TEST & MEASUREMENT PRODUCTS CATALOG

2001



LeCroy

Extreme Vision — Maximum Insight

wavepro™

The new WavePro family of scopes gives you more samples on your edge, accurate capture of long, complex waveforms, and easy access to a wide range of important measurements.

Only WavePro scopes provide:

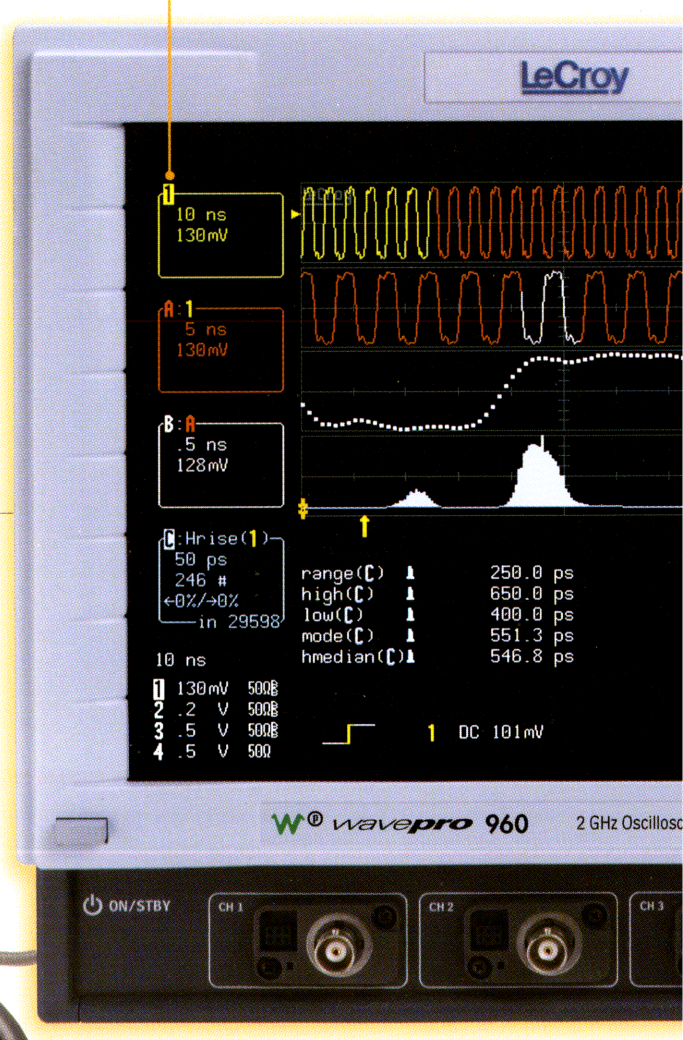
- **Fastest Sample Rate (Up to 16 GS/s)**
- **Longest Memory (Up to 64 MPts)**
- **Most Measurements (40 custom parameters available!)**

and

- **Super Easy Viewing of Signals, using QuickZoom and the Wavepilot Toolbar**

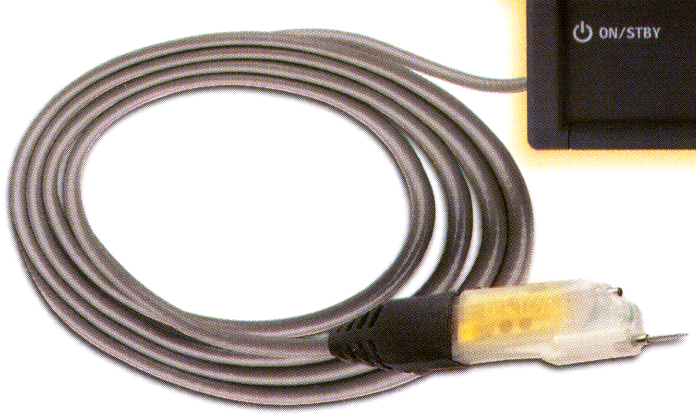
Large 10.4" TFT LCD Display

The large, sharp, bright color display makes it easy to see signal details.



Connectivity to Windows

- Connect your scope to Windows-based ScopeExplorer using the Ethernet (option), GPIB or RS-232 interfaces. Click and drag files or operate from the virtual front panel. Download new software updates via the web.



NEW

HFP Series

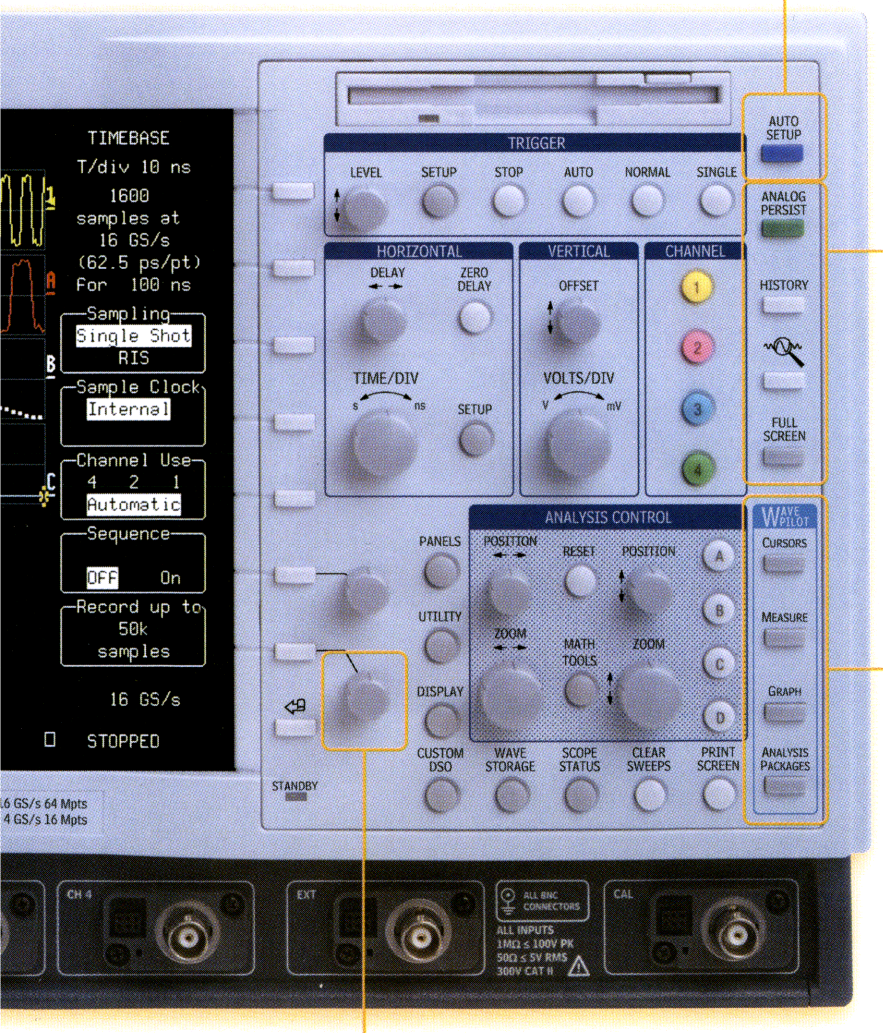
High Bandwidth Probes with AutoColor ID

WAVEPRO

WavePro

Auto Setup

Press one button and automatically get your signal on the screen.



Fast, Easy Access

to powerful but simple features that help you solve real problems quickly!

Analog Persistence™

Press the green button to switch between analog view and digital view so you can visually explore the full depth of signal information. Display the *HISTORY* of persistence snapshots, then scroll, identify and analyze the tough problems.

QuickZoom

Automatically displays 10X magnified traces of all signals on multi-grids, ensuring maximum resolution and S/N ratio.

Full Screen

Maximizes the display area for signal viewing. It's great for visual signal analysis and measurements with cursors so you really see details and anomalies.

Wavepilot™ Toolbar

For easy access to powerful signal analysis capabilities that help you gain insight and track problems right to the source.

Cursors

Press to measure signals using a full complement of cursors with on-screen measurement display.

Measure

Automatically displays up to 26 signal parameters and the signal.

Graph

For fast insight into problems, display histograms, FFT spectrum analysis or LeCroy's TrackView capability.

Analysis Packages

- JitterPro
- Communications Mask Testing
- Optical Recording
- PowerMeasure
- Disk Failure Analysis

NEW

CUSTOM DSO

Create your own custom applications then assign them to soft-keys, making it easy to perform repetitive work fast and accurately.

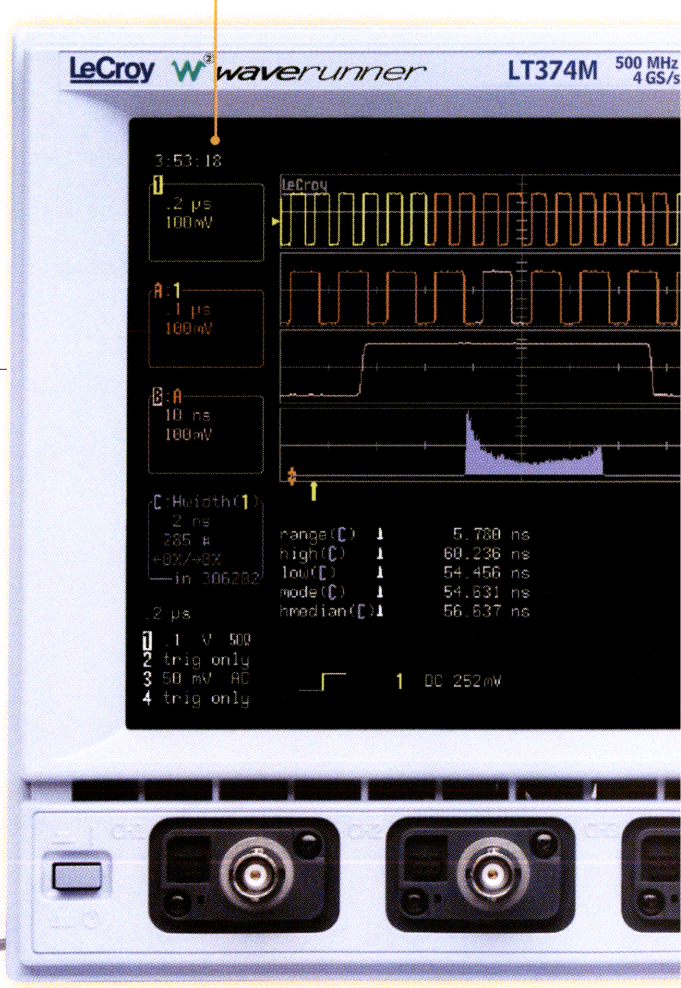
See Into Your Signal

waverunner™

Why walk when you can run? Discover the scopes that defined accessibility and affordability. Now get Waverunner-2 models, with instant access to unique Wavepilot functions and to History and Quick Zoom. Run, don't walk… take a look at the new Waverunner-2 scopes!

Large 8.4" TFT LCD Display

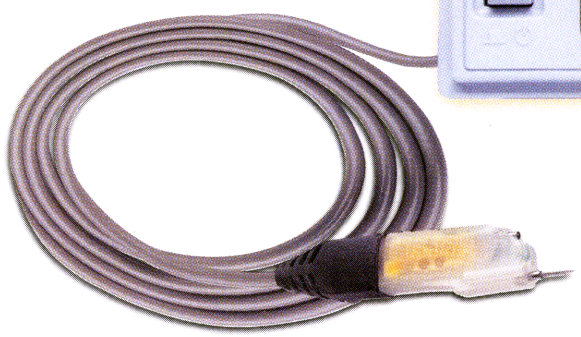
The large, sharp, bright color display makes it easy to see signal details.



Up to 500 MHz Bandwidth and 8 Million Sample Points of Waveform Data at 4 GS/s

Connectivity to Windows

- Connect your scope to Windows-based ScopeExplorer using the Ethernet (option), GPIB or RS-232 interfaces. Click and drag files or operate from the virtual front panel. Download new software updates via the web.



NEW

High Bandwidth Probes. The HFP probes provide low circuit loading, high bandwidth and a variety of interchangeable tips... and AutoColor ID.

Fast, Easy Access

to powerful but simple features that help you solve real problems quickly!

Auto Setup

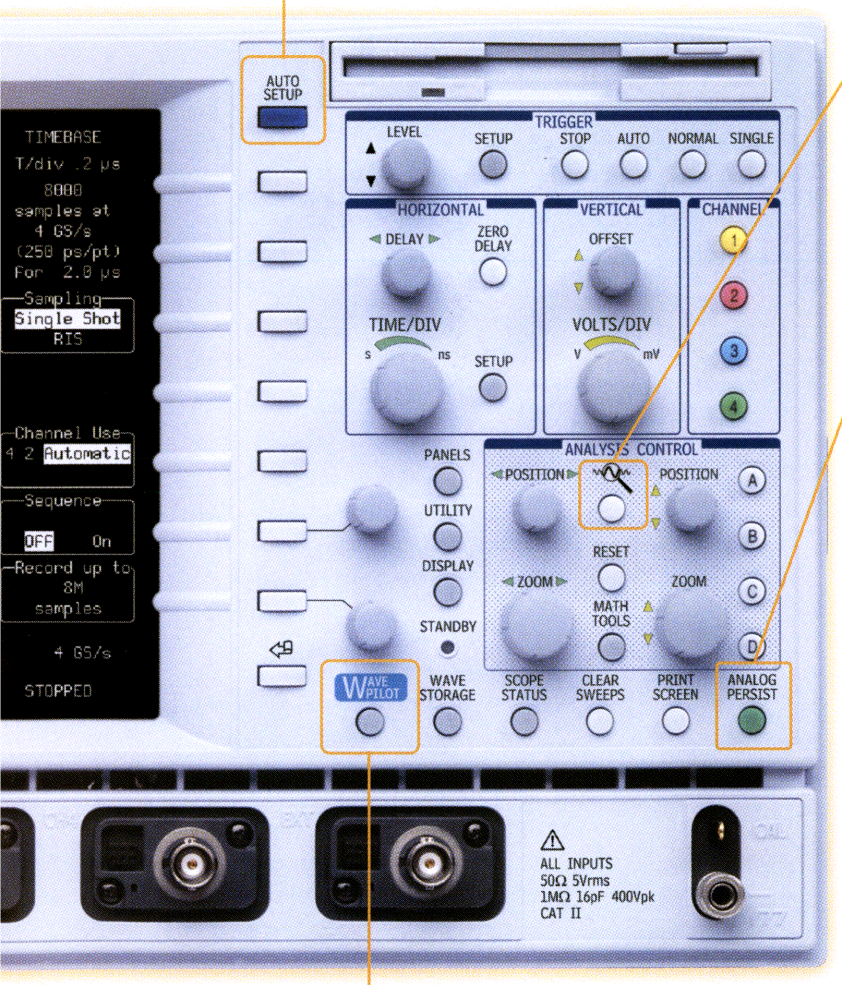
Press one button and automatically get your signal on the screen.

QuickZoom

Automatically displays 10x magnified traces of all signals on multi-grids, ensuring maximum resolution and S/N ratio.

Analog Persistence™

Press the green button to activate Analog Persistence view so you can visually explore the full depth of signal information. Display the *HISTORY* of persistence snapshots, then scroll, identify and analyze the tough problems.



Wavepilot™

Easy access to powerful signal analysis capabilities that help you gain insight and track problems right to the source.

Wavepilot Accesses these Functions:

Cursors

Measure signals using a full complement of cursors with on-screen measurement display.

Measure

Automatically displays up to 26 signal parameters with the signal.

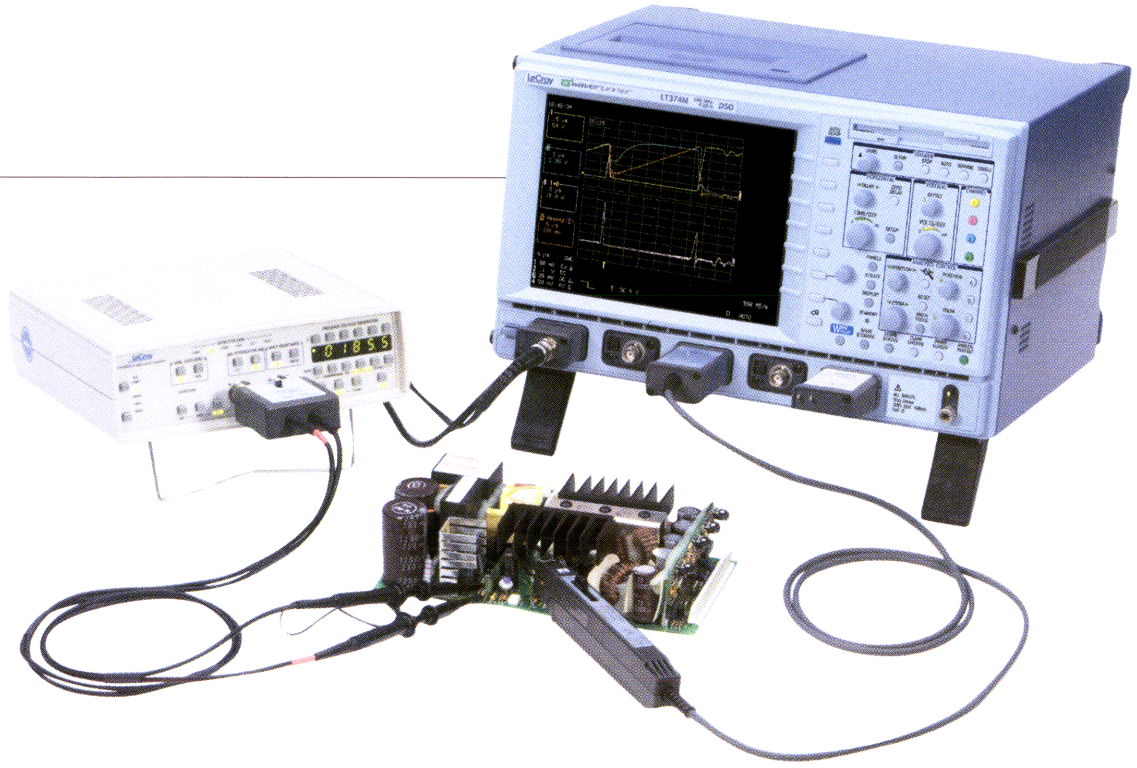
Graph

For fast insight into problems, display of histograms, FFT spectrum analysis, or LeCroy's TrackView capability.

Analysis Packages

- Communications Mask Testing
- Optical Recording
- PowerMeasure

PowerMeasure™ Systems



LeCroy's PowerMeasure System not only makes your routine power measurements simple, it makes easy work of even your most complex, difficult measurements.

No more crossing your fingers and hoping your power supply or motor drive won't fail. No more trial and error — or expensive, over-designed systems. Now you can focus on what's important in power design — confident that the testing is accurate and exhaustive. You won't have to worry about product failures or recalls.

The PowerMeasure System is the most complete high-performance design system available for the power conversion engineer. It includes an easy-to-use, high-performance, full-featured digital storage oscilloscope (DSO); high-performance current and differential voltage measurement capabilities; and powerful software for your key measurements.

The PowerMeasure Analysis (PMA1) software's dedicated menus and shortcuts let you quickly and easily set up the scope to acquire, view, and analyze power signals. A "Setup Helper" is built in to support users step-by-step, ensuring correct and accurate measurements. A dedicated manual comes with PMA1 that details the best way to optimize the scope and probe setups for voltage, current, power, and energy measurements.

The DA1855A is a stand-alone, high- performance 100 MHz differential amplifier that acts as a fully integrated signal conditioning preamplifier. It provides unequalled common mode rejection ratio (CMRR), fast overdrive recovery, and significantly widens oscilloscope offset range.

The amplifier can be fully controlled from the oscilloscope's front panel, the amplifier's front panel, or by using remote commands (GPIB or RS-232-C).

Make Complex Measurements — easily

LeCroy scopes offer more math capability as standard equipment than any other manufacturer.

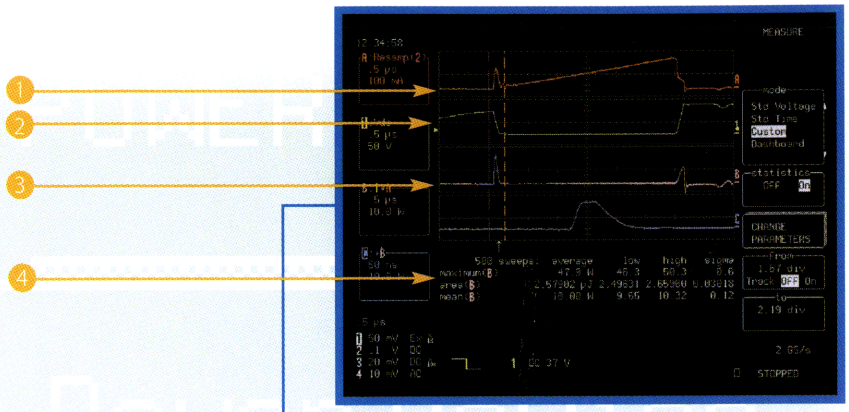
1. A precision AC/DC current probe, such as the AP015, acquires the power device's drain current waveform, and Power Device Analysis displays it properly time-deskewed in relationship to the voltage waveform.
2. The DA1855A/DXC100A differential amplifier and probes have unique capabilities to allow a power FET's drain-source voltage to be safely acquired while the device operates in a power supply's line-referenced primary circuit.
3. LeCroy's PowerMeasure System assists you with the set up for instantaneous power waveforms.
4. Using the measure menu, turn-on and turn-off switching transitions are easily measured.

You can also perform modulation analysis, analyze harmonics, examine dynamic turn-on resistance, and measure other important power device characteristics.

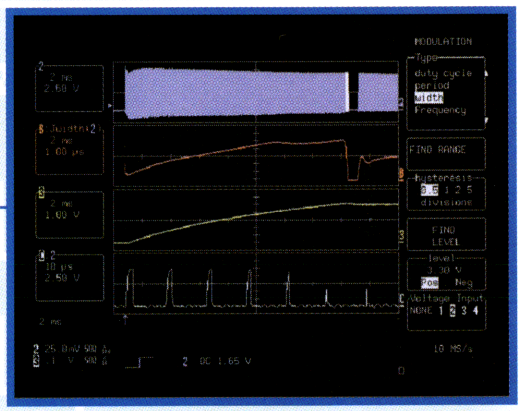
The AP015 50 MHz current probe measures the current flowing through a conductor. The probe is based on a combination of Hall effect and transformer technology that allows measurements to be made on DC, AC, and impulse currents. Its rugged design uses a split-core transformer enabling the probe head to be clamped around a conductor that remains in circuit.

The DXC100A is a high-performance, passive, matched differential probe pair designed for use with the DA1855A. It increases the maximum input signal and common mode ranges in proportion to their attenuation ratio, up to a ±500 V (1000 V differential) voltage rating. Other LeCroy probe pairs offer ranges up to ±2500 (5000 V differential).

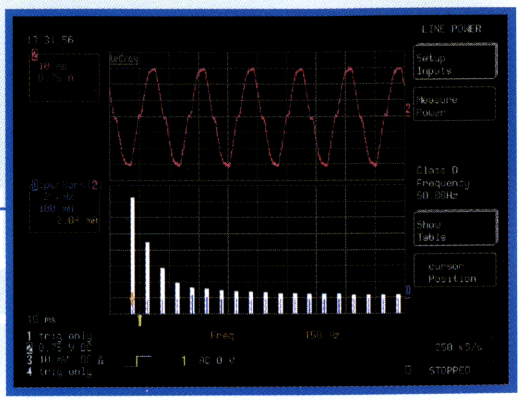
The DCS015 provides time-coincident voltage and current signals that are used as references for deskewing current and voltage measuring systems.



Measure power device characteristics — in circuit. In this example, a device's turn-on transition loss is measured with a parameter table between window cursors.



Use modulation analysis to determine a control loop's step response to line/load changes and soft start performance.

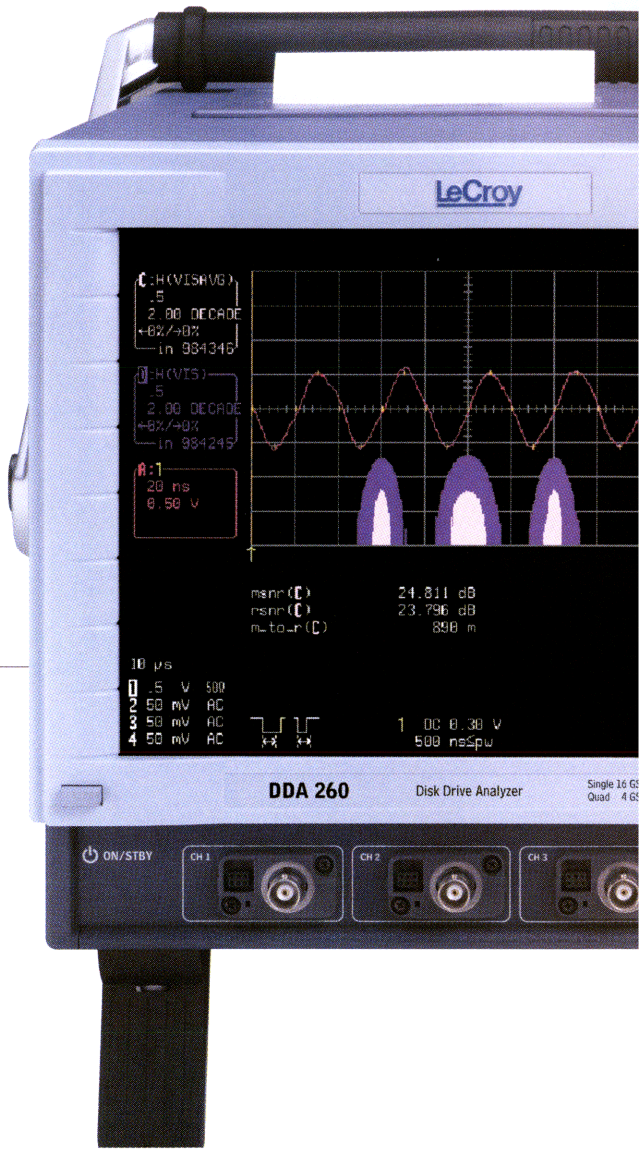


Analyze power factor and line current harmonics.

DDA 260
Powered for Drive Analysis

This instrument offers the highest performance in the industry for data storage design and test. It has the longest memory, loads of signal analysis tools AND offers the highest sampling rate for signals whose duration is greater than 2 msec.

The power to get your job done quickly and easily, and with all the insight you could want. LeCroy Disk Drive Analyzers have performance specifications, capture and analysis features, and a drive-oriented user interface that all provide maximum value to the disk drive engineer.





Performance

- Up to 16 GS/s on a single channel
- Up to 64 Mpts on a single channel
- 2 GHz Bandwidth
- 256 Mbyte processing memory
- 500 MHz external clock input

Drive-Specific Triggers

Only in the DDA series will you find disk drive triggers defined in disk drive terminology.

Customized triggering is available for selecting the n'th servo gate or triggering on every servo gate after the index pulse. The Read Gate Trigger can be customized to select pulses from 100 ns to 50 ms. The PES Trigger will activate signal acquisition when the Position Error Signal exceeds threshold. Finally, the Sector Pulse Trigger allows selection of any particular sector.

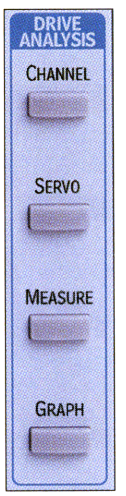
Disk Drive Noise Analysis

Characterize head and media noise. Separate media noise from electronics noise.

PRML Analysis

Channel emulation of PR4, EPR4, E2PR4, and other head signals. You can compute NLTS, ACSN, or view maximum likelihood markers indicating ideal sampling points for a PRML signal.





Drive Analysis

Special front-panel keys provide easy access to a powerful set of drive analysis capabilities.

Analyze your channel from head signal through PRML channel emulation

Analyze servo wedges and position error signal for insights into positioning errors

Easy access to a rich set of drive measurements

View drive-specific graphical analysis such as PRML dot plots, SAM histograms, and media noise analysis measurements

Basic Disk Drive Measurements

The DDM package includes a wide range of basic measurements: TAA, PW50, Overwrite, Resolution, and others. It also offers many local parameters such as local minimum, maximum, time under threshold, and base.

Internal Graphics Printer

A high-resolution internal graphics printer comes standard with the DDA 260. Get hard-copy output in less than 10 seconds, or use the strip chart mode to view all the details in a long, complex signal.

NEW

CustomDSO

Customize your DDA 260 with shortcut keys, or create application-specific tests and menus.

External Interfaces Standard

Built-in printer, GPIB, Floppy, PCMCIA port for memory cards or portable hard drives and VGA port. Bidirectional RS-232-C and Centronics ports are also provided.

Ethernet Port (optional)

10 BaseT, TCP/IP protocol

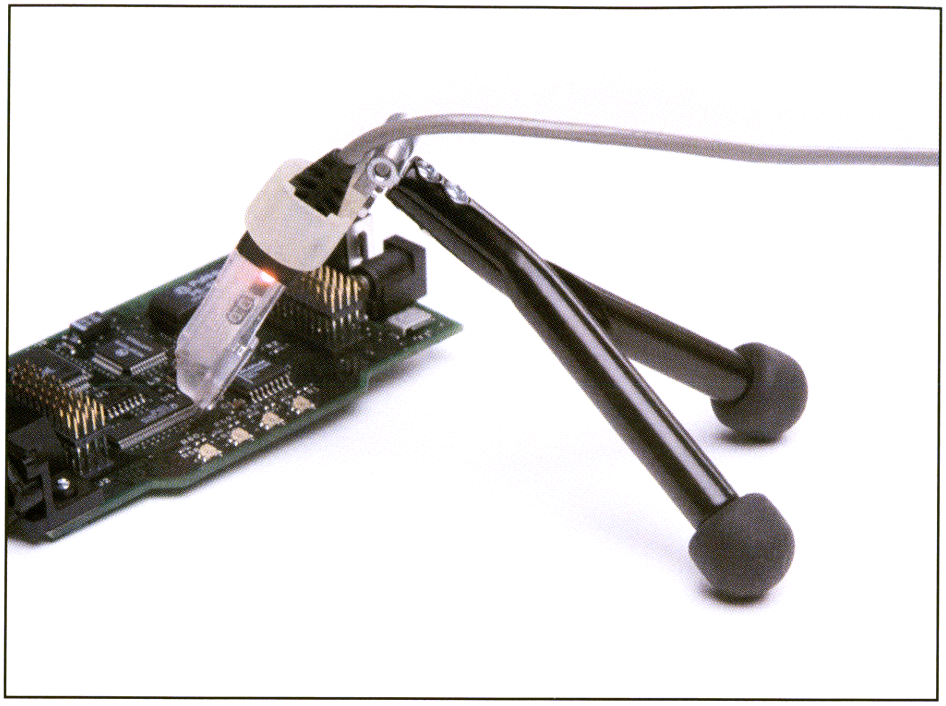
Unique Probing Solutions

LeCroy has been making significant advancements in oscilloscope probe technology.

Introducing the HFP series of active probes, designed to help engineers access difficult SMT circuits and measure them accurately.

And the new CP probes make challenging current measurements easier than ever to perform and they virtually eliminate operator error!

When you think probes, think LeCroy. Our solutions are innovative, designed for the task, and affordable.



New HFP2500 probe with *FreeHand* probe holder.

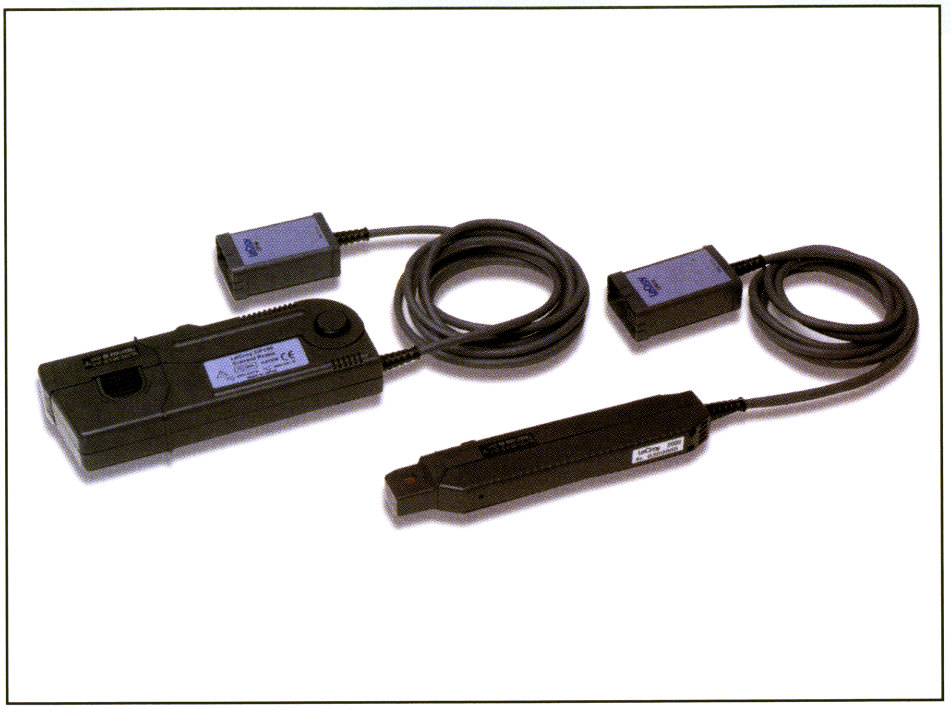
New HFP Active Probes

Our three active probes, the HFP series, are nifty, nimble and new! A variety of smart accessories make SMD probing easier than ever. The most important feature of a probe is that it should not affect the signal under test. With an input impedance of 100 kΩ and only 0.7 pF capacitance, the HFP series provides very low circuit loading.

Five different application-specific tips are available for the HFP probes, and all come standard with the 1500 and 2500 models. Installing and removing tips is a breeze with a tip socket system; just plug and probe! Additionally, the tip socket is on a removable cartridge. You don't have to buy a brand new probe if you damage the tip socket--simply insert a new cartridge!

To solve the problem of how to use four probes with only two hands, there is the *FreeHand* probe holder. Designed to keep most of the weight on the probe tip, *FreeHand* allows the user to probe multiple points with both hands free. Now the waveforms get your attention, not keeping the probes connected to the test point.

LeCroy's patent pending AutoColor ID feature automatically illuminates the probe head in the channel's default trace color! "Chicken bands" or tape are no longer needed to identify which probe is plugged into which channel.



New current probes - CP150 (left) and CP015 (right)

New CP Current Probes

Our new current probes are one more example of LeCroy innovation. The new CP015 and 150 AC/DC ProBus-powered probes have a smaller form factor for easy access to circuits without sacrificing a large-jaw size.

The CP015 has a 50 MHz bandwidth and 50 A peak. The CP150 has a 10 MHz bandwidth and measures pulses up to 500 A peak.

With great pricing, AC/DC versatility and ProBus compatibility, the new CP probes eliminate the external amplifier and save you money. Power measurements just became a lot more powerful, thanks to the CP probes.

Our new current probes are one more example of LeCroy innovation. Based on a combination of Hall effect and transformer technology, these current probes are ideal for making accurate power measurements.

Insulated wires aren't easily accessible, which is why a small form factor solution will greatly simplify measuring. However, while retaining a small form factor, the CP015 and CP150 have a large jaw size, enabling most common insulated wires (in the current range of the respective probes) to be measurable.

Measuring units and scale factors are all controlled from the oscilloscope's front panel. This means all measurements and units will be correct without the need to compensate for attenuation differences between the probe and the oscilloscope.

Degaussing the probe and auto-zeroing any residual offset can be easily done by pressing a button in the coupling menu. This makes it easy to get accurate measurements.

The 150 A RMS CP150 is the only current probe in its class that is oscilloscope-powered, and does not require an external amplifier to operate.

