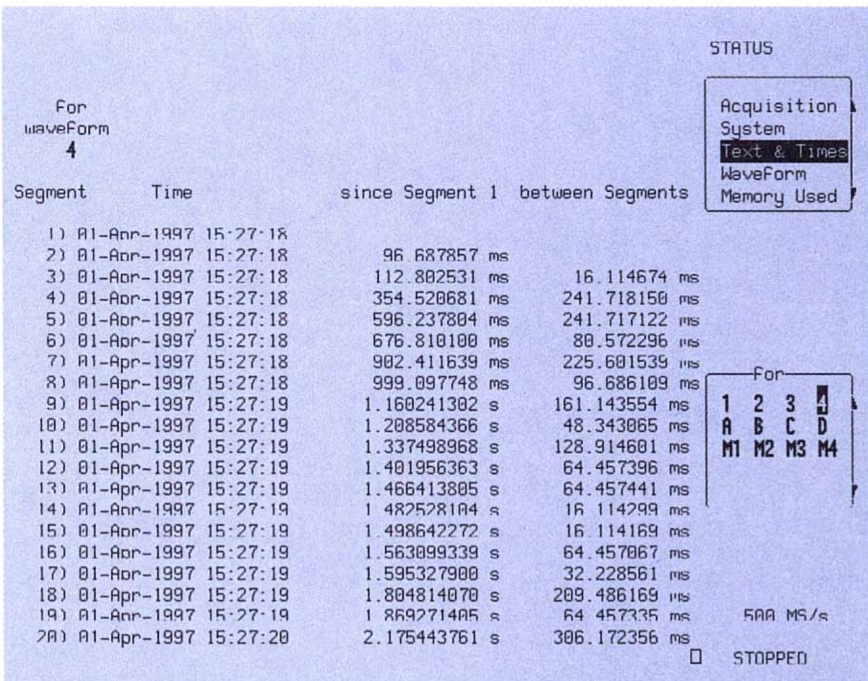
Figure 8 shows an Analog Persistence display of the 33 MHz bus clock, the low-asserted column address strobe (CAS-), address bit A1, and address bit A0.

We suspect that the unusual perturbations appearing on address line A0—shown in Trace 4—appear to be a problem. The perturbations appearing as bumps occur when CAS- is asserted and, as shown by the amplitude cursor, appear to exceed 2.0 V in some cases. Bit A1—displayed on Trace 3—exhibits proper behavior. LeCroy's Analog Persistence mode displays the events occurring most frequently with the highest trace intensity and those least frequently with the least intensity—similar to an analog scope display. The problem is easily seen with this approach. However, the cause is not yet understood. We must determine if the observed glitches are a result of transmission line effects, ringback, coupling, or another factor.

The appearance of glitches leads to the decision to use a glitch trigger, with suitable values for pulse duration (<12.5 ns) and level (0.5 volts). While it is difficult to maintain a stable display by triggering in this manner, the use of sequence mode makes it is possible to capture a number of signal segments for closer examination. Sequence mode, along with Lecroy's long record length, enables capturing up to 2000 segments in single-shot mode, minimizing acquisition dead time. The data, as well as the trigger time for each sequence, is stored, providing valuable debug information. As shown in Figure 9, each segment contains glitches that satisfy the glitch trigger condition.

Zoom Trace A is used to closely examine each of the captured segments to determine which ones contain the "problem" glitch. Note that the peak of the highlighted glitch is over 2 volts.

The scope's status display shown in Figure 10 indicates the time that each



Segment	Time	since Segment 1	between Segments
1)	01-Apr-1997 15:27:18		
2)	01-Apr-1997 15:27:18	96.687857 ms	
3)	01-Apr-1997 15:27:18	112.802531 ms	16.114674 ms
4)	01-Apr-1997 15:27:18	354.520681 ms	241.718150 ms
5)	01-Apr-1997 15:27:18	596.237804 ms	241.717122 ms
6)	01-Apr-1997 15:27:18	676.810100 ms	80.572296 ms
7)	01-Apr-1997 15:27:18	902.411639 ms	225.601539 ms
8)	01-Apr-1997 15:27:18	999.097748 ms	96.686109 ms
9)	01-Apr-1997 15:27:19	1.160241302 s	161.143554 ms
10)	01-Apr-1997 15:27:19	1.208584366 s	48.343065 ms
11)	01-Apr-1997 15:27:19	1.337498968 s	128.914601 ms
12)	01-Apr-1997 15:27:19	1.401956363 s	64.457396 ms
13)	01-Apr-1997 15:27:19	1.466413805 s	64.457441 ms
14)	01-Apr-1997 15:27:19	1.482528104 s	16.114299 ms
15)	01-Apr-1997 15:27:19	1.498642272 s	16.114169 ms
16)	01-Apr-1997 15:27:19	1.563099339 s	64.457067 ms
17)	01-Apr-1997 15:27:19	1.595327900 s	32.228561 ms
18)	01-Apr-1997 15:27:19	1.804814070 s	209.486169 ms
19)	01-Apr-1997 15:27:19	1.869271405 s	64.457335 ms
20)	01-Apr-1997 15:27:20	2.175443761 s	306.172356 ms

Figure 10. This status display shows time stamps with 1 ns resolution for each acquired segment. The captured glitches are occurring at 16 ms intervals.

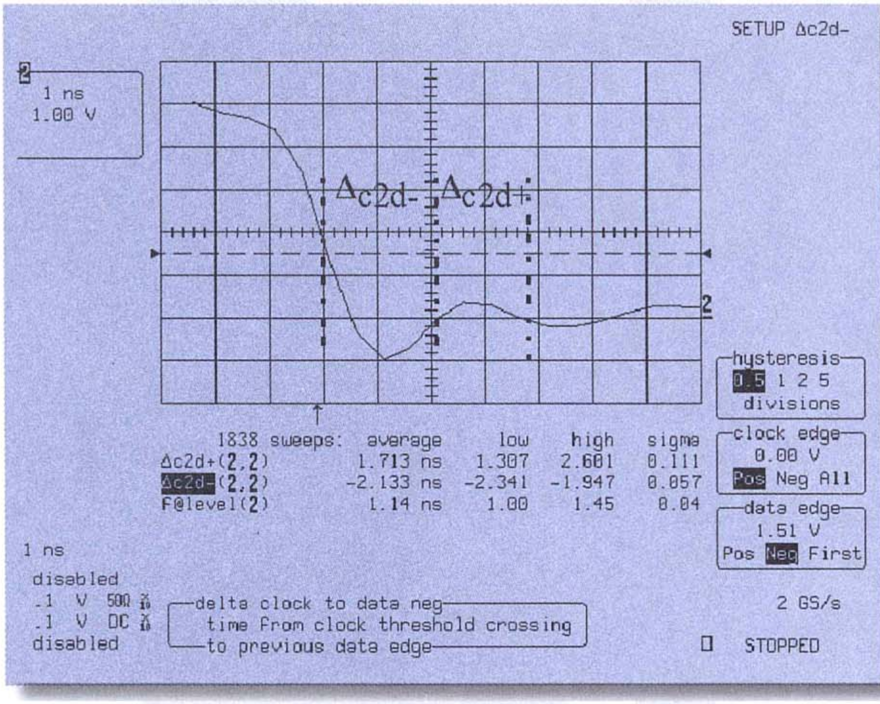


Figure 11. LeCroy LC574 display showing the high-to-low transition of a data line. Automatic parameters are used to measure ringback duration, ringback delay, and edge rate, respectively.

of the segments was acquired. From the times displayed, it is immediately apparent that many of the segments occur at relative times which are multiples of 16 ms—the DRAM refresh period!

Based on these results, the DRAM controller is carefully evaluated and replaced thereby eliminating the problem.

Evaluating Signal Quality

The qualities of signals on high-speed buses ultimately limit the performance of digital systems. Transmission line effects and noise can severely distort signals, reducing noise margins and introducing excessive delay.

Some capabilities to consider when selecting a scope for evaluating signal quality include the typical performance related characteristics such as bandwidth and sample rate. Capabilities to look for include those that aid in improving your productivity such as flexible and powerful processing, parameter measurements as well as the tools—histograms, trends, statistical analysis, pass/fail limit and mask testing—that help you interpret the measurement results. Display capabilities such as LeCroy's Analog Persistance display mode can prove to be effective as a qualitative indicator of signal quality and behavior.

Overshoot and Ringback

Overshoot and ringing are transmission line effects associated with fast edge transitions. Large overshoot values can lead to component failure as a result of exceeding specified voltages limits. The ringback characteristic, which is a transition in the opposite direction from the overshoot, can reduce timing margin in high-speed logic circuits.

Figure 11 shows the high-to-low transition of a data signal on a LeCroy LC574 DSO. Automatic parameters are effective in evaluating several important ringback characteristics; The Δc2d+ and Δc2d- parameters are used to measure the ringback pulse's duration and

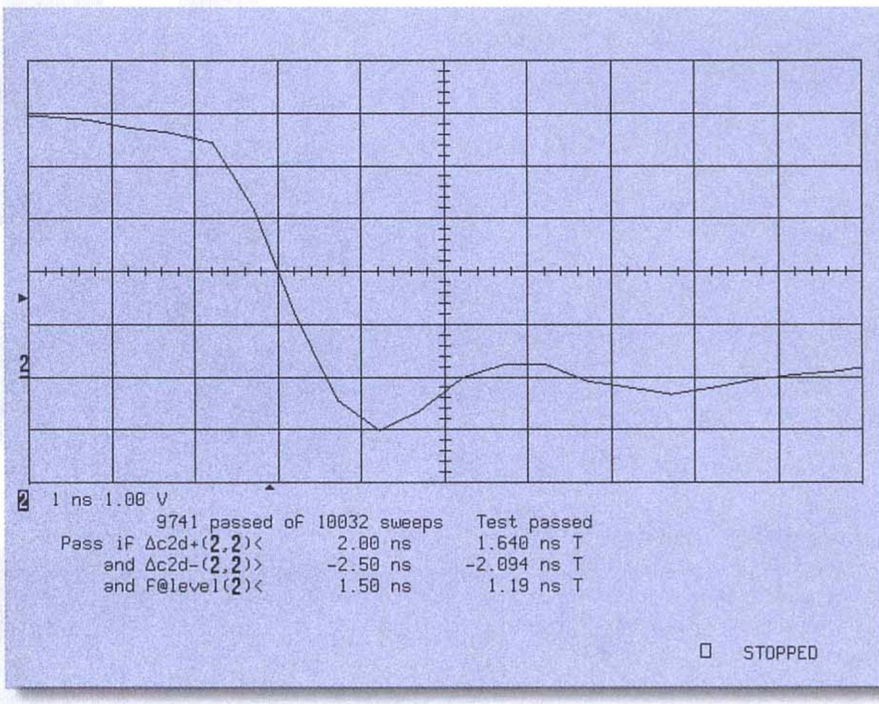


Figure 12. Automatic testing is setup to pass as long the three timing parameters are within the specified threshold values. Various actions can be taken upon failure such as halting execution, dumping the DSO screen to a printer, or transferring captured values via GPIB.

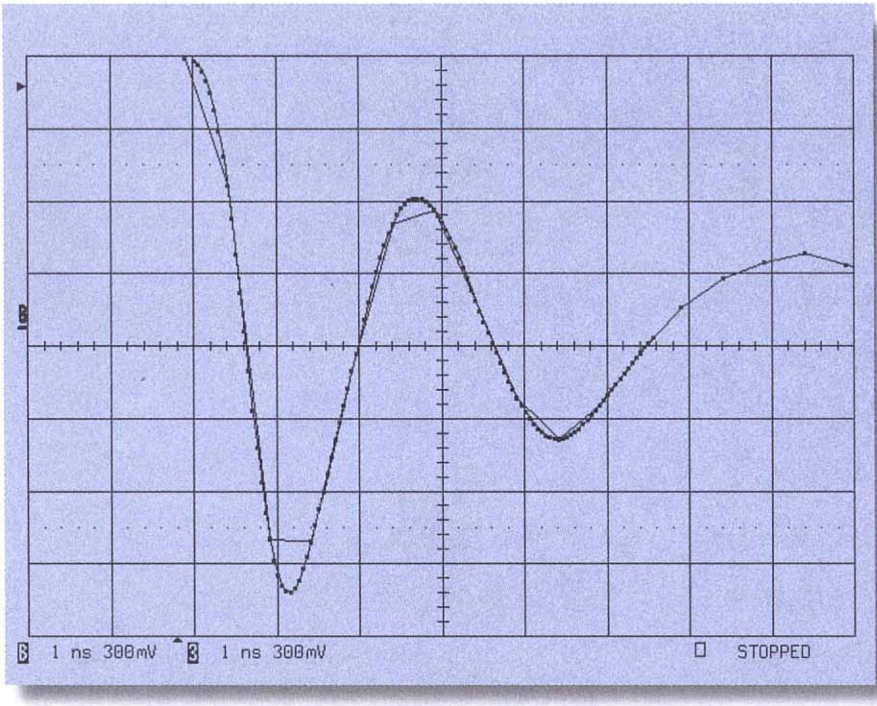


Figure 13. A trace shows a signal using e linear interpolation—the default display mode on LeCroy DSOs. The smoother trace uses the sin(x)/x math function to create the line between sample points. The dots show the 2 GS/s sample points.

delay, respectively. The f@level (falltime between two specified voltage levels) parameter is used to measure the signal's edge rate (Δv/Δt). These three measurements are key to determining the impact ringback will have on setup time at the receiving device.

Although the Δc2d- and Δc2d+ parameters are typically used to measure the setup and hold time between signals, they are effective in measuring other types of timing characteristics as well. In this example, Δc2d- and Δc2d+ are used to measure two intervals on the same signal. Two edge thresholds can be set for each parameter. The falling edge of the Δc2d- parameter is set to 1.5 volts, the switching threshold for the data signal, and the rising edge threshold is set to the zero crossing. For the Δc2d+ parameter, both edge thresholds are set to the zero crossing. This measurement indicates a ringback delay of -2.1 ns and ringback duration of 1.6 ns. The negative sign indicates the direction of the delay as measured relative to the zero crossing.

The f@level parameter also provides a dual threshold setting. Looking at the signal between 4 V and the zero crossing results in a fast dv/dt measurement of approximately 3.5 V/ns (4 / 1.14).

Parameter measurements, when coupled with the pass/fail test capabilities of LeCroy oscilloscopes, provide a simple method of quantifying problems. Figure 12 shows an example of the three parameters set to pass when they are within specified threshold limits. In this case, 97% of the sweeps are within the set limits. The LC574 permits any combination of five parameters and masks to be used for pass/fail testing. (Masks will be discussed shortly.)

Interpolation Considerations

The signal's fast edge time, the 1 ns timebase setting, and the linear interpolation setting of the DSO results in the somewhat jagged appearance of the signals shown in Figures 11 and 12. The 2 GS/s sample rate is fast enough to faithfully capture the signal which has a 20% to 80% risetime of slightly over 1 ns. DSOs can also utilize a sin(x)/x interpolation to smooth the displayed signals. The type of interpolation used will generally not impact

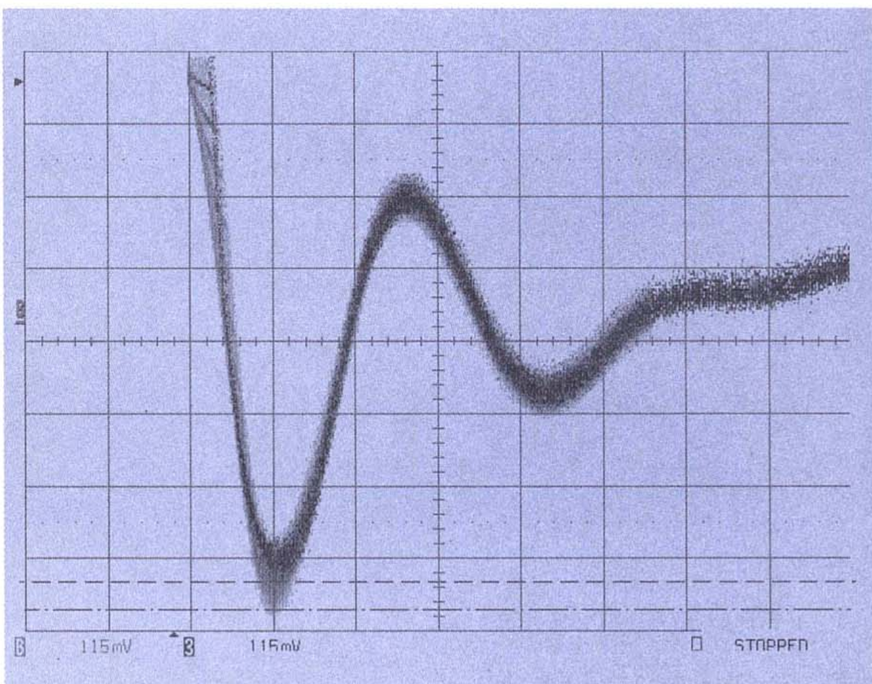


Figure 14. An Analog Persistence' display is used show the error introduced by sin(x)/x interpolation over many sweeps. The relative time cursors show an error in the undershoot measurement of 115 mV.

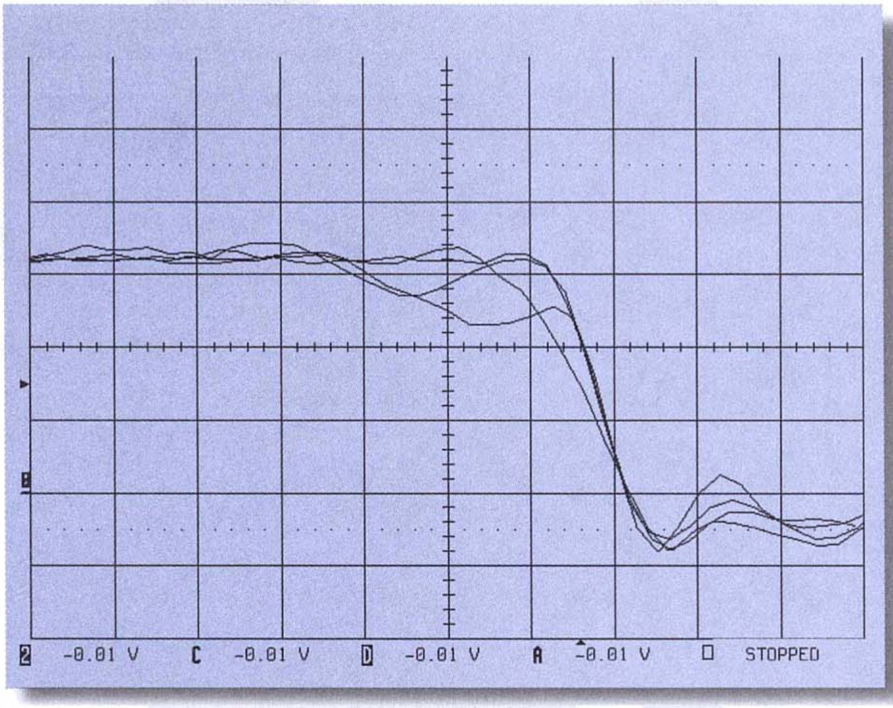


Figure 15. Several sweeps of an address bit are stored to memory and then displayed simultaneously. At first glance, it is difficult to determine what is causing the distortion on the signal edge

time measurement accuracy as long as an adequate sample rate is used. However, caution should be used with sin(x)/x interpolation when measuring transmission line effects such as undershoot or overshoot.

Figure 13 shows a ringing signal with both linear and sin(x)/x interpolation. Whenever sample points fall near the peak of the undershoot, the sin(x)/x function introduces significant error.

The same signals are shown in Figure 14 using an Analog Persistence display.

Over many sweeps, the magnitude of the error becomes apparent. The relative amplitude cursors show a 115 mV over-estimate in the undershoot when using sin(x)/x interpolation. This represents a 9% to 10% measurement error.

Noise

Noise on digital signals results from many sources including power plane disturbances, such as ringing and ground bounce, as well as coupling effects such as crosstalk. Noise can cause subtle timing problems that are difficult to characterize. Parameter measurements, histograms, and Analog Persistance, are effective tools for analyzing noise-related timing problems.

Figure 15 shows an SRAM's address bit. The timing budget for the bus cycle assumes a maximum address transition time of 2 ns to meet the setup time requirements for address to write enable. The DSO was used to capture the signal with a single shot acquisition. Several acquisitions were made, stored to memory, and then displayed simultaneously as shown. It appears that one of the acquisitions captured a signal with a slow falltime. Other acquisitions indicate that there is some distortion on the signal close to the falling edge.

Examining a neighboring device reveals that several data bits are switching simultaneously, a few nanoseconds before the address transition. Traces 2 and 3 of Figure 16 show the address bit and a data bit, respectively, using Analog Persistence. An interval trigger—set to 100 ns—was selected for Trace 2 in order to prevent the acquisition of runts resulting from canceled bus cycles. Including the runts in the

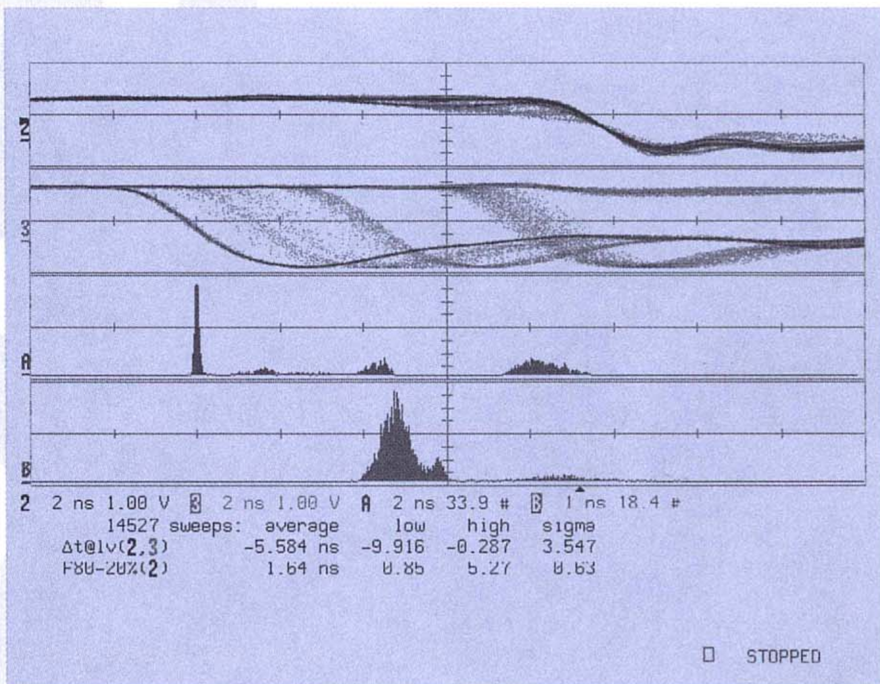


Figure 16. A switching data bus on a neighboring device, represented by Trace 3, is the likely cause of the signal edge distortion on Trace 2. Histograms in Traces A and B imply a relationship between the switching time and the falltime of the address bit.

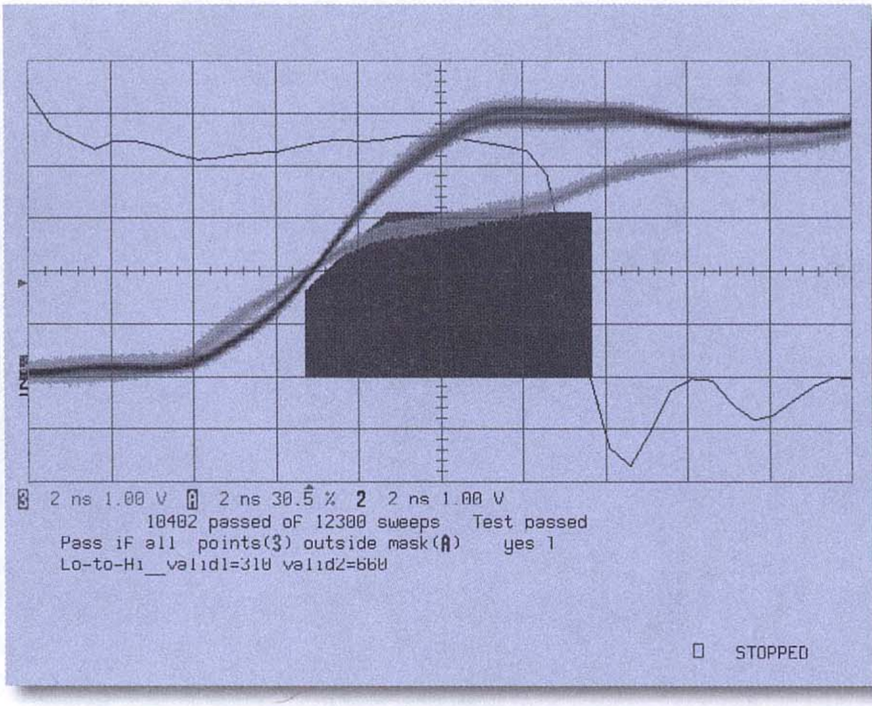


Figure 17. The distorted edge of an address bit, shown using Analog Persistence, intrudes on the mask in 15% of the sweeps during automatic pass/fail testing.

display would obscure the edge variations that are occurring on valid bus cycles.

There appears to be a strong correlation between the edge variation on the address and the later transitions on the data bit. The histogram displayed on Figure 16 Trace A shows a distribution of delays between the falling edge of the address bit and the data bit. Several peaks are observed with the largest at approximately 8 ns. The smaller peak, centered at about a 2 ns delay, is the most likely source of trouble. Several of the other data bits (not shown) have similar distributions.

Trace B shows the histogram for the 80% to 20% fall time for the address bit. The distribution indicates that the falltime is within the specified 2 ns window most of the time. On occasion, the falltime is greatly increased to as much as 5 ns.

It appears that the falling edge of the address is being disturbed whenever several of the data bits switch together just before the address becomes valid. The problem is surely due to noise induced on the address bit by transitions on the data bus, but it is difficult to determine if coupling internal to the SRAM, ground bounce, or crosstalk between PCB traces is the true culprit.

Signal Edge Distortion

Transmission line effects and noise can work in combination to distort the edge transitions of signal drivers. Slow or distorted signal edges can reduce timing margin in a similar way as ringback related effects. As a result of these effects, some microprocessor manufacturers specify signal edge quality including the regions in which the signal edge must not intrude.

Any high-performance oscilloscope can be used to assess the quality of the signal edge by way of visual inspection. However, some DSOs offer capabilities that make this measurement task easier and more accurate.

Figure 17 shows an address bus signal and the bus clock. The address bit is shown using LeCroy's Analog Persistence display (signal going from lower left to upper right), which enables observing the signal's history over many sweeps.

The black area in the center of the display is a mask defining a non-intrusion region for the low-to-high transition of the address in reference to the active edge of the clock. Considering the device specifications, the width of the mask is selected such that:

W = Tsu + Thd

Tsu and Thd represent the address setup time and hold time to the clock, respectively. The slope of the upper left side of the mask is set to 0.3 V/ns, the minimum acceptable edge rate. Device-specific reference voltages determine the left and top edges of the mask.

The mask shown in Figure 17 was generated with a simple PC-based utility supplied as freeware for use with LeCroy oscilloscopes. The figure shows that, most of the time, the address bit avoids the non-intrusion region defined by the mask. Using the mask for automatic pass/fail testing reveals that the address line exhibits a slow, distorted edge about 15% of the time. These results are likely caused by differences between drivers and signal paths on the multiplexed address bus.

Summary:

Debug and Characterization

Most oscilloscopes with adequate bandwidth may be used to debug simple timing problems. Debugging nonrepetitive bus operations requires the single-shot acquisition capability of a DSO with sufficient sample rate to view signal details.

Color-graded as well as Analog Persistence displays can be used effectively to view anomalies on digital buses. However, it is difficult to characterize glitches and infrequent unique events when using simple edge triggering. The powerful triggering capability provided by a DSO is the key to capturing and characterizing elusive events.

Advanced DSO measurement capabilities including automated parameters measurements, parameter statistics, histograms, and time stamping are essential characterization tools that can simplify and reduce the time required to debug digital systems.

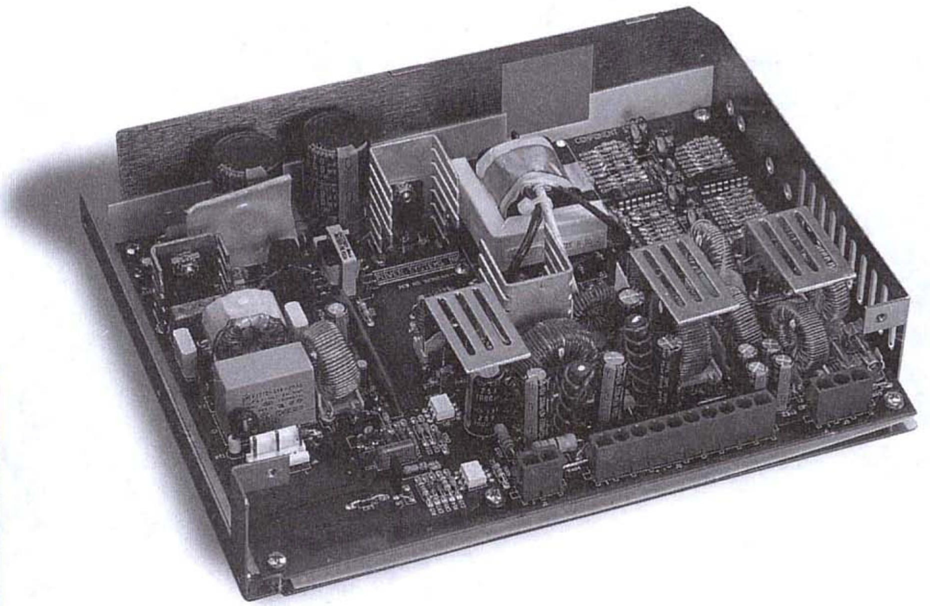
Assessing Signal Quality

Visual analysis provides both a subjective and quantitative method of assessing signal quality. However, visual analysis does not result in the measurement ease, repeatability, or ease of analysis provided by LeCroy's DSOs.

As manufacturers develop new signal specifications that must be achieved for optimizing speed, performance and quality, the measurement and evaluation of signal details is of greater importance then ever before.

A DSO must have the flexibility and analysis capability needed to respond to rapidly changing requirements while avoiding obsolescence.

Benefits of Digital Oscilloscopes in Power Supply Design & Test



This technical note focuses on the uses of digital scopes for measuring power supply characteristics. Examples are given of measuring power supply turn-on, hold-up time when AC power fails, in rush current and ripple/noise. Examples are given of Pass/Fail testing and power calculation. There is also a brief discussion of triggering and of the possibility of storing test sequences.

Introduction

The last decade has seen dramatic improvements in power supplies and particularly in switch-mode power supplies. Due to improvements in power MOSFETs, regulators and control circuitry, switching power supplies are becoming smaller with power densities already greater than one watt per cubic inch and efficiencies reaching 90%.

As with many other technologies, the product life cycle is shortening rapidly, and manufacturer competition is becoming tougher. When the designs are very similar, a shorter time-to-market (for a new product), or a shorter production cycle, can make the winning difference. Test time, for instance, can now be reduced by using the latest developments in digital oscilloscopes. We describe here a number of applications where digital oscilloscopes can considerably shorten design and test times.

Benefits of DSOs

As with analog oscilloscopes, the primary job of a digital oscilloscope is to display the input waveforms. Unlike analog oscilloscopes, the technique used to achieve this is to sample the input waveforms at regular intervals. The sampled analog values are then converted into digital numbers which in turn are stored into an internal memory. An input waveform is stored in the scope as a sequence of numbers, as many as the memory length. The waveform display is done by retrieving these numbers and representing them on the screen.

The use of this digital technology has many implications. Those which affect power supply testing include the following:

- Multi-channel single-shot capture: A DSO can capture single-shot phenomena like power ON/OFF or failure conditions synchronously on up to four channels at the same time.
- Waveform processing: Since the DSO internally uses a microprocessor, it can also perform various types of processing on the acquired waveform.

For example, automatic calculation of pulse parameters and basic waveform mathematics (sum, difference, product, ratio) are standard features of all LeCroy DSOs. More advanced diagnostic mathematics like integral, derivative, exponential, logarithm, extended averaging, digital filtering, extreme values and Fast Fourier Transform are also available.

- Data storage and archiving: LeCroy DSOs have built-in memories which can store reference waveforms. They also offer DOS-compatible memory card, portable hard drive and floppy-disk options for non-volatile mass storage. The scopes offer an optional, high-speed internal graphics printer and can be easily interfaced to a large variety of plotters and printers for high-quality hard copies. The user can download the data and screen graphics as TIFF files directly into Microsoft Word or other publishing software.
- More trigger possibilities: DSOs also offer a wealth of trigger capabilities not found in analog oscilloscopes. For instance, it is possible to trigger on faulty conditions and look at pre-trigger data to understand the history leading to the fault.

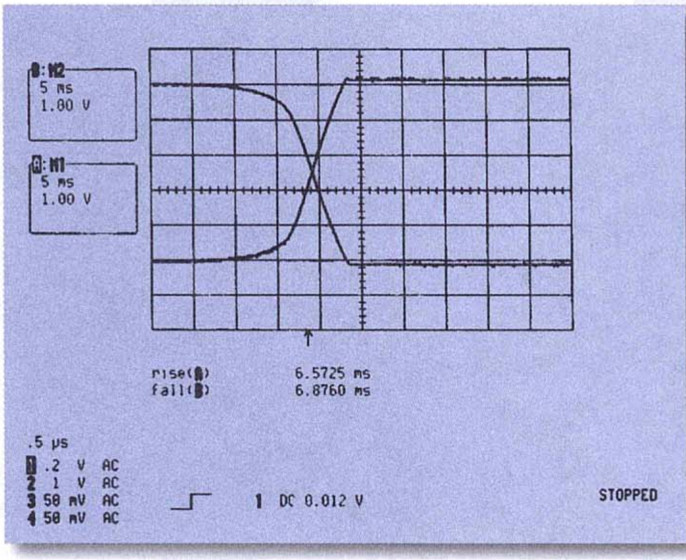


Figure 1: Switch-on transition of a dual output power supply (+5 V and -5 V). Symmetric behavior of the two voltages is often required. The automatic calculation of pulse parameters (rise and falltimes in this case) simplify this test.

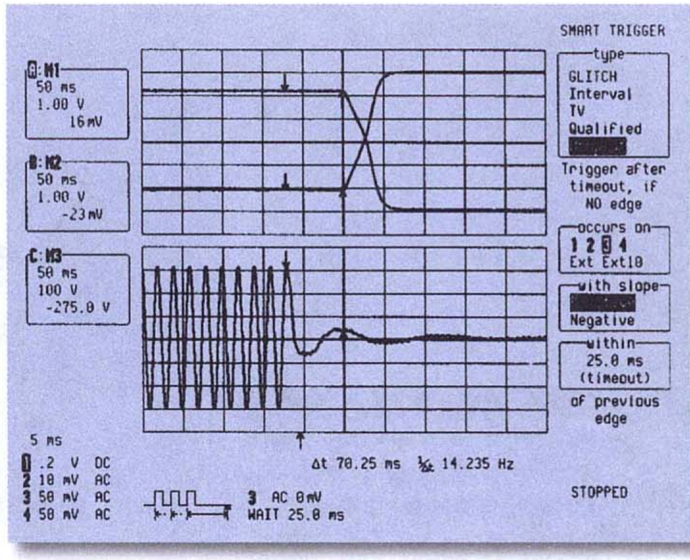


Figure 2: Measurement of the hold-up time. LeCroy's Dropout trigger mode is used, causing the scope to trigger on the mains drop which occurs at the left of the lower trace.

- Stored test sequences: All LeCroy oscilloscopes offer the facility to store entire instrument setups in internal, non-volatile memories. Many more setups can be stored on to memory cards, portable hard drive, or floppy disks, depending on what mass storage option is installed. These setups can be easily recalled either manually or under computer control. The user can then recall these predefined setups as part of a fully automatic (or semi-automatic) test sequence, eliminating the need for time-consuming manual adjustments.
- Automatic Pass/Fail testing: LeCroy DSOs provide two kinds of automatic testing. The user can define a mask waveform and specify that any input waveform must be contained within the mask. Alternatively, the user can select a set of waveform parameters which will be automatically calculated, and compare them to predetermined limits. If the waveform or the parameters fall outside the desired limits, a number of actions can be taken, including: freeze the display (for visual inspection); screen-dump to a printer or waveform storage to disk, portable hard drive or memory card; send an interrupt to a computer; produce an audible alarm. The DSO also tracks the statistics of passing and failing events.

Monitoring at Power-On

Figure 1 shows the Power-On transitions in a multi-voltage power supply. The simultaneous monitoring of all these transitions is useful to verify that any phase shifts are within acceptable limits. In fact, any voltage imbalances could be damaging to the load circuits. The switching time can also be automatically calculated, as shown in the figure.

Hold-Up Time

The hold-up time is the time for which the output voltage remains stable, at full load, after the loss of AC power. A digital oscilloscope is the ideal instrument for measuring this because of both the powerful trigger system and the single shot capture capability. (An oscilloscope with deep memory is normally required.)

Figure 2 shows such a hold-up time. The trigger condition used is LeCroy's Dropout trigger. As shown at the bottom of the display, the scope triggers when the pulse train on Channel C (the AC line) disappears for longer than 25 ms. The trigger conditions are also shown on the trigger setup menu, at the right of the display. The cursors positioned on the waveforms measure a hold-up time of about 70 ms.