Insight into Circuit Timing

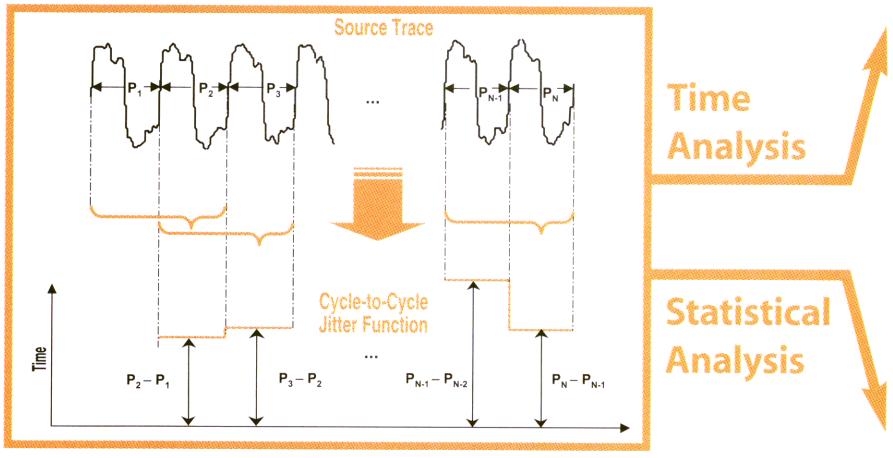
LeCroy offers a selection of application packages for measuring and troubleshooting timing problems. The basic Jitter and Timing Analysis (JTA) package is available for general-purpose use, while the JitterPro package is targeted to high-speed design engineers who need maximum performance and accuracy. JitterPro's Clock Certification and Test Module (CCTM) is specifically oriented to testing high-speed clocks, such as those used in Rambus® technology.

Whether you're designing computer chips, high-speed data buses, switches or routers for high-speed networks, or other applications where signal timing is of high importance, LeCroy's Jitter and Timing packages can be the stabilizing force in your design process.

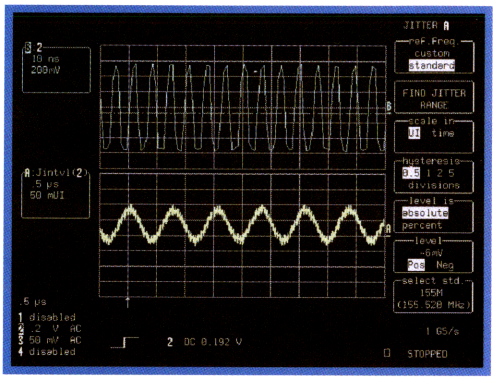
You can:

- Perform measurements with very high accuracy
- Measure period stability, cycle-to-cycle jitter, and other key timing parameters
- Perform unparalleled jitter analysis
- View data in three domains — time, frequency, and statistical — to debug circuit timing problems
- Perform single-shot measurements, making full use of the deep memory available in LeCroy scopes

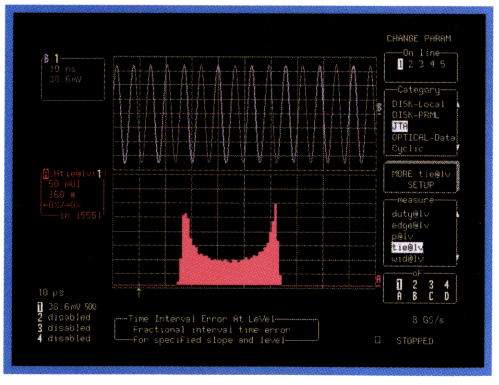
JitterTrack



Cycle-to-Cycle JitterTrack is the ideal tool for measuring short-term stability — for example, to characterize a Phase Locked Loop (PLL).
Each parameter calculation is performed over all cycles or edges present in the input signal, without limitation.

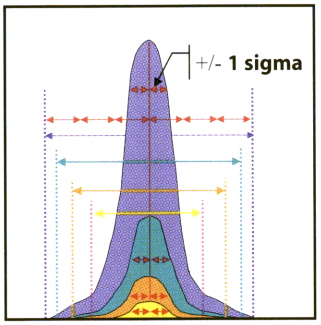


Cumulative jitter on a 155 Mbytes/s clock. Note the 1 MHz sine-shaped modulation.



The same variation characterized with a histogram. Note the $\cos^2$-shaped histogram.

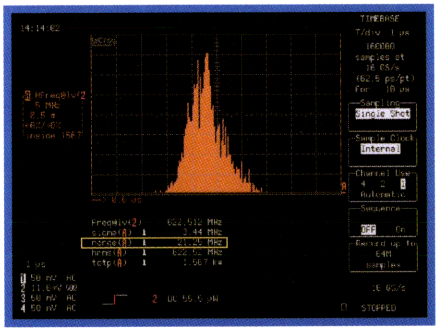
With Jitter, Statistics Count



As more individual measurements are accumulated, their distribution can be displayed in a histogram. The peak-to-peak value grows statistically as more measurements are made.

Measurement of Clock Jitter

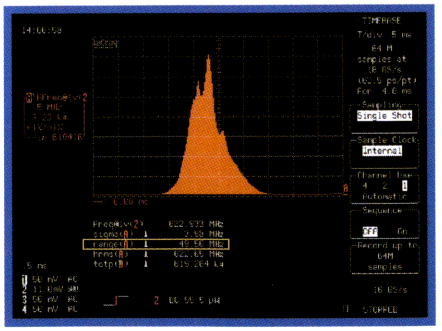
Short-memory oscilloscope (160 kpoint)



Short-memory instruments may only make 1567 measurements of frequency jitter.

Note the jitter range is 21.25 MHz.

Long-memory oscilloscope (64 Mpoint)

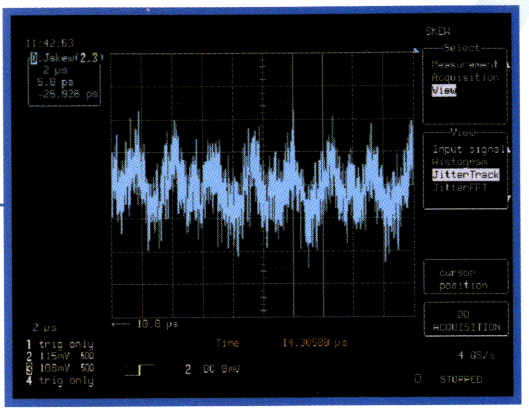


In this example, a long-memory instrument makes 619,418 measurements of frequency jitter.

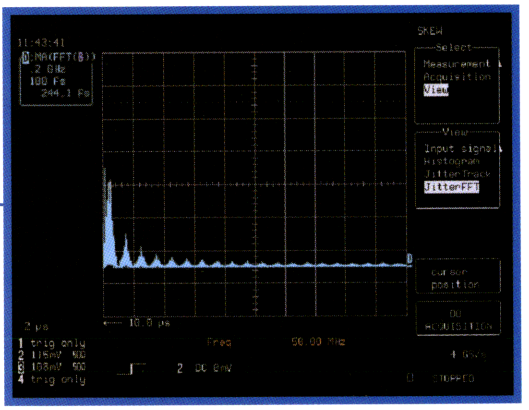
The jitter range is a more accurate 49.5 MHz.

LeCroy's exceptional jitter products use long memory, high stability clock, and extensive display and analysis tools. Our scopes let you capture, view, and analyze a million or more clock edges in a single shot with zero dead time. Other scopes capture a small number of signal edges per trigger and have 90% or more dead time between triggers.

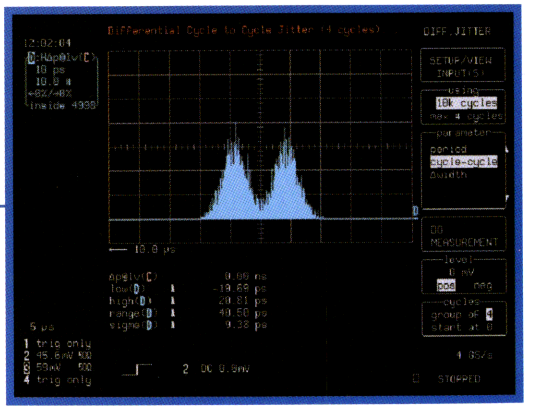
Three Views of Jitter



Time Domain View — JitterTrack reveals patterns in timing/jitter behavior.



Frequency Domain View — An FFT of the JitterTrack waveform shows the spectral content of jitter sources.

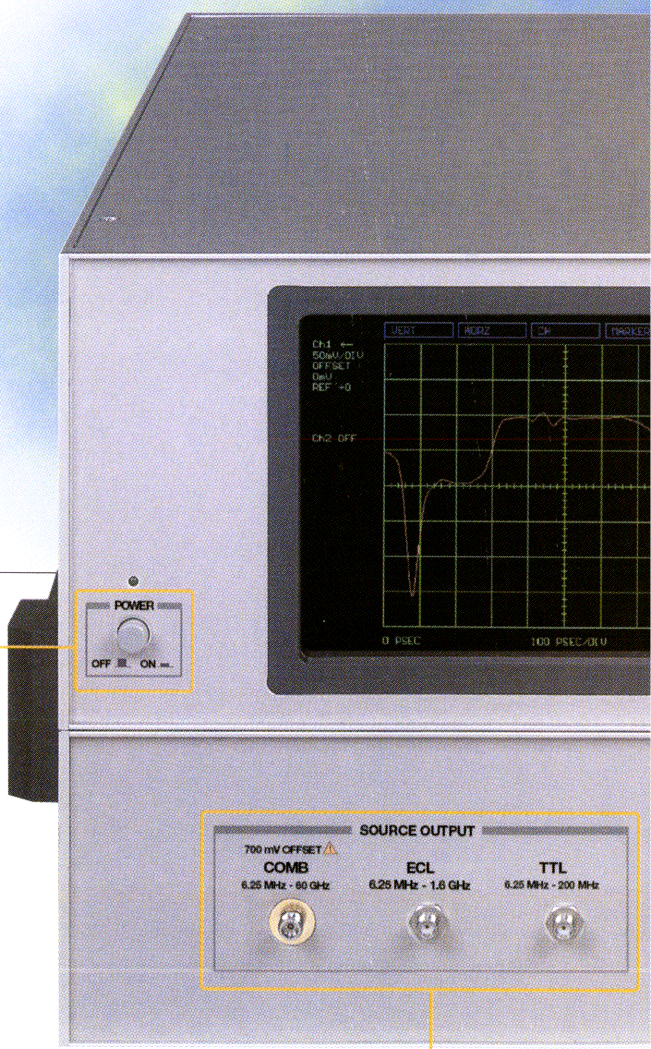


Statistical View — Histograms give accurate peak-to-peak jitter and reveal circuit behavior such as the bimodal cycle-to-cycle distribution above.

Microwave Communications Analyzer

With an outstanding spec of 60 GHz bandwidth, you know this Communications Analyzer really moves! Unlike other communication measuring devices, the MCA 1060 is a broad based microwave signal and component analysis subsystem. It includes signal sources for stimulating passive and active networks up to 60 GHz, You can measure rise and fall times to 6 psec, quantify time delay, pulse width, amplitude, and wander with femtoseconds resolution. Use it as a vector network analyzer to measure group delay, transmission and reflection, both amplitude and phase.

The MCA 1060 A complete test system of stimulus signals and waveform capture/analysis for communications signals from OC-1 to OC-768.



LEADING SPECIFICATIONS

- *60 GHz Bandwidth*
- *Measure waveforms, rise and fall times to 6 psec.*
- *Quantify time delay, pulse width, amplitude, and wander with femtoseconds resolution.*
- *Use as a vector network analyzer to measure group delay, transmission and reflection, both amplitude and phase. Fully corrected high-speed calibration.*
- *Use as a spectrum analyzer.*
- *Broadband TDR capability*
- *Built in frequency synthesizer with a resolution of up to .0000002 Hz.*

Flat Panel Display

The 6.4" flat panel TFT LCD color display shows crisp waveforms in 3 graticule formats: rectangular, polar and Smith chart.

3 Built-in Sources

- Impulse generator with spectral output beyond 60 GHz
- TTL - 200 MHz
- ECL - 1.6 GHz



Standard Numeric Keypad

Controls all instrument functionality

3.5" Floppy Drive

File Formats

- SPICE - PWL Stimulus and Circuit File
- S-Parameter - S-Parameter output for Touchstone and Eagleware

2 Input Channels

"V" Connector 1.85 mm

50Ω Inputs

-90 dB Isolation

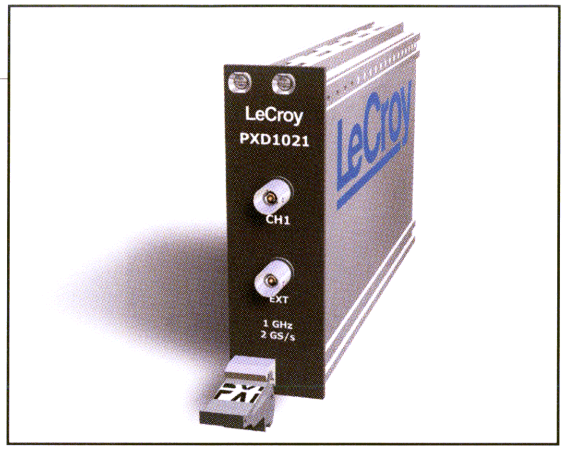
World's Fastest Acquisition System

Modular PXI Digitizers

PXD Series

Leading Features

- ***Complete family 150 MHz – 1 GHz bandwidth***
- ***Up to 2 GS/s sample rate***
- ***Up to 8 million points of acquisition memory***
- ***Up to 50 GS/s Random Interleaved Sampling for repetitive applications***
- ***Complete line of 3U PXI***
- ***Fast PCI bus data transfer rates***
- ***QuickStart software***
- ***IVI scope drivers***



The PXD series features a complete line of PXI digitizers with bandwidths ranging from 150 MHz to 1 GHz. It also features high channel density with up to 8 channels in a single 3U eight slot PXI chassis. These features allow for the capture of long complex signals with excellent accuracy within the compact, rugged, modular architecture of PXI.

The PXD series digitizers are fully PXI compliant and based on the desktop computer industry standard PCI bus. Fast data transfer rates and improvements in test times are realized compared to traditional GPIB instruments. The plug and play functionality of these PXI digitizers provides ease of set-up and use.

PXD series digitizers include several software tools to help you quickly get started and develop test software in LabView, CVI, Visual C++ or Visual Basic. The PXD series software includes an IVI-Scope-compliant instrument driver, ActiveX control and a custom LeCroy PXD getting-started application program for interactive control.

The LeCroy PXD series provides a cost effective, space efficient, high performance digitizer solution for production test applications including:

- Analytical Instruments
- Disk Drive Testing
- Communications Test Systems
- Automotive
- Aerospace and Defense

Acquisition System

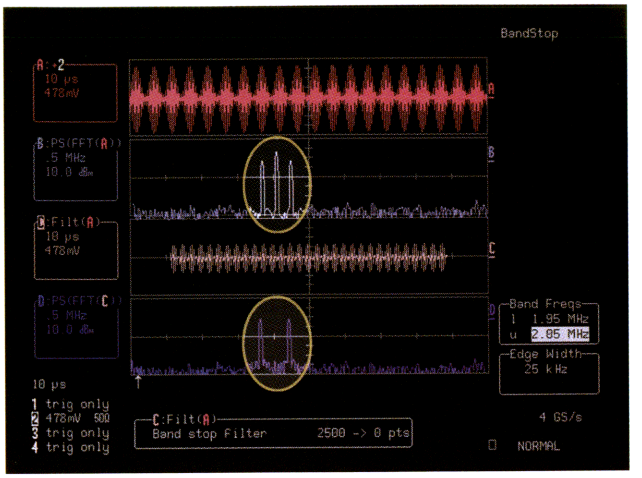
Model	PXD1022	PXD1021	PXD522	PXD514	PXD512	PXD214	PXD212	PXD114
Bandwidth	1 GHz	1 GHz	500 MHz	500 MHz	500 MHz	250 MHz	250 MHz	150 MHz
Maximum Single Shot Sample Rate	2 GS/s	2 GS/s	2 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s
Maximum Repetitive Sample Rate	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s
Channels	2	1	2	4	2	4	2	4
3U PXI Slots	3	2	3	3	2	3	2	3
Acquisition Memory Standard	256 K	256 K	256 K	256 K	256 K	256 K	256 K	256 K
Acquisition Memory Option 1	4 M	4 M	4 M	4 M	4 M	4 M	4 M	4 M
Acquisition Memory Option 2	8 M	8 M	8 M	NA	NA	NA	NA	NA
Single Shot Capture Window	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s
Repetitive Capture Window	2 ns–10 us	2 ns–10 us	2 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us
Sequential Mode Max Segments	8192	8192	8192	4096	4096	4096	4096	4096

Digital Filter Package (DFP)

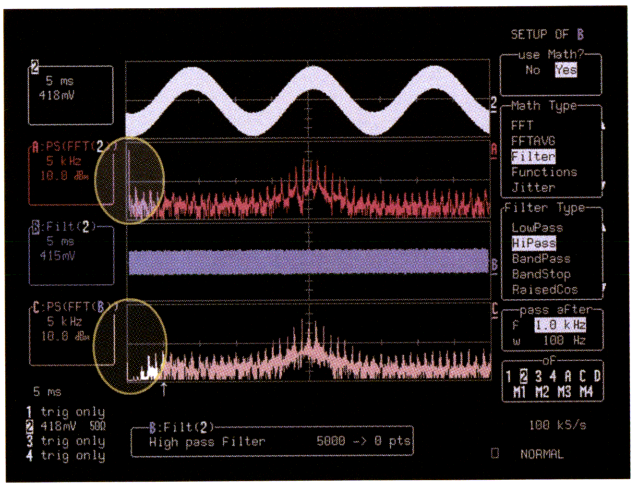
DFP implements a set of linear-phase Finite Impulse Response (FIR) filters. The package enhances your ability to examine important signal components by filtering out undesired spectral effects, such as noise.

This utility is perfect for creating a wide range of digital filters, from low pass, to high pass, to band pass, to band stop, to raised cosine, to raised root cosine, to Gaussian. It is easy to set up and configure these types of filters and DFP can be coupled with other LeCroy analysis packages, like PowerMeasure, Disk Drive and JitterPro/JTA.

You can design your own filters with DFP! Use a digital filter design or math package such as MATLAB or Mathcad to design a custom filter, then download the filter coefficients into a LeCroy scope with the DSO filter utility.



Example of an amplitude modulated high-frequency signal (A) and a 2 MHz carrier modulated with 200 kHz . The signal is filtered by a Band Stop Filter (between 1.95 MHz to 2.05 MHz with narrow edges — only 25 kHz), which removes the 2 MHz carrier leaving only the side bands (C). The unfiltered signal's FFT is shown by (B). The FFT of the filtered signal (D) reveals the absence of the 2 MHz carrier.



Example of a high pass filter, used to block power supply hum (60 Hz frequency component) from a higher frequency signal. The cutoff frequency is set to 1 kHz with a narrow transition region of 1% (very steep). Channel 2 displays the unfiltered signal, while B shows the filtered result. The FFT analysis of the signal before and after the filtration is displayed by traces A and C. Notice the disappearance of the 60 Hz component.

Raising the Bar ... Everyday.

LeCroy Corporation is both a practical and an imaginative company. We adhere to strict processes and design rules, while at the same time priding ourselves on being intense innovators. We think those two orientations work well together to make oscilloscope advancements which meet the needs of design engineers. Our employees rigorously follow Quality processes and recently achieved first-in-the-world recognition for meeting ISO9001-2000 standards. They strive to attain leading-edge positions in our core competencies - the capture, display and analysis of complex, high-speed signals. Customer orientation is at the heart of the Quality program at LeCroy -- so much so that 85% of the plans LeCroy has for new products and product improvements were initially suggestions sent to us by our customers. We bring great products to the market and customers tell us what they want next.



The ISO 9001-2000 flag flies at the Chestnut Ridge, New York headquarters of LeCroy Corporation. On December 15, 2000, LeCroy was the first company to be awarded this significant certification, indicating systematic compliance with the new standard of the ISO organization. LeCroy made Quality history by meeting the new standards for customer orientation.

Hot Products:

Two new products from LeCroy Corporation were just cited by the editors of "EDN" magazine as being HOT: The WavePro 960 flagship oscilloscope and the MCA 1060 Microwave Communications Analyzer. These are breakthrough products featured extensively in this catalog and highlighted in the HOT 100 issue of "EDN".



Best in Test:

"Test and Measurement World" Magazine recognized our new HFP probes as being innovative in the 2001 Best in Test award. The US patent office has 8 patents pending. HFP Probes are unique: they are small, versatile, and lightweight. What's more, they have high impedance and low capacitance which translate into little disturbance of the signal. You can use a *FreeHand* probe holder for truly hands-free operation and interchangeable tips to solve difficult probing problems.



Customer Service:

Our expertise is measurement. We measure customer satisfaction across the board. And the measure of our working diligently to keep customers satisfied is the high ratings we receive from our customers for support. From our service facilities with hundreds of man-years of experience to application engineers positioned around the world to help scope users get up-to-speed on a new product.... LeCroy is synonymous with customer focus. You'll see it in sales, in support, in service, and, of course, in your scope.



LeCroy Test and Measurement Products

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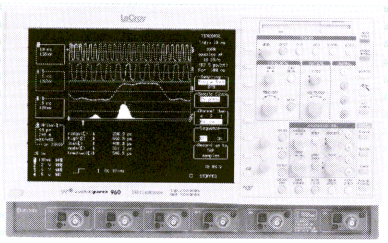
Scope Selection Guide

Digital Oscilloscopes

WavePro

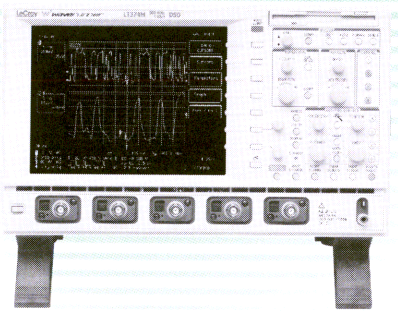


LeCroy DSO Model Number	Number of Channels	Bandwidth	Sample Rate per Channel/1 Ch	Memory per Channel/1 Ch	Display
960	4	2 GHz	4-16 GS/s	250 k/1 M	10.4" TFT
950	4	1 GHz	4-16 GS/s	250 k/1 M	10.4" TFT
940	4	500 MHz	4- 8 GS/s	250 k/1 M	10.4" TFT

Memory Options

M	1 Mpt/ch	4 Mpt maximum
L	4 Mpt/ch	16 Mpt Maximum
VL	8 Mpt/ch	32 Mpt Maximum
XL	16 Mpt/ch	64 Mpt Maximum (Model 960 only)

Waverunner - 2

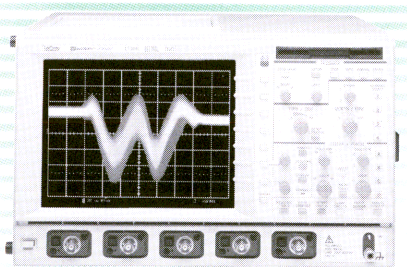


LT374	4	500 MHz	2-4 GS/s	250 k/500k	8.4" TFT
LT372	2	500 MHz	2-4 GS/s	250 k/500k	8.4" TFT
LT264	4	350 MHz	1 GS/s	100k	8.4" TFT
LT262	2	350 MHz	1 GS/s	100k	8.4" TFT

Memory Options

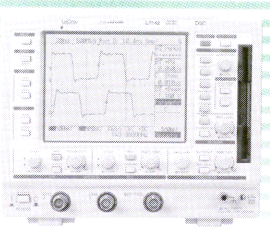
M	1 Mpt/ch; (Models 374 and 264)
L	4 Mpt/ch; (Model 374 only)

Waverunner Scopes



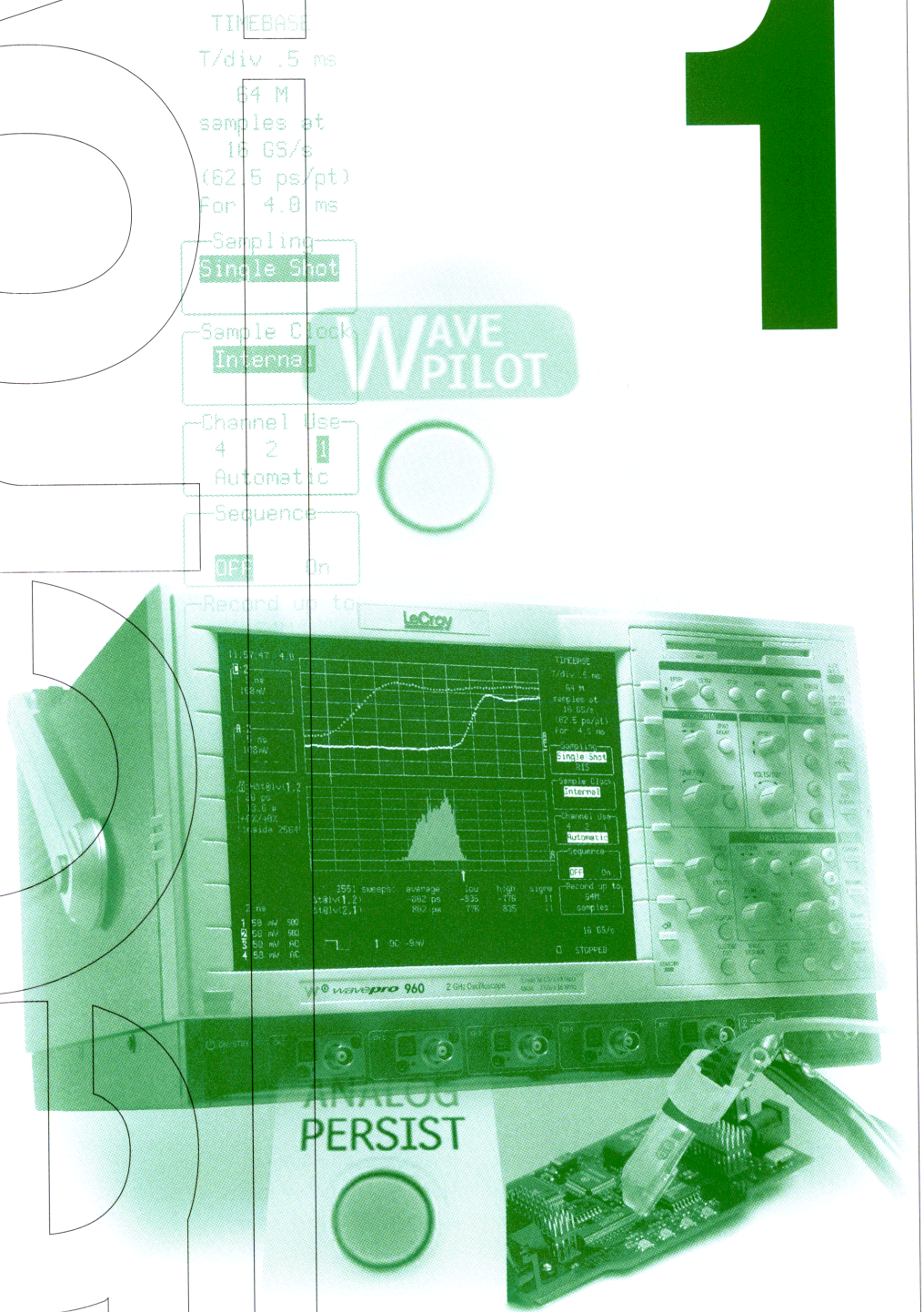
LT364	4	500 MHz	500 MS/s -1GS/s	250 k/500k	8.4" TFT
LT364L	4	500 MHz	500 MS/s -1GS/s	1 M/2 M	8.4" TFT
LT344	4	500 MHz	500 MS/s	250 k	8.4" TFT
LT344L	4	500 MHz	500 MS/s	1 M	8.4" TFT
LT342	2	500 MHz	500 MS/s	250 k	8.4" TFT
LT342L	2	500 MHz	500 MS/s	1 M	8.4" TFT
LT322	2	500 MHz	200 MS/s	100 k	8.4" TFT
LT224	4	200 MHz	200 MS/s	100 k	8.4" TFT

Literunner

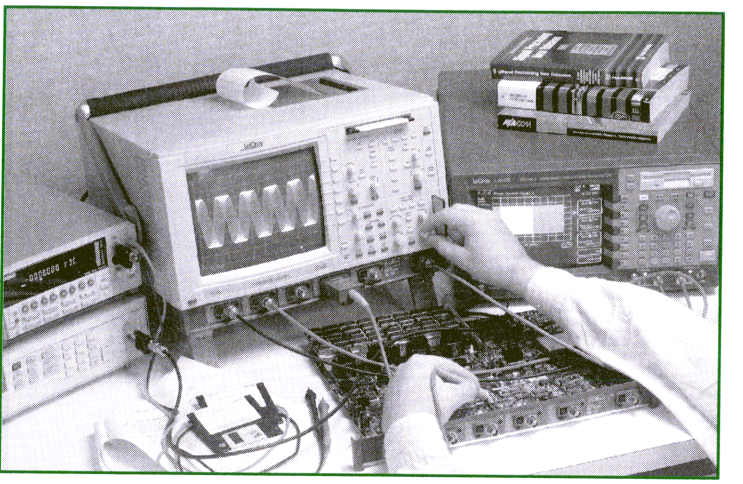


LP142	2	100 MHz	500 MS/s	100 k	5.7" LCD

1


TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
LeCroy
wavepro 960
ANALOG
PERSIST

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).

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 that 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 that 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.

Some oscilloscopes will:

- Monitor parameters such as amplitude fluctuations, timing jitter, risetime, etc., and display worst-case values.
- Provide histograms of parameter measurements to accurately identify important signal characteristics.
- Let you use the full screen as a signal-viewing area.
- Allow signals to be saved or recalled from PC card devices such as portable hard drives, ATA Flash Cards, or IC memory cards.

The Instrument Solution

When you purchase an instrument, you need to understand basic digitizer specifications and architectures to make sure you've selected 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, waveform memory length, vertical resolution, 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 the following questions regarding your signal and the types of measurements needed will help you choose the right instrument. In the long run, this preparation will save time and money.

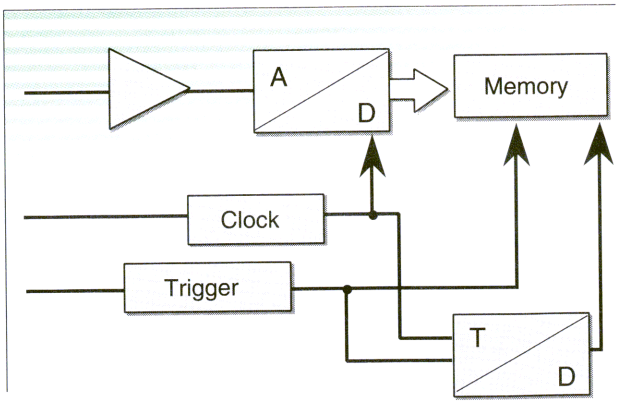
1. What is the signal bandwidth?
2. How small are the details you need to resolve relative to the peak-to-peak voltage?
3. How accurately do you want to measure voltages and times on the waveforms?
4. How long a waveform portion do you want to capture?
5. What conditions do you need to trigger on?
6. How often should the display update with new waveforms and analyzed results?
7. What kinds of diagnostic tools do you want?

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.

Transient digitizers contain an ADC and waveform memory. Once "armed", the ADC digitizes the signal continuously and feeds the samples into 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, the ADC would stop sending data as soon as the trigger arrived. If the user selected 100% post-trigger, the system would fill every memory location one more time and stop. Memory would contain the waveform data that occurred after the trigger.

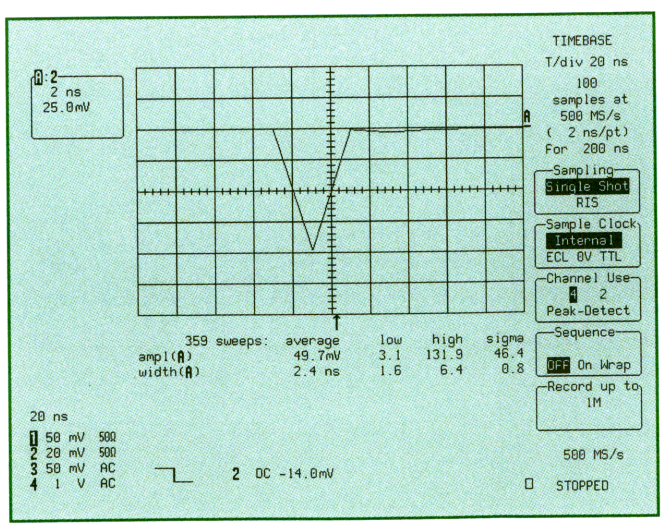
RIS digitizers consist of a transient digitizer with the addition of an interleaved mode. For each trigger, the RIS digitizer records a set of waveform sample points. The digitizer interleaves sample point sets from additional triggered acquisitions to construct a detailed representation of the original waveshape.



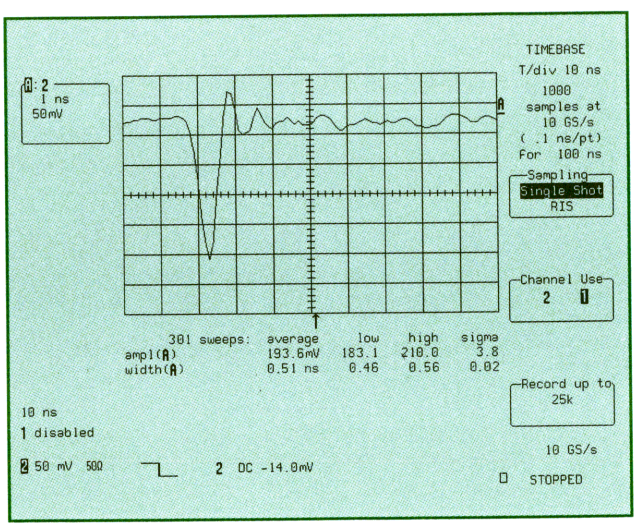
RIS digitizer block diagram.

Because the digitizer has no way to know when the trigger will arrive, the sample clock and 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 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. Because the sample points are delayed from the trigger point, sampling digitizers cannot record pre-trigger information.



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 can be accurately measured.

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.

Bandwidth and Sample Rate

Bandwidth is an important specification for digitizers, just like for analog scopes. The digitizer's filters and input amplifiers 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.

How much bandwidth is enough? To accurately indicate signal peak amplitudes, the digitizer bandwidth should exceed the signal bandwidth. 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:

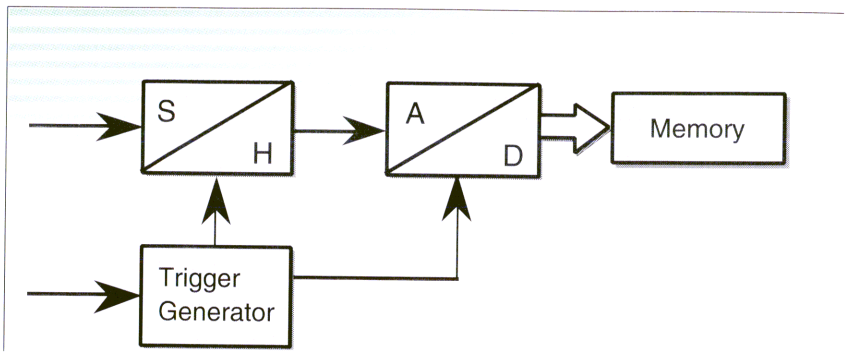
Signal Bandwidth ≈ 0.35/(10% - 90% risetime)

For example, a signal with 1 ns risetime (1×10^{-9} s) has a bandwidth of 350 MHz (350×10^{6} per second).

Note that real world instruments which measure signal risetimes are rarely a simple single pole system. The factor of 0.35 used in the equation above could range as high as 0.5.

The bandwidth of a signal digitizer system is determined by measuring the pass band. Typically, a sinewave with fixed amplitude is used as an input and the frequency is increased to the point 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.