In-Rush Current

At power-on, the input current absorbed by the power supply has a spike which should not exceed the maximum allowable input current. The upper trace in Figure 3 shows an example of in-rush current. The lower trace shows the simultaneously acquired input voltage.

The oscilloscope used, a 9314CM, utilizes a bi-slope trigger, as shown in the trigger icon, at the bottom of the screen. That is, the oscilloscope would trigger on Channel 1 for whatever slope of the input pulse, provided it exceeds +0.5 V. The oscilloscope can test the In-Rush current automatically and in two different ways. It can calculate the current peak value and verify that it is smaller than a preset limit.

Alternatively, it can compare the full current waveform with a reference mask. If the test fails, that is, if the in-rush current exceeds the set limits, several actions can be taken.

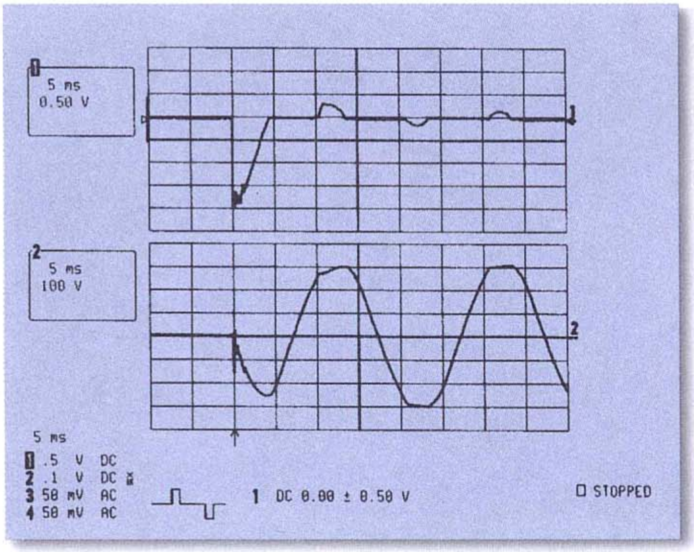


Figure 3: The in-rush current of a switching power supply (upper trace) is shown together with the input voltage. LeCroy's Bi-slope trigger is used to trigger on current transitions of any slope.

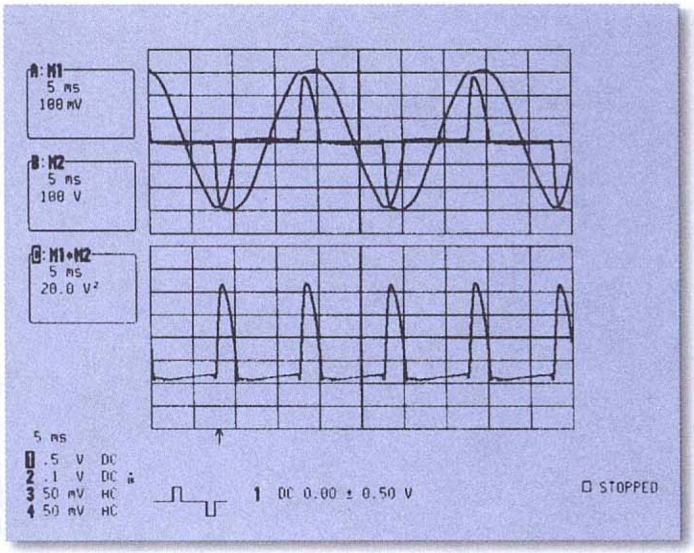


Figure 4: The power supply input voltage and input current (upper traces) are multiplied to provide the input power (lower trace).

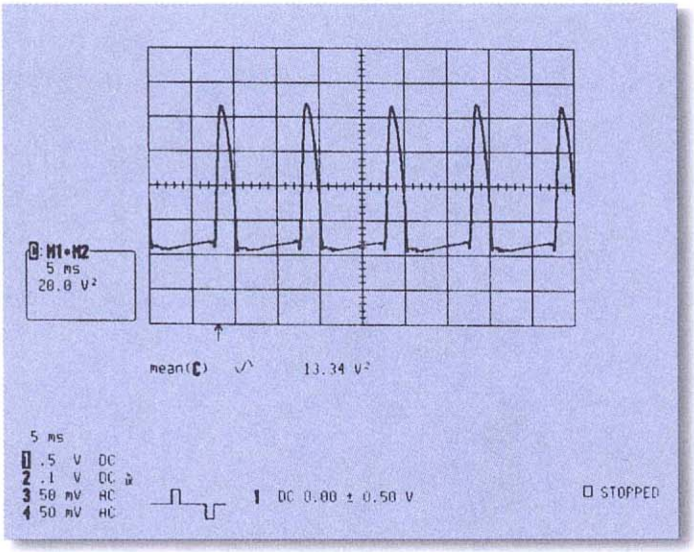


Figure 5: The same power waveform as in Figure 4 has been used to automatically calculate the mean value of the power.

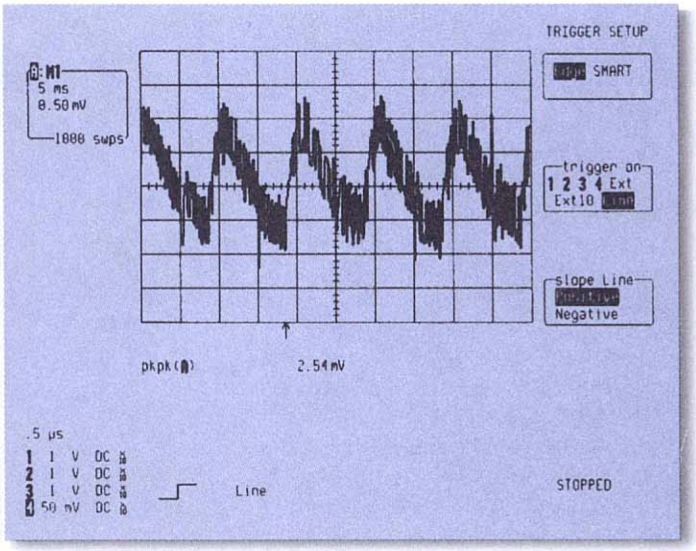


Figure 6: The output ripple is measured by averaging 1,000 acquisitions using Line trigger. A peak-to-peak voltage of 2.5 mV is automatically measured.

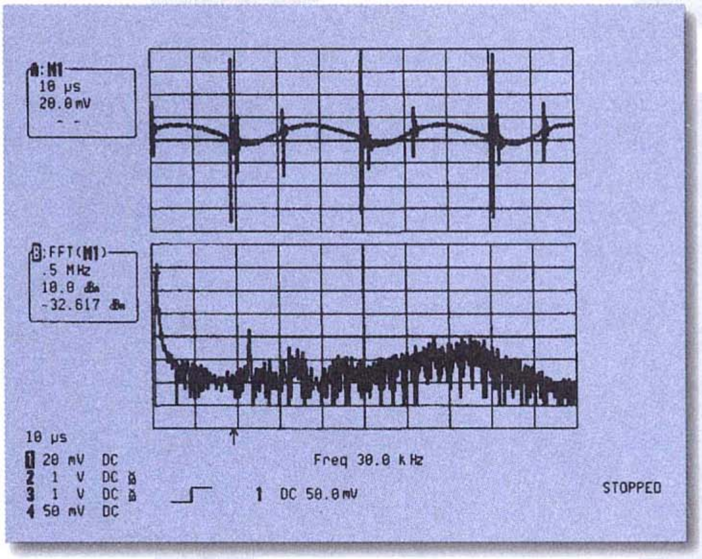


Figure 7: The high-frequency noise induced by the power switching. The Fast Fourier Transform (lower trace) shows frequency components at much higher frequency than the switching frequency indicated by the cursor (30 kHz).

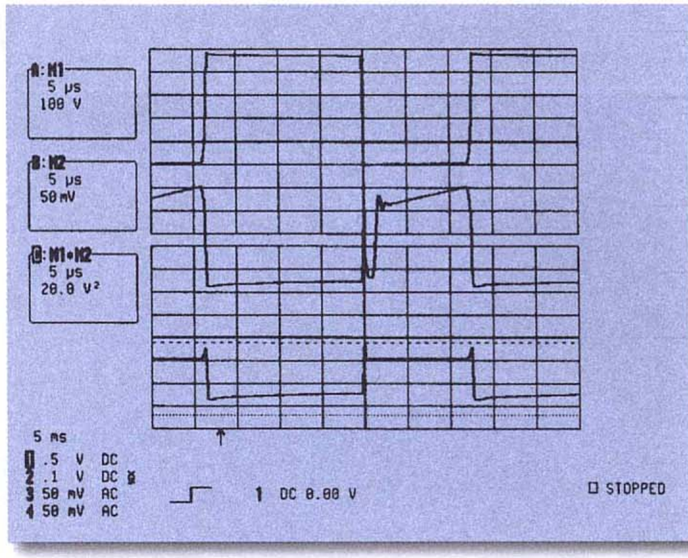


Figure 8: Voltage and current across the switching element. The product of the two gives the power waveform at the bottom. The oscilloscope can perform a Pass/Fail test on the peak power, alerting the operator when violations of the Safe Operating Area are found.

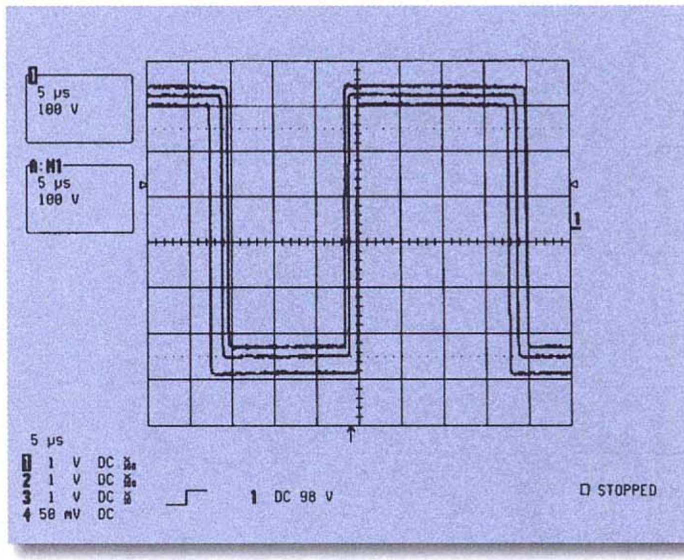


Figure 9: Automatic Pass/Fail test on the PWM waveform. The scope automatically tests that any input signal (inner waveform) lies inside the two outer waveforms (reference mask). Actions can be taken in case of failure.

Power Calculation

The oscilloscope can be used to compute power. This is shown in Figure 4 where the two upper waveforms are respectively voltage and current at the input of a power supply. These two waveforms are multiplied point-by-point to provide the power waveform at the bottom.

Figure 5 shows again the same power waveform together with the mean value of the power, automatically calculated below the grid. The ratio of the output power (a DC value) to the mean value of the input power would provide the power supply efficiency.

Ripple and Noise

Figure 6 shows an example of ripple measurement (i.e. a measurement of the remaining AC component on the output). The displayed trace is obtained using Line trigger, and averaging the input waveform on Channel 1 a thousand times, to remove the asynchronous noise. The scope automatically calculates the peak-to-peak ripple value of 2.5 mV, which is displayed below the grid.

Figure 7 shows a single-shot measurement of the high-frequency switching noise (upper trace). The bottom trace shows the Fourier transform of the in-put waveform which can be calculated even though this was taken as a single shot. The frequency analysis of the output noise can give valuable information about the origin of the noise.

Safe Operating Area

In a switching power supply, the switching transistor(s) is probably the most stressed component, and it is often important to verify that its working points lie inside the Safe Operating Area.
The upper trace in Figure 8 shows the collector-to-emitter voltage of a switching transistor, while the middle trace is the emitter current. The bottom trace is the product of the previous two traces, and it shows, therefore, the power dissipated inside the transistor. The two horizontal cursor lines show the limits imposed by the Safe Operating Area.

Automatic Pass/Fail Testing

The Safe Operating Area test just described can also be done completely automatically. The user selects the "Peak-to-Peak" parameter and applies it to the third (dissipated power) trace of Figure 8. He can then specify that this peak-to-peak power must be, for

Power Supply Regulation Measurements Using Trend Plots

Trend plots, which are available in LeCroy oscilloscopes, graphically display up to 20,000 individual parameter measurements on each trace.

Any of over 100 available parameters can be used as a source of the trend plot. When two trends are cross-plotted on an X-Y display, the functional relationships between the two parameters can easily be examined. As an example, consider Figure 10 which shows the pulse width of a switching power supply regulator as a function of the RMS line voltage input. This plot includes data for three different values of output load current. Each of these trends (Trms[A] or Twidth[D]) contains 200 measured values. Trend plots are setup by defining one of the zoom/math traces using the ZOOM+MATH menu as shown in Figure 10.

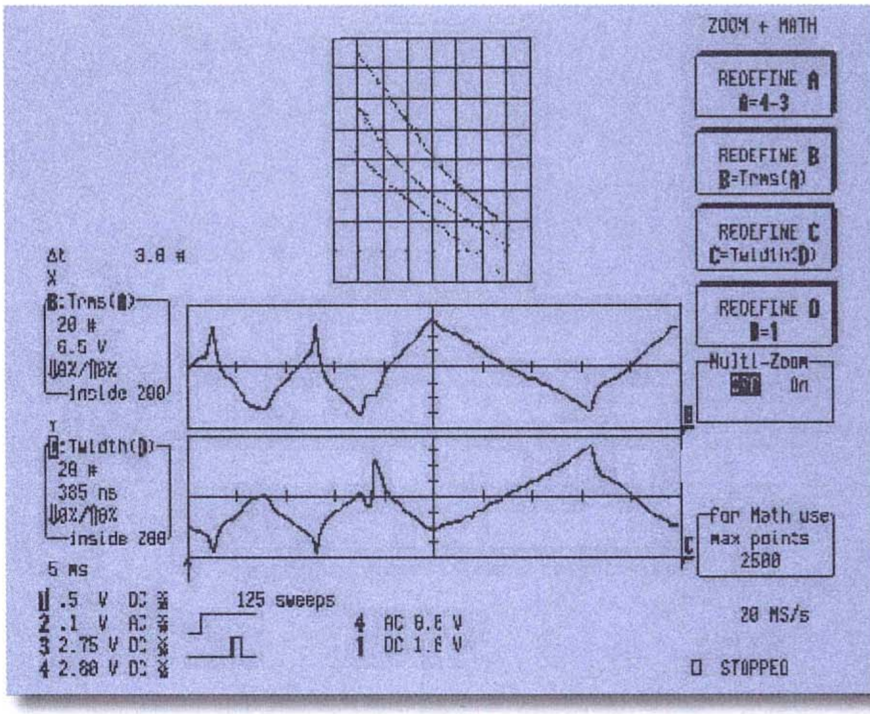
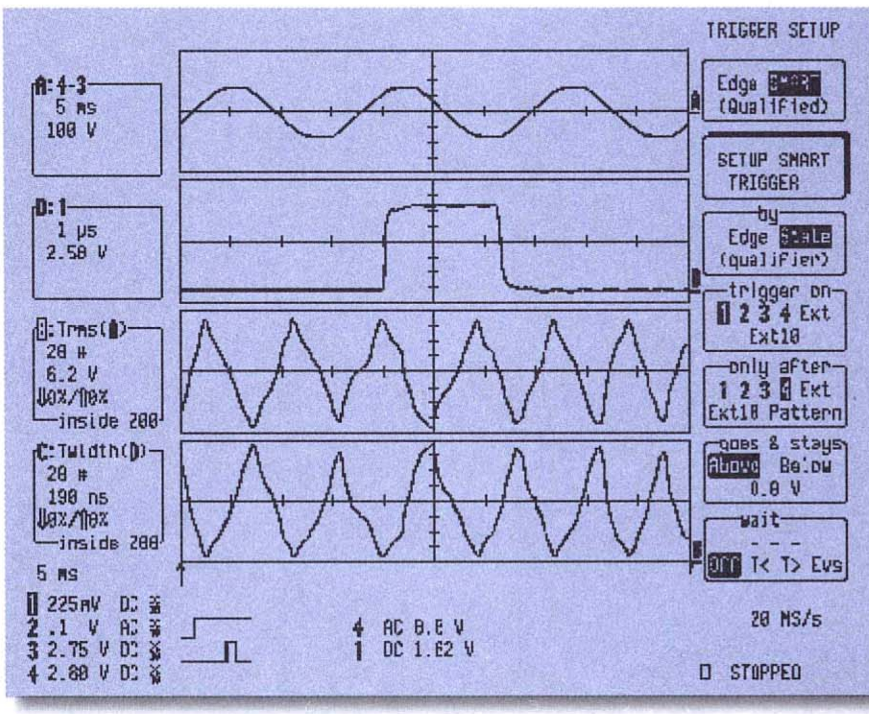


Figure 10: A cross-plot of power supply regulator pulse width as a function of RMS line voltage with output load current as a parameter. Infinite display persistence retains all 3 cross-plots.

It is easy to see from the XY plot at the top of Figure 10 that the regulator pulse width (vertical axis) and input voltage (horizontal axis) are related to each other and that increasing line voltage results in decreasing pulse width. As the output load current was increased, the plotted data moved upward indicating that the pulse width increases with increasing load. This type of analysis also depends on several other features in the oscilloscope. First, the two parameters are measured over vastly different timing intervals. We use LeCroy's SMART Trigger to keep the measurements synchronous. A qualified trigger is used so that the oscilloscope is triggered on the first regulator output pulse after a line voltage zero crossing. This guarantees that the pulse width and RMS voltage measurements are correlated in time. Similarly, because of the difference in timing intervals, this measurement requires the use of very long memories. Note that we are sampling the data at 20 MS/s for a total time of 50 ms. This means that the oscilloscope is acquiring over 1,000,000 samples (50 ms * 20 MS/s = 1 MS). If this memory were not available, then the sam-

Figure 11: The trigger setup for the measurement.



pling rate would have to be decreased and timing resolution would suffer.

The basic setup for this measurement is shown in Figure 11. The input voltage to the supply is measured differentially. We subtract the neutral side of the line (Channel 3) from high side (Channel 4). This could also be done using a differential amplifier or differential probe. We also use a zoom display to look at a single regulator output pulse. The trend data is accumulated on the RMS value of the line voltage and the width of the regulator pulse width. Figure 12 shows another example of a cross-plot of trend data. Here, the pulse width of the regulator is plotted as a function of the output load current. This cross-plot shows evidence of the non-linear characteristics of the power supply transformer. Trend plots eliminate the need to make and record a large number of individual measurements. The oscilloscope makes the measurements automatically and plots the values in the order the values are taken. Multiple trends, acquired simultaneously, can be cross-plotted as shown in the examples. Once set up, the trend plots are generated automatically as the data is acquired.

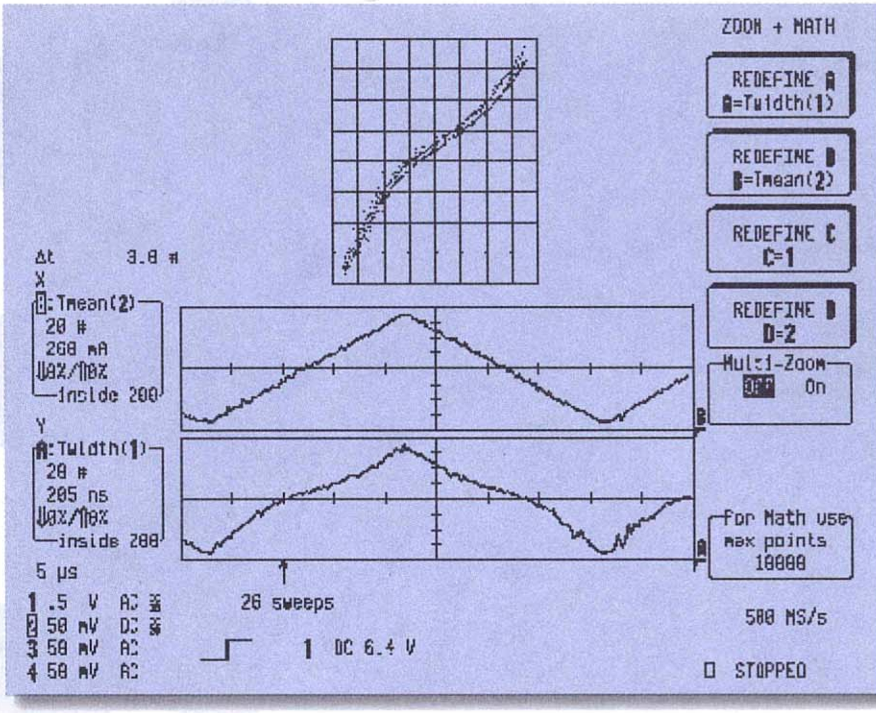
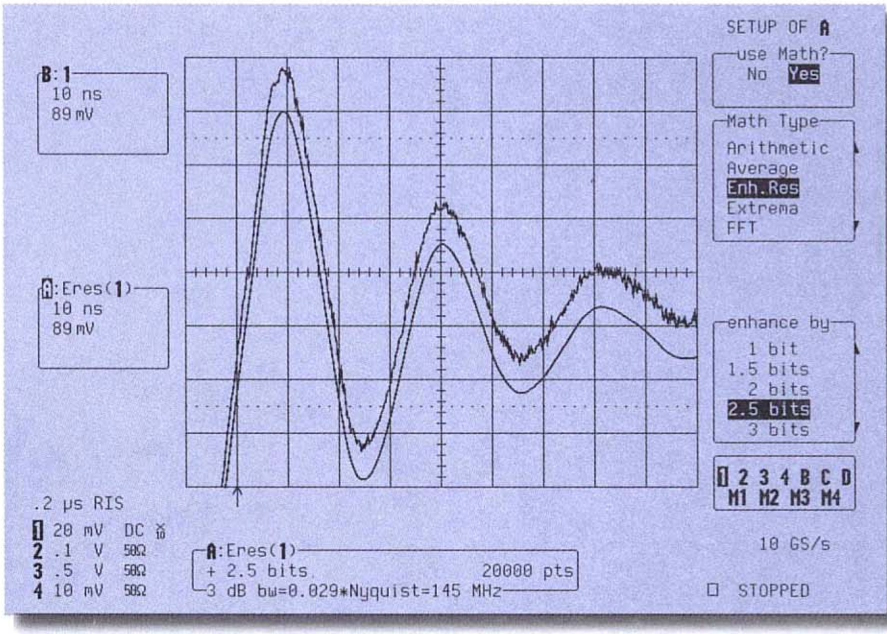


Figure 12: Cross-plot of trends of regulator pulse width (Y axis) and mean output load current (X axis) showing the relationship between these two measured parameters.

Enhanced Resolution in LeCroy Digital Oscilloscopes



Summary

The sampling rate of digital oscilloscopes – especially those with long record length – is often much higher than is actually required, considering the frequency spectrum of the signal under analysis. This oversampling can be used to your advantage, either by filtering the digitized signal in order to increase the effective resolution of the displayed trace, or to remove unwanted noise.

What is Enhanced Resolution?

Applying the Enhanced Resolution FIR (Finite Impulse Response) function is similar to smoothing the signal with a simple moving average filter, except that it is more efficient in terms of bandwidth and has better passband characteristics. New applications for this function may be found in situations where the averaging of successive traces would be useful but cannot be employed, because the signal has single-shot characteristics.

The Advantages of Enhanced Resolution

Two subtly different characteristics of the instrument are improved by the Enhanced Resolution filtering:

1. In all cases, the resolution (i.e. the ability to distinguish closely-spaced voltage levels) is improved by a fixed amount for each filter. This is a true increase in resolution which occurs whether or not the signal is noisy and whether or not it is a single-shot or a repetitive signal.

2. The signal-to-noise ratio (SNR) is improved in a manner which depends on the form of the noise in the original signal. This occurs because the Enhanced Resolution filtering decreases the bandwidth of the signal and will therefore filter out some of the noise.

Enhanced Resolution in LeCroy scopes

LeCroy DSOs implement a set of linear-phase FIR filters, optimized to provide fast computation, excellent step response and minimum bandwidth reduction for resolution improvements of between 0.5 and 3 bits in 0.5-bit steps. Each 0.5-bit step corresponds to a bandwidth reduction by a factor of two, allowing easy control of the bandwidth/resolution trade-off. The parameters of the six filters available in these scopes are given in Table 1 on the following page.

The filters used are low pass filters, so the actual increase in SNR obtained in any particular situation will depend on the power spectral density of the noise present on the signal. The filters will give the same SNR improvement ratio as their resolution improvement ratio if white noise is present in the signal (i.e. evenly distributed across the frequency spectrum). If the noise power is biased towards high frequencies, then the SNR improvement wili be better than the resolution improvement. Whereas, if the noise is mostly at lower frequencies, the improvement may not be as good as the resolution improvement. The improvement in the SNR due to the removal of coherent noise signals (for example, feed-through of clock signals) depends on whether the signal is in the passband of the filter or not. This can easily be deduced by using the Spectrum Analysis option of the digital scopes.

As an aid to choosing the appropriate filter for a given application, the Enhanced Resolution menu (see Fig. 1) indicates the -3 dB bandwidth of the current filter in two ways. It is given firstly as a percentage of the Nyquist frequency, and secondly, as the actual frequency corresponding to the timebase setting of the current waveform.

The filters used for the Enhanced Resolution function have an exactly linear phase response. This has two desirable properties. Firstly, the filters do not distort the relative position of different events in the waveform, even if the frequency content of the events is different. Secondly, the waveforms being stored, the delay normally associ-

Resolution Enhancement [Bits]	-3dB Bandwidth [x NyQuist]	Filter Length [samples]
0.5	0.5	2
1	0.241	5
1.5	0.121	10
2	0.058	24
2.5	0.029	51
3	0.016	117

Table 1: Parameters of the Enhanced Resolution FIR Filters.

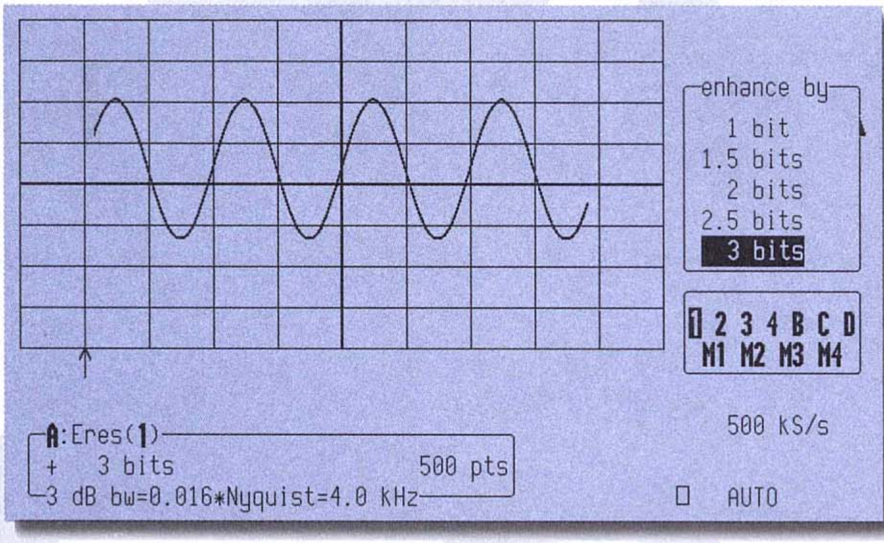


Figure 1: The enhanced resolution menu in LeCroy DSOs.

ated with filtering (between the input and output waveforms) can be exactly compensated for during the computation of the filtered waveform.

When Should Enhanced Resolution be Used?

There are two main situations for which Enhanced Resolution is especially useful. If the signal is noticeably noisy (and measurements of the noise are not required), the signal can be "cleaned up" by using the Enhanced Resolution function. Also, even if the signal is not particularly noisy, but high-precision measurements of the waveform are required (perhaps when using Expand with high vertical gain), then Enhanced Resolution will increase the resolution of the measurements.

In general, Enhanced Resolution replaces the Averaging function in situations where the data record has a single-shot or slowly repetitive nature and averaging cannot be used.

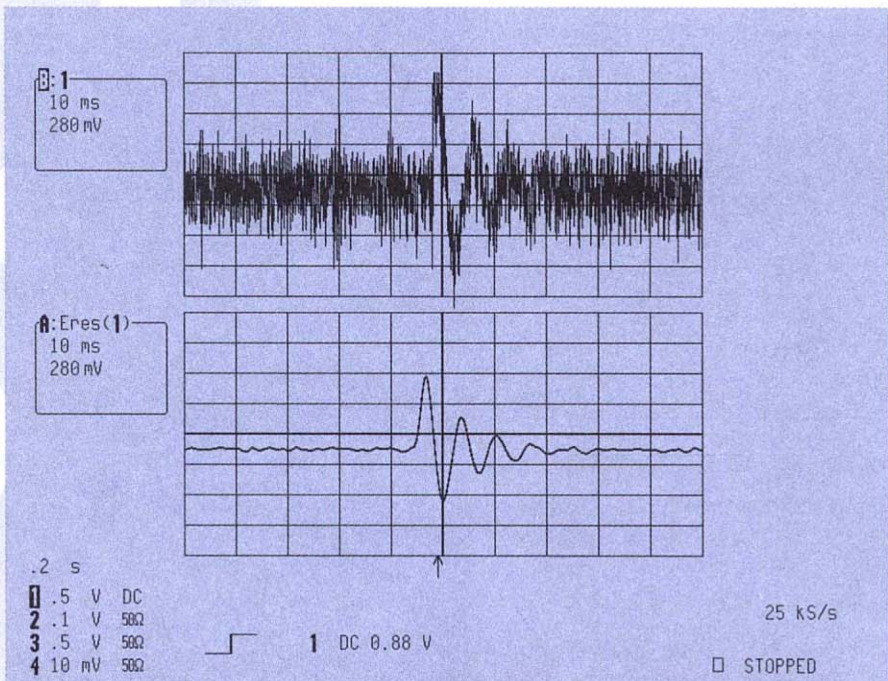
The following examples illustrate uses of the Enhanced Resolution function in these situations.

Filtering-Out Noise

Figure 2 shows the effect of Enhanced Resolution on a noisy signal, containing a ringing spike almost buried in noise on the upper grid. The lower grid shows the same signal after a 3-bit resolution enhancement: the spike is now clearly visible, and measurements such as frequency, amplitude or cycles can now be performed on the signal of interest.

The same signal viewed in the frequency domain shows the low-pass filtering effect of the Enhanced Resolution function. Figure 3 shows the power spectrum of the signals from Figure 2. The upper trace shows the spectrum of the unfiltered signal, while the lower trace shows the spectrum of the signal after the 3-bit resolution enhancement.

Figure 2: Noisy signal cleaned up with a 3-bit resolution enhancement.



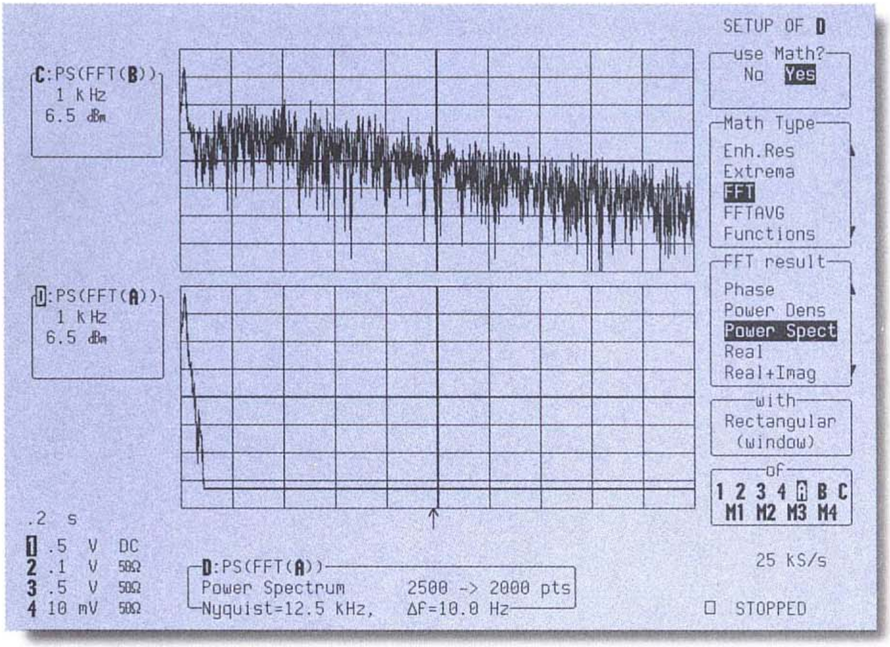


Figure 3: Frequency spectrum of signals from Figure 2. Notice the low-pass filter effect of the Enhanced Resolution function.

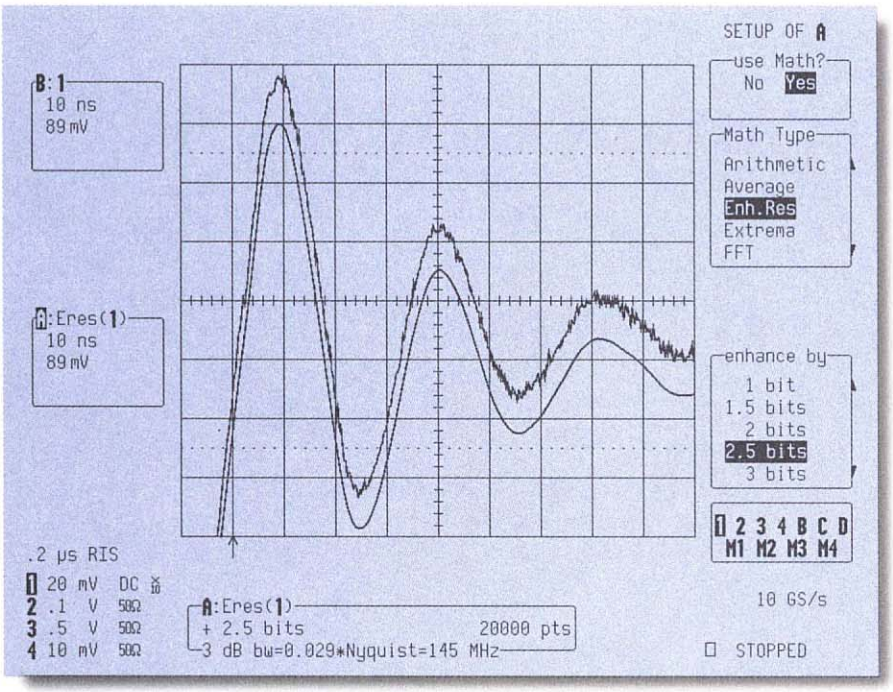


Figure 4: Resolution improvement on a RIS waveform viewed with vertical expansion.

The 3-bit enhancement filter has a -3 dB bandwidth of 0.016 times the Nyquist frequency, which is about 1/6 of a horizontal division. The filter removes energy from the signal above this frequency.

Improving Vertical Resolution

Enhanced Resolution can generally be used on RIS waveforms without any loss of bandwidth, because the RIS traces are usually highly oversampled with respect to the analog bandwidth of the oscilloscope. For example, at least one-bit enhancement can always be used for RIS waveforms with a timebase of 1 µs/div or faster. This is illustrated in Figure 4 where a 25 MHz damped sinewave signal is displayed without (top trace) and with (lower trace) 2.5-bit resolution enhancement. The improvement can easily be seen. In this case, the -3 dB bandwidth of the digital Enhanced Resolution filter is 145 MHz and thus has no significant distortion on the signal bandwidth of the instrument.

Conversely, RIS is very useful for increasing the sampling frequency of repetitive signals prior to Enhanced Resolution filtering, even if RIS would not be used for the normal trace. This is because the -3 dB bandwidth of the filter is increased by the greater effective sampling frequency, and more filtering (greater enhancement) can be used for a similar loss of bandwidth.

Cautionary Notes

The Enhanced Resolution function only improves the resolution of a trace. It cannot improve the accuracy or linearity of the original quantization by the 8-bit ADC.

The constraint of good temporal response for the high-resolution filters excludes the use of maximally-flat filters. Therefore, the passband will cause slight signal attenuation for signals near the cut-off frequency. One must be aware, therefore, when using these filters, that the highest frequencies passed may be slightly attenuated. The frequency response of a typical High Resolution filter (the 2-bit enhancement filter) is shown in Figure 5. The -3 dB cut-off frequency at 5.8% of the Nyquist frequency is marked.

The filtering must be performed on finite record lengths. Therefore, the discontinuity at the ends of the record cause data to be corrupted at these points. These data points are not displayed by the digital scopes, and so the trace becomes slightly shorter after filtering. The number of samples lost is exactly equal to the length of the impulse response of the filter used and thus varies between 2 and 117 samples.

Because the scopes in focus here have very long waveform memories, this loss is normally not noticed (it is only 0.2% of a 50,000 point trace, at worst). However, it is possible to ask for filtering on a record so short that there would be no data output. In this case, the DSO will not allow filtering.

Conclusion

The examples above each illustrate one feature of the Enhanced Resolution Function: noise-reduction and low-pass filtering for one, and vertical resolution improvement for the other. In many cases, however, these two features coexist, and their effects are combined on the resulting Enhanced Resolution trace in a manner which is very similar to averaging. Therefore, in single-shot applications, Enhanced Resolution can be an ideal alternative to averaging.