Input Frequency (Relative to -3 dB Frequency (F_0))	Attenuation	
	dB	%
1.0 F_0	-3 dB	29%
0.5 F_0	-1 dB	-11%
0.1 F_0	0.1 dB	-1%

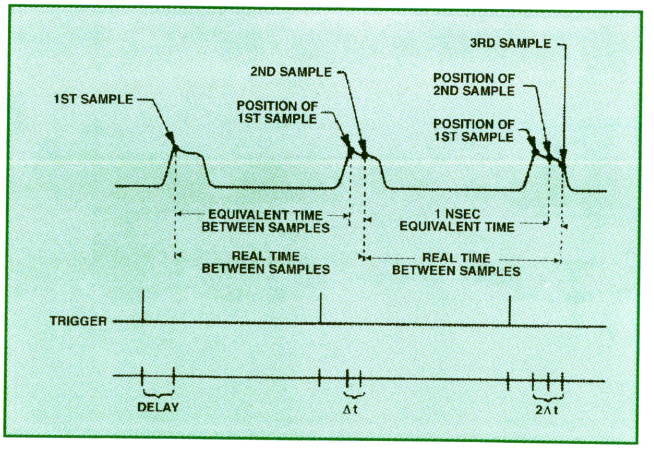


Sampling digitizer block diagram.

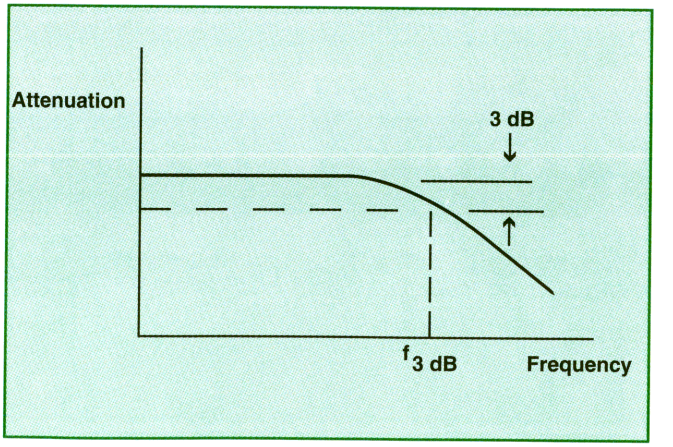
Sample Rate Effects on Usable Bandwidth

The digitizer sample rate can degrade the usable bandwidth. To ensure adequate sampling, obtain at least four samples per cycle of the fastest signal in the waveform. For precision measurements, 10 samples per cycle may be desirable. 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, the faster equivalent-time sample rate can be used. LeCroy WavePro oscilloscopes can sample at rates up to 16 GS/s in real time or 50 GS/s in a repetitive (RIS) mode.

Given this ideal – the digitizer with no noise and 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



Sampling digitizer operation.



Attenuation occurs within the passband, not just at the cutoff (-3 dB) frequency.

words, the highest input frequency cannot exceed one half the sample rate. Given this scenario, a sin(x)/x interpolation algorithm can reproduce the digitized input signal fairly accurately. The sin(x)/x algorithm fits curve segments between sample points to create a smooth waveform representation. Unfortunately, sin(x)/x interpolation can amplify noise. Because noise exists in real signals and digitizers, sin(x)/x should be used cautiously, especially with less than four samples per cycle.

Sin(x)/x algorithms also can create undesirable overshoot and preshoot on fast edges. At least two data samples are required on the fastest signal edge. It is important that the user be able to examine the number of raw data points acquired in any scope using sin(x)/x display.

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:

$$\text{Sample Rate} = \frac{\text{Waveform Memory}}{(\text{Timebase Setting}) * (\#\ \text{CRT Horiz. Divisions})}$$

For example, if the digitizer contained 50,000 points of memory and 10 CRT display divisions and the timebase was set to 5 µs/div, the sample rate could be as high as 1 GS/s 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 to make more accurate measurements.

Benefits of Long Memories in Digital Oscilloscopes

Increasing the DSO memory length 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 that are unpredictable in time.
- No dead time between acquired events by using long memory to seamlessly acquire those events.
- The ability to segment long memory into a sequence of separately triggered events with minimal deadtime (typically 25-30 µ sec).

No Missed Details

Figures 1 and 2 show the same waveform (a 20 ms video signal) acquired by two different scopes configured with memory lengths of one 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 ms/div). Thus, the 100 kpoint scope is digitizing at:

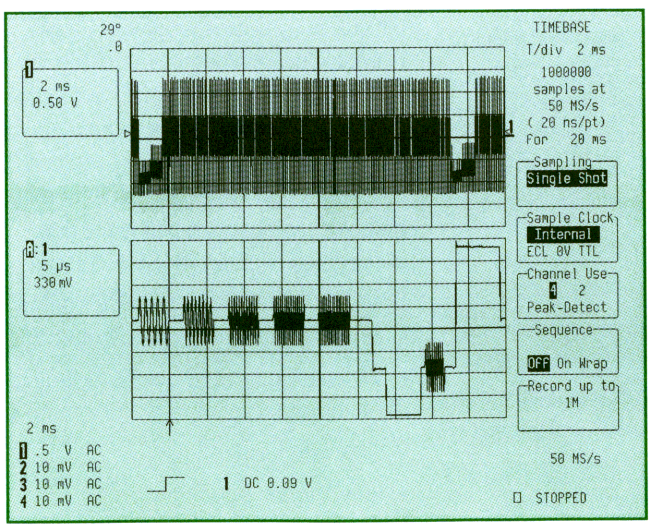


Figure 1: Capturing a frame of video using 1 million points of acquisition memory allows 20 ms of data to be sampled at 50 MS/s.

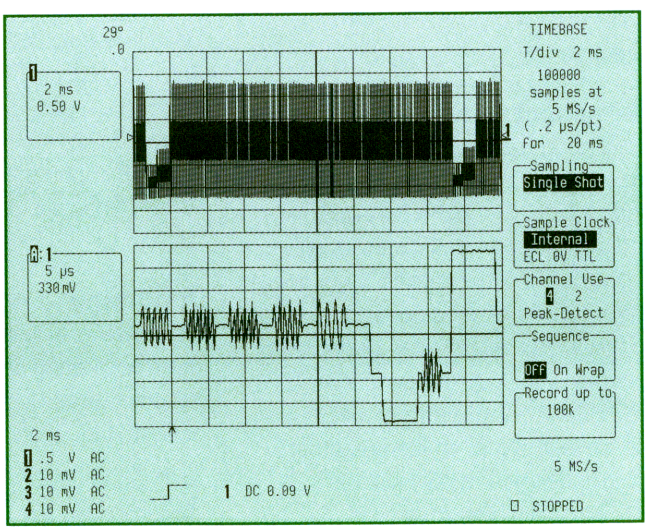


Figure 2: The same signal captured by a 100 k memory scope. The trace is undersampled as shown in the expansion below the main trace. The same 20 ms of data causes the sampling rate to become 5 MS/s due to shorter memory.

20 ms/100,000 = 0.2 µs per point
= 5 MS/s

while the 1 Mpoint 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 scopes, the easiest-to-use default setup automatically digitizes the signal at a memory length and sampling rate optimized to yield the highest sampling rate for that timebase setting. Scopes from other vendors may have a default setting that results in a 500-point digitization and 500-point display. Given the length of the waveform to be measured, an alternate setup then has to be selected for it to capture and display the entire signal. 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 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, so that a live waveform can be displayed together with up to three expanded views. This is done using a proprietary compaction algorithm; it ensures that any glitch, representing as little as 1/16,000,000th of the displayed waveform, will always be captured accurately and displayed.

Better Time and Frequency Resolution

Comparing the different scopes in Figures 1 and 2, the first scope offers 10 times more horizontal points and better horizontal resolution by a factor of 10:1. Better horizontal resolution improves the accuracy of any time-related measurement. It also results in improved frequency domain (i.e., Fourier transformed) displays, because 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).

Minimizing 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. Some signals have bursts of activity separated by relatively long periods of time.

One way to acquire such bursts is to segment the scope's acquisition memory into many shorter memories. This technique reduces the measurement dead time from milliseconds to less than 100 µs. The signal bursts can be stored into many separate, time-stamped memories. The time stamp for each trigger is important, because users often want to know the time when each event occurred.

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 trigger's flexibility and sophistication. 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 that 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-priced 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 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, Ext/5, 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.

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 (and glitch), including Exclusion trigger
- Slew rate trigger
- Runt trigger
- Pattern trigger
- Dropout trigger
- State-qualified trigger

- Edge-qualified trigger
- TV trigger (Waverunner series)

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 by number of events.

Hold-off by time: Many oscilloscope measurements require the ability to acquire a complex waveform that 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.

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 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, telecommunications, ATE, EMI, 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 3.

In a broader sense, a glitch can be defined as a pulse that is much narrower than the waveform under observation. Because glitches are a source of problems in many applications, the possibility of triggering on a glitch, investigating what generated it, and measuring the damage it caused represents a fundamental research tool. The width-based trigger provides this capability.

In addition to triggering on short widths (glitches), "width" trigger has another substantial benefit. 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 >xy). 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 4.

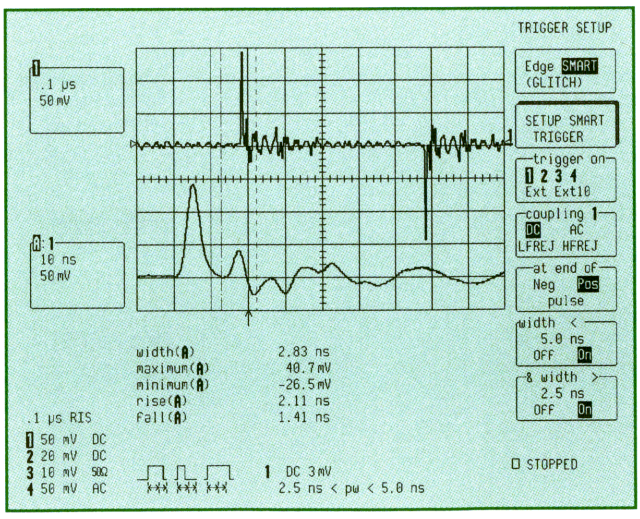


Figure 3: Selective trigger on a 2.83 ns glitch. The DSO has been set to trigger on any pulse narrower than 5.0 ns and wider than 2.5 ns. Pulse parameters are used to characterize this phenomenon after expansion in the bottom trace.

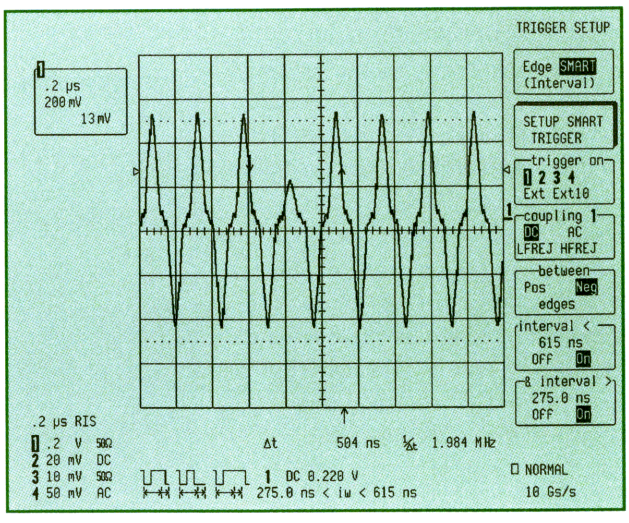


Figure 4: Triggering on a missing bit when reading a magnetic disk. A missing bit can be interpreted as a pulse wider than the period of the pulses or a pulse separation greater than the pulse period. The "interval width >" is used to trigger on this condition.

Runt, Slew Rate, and Glitch Triggers

High-speed digital designers often need to troubleshoot problems caused by fast glitches and runts or by signal edges that have incorrect slew rates. LeCroy offers a very fast trigger for these types of phenomena. It can be adjusted to trigger on signal features down to 600 ps in duration.

Dropout Trigger

The dropout trigger allows the user to trigger when a signal stops occurring. Common applications are network hangups, microprocessor crashes, 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.

Display

Analog oscilloscopes update their displays up to one million times per second. Digitizers update much less frequently. There is, however, a wide range of rates, and some digitizers are more responsive than others. 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 and speed, analysis algorithm efficiency, and display algorithm are determining factors in the display update rate. Some vendors offer fast acquisition modes but compromise performance by capturing only a limited number of points into a persistence display mode. A good method to test the responsiveness of an oscilloscope is to move the vertical offset up and down while acquiring a moderate record length. Does the offset move quickly?

The Analog Persistence™ display mode found in the LC, *Waverunner*,™ and WavePro series DSOs from LeCroy offers the same type of brightness-graded intensity as analog scopes without compromising signal fidelity as in the special display modes of other digital scopes.

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 high-speed 32-bit processors minimize the effect of the additional calculations. Other display algorithms, such as smoothing or sin(x)/x interpolation, require many calculations and, therefore, more processing time.

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 affects display update rates tremendously.

Use of multiple, fast-clocked, 32-bit processors plus dedicated digital signal processors can enable 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 operate slowly.

Analysis

One of the greatest advantages of digitizing is the ability to analyze the data. Because the digitizer has converted the analog signal into digital data, either an external computer or the internal digitizer processor can analyze the data. Most digital scopes now have a wide spectrum of analysis built in. Others offer customized capabilities to analyze signals from power devices, data storage heads/media, and optical signals and can even act as jitter analyzers.

Pulse Parameters

Cursor readouts allow 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 param-

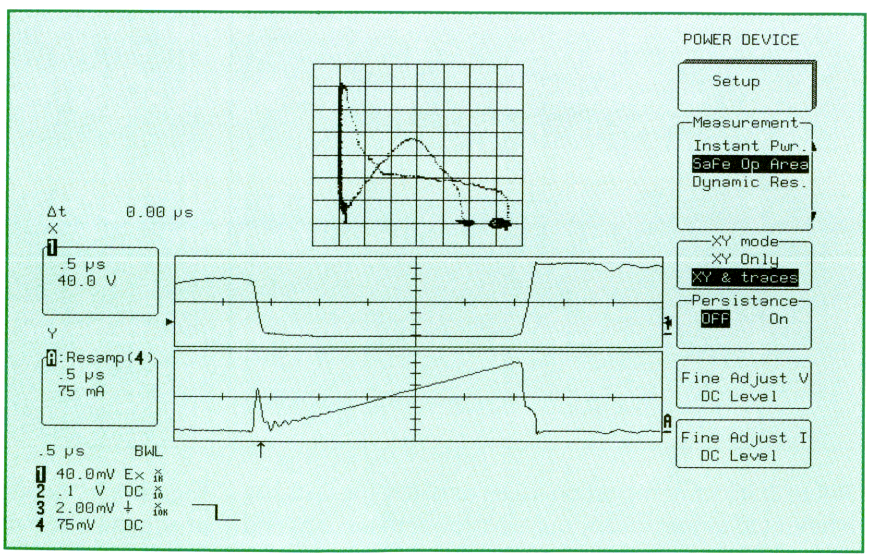


Figure 5: Current and voltage waveforms and XY plot of Safe Operating Area (SOA).

eters 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.

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 an important feature – the ability to daisy-chain math functions and to perform application-specific analysis. Figure 5 shows voltage and current waveforms, plus an XY plot of Safe Operating Area (SOA).

Signal Variation

Digitizers can accurately indicate subtle changes in a repetitive signal via either a roof/floor envelope or a persistence mode (e.g., "eye diagrams"). The roof/floor envelope (also called "extrema") records and displays the maximum and minimum 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.

Frequency Domain

The Fourier transform converts sampled waveform information into a unique set of sinewave components. The data is usually plotted as frequency versus amplitude. Two algorithms are common: the discrete Fourier transform (DFT) and the fast Fourier transform (FFT). Practical implementations use FFT (Figure 7), as it is many times faster to calculate. The FFT can expose information not easily visible in the time domain (time versus amplitude). Ideal uses include measuring frequency components of communication signals, monitoring drift in an oscillation, etc. The FFT frequency resolution is directly proportional to the number of time-domain points the FFT algorithm can handle. Some companies make scopes with eight million data points, but their FFT algorithms can accept only ten thousand. They have 1% as much resolution as a LeCroy scope, which can perform one-million-point FFTs.

Statistical Domain

The existence of measured waveforms in digital representations permits convenient utilization of the data inherent in those measurements. In addition to the analysis of signals in the frequency domain and the ability to perform mathematical operations and signal averaging on the data, you 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, you 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.

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 structures for common digitizer settings, such as voltage range, sample rate, etc. Therefore, digitizers that conform to IEEE-488.2 have easily understood, mnemonic commands. Another important, high speed method of accessing an oscilloscope is through an ethernet port. The ethernet option

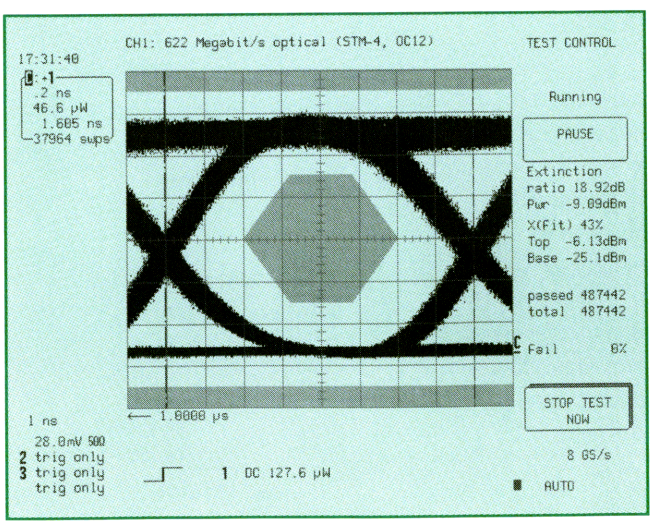


Figure 6: Persistence mode displays a user-selected or infinite number of signal acquisitions. In this example, a 622 Mbit/s optical telecom signal is acquired 37,964 times and compared to a test mask.

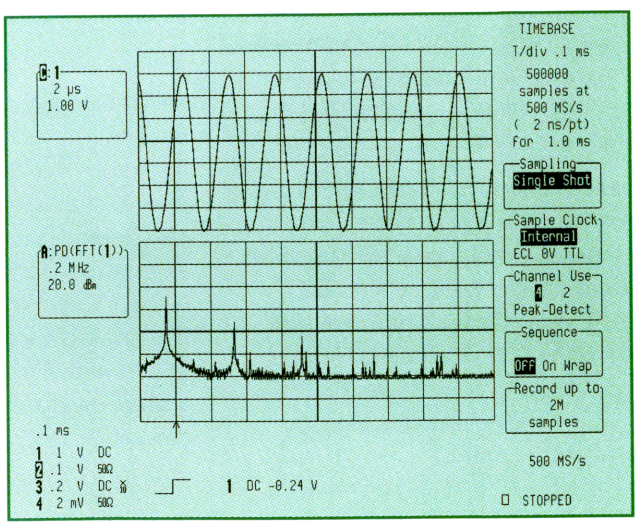


Figure 7: The FFT of a sinewave shows harmonics not visible in time domain.

available from LeCroy has an important advantage for automated testing. It allows full control from a computer.

One of the problems associated with high-accuracy digitizers in an 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.

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 8, 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 vs. 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.

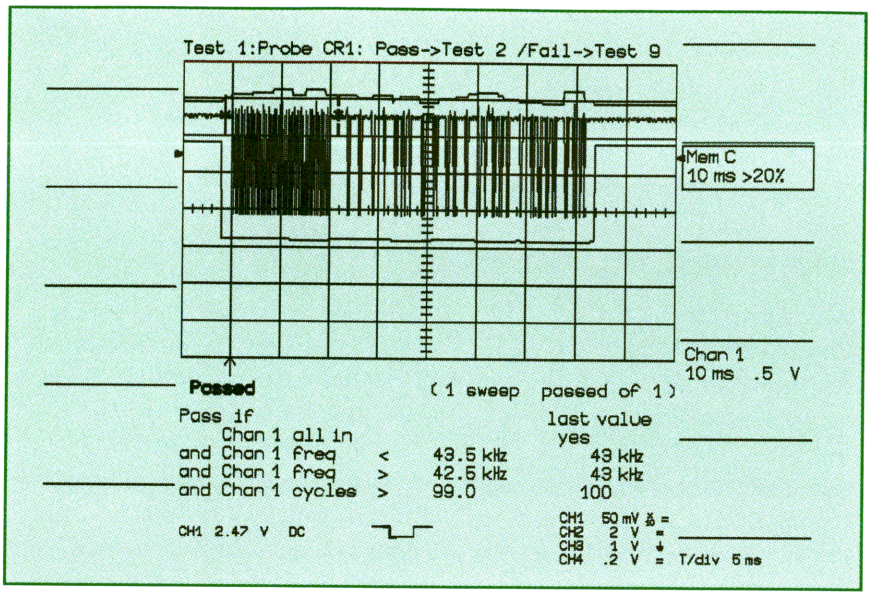


Figure 8: Testing an infrared remote control unit. Note the simultaneous use of both parameters, such as frequency and number of cycles, and tolerance mask testing. Pass/Fail tests can incorporate up to five user-defined test conditions.

Storing and Recalling Waveforms and Parameters

A few digital oscilloscopes have built-in mass storage for large numbers of waveforms. This capability is powerful and timesaving. Internal floppy drives or hard disks 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, and portable hard drives, all in DOS-compatible format. After storing waveforms, the memory card, diskette, or hard drive can be accessed by a software utility such as LeCroy's ScopeExplorer™ or removed from the oscilloscope and transferred to a PC for further storage, manipulation, or analysis. Using an optional ethernet port, data can be sent over the network to another PC or printer. LeCroy scopes also can be controlled via the network connection.

Absolute consistency can be maintained in testing via this method, as all locations share the same waveform files.

Most LeCroy digital oscilloscopes have standard GPIB and RS-232-C output. In addition to 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 used as a test stimulus applied to other devices.

The Benefits of Digital Oscilloscopes

Digital scopes are key tools used in the diagnosis, test, and evaluation of electronic circuits and systems. LeCroy 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 valuable time solving problems. LeCroy's performance DSOs provide the power needed to capture, view, and analyze signals, all in an easy-to-use instrument.

Capture

Capturing signals over a wide range of timebase settings at high sample rates while maintaining a fast, responsive front panel is made possible by LeCroy's long record lengths and a high-speed RISC microprocessor-based system with up to 256 Mbytes of RAM. LeCroy scopes offer the longest record length in the industry 16 Mbytes of data acquisition memory per channel, which can be combined to 64 Mbytes on a single channel. 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 that shows the important signal features, and
- Assigns resources of computational and storage RAM to the tasks selected.

Capturing a signal at the appropriate timebase setting with the best accuracy, coupled with rapid data resource assignment and processing, lets you solve problems more quickly.

View

LeCroy DSO displays offer a large viewing area where you can really see the signal details. LeCroy's newest offering – the WavePro series – provides a huge 10.4", flat-panel, color TFT LCD display. Some models in the LC series feature the same 10.4" display while others have a large 9" display. The Waverunner series features an 8.4" flat panel color screen. Engineers who spend much of their day in front of an oscilloscope appreciate the large view of the signal, and with a choice of 1, 2, 4, or 8 grids. It's easy to separate waveforms and numerical measurements while maintaining maximum signal fidelity. LeCroy scopes offer traditional color-graded persistence and Analog Persistence intensity-graded color display modes. Seeing more details in a set of signals on a LeCroy DSO's large viewing area 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. In many cases, they can eliminate the need to transfer captured signals for off-line analysis. This includes the measurement of more than 40 signal parameters, worst-case analysis (maximum, minimum, average, and standard deviation) on those parameters, an FFT package with capability to resolve four million time domain samples into the frequency domain, and the ability to daisy-chain math functions (such as filtering a waveform and then performing an FFT). LeCroy offers an unmatched advanced math package with integration, differentiation, square root, absolute value, ratio, exponential, log, and a set of six adjustable digital filters. The optional histogramming and trend capabilities help 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/no go" 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, PC card portable hard drive, or an internal, high-speed graphics printer.

Power Tools for Engineers

Engineers who use a scope for troubleshooting 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 four 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 to 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 scope's large display 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 dead time 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 the LeCroy DSO display/triggering modes take advantage of the data acquisition memory's full power 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 WavePro series offers four channels of simultaneous 4 GS/s sampling with up to 16 Mbytes of memory per channel. This can be combined to provide two channels at twice the sampling rate and doubled acquisition memory, or (in models 950 and 960) one channel with four times the sample rate and quadruple record length. The "XL" version of the WavePro 960 is the world's longest memory scope. It achieves 64 Mpoint maximum record length. Long memories let the DSO 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 256 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 a fast screen update rate and lively front-panel controls. This capability is achieved through the integrated use of a a high-speed databus and copius RAM. Competing DSOs that lack LeCroy's integrated processing power and memory capacity are unable to effectively deliver this capability. Other DSOs might capture long data records but will only be able to perform an FFT, high-resolution computations or waveform math on shorter record lengths. Those types of barriers are eliminated in LeCroy digital scopes.

Mass Storage for DSOs

A PC card hard disk capability is optionally available for any LeCroy DSO. A removable hard disk of 520 Mbytes provides great capacity and flexibility for fast storage and retrieval of waveforms and instrument settings. The 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, optional IC memory card interface (PC card port), and a built-in, high-speed graphics printer. These tools improve productivity by making the data captured by a LeCroy scope easily accessible and transferable. GPIB, Centronics, RS-232-C and optional ethernet 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 digital scopes are supplied with LeCroy's ProBus® Intelligent Probe Interface. This unique feature permits them to be used with a range of probes, controlling the probe from the scope's front panel. Optional active probes, including the new HFP series, provide extremely low (100 kohm, 0.7pF) circuit loading and up to 2.5 GHz bandwidth. Passive probes are provided as standard accessories with most models. A wide range of optional accessories are available including differential amplifiers with gain to 1000, CMRR to 100,000:1, and bandwidth to 250 MHz. Wideband differential probes are also available with bandwidths to 1 GHz. A range of current probes are effective for measuring DC, AC, and impulse currents. The PPE series of high-voltage probes provides a selection of models ranging from 100 to 400 MHz and 600 to 20 kV.

SMART Trigger and Waveform Processing

Some DSO manufacturers put their best troubleshooting triggers only in their most expensive scopes. Because most engineers 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, and dropout triggers. Time and events holdoff also are provided. The scopes include LeCroy's exclusion trigger mode, which lets you set the oscilloscope to trigger only when an abnormal signal width or period occurs. Runt and slew rate triggers are both frequently used in digital design and are included in the WavePro series. These triggers are avilable as an option for the Waverunner series which also offers TV trigger.

Optional Analysis Packages

The WaveAnalyzer (WAVA) Package 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 unique integrated tools 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 also is used for magnetic media testing and allows the calculation of autocorrelation, non-linear transition shifts, and autocorrelation signal-to-noise. The advanced analysis can be displayed in histograms and as worst-case parameters.

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

Telecommunications Mask Test packages, with balanced and coax adaptors, are available for ITU G.703 and ANSI T1.102 electrical telecom standards and for STM-1/OC3 and STM-4/OC12 optical standards. These packages transform LeCroy oscilloscopes into dedicated telecommunications 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.

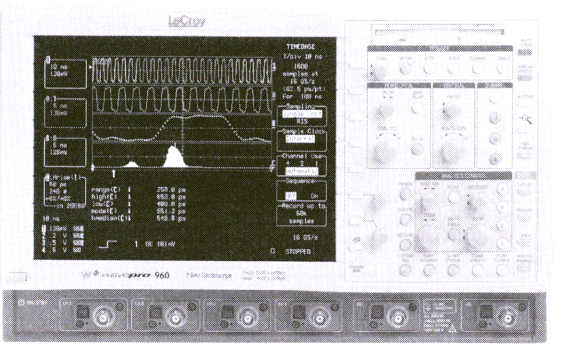
Upgrade Your DSO

Digital scopes are capital equipment with a cost ranging from US $5,000 to US $40,000 or more. To protect 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 very fast measurement results. You can upgrade to 256 Mbytes of RAM and add an analysis package. LeCroy is the first scope vendor that offered to 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 PC card portable hard drive, fast internal printer, PC memory card or ethernet port.

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.

WavePro™ Color Oscilloscopes



***WavePro* oscilloscopes provide all you need to quickly capture, view, and analyze your signals — accurately and reliably:**

- **500 MHz – 2 GHz bandwidth**
- **8-16 GS/s max, single-shot sample rate**
- **50 GS/s for repetitive signals**
- **Up to 64 million data points to view signals**

***WavePro* scopes provide a minimum of 8x oversampling and the deepest memory available in their class for superior signal acquisition and fidelity on long-duration signals.**

Simple, Fast Access to Powerful Capabilities

This new class of scopes brings you the power of LeCroy signal acquisition, viewing and analysis capabilities with simple one-button access. It's easier than ever to capture, view, and analyze high-speed signals of long time duration, with high resolution, so you get accurate, precise results.

Easy to Use

The *WavePro* scope is designed to get you up and running quickly. Its color-coded front panel and simple menu system are easy to understand, so your focus is on the work, not the tool. Common tasks are automatic. Navigation is streamlined and intuitive. You'll easily master its powerful operations.

The Right Price

WavePro oscilloscopes raise the bar when it comes to performance capability and value — you get more for your money than with any other scope in this class. And because the *WavePro* scope memory can be upgraded, you can extend its life to meet future needs.

Increase Your Productivity

The Wavepilot toolbar makes it easy and quick to inspect or measure signal details, to perform automatic measurements on signals or to graph measurements in frequency sprectra, histograms and trends. With TrackView, you can track problems to the source in both the time and frequency domain. Additional signal analysis capabilities let you datalog, integrate, chain math functions, and more. LeCroy's signal diagnostic and troubleshooting tools provide a complete solution for characterization, debug and signal analysis.

From Circuit to Scope

With new LeCroy HFP small, lightweight probes, you're assured of high bandwidth, low capacitance connections to your circuit. Interchangeable probe tips are included for SMD and circuit vias — making the HFP probes the best choice for use with *WavePro* scopes.

WavePro Color Digital Oscilloscopes Selection Guide

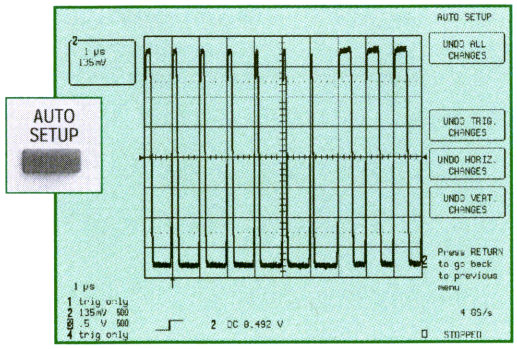
Model	Bandwidth	Channels	Max Sample Rate	Acquisition Memory
WavePro 960	2 GHz	Four	16 GS/s (1 Ch)	Standard 1 Mpts *Optional 4-64 Mpts (1 Ch)*
WavePro 950	1 GHz	Four	16 GS/s (1 Ch)	Standard 1 Mpts *Optional 4-32 Mpts (1 Ch)*
WavePro 940	500 MHz	Four	8 GS/s (2 Ch)	Standard 1 Mpts *Optional 4-32 Mpts (1 Ch)*

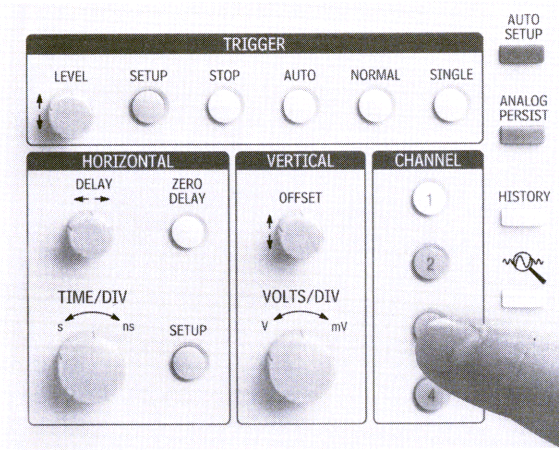
Simplified Operation

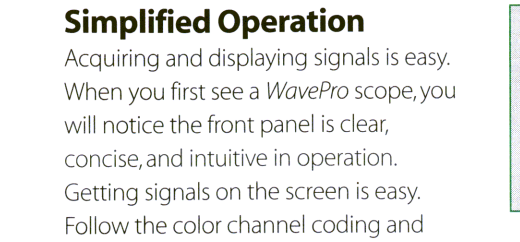
Acquiring and displaying signals is easy. When you first see a *WavePro* scope, you will notice the front panel is clear, concise, and intuitive in operation. Getting signals on the screen is easy. Follow the color channel coding and press *Auto Setup*. Adjust horizontal or vertical settings to view the way you want, and unleash the power of LeCroy SMARTMemory with the press of *QuickZoom*. If you are concerned with intermittent runts or timing problems, just press the green button and see infrequent signal anomalies.

Auto Setup

Simply connect your signal, press *AUTO SETUP*, and view. Horizontal, Vertical, and Trigger settings are automatically set. LeCroy SMARTMemory ensures the highest time resolution for the time window displayed.







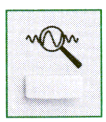
Many Ways to View your Signal

Capturing and viewing the signal is as easy as 1-2-3. Analog Persistence shows three dimensions of signal information. *HISTORY* lets you get further insight into the third dimension by recording snapshots of the signal into memory. Then analyze signals in the sequence they were captured to find the problem.



Full Screen

Spotting problems is easier because this *FULL SCREEN* tool maximizes the display viewing area. Toggle back and forth for the biggest view from any scope.



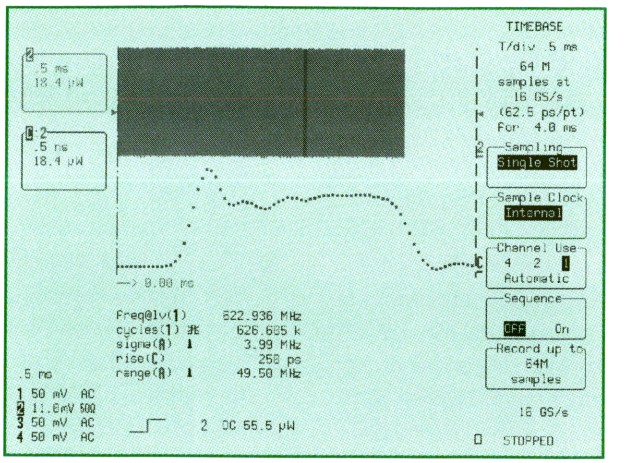
Quick Zoom

Press the *QUICK ZOOM* button, and view up to 4 zooms of up to 4 input signals. Magnify, inspect, search and scan your signal to see details and understand problems.

High Speed, Precision, and Accuracy

The *WavePro* scope is the only one in its class capable of capturing, viewing and analyzing signals of 2 GHz bandwidth, with a sample rate of 16 GS/s (8x oversampling) and up to 4 ms duration. This lets you view and analyze the full signal and assures maximum signal fidelity to gain insight into your designs. The SMARTMemory system automatically manages memory and sample rate, ensuring the most accurate view of the signal without aliasing.

The precision Analog-to-Digital converters and timebase sample your waveform every 62.5 picoseconds. That's one measurement in the time it takes light to move across an engineer's thumbnail. Every *WavePro* scope comes standard with 4 GS/s sample rate and 250 kpoints of memory on each channel. When you use a *WavePro* scope, it automatically samples at the maximum rate, with maximum memory depth based on the channels in use, so you don't have to even think about it. Extend your signal viewing up to 64 times longer with memory options from 4 Mpoints to 64 Mpoints. The *WavePro* scope's architecture gives you the right capability today with expandability for tomorrow.



With a sample rate up to 16 GS/s, you can precisely (5 ps resolution) measure critical sub-nanosecond timing over long time intervals. Oversampling at 8x the bandwidth, 64 Mpts for signal acquisition, and 4 zoom traces assure maximum signal fidelity and precise measurements on long acquisitions.

Wavepilot with Insight

Expand Your Vision

From beginner to expert, it is now easier than ever to apply the power of the unique analysis tools available from LeCroy. The Wavepilot toolbar provides single button access to powerful, easy-to-use signal analysis for real insight into problems.