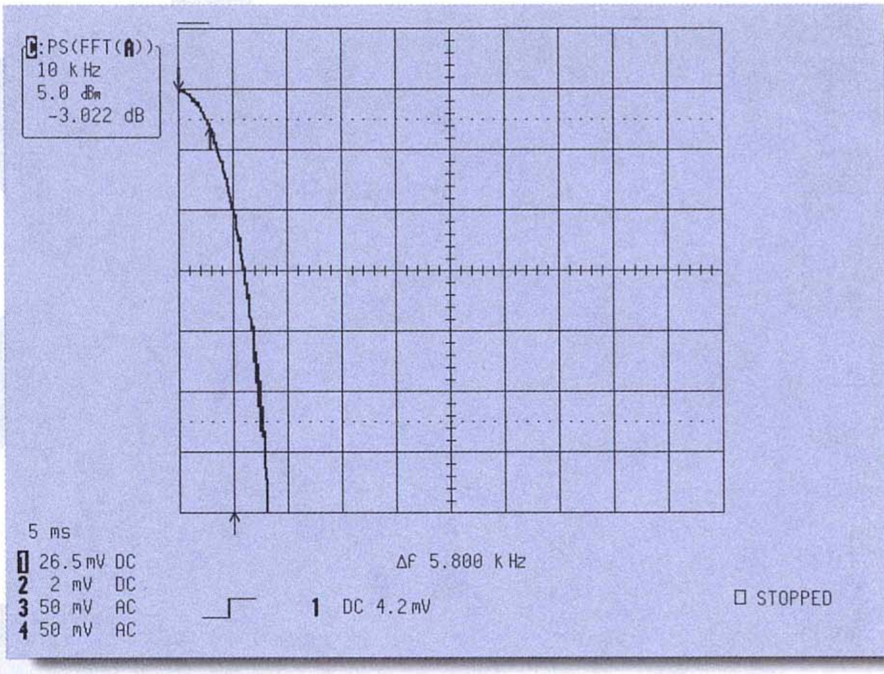
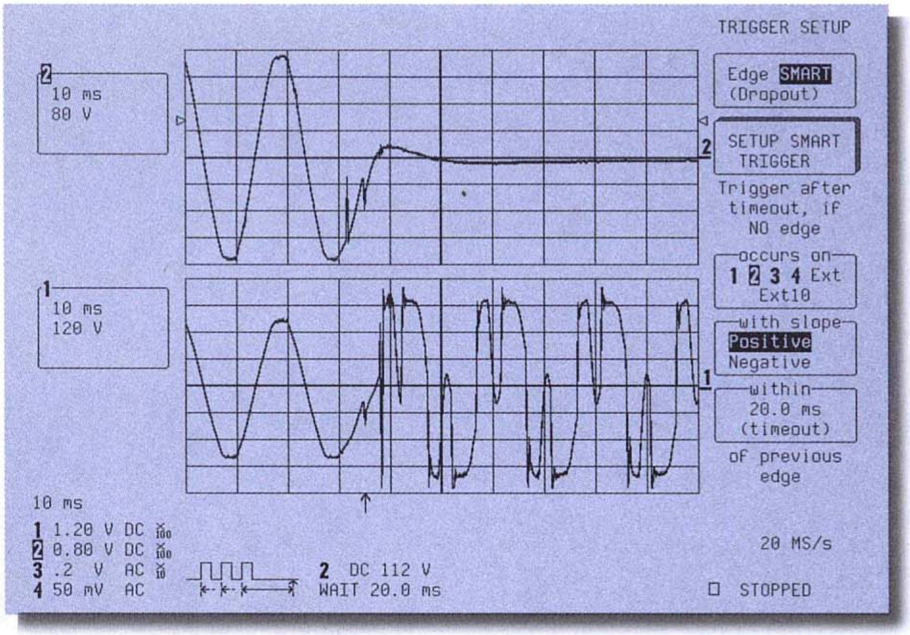


Figure 5: Frequency response of a typical FIR filter.

Capturing the Most Elusive Events with the SMART Trigger



Summary

The triggering circuit is an essential element in a modern digital oscilloscope. When used effectively, it can prove to be a very powerful elusive-event finder, particularly useful for capturing transient signals (one of the DSO's strongest points).

The purpose of this application note is to demonstrate the benefits of the triggering system in a digital oscilloscope, illustrated with real application examples ranging from microprocessor debugging to telecommunications and from magnetic disc testing to power line monitoring.

Introduction

Digital oscilloscopes are continuously improving their sampling rate, bandwidth and memory length performance.

An important criterion, however, often overlooked when choosing a digital oscilloscope, is the flexibility and sophistication of the trigger. Capturing rare phenomena such as glitches or spikes, logic states or missing bits, requires a much more powerful trigger system than those found in conventional oscilloscopes.

The LeCroy 9300 and LC series' trigger system and various application examples are described in the following pages.

The Edge Trigger

The Edge Trigger, as in a conventional analog oscilloscope, generates a trigger at a specified voltage directly adjustable through the front-panel controls. Different trigger couplings are available: DC, AC, LF Reject, HF Reject and HF.

The trigger delay can be adjusted between 1,000 screen widths after the trigger and one screen width before the trigger. In combination with the large record lengths, this enables the monitoring of events occurring much later or much earlier than the trigger itself.

A very distinctive feature of the LeCroy trigger is that coupling, slope (positive, negative or "window") and level can be adjusted separately for each trigger source, allowing more powerful triggering.

In "window" mode, a valid trigger occurs when the signal goes outside a predefined amplitude window, in either direction.

Holdoff is an additional characteristic of the trigger circuitry. This feature disables the oscilloscope's trigger circuit for a definable time or number of events.

Figure 1 shows a LeCroy oscilloscope display. The trigger level is indicated by the small triangles at the left and right borders of the grid, and the trigger timing position by the arrow at the bottom of the grid. In this tutorial, a trigger overview, including LeCroy's trigger icons, summarizes the trigger conditions.

The SMART Trigger

A menu button switches between Edge and SMART Trigger. SMART accesses a variety of powerful trigger modes (Figure 2) based on two important features:

1. The ability to preset the logic state of the different trigger sources, CH1, CH2, CH3, CH4, EXT, and EXT/10.

2. A presettable counter, which can be used to count a number of events between 1 and 10^9 or to measure time intervals from 2.5 ns up to 20 s in steps of 1% of the time scale (minimum step 2.5 ns).

Combining these two facilities opens the door to such a large variety of trigger conditions that the oscilloscope could potentially become cumbersome and difficult to use. However, great care has been taken to make the SMART Trigger mode easy to use – without losing any of its versatility. On the screen, graphical trigger icons illustrate the trigger conditions for every trigger mode. Examples of these

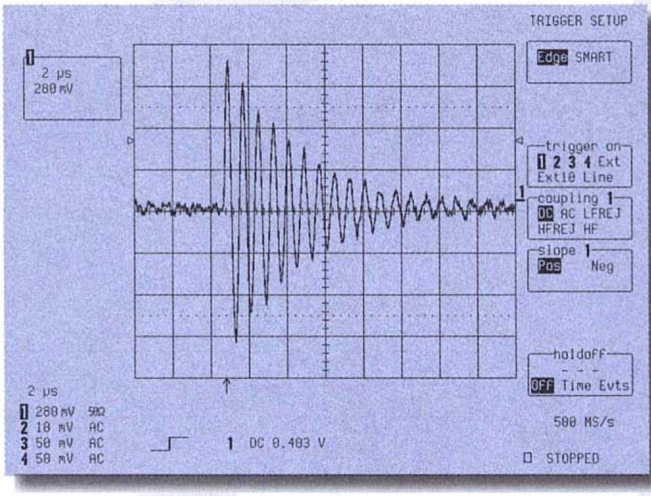


Figure 1: Edge Trigger on a damped sinewave. Notice the trigger summary and its graphical icon, below the grid, which indicates positive edge on Channel 1, DC coupling 430 mV level.

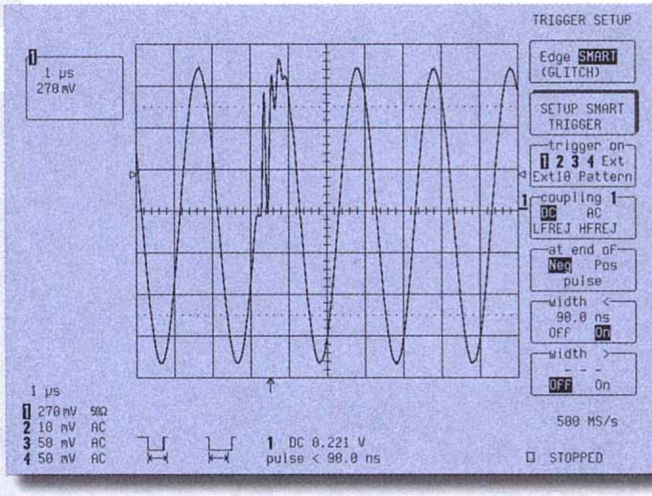


Figure 2: Selective trigger on a glitch narrower than 90 ns. Glitch Trigger is used to detect a glitch of 80 ns in a 2 ms period sinewave.

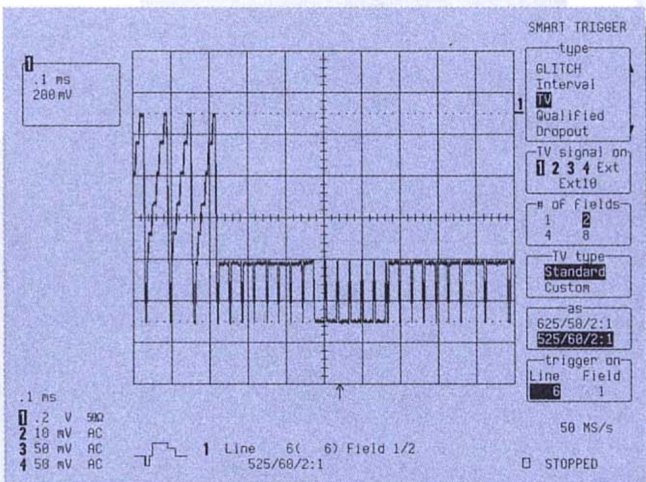


Figure 3: Illustration of a TV Trigger performed on a frame sync in a PAL signal.

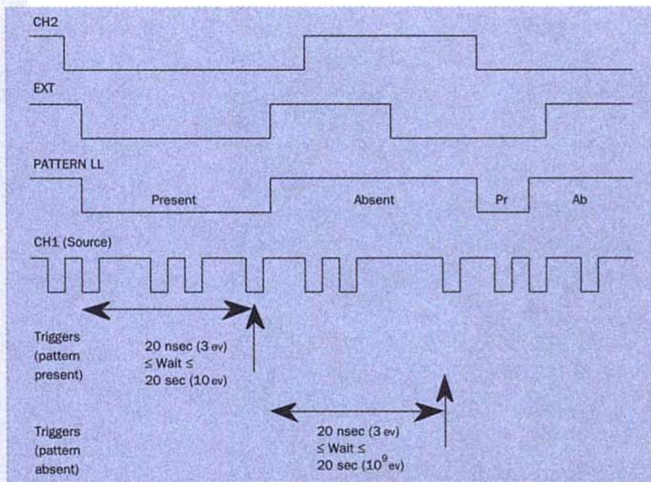


Figure 4: Timing diagram of the State-Qualified Trigger.

graphics can be found below the grid in all the screen figures. Five types of SMART Trigger will be described in this section:

- Glitch / Interval Trigger
- TV Trigger
- State- / Edge-Qualified Trigger
- Dropout Trigger
- Pattern Trigger

Glitch / Interval Trigger

The Glitch Trigger is predominantly used to find glitches, defined as faster transitions – or shorter pulses – than the normal signal contains. The system will therefore be set up to trigger on a width smaller than the signal's "normal" pulse width. The desired source and its coupling, level and pulse sign – positive or negative – can be chosen.

This feature offers a wide range of capabilities for applications as diverse as digital and analog electronic development, ATE, EMI, telecommunications, and magnetic media studies. Catching elusive glitches becomes very easy.

The Interval Trigger is very similar to the Glitch Trigger: instead of looking at a pulse – defined as the time between two contiguous transitions of different slopes – it looks at an interval – defined as the time between two contiguous transitions of the same slope.

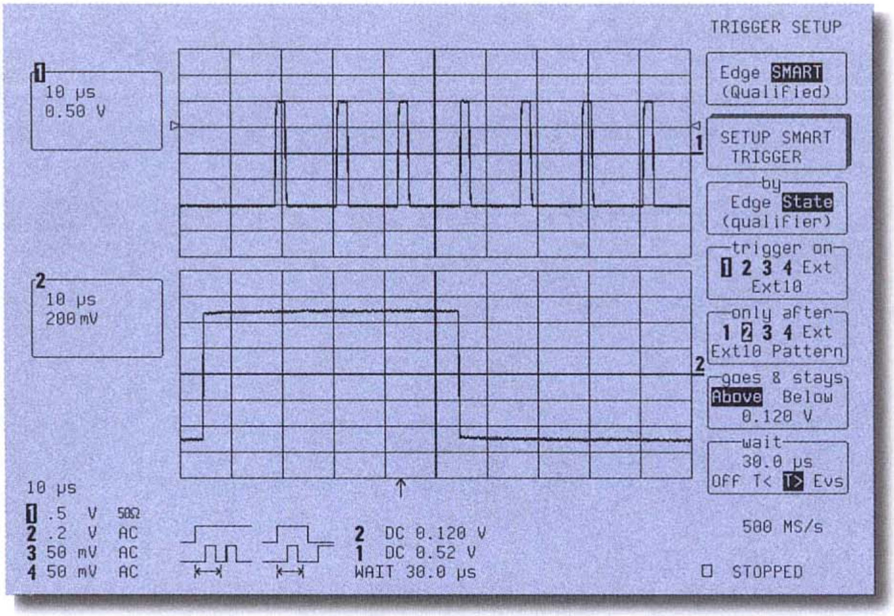


Figure 5: Example of a State-Qualified Trigger on logic signals. As soon as Channel 2 verifies the qualifying condition, the instrument "waits" 30 µs before triggering on the next available high-to-low transition on Channel 1.

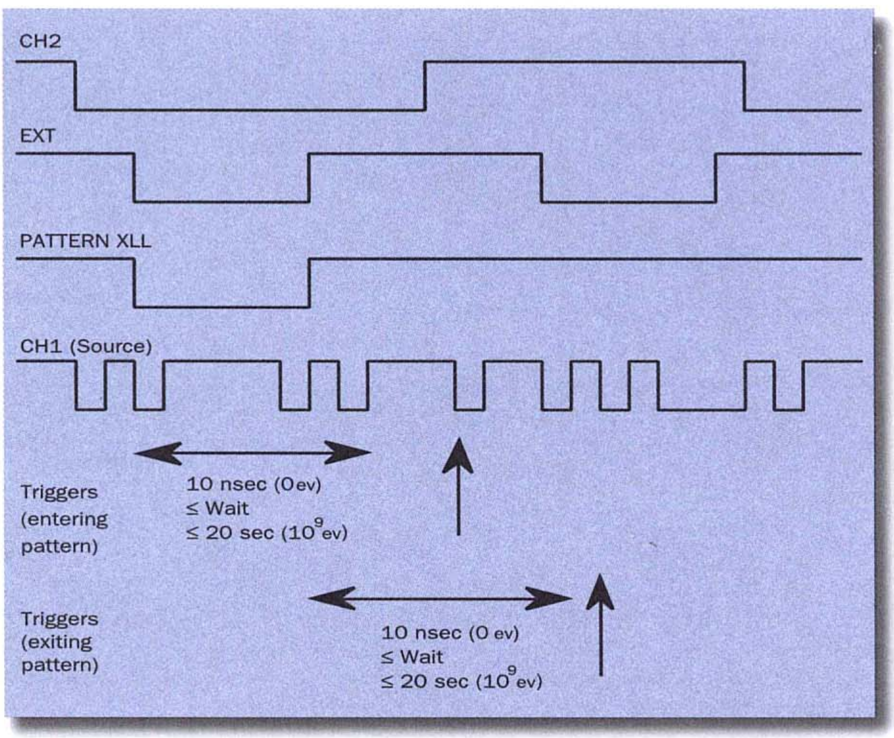


Figure 6: Timing diagram of the Edge-Qualified Trigger.

TV Trigger

The TV Trigger on LeCroy digital oscilloscopes offers many convenient features. It supports NTSC, PAL-M, PAL and SECAM-625 standards, and a user-defined setting allows triggering on frames of up to 1500 lines. The instrument can be set to synchronize on a given line and on a given field – odd, even, or for color TV, four or eight different color fields.

State-Qualified Trigger

This trigger enables the oscilloscope to trigger on one source, CH1, CH2, CH3, CH4, EXT, EXT/10 or Pattern as soon as a selected logic condition on another source – the qualifier - has been verified. The qualifying state must remain valid until the oscilloscope triggers. Different coupling, slope and trigger level settings can be chosen for each channel.

It is also possible to choose a delay by time or number of events which starts as soon as the logic pattern is valid, as illustrated in the timing diagram shown in Figure 4. Typical applications for this trigger can be found wherever time violations occur, for instance in microprocessor debugging or in telecommunications (see Figure 5).

Edge-Qualified Trigger

The Edge-Qualified Trigger is similar to the State-Qualified Trigger, except for one feature: it does not need the qualifying logic state to be maintained until the trigger occurs. From the moment that this logic state is present or absent, a delay can be defined in terms of time or number of events. When the delay has elapsed, triggering is enabled as shown in Figure 6. This feature provides a solution to applications which involve systems with long firing jitter time, e.g., lasers and magnetic discs. Other applications can be found in telecommunications or microprocessors for the debugging of asynchronous data buses.

As an example of an Edge-Qualified Trigger application, a DSO is set up to trigger off the fifth pulse out of an optical shaft encoder. The Edge-Qualified SMART Trigger is used with the positive-going edge of the index pulse, enabling the trigger on the positive-going edge of the signal on Channel 1. Holdoff by event is set to trigger after four trigger events. Thus, the oscilloscope triggers on the desired fifth positive-going edge (see Figure 7).

Dropout Trigger

This trigger is a unique feature available only in LeCroy DSOs. In this mode, a trigger is generated whenever the signal disappears for a selectable period of time. The trigger event is generated at the end of the time-out period following the "last" trigger source transition.

A typical application is to look for the last "normal" interval of a signal that has disappeared completely. This is essentially a single-shot application, usually with a pre-trigger delay.

This trigger is ideal for detecting interruptions in data streams (network hang-ups, microprocessor crashes etc).

Pattern Trigger

The Pattern Trigger is based on the logic state of the input channels, CH1, CH2, CH3, CH4 and EXT. Coupling and trigger level can be set independently for each channel. A pattern trigger can be viewed as a logical AND combination of the channel states defined as being either low (L), high (H) or don't care (X). The required logic state is defined for each input, and the instrument can be set to trigger either at the beginning of the defined pattern or at the end, i.e. when the pattern is "entered" or "exited."

This type of trigger is highly appreciated when testing for complex logic. Typical applications include: computer or microprocessor debugging; high energy physics where a physical event is identified by several events occurring simultaneously; and debugging of data transmission buses in telecommunications.

Conclusion

The LeCroy 9300 and LC series scopes offer one of the most comprehensive trigger systems available in an oscilloscope. Versatility has been combined with user friendliness to provide instruments with exceptionally powerful triggers.

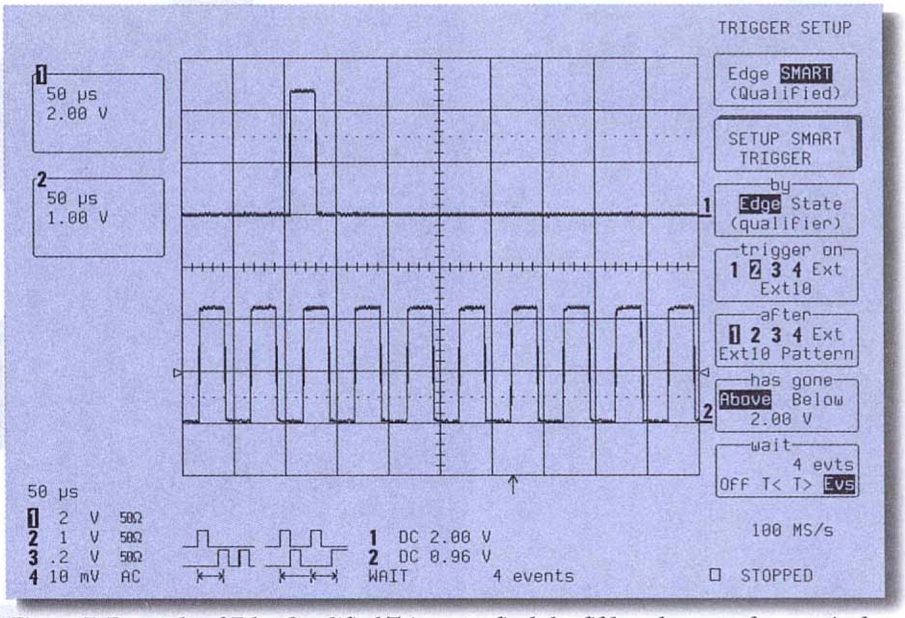


Figure 7: Example of Edge-Qualified Trigger to find the fifth pulse out of an optical shaft encoder. This pulse represents a 1.75° rotation of the shaft, where 1024 pulses represent a full rotation.

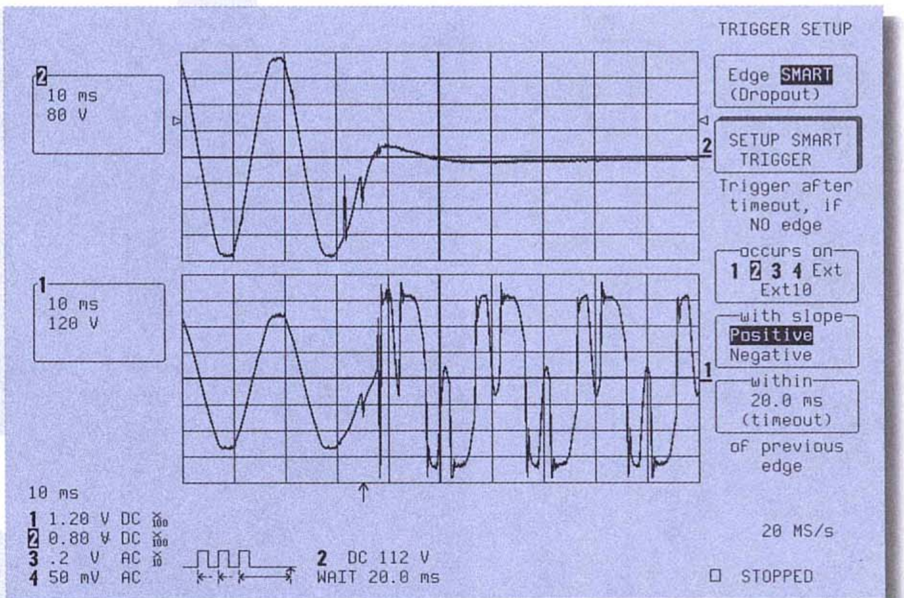


Figure 8: An Uninterrupted Power Supply for neon light. The Dropout Trigger is generated when the main power supply ceases for more than 20 ms; then UPS ensures an uninterrupted power supply as shown on Channel 1.

LeCroy Sales & Service

LeCroy sales engineers are experts in the field of measurement. Many of them have a BSEE, Masters degree or doctorate in addition to several years experience in solving measurement problems. Customers find that the advice of a LeCroy Corporation sales engineer allows them to find the instrument most ideally suited to their application. The result is better quality work, shorter time to market for new designs, higher manufacturing throughput and lower costs for equipment. While other companies are changing to distribution outlets that give a lower level of customer support, LeCroy is expanding its sales service to customers.

LeCroy Corporation personnel have a strong commitment to exemplary support of our customers. Our aim is to provide timely and thorough responses to your questions and requests, whether prior to ordering or after taking delivery.

Registering your LeCroy product will further ensure that you are kept up to date on product line enhancements, general updates, and new offers. Be sure to fill out and send in the Product Registration Card found in all shipments of new products.

Free Product Assistance

Answers to questions concerning installation, calibration, and use of LeCroy equipment are available from your local field office (see pages 262 and 263 for the office nearest you) or from our Customer Support Center, 700 Chestnut Ridge Road, Chestnut Ridge, New York 10977-6499. Calling 800-553-2769 (in the USA) will get you to the correct party.

In the USA

Sales, Technical Assistance and General Information

1-800-5-LeCroy
(1-800-553-2769)

Test Drives

Some instrument users prefer to "test drive" a product prior to purchase. A few days using the instrument at his own bench with typical signals gives the customer excellent insight into whether the product is right for him. This can be especially true for people who are converting from analog scopes to digital oscilloscopes or for those who want to compare a more powerful scope with an older digital scope to see if they can do their job better. LeCroy can often arrange for a "test drive" by having a salesperson drop off the instrument and give a brief tutorial on its use. You can arrange a test drive in the USA by calling 1-800-5-LeCroy (1-800-553-2769).

Software Utilities

LeCroy's Website allows customers to download utility programs, send their programs to LeCroy, send samples of interesting data or receive customized programs from the factory. Popular programs include Windows based ScopeExplorer, interface routines for GPIB and RS-232, basic graphing to draw the data on PCs and other utilities. Customers should call the LeCroy Customer Support Center (1-800-5-LeCroy) if they want to send data or programs to the factory for analysis. LeCroy's Website address is:

http://www.lecroy.com

Repair Service

The typical turnaround time to repair a LeCroy portable DSO at any LeCroy service office is 7 days. In the USA, you should obtain a Return Authorization Number by calling 1-800-553-2769 prior to sending in the item. This will speed processing when your unit arrives at LeCroy's service office. LeCroy has standard prices for repair of its products after expiration of the warranty. The standard prices allow for quick and easy paperwork. A customer can usually know the price of a repair before it is sent in for work. LeCroy runs a complete calibration check on every item received for repair or upgrade. Copies of test data and calibration certificates are available at a nominal fee.

Service in the USA

Call 1-800-5-LeCroy
(1-800-553-2769)

LeCroy Corporate Headquarters

USA

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977-6499

Customer Support Center

Tel: (800) 553-2769
FAX: (914) 578-5985

LeCroy International Service Offices

Germany
LeCroy Europe GmbH
(06221) 82700 - Heidelberg

France
LeCroy SARL
1 69 18 83 20 - Les Ulis (Paris)

Italy
LeCroy Srl
(41) 456 9700 - Venice

Japan
LeCroy Japan
(06) 330 0961 - Osaka
(03) 3376 9400 - Tokyo

Switzerland
LeCroy SA
(022) 719 21 11 - Geneva

United Kingdom
LeCroy Ltd
(1235) 533 114 - Abingdon

LeCroy European Manufacturing
LeCroy SA
2, rue du Pre-de-la-Fontaine
PO Box 341
CH-1217 Meyrin 1 Geneva
Switzerland
Tel: (022) 719 22 28
FAX: (022) 719 22 30

United States

Direct Sales Representation throughout the United States

For Sales, Technical Support, Repair or Calibration, call

LeCroy Corporation
700 Chestnut Ridge Road
Chestnut Ridge, NY 10977

1-800-5-LeCroy
(1-800-553-2769)
(914) 578-6020

LeCroy International

AUSTRALIA/SOUTHERN ASIA
LeCroy Pty Ltd
Suite 207,
28 Blackburns Road
PO Box 317
Blackburns 3130, Victoria
Australia
Phone: (61) 9877 9322
FAX: (61) 9849 0861

FRANCE
LeCroy SARL
Les Conquerants
Immeuble Fuji-Yama
1, avenue de l'Atlantique
L.P. 903 - Les Ulis
F-91976 Courtaboeuf Cedex
Phone: (1) 69 18 83 20
FAX: (1) 69 07 40 42

GERMANY
LeCroy Europe GmbH
Waldhofer Str. 104
D-69123 Heidelberg
Phone: (06221) 82700
FAX: (06221) 83 46 55

HONG KONG/NORTHERN ASIA
LeCroy Corp
15/F Radio City
505 Hennessy Road
Causeway Bay
Phone: (852) 2836 7361
FAX: (852) 2836 7007

ITALY
LeCroy S.r.l.
Centro Direzionale Valecenter Office
Via E. Mattei 1/102
I-30020 Marcon (Venice)
Phone: (39) 41 456 97 00
FAX: (39) 41 456 95 42

JAPAN
LeCroy Japan Corporation
Nakao Royal Bldg 4F - 4th Floor
14-10, 2-Chome, Miyahara
Yodogawa-ku, Osaka City
Osaka 532
Phone: (06) 396 0961
Fax: (06) 396 0962

LeCroy Japan Corporation
Sasazuka Center Bldg 6th Floor
1-6, 2-Chome, Sasazuka, Shibuya-ku
Tokyo 151
Phone: (03) 3376 9400
FAX: (03) 3376 9587

LeCroy Japan Corporation
Kantetsu Tsukuba Building 6F
1-1, 1-Chome
Oroshi - Machi
Tsuchiura City, Ibaragi 300
Phone: (298) 41 5810
FAX: (298) 41 5830

SWITZERLAND
LeCroy SA
2, rue du Pré-de-la-Fontaine
P.O. Box 341
CH-1217 Meyrin 1 Geneva
Phone: (022) 719 21 11
FAX: (022) 719 22 30

LeCroy SA
Lenzhardweg 43
CH-5702 Niederlenz
Phone: (41) 62 885 8050
FAX: (41) 62 885 8055

UNITED KINGDOM
LeCroy Ltd
28 Blacklands Way
Abingdon Business Park
Abingdon, Oxon OX14 1DFY
Phone: (44) 1 235 536973
FAX: (44) 1 235 528796

Representing LeCroy Worldwide

ARGENTINA
Search SA
Araoz 823
1414 Buenos Aires
Phone: (01) 777 4000
FAX: (01) 777 4000 (same as phone)

AUSTRALIA
Philips Test & Meaasurement
34 Waterloo Road
PO Box 119
North Ryde NSW 2113
Phone: (612) 9888 8222
FAX: (612) 9888 0440

AUSTRIA
Dewetron Elektronische Messgeraete GesmbH
Riesstrasse 146
A-8010 Graz
Phone: (43) 316 3070
FAX: (43) 316 3070/90

BRAZIL
ATP/Hi-Tek Electronica Ltda
Alameda Araguaia 933, Conjustos 71 e 74
06455-000 Alphaville, Baruei - SP
Phone: (011) 725 5822
FAX: (011) 421 5032

CANADA
Allan Crawford Associates Ltd
5835 Coopers Ave
Mississauga, Ontario L4Z 1Y2
Phone: (905) 890-2010
FAX: (905) 890-1959

CHILE
Sistemas de Instrumentacion Ltda
Concha y Toro N° 65 Stgo - Centro
Casilla 51888 Stgo-1
Santiago
Phone: (02) 695 1137
FAX: (02) 696 9665

DENMARK
Lutronic ApS
Naverland 2
DK-2600 Glostrup
Phone: (43) 42 97 64
FAX: (43) 42 97 65

EASTERN EUROPE
Elsinco GmbH
Breitenfurter Str 13
A-1120 Vienna Austria
Phone: (431) 815 0400
FAX: (431) 815 0700

EGYPT
MENC
21 El-Ohoar Buildings
Salah Salom St.
Cairo
Phone: (20) 226 32771
FAX: (20) 240 28057

FINLAND
Orbis OY
PO Box 15
SF - 00421 Helsinki
Phone: (90) 478 830
FAX: (90) 531 604

GREECE
IFIPCO - John Fourniadis & Co.
213-215 Mesoglion Ave
GR-11510 Athens
Phone: (1) 6725 970
FAX: (1) 6746 331

HONG KONG/PRC
Schmidt Electronics
36/F Dorset House, Taikoo Place
979 King's Road
Quarry Bay, Hong Kong
Phone: (852) 2507 0222
FAX: (852) 2827 5656

INDIA
Kingsly Instrumentation & Communication Pvt. Ltd
No 213, 5th Main, 5th Cross
Ganganagar, Bangalore - 560 032
Phone: (80) 984 503 5675
FAX: (80) 333 9120

ISRAEL
Lahat Electronics
55 Hanevim Street
PO Box 1725
47116 Ramat-Hasharon
Phone: (03) 547 2741
FAX: (03) 547 2742

KOREA
Woojoo Hi-Tech Corporation
Sinkwang Building 5F
160-8 Karak 2-Dong
Songpa-Ku
Seoul 138 162
Phone: (02) 449 5500
FAX: (02) 449 5523

MEXICO
Electroingenieria de Precision, SA
Uxmal No. 520
Col. Vértiz Narvarte
03600 Mexico, DF
Phone: (5) 559 7677
FAX: (5) 575 3381

NEW ZEALAND
Philips Test & Measurement
Private Bag 41904
St.Lukes
Auckland 3
Phone: (649) 8494 160
FAX: (649) 8497 814

NORWAY
Avantec A/S
Rosenholmveien 20
N-1252 Oslo
Phone: (22) 76 38 70
FAX: (22) 61 07 59

PORTUGAL
M.T. Brandao, Lda
Rua do Quanza, 150
4000 Porto
Phone: (02) 830 2709
FAX: (02) 830 2710

RUSSIA
IRIT
P.O. Box 178
Moscow 115211
Phone: (095) 344 9921
FAX: (095) 344 6785

SAUDI ARABIA
Arab Engineers for Trading Co. Ltd.
P.O. Box 4136
Khobar 31952
Phone: (966) 3899 0220
FAX: (966) 3899 0330

SINGAPORE/MALAYSIA
Abex Engineering Pte Ltd
37 Kallang Pudding Road #08-08
Tong Lee Building, Block B
Singapore 1334
Phone: (65) 841 2818
FAX: (65) 841 5988

SOUTH AFRICA
Westplex Test and Measurement (Pty) Ltd.
PO Box 1765
2nd Floor, West Block
367 Oak Avenue
Randburg 2194
Republic of South Africa
Phone: (011) 787 0473
FAX: (011) 787 0237

SPAIN
M.T. Brandao (Espana) SL
Ronda de Poniente 2
E-28760 Tres Cantos Madrid
Phone: (91) 803 1767
FAX: (91) 803 1536

SWEDEN
Measurement Systems Scandinavia AB
Enhagsvagen 7
Box 504
S-183 25 Taby
Phone: (08) 540 829 50
FAX: (08) 540 665 36

TAIWAN
LeColn Technology Co. Ltd.
5F, No. 649, Chung-Jeng Road
Yung-Ho City, Taipei Hsien
Phone: (02) 232 6368
FAX: (02) 231 9731

THAILAND
Measuretronix Ltd
2102/31 Ramkamhang Road
Bangkok 10240
Phone: (02) 375 2733
FAX: (02) 374 9965

TURKEY
NETES Ltd Sti
Bankalar Okcu Musa Cad.
Menevse Han 54/131
Karakoy 80020 Istanbul
Phone: (212) 237 32 26 / 27
FAX: (212) 254 54 52

VIETNAM
Schmidt Vietnam Co Ltd
8/F Schmidt Tower
Hanoi International Technology Centre (HITC)
Cau Guay IPO Box 89
Tu/Liem - Hanoi
Phone: (04) 8346 186
FAX: (04) 8346 188

Upgrades

A substantial benefit of owning LeCroy equipment is the availability of upgrades to the operating system. If LeCroy improves the performance of a product, those improvements can often be passed on to customers by installing new software or firmware in their units. In some cases, features such as floppy disk drives, built-in printers, spectrum analysis software or other new features can be added at a reasonable cost. LeCroy always endeavors to make new features retrofittable into previous designs. This protects your investment against obsolescence.

LeCroy even offers the capability to upgrade the acquisition memory and processing RAM in most oscilloscopes. This very important upgrade path is not available from other companies.

Calibration

LeCroy recommends annual verification of the calibration for all its instruments. You can arrange for calibration from local LeCroy field service offices anywhere in the world, from our factory headquarters in NY or from our European headquarters in Switzerland. LeCroy will check the calibration of any instrument under warranty once per year at no charge. Customers who require copies of test data and traceable certificates for NIST, ISO9000 or MIL-STD quality standards may obtain those documents for a reasonable service fee. Calibrations performed according to LeCroy standards are substantially more rigorous than those performed by the test systems of other manufacturers or by "calibration houses." For example, few users of oscilloscopes use them to measure DC voltages, but most oscilloscope calibration systems only verify DC accuracy. LeCroy's calibration service checks the accuracy of the scope using sine waves of various frequencies and amplitudes. LeCroy tests include trigger modes, probe calibrator accuracy, ground line accuracy, pulse response, GPIB data transmission, and a variety of other tests in addition to the usual bandwidth, DC accuracy and timebase verification.

Extended Maintenance Contracts

LeCroy makes it easy for customers to provide for future service of their instruments by offering optional five-year repair warranty, five-year calibration contracts or five-year total coverage which includes repair and calibration. These services make future support of the instrument easy. No P.O. is needed for future repair or calibration, the customer doesn't have to worry about budgeting money for maintenance. The lifetime cost of the instrument (which is often depreciated over five years) can be set in one lump sum.

Warranty

LeCroy warrants its digital oscilloscopes to operate within specifications under normal use and service for a period of three years from the date of shipment. 9200 Series pulse generators are warranted for five years and all other instruments for one year. Component products, replacement parts, and repairs are warranted for 90 days. This warranty extends only to the original purchaser. Software is thoroughly tested but is supplied "as is" with no warranty of any kind covering detailed performance. Accessory products not manufactured by LeCroy are covered by the original equipment manufacturer's warranty only.

In exercising this warranty, LeCroy will repair or, at its option, replace any product returned to the factory or an authorized service facility within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and has not been caused by misuse, neglect, accident or abnormal conditions or operations.

The purchaser is responsible for the transportation and insurance charges arising from the return of products to the servicing facility. LeCroy will return all in-warranty products with transportation prepaid.