Cursors

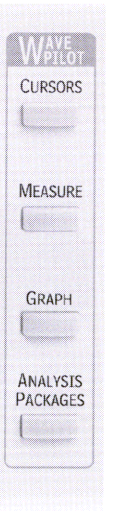
Turn *CURSORS* on, and turn the knob for manual adjustment and measuring between sections of your signal.

Measure

Press *MEASURE* to display up to 26 parameters on the signal of your choice and quickly switch from trace to trace. *MEASURE* is context-sensitive, so when you display a histogram, you will see statistical parameters. *MEASURE* lets you expand your selection to over 40 parameters to characterize your signal.

Graph

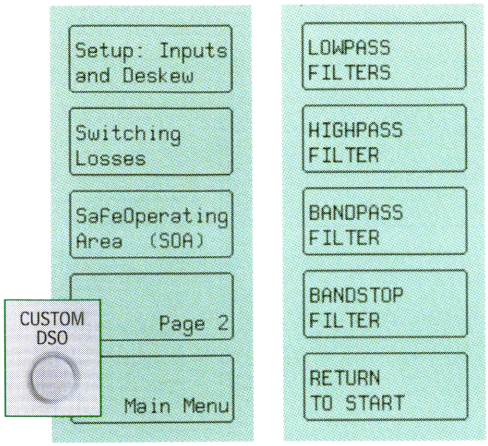
The *GRAPH* button automatically displays a histogram, trend, FFT or TrackView. Setting up signal analysis is simple with the Wavepilot toolbar menus.



Expand your insight into any signal with one touch on the Wavepilot toolbar, which provides fast access into powerful signal analysis.

Analysis Packages

Direct access to select application-specific solution packages including telecommunications Mask Test, Jitter and Timing, and Data Storage solutions.



Create custom menus and your own applications with this new capability.

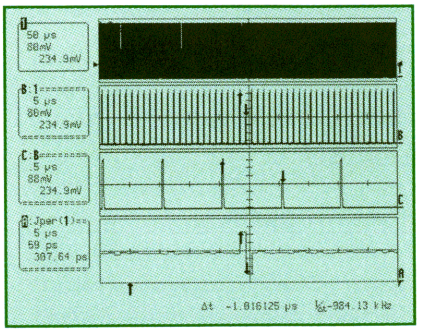
CustomDSO

The *WavePro* scope is designed to keep things easy to use. When you want to increase productivity or personalize your scope, CustomDSO lets you set up your own screen menus and labels, as well as engineering test sequences. Incorporate a series of scope measurement steps, so engineers and technicians in any department, regardless of technical background, can make measurements in a repeatable way. Edit your test sequences with Windows-based ScopeExplorer, see them on the scope screen, and store them into scope non-volatile memory. *WavePro* scopes come with good examples to get you started.

TrackView and JitterTrack™

Show deviations directly synchronized to the signal — patterns you would never see without this view. Press the *GRAPH* button for easy access, and zoom in on both the "where" and the "why" of the problem; you can see it and fix it! Quickly gain insight into the source of timing and signal integrity problems.

- TrackView shows the time evolution of signal amplitude. Quickly locate the problem, and see a statistical view showing the range and distribution of voltage variations.
- The TrackView, Histogram and FFT functions in *WavePro* scopes provide insight into signals better than any other oscilloscope. The WaveAnalyzer Pro (WAVAPRO) option extends the measurement capability further, allowing the longest measurements and additional views into the signal. Measuring the time evolution of jitter in a signal can reveal the exact location of timing problems.

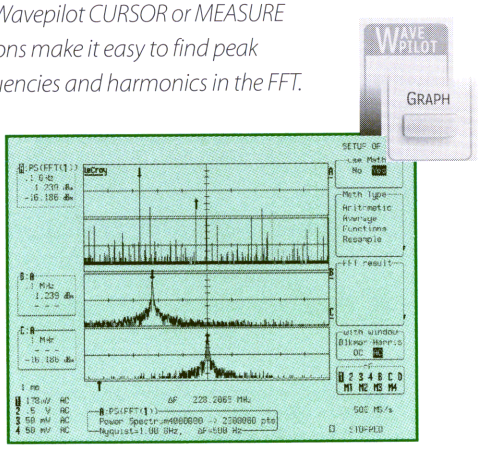


Jitter TrackView
Shows timing variation as it tracks the signal, cycle by cycle.

FFT Spectrum Analysis

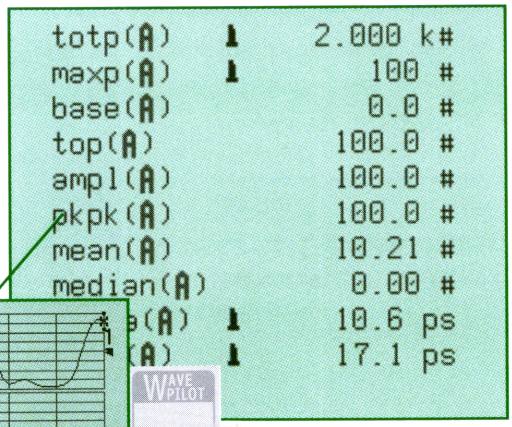
When you need to understand the frequency content of your signal, spectrum analysis is easily accessed at the press of the GRAPH button. View the FFT of a waveform while the signal updates on the screen. The combination of long acquisition memory, high sample rate, and a wide variety of FFT windows gives you measurement flexibility to fully analyze your signal.

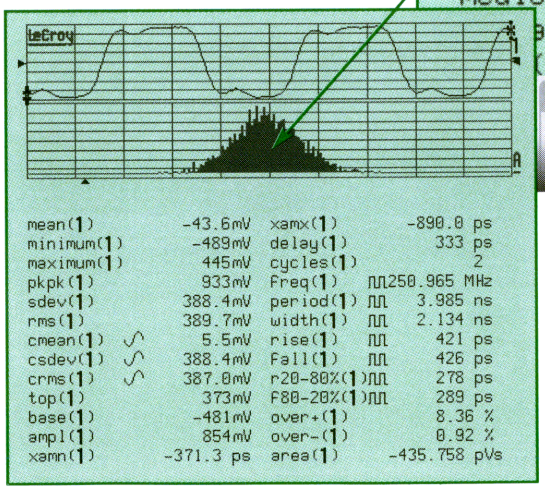
The Wavepilot CURSOR or MEASURE buttons make it easy to find peak frequencies and harmonics in the FFT.



FFT Spectrum Analysis
High sample rate and long memory enable high resolution and a wide frequency span. Multiple zoom traces and cursors make it easy to measure the frequency content.

Select Trace A: the Histogram trace and Histogram parameters are displayed in place of signal parameters.





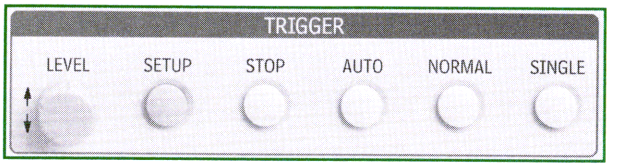


Histogram with Signal Measurements
MEASURE is simple to activate from the Wavepilot toolbar. The Dashboard View displays up to 26 standard signal parameters. Selecting a custom parameter set is easy.

Speed Up Debug and Analysis

SMART Triggers

The *WavePro* scope's trigger bar is simple to operate. Run the scope in normal or auto trigger modes or capture one-time events into scope memory up to 64 Mpts with a single-shot trigger. Triggering with *WavePro* is direct and easy to read and to understand.

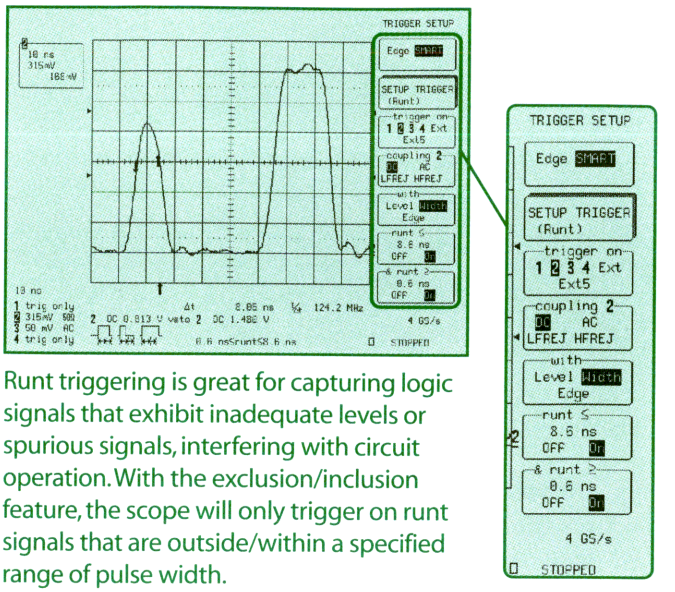


SMART Trigger provides the flexibility needed to quickly trigger on the specific signal characteristic or pattern you are searching for. Trigger not only on what you expect but also on abnormal signals. Exclusion triggers can exclude normal signals and capture only the abnormal ones, speeding up the debug of your circuits and systems. Trigger on signals down to 600 ps. All *WavePro* oscilloscopes include SMART Triggers. Select multiple threshold levels, as well as the pulse width, for the flexibility you need to catch the waveform you want to view and analyze.

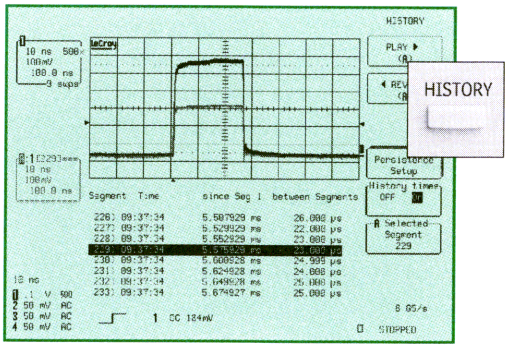
Use HISTORY Views to Find Intermittents

Pressing the *HISTORY* button converts the scope into a fast Analog Persistence fault-finder. The lifetime of your signal is written into the History memory and mapped on screen. You can measure each signal, see its trigger time, and identify rare events. Up to 8,000 events can be acquired for playback. This is useful when you have intermittent problems and want to know if they occur at a rate related to other circuit or system timing events.

Press "play" to replay the signal history and automatically scan and search from sweep to sweep. Stop when you see something of interest. The display shows the Analog Persistence view of all acquired sweeps as well as the individual sweep under inspection. When used with a SMART Trigger such as runt or slew rate, you can easily determine the rate of occurrence. The time of the trigger event is displayed with a resolution of 1 ns.



Runt triggering is great for capturing logic signals that exhibit inadequate levels or spurious signals, interfering with circuit operation. With the exclusion/inclusion feature, the scope will only trigger on runt signals that are outside/within a specified range of pulse width.



HISTORY lets you see the intermittent, trigger on the problem and find how often it's disrupting your design.

WavePro Basic Triggers

Name	Description
Edge	Select + or - slope and holdoff by time or events.
Window	Triggers when signal crosses outside the window in either direction.

WavePro SMART Triggers

Name	Triggers Conditions
Glitch	From 600 ps - 20 s and when pulse is >, <, or in or out of a range.
Interval	Between edges and ranges of 600 ps - 20 s.
Qualified	By edge or state on a channel or a pattern is present or absent.
Qual First	A single pulse qualifies a sequence of triggers.
Dropout	If input drops out after a time from 2 ns - 20 s.
Runt	Pulse levels, edge, widths from 600 ps - 20 s.
Slew Rate	Slope, dV, dT from 600 ps - 20 ns.
Pattern (logic)	Logical combination of up to 5 inputs. Can also be used in combination with Qualified.

High Bandwidth Active Probes

Convenient, Hands-Free Probing

To access the ever-increasing variety of test points, today's probing solutions need to be versatile, small, and light-weight. The new HFP series of probes meets these needs with high bandwidth, miniature size and a variety of tip styles, making probing easier than ever.

In combination with these innovative probe tips, the unique HFP *FreeHand* probe holder will hold the probe on test points to maintain signal fidelity. The end result of HFP "hands-free" probing is the enhanced ability to analyze waveforms instead of having to focus energy on keeping the probe itself in place.

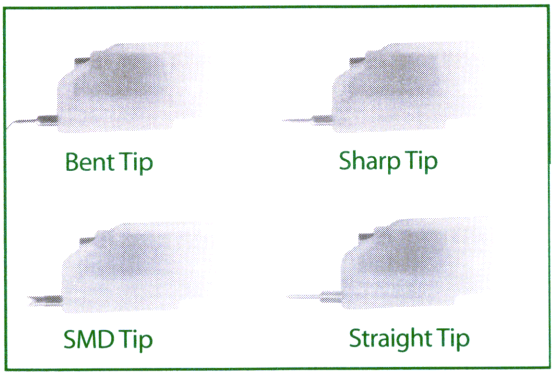
HFP 1000, HFP 1500, HFP 2500 Probe Models

Leading Specifications

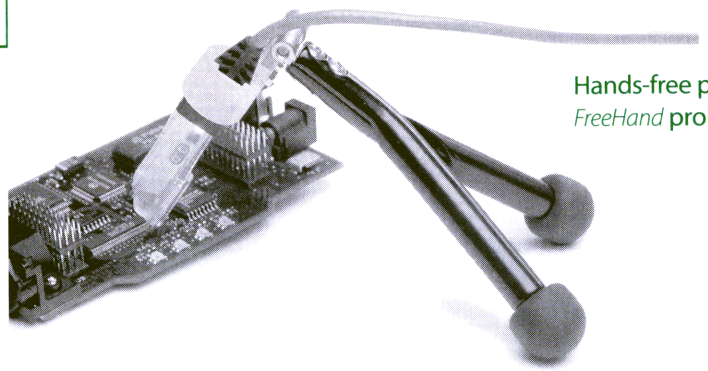
- 1 GHz, 1.5 GHz, and 2.5 GHz Bandwidth
- <1 pF Input Capacitance
- ±8 V Dynamic Range
- ±12 V Offset Range
- 4 Interchangeable Tips for Probing a Variety of Test Points
- Replaceable Probe Tip Socket
- Hands-Free Probing with *FreeHand* probe holder
- AutoColor ID Feature Matches the Probe Color to the Trace Color

AutoColor ID

When the probe is connected to a *WavePro* scope, our new patent-pending AutoColor ID feature automatically senses and illuminates the probe head in that channel's trace color. You no longer need to worry about plastic rings or colored tape to identify which channel on the scope is connected to a particular test point.



Interchangeable HFP Probe Tips



Hands-free probing with *FreeHand* probe holder.

WAVAPRO — Ultimate Signal Analysis

In today's high-bandwidth products, signal complexity is increasing. The Wavepilot toolbar and the Analysis Control Area both access the largest set of signal analysis tools and processing power in oscilloscopes today. Optional packages expand your oscilloscope to a complete signal analyzer.

WaveAnalyzer Pro (WAVAPRO)

The WaveAnalyzer Pro option is the ultimate tool for characterization and troubleshooting in time, frequency, and statistical domains for design and research applications. It includes:

- WaveAnalyzer Signal Analysis (WAVA)
- Jitter and Timing Analysis (JTA)
- Digital Filter Package (DFP)

WaveAnalyzer Signal Analysis (WAVA)

Waveform averaging increases to one million sweeps. The FFT spectrum analysis is expanded to process all acquired data up to 25 Mpts and provides additional spectral views: FFT averaging, real and imaginary components, and more. Histograms and trends let you view and measure statistical variations of signal parameters.

Jitter and Timing Analysis (JTA)

JTA has broad applications from high-speed clock measurements to lower-speed digital electronics or mechanically related measurements. Measure a wide variety of timing parameters: cycle-to-cycle, period, frequency, time interval, and width. Use JitterTrack to plot cycle-to-cycle jitter, interval error, period, or pulse width versus time. Use persistence trace histograms to measure jitter and noise on eye diagrams.

Digital Filter Package (DFP)

DFP implements a set of linear-phase Finite Impulse Response (FIR) filters. The package enhances your ability to examine important signal components by filtering out undesired spectral components such as noise.

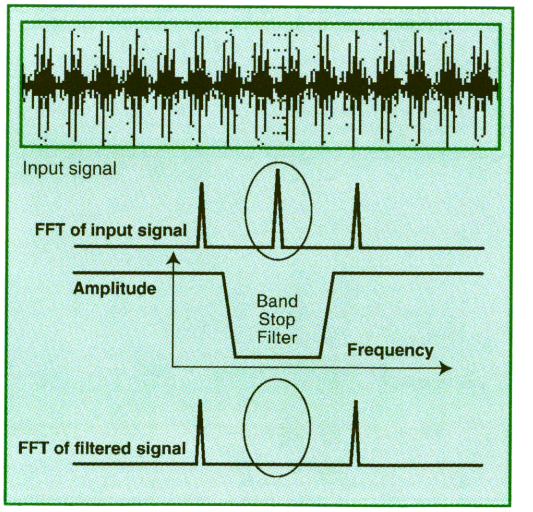
Use a digital filter design or math package such as MATLAB® or Mathcad® to design a custom filter, then download the filter coefficients into the WavePro scope with the DSO-Filter utility.

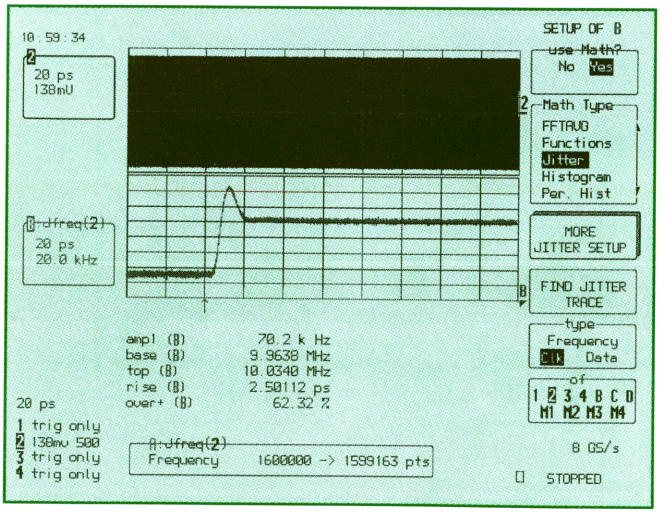
Filters include:

Low Pass	Raised Cosine
High Pass	Raised Root Cosine
Band Pass	Gaussian
Band Stop	Custom

Up to 4 filters can be cascaded

Design your own filters with DFP.





JitterTrack clearly shows a PLL's step response, including frequency overshoot.

Windows Connectivity

Connect your scope to Windows-based ScopeExplorer using the Ethernet (option), GPIB or RS-232 interfaces. Click and drag files, or operate from the virtual front panel. Update your software via the web.

Windows Software to Enhance Your Productivity

ScopeExplorer and ActiveDSO are Windows (95, 98, 2000, ME or NT) PC-based connectivity tools that make it easy to interface your *WavePro* scope with a PC via Ethernet, RS-232-C, or GPIB. It's easy to integrate scope data with Windows applications, as well as to control the *WavePro* scope from your PC.

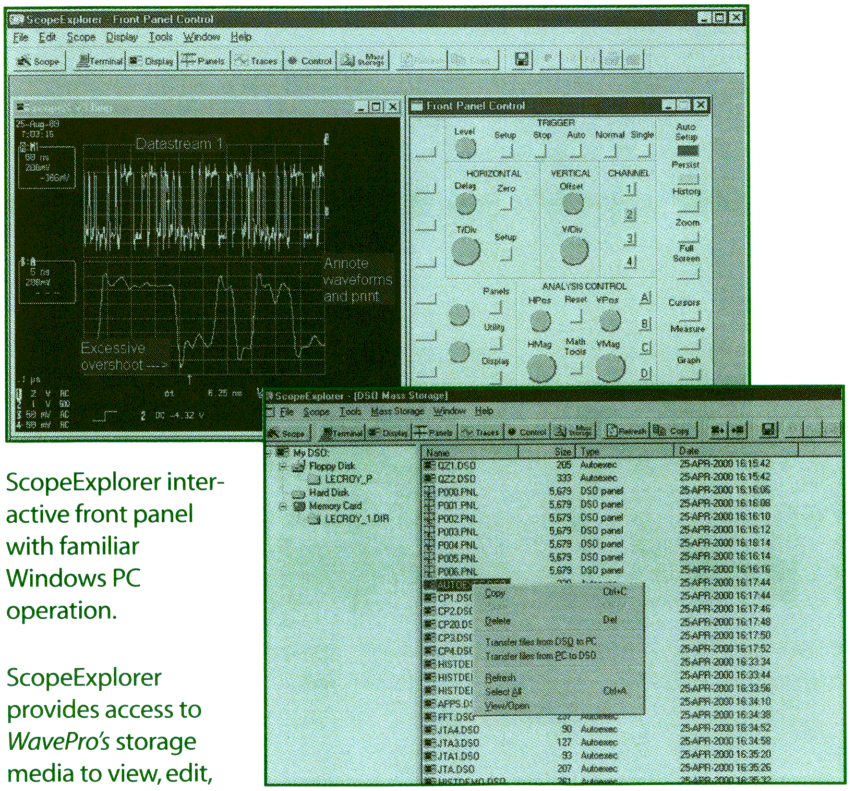
ScopeExplorer

Annotate and print screen shots, drag and drop files, save and load scope setup panels, and run CustomDSO applications. Click on the print icon to send the file to the printer of your choice.



All it takes is a PC with Windows and a GPIB, RS-232-C, or the Ethernet option.

Access files on storage media, including PC Cards, hard drives, and diskettes inserted in a *WavePro* scope.



ScopeExplorer interactive front panel with familiar Windows PC operation.

ScopeExplorer provides access to *WavePro's* storage media to view, edit, save, load, and run scope setup and CustomDSO applications.

ActiveDSO

ActiveDSO is a LeCroy software utility for ActiveX control of LeCroy digital scopes.

Exchange *WavePro* scope data with applications that support the ActiveX standard. Many applications (such as Excel, PowerPoint, Internet Explorer, Visual Basic, Visual C++ and Labview) allow users to incorporate ActiveX controls.

MaskMaker and DSO-Filter

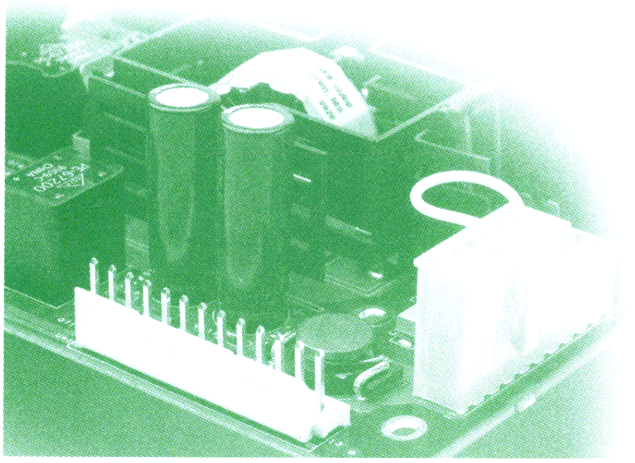
These easy-to-use Windows-based graphic utilities let you create and edit test masks and digital filters for use on *WavePro* scopes. Use MaskMaker with the PolyMask tolerance mask-testing option. You can even create XY masks.

With the DSO-Filter PC utility and DFP, you can specify a set of filter coefficients in an Excel spreadsheet and load them directly into the oscilloscope.

Powerful Applications

Power Supply

Nearly every type of electronic product incorporates some type of power supply. It may be a battery, AC-DC converter, switchmode power supply or other type of device. The stability and reliability of the power supply is of critical importance to product performance, maintenance costs and customer satisfaction. Factors of concern are battery life, safe operating area of power transistors, efficiency, the performance of soft-start circuits, dynamic on-resistance, emitted/conducted EMI, response to changes in load and robustness in non-standard operating conditions such as power surges.



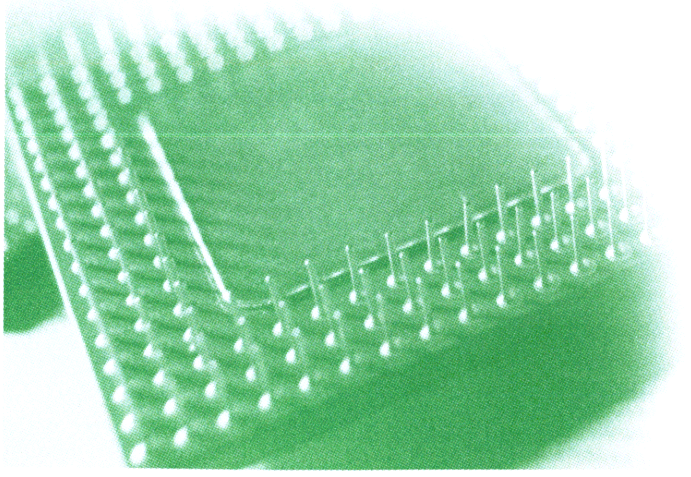
Communications

Communications products range from wireless devices to broadband networks and fiber-optic transmission lines. Though data speeds and encoding standards vary, all of these applications are driven by the need to accurately transmit and receive complex data streams. Emerging trends for transmission of video, audio and other complex sources of information—as quickly as possible—will continue to drive both the clock speed of communications protocols and the need for encoding methods that allow efficient data transmission.



Microprocessors

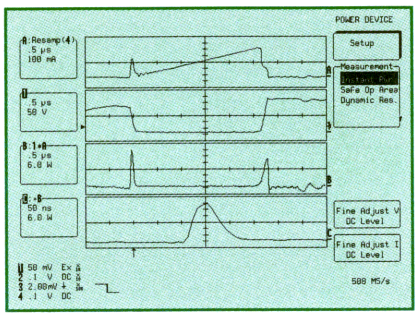
Devices ranging from automobiles to refrigerators and computers have a microprocessor as the "brains" of their control system. These devices may be low-speed, inexpensive chips or the latest high-cost, high-speed semiconductors. The functioning of the microprocessor is key to system performance and reliability. In general, the microprocessor needs to handle incoming instructions/data and send the proper responses back to the product in which it is embedded. As the level of demand grows for more sophisticated computations or for faster system operation, microprocessor speed increases and the complexity of tasks handled by the CPU also goes up.



Here are five solution packages from LeCroy targeted to your specific test applications. You'll find that these packages will bring precise measurements and fast analysis to your workflow.

Power Measurement Solutions

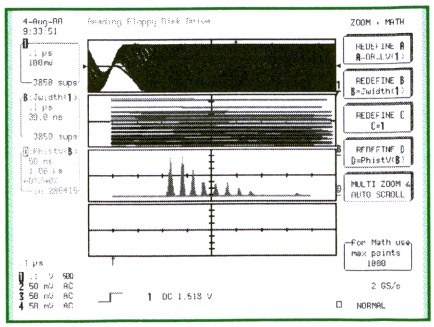
With LeCroy PowerMeasure Systems, you can analyze power devices' performance while they are operating in circuit. The PowerMeasure System combines the required current and differential voltage measuring capability with unequalled DSO triggering, long record capture, and waveform math to make these difficult measurements as simple as the push of a very few buttons.



Current, voltage, instantaneous power and energy dissipation measurements.

JitterPro (JPRO)

This analysis package provides a comprehensive set of precise timing measurements for clock, clock-to-data, and datastream analysis. JPRO includes all the capabilities of JTA plus the JitterWizard that turns a *WavePro* DSO into a dedicated jitter and timing analyzer. Get incredible ease of operation, combined with unparalleled analysis capabilities.



An example of a PlayStation-2 DVD. Channel 1 represents the data from the DVD, while the pulse/width modulation is shown on Trace B. Trace D is a histogram of B. The pulse widths are well defined within narrow bands with no interference.

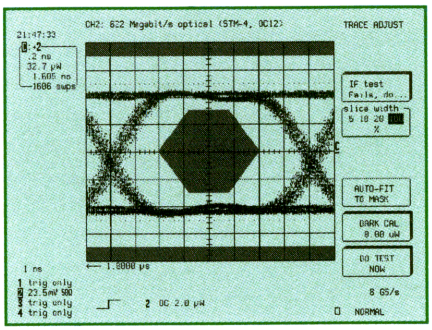
Clock Certification & Test Module (CCTM)

CCTM is specified by Rambus Inc. as the first approved tool for compliance testing of DRCG (Direct Rambus® Clock Generator) jitter. All jitter measurements as required by Rambus are automatically configured and easily performed through the CCTM wizard.

Telecom Mask Test Packages

MT series Mask Testing options for optical and electrical communication signals are available with *WavePro* scopes. Mask Testing compares a trace against a mask template to check if it falls inside or outside the mask boundaries. Several actions may be initiated if the trace fails the test, including "stop", "output a pulse", and "datalog."

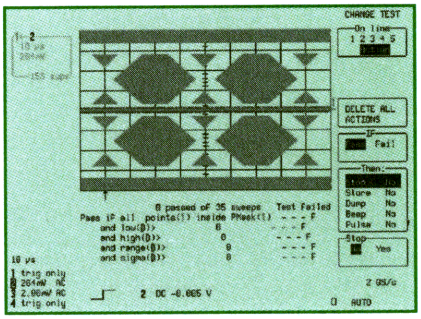
With the exclusive Finder Function, pulses, patterns or even random bit streams are easily isolated. MT packages take control of the *WavePro* scope, displaying only relevant test menus.



Mask Testing and extinction ratio measurements of an OC-12 optical signal.

PolyMask

PolyMask is a powerful, general-purpose testing application that lets you view and test against complex masks. PolyMask locates and clearly depicts signal failures. In pass/fail testing, failures are highlighted with colored circles. Creating masks is greatly simplified with the MaskMaker utility, a simple program that runs on any PC with Windows. Masks can be used in either 8x10 or XY display mode (useful for applications such as power measurement).



An Ethernet 100 Base-T mask created with the MaskMaker utility.

WavePro Specifications

Vertical System	WavePro 960	WavePro 950	WavePro 940
Input Channels		4	
Analog Bandwidth @ 50 Ω (-3 dB)	2 GHz*	1 GHz	500 MHz
Bandwidth Limiters		20 MHz, 200 MHz	
Input Impedance		50 Ω ± 1.5%; 10 MΩ // 11 pF typical (using PP005 probe)	
Input Coupling		1 MΩ : AC, DC, GND; 50 Ω : DC, GND	
Maximum Input		50 Ω : 5 Vrms; 1 MΩ : 100 Vmax (peak AC ≤5 kHz + DC)	
Vertical Resolution		8 bits; up to 11 bits with enhanced resolution (ERES)	
Sensitivity		50 Ω : 1 mV – 1 V/div fully variable ; 1 MΩ : 1 mV – 2 V/div fully variable	
DC Accuracy		± 2.0% full scale + 1.5% offset value @ gain > 10 mV	
Offset Accuracy		± (1.5% + 0.5% of full scale + 1 mV)	
Offset Range		50 Ω or 1 MΩ : 1 mV – 4.99 mV/div: ±400 mV	
		50 Ω : 5 mV – 99 mV/div: ±1 V; 0.1 V – 1 V/div: ±10 V	
		1 MΩ: 5 mV – 100 mV/div: ±1 V; 101 mV – 2 V/div: ±20 V	
Isolation — Channel-to-Channel		> 250:1 at same V/div settings	

**with sample speeds > 4 GS/s*

Timebase System	
Timebases	Main and up to four independent zoom traces simultaneously
Ranges	200 ps/div – 1000 s/div
Clock Accuracy	≤10 ppm
Interpolator Resolution	5 ps
External Clock Frequency	500 MHz maximum, 50 Ω, or 1 MΩ impedance
Roll Mode – Operating Range	time/div 500 ms – 1000 s/div or sample rate < 100 kS/s max
External Reference	10 MHz timebase reference clock available with input on rear panel
External Timebase Clock	500 MHz maximum external sample clock input on front panel EXT BNC

Acquisition System			
Single-Shot Sample Rate			
1 Channel Max.	16 GS/s	16 GS/s	8 GS/s
2 Channels Max.	8 GS/s	8 GS/s	8 GS/s
3 – 4 Channels Max.	4 GS/s	4 GS/s	4 GS/s
Maximum Acquisition Points/Ch		(1 Ch) / (2 Ch) / (3 – 4 Ch)	
Standard	1M / 500k / 250k	1M / 500k / 250k	1M / 500k / 250k
M – Memory Option	4M / 2M / 1M	4M / 2M / 1M	4M / 2M / 1M
L – Memory Option	16M / 8M / 4M	16M / 8M / 4M	16M / 8M / 4M
VL – Memory Option	32M / 16M / 8M	32M / 16M / 8M	32M / 16M / 8M
XL – Memory Option	64M / 32M / 16M	–	–

Acquisition Modes

Random Interleaved Sampling (RIS): 50 GS/s for repetitive signals: 200 ps/div – 1 µs/div

Single-Shot: For transient and repetitive signals: 200 ps/div – 1000 s/div

Sequence: 2 – 8000 segments

Intersegment Time: Typically 30 µs

Acquisition Processing

Averaging: Summed averaging to 10^3 sweeps (standard). Continuous averaging up to 10^6 sweeps with weighting range from 1:1 to 1:1023 (option).

Enhanced Resolution (ERES): From 8.5 to 11 bits vertical resolution

Envelope (Extrema): Envelope, floor, roof for up to 10^6 sweeps

Triggering System

Modes: Normal, Auto, Single, and Stop

Sources: Any input channel, external, Ext/5 or line; slope, level, and coupling unique to each source (except line trigger)

Slope: Positive, Negative, Window

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

AC Cutoff Frequency: 7.5 Hz Typical
HFREJ, LFREJ: 50 kHz typical

Pre-trigger delay: 0 – 100% of horizontal time scale

Post-trigger delay: 0 – 10000 divisions

Hold-off by time or events: Up to 20 s or from 1 to 99 999 999 events

Internal trigger range: ±5 div

Max trigger frequency: Triggers up to maximum bandwidth (HF), 500 MHz (AC, DC)

External trigger input range: ±0.5 (±2.5 V with Ext/5 selected)

Maximum ext. input @ 50 Ω: ±5 V DC or 5 Vrms

Maximum ext. input @ 1 MΩ: 100 Vmax (DC + peak AC < 5 kHz)

Automatic setup

Auto Setup: Automatically sets timebase, trigger, and sensitivity to display a wide range of repetitive signals

Vertical Find: Automatically sets the vertical sensitivity and offset for the selected channels to display a waveform with maximum dynamic range

Probes

Model PP005: 10: 1, 10 MΩ with autodetect (one per channel)

Probe System/ProBus: Automatically detects and supports a wide variety of differential amplifiers; active, high-voltage, current, and differential probes

Scale Factors: Up to 12 automatically or manually selected

Color Waveform Display

Type: Color 10.4" flat-panel TFT-LCD

Resolution: VGA 640 x 480 pixels

Screen Saver: Display blanks after 10 minutes (when screen saver is "on").

Real Time Clock: Date, hours, minutes, and seconds displayed with waveform

Number of Traces: Display a maximum of eight traces. Simultaneously display channel, zoom, memory, and math traces.

Grid Styles: Single, Dual, Quad, Octal, XY, Single + XY, Dual + XY; Full Screen gives enlarged view of each style.

Intensity Controls: Separate intensity control for grids and waveforms

Waveform Styles: Sample dots joined or dots only — regular or bold sample point highlighting

Trace Overlap Display: Select opaque or transparent mode with automatic waveform overlap management.

Analog Persistence Display

Color and Intensity Graded Persistence: Variable saturation levels; stores each trace's persistence data in memory.

Trace Selection: Activate Analog Persistence on a selected trace, top 2 traces, or all traces.

Persistence Aging Time: Select from 500 ms to infinity.

Trace Display: Opaque or transparent overlap

Sweeps Displayed: All accumulated or all accumulated with last trace highlighted

Zoom Expansion Traces

Display up to Four Zoom Traces:

Vertical zoom: up to 5x expansion, 50x with averaging

Horizontal zoom: expand to 2 pts/div, magnify to 50000x

Auto Scroll: automatically scans and displays any zoom or math trace.