This warranty is in lieu of all other warranties, express or implied, including but not limited to any implied warranty of merchantability, fitness, or adequacy for any particular purpose or use. LeCroy will not be liable for any special, incidental, or consequential damages, whether in contract or otherwise.

Software Licensing Agreement

Software products are licensed for a single machine. Under this license you may:

- Copy the software for backup or modification purposes in support of your use of the software on a single machine.
- Modify the software and/or merge it into another program for your use on a single machine.
- Transfer the software and the license to another party if the other party accepts the terms of this agreement and you relinquish all copies, whether in printed or machine-readable form, including all modified or merged versions.

Unpacking & Inspection

LeCroy recommends that the shipment be thoroughly inspected immediately upon delivery. All material in the container(s) should be checked against the enclosed Packing List and shortages reported to the carrier promptly. If the shipment is damaged in any way, please notify the carrier. If the damage is due to mishandling during shipment, you must file a damage claim with the carrier. The LeCroy field service office can help with this. LeCroy tests all products before shipping and packages all products in containers designed to protect against reasonable shock and vibration.

Service Procedure

Products requiring maintenance should be returned to the factory or authorized service facility. If under warranty, LeCroy will repair or replace the product at no charge. The purchaser is only responsible for the transportation charges arising from return of the goods to the service facility.

For all LeCroy products in need of repair after the warranty period, the customer must provide a P.O. number before any inoperative equipment can be repaired or replaced. The customer will be billed for the parts and labor for the repair as well as for shipping.

Returns

All products returned for repair should be identified by the model and serial numbers and include a description of the defect or failure and the name and phone number of the user. In the case of products returned, a Return Authorization Number is required and may be obtained by contacting the Service Office in your area. Any returned goods should be shipped in the original packaging material. Returned goods that have not been packed in the original packing material and have been damaged in shipping will not be repaired under warranty. Any goods returned for credit are subject to a 20% restocking charge.

Requests For Quotations and Technical Information

LeCroy's worldwide network of offices and technical sales engineers will assist you in specifying, ordering, installing and operating LeCroy equipment. Please refer to the Sales and Service Office listing on Page 262 & 263 for the one nearest you.

Pricing

Export prices are available from our worldwide sales offices. Prices in the U.S.A. can be obtained by calling

1-800-5-LeCroy

How to Order

When placing an order, please specify the model number as well as the name of the instrument. Many model numbers include letter designations such as the LCXXX-SCC or the OC9003A. Some models are offered with several options designated by a slash followed by a number such as MT01/02. Special care should be taken to include these alphanumeric designations on your order.

Minimum Order

All purchase orders are subject to a $100 minimum value for U.S.A. products and SFR 200 - for Swiss products.

U.S. Government Sales: Most products listed in this catalog are on G.S.A. Federal Supply Schedule Contract. Prices are available upon request.

Where to Order & Currency

Purchase orders may be forwarded to your local sales office or directly to the manufacturing facility producing the product you desire. Your local currency may be used for orders placed with direct LeCroy subsidiaries or sales representatives.

Rental company orders within the U.S.A. should be called in directly to Corporate Headquarters in New York at 800-553-2769.

Acknowledgment

When a purchase order is accepted by LeCroy Corporation, an acknowledgment is issued immediately confirming the equipment type, quantity and price, and indicating an estimated delivery date. Please read this acknowledgment carefully. Any unacceptable discrepancy between the purchase order and the acknowledgment should be reported immediately to the local sales office.

Shipping

The standard FOB point for all orders placed in the United States is Chestnut Ridge, New York except for GSA orders, where FOB is destination. The standard shipping method for GSA orders is via two-day parcel service. Some products require either air freight or motor freight.

Special shipping instructions should be arranged prior to placing a purchase order, so that any additional shipping charges are properly taken into account.

Terms

Domestic Orders: Payment terms are "Net 30 Days, acceptance period included" for all orders originating within the United States. The 30-day period begins on the actual shipping date. Any exception to these payment terms should be requested before placing a purchase order. Credit references will be required for new customer accounts.

GSA Prompt Payment Terms: 1% - 10 days. Net 30 days.

Export Orders: For orders placed directly with LeCroy's main location in Chestnut Ridge, New York, in U.S. dollars, payment terms for orders less than $5,000 are via 30-day date draft, acceptance period included. For orders greater than $5,000 - Irrevocable Letter of Credit in favor of LeCroy Corporation payable at The Chase Manhattan Bank, N.A., Letter of Credit Department, 4 Chase MetroTech Center, 8th floor, Brooklyn, New York, 11245, U.S.A.

For orders placed in Swiss Francs directly with LeCroy's European Headquarters in Geneva, Switzerland, for digital oscilloscope products, payment terms for less than SFR 10,000 are 30-day date draft, acceptance period included. For orders greater than SFR 10,000 - Irrevocable Letter of Credit drawn on Credit Suisse, Charmilles - Balexert, Geneva, Switzerland.

Terms for orders placed with LeCroy export sales subsidiaries are Net 30 days, unless other special arrangements have been made in advance.

An end use statement is required for any item purchased in the U.S.A. that will be exported.

Glossary of Technical Terms

Acquisition Time: In a sample-and-hold or track-and-hold circuit, the time required after the sample or track command for the output to slew through a full scale voltage change and settle to its final value to within a specified error band.

ADC: Analog-to-digital converter.

Aliasing: Whenever a dynamic signal is synchronously sampled, a possibility of misunderstanding its frequency content exists. This difficulty is termed "aliasing" and occurs whenever the sampling rate is less than twice the highest frequency component in the signal being measured.

AND: Logical designation or circuit function meaning that all inputs must be in the TRUE state for a TRUE output.

Aperture Jitter: In a sample-hold or ADC, the jitter between the time of the sample (or convert) command pulse and the time the input signal is actually sampled. This jitter is usually due to thermal noise. It leads to an uncertainty in the sampled amplitude equal to $\Delta t * dV/dt$, where Δt is the aperture jitter, and dV/dt is the rate of change of the input voltage at the time of sampling. The terms "aperture jitter" and "aperture uncertainty" are often used interchangeably.

Aperture Uncertainty: In a sample-hold or ADC, the total uncertainty in the time of the sample (or convert) command pulse and the time the input signal is actually sampled, due to all causes including noise, signal amplitude-dependent delay variation (as in a flash ADC), temperature, etc. Often used interchangeably with "aperture jitter," but "aperture uncertainty" is the more inclusive term.

Area: In a time domain DSO waveform measurement, area is the sum of the sampled values between the cursors times the duration of a sample.

Artifact Rejection: Used in summation averaging to exclude waveforms which have exceeded the dynamic range of the recording system.

Automatic Setup: In an oscilloscope, automatic scaling of the timebase, trigger, and sensitivity settings. Provides a stable display of repetitive input signals.

Average: See Mean Value, Summation Averaging and Continuous Averaging.

Bandwidth: In normal use, the frequency range over which the gain of an amplifier or other circuit does not vary by more than 3 dB.

BER: See Bit Error Rate.

Binning: A technique for combining points in a histogram to be compatible with the resolution of the display device.

Bit: An abbreviation of "binary digit," one of the two numbers, 0 and 1, used to encode data. A bit is often expressed by a high or low electrical voltage.

Bit Error Rate: Ratio of the number of bits of a message incorrectly received to the total number received.

CCD: Charge Coupled Device. An integrated circuit which allows the transfer of a variable amount of charge through a series of cells; an analog shift register.

Channel: A path through an arrangement of components (modules and electrical and/or optical cabling) along which signals can be sent (e.g. a data channel, voice channel, etc.).

Clamping: Holding a circuit point to some reference level (frequently ground) by means of a low-impedance element such as a saturated transistor, FET, forward-biased diode, relay, etc.

Coherent Gain: The normalized coherent gain of a filter corresponding to each window function is 1.0 (0 dB) for the rectangular window and less than 1.0 for other windows. It defines the loss of signal energy due to the multiplication by the window function.

Common Mode Range: The maximum range (usually voltage) within which differential inputs can operate without a loss of accuracy.

Common Mode Rejection Ratio: The ratio of the common-mode input voltage to the output voltage expressed in dB. The extent to which a differential amplifier does not provide an output voltage when the same signal is applied to both inputs.

Common Mode Signal (Noise): The signal (usually noise) which appears equally and in phase on each of the differential signal conductors to ground. See Differential Input.

Continuous Averaging: Sometimes called "exponential averaging," the technique consists of the repeated addition, with unequal weight, of successive source waveforms. Each new waveform is added to the accumulated average according to the formula:

$$S(i,new) = N/(N+1) * [S(i,old) + 1/(N+1) * W(i)]$$

where

i	= index over all data points of the waveforms
W(i)	= newly acquired wave form
S(i,old)	= old accumulated average
S(i,new)	= new accumulated average
N	= weighting factor (1,3,7...)

Conversion Cycle: Entire sequence involved in changing data from one form to another, e.g. digitizing an analog quantity, changing binary data to BCD, etc.

Crosstalk: Unwanted coupling of a signal from one channel to another.

Cursor: A visible marker that identifies a horizontal and/or vertical position on an oscilloscope display. LeCroy DSOs offer "waveform riding" cursors which conveniently give both the horizontal and vertical values without selecting one or the other.

DAC: Digital-to-analog converter.

Data Logger: An instrument which accepts input signals (usually slow analog), digitizes them, and stores the results in memory for later readout. The digital equivalent of a strip-chart recorder.

DC: Direct current. Normally means a voltage or current which remains constant.

DC Level Shift: A change in the nominal DC voltage level present in a circuit.

DC Offset: See DC Level Shift. This term may imply that the shift is intentional, for example, adjustable by a control knob.

DC Overload: An overload signal of long duration compared to the normal input pulse width or duty ratio of a circuit.

Dead Time: In a digital oscilloscope, the dead time is the time from the end of one acquisition of data to the start of the next acquisition.

Decimation: The process of reconstructing a source waveform with a reduced number of data points by using only every nth data point, where n is an integer.

Differential Input: A circuit with two inputs that is sensitive to the algebraic difference between the two.

Differential Linearity: A term often inappropriately used to mean differential non-linearity.

Differential Non-Linearity:
1. The percentage departure from the average of the slope of the plot of output versus input from the slope of a reference line.

2. The percentage of variation in ADCs or TDCs from the mean of the analog (or time) width of any single digital step. It is usually measured by driving the input with a large number of random amplitude pulses and then measuring the relative number of events in each digital bin.

Differential Output: A circuit with two outputs supplying one normal and one complementary level of output signal.

Differential Pulses: Two opposite polarity pulses coincident in time.

Dithering: Typically used when averaging signals (which have low noise content) to improve vertical resolution and decrease the effects of an ADC's non-linearities. The technique applies different offsets to each incoming waveform to ensure the signal is not always digitized by the same portion of the ADC. The offsets must be subtracted from the recorded signals before being included in the summed average.

Digital Filtering: The manipulation of digital data to both enhance desirable and to remove undesirable aspects of the data.

Dropout Trigger: A trigger that occurs if the input signal drops out for a time period longer than a preset amount (between 25 ns to 20 s on some LeCroy DSOs).
This is very useful for triggering on microprocessor crashes, network hangups, bus contention problems or other phenomena where a signal stops occurring.

Duty Cycle: A computed value in digital scopes representing the average duration above midpoint value as a percentage of the period for time domain waveforms.

Dynamic Range: The ratio of the largest to smallest signal which can be accurately processed by a module.

Dynamic RAM (DRAM): A random access memory in which the internal memory must be refreshed periodically.

ECL: Emitter-coupled logic, an unsaturated logic performed by emitter-coupled transistors. Usually, ECL LOGICAL 1 = -1.6 V and LOGICAL 0 = -0.8 V.

EMI: Electromagnetic interference caused by current or voltage induced into a signal conductor by an electromagnetic field in the conductor's environment.

ENBW (Equivalent Noise Bandwidth): For a filter associated with each frequency bin, ENBW is the bandwidth of an equivalent rectangular filter (having the same gain at the center frequency) which would collect the same power from a white noise signal.

Enhanced Resolution (ERES): A facility in LeCroy DSOs to increase the amplitude resolution of single-shot waveform measurements. This technique, which applies digital filtering to achieve resolution enhancement at a reduced bandwidth, is optimum when the sampling rate of the instrument exceeds that required for the input signal bandwidth. For repetitive signals, either ERES or Signal Averaging, or both, can be used to achieve higher resolution with substantially smaller loss of bandwidth than for single-shot signals.

Envelope: The maximum, minimum, or maximum and minimum values of a sequence of measured waveforms. In LeCroy DSOs, the number is programmable from 1 to 10^6.

EPROM: Erasable, programmable read-only memory. An integrated circuit memory array that is made with a pattern of either all logical zeros or ones and has a pattern written into it by the user with a special hardware program.

Equivalent Time Sampling (EQT): (Also known as ETS) A means of exploiting multiple acquisitions of a repetitive signal to increase the usable bandwidth of a digitizer by making it appear to sample more rapidly than its maximum single shot sample rate. Works only with stable, repetitive signals.

Extrema: The computation of a waveform envelope, by repeated comparison of successive waveforms, of all maximum points (roof) and all minimum points (floor). Whenever a given data point of the new waveform exceeds the corresponding maximum value in the roof record, it is used to replace the previous value. Whenever a given data point of the new waveform is smaller than the corresponding floor value, it is used to replace the previous value.

Falltime: Unless otherwise defined, the time required for a pulse to go from 90% to 10% of full amplitude. Can also refer generally to the trailing edge of a pulse.

Fast Fourier Transform (FFT): In signal processing applications, an FFT is a mathematical algorithm which takes a discrete source waveform, defined over n points, and computes n complex Fourier coefficients, which are interpreted as harmonic components of the input signal. For a "real" source waveform (imaginary part equals 0), there are n/2 independent harmonic components.

Feedthrough: Unwanted signal which passes a closed gate or disabled input.

FFT: See Fast Fourier Transform.

FFT Frequency Bins: A Fast Fourier Transform (FFT) corresponds to analyzing the input signal with a bank of n/2 filters, all having the same shape and width, and centered at n/2 discrete frequencies. Each filter collects the signal energy that falls into the immediate neighborhood of its center frequency, and thus it can be said that there are n/2 "frequency bins." The distance, in Hz, between the center frequencies of two neighboring bins is always: $\Delta f = 1/T$, where T is the duration of the time-domain records in seconds. The nominal width of bin is equal to Δf.

FFT Frequency Range: The range of frequencies computed and displayed in an FFT is 0 Hz to the Nyquist frequency.

FFT Frequency Resolution: In a narrow sense, the frequency resolution is equal to the bin width, Δf. That is, if the input signal changes its frequency by Δf, the corresponding spectrum peak will be displaced by Δf. For smaller changes of frequency, only the shape of the peak will change.

However, the effective frequency resolution (i.e. the ability to resolve two signals whose frequencies are almost the same) is further limited by the use of window functions. The ENBW value of all windows other than the rectangular is greater than Δf (i.e. greater than the bin width).

FFT Number of Points: FFT is computed over the number of points (Transform Size) whose upper bound is the source number of points. FFT generates spectra having n/2 output points.

FFT Total Power: Area under the power density spectrum in frequency-domain measurements.

FIFO: First-in, first-out shift registers (sometimes called first-in, first-out memory).

Filter: An electronic circuit or digital data manipulation routine that either enhances desirable or removes undesirable aspects of an analog waveform or its digital representation. Filters are used to block specific frequency components from passing through a circuit, to linearize otherwise identical components (such as CCDs) used in a common circuit, or to perform waveform integration, differentiation, or smoothing, just to name a few types.

Flash ADC: A very fast analog-to-digital converter in which the analog signal simultaneously is compared to 2n - 1 different reference voltages, where n is the ADC resolution. Also called a parallel converter. A very fast analog-to-digital converter usually consisting of a large set of fast comparators and associated logic.

Floor: The record of points which make the bottom (or minimum) of an envelope created from a succession of waveforms.

FWHM: Full-Width Half Maximum. The width of a pulse or waveform at 50% amplitude used to measure the duration of a signal.

Gate:
1. A circuit element used to provide a logical function (e.g. AND, OR);
2. An input control signal or pulse enabling the passage of other signals.

Glitch: A spike or short-time duration structural aberration on an otherwise smooth waveform that is normally characterized by more gradual amplitude changes. In digital electronics, where the circuit under test uses an internal clock, a glitch may be considered to be any pulse narrower than the clock width.

Glitch Trigger: A trigger on pulse widths smaller than a given value.

Ground Loop: A long ground connection along which voltage drops occur due either to heavy circuit current or external pick-up, with the result that circuit elements referred to different points along it operate at different effective ground references.

HF Sync: Reduces the trigger rate by including a frequency divider in the trigger path, enabling the input trigger rate to exceed the maximum for repetitive signals.

Histogram: A graphical representation of data such that the data is divided into intervals or bins. The intervals or bins are then plotted on a bar chart where the height is proportional to the number of data points contained in each interval or bin.

Hold-off by Events: Selects a minimum number of events between triggers. An event is generated when the trigger source meets its trigger conditions. A trigger is generated when the trigger condition is met after the selected number of events from the last trigger. The hold-off by events is initialized and started on each trigger.

Hold-off by Time: Selects a minimum time between triggers. A trigger is generated when the trigger condition is met after the selected delay from the last trigger. The timing for the delay is initialized and started on each trigger.

HPGL: Hewlett-Packard Graphics Language Format; Hewlett-Packard Company.

Hybrid Circuit: A small, self-contained, high-density circuit element usually consisting of screened or deposited conductors, insulating areas, resistors, etc., with welded or bonded combinations of discrete circuit elements and integrated circuit chips.

IC: Integrated Circuit. A self-contained, multiple-element circuit such as a monolithic or hybrid.

Integral Linearity: A term often used inappropriately to mean integral non-linearity.

Integral Non-Linearity: Deviation of ADC response from an appropriate straight line fit. The specification is sometimes defined as maximum deviation, expressed as a fraction of full scale. More recent ADCs have a specification expressed as a percent of reading plus a constant.

Interleaved Clocking: Supplying clock pulses of equal frequency but different identical circuits or instruments in order to increase the system sample rate. For example, use of two transient recorders with inputs in parallel but complementary clocks to allow operation at twice the maximum rate of a single unit.

Interval Trigger: Selects an interval between two edges of the same slope. The trigger can be generated on the second edge if it occurs within the selected interval or after the selected interval. The timing for the interval is initialized and restarted whenever the selected edge occurs.

Jitter: Short-term fluctuations in the output of a circuit or instrument which are independent of the input.

Leakage: When observing the Power Spectrum of a sine wave having an integral number of periods in the time window using the rectangular window, leakage is the broadening of the base of the peak spectral component that accurately represents the source waveform's amplitude.

Limiter: A circuit element which limits the amplitude of an input (used for input protection, pulse standardizing, etc.).

Logical 1: A signal level indicating the TRUE state; corresponds to the unit being set (i.e. if interrogated, the answer is yes).