Rapid Signal Processing

Processor: Power PC

Processing Memory: Up to 256 Mbytes

Realtime Clock: Dates, hours, minutes, seconds

Internal Waveform Memory

Waveform: M1, M2, M3, M4 (Store full-length waveforms with 16 bits/data point)

Zoom and Math: Four traces A, B, C, D with chained trace capability

Setup Storage

Front Panel and Instrument Status: Four non-volatile memories and floppy drive are standard. Hard drive and memory card are optional.

CustomDSO: Customize and access scope settings with up to 6 CustomDSO files stored in non-volatile Virtual Disk (VDisk).

Interface

Remote Control: Full control of all front panel controls and internal functions via RS-232-C, GPIB, or Ethernet

RS-232-C: Asynchronous transfer rate of up to 115.2 kbaud

GPIB Port: Full control via IEEE – 488.2; configurable as talker/listener for computer control and data transfer

Floppy Drive: Internal, DOS-format, 3.5" high-density

Ethernet (optional): 10 Base-T Ethernet interface

PC Card Slot (optional): Supports memory and hard drive cards

External Monitor Port Standard: 15-pin D-Type VGA-compatible

Centronics Port: Parallel printer interface

Internal Graphics Printer (optional): Hard-copy output in <10 seconds or strip chart mode up to 200 cm/div

Outputs

Calibrator Signal: 500 Hz – 2 MHz square wave or 25 ns pulse; into 1 MΩ output on front panel BNC

Control Signals: Trigger ready, trigger out, pass/fail status.

Pass/Fail and Trigger Output: Front or rear output provides choice of trigger ready, trigger out, or pass/fail pulse.

Math Tools (Standard)

Simultaneously perform up to four math (signal) processing functions; traces can be chained together to perform math-on-math.

absolute value
average (summed to 1000 sweeps)
difference
differentiate
enhanced resolution (to 11 bits vertical)
envelope
exp (base e)
exp (base 10)
FFT of 50 kpoint waveforms
floor
histogram of 200 events
identity
integrate
log (base e)
log (base 10)
negate
parameter trackview
product
ratio
reciprocal (invert)
resample (deskew)
rescale (with units)
roof
sin x/x
square
square root
sum
trend (datalog)

Measure Tools (Standard)

Dashboard displays up to 26 parameters; Display any five parameters together with their average, high, low, and standard deviations.

Automated Measure Tools

amplitude
area
base
cycle std. deviation
cycle mean
cycle rms
cycles
delay
fall 90-10%
fall 80-20%
frequency
maximum
mean
minimum
+overshoot
–overshoot
peak-to-peak
period
rise 10-90%
rise 20-80%
rms
std. deviation
top
width
xamn
xamx
Δ delay
Δ time @ level; % and volts
Δ time @ level from trigger
Δ time from clock to data + (setup time)
Δ time from clock to data - (hold time)
cycle median
data
duration
duty cycle
fall @ level; % and volts
first point
last point
median
number of points
phase
rise @ level; % and volts
time @ minimum (min)
time @ maximum (max)

Pass/Fail

Test any five parameters against selectable thresholds. Limit testing is performed using masks created on the scope or PC. Set up a pass or fail condition to initiate actions such as hard-copy output, saving waveform to memory, GPIB SRQ, or pulse out.

WaveAnalyzer Pro (WAVAPRO)

This package provides the most comprehensive set of signal analysis tools for expanding the capability of *WavePro* oscilloscopes. It includes the Digital Filter Package (DFP), Jitter and Timing Analysis (JTA) plus all the Wave Analyzer (WAVA) capabilities:

- Histograms with 18 histogram parameters on 2 billion events
- Summed averaging to one million sweeps
- Continuous weighted averaging
- FFT capability expands the basic FFT to include:
  - FFT power averaging
  - FFT power density – real and imaginary
  - FFT on all acquisition points up to 25 Mpts

Other Application Solutions Available

Jitter Pro (JPRO)
Clock Certification and Test Module—for

- Rambus clock generator (CCTM)
- Jitter and Timing Analysis (JTA)
- WaveAnalyzer Package (WAVA)
- Polymask Mask Testing (PMSK)
- Advanced Optical Recording Measurements (AORM)
- Disk Drive Measurements (DDM)
- PRML Analysis (PRML)
- PowerMeasure Analysis (PMA)

Software Utilities

ScopeExplorer

Easy-to-use utility that provides a simple but powerful Windows interface to control your scope remotely over RS-232-C, GPIB, or Ethernet.

ActiveDSO

ActiveX controls for flexible Windows applications programming with remote control.

MaskMaker

Create custom tolerance masks offline for use withthe PolyMask package. MaskMaker is available for download from www.lecroy.com.

DSO Filter

Specify a set of filter coefficients offline and load them into the scope.

Basic Triggers

Edge/Slope/Window/Line: Triggers when signal meets slope and level condition

SMART Triggers

State or Edge Qualified: Triggers on any input source only if a defined state or edge occurred on another input source. Delay between sources is selectable by time or events.

Dropout: Triggers if signal drops out for longer than selected time between 2 ns and 20 s

Pattern: Logic combination of 5 inputs (4 channels and external trigger input); each source can be high, low, or don't care. Trigger at start or end of the pattern.

SMART Triggers with Exclusion Technology

Signal or Pattern Width: Triggers on glitches or on pulse widths selectable from 600 ps to 20 s or on intermittent faults

Signal or Pattern Interval: Triggers on intervals selectable between 2 ns and 20 s

Slew Rate: Triggers on edge rates; select limits for dV, dt, and slope

Runt: Positive or negative runts defined by two voltage limits and two time limits selectable between 600 ps and 20 ns

Hard Copy

Print Screen is activated by a front-panel button or via remote control. Store screen image files or print to external printers.

Supported printers include:

B/W: LaserJet, DeskJet, Epson

Color: DeskJet 550C, Epson Stylus, Canon 200/600/800 series

An optional, internal high-resolution graphics printer is also available for screen dumps; stripchart output formats capable of up to 200 cm/div.

Hard copy Formats: TIFF b/w, TIFF color, BMP color, and BMP compressed

Waveform Output

Store waveforms to floppy disk or optional PC-Card hard drives and memory cards.

Save any trace you choose and select Auto Store to automatically store the waveform after each trigger.

Output Formats: The ASCII waveform output is compatible with spreadsheets, Matlab, Mathcad, etc. Binary output is also available for reduced file size. Binary files can be converted to ASCII in a PC using the ScopeExplorer utility.

Documentation

Included with all WavePro Oscilloscopes:

Operations Manual — hard copy

Remote Programming Manual — hard copy

CD-ROM — PDF formatted manuals plus software utilities including: ScopeExplorer, ActiveDSO, MaskMaker and DSO Filter.

PDF formatted manuals, ScopeExplorer, Active DSO, MaskMaker, and DSO Filter are all available at www.lecroy.com

Environmental and Safety

Operating Conditions

Temperature: 5 – 40° C rated accuracy (41° to 104° F)
0° – 45° C-operating
-20° – 60°-C non-operating

Humidity: 75% max relative humidity, non-condensing at 45° C

Altitude: 3,000 meters (10,000 feet) operating at 25° C; 4 500 meters (15,000 feet) non-operating

CE Approved

EMC: EMC Directive 89/336/EEC; EN 61326-1 Emissions and Immunity

Safety: Low Voltage Directive 73/23/EEC; EN 61010-1 Product Safety (Installation Category II, Pollution Degree 2)

UL and cUL approved: UL Standard UL 3111-1
cUL Standard CSA-C22.2 No. 1010-1

General

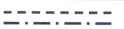
Auto Calibration: Ensures specified DC and timing accuracy is maintained for 1 year minimum

Auto Calibration time: <500 ms

Power Requirements: 90 – 132 V AC & 180–250 V AC; 45 – 66 Hz; max power dissipation: 150 VA – 230 VA, depending on model

Battery Backup: Front panel settings retained for two years minimum

Cursor Measurements

Type	Symbol	From	To
Relative time		First point on waveform	Any other point on waveform
Relative voltage		Select voltage level	Any other voltage level
Absolute time		Time and voltage relative to	Trigger and ground
Absolute voltage		Voltage	Ground

Warranty and Calibration: Three years; calibration recommended yearly

Physical Dimensions

Dimensions (HWD): 264 mm x 397 mm x 453 mm; 10.4" x 15.65" x 17.85" (height excludes feet)

Weight: 14 kg; 31 lbs (with internal printer)

Shipping Weight: 22.2 kg; 49 lbs

Service

LeCroy service programs include unique service upgrades for LeCroy oscilloscopes, metrology modules customized for your company, and more. Whether you own one LeCroy instrument or hundreds, whether you need prompt attention from our service offices or an onsite service contract, LeCroy is committed to your success. Call your LeCroy service representative to discuss your company's specific requirements.

Ordering Information

WavePro Digital Oscilloscopes	Product Code
2 GHz, 16 GS/s, 250 kpts/ch, 4 Channel Color	WAVEPRO 960
1 GHz, 16 GS/s, 250 kpts/ch, 4 Channel Color	WAVEPRO 950
500 MHz, 8 GS/s, 250 kpts/ch, 4 Channel Color	WAVEPRO 940

Included with Standard Configuration:	
10:1 10 MΩ Passive Probe (1 per channel)	PP005
Operator's Manual, Quick Reference Guide, CD-ROM with OM/RCM PDF manuals, and utility software	WAVEPRO-OPDOCS
Remote Control Manual	WP-RCM
Floppy Disk Drive	
GPIB, RS-232-C, Centronics Parallel Port, VGA Video Output Port	
Protective Front Cover	
Performance Certificate	
Three-Year Warranty	

Memory Options	960	950	940
M 4 Mpts max, 1 Mpts/ch	•	•	•
L 16 Mpts max, 4 Mpts/ch	•	•	•
VL 32 Mpts max, 8 Mpts/ch	•	•	•
XL 64 Mpts max, 16 Mpts/ch	•	–	–

Hardware Options	
Internal Graphics Printer	WAVEPRO-GP02
10 Base-T Ethernet LAN option	WAVEPRO-LAN10BT
PC Card Slot	PCSLOT
PC Card Slot including 1 hard drive card and 1 memory card	PCMEDIA

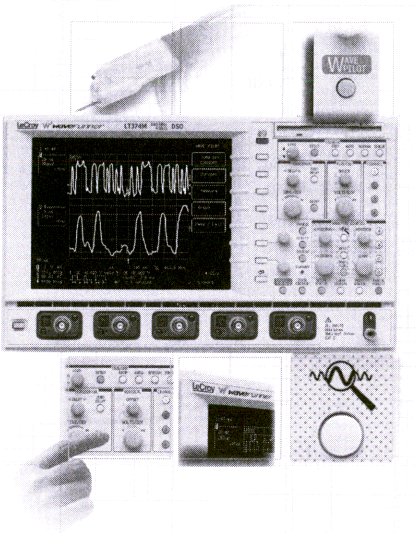
Software Options	
WaveAnalyzer Pro Analysis Package (includes WAVA, JTA, and DFP)	WAVAPRO
WaveAnalyzer Analysis Package	WAVA
ITU G.703 Fully Automated Mask Tester	MT01
ANSI T1.102 Fully Automated Mask Tester	MT02
ITU G.957 STM-1 and STM-4 Fully Automated Mask Tester with O/E converter and reference receiver	MT03 (not available on model 940)
Jitter and Timing Analysis Package	JTA
JitterPro	JPRO
Clock Certification Timing Module (requires JitterPro)	CCTM
Digital Filter Package	DFP
Disk Drive Measurements	DDM
Supplementary Disk Drive Measurements	PRML
Advanced Optical Recording Measurements	AORM
PowerMeasure Analysis Software	PMA1

Selected Accessories	
Graphic Printer Paper/10 Rolls	GPR10
Oscilloscope Cart	OC-PRO
I GHz Active Voltage Probe	HFP 1000
I.5 GHz Active Voltage Probe	HFP 1500
2.5 GHz Active Voltage Probe	HFP 2500

Warranty & Calibration	
NIST Calibration Certificate	CCNIST
MIL STD Calibration	CCMIL
Swiss OFMET Standard	CCOFMET
5-Year Repair Warranty	W5
5-Year Annual NIST Calibration Contract	C5
5-Year Warranty & NIST Calibration	T5

Waverunner-2 Series Color Oscilloscopes

waverunner™



Main Features

Waverunner-2 oscilloscopes provide all you need to quickly capture, view and analyze your signals — accurately and reliably:

- **350 MHz – 500 MHz bandwidth**
- **1 – 4 GS/s max, single-shot sample rate**
- **50 GS/s for repetitive signals**
- **Up to 8 million data points to view signals**

From troubleshooting to timing analysis to production testing, the Waverunner-2 scopes are uniquely qualified to meet your requirements — all at a great value!

Catch the New Wave

Easy as 1-2-3

Simple, Fast Access to Powerful Capabilities

Waverunner-2 scopes are the second generation of the popular Waverunner series. They bring you the power of LeCroy signal acquisition, viewing and analysis capabilities with simple one-button access. Using the new Wavepilot™ feature, it's easier than ever to capture, view and analyze long time duration, high-speed signals with high resolution for accurate, precise results.

Easy to Use

Waverunner-2 scopes are designed to get you up and running quickly. Their color-coded front panels and simple menu systems are easy to understand, so your focus is on the work, and not the tool. Common tasks are automatic. Navigation is streamlined and intuitive. You'll easily master their powerful operations.

The Right Price

Waverunner-2 oscilloscopes raise the bar for capability and value — you get more for your money than with any other scope in this class. And because *Waverunner-2* scopes can be upgraded, you can extend their life to meet future needs.

Increase Your Productivity

The new Wavepilot and QuickZoom buttons make it simple to magnify, view, inspect or measure signal details, to perform automatic measurements on signals, and to graph measurements in frequency spectra, histogram, or trend format. With TrackView, you can track problems to the source. Additional signal analysis capabilities let you datalog, chain math functions and more. LeCroy's signal diagnostic and troubleshooting tools provide a complete solution for characterization, debug and signal analysis.

From Circuit to Scope

A variety of accessories are offered for effectively connecting the *Waverunner-2* to your circuit. The LeCroy HFP small, lightweight probes assure you high bandwidth, low capacitance connections to your circuit. In addition, five inter-changeable probe tips are available for probing surface mount devices, circuit vias, IC leads and other difficult spots — making the HFP probes the best choice for probing high-frequency circuits. Current probes, differential probes and amplifiers are also available.

Waverunner-2 Color Digital Oscilloscopes

Model	Bandwidth	Channels	Sample Rate/ch	Maximum Sample Rate	Acq. Memory per Ch/Max	Option M per Ch/max	Option L
LT374	**500 MHz**	**Four**	**2 GS/s**	**4 GS/s**	**250 k/500 kpt**	**1/2 Mpts**	**4/8 Mpts**
LT372	500 MHz	Two	2 GS/s	4 GS/s	250 k/500 kpt		
LT264	350 MHz	Four	1 GS/s	1 GS/s	100 k/100 kpt	1/1 Mpt-	
LT262	350 MHz	Two	1 GS/s	1 GS/s	100 k/100 kpt		

** Model LT372 doubles the memory and sampling rate when using a single channel.*

*** Model LT374 doubles the memory and sampling rate when using one or two channels.*

Extreme Vision – See Into Your Signal

Connectivity to Windows

- Connect your scope to Windows-based ScopeExplorer using the Ethernet (option), GPIB or RS-232 interfaces. Click and drag files or operate from the virtual front panel. Download new software updates via the web.

Fast, Easy Access

Fast, easy access to powerful but simple features that help you solve real problems quickly!

The Wavepilot Accesses these Functions:

Cursors
Measure signals using a full complement of cursors with on-screen measurement display.

Measure
Automatically displays up to 26 signal parameters with the signal.

Graph
For fast insight into problems, display of histograms, FFT spectrum analysis, or LeCroy's TrackView capability.

Analysis Packages

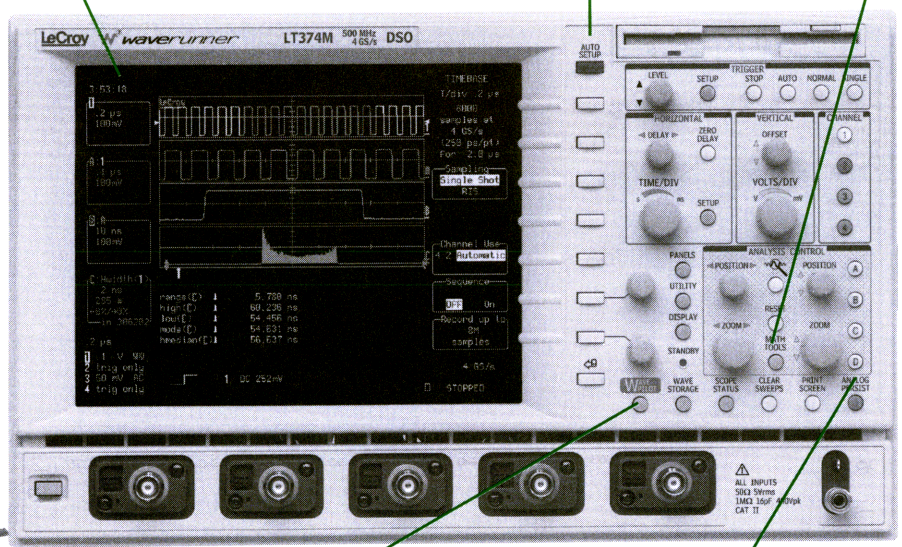
- Communications Mask Testing
- Optical Recording
- PowerMeasure

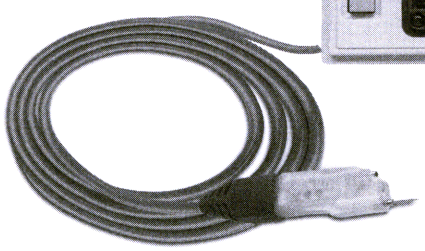
QuickZoom
Automatically displays 10x magnified traces of all signals on multi-grids, ensuring maximum resolution and S/N ratio.

Large 8.4" TFT LCD Display
The large, sharp, bright color display makes it easy to see signal details.

Auto Setup
Press one button and automatically get your signal on the screen.

New! Up to 500 MHz Bandwidth and 8 Million Sample Points of Waveform Data at 4 GS/s The large, sharp, bright color display makes it easy to see signal details.





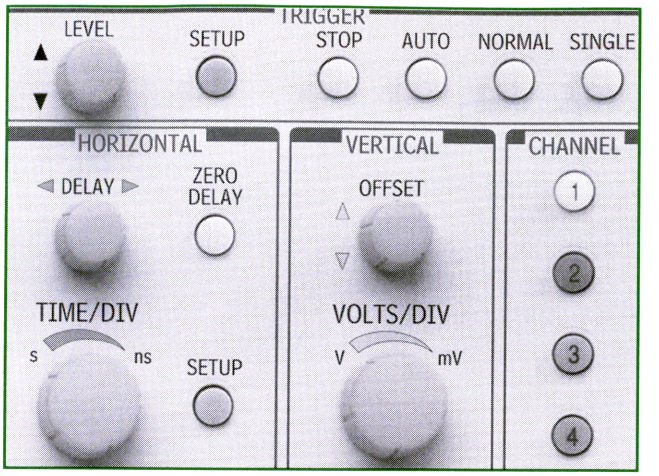
New! High Bandwidth Probes with AutoColor ID. The HFP series of probes provide low circuit loading, high bandwidth and a variety of inter-changeable tips.

Wavepilot
Easy access to powerful signal analysis capabilities that help you gain insight and track problems right to the source.

Analog Persistence™
Press the green button to activate Analog Persistence view so you can visually explore the full depth of signal information. Display the HISTORY of persistence snapshots, then scroll, identify and analyze the tough problems.

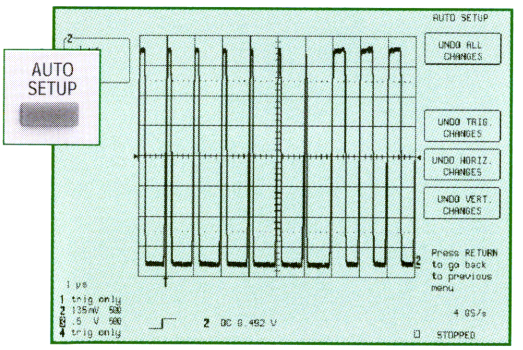
Simplified Operation

Acquiring and displaying signals is easy. When you first see a *Waverunner-2* scope, you will notice the front panel is clear, concise and intuitive in operation. Getting signals on the screen is easy: follow the color channel coding and press *Auto Setup*. Adjust horizontal or vertical settings to view the way you want and unleash the power of LeCroy Smart Memory with the press of *QuickZoom*. If you are concerned with intermittent runts or timing problems, just press the green button to see infrequent signal anomalies.



Auto Setup

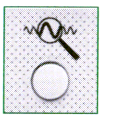
Simply connect your signal, press *AUTO SETUP*, and view. Horizontal, Vertical, and Trigger settings are automatically set. LeCroy SMARTMemory ensures the highest time resolution for the time window displayed.



Many Ways to View your Signal

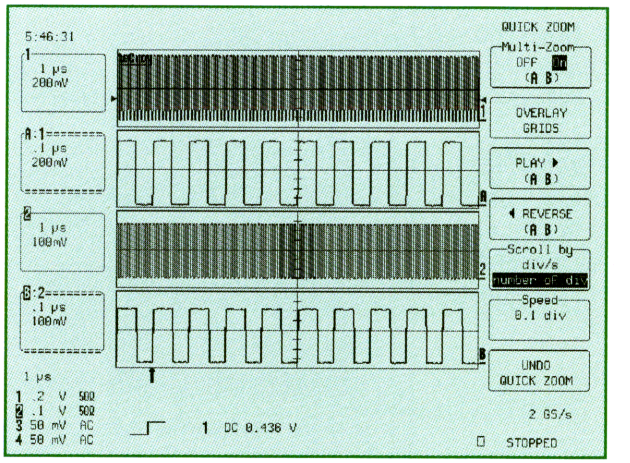


Capturing and viewing the signal is as easy as 1-2-3. Analog Persistence shows three dimensions of signal information. *HISTORY* gives you further insight into the third dimension by recording snapshots of the signal into memory. Then analyze signals in the sequence they were captured to find the problem.



Quick Zoom

Press the *QUICK ZOOM* button and view up to 4 zooms of up to 4 input signals. Magnify, inspect, search and scan your signal to see details and understand problems.



QuickZoom automatically displays 10x magnified traces of all signals on multi-grids.

Wavepilot with Insight

Expand Your Vision

From beginner to expert, it is now easier than ever to apply the power of the unique analysis tools available from LeCroy. The Wavepilot function provides simple access to powerful, easy-to-use signal analysis for real insight into problems.

Cursors

Press *Wavepilot* and select *CURSORS,* then turn the knob for manual adjustment and measurement between sections of your signal.

Measure

Select *MEASURE* to simultaneously display up to 26 parameters on the signal of your choice and quickly switch from trace to trace. The Measure dashboard is context-sensitive, so when you display a histogram, you will see statistical parameters.

Graph

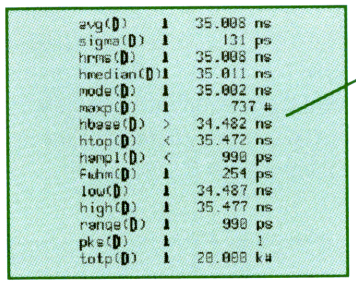
Select *GRAPH* to automatically display an FFT, histogram (optional) or TrackView (optional). Setting up signal analysis is simple with the Wavepilot menus.

Application Packages

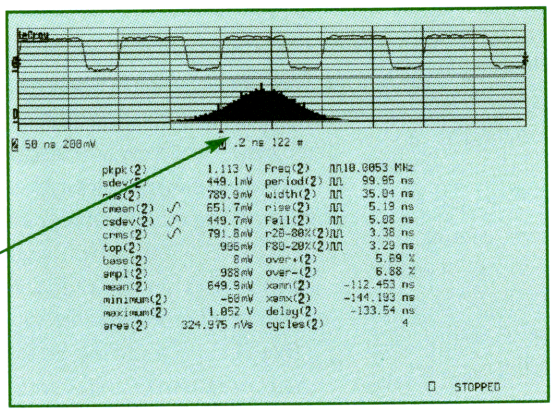
Select access to choose optional application-specific solution packages including Telecommunications Mask Test, Jitter and Timing, Power Measurements, and Data Storage solutions.

GRAPH — Histogram

Histograms and Trends (optional) are popular tools used to summarize measurement results. LeCroy has made them easier than ever with Wavepilot. Parameter selection is simple, and graphs are automatically setup, scaled and displayed.



Select Trace A: When viewing a Histogram trace, the Histogram parameters can be displayed instead of signal parameters.



Histogram with Signal Measurements

MEASURE is simple to activate from the Wavepilot toolbar. The *DASHBOARD* view displays up to 26 standard signal parameters. You can also select a set of custom parameters.

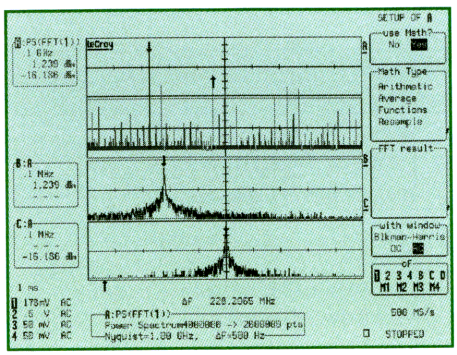
One-touch insight into any signal!

The Wavepilot function provides fast access to powerful signal analysis.



FFT Spectrum Analysis

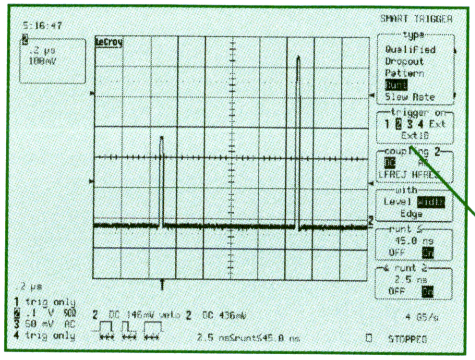
When you need to understand the frequency content of your signal, spectrum analysis is easily accessed through the Wavepilot button.



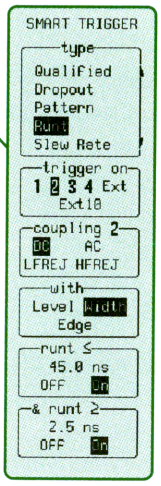
Speed Up Debug and Analyze

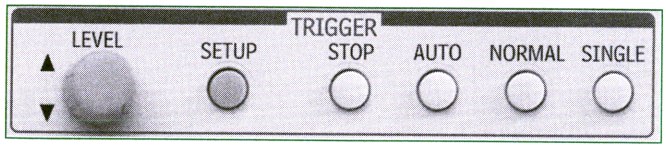
SMART Triggers®

The *Waverunner-2* scope's trigger bar is simple to operate. Run the scope in normal or auto trigger modes, or capture one-time events into scope memory as large as 8 Mpts with a single-shot trigger. Triggering with *Waverunner-2* is direct, easy to read and easy to understand.



Runt triggering is great for capturing logic signals that exhibit inadequate levels or spurious signals that interfere with circuit operation. With the exclusion/inclusion feature, the scope will only trigger on runt signals that are outside/within a specified range of pulse width.



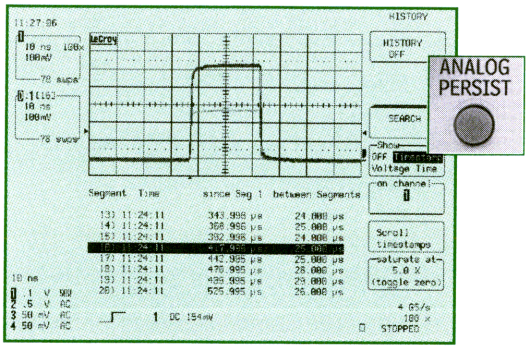


SMART Trigger provides the flexibility needed to quickly trigger on the specific signal characteristic or pattern you are searching for. All *Waverunner-2* oscilloscopes include SMART Triggers. Trigger not only on what you expect, but also on unusual signals. Exclusion triggers can exclude normal signals and capture only the abnormal ones, speeding up the debug of your circuits and systems. Trigger on signals down to 2 ns in width. The optional Advanced Trigger Package (ATP) extends *Waveunner-2's* SMART Trigger capability by adding runt and slew rate trigger for the capture of intermittent events.

Use HISTORY Views to Find Intermittents

Pressing the green *Analog Persist* button and selecting *History* converts the scope into a fast Analog Persistence fault-finder. The lifetime of your signal is written into the History memory and mapped on screen. You can measure each signal, see its trigger time, and identify rare events. Up to 4,000 events can be acquired for playback. This is great when you have intermittent problems and want to know if they occur at a rate related to other circuit or system timing events.

Press "play" to replay the signal history and automatically scan and search from sweep to sweep. Stop when you see something of interest. The display shows the Analog Persistence view of all acquired sweeps as well as the individual sweep under inspection. Since the time of each trigger event is displayed with a resolution of 1 ns, you can easily determine the rate of occurrence.



HISTORY lets you see the intermittent, trigger on the problem and find how often it's disrupting your design.

Waverunner-2 Basic Triggers

Name	Description
Edge	Select + or - slope and holdoff by time or events.
Window	Triggers when signal crosses outside the window in either direction.

Waverunner-2 SMART Triggers

Name	Triggers Conditions
Glitch	From 2 ns - 20 s and when pulse is >, <, or in or out of a range.
Interval	Between edges and ranges of 10 ns - 20 s.
Qualified	By edge or state on a channel or if a pattern is present or absent.
Qual First	A single pulse qualifies a sequence of triggers.
Dropout	If input drops out after a time from 25 ns - 20 s.
Runt*	Pulse levels, edge, widths from 2 ns - 20 s.
Slew Rate*	Slope, dV, dT from 1 ns - 20 ns.
Pattern (logic)	Logical combination of up to 5 inputs (3 on two channel models). Can also be used in combination with Qualified.

**Optional Advanced Trigger Package (ATP)*

Probing Solutions
Active Probes

Convenient, Hands-Free Probing

To access the ever-increasing variety of test points, today's probing solutions need to be versatile, small and light-weight. The new HFP series of probes meets these needs with high bandwidth, miniature size and a variety of tip styles, making probing easier than before.

In combination with these innovative probe tips, the unique HFP *FreeHand* probe holder will hold the probe on test points to maintain signal fidelity. The end result of HFP "hands-free" probing is the enhanced ability to analyze waveforms instead of having to focus energy on keeping the probe itself in place.

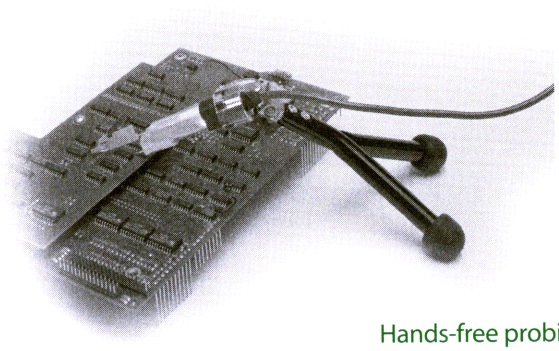
AutoColor ID

When the probe is connected to a *Waverunner-2* scope, our new patent-pending AutoColor ID feature automatically senses and illuminates the probe head in that channel's trace color. You no longer need to worry about plastic rings or colored tape to identify which channel on the scope is connected to a particular test point.

HFP 1000

Leading Specifications

- 1 GHz Bandwidth
- 0.7 pF Input Capacitance
- 100 kΩ DC Input Resistance
- ±8 V Dynamic Range
- 5 Interchangeable Tips available for Probing a Variety of Test Points
- Replaceable Probe Tip Socket
- Hands-Free Probing with *FreeHand* probe holder (optional with HFP 1000)
- AutoColor ID Feature Matches the Probe Color to the Trace Color



Hands-free probing with *FreeHand* probe holder and HFP probe.



The new current probes, CP150 and CP015.

Current Probes

CP150 and CP015 are high performance current probes capable of measuring 150 amp and 15 amp current signals. They incorporate Hall effect and transformer technology to measure both DC and AC currents. LeCroy also offers the best differential amplifiers available on the market, the DA1800 series.

Other useful accessories for the Waverunner-2 series are low cost active differential probes, high voltage probes, an internal graphics printer and a choice of two scope carts.

Signal Measurements and Analysis

The new Wavepilot button and the Analysis Control Area provide quick access to a comprehensive, easy to use set of signal analysis tools that help you solve problems fast. Optional packages expand the *Waverunner-2* scope to a complete signal analyzer.

Standard in All Models

Press *Wavepilot* and select the *Parameter Dashboard* and view up to 26 automatic measurements that update with your waveform — in real-time, on screen. Select *Graph* and view an FFT of a signal—up to 50 kpoints. Process signals with *Math Tools* including averaging to 1,000 sweeps to reduce noise or use enhanced resolution for up to 11 bits of vertical resolution. Chain up to 4 math functions and display the final waveform or any of the intermediate steps.

Extended Math and Measurements (EMM)

The *EMM* option provides basic graphical signal analysis tools including Histograms (200 events) and Trending of parameters (expanded to over 40). Additional *Math Tools* include signal integration and differentiation.

WaveAnalyzer with JTA (JTWA)

The WaveAnalyzer JTA option is the ultimate tool for characterization and troubleshooting in time, frequency, and statistical domains. It includes:

- WaveAnalyzer Signal Analysis (WAVA)
- Jitter and Timing Analysis (JTA)

WaveAnalyzer Signal Analysis (WAVA)

Waveform averaging capability increases to one million acquisitions. The FFT spectrum analysis expands to process all acquired data up to 8 Mpts and provides additional spectral views. *Histograms* (up to 2 billion events) and *Trends* let you view and measure statistical variations of signal parameters.

Jitter and Timing Analysis (JTA)

JTA has broad applications in measuring and anlayzing digital electronics or mechanically related signals. Measure a wide variety of timing parameters: cycle-to-cycle, period, frequency, time interval and width. Use JitterTrack to plot the parameter variation vs. time.

Digital Filter Package (DFP)

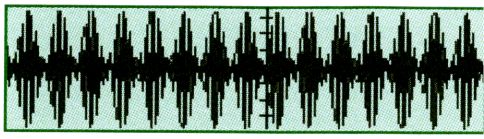
The DFP option implements a set of linear-phase Finite Impulse Response (FIR) filters. The package enhances your ability to examine important signal components by filtering out undesired spectral components such as noise.

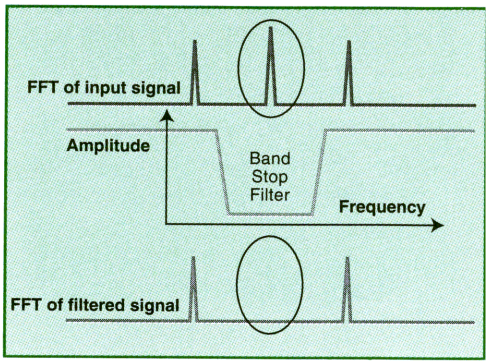
Filters Include:

Low Pass	Raised Cosine
High Pass	Raised Root Cosine
Band Pass	Gaussian
Band Stop	Custom

Up to 4 filters can be cascaded

Design your own filters with DFP.p40



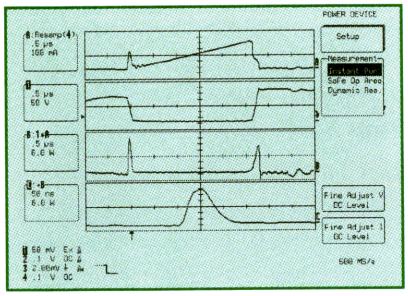


Powerful Applications

Here are four solution packages from LeCroy targeted to your specific test applications. You'll find that these packages will bring precise measurements and fast analysis to your workflow.

World Class Power Measurement Solutions

With LeCroy PowerMeasure Systems, you can analyze power devices' performance while they are operating in circuit. The PowerMeasure System combines the required current and differential voltage measuring capability with unequalled DSO triggering, long record capture, and waveform math to make these difficult measurements as simple as the push of a very few buttons.



Current, voltage, instantaneous power and energy dissipation measurements.

Jitter & Timing Analysis (JTA)

This analysis package provides a comprehensive set of precise timing measurements for clock, clock-to-data, and datastream analysis. TrackViews show deviations directly synchronized to the signal — patterns you would never see without this view. Press the Wavepilot button for easy access, and zoom in on both the "where" and the "why" of the problem; you can see it and fix it! Quickly gain insight into the source of timing and signal integrity problems.

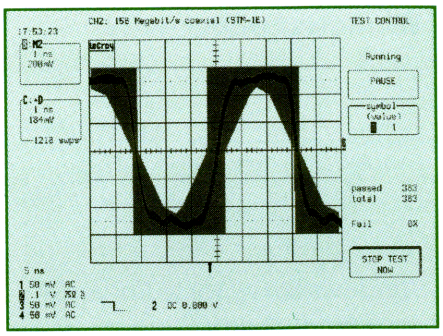
Telecom Mask Test Packages

MT series Mask Testing options for electrical communications signals are available with Waverunner-2 scopes. Mask Testing compares a trace against a mask template to check if it falls inside or outside the mask boundaries. Several actions may be initiated if the trace fails the test, including 'stop,' 'output a pulse', and 'datalog'.

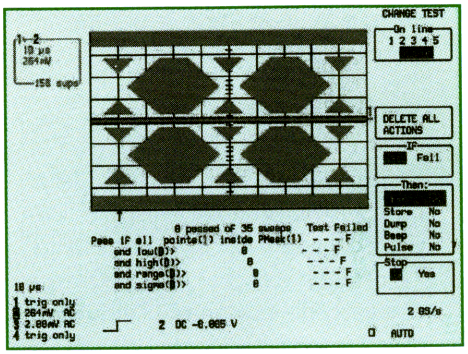
With the exclusive Finder Function, pulses, patterns or even random bit streams are easily isolated. MT packages take control of the Waverunner scope, displaying only relevant test menus.

PolyMask

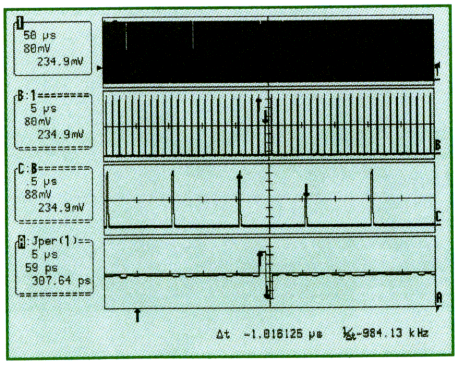
PolyMask is a powerful, general-purpose testing application that lets you view and test against complex masks. PolyMask locates and clearly depicts signal failures. In pass/fail testing, failures are highlighted with colored circles. Creating masks is greatly simplified with the MaskMaker utility, a simple program that runs on any PC with Windows. Masks can be used in either normal or X-Y display mode (useful for applications such as power measurement.)



Mask Testing and extinction ratio measurements of a 156 Megabit/s coaxial (STM1-E)



An Ethernet 100 Base-T mask created with the MaskMaker utility.



JitterTrack clearly shows timing variation as it tracks the signal cycle by cycle.

Windows Connectivity

Connect your scope to Windows-based ScopeExplorer using the Ethernet (option), GPIB or RS-232 interfaces. Click and drag files, or operate from the virtual front panel. Update your software via the web.

Windows Software to Enhance Your Productivity

ScopeExplorer and ActiveDSO are Windows (95, 98, 2000, or NT) PC-based connectivity tools that make it easy to interface your *Waverunner-2* scope with a PC via Ethernet, RS-232-C, or GPIB. It's easy to integrate scope data with Windows applications, as well as to control the *Waverunner-2* scope from your PC.

ScopeExplorer

Annotate and print screen shots, drag and drop files, save and load scope setup panels, and run CustomDSO applications. Click on the print icon to send the file to the printer of your choice. Access files on storage media, including PC-Cards, hard drives, and diskettes inserted in a *Waverunner-2* scope.



All it takes is a PC with Windows and a GPIB, RS-232-C, or the Ethernet option.

ActiveDSO™

ActiveDSO is a LeCroy software utility for ActiveX control of LeCroy digital scopes.

Exchange *Waverunner-2* scope data with applications that support the ActiveX standard. Many applications (such as Excel, PowerPoint, Internet Explorer, Visual Basic, Visual C++ and Labview) allow users to incorporate ActiveX controls.

MaskMaker and DSO Filter

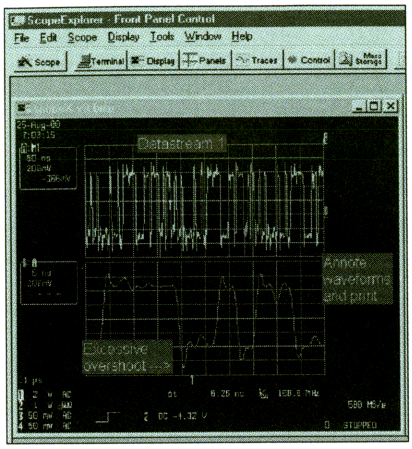
These easy-to-use Windows-based graphic utilities let you create and edit test masks and digital filters for use on *Waverunner-2* scopes. Use MaskMaker with the PolyMask tolerance mask-testing option. You can even create XY masks.

With the DSO-Filter PC utility and DFP (Digital Filter Package), you can specify a set of filter coefficients in an Excel spreadsheet and load them directly into the oscilloscope.

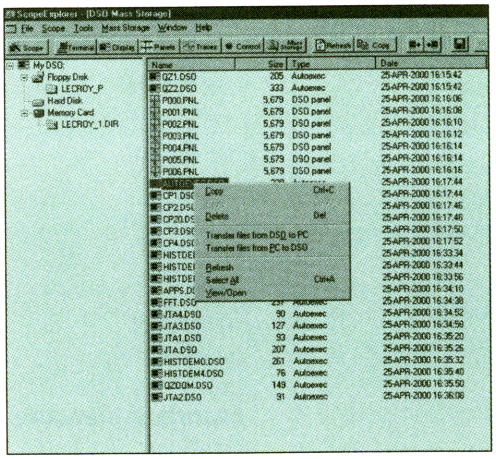
Waverunner-2 Series Selection Guide

	LT374	LT372	LT264	LT262
Bandwidth	500 MHz	500 MHz	350 MHz	350 MHz
Input Channels	4	2	4	2
Single-Shot Sample Rate				
1 Channel max.	4 GS/s	4 GS/s	1 GS/s	1 GS/s
2 Channels max.	4 GS/s	2 GS/s	1 GS/s	1 GS/s
3-4 Channels max.	2 GS/s	NA	1 GS/s	NA
Random interleaved Sampling (RIS)	50 GS/s for repetitive signals: 500 ps/div – 1 us/div			
Maximimum Acquisition Points/Ch	(1 Ch) / (2 Ch) / (3-4 Ch)			
Standard	500 k / 500 k / 250 k	500 k / 250 k / NA	100 k / 100 k / 100 k	100 k / 100 k/ NA
M – memory option	2 M / 2 M / 1 M	NA	1 M / 1 M / 1 M	NA
L – memory option	8 M / 8 M / 4 M	NA	NA	NA

**Waverunner Series scopes do not offer the wavepilot, quickzoom, OC ATP trigger option which are available for the Waverunner-2 series.*

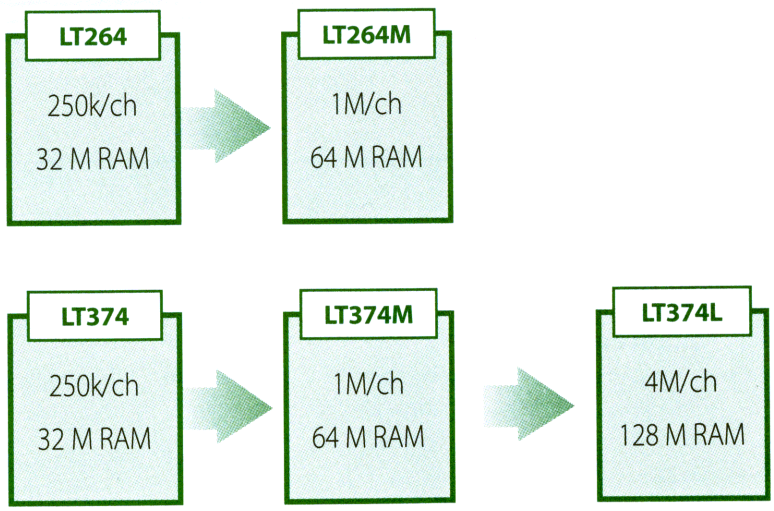


ScopeExplorer interactive front panel with familiar Windows PC operation.



ScopeExplorer provides access to the scope's storage media to view, edit, save, load, and run scope setup and Custom DSO applications.

Waverunner-2 Series Upgrade Guide



EMM – Extended Math and Measurements Software Option

Adds math and advanced measurements for general-purpose applications. Includes all standard math and measurement tools, plus extended tools.

Standard Math Tools

average (summed to 4000 sweeps)
difference
enhanced resolution (to 11 bits vertical)
envelope
FFT of 50 kpoint waveforms
floor
identity
negate
product
ratio
reciprocal (invert)
resample (deskew)
rescale (with units)
roof
sin x/x
sum

Extended Math Tools

absolute value
differentiate
exp (base e)
exp (base 10)
log (base e)
log (base 10)
integrate
square
square root
trend (datalog)

Standard Measure Tools

amplitude
area
base
cycle mean
cycle rms
cycles
data
delay
Δ delay
duty cycle
fall 90-10%
fall 80-20%
frequency
maximum
mean
median
minimum
+overshoot
-overshoot
peak-to-peak
period
phase
rise 10-90%
rise 20-80%
rms
top
width

Extended Measure Tools

cycle median
cycle standard deviation
Δ time @ level, % and volts
Δ time @ level from trigger
Δ time from clock to data + (setup time)
Δ time from clock to data - (hold time)
duration
fall @ level; % and volts
first point
last point
number of points
rise @level; % and volts
standard deviation

WAVA – WaveAnalyzer Software Option

- Enhancements to averaging and FFT capabilities
- Histogramming and trending of signal parameters
- Additional math functions

Includes all the standard math and measurement tools (see previous page) plus...

Extended Averaging

Summed, average of up to one million waveforms; Continuous average

Extended FFT

Fast Fourier Transform to one million points; FFT Average; Power Averaging, Power Density, Real, Real + Imaginary

Histograms

Graphical Analysis with Histograms and Histogram Analysis Parameters

Trending

Plot a parameter vs. time or vs. another parameter

Math Functions

Absolute Value, Derivative, Exp (base e), Exp (base 10), Integral, Log (base e), Log (base 10), Reciprocal (1/x), Square, Square Root

Parameter Measurements

cmedian Cyclic median; The average of base and top values over an integral number of cycles

csdev Cyclic standard deviation

Δc2d± Δ clock to data ± (setup and hold time)

Δt@lv The transition time between selected levels on a single trace or between two traces

first Indicates value of horizontal axis at left cursor

last Time from trigger to last (rightmost) cursor

median The average of base and top values

r@level Risetime between selected voltage levels

Points Number of points in the waveform between the cursors

t@level Time from trigger (t=0) to crossing at a level

f@level Falltime between selected voltage levels

dur The time between triggers in segment or other history modes

Waverunner-2 Specifications

Vertical System	LT374 / M / L	LT372	LT264/M	LT262
Input Channels	4	2	4	2
Analog Bandwidth @ 50 Ω (-3 dB)	500 MHz	500 MHz	350 MHZ	350 MHz
Hardware Bandwidth Limits	20 MHz or 200 MHz			
Input Impedance	50 Ω ± 1%; 10 MΩ /12 pF typical (using PP006 probe)			
Input Coupling	1 MΩ: AC, DC, GND; 50 Ω: DC, GND			
Maximum Input	50 Ω: 5 Vrms; 1 MΩ: 400 Vmax (peak AC ≤ 5 kHz + DC)			
Vertical Resolution	8 bits; up to 11 bits with enhanced resolution (ERES)			
Sensitivity (50 Ω or 1 MΩ)	2 mV – 10 V/div fully variable			
DC Gain Accuracy	± (1.5% + 0.5% of full scale)			
Offset Accuracy (50 Ω or 1 MΩ)	± (1.5% + 0.5% of full scale + 1 mV)			
Offset Range	2 mV – 99 mV/div: ±1 V 100 mV – 99 V/div: ±10 V 1 V – 10 V/div: ±100 V			
Isolation — Channel to Channel	>250:1 at same V/div settings			

Timebase System				
Timebases	Main and up to four independent zoom traces simultaneously			
Ranges	500 ps/div – 1000 s/div		1 ns/div – 1000 s/div	
Clock Accuracy	≤10 ppm			
Interpolator Resolution	5 ps			
External Clock Frequency	500 MHz maximum, 50 Ω, or 1 MΩ impedance			
Roll Mode – Operating Range	time/div 500 ms – 1000 s/div or sample rate <100 kS/s max			
External Timebase Clock	500 MHz maximum external sample clock input on front panel EXT BNC			

Acquisition System				
Single Shot Sample Rate				
1 Channel Max.	4 GS/s	4 GS/s	1 GS/s	1 GS/s
2 Channels Max.	4 GS/s	2 GS/s	1 GS/s	1 GS/s
3 – 4 Channels Max.	2 GS/s	NA	1 GS/s	NA
Maximum Acquisition Points/Ch				
1 Channel Max.	500k / 2M / 8M	500k	100k / 1 M	100k
2 Channels Max.	500k / 2M / 8M	250k	100k / 1 M	100k
3 – 4 Channels Max.	250k / 1M / 4M	NA	100k / 1 M	NA

Acquisition Modes	
Random Interleaved Sampling (RIS)	50 GS/s for repetitive signals: 500 ps/div – 1 µs/div
Single Shot	For transient and repetitive signals: 1 ns/div – 1000 s/div
Sequence	
LT262/264	2 – 400 segments
LT372/374	2 – 1 000 segments
Memory Option M or L	2 - 4 000 segments
Intersegment Time	50 µsec max.

Acquisition Processing	
Averaging	Summed averaging to 103 sweeps; continuous averaging with weighting range from 1:1 to 1:1023 (standard). Summed averaging up to 106 sweeps (optional with WAVA)
Enhanced Resolution (ERES)	From 8.5 to 11 bits vertical resolution
Envelope (Extrema)	Envelope, floor, roof for up to 106 sweep

Waverunner-2 Specifications (continued)

Triggering System

Modes: Normal, Auto, Single, and Stop

Sources: Any input channel, external, Ext/10 or line; slope, level, and coupling unique to each source (except line trigger)

Inactive channels usable as trigger inputs.

Slope: Positive, Negative, Window

- **Coupling modes:** DC, AC, HFREJ, LFREJ
- **AC Cutoff Frequency:** 7.5 Hz Typical
- **HFREJ, LFREJ:** 50 kHz typical
- **Pre-trigger delay:** 0 – 100% of horizontal time scale
- **Post-trigger delay:** 0 – 10 000 divisions
- **Hold-off by time or events:** Up to 20s or from 1 to 99 999 999 events
- **Internal trigger range:** ±5 div

Max trigger frequency: 500 MHz (350MHz on LT264, LT262)

- **External trigger input range:** ±0.5 (±5 V with Ext/10 selected)
- **Maximum ext. input @ 50 Ω:** ±5 V DC or 5Vrms
- **Maximum ext. input @ 1 MΩ:** 400 Vmax (DC + peak AC < 5 kHz)

Automatic Setup

Auto Setup: Automatically sets timebase, trigger, and sensitivity to display a wide range of repetitive signals

Vertical Find: Automatically sets the vertical sensitivity and offset for the selected channels to display a waveform with maximum dynamic range

Probes:

Model PP006: 10:1, 10 MΩ with auto-detect (one per channel)

Probe System: ProBus: Automatically detects and supports a wide variety of differential amplifiers; active, high-voltage, current, and differential probes

Scale Factors: Up to 12 automatically or manually selected

Color Waveform Display

Type: VGA color 8.4" flat-panel TFT-LCD

Resolution: VGA 640 x 480 pixels

Screen Saver: Display blanks after 10 minutes (when screen saver is "on")

Real Time Clock: Date, hours, minutes, and seconds displayed with waveform

Number of Traces: Display a maximum of eight traces. Simultaneously display channel, zoom, memory, and math traces.

Grid Styles: Single, Dual, Quad, Octal, XY, Single + XY, Dual + XY; Full Screen gives enlarged view of each style.

Intensity Controls: Separate intensity control for grids and waveforms

Waveform Styles: Sample dots joined or dots only — regular or bold sample point highlighting

Trace Overlap Display: Select opaque or transparent mode with automatic waveform overlap management.

Analog Persistence Display

Analog & Color-Graded Persistence: Variable saturation levels; stores each trace's persistence data in memory

Trace Selection: Activate Analog Persistence on a selected trace, top 2 traces, or all traces

Persistence Aging Time: Select from 500 ms to infinite

Trace Display: Opaque or transparent overlap

Sweeps Displayed: All accumulated or all accumulated with last trace highlighted

Zoom Expansion Traces

Display up to Four Zoom Traces

- **Vertical Zoom:** Up to 5X expansion, 50X with averaging
- **Horizontal Zoom:** Expand to 2 pts/div, magnify to 50,000X
- **Auto Scroll:** Automatically scan and display any zoom or math trace.

Rapid Signal Processing

Processor: Power PC

Processing Memory: Up to 128 Mbytes

Realtime Clock: Dates, hours, minutes, seconds, and time stamp trigger time to 1 ns resolution

Internal Waveform Memory

Waveform: M1, M2, M3, M4 (Store full-length waveforms with 16 bits/data point)

Zoom and Math: Four traces A, B, C, D with chained trace capability

Setup Storage

Front Panel and Instrument Status: Four non-volatile memories and floppy drive are standard. Hard drive and memory card are optional.

Interface

Remote Control: Full control of all front panel controls and internal functions via RS232C, GPIB, or Ethernet (optional)

RS-232-C: Asynchronous transfer rate of up to 115.2 kbaud

GPIB Port: Full control via IEEE – 488.2; configurable as talker/listener for computer control and data transfer

Ethernet (optional): 10 Base-T Ethernet interface

Floppy Drive: Internal, DOS-format, 3.5" high-density

PC Card Slot (optional): Supports memory and hard drive cards

External Monitor Port Standard: 15-pin D-Type VGA-compatible

Centronics Port: Parallel printer interface

Internal Graphics Printer (optional): Provides hard copy output in <10 seconds

Outputs

Calibrator Signal: 500 Hz – 1 MHz square wave or DC level; Select from -1.0 to +1.0 into 1 M ohm, output on front panel test point and ground lug.

Control Signals: Rear Panel, TTL level, BNC output; Choice of trigger ready, trigger out, pass/fail status. (output resistance 300Ω ± 10%)

Environmental and Safety

Operating Conditions

Temperature:
5 – 40 °C rated accuracy
0 – 45 °C operating
-20 – 60 °C non-operating

Humidity: 80% max RH, non-condensing up to 35 °C; Derates to 50% max RH, non-condensing at 45 °C

Altitude: 4 500 m (15 000 ft) max. up to 25 °C; Derates to 2 000 m (6 600 ft) at 45 °C

CE Approved

EMC: EMC Directive 89/336/EEC; EN 61326-1 Emissions and Immunity

Safety: Low Voltage Directive 73/23/EEC; EN 61010-1 Product Safety (Installation Category II, Pollution Degree 2)

UL and cUL approved:

UL Standard UL 3111-1
cUL Standard CSA C22.2 No. 1010-1

General

Auto Calibration: Ensures specified DC and timing accuracy is maintained for 1 year minimum

Auto Calibration time: < 500 ms

Power Requirements:
90 – 132 VAC at 45 - 440 Hz
180 - 250 VAC at 45 - 66 Hz
Automatic AC voltage selection
Power Consumption: 150 – 230 VA depending on model

Battery Backup: Front panel settings retained for two years minimum

Warranty and Calibration: Three years; calibration recommended yearly

Physical Dimensions

Dimensions (HWD): 210 mm x 350 mm x 300 mm; 8.3" x 13.8" x 11.8" (height excludes feet)

Weight: 18 lbs (8 kg)

Shipping Weight: 27 lbs (12 kg)

Math Tools (Standard)

Simultaneously perform up to four math (signal) processing functions; traces can be chained together to perform math on math.

average (sum to 4 000 sweeps)
average (continuous weighted)
difference
enhanced resoltuion (to 11 bits)
envelope
FFT of 50 kpoint waveforms
floor
identity
negate
product
ratio
reciprocal (invert)
resample (deskew)
rescale (with units)
roof
sin x/x
sum

Measure Tools (Standard)

Automated Measurements: Display any five parameters together with their average, high, low, and standard deviations.

amplitude	fall 90-10%	period
area	fall 80-20%	phase
base	frequency	rise 10-90%
cycle mean	maximum	rise 20-80%
cycle rms	mean	rms
cycles	minimum	sdev
delay	+overshoot	top
Δ delay	–overshoot	width
duty cycle	peak-to-peak	xamn
		xamx

Pass/Fail

Test any five parameters against selectable thresholds. Limit testing is performed using masks created on the scope or PC. Set up a pass or fail condition to initiate actions such as hard copy output, saving waveform to memory, GPIB SRQ, or pulse out.

Options

Extended Math and Measurement: Adds math and advanced measurements for all general purpose applications. Includes all standard math and measurement tools, plus the following tools:

Extended Math Tools

absolute value	integrate
differentiate	square
exp (base e)	square root
exp (base 10)	trend (datalog)
log (base e)	Histogram (200 events)
log (base(10)	

Cursor Measurements

Type	Symbol	From	To
Relative time		First point on waveform	Any other point on waveform
Relative voltage		Select voltage level	Any other voltage level
Absolute time		Time and voltage	Ground and trigger relative to
Absolute voltage		Voltage	Ground

Waverunner-2 Specifications (continued)

Extended Measure Tools

cycle median
cycle std. deviatio
Δ time @ level; % and volt
Δ time @ level from trigger
Δ time from clock to data + (setup time)
Δ time from clock to data - (hold time
fall @ level; % and volts
first point
last point
number of points
median
rise @ level; % and volts
std. deviation
duration

WaveAnalyzer

Includes the Extended Math and Measure Tools as well as expanded capabilities for performing FFTs, averaging, histograms, and histogram parameters.

WaveAnalyzer Tools (Standard)

Histogram up to 2 billion events.
Analyze with 18 histogram parameters
Summed averaging to 1 million sweeps
WaveAnalyzer FFT capability expands the basic FFT to include:
FFT power averaging
FFT power density, real, and imaginary
FFT on all acquisition points
With WaveAnalyzer FFT you get maximum resolution at wide frequency spans

Other Application Solutions

Jitter and Timing Analysis (JTA)
Digital Filter Package (DFP)
PowerMeasure Analysis (PMA1)
Communications Mask Testing (MT01/MT02)
Polymask Mask Testing (PMSK)
Advanced Optical Recording Measurements (AORM) for LT37X scopes
Disk Drive Measurements (DDM)
PRML Analysis (PRML)

Free Software Utilities

ScopeExplorer: Easy to use utility that provides a simple but powerful way to control your scope remotely over RS232C, GPIB, or Ethernet.

ActiveDSO: ActiveX controls for flexible windows applications programming with remote control.

MaskMaker: Create a tolerance test mask offline with this graphic tool.

DSO Filter: Specify a set of filter coefficients and load them into the scope.

Basic Triggers

Edge/Slope/Window/Line: Triggers when signal meets slope and level condition

SMART Triggers

State or Edge Qualified: Triggers on any input source only if a defined state or edge occurred on another input source. Delay between sources is selectable by time or events.

Dropout: Trigger if signal drops out for longer than selected time between 25 ns and 20 s.

Pattern: Logic combination of 5 inputs (on 2 channel models); Each source can be high, low, or don't care. Trigger entering or exiting the pattern

TV-Video: Triggers selectable fields (1, 2, 4, or 8) for NTSC, PAL SECAM, or nonstandard video (up to 1500 lines)

SMART Triggers with Exclusion Technology

Signal or Pattern Width: Triggers on glitches or on pulse widths selectable from <2.5 ns to 20 s or on intermittent faults.

Signal or Pattern Interval: Triggers on intervals selectable between 10 ns and 20 s.

Slew Rate*: Trigger on edge rates; select limits for dV, dt, and slope. Select edge limits between 2.5 ns and 20 s.

Runt*: Positive or negative runts defined by two voltage limits and two time limits. Select between 2.5ns and 20 ns.

Hard Copy

Print Screen is activated by a front-panel button or remote control. Store screen image files or print to external printers including network printers and directories. Network printing and file access requires the LAN10BT Ethernet option.

Supported Printers

B/W: LaserJet, DeskJet, Epson
An optional, internal high-resolution graphics printer is also available for screen dumps; stripchart output formats capable of up to 200 cm/div.

Color: DeskJet 550C, Epson Stylus, Canon 200/600/800 series, HP7470 and HP7550

Hard copy Formats: TIFF b/w, TIFF color, BMP color, BMP compressed, and HPGL

Waveform Output

Store Waveforms to floppy disk or optional PC-Card Hard Drives and memory cards.

Save any trace you choose and select Auto-Store to automatically store the waveform after each trigger.

Output Formats: The ASCII waveform output is compatible with spreadsheets, MATLAB, Mathcad, etc. Binary output is also available for reduced file size.

Documentation

Included with Waverunner-2:
Oscilloscopes:
Operators Manual — hard copy
Remote Programming Manual — hard copy
CD-ROM — PDF formatted manuals plus software utilities including ScopeExplorer, ActiveDSO, MaskMaker, DSO-Filter, and DSONet Print Gateway

** optional Advanced Trigger Package*

Ordering Information

Waverunner-2 Digital Oscilloscopes	Product Code
500 MHz, 2 GS/s, 250 kpts/ch, 4 Channel Color	LT374
500 MHz, 2 GS/s, 250 kpts/ch, 2 Channel Color	LT372
350 MHz, 1 GS/s, 100 kpts/ch, 4 Channel Color	LT264
350 MHz, 1 GS/s, 100 kpts/ch, 2 Channel Color	LT262
Included with Standard Configuration	
10:1 10 MΩ Passive Probe (1 per channel)	PP006
Operator's Manual, Quick Reference Guide, CD-ROM	WR2-OMCD-E with OM/RCM PDF manuals, and utility software
Operator's Manual	WR2-OM-E
Remote Control Manual	WR2-RCM-E
Floppy Disk Drive	
GPIB, RS-232-C, Centronics Parallel Port, VGA Video Output Port	
Protective Front Cover	
Performance Certificate	
Three-Year Warranty	

Memory Options	LT264	LT374
M: 1 Mpts/ch	•	•
L: 4 Mpts/ch	N/A	•

Hardware Options	
Internal Graphics Printer	GP02
10 Base-T Ethernet LAN option	LAN10BT
PC Card Slot	PCSLOT
PC Card Slot including 1 hard drive card and 1 memory card	PCMEDIA
Software Options	
Wave Analyzer Analysis Package	WAVA
Jitter Analysis and Wave Analyzer	JTWA
Extended Math and Measurement Package	EMM
ITU G.703 Fully Automated Mask Tester*	MT01
ANSI T1.102 Fully Automated Mask Tester*	MT02
Jitter and Timing Analysis Package	JTA
Digital Filter Package	DFP
Disk Drive Measurements	DDM
Supplementary Disk Drive Measurements	PRML
Advanced Optical Recording Measurements**	AORM
Power Measure Analysis Software	PMA1
Advanced Trigger Package	ATP
Selected Accessories	
1 GHz Active probe	HFP 1000
Differential Probe	ADP300 series
Current Probe	CP and AP series
Differential Amplifiers	DA1800 series
50Ω to 75Ω adapter	PP090
Oscilloscope Cart	OC-RUNNER, OC-PRO
Graphic Printer Paper/10 Rolls	GPR10
Service and Extended Warranties	
US NIST Standard Calibration	CCNIST
US Military Standard Calibration	CCMIL
Swiss OFMET Standard Calibration	CCOFMET
Five-Year Warranty at time of scope purchase	W5
Five-Year Warranty and NIST Calibration at time of scope purchase	T5

** Test Masks available are dependent upon oscilloscope bandwidth.*
*** optional on LT37X series*

Waverunner™ Series Color Oscilloscopes

Catch the fresh wave of thinking in oscilloscope design – the LeCroy Waverunner. Unlike any other scope in its class, it puts complete functionality with maximum power on your desk or workbench. And all of this capability is available in one remarkably easy-to-use format. From troubleshooting to timing analysis to production testing, the LeCroy Waverunner series is uniquely qualified to meet your requirements.

The *Waverunner* oscilloscopes provide all you need to quickly view, measure, and evaluate your signals – accurately and reliably:

- 200-500 MHz bandwidth
- Up to 1 GS/s single-shot sample rate and 25 GS/s for repetitive signals
- Up to one million data points to view signals with high resolution over longer time intervals.

Its powerful, integrated processors provide rapid response. Turn a knob or press a button– *Waverunner* scopes respond instantly.

Analog Persistence for a Fresh View

This affordable new class of scopes brings you the power of LeCroy Analog Persistence. All it takes is one touch of the green button to get an analog-like view of your waveforms and explore the full depth of signal information. Then the 8.4" color display lets you clearly see the information you might have missed.

Easy to Use

The *Waverunner* series is designed to quickly get you up and running. Its color-coded front panel and simple menu system are quick to understand, so your focus is on the work, not the tool. Common tasks are automatic. Navigation is logical and intuitive. You'll quickly master its powerful operations.

The Right Price

The *Waverunner* scope raises the bar when it comes to value – you get more for your money than with any other scope in this class. And because *Waverunner* can be upgraded, you can extend its life to meet future needs.

Increase Your Productivity

Expand the vertical resolution, view the spectrum of a signal with an FFT, average to reduce noise, and more. Two optional measurement packages give you additional capabilities to datalog, integrate, and more. LeCroy's signal diagnostic and trouble-shooting tools provide a complete solution for jitter and timing analysis and power measurement.

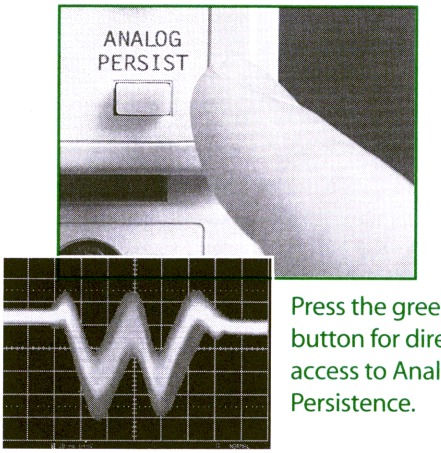
Getting Started

Waverunner scopes give you three quick ways to find the information you need:

- Quick Reference Guide
- In-depth Operator's Manual organized both for first-time and experienced users
- HTML Manual on CD-ROM

See the Third Dimension

Scopes are great tools that help technicians and engineers understand the operation of electrical and electronic systems. With Analog Persistence, you see a third dimension. Are you concerned with intermittent runts or timing problems? Just press the green button and see infrequent signal anomalies such as slow edges, pulse width variations, runts, and glitches. The intensity and color variation indicate the relative rate, such as a clock's period varying once every 100 cycles. Analog Persistence gives you insight into what is happening in your system.



Press the green button for direct access to Analog Persistence.

SMART Trigger

Another touch of a button expands your ability to lock onto a problem signal. The SMART Trigger function uses an icon display and menu control, so you can set trigger conditions like timing intervals, edges, and TV formats. *Waverunner* oscilloscopes can trigger on hard-to-find glitches down to 2 ns, catch signal dropouts, or trigger when the signal falls within a window. You can even set up an exclusion trigger to find events that differ from the nominal signal.

Measure on the Screen

Cursor measurements let you dial into a specific section of your waveform to measure the peak voltage or the time between signal features, such as glitches

on two different channels. The user interface and large display let you quickly perform basic measurements. Cursors work in XY display mode so you can read the angle in degrees and the radius in volts for CDMA signals.

Many Ways to Acquire Your Signal

Waverunner scopes capture and display waveforms in several ways. Capturing and viewing the signal is as easy as 1-2-3. The scope can also record signals in a segmented memory to take snapshots of a fast-changing event. For slower signals, Roll Mode uses the high-resolution display to give a strip chart view of up to four channels. These capabilities make the scope unique for a variety of applications, from electronic devices and sensors to electro-mechanical systems.

The Scope with Solutions

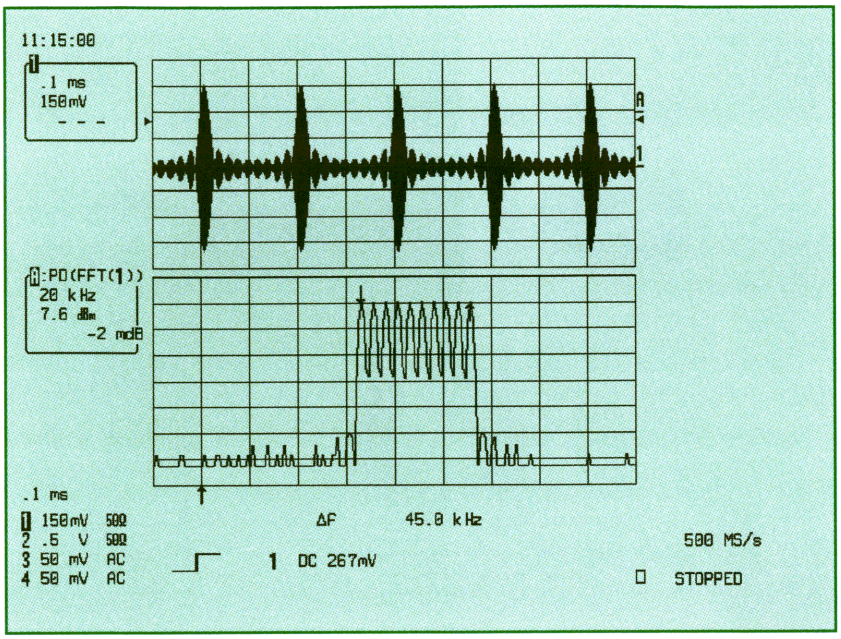
The *Waverunner* series provides the best set of troubleshooting and analysis tools available. It gives you maximum power to measure and analyze in the time domain and in the frequency domain with FFTs.

Measure & Math Tools

Choose from 25 automatic measurements that update with your waveform – live, on-screen. Turn on statistics for the parameters average and standard deviation to fully characterize or troubleshoot your circuit. Math Tools let you average (1000 sweeps) to reduce random noise or increase vertical resolution (to 11 bits). Select an optional analysis package for even more power using the same, easy-to-navigate menu system.

Spectrum Analysis with FFTs

View the FFT of a 50 kpoint waveform while the signal trace updates on the screen. Simultaneously see both the time and frequency domains, even on transient signals. Use cursors to measure the frequency of peaks in the FFT. Perform Pass/Fail testing of the spectra to a tolerance mask.



See transient signals with the time waveform and the frequency spectrum in different colors.

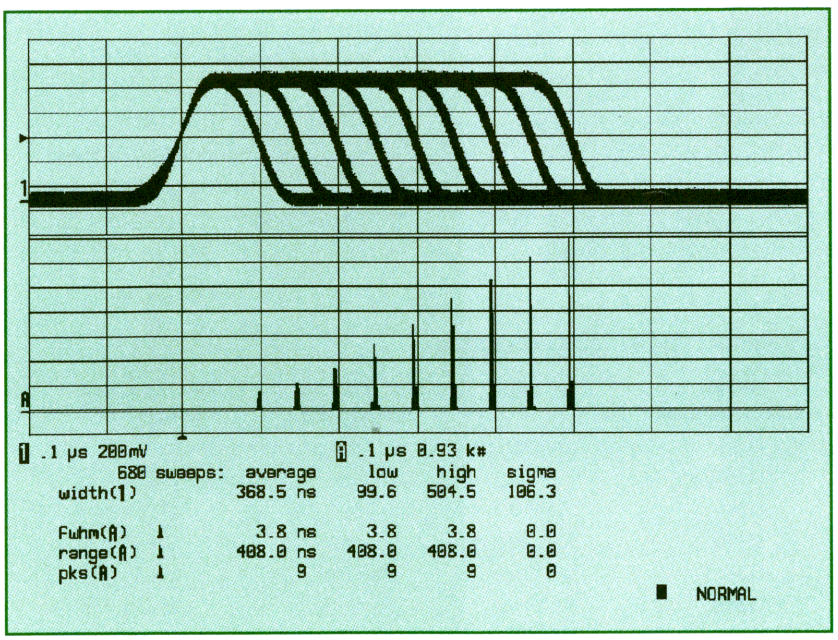
Extended Math & Measurements

This option gives you over 40 measurement parameters and additional math tools to increase your productivity (integrate, differentiate, square, log). You can even datalog measurements with the trend function.