Logical 0: A signal level indicating the FALSE state; corresponds to the unit NOT being set (i.e. if interrogated, the answer is no).

Long-Term Stability: Refers to stability over a long time, such as several days or months.

MCA: Multichannel Analyzer (e.g. pulse height analyzer).

Mean Value: Average or DC level of all data points selected in a waveform. i.e.

$$\frac{1}{N}\sum_{i=1}^{N} v_i$$

Median Value: The data value of a waveform above and below which there are an equal number of data points.

Mode Value: The most frequently occurring data value of a waveform.

Monolithic IC: An integrated circuit whose elements (transistors, diodes, resistors, small capacitors, etc.) are formed on or within a semiconductor substrate.

Monotonic: A function with a derivative that does not change sign.

Multiplexer: A device used to selectively switch a number of signal paths to one input or output.

NAND: An AND circuit, except with a complementary (negative true) output.

Negation: The process of transposing all negative values into positives and all positive values into negatives.

Noise Equivalent Power: NEP (W); the RMS value of optical power which is required to produce unity RMS signal-to-noise ratio.

NOR: An OR circuit, except with a complementary (negative true) output.

Nyquist Frequency: The Nyquist frequency (f/2) is the maximum frequency that can be accurately measured by a digitizer sampling at a rate of (f). In other terms, a digitizer sampling at a rate of (f) cannot measure an input signal with bandwidth components exceeding f/2 without experiencing "aliasing" inaccuracies.

Offset: The amount by which an analog or digital output or input baseline is shifted with respect to a specific reference value (usually zero).

OR: A logic circuit having the property that if at least one input is true, the output is true.

Overshoot, Negative: A time-domain parameter in waveform measurements, equal to the base value of a waveform minus the minimum sample value, expressed as a percentage of the amplitude.

Overshoot, Positive: A time-domain parameter in waveform measurements, equal to the maximum sample value minus the top value, expressed as a percentage of the amplitude. The top value is the most probable state determined from a statistical distribution of data point values in the waveform.

Parallel Converter: A technique for analog-to-digital conversion in which the analog signal is simultaneously compared to 2n - 1 different reference voltages, where n is the ADC resolution.

Pass/Fail Testing: Post-acquisition testing of a waveform against a reference mask or of waveform parameters against reference values.

Pattern Trigger: The pattern trigger logically combines the states of the trigger inputs. The combination, called a pattern, is defined as the logical AND of the trigger states. A trigger state is either high or low; high when a trigger source is greater than the trigger level and low if it is less that the trigger level. For example, the pattern can be defined as present when the trigger state for channel 1 is high, 2 is low, and EXT is high. If any are not met, the pattern state is considered absent.

Pattern Width: Selects a pattern width, either maximum or minimum. If the width is less than the selected width, the trigger is generated when the pattern ends. If the width is greater than the selected width, the trigger is generated when the pattern ends. The timing for the pattern width is initialized and restarted at the beginning of the pattern.

PCMCIA: Personal Computer Memory Card Industry Association standard for PC memory cards. Also known as JEIDA in Japan.

PCX: The PC Paintbrush Format for graphic images; ZSoft Corporation, Marietta, GA.

Peak Spectral Amplitude: Amplitude of the largest frequency component in a waveform in frequency domain analysis.

Period: A full period is the time measured between the first and third 50% crossing points (mesial points) of a cyclic waveform.

Persistence: A display operating mode of a DSO where a user-determined number of measured traces remain on the display without being erased and overwritten.

PHA (Pulse Height Analyzer): A device that gives a measure of the amplitude of a signal applied to its input.

Picket Fence Effect: If a sine wave has a whole number of periods in the time-domain record, the Power Spectrum obtained with the rectangular window will have a sharp peak, corresponding exactly to the frequency and amplitude of the sine wave. If it does not, the spectrum obtained will be lower and broader. The highest point in the power spectrum can be 3.92 dB lower (1.57 times) when the source frequency is halfway between two discrete bin frequencies. This variation of the spectrum magnitude is called the Picket Fence Effect (the loss is called the Scallop Loss). All window functions compensate this loss to some extent, but the best compensation is obtained with the Flat Top window.

Power Spectrum: The square of the magnitude spectrum (V^2). The Power Spectrum is displayed on the dBm scale, with 0 dBm corresponding to V^2_{ref} = (0.316 V peak)^2, where V_{ref} is the peak value of the sinusoidal voltage which is equivalent to 1 mW into 50 Ω.

Power Density Spectrum: The Power Spectrum divided by the equivalent noise bandwidth of the filter (V^2/Hz), in Hz. The Power Density Spectrum is displayed on the dBm scale, with 0 dBm corresponding to (V^2_{ref}/Hz).

Pre-trigger Sampling: A design concept used in transient recording in which a predetermined number of samples taken before a stop trigger are preserved.

Pulse Width: Determines the duration between the Pulse Start (mesial point, i.e. the 50% magnitude transition point, on the leading edge) and the Pulse Stop (mesial point on the trailing edge) of a pulse waveform.

Pulse Start: The 50% magnitude transition point (mesial point) on the leading edge of a pulse waveform.

Pulse Stop: The 50% magnitude transition point (mesial point) on the trailing edge of a pulse waveform.

Pulse Trigger: Selects a pulse width, either maximum or minimum. The trigger is generated on the selected edge when the pulse width is either greater than or less than the selected width. The timing for the width is initialized and restarted on the edge opposite to the edge selected.

RAM: A memory in which each data address can either be written into or read from at any time.

Random Interleaved Sampling (RIS): One method of EQT (or ETS). Acting upon stable, repetitive signals, it represents the process of storing different full sampling sweeps in a DSO or digitizer system, where each sweep is slightly offset from the other to achieve a higher effective sampling rate than the single-shot rate. A major advantage of RIS over other EQT techniques is "pretrigger viewing."

Real Time: A process that occurs without having to pause for internal conversions and references. Real Time processes usually have little or no intrinsic dead time and are able to proceed at a rate which permits almost simultaneous transitions from inputs to outputs.

Reciprocal: The division of unity by the data value being processed.

Reflection Coefficient: The amount of signal amplitude that is reflected from an input, expressed as a percentage of the original input signal.

Resolution: The minimum measurable increment, such as one bit level of an ADC.

Reverse Termination: An output so constructed that pulses reflected back from the rest of the system meet a matching impedance and are absorbed.

RF (Radio Frequency): Normally in the megahertz range.

RFI (Radio Frequency Interference): A special case of EMI wherein the field causing the induced signal falls into the radio portion of the electromagnetic spectrum.

Risetime: Unless otherwise defined, the time required for a pulse to go from 10% to 90% of full amplitude. Can also refer generally to the leading edge of a pulse.

RMS (Root Mean Square): Is derived from the square root of the average of the squares of the magnitudes, for all the data as described above.

$$\frac{1}{N}\sqrt{\sum_{i=1}^{N} V_i^2}$$

For time-domain waveforms, the square root of the sum of squares divided by the number of points for the part of the measured waveform between the cursors. For histogram waveforms, the square root of sum of squares divided by number of values computed on the distribution.

ROM: Read-only memory is any type of memory which cannot be readily rewritten. The information is stored on a permanent basis and used repeatedly. Usually randomly accessible.

Roof: The record of points which make the top (or maximum) of an envelope created from a succession of waveforms.

Sample and Hold: A circuit that, on command, stores on a capacitor the instantaneous amplitude of an input signal.

Sampling Frequency: The clock rate at which samples are taken during the process of digitizing an analog signal in a DSO or digitizer.

Scallop Loss: Loss associated with the picket fence effect.

Sensitivity:
1. The minimum signal input capable of causing an output signal with the desired characteristics.
2. The ratio of the magnitude of the instrument response to the input magnitude (e.g. a voltage ADC has a sensitivity that is usually measured in counts/mV). Often, sensitivity is referred to the input and is therefore stated as the inverse.

Shot Noise: Noise caused by current fluctuations, due to the discrete nature of charge carriers and random emission of charged particles from an emitter. Many refer to shot noise loosely, when speaking of the mean square shot noise current (amps) rather than a noise power (watts).

SMART Trigger: The SMART Trigger allows setting additional qualifications before a trigger is generated. These qualifications can be used to capture rare phenomena such as glitches or spikes, specific logic states or missing bits. One qualification can include, for example, generating a trigger only on a pulse wider or narrower than specified.

Smoothing, N-Point The process of evening out the display of a waveform by displaying a moving average of "N" adjacent data points added to each other.

SNR: Signal-to-Noise Ratio is the ratio of the magnitude of the signal to that of the noise.

Square: The process of multiplying a value by itself.

Stage Delay: The time delay in circuit between input and output, usually measured between the front edges (half maximum) of the respective signals.

Standard Deviation: The standard deviation of the measured points from the mean. It is calculated from the following formula:

$$\frac{1}{N-1}\sum_{i=1}^{N}(v_i - mean)^2$$

Standard Trigger: Standard Trigger causes a trigger to occur whenever the selected trigger source meets its conditions. The trigger condition is defined by the trigger level. coupling, high frequency sync, and slope.

State Qualified: State-Qualified triggering generates a trigger when the trigger source meets its conditions during the selected pattern. A pattern is defined as a logical AND combination of trigger states. A trigger state is either high or low. High when a trigger source is greater than the trigger level, and low if it is less than the trigger level.

Stop Trigger: A pulse which is used to stop a transient recording or similar sequence.

Summation Averaging: The repeated addition, with equal weight, of successive waveforms divided by the total number of waveforms acquired.

TDC: Time-to-digital converter.

Terminate: Normally, to provide a matching impedance at the end of coaxial cable to prevent reflections.

Test Template: A general form of waveshape limit test, which defines an arbitrary limit (or non-uniform tolerance) on each measured point in a waveform.

Threshold: The voltage or current level at which a circuit will respond to a signal at its input. Also referred to as trigger level.

TIFF (Tagged Image File Format): Industry standard for bit-mapped graphic files.

Time Between Patterns: Selects a delay, either maximum or minimum, between exiting one pattern and entering the next. The trigger is generated on entering the second pattern either within the selected time or after the selected minimum time.

Timeout: A Timeout occurs when a protective timer completes its assigned time without the expected event occurring. Timeouts prevent the system from waiting indefinitely in case of error or failure.

Time Qualified: Time-Qualified triggering generates a trigger when the trigger source meets its trigger condition after entering or exiting the pattern. The trigger can occur even if the pattern disappears before the trigger meets its trigger conditions. See "Pattern Trigger."

Tolerance Mask: A form of waveshape limit test which defines a maximum deviation equal to a uniform tolerance on each measured point in a waveform.

Track and Hold: A circuit that precedes an analog-to-digital converter which has the ability on command to store instantaneous values of a rapidly varying analog signal. Allows the ADC to accurately digitize within tighter time domains.

Transient Recorder: See Waveform Digitizer.

TTL (Transistor-Transistor Logic): Signal levels defined as follows: LOGICAL 0 = 0 to 0.8 V and LOGICAL 1 = 2.0 to 5.0 V.

Trend: Plot of a parameter value or other characteristic of a measurement over a period of time.

Waveform Digitizer: An instrument which samples an input waveform at specified intervals, digitizes the analog values at the sampled points and stores the results in a digital memory.

Window Functions: Used to modify the spectrum of a truncated waveform prior to Fourier analysis. Alternately, window functions determine the selectivity (filter shape) in a Fourier transform spectrum analyzer. In LeCroy scopes, all window functions belong to the sum of cosines family with 1 to 3 non-zero cosine terms ($W = \sum a_m \cos(2\pi k/N)$, where N is the number of points in the decimated source waveform, and k is the time index).

X-Y Display: A plot of one trace against another trace. This technique is normally used to compare the amplitude information of two waveforms. It can reveal phase and frequency information through the analysis of patterns called Lissajous figures.

Credits

Apple and Macintosh are registered trademarks of Apple Computer, Incorporated.

BubbleJet is a registered trademark of Canon USA, Incorporated.

Centronics is a registered trademark of Data Computer Corporation.

Compaq, Compaq III and Compaq 386 are trademarks of Compaq Computer Corporation.

EASYWAVE is a registered trademark of LeCroy Corporation.

Epson MX, FX, and LQ are a registered trademarks of Seiko Epson Corporation.

FASTGLITCH, WAVEFORM CATALYST, SMART Trigger and SMART Memory ScopeStation are trademarks of LeCroy Corporation.

Graphtec is a registered trademark of Graphtec Corporation.

HP, HPGL, ThinkJet, QuietJet, DeskJet, PaintJet and LaserJet are registered trademarks of Hewlett Packard Corporation.

IBM, IBM PC, IBM PC/XT, IBM PC/AT, and IBM Personal System 2 are registered trademarks of International Business Machines Corporation.

LabWindows and LabView are registered trademarks of National Instruments Corporation.

MathCad is a registered trademark of MathSoft Incorporated.

Microsoft, MS-DOS, QuickBasic and Windows are a registered trademarks of Microsoft Corporation

Novell and Netware are registered trademarks of Novell Corporation.

PC-2 and PC-2A are trademarks of National Instruments Incorporated.

PCX is a file format developed by ZSoft Corporation for use with PC paint programs.

Philips is a registered trademark of Philips Test & Measurement Incorporated.

PSpice is a registered trademark of MicroSim Corporation.

Quantum is a registered trademark of Quantum Corporation.

Quantum Grand Prix™ 4.3 GB Disk Drive photo courtesy of Quantum Corporation.

SUN is a trademark of SUN Microsystems.

UNIX is a registered trademark of AT&T.

VAX, MicroVAX, VMS, QBUS, and UNIBUS are registered trademarks of Digital Equipment Corporation.

W.A.V.E. is a product of Vespine Division of Electronic Decisions Incorporated.

Notes

Notes

Notes

Notes

Notes

Notes

Announcing...

More Power for Solving Jitter and Timing Problems

LeCroy offers unmatched capabilities to **CAPTURE, VIEW and ANALYZE** the timing characteristics of complex signals found in leading edge circuits.
You can combine the performance of the most advanced oscilloscope in LeCroy's product line (the model LC584AL) which offers sampling rates up to 8 GS/s into 8 Mbytes of acquisition memory, the new Jitter & Timing Analysis Package and 1 GHz FET probes (model AP020) with surface mount technology probing accessories (PK106).

Or if your circuit uses high speed differential signals the new AP033 500 MHz differential probe is an excellent tool.

- **Maximum sample rate of 8 GS/s for high precision**
- **Up to 8 Mbytes of acquisition memory for capture of data streams**
- **Advanced parameter analysis of signal jitter, cycle to cycle timing measurements, time interval error and other timing parameters**
- **Measure variations in the width and duty cycle of pulses**
- **View and Measure the details of Pulse Edges**
- **Measure Jitter and Noise on Eye Diagrams**
- **Analyze Jitter and Timing Problems using Histograms or Trend lines of over 40 Parameters**
- **1 GHz bandwidth FET probes with SMT accessories**
- **500 MHz differential probes with excellent gain, offset and low noise**

Jitter and Timing problems are often the most difficult and important challenges an engineer faces. LeCroy offers advanced parameters for timing measurements and 42 standard parameters to characterize circuit performance, the ability to use histograms & trend lines to analyze key signal parameters, LeCroy's patented max/min binning algorithm to view deviations in signal shape and a variety of other advanced features.

There are also three new timing functions for analysis of persistence displays--the Jitter Function, Persistence Histograms and Persistence Traces. These new functions allow insights into the jitter/timing of signals that have not been available with previous instruments. The combination of tools available from LeCroy offers the most advanced capabilities for solving your hardest problems.

LeCroy

LeCroy Sales Offices:

Asia South: Australia
Phone (61) 3 9877 9322
Fax (61) 3 9849 0861

Asia North: Hong Kong
Phone (852) 2836 7361
Fax (852) 2836 7007

France: Les Ulis
Phone (33) 1 6918 8320
Fax (33) 1 6907 4042

Germany: Heidelberg
Phone (49) 6221 827 00
Fax (49) 6221 834 655

Italy: Venice
Phone (39) 41 456 97 00
Fax (39) 41 456 95 42

Japan: Osaka
Phone (81) 6 396 0961
Fax (81) 6 396 0962

Japan: Tokyo
Phone (81) 3 3376 9400
Fax (81) 3 3376 9587

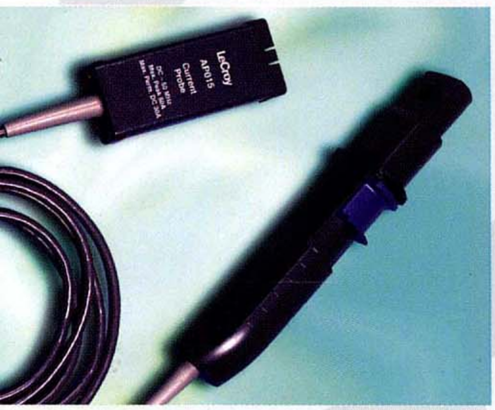
Japan: Tsukuba
Phone (81) 2 9841 5810
Fax (81) 2 9841 5830

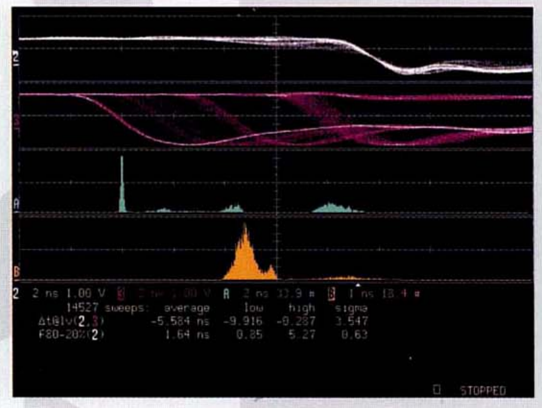
Switzerland North: Niederlenz
Phone (41) 62 885 8050
Fax (41) 62 885 8055

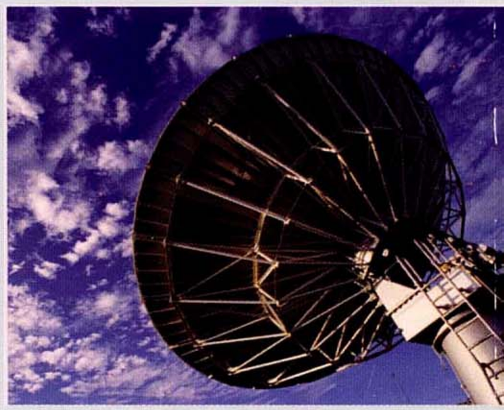
Switzerland West: Geneva
Phone (41) 22 719 2111
Fax (41) 22 719 2230

U.K.: Abingdon
Phone (44) 1 235 536973
Fax (44) 1 235 528796

U.S.A.: Chestnut Ridge
Phone (1) 914 578 6020
Fax (1) 914 578 5985







Sales and Service Throughout the World

Corporate Headquarters
700 Chestnut Ridge Road
Chestnut Ridge, NY 10977
USA

http://www.lecroy.com

TMCAT98 0498
BAW60M

LeCroy