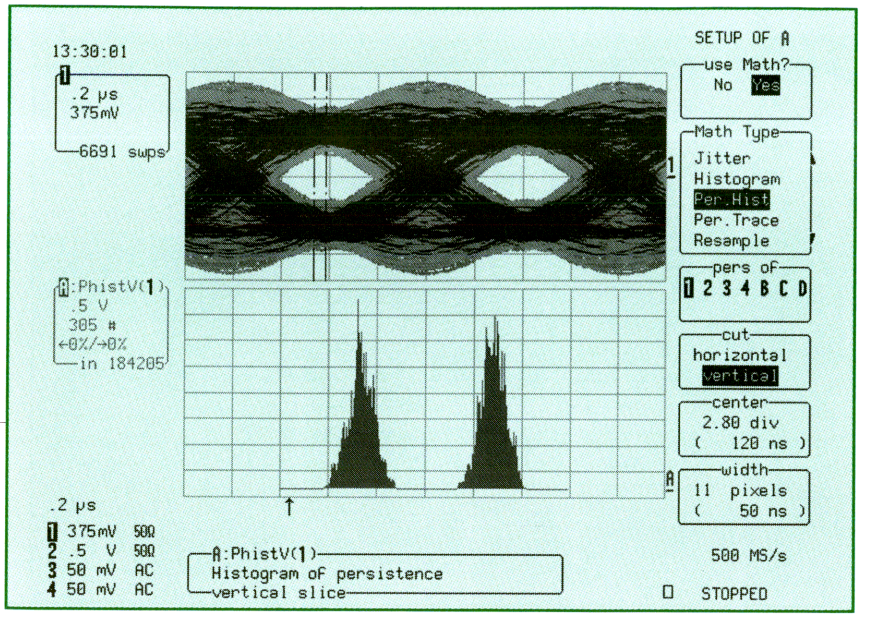
Waverunner lets you perform math-on-math. Deskew the channels, measure current and voltage, multiply for power, then integrate for energy.

The Comprehensive Wave Analyzer

The WaveAnalyzer option is the ultimate tool for characterization and



Automatic measurements and histograms help characterize circuits.



The JTA persistence histogram shows the variation of the waveform within amplitude or time slices of an eye diagram.

troubleshooting in time, frequency, and statistical domains for design and research applications. Waveform averaging increases to one million sweeps and FFT spectrum analysis to one million points. Histogram analysis lets you view and measure statistical variations.

Powerful Applications

The *Waverunner* oscilloscope acquires signals with high fidelity and integrity. A variety of measurement and analysis tools, as well as probes and accessories, are available. And it's easy to upgrade.

Whether you are troubleshooting, debugging, characterizing circuits and systems, or testing in production, *Waverunner* scopes get the job done. Standard features include Analog Persistence, SMART Trigger, FFTs, automatic measurements, waveform math, and Pass/Fail test.

Use the standard passive probes for 500 MHz bandwidth at the probe tip. Choose an active probe to minimize loading on your circuit, or for differential measurements, select the active 500 MHz differential probe. ProBus automatically controls and configures your LeCroy probes.

A Time Analyzer in a Scope

Jitter and Timing Analysis (JTA) with second-generation persistence technology (patent pending) enables precise measurements with enhanced timing resolution.

JTA lets you display the jitter function as well as its source signal. Both are perfectly time-correlated, so anomalies can be directly observed on the source trace. Use the JitterTrack™ feature to plot cycle-to-cycle jitter, interval error, period, pulse width, or duty cycle versus time. Use persistence trace histograms to measure jitter and noise on eye diagrams.

World-Class Power Measurement system

LeCroy's PowerMeasure System provides a complete solution that makes easy work of even your most difficult power-related measurements. Perform power device, modulation, and line power analyses quickly and easily.

The PowerMeasure Analysis Software's dedicated menus and shortcuts let you quickly and easily set up the scope to acquire, view, and analyze power signals. A "Setup Helper" is built in to support users step-by-step, ensuring correct and accurate measurements.

Telecom Mask Test Package

This package is designed for manufacturing, type approval, and field testing. The exclusive Finder function makes it easy to isolate pulses or patterns, even from random-bit streams. Mask alignment is totally automatic and cleanly isolates the necessary pattern in a PRBS data stream, saving valuable test time. It's easy to use; the Mask Tester takes control of the *Waverunner* oscilloscope, displaying only the relevant test menus.

Waverunner Series Selection Guide

LeCroy Model Number	Bandwidth	Max Transient Sample Rate	Max Repetitive Sample Rate	Number of Channels	Memory per Channel
LT364	500 MHz	1 GS/s	25 GS/s	4	250 k (500k on 2 channels)
LT364L	500 MHz	1 GS/s	25 GS/s	4	1 M (2 M on 2 channels)
LT344	500 MHz	500 MS/s	25 GS/s	4	250 k
LT344L	500 MHz	500 MS/s	25 GS/s	4	1 M
LT342	500 MHz	500 MS/s	25 GS/s	2	250 k
LT342L	500 MHz	500 MS/s	25 GS/s	2	1 M
LT322	500 MHz	200 MS/s	10 GS/s	2	100 k
LT224	200 MHz	200 MS/s	10 GS/s	4	100 k

Waverunner Series Selection Guide

	LT364	LT342	LT344	LT322	LT224
Bandwidth	500 MHz	500 MHz	500 MHz	500 MHz	200 MHz
Input Channels	4	2	4	2	4
Single-Shot Sample Rate					
1 Channel max.	1 GS/s	500 MS/s	500 MS/s	200 MS/s	200 MS/s
2 Channels max.	1 GS/s	500 MS/s	500 MS/s	200 MS/s	200 MS/s
3-4 Channels max.	500 MS/s	NA	500 MS/s	NA	200 MS/s
Max Repetitive Sample Rate	25 GS/s	25 GS/s	25 GS/s	10 GS/s	10 GS/s
Maximum Acquisition Points/Ch	1-2 ch / 3-4 ch	1-2 ch / 3-4 ch	1-2 ch / 3-4 ch	1-2 ch / 3-4 ch	1-2 ch / 3-4 ch
Standard Memory	500 k / 250 k	250 k / NA	250 k / 250 k	100 k/ NA	100 k / 100 k
L – Memory Option	2 M / 1 M	1 M / 1 M	1 M / 1 M	NA	NA

**Waverunner Series scopes do not offer the Wavepilot, Quickzoom, or ATP trigger option which are available in the Waverunner-2 series.*

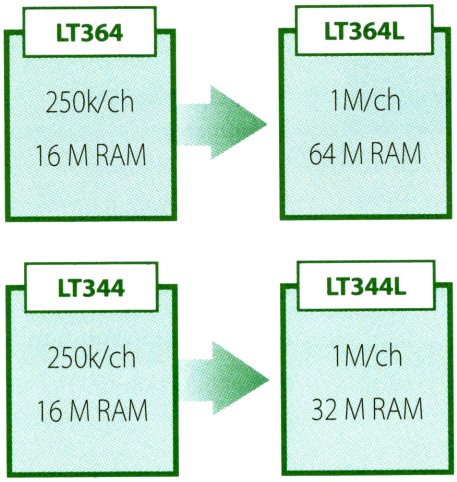
Twisted-pair and 75 Ω lines are easy to interface to *Waverunner* via intelligent ProBus adapters, providing line termination, accurate signal reproduction, and low distortion.

Software to Enhance Productivity

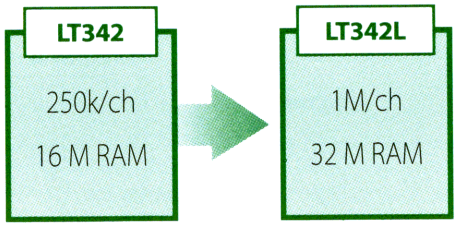
ScopeExplorer and ActiveDSO are Microsoft Windows (95, 98, or NT) PC-based connectivity tools that make it easy to interface your *Waverunner* scope with a PC via RS-232-C or GPIB. It's easy to integrate scope data with Windows applications, as well as to control the scope from your PC. Both tools and the interfaces are standard.

Waverunner Series Upgrade Guide

LT364 and LT344 Series – 500 MHz 4 Channel DSOs



LT342 Series – 500 MHz; 2 Channel DSOs



LT364, LT364L, LT342, LT342L LT344, LT344L, LT322 & LT224

Main Features

- **200-500 MHz bandwidths**
- **8.4" color TFT display**
- **Up to 1 GS/s single-shot sample rate**
- **Up to two million points of acquisition memory**
- **SMART Trigger**
- **Analog Persistence**
- **Floppy disk, RS-232, and GPIB all standard**

Acquisition System

Bandwidth (-3dB): 500 MHz @ 50 Ω (200 MHz for model LT224) and at probe tip with PP006; select bandwidth limit (25 or 200 MHz) independently by channel.

Input Impedance: 50 Ω ±1.0%; 1 MΩ // 12 pF typical

Input Coupling: 1 MΩ: AC, DC, GND; 50 Ω: DC, GND

Max Input: 50 Ω: 5 Vrms; 1 MΩ: 400 Vmax (peak AC <-5kHz + DC)

Single-Shot Sampling Rate: 500 MS/s max per channel (200 MS/s for models LT322 and LT224); 1 GS/s when using 2 channels of model LT364 or LT364L

Acquisition Memory: 250 kpts/Ch, 1 Mpoint/Ch on L models (LT364 and LT364L have 2 Mpoints/ch when using 2 inputs)

Vertical Resolution: 8 bits

Sensitivity: 2 mV - 6 V/div fully variable

Gain Accuracy: ±(1.5% + 0.5% FS)

Offset Range:
2 mV–50 mV/div: ±1 V
100 mV–500 mV/div: ±10 V
1 V–10 V/div: ±100 V

Offset Accuracy: ±(1.5% + 0.5% FS + 1 mV)

Timebase System

Timebases: Main and up to four zoom traces simultaneously

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

Clock Accuracy: ≤10 ppm

Interpolator Resolution: 5 ps

External Clock: ≤500 MHz, 50 Ω, or 1 MΩ impedance (≤200 MHz on LT322, LT224)

Triggering System

Modes: Normal, Auto, Single, and Stop

Sources: Any input channel, external, Ext/10 or line; slope, level, and coupling are unique to each source (only slope for line trigger).

Coupling Modes: DC, AC, HF, HFREJ, LFREJ (reject frequency 50 kHz typ)

Pre-Trigger Recording: 0–100% of horizontal time scale

Post-Trigger Delay: 0–10,000 divisions

Holdoff by Time or Events: Up to 20 s or from 1 to 99,999,999 events

Internal Trigger Range: ±5 div

Maximum Trigger Frequency: Up to 500 MHz with HF coupling

External Trigger Input: ±.5 V, ±5 V with Ext/10; max input same as input channels

Auto Setup

Automatically sets timebase, trigger, and sensitivity to display a wide range of repetitive signals; vertical find automatically sets sensitivity for the selected input signal.

Probes

Model PP006: 10:1, 10 MΩ with autodetect (one per channel)

Probe System: ProBus Intelligent Probe System supports differential amplifiers and active, high-voltage, current, and differential probes.

Waverunner Triggers

Name	Description	Edge or SMART Trigger
Edge/Slope/Window/Line	Triggers when signal meets slope and level condition.	Edge
Signal pulse width	Triggers on glitches down to 2 ns. Width selectable from <2.5 ns to 20 s or on intermittent faults.	SMART
Signal interval	Triggers on intervals selectable between 10 ns and 20 s.	SMART
State or edge qualified	Triggers on input only after a defined state or edge occurred on another channel. Delay between sources is selectable by time or events.	SMART
Dropout	Triggers if the input signal drops out for longer than selected time between 25 ns and 20 s.	SMART
TV	Triggers on line (up to 1500) in odd or even fields for PAL, NTSC, or nonstandard video.	SMART

Acquisition Systems

	LT364/LT364L	LT344/LT344L	LT342/LT342L	LT322	LT224
Bandwidth	500 MHz	500 MHz	500 MHz	500 MHz	500 MHz 200 MHz
Single Shot Sample Rate	500 MS/s-1 GS/s	500 MS/s	500 MS/s	200 MS/s	200 MS/s
Repetitive Sample Rate	25 GS/s	25 GS/s	25 GS/s	10 GS/s	10 GS/s
Acquisition Memory	250 kpts/1 Mpoint	250 kpts/1 Mpoint	250 kpts/1 Mpoint	100 kpts	100 kpts
Sequential Acquisition Memory	2-1000/2-4000	2-1000/2-4000	2-1000/2-4000	2-400	2-400
Single Shot Time Base Setting	10 ns/div-1000 s/div	10 ns/div-1000 s/div	10 ns/div-1000 s/div	20 ns/div-1000 s/div	20 ns/div-1000 s/div
Repetitive Time Base Setting	1 ns/div-5 µs/div	1 ns/div-5 µs/div	1 ns/div-5 µs/div	1 ns/div-10 µs/div	1 ns/div-10 µs/div
Bandwidth Limit Selections	25 or 200 MHz	25 or 200 MHz	25 or 200 MHz	25 or 200 MHz	25 MHz

Color Waveform Display

Type: Color 8.4" flat panel TFT-LCD with VGA output

Screen Saver: Display blanks after 10 minutes.

Real Time Clock: Date, hours, minutes, and seconds displayed with waveform

Number of Traces: Maximum eight on LT344, six on LT342; simultaneously display channel, zoom, memory, and math traces

Grid Styles: Single, Dual, Quad, Octal, XY, Single+XY, Dual+XY; Full Screen gives enlarged view of each style.

Waveform Styles: Sample dots joined or dots only – regular or bold

Analog Persistence Display

Analog and Color-Graded Persistence: Variable saturation levels; stores each trace's persistence data in memory

Trace Display: Opaque or transparent overlap

Zoom Expansion Traces

Style: Display up to four zoom traces

Vertical Zoom: Up to 5x expansion, 50x with averaging

Horizontal Zoom: Expand to 2 pts/div, magnify to 50,000x

Auto Scroll: Automatically scan and display a captured signal

Rapid Signal Processing

Processor: 96 MHz PowerPC

Internal Waveform Memory

Waveform: M1, M2, M3, M4*

Zoom and Math: A, B, C, D*

**Store full-length waveforms with 16 bits/data point.*

Setup Storage

For Front Panel and Instrument Status: Four non-volatile memories and floppy drive are standard. Hard drive and memory card are optional.

Math Tools

Simultaneously perform up to four math processing functions; traces can be chained together to perform math on math.

Standard Math Tools:

average (summed to 1000 sweeps)
difference
enhanced resolution (to 11 bits vertical)
FFT of 50 kpoint waveforms
identity
product
resample (deskew)
rescale (with units)
sin x/x
sum

Measure Tools

Automated Measurements: Display any five parameters together with their average, high, low, and standard deviations.

Standard Measure Tools:

amplitude
area
base
cycle mean
cycle rms
cycles
delay
Δ delay
duty cycle
fall
fall 80-20
frequency
maximum
mean
minimum
rms
+overshoot
-overshoot
peak-to-peak
period
phase
rise
rise 20-80
top

Cursor Measurements

Type	Symbol	From	To
Relative time		first point on waveform	any other point on waveform
Relative voltage		select voltage level	any other voltage level
Absolute time		time and voltage relative to	trigger and ground
Absolute voltage		voltage	ground

Pass/Fail: Test any five parameters against selectable thresholds. Limit testing is performed using masks created on the scope or on a PC. Setup a pass or fail condition to initiate actions such as hardcopy output, save waveform to memory, GPIB SRQ, or pulse out.

Extended Math and Measurements Option

Adds math and advanced measurements for general purpose applications. Includes all standard math and measurement tools, plus:

absolute value
differentiate
exp (base e)
exp (base 10)
log (base e)
log (base 10)
integrate
reciprocal (invert)
square
square root
trend (datalog)
cycle median
cycle std. deviation
Δ time @ level % and volts
Δ time @ level from trigger
Δ time from clock to data + and -
duration
fall @ level; % and volts
first point
last point
median
number of points
rise @ level; % and volts
std. deviation

WaveAnalyzer

Includes the Extended Math and Measure Tools as well as expanded capabilities for performing FFTs, averaging, histograms, and histogram parameters.

WaveAnalyzer Tools:

Histograms with 18 histogram parameters
Summed averaging to 1 million sweeps
Continuous weighted averaging
FFT (up to 1 Mpoint waveforms)
FFT power averaging
FFT power density, real, and imaginary

Other Application Solutions

Jitter and Timing Analysis
PowerMeasure Analysis

Waverunner Ordering Information

Digital Oscilloscopes		Product Code
Four-Channel Color, 500 MHz, 500 MS/s, 250 kpts/4 ch	1 GS/s, 500kpts/2ch	LT364
Four-Channel Color, 500 MHz, 500 MS/s, 1 Mpts/4 ch	1 GS/s, 2Mpts/2ch	LT364L
Two-Channel Color, 500 MHz, 500 MS/s, 250 kpts/ch		LT342
Two-Channel Color, 500 MHz, 500 MS/s, 1 Mpts/ch		LT342L
Four-Channel Color, 500 MHz, 500 MS/s, 250 kpts/ch		LT344
Four-Channel Color, 500 MHz, 500 MS/s, 1 Mpts/ch		LT344L
Two-Channel Color, 500 MHz, 200 MS/s, 100 kpts/ch		LT322
Four-Channel Color, 200 MHz, 200 MS/s, 100 kpts/ch		LT224
Included with Standard Configuration		
10:1 10 MΩ Passive Probe (1 per channel)		PP006
Operator's Manual, CD-ROM with OM/RCM, Quick Reference Guide		LT34X-OPDOCS-E
Remote Control Manual		LT34X-RCM
Math Analysis with FFT		
Floppy Disk Drive		
GPIB, RS-232-C, Centronics Interfaces and VGA Output Port		
Performance Certificate		
Three-Year Warranty		
Selected Probes & Accessories*		
50 MHz/30 amp (50 amp peak) Current Probe		AP015
120 kHz/150 amp Current Probe		AP011
10 MHz Differential Amplifiers		DA1820A/DA1822A
100 MHz Differential Amplifiers		DA1850A/DA1855A
250 MHz, 100:1 or 10:1 Selectable, Passive Differential Probe Pair		DXC100A
1 GHz 10:1 FET Probe with SMD Kit		AP020
DC-500 MHz Active Differential Probe		AP033
ProBus 75 to 50 Ω Adapter		PP090
Graphics Printer Paper/10 rolls		GPR10

(continued on next page)

* The CP series of current probes and ADP series of active differential probes are also recommended for use with Waverunner oscilloscopes.

Interface

Remote Control: Full control via GPIB and RS-232-C

Floppy Drive: Internal, DOS-format, 3.5" high-density

PC Card Slot (optional): Supports memory and hard drive cards.

External Monitor Port: 15-pin D-Type
VGA-compatible

Centronics Port: Parallel printer interface

Internal Graphics Printer (optional): Provides hardcopy output in <10 seconds.

Outputs

Calibrator signal: 500 Hz - 1 MHz square wave, -1.0 to +1.0, test point and ground lug on front panel

Control signals: Choice of trigger ready, trigger out, or pass/fail status; TTL levels into 1 MΩ at rear panel BNC (output resistance 300 Ω ±10%)

General

Operating Conditions: Temperature 5 - 40° C; humidity 80% non-condensing at 40° C; altitude ≤2,000 meters

Shock and Vibration: Conforms to MIL-PRF-28800P; Class C

Power Requirements: 90 - 132 V AC and 180 - 250 V AC; 45 - 66 Hz; maximum power dissipation: 150 VA–230 VA, depending on model

Certifications: CE, UL and cUL

Dimensions (HWD): 210 mm x 350 mm x 300 mm; 8.3" x 13.8" x 11.8" (height excludes feet)

Weight: 8 kg; 18 lbs

Warranty and Calibration: Three years; calibration recommended yearly

CE

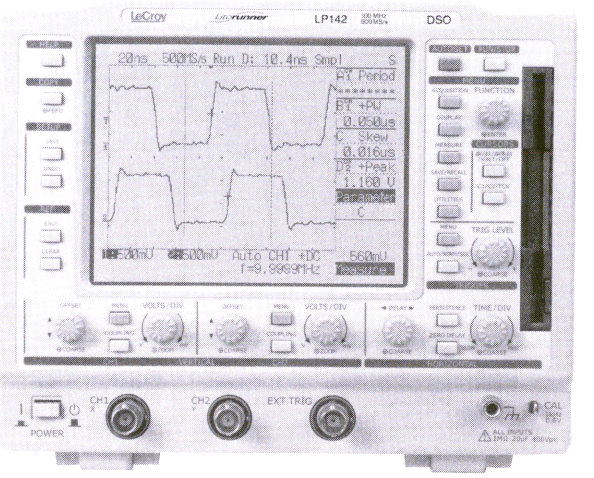
Waverunner Ordering Information (continued from previous page)

	Product Code
Applications Packages	
Extended Math and Measurement Package	EMM
WaveAnalyzer Package including Histograms	WAVA
Jitter and Timing Analysis Package	JTA
Disk Drive Measurements (includes Parameter Analysis Option WP03)	DDM
Supplementary Disk Drive Measurements	PRML
PowerMeasure Analysis Software	PMA1
Telecom Mask Tester and Adapters for ITU G.703	MT01
Telecom Mask Tester and Adapters for ANSI T1.102	MT02
Telecom Mask Tester and Adapters for ITU G.703 and ANSI T1.102	MT01/02
Selected Hardware Options	
Internal Graphics Printer	GP02
PC Card Slot with HD02 and MC04	PCMEDIA
PC Card Slot	PCSLOT
PC Card Hard Disk (520 Mbytes)	HD02
512 kbytes SRAM Memory Card	MC04
64 Mbytes System Memory	64MBSM
Manuals	
Service Manual for LT34X Series	LT34X-SM
Service Options	
Swiss OFMET Standard	CCOFMET
US NIST Standard	CCNIST
US Military Standard	CCMIL
Five-Year Warranty	W5
Five-Year Warranty & NIST Calibration	T5

Literunner™ Digital Oscilloscopes

Main Features

- **Compact and Portable: At 6.6 lbs (3 kg), this compact scope is easy to carry and fits very easily onto crowded workbenches.**
- **High-speed sampling rate and long memory: Operates at 500 MS/s sampling rate with 100 MHz analog bandwidth. Each channel has a long 100 kpoints acquisition memory.**
- **High accuracy: Vertical accuracy is within 2% and horizontal accuracy is 50 ppm (0.005%).**
- **Cursor measurements: Two cursors (two vertical or two horizontal) let you measure voltage difference (ΔV), time difference (Δt), frequency (1/Δt), and V at t for a specific waveform.**
- **Auto copy: Display or waveform data can be output automatically to a specified device (built-in printer, ATA card, or floppy disk).**
- **Simple to use, yet powerful: Features a variety of automatic measurements, triggers, floppy, internal printer, and interfaces to external devices.**
- **Great value: Lots of information at an amazingly low cost!**



Easy-to-Use Menu Selection

Just turn the function knob to select a menu item, then press to activate it.

Help Menu

Explains the various menu functions. Useful for beginners or for advanced users needing to know what a particular function does.

Event Trigger

Wide range of triggers, including event triggers (count/burst/extra/missing) and TV triggers (NTSC/PAL/SECAM).

Hardware Five-Digit Frequency Counter

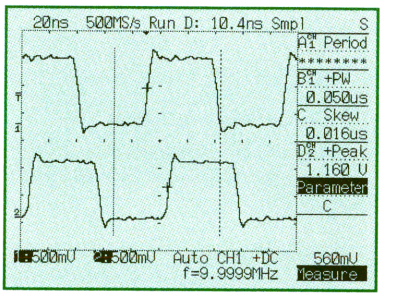
Input signal frequency can be shown in five digits. No more guessing about signal aliasing.

13 Automatic Measurements

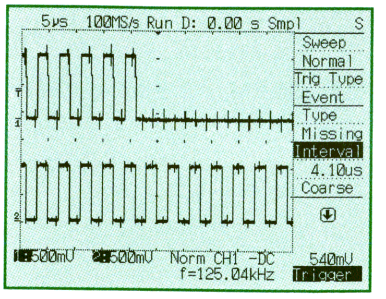
All the basic automatic functions required for common measurements are provided, assuring quick, accurate results and improving working efficiency.

25 GS/s Equivalent Sampling

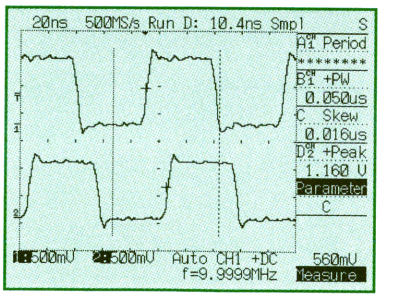
Using the equivalent sampling method, the time resolution is increased up to 40 ps (equivalent to 25 GS/s). Pre-trigger information is available.



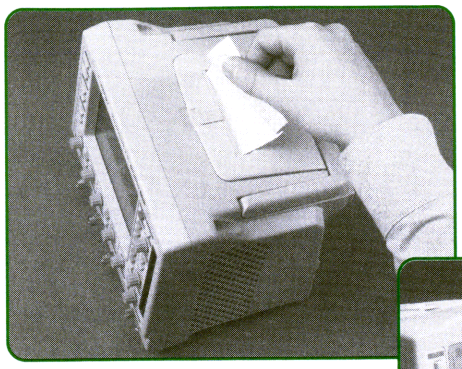
Troubleshoot signal interruptions



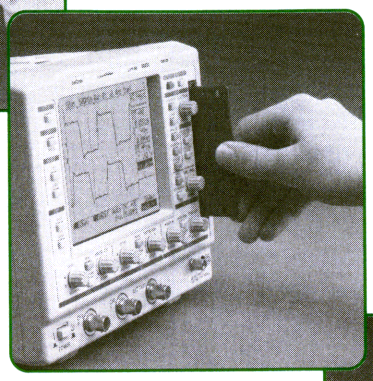
Help when you need it



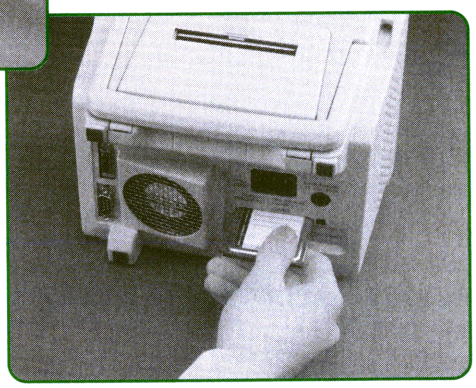
Cursors and parameters



Internal printer



Floppy disk



ATA Card

Specifications

Acquisition System
(Common to CH1, CH2)

Sensitivity: 2 mV/div – 10 V/div (1-2-5 steps) (0.8 mV/div zoomed)

Bandwidth: DC – 100 MHz (frequency cutoff is 10 Hz for AC coupling)

Max single-shot sampling rate: 500 MS/s

Equivalent sampling mode: 25 GS/s

Peak detect: 500 MS/s

Resolution: 8-bit

Acquistion Memory: Short – 5 kpts/ch; Long – 100 kpts/ch

Storage Modes: Normal, equivalent sampling, peak detect, average, roll

Triggering System
Modes: Auto, Normal Single

Sources: CH1, CH2, EXT

Types: Edge, Event, TV

Event trigger: Count, Burst, Missing, Extra

Timebase System
Time/div range: 5 ns – 50 s/div (1-2-5 steps)

Roll Mode: 500 ms – 1000 s/div

Display Functions
Display: 5.7" (145 mm) backlit LCD display

XY display: X = CH1, Y = CH2

Help function: Available on screen in reverse video

Waveform Storage
Save and Recall

Media: ATA card, floppy disk (3.5")

Data type: Setup, waveform

Record format: Binary and ASCII formats are available for waveform data.

Comment: Text comments can be appended to waveform files.

Auto copy: Waveforms can be automatically copied to a storage device after each trigger.

Math and Measurement Functions
Cursors: ΔV, Δt, 1/Δt, V at t

Parameters: Tr, Tf, Vrms, Vmean, etc. (total 13 items)

Arithmetic functions: +, -, x

Frequency counter: Five display digits, 1 Hz – 100 MHz frequency range

Other Features
Auto Setup: Automatically setup V, H range and trigger for repetitive signals

Interface: RS-232-C

Data output: Centronics

Built-in printer: Line thermal printer, roll print available

Floppy, ATA card: Output format TIFF, BMP

Centronics formats: DPU-414, ESC-P09, ESC-P24, PC-PR201, TIFF, BMP

Power Supply
Voltage range: AC 100 – 240 V

Power consumption: 90 VA max (with built-in printer operation)

Dimensions and Weight
Dimensions (width, height, length): 8.4" x 6.7" x 6.5" (214 mm x 170 mm x 166 mm)

Weight: Approx. 6.6 lbs (3.0 kg) excluding accessories

Ordering Information

Literunner™ Digital Oscilloscope	Product Code
2 channel 100 MHz, 500 MS/s, 100 kpts/ch	LP142

Applying the Power of DSOs to High-Speed Digital Design

In high-speed digital design, elements such as integrated-circuit packages, circuit board imperfections, and point-to-point wiring affect electrical performance. They have an influence on signal propagation, causing ringing and reflections. They generate interaction between signals including crosstalk and ground bounce effects. These effects can create timing violations that result in data transmission errors.

This undesired behavior is most common in high-speed digital design, whereas in low-speed design, signals generally remain clean and match the binary model in performance. As speeds of microprocessors and logic devices increase to several hundred MHz, problems which were once specific to the high-frequency analog designer now also challenge digital designers. Today, the high-speed digital designer has to take analog design principles into account.

In the virtual world, design and simulation tools integrate HF analog effects into the design of digital boards. In the real world, the logic analyzer allows analysis of digital patterns, whereas the digital storage oscilloscope (DSO) is the ideal tool to identify and isolate unwanted timing violations, signal distortion, and other "analog effects" in high-speed digital circuits.

Measuring Signals 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 can make effective probe grounding difficult. In either case, noise can dramatically mask measurement (Figure 1).

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 overshoot on large signals. Figure 2 shows the effect of averaging the noisy waveform shown in Figure 1.

Crosstalk

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 3 illustrates how crosstalk can distort a signal and corrupt data.

Crosstalk can be caused by:

- Mutual capacitance between two circuits – the voltage on one circuit creates an electrical field, which affects the second circuit.

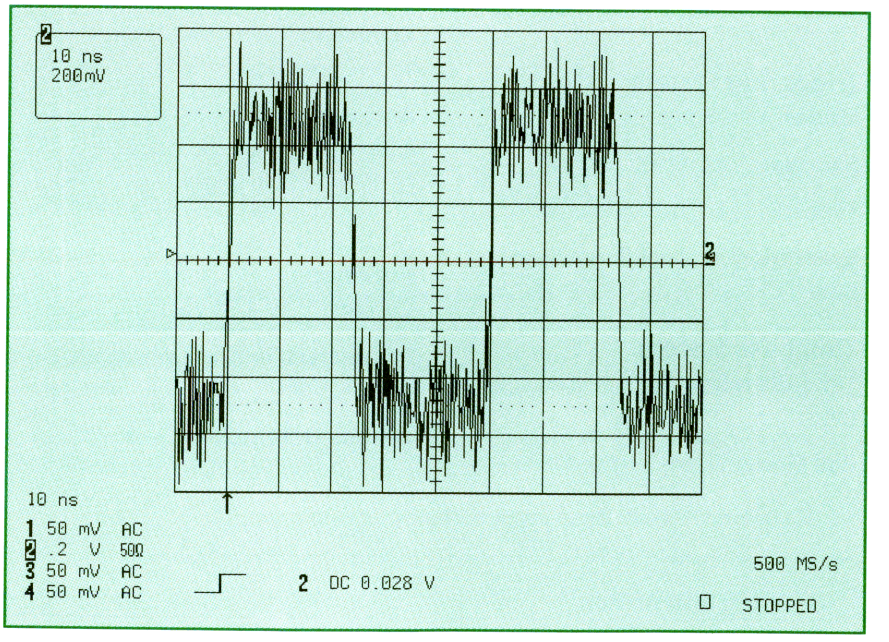


Figure 1: Pulse characteristics are masked by noise.

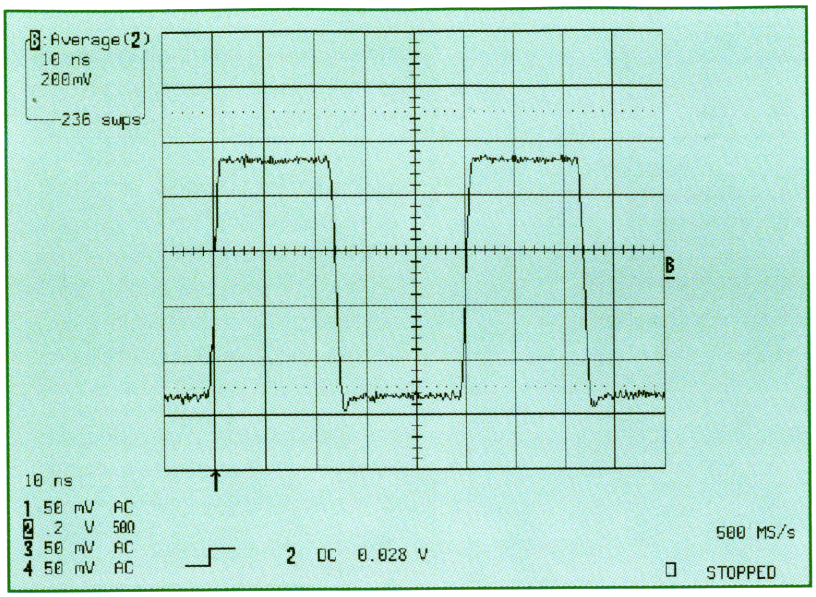


Figure 2: Noise removed by averaging.

- Mutual inductance by two loops of current on Circuits 1 and 2; these two loops interact to create interference called mutual inductance. For example, a mutual inductance L_M injects a noise voltage V_2 into Circuit 2 proportional to the change of current in Circuit 1 in accordance with the following rule $V_2 = L_M \, dI_1/dt$. This is critical in high-speed digital circuits, where fast transitions imply quick changes in currents.

The consequences of crosstalk in high-speed electronics include:

- Data transmission error due to data lines being coupled together,
- Reduced logic margins because of ringing, and
- Transient noncompliance with setup and hold timing requirements.

In analyzing crosstalk phenomena, it is fundamental to detect the resultant glitches in order to measure their amplitude and width. Crosstalk is, by its nature, difficult to observe, because it will be represented by very narrow glitches of low amplitude. The DSO glitch trigger capabilities are extremely useful for such applications, especially if the instrument has a very high sampling resolution.

Ground Bounce

When IC device packages are used at high speeds, the inductance of individual leads creates a problem on the logic inputs called ground bounce. This effect causes unwanted glitches on ground pins when the device outputs switch from one state to another. This unwanted voltage is due to capacitor discharge of the output driver to ground, causing a massive current surge through the ground pin. Even if these glitches have no impact on the input signals, they can affect the outputs of the circuit and create unwanted logic states. For instance, on flip-flops, the glitches modify the clock voltage seen by the circuit $V_{CLOCK} - V_{GND}$. The glitches added on the clock voltage caused by V_{GND} can clock flip-flops and cause errors called double-clocking. The faster the switching time, the higher the glitch magnitude of ground bounce will be.

Timing Issues for Clock Signals

1. Timing margin, propagation delay and clock skew

One of the main causes of digital system failure is timing violation issues somewhere in the circuit. This type of timing problem creates metastability in digital circuits. To avoid this potential problem, the digital designer has to allow for the skew in the clock distribution and for propagation delay of the data through and between the logic components (flip-flop, gates, etc.) and add a timing margin in the timing budget calculation.

Skew is due to the differences in propagation delays to different points of the circuit where the clock is required. Clock signals are critical in high-speed

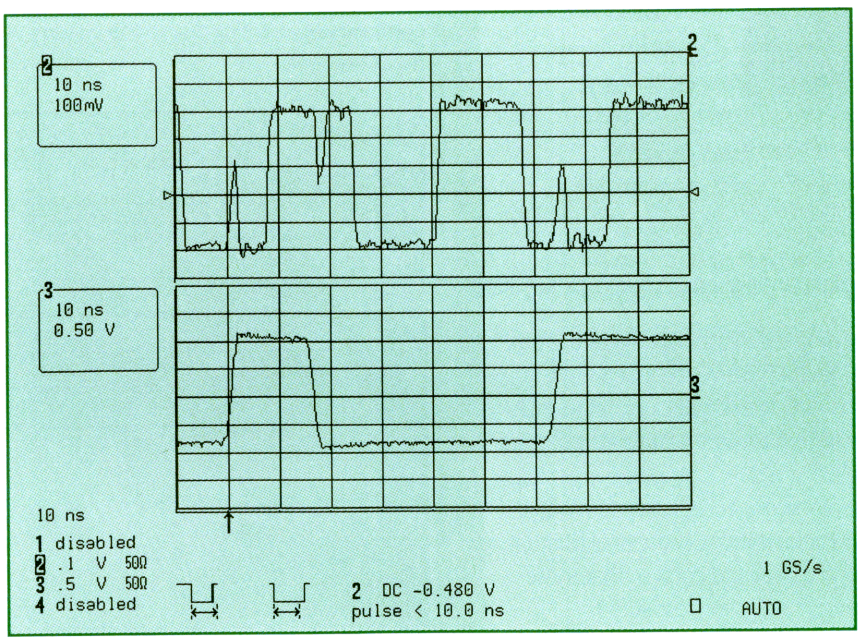


Figure 3: Crosstalk effects on a pulse train.

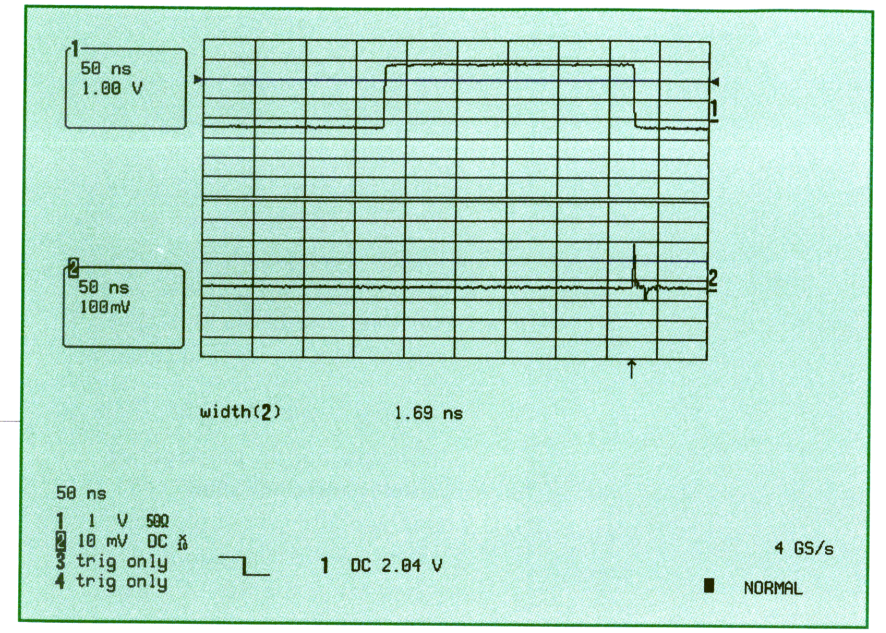


Figure 4: A ground bounce effect is observed on the ground line (2) in correlation with the output (1) of a flip-flop.

electronic design, particularly as they get faster and faster – exceeding 400 MHz in many cases – as the circuit typically advances with the clock edge. Furthermore, clocks are the most widely distributed signals in a digital system and are typically faster than all the other signals. This issue becomes more critical when the clock is distributed to different boards. For these reasons, the designer has to pay special attention to clock signals.

	TTL	CMOS FAST	ECLinPS FACT
Gate Propogation Delay (ns)	3	5	0.3
Output Rise/Fall Time (ns)	2	2	0.5

Typical timing values for logic families

The digital designer calculates the timing margin (being an excess of time remaining in each clock cycle) to make the system tolerant of delays to protect against crosstalk, logic delays, miscalculation, and minor changes due to the final circuit layout. On the final board, it is critical to test and confirm that these timing margins are respected.

2. Clock skew measurement

To measure clock skew accurately, the user must first eliminate any skew attributable to the DSO and probes. In the LeCroy DSO, the digital designer can eliminate this interchannel skew using the Resample function. One of the distributed clock signals to be observed (Channel 2) is defined as Function A (called Resample). Using the "delay" control, the user can accurately compensate for delay due to the system measurement.

The Δt@lv parameter (time difference between two signals at voltage level) is used to measure the propagation delay between the two clock paths (Channel 1 and Function A). In this example, timing is measured at the 50% point of the two clock edges, but another voltage value could be specified either in percentages or in volts. The same procedure could be used to measure the propagation delay from the input to an output of a logic buffer.

As an alternative to this procedure, the LeCroy JitterPro™ package allows the user to adjust the timing between two channels when making a clock skew measurement.

3. Clock Jitter

Crystal oscillators and PLLs are the basis for clock generation in digital circuits. Their main specifications are the accuracy and stability of the output frequency, which determine the quality of the generated clock signal.

To guarantee a timing budget that conforms to design requirements, the digital designer has to study short-term and long-term stability. The clock jitter reflects the stability or variation of the output clock transition compared to its ideal position. Jitter is due to noise emanating from a combination of different factors – thermal noise, mechanical noise, the oscillator's

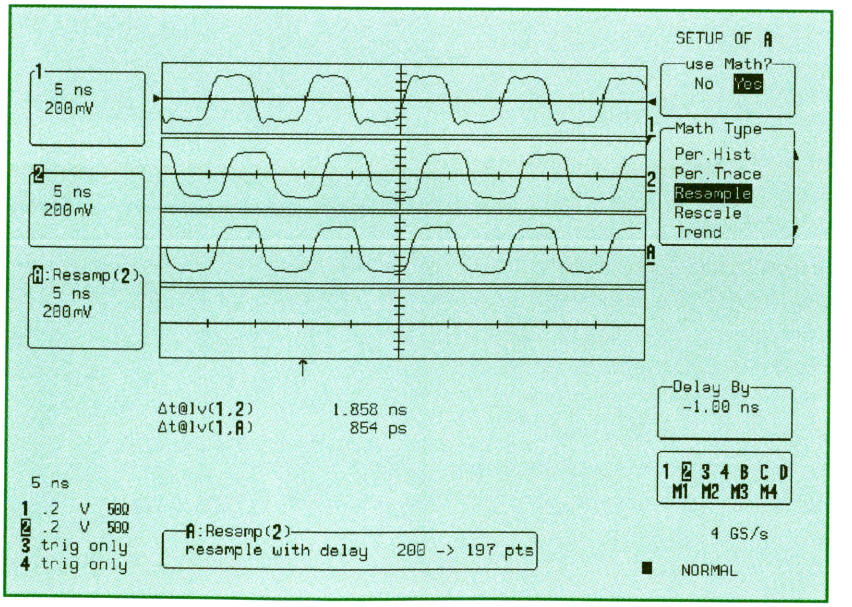


Figure 5: Propagation delay measurement with deskewing compensation.

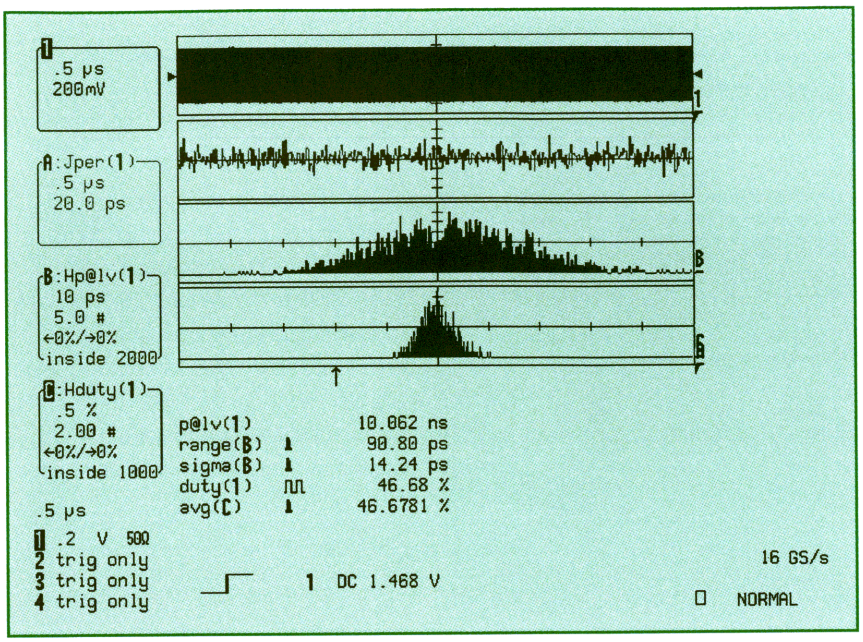


Figure 6: Clock jitter measurements.

amplifier self-noise, and power supply noise. This last one is intermittent and difficult to track.

The duty cycle also is an important specification; it must be close to 50%. This ideal value permits the use of the inverted clock as well as the direct clock. The drift from the initial 50% value or pulse width distortion is caused by the different propagation delays for rising and falling edges in the logic gates.

The CCTM (Clock Certification and Test Module) will perform all the tests required to certify the performance of the DRCG (Direct Rambus Clock Generator). This includes measuring duty cycle error.

With the Jitter and Timing Analysis function or with JitterPro, LeCroy DSOs provide a very efficient tool to study these types of instability. In particular, the JitterTrack™ function applied to a clock signal shows phase changes and timing issues. These changes are perfectly correlated with the clock signal. The Jitter Analysis is applied on the total acquisition memory length, thereby taking account of all variation in the clock signal. This long observation window is combined with a high-stability sampling clock in the oscilloscope to allow very precise and repeatable timing measurements.

A short-term stability measurement is displayed in Figure 6, with a clock variation study using the Period Jitter function (Jper on Trace A). This variation analysis is complemented by a histogram analysis of the signal period (Hp@lv on Trace B), which provides information on the range of the period variation and on the period standard deviation (sigma). The duty cycle drift can be observed on LeCroy DSOs with a histogram of the duty cycle parameter (Hduty on trace C) with the calculation of its average value.

The ability to capture and analyze 100,000 or more measurements in a histogram is crucial to verifying the peak-to-peak jitter in a circuit. Jitter measurements are statistical in nature, so making a small number of measurements can be misleading.

The same Jitter Analysis package can be applied to clock distribution driver chip outputs. Furthermore, the JitterTrack trace, perfectly time-correlated with the source signal, can be used as a visual tool to locate timing issues such as crosstalk, power supply spikes, or ground bounce on a long window acquisition of a clock signal.

Violation of Setup-and-Hold Times

Setup-and-hold time violations can also be analyzed with persistence display, with Pass/Fail test modes or by using simple, but powerful, tools in the JitterPro package. A persistence mode display offers the capability to view a history of signal timing variation. The Pass/Fail test can be done by comparing the signal to a mask or by comparing measured parameter values to a reference to analyze timing violations.

With JitterPro, hundreds of thousands of setup and hold measurements can be made. The results can be displayed in a histogram, in a time line (using JitterTrack), or in the frequency domain.

In Figure 7, Pass/Fail testing is used to verify if the occurring data are outside the specified setup time limits. The test is based on the comparison between the parameter calculating the time from the clock to the previous data transition (Δc2d-) and the setup time violation reference. The test fails when there is a setup time violation.

Analog Persitence displays the occurrence of each data event with a graded color.

Microprocessor Crashes

During the final phase of many designs, microprocessor crashes or lockups are common. They can 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 the DSO on the restart condition.

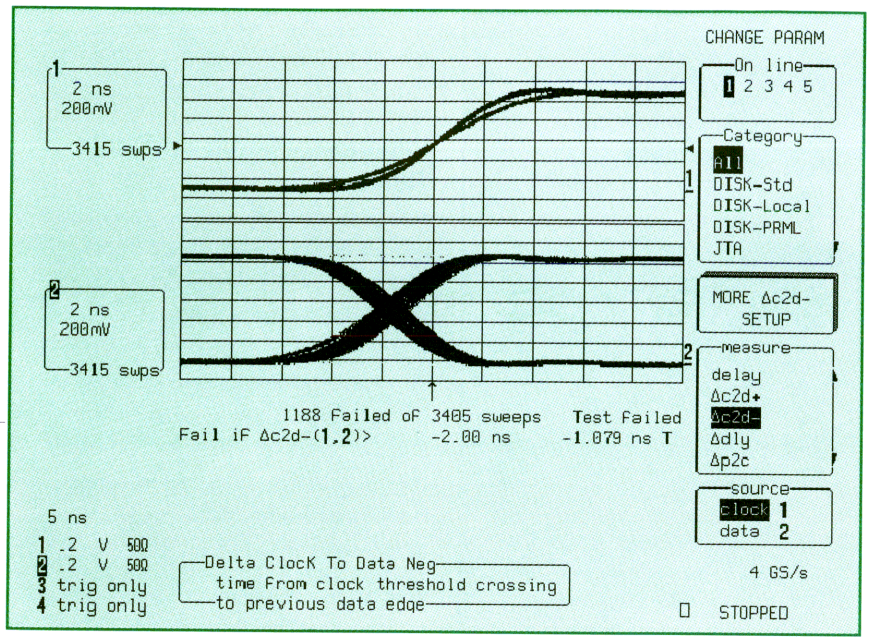


Figure 7: Setup time violation.

A convenient way to trigger on microprocessor 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 pre-trigger memory allows observation of several signals for milliseconds or even seconds before the crash.

Triggering on a successful restart is possible with LeCroy's 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 monitored signal could in fact be a dedicated Watchdog Timer output.)

Setting a logic combination (High, Low, Don't Care) between channels and triggering on it is useful, for instance, during read or write data cycles. This type of signal acquisition can be set up by using the pattern trigger.

Metastability

The data input to a flip-flop should be stable for a given period of time before (setup time) and after (hold time) the clock pulse.

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. While it remains in this indeterminate state, the signal is said to be metastable.

Figure 8 shows the output of a flip-flop, with many successive acquisitions overlaid in Analog Persistence display mode. A region of metastability is clearly visible during the 5 ns following the low-to-high transition.

A runt trigger occurs when a signal's amplitude is between two specified levels. It offers the designer the capability to isolate data between high and low logic levels. This mode can be combined with Glitch trigger detection to complete an accurate investigation of the metastable states of the studied flip-flop.

In a more general context, Runt trigger determines if the voltage margins of the logic family used are respected.

Transition Analysis

Digital logic devices are provided with specifications on falltime and risetime that should be respected for correct operation. The transition of signals slows down due to propagation pathways, including device packaging, board layout, and connectors. This problem is especially crucial in high-speed digital design, where the specified chip transitions are very fast.

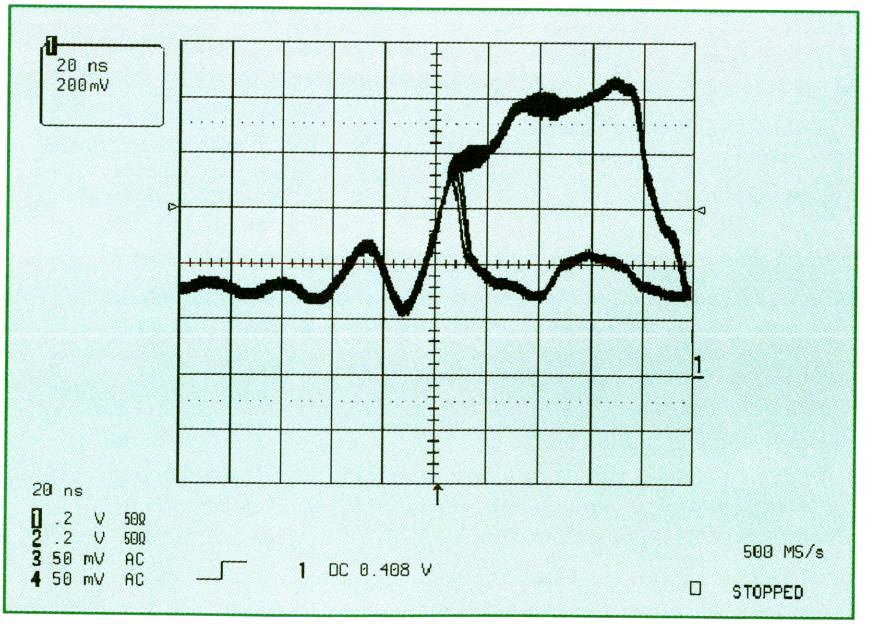


Figure 8: Flip-flop output exhibiting metastability.

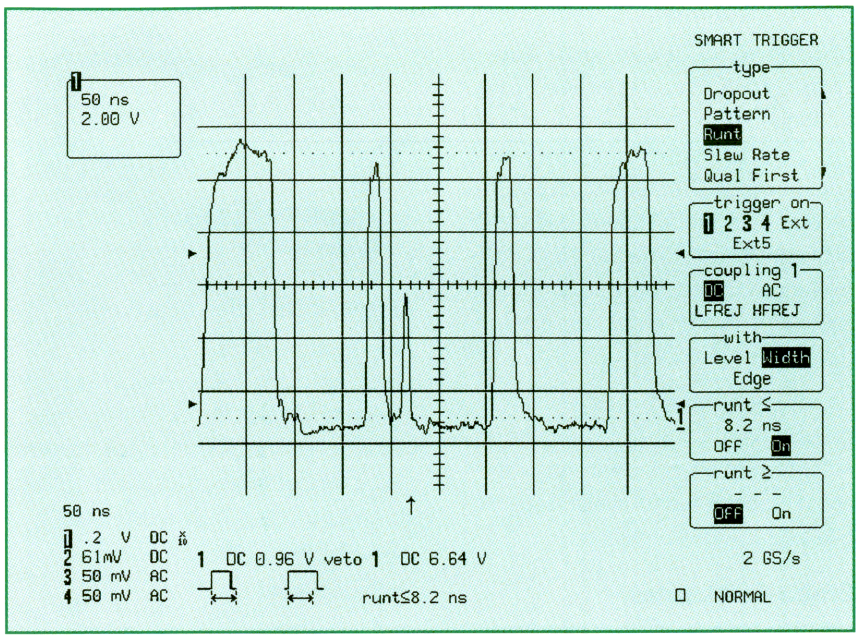


Figure 9: Runt Trigger to detect a metastability event.

A digital scope can also provide a simple way to check the transitions with a trigger mode called Slew Rate. In this application, the trigger mode is set to capture an event when too slow a transition occurs to protect against a specification violation.

The digital designer can also check that the transition doesn't become too fast, generating unintended harmonics on the transmission lines. Too fast a risetime causes crosstalk problems through two distinct mechanisms:

- It generates a high dV/dt, which can affect the signal on circuits through a mutual capacitance generation.
- It drives sudden changes in current with a too-high dI/dt and can generate a mutual inductance with another circuit.

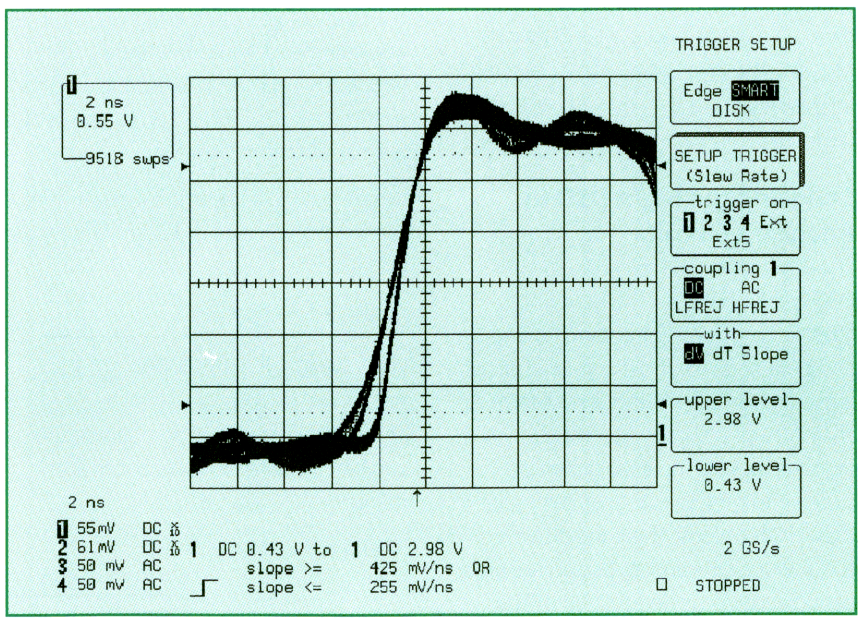


Figure 10: Undersirable transitions captured with Slew Rate exclusion trigger.

Both triggering modes can be combined with the Exclusion Slew Rate mode. In the example, a trigger will occur if transition is slower or faster than specified values. The Analog Persistence display retains all the transitions outside the limits.

Probing Circuits

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.

The two main factors to consider when selecting a probe are bandwidth and impedance. The effects of low probe bandwidth are obvious – the composite oscilloscope/probe bandwidth is degraded.

Probe Impedance Considerations

Low-impedance passive probes offer very high bandwidth (typically several GHz) and 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 can be a problem when using TTL with 1 kΩ pull-up resistors or some CMOS devices, which are incapable of sourcing the current required. It is usually not a problem for ECL, FACT, and LCX CMOS to drive a 50 Ω transmission line directly.

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 risetime 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, which has bipolar or field effect transistors in the probe tip that 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 because of over-voltage abuse. The HFP series probes offer the best performance for scopes in the 500 MHz to 26Hz range. Their 100 kΩ impedence and 0.7 pF capacitance provide very low circuit loading while the unique modular tips and color coded ID features make them easy to use.

Differential Probes

Differential probes are the best solution for measuring voltage signals that are not referenced to ground and those that have balanced source impedance. However, in many cases, even measurements of ground-referenced signals will benefit from a differential measurement.

As its name implies, a differential probe produces a calibrated output voltage that represents the voltage difference between the two inputs. Any voltage component that is identical on both inputs is rejected. The output signal is ground-referenced, allowing it to be measured with an oscilloscope. Unlike a standard single-ended probe, both inputs have high impedance. Conventional probes, both passive and active, measure the signal difference between the input tip and the ground lead. The ground lead represents a very low-impedance path to earth ground. This can cause measurement problems.

Connecting the ground lead of a single-ended probe to the ground in the circuit under test introduces an alternate ground path. The alternate path changes the ground current distribution, which can mask the very problem the oscilloscope is being used to look for. This is often the case with ground bounce in digital systems.

The differential probes also help solve ground loop noise injection. This phenomenon occurs when there is a voltage difference between the ground of the circuit under test and the scope's chassis ground. It causes a current flow through the loop composed by the oscilloscope's common ground power lines and the circuit, the probe cable, and the oscilloscope's probe ground lead. Using a differential probe to measure ground-referenced signals does not introduce an alternate ground path, thereby eliminating these problems.

LeCroy offers two active differential probes: The 500 MHz AP033 and the AP034, which offers 1 GHz bandwidth and is especially useful in high-speed digital circuit measurements.

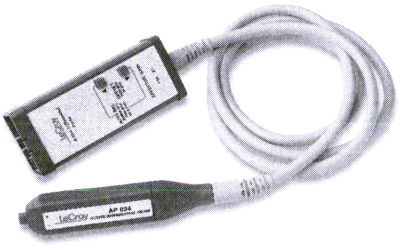
Probe Accessories

In typical applications, the probe tip is connected to the circuit under test, and the ground lead is connected to a close ground reference. If the ground connection is made using a wire several inches long, the resulting ground loop has a self-inductance, which affects the probe's risetime and causes artificial ringing and overshoot.

LeCroy offers a variety of accessories to avoid using a long ground wire and to assist probing of surface-mount components, thus improving measurement accuracy. These accessories allow direct connection to board pins or clip (0.8mm, 0.5 mm) connections to pins of QFP or SOIC ICs. The best connection is the PCB adapter soldered directly to the board under test.

Choosing the Right DSO to Analyze a Circuit

The schematic of a typical single-shot DSO is shown below. The front-end amplifier provides signal conditioning and buffering. A Sample-and-Hold circuit is used to sample the input waveform. An analog-to-digital converter (ADC) then digitizes these samples, and they are stored into memory. A separate trigger circuit determines where the displayed acquisition starts and stops, and the time period acquired is determined by the timebase.



AP034 Active Differential Probe

There are many DSOs available for high-speed work; each has its relative merits and applications. Specifications that need to be well understood for DSO selection to be a success in high-speed digital design analysis are:

- Bandwidth
- Sample rate
- Memory length
- Triggering and waveform analysis tools

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.

When making a risetime measurement, the measured value is determined by the equation:

$$\text{Measured risetime (tr)} = \sqrt{(\text{tr signal})^2 + (\text{tr scope})^2}$$

This typical risetime of an oscilloscope can be calculated from its bandwidth rating:

$$\text{Risetime (in nanoseconds)}: \frac{350 \text{ to } 500}{\text{bandwidth (MHz)}}$$

The factor in the numerator depends on the characteristics of the acquisition system. A value of 350 is accurate for a simple amplifier with a single pole while more complex systems will have higher values. As a typical example, a 400 MHz oscilloscope might have a risetime of 1 nanosecond. A 2 GHz scope will have a risetime between 175 and 250 psec.

Using a 400 MHz scope to measure a 1 ns risetime will yield a result of about 1.4 ns, a 40% measurement error!

Figure 11 shows measurement error versus signal risetime for DSO bandwidths equal to 25 MHz, 200 MHz, and 1 GHz for a 1 ns risetime pulse. All these bandwidths introduce error, especially the 200 MHz and 25 MHz bandwidth instruments. The least important measurement error is for the 1 GHz bandwidth with a 10% error. To make a high speed single shot measurement such as this, a 2 GHz bandwidth scope would be preferable.

If extremely accurate measurement of signal risetimes is important, use of a 10 GHz or faster sampling scope is recommended. LeCroy produces the MCA line of very high bandwidth Microwave Communication Analyzers for these types of applications. But for typical jobs of troubleshooting glitches, signal jitter, crosstalk, or other problems, a scope with 2 GHz bandwidth is usually sufficient.

Sample Rate

A DSO's sample rate also limits the fastest signal 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, to make precise measurements, the sample rate should be approximately four to ten times faster than the frequencies measured. As an example, using a WavePro series scope at 4-16 GS/s is an excellent match to the requirements of sampling a 400 MHz Rambus DRCG clock.

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, requires the high resolution provided by fast sampling. Figure 12 shows the effect of sampling a pulse at 500 MS/s, and 1, 2, and 8 GS/s. The sample points are in bold, and a linear interpolation is used between points. The pulse shape is becoming worse, and an error is introduced on the risetime measurement when the sampling rates decreased.

We have seen that DSO bandwidth and sample rate affect the measured signal in different ways. The 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. It allows triggering on the consequence of an anomaly, such as an alarm signal or a reset signal, and analysis of the cause by using a large amount of pre-trigger data.

A good compromise is the "general-purpose" DSO, which offers both high bandwidth and fast single-shot sampling. A good example is LeCroy's WavePro series of four-channel color DSOs with 500 MHz to 2 GHz bandwidth and 8-16 GS/s single-shot digitizing. These instruments include DSOs with up to 64 million points of acquisition memory. The advantage of a long acquisition memory is described in the next section.

Memory Length

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 – longer memory equals faster sampling.

For instance, the 64 million points available on the WavePro 960 and

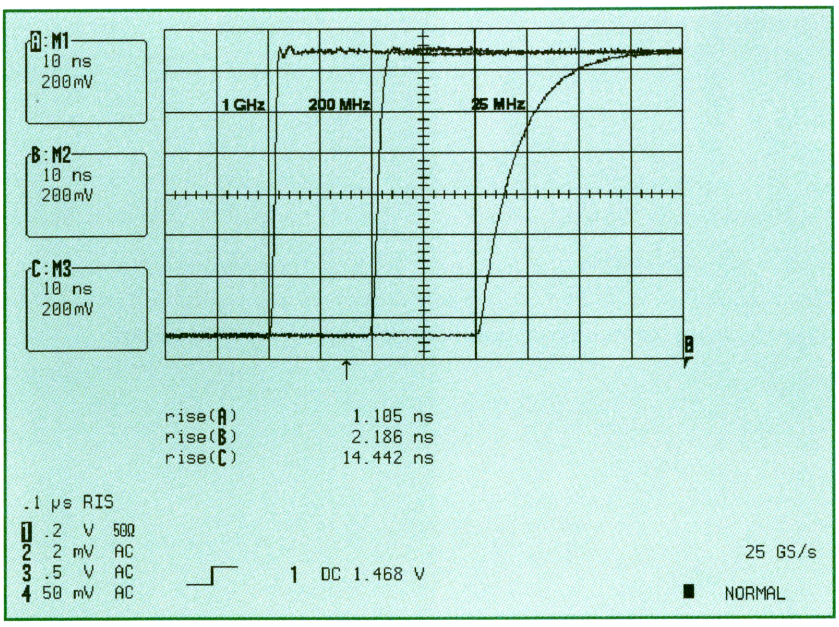


Figure 11: A 1 ns edge as measured with bandwidths of 1 GHz, 200 MHz, and 25 MHz.

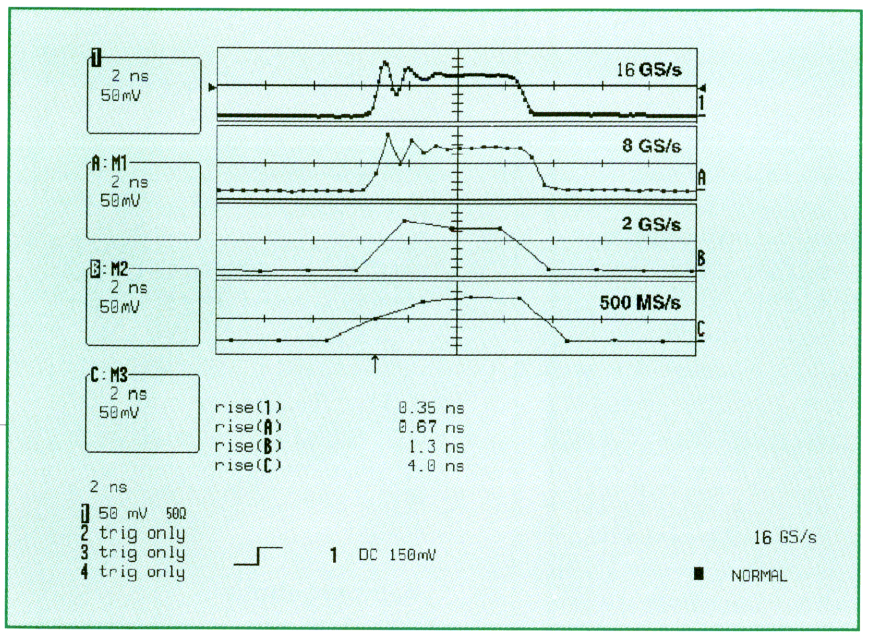


Figure 12: A pulse acquisition with risetime measurement at different sampling rates.

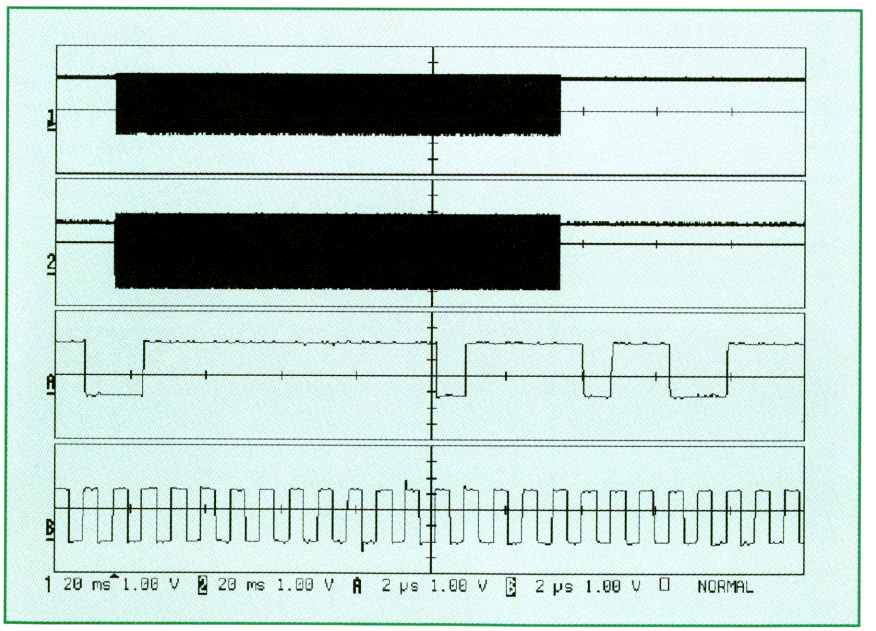


Figure 13: Long data stream acquisition, clock, and correlated zooms.

DDA260 allow the acquisition of a 4 ms time window at 16 GS/s.

This is particularly important in communications applications and debugging microprocessor-based systems. Circuits with data packets or asynchronous events are easier to debug with fast digitizing over long time windows.

Figure 13 illustrates a typical example of this. The top trace shows the capture of a burst data stream and its associated clock coming from a PROM to an FPGA. The long duration of the data stream requires a large acquisition memory to maintain a high sample rate. The data stream and the clock are zoomed simultaneously to observe signal details.

Triggering and Waveform Analysis Tools

The basic characteristics – bandwidth, sample rate, and acquisition memory length – have to be combined with powerful triggering tools to allow capture of fast transient events and full-memory waveform analysis.

These necessary tools have been detailed earlier in this application note.

- Triggering functions – fast glitch and transient events capture, runt, slew rate, pattern, drop out and qualified triggers.
- Waveform analysis such as an easy-to-use zoom mechanism, Pass/Fail testing, a large variety of timing parameters, and a powerful Jitter Analysis package.

The choice of the right DSO in high-speed digital design has to allow for consideration of all these factors.

Reference

Howard Johnson and Martin Graham, *High-Speed Digital Design: A Handbook of Black Magic*, Prentice Hall PTR, Upper Saddle River, New Jersey.

2

LeCroy
TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
ANALOG PERSIST
WavePro 960

PXI Digitizers

- **Complete family 150 MHz – 1 GHz bandwidth**
- **Up to 2 GS/s sample rate**
- **Up to 8 million points of acquisition memory**
- **Up to 50 GS/s Random Interleaved Sampling for repetitive signals**
- **Complete line of 3U PXI**
- **Fast PCI bus data transfer rates**
- **QuickStart software**
- **IVI scope drivers**



The PXD series features a complete line of PXI digitizers with bandwidths ranging from 150 MHz to 1 GHz. It also features high channel density with up to 8 channels in a single 3U eight-slot PXI chassis. The combinations of these features allow for the capture of long, complex signals with excellent accuracy within the compact, rugged, modular architecture of PXI.

The PXD series digitizers are fully PXI compliant and based on the desktop computer industry standard PCI bus. Fast data transfer rates and improvements in test times give advantages over traditional GPIB instruments. The plug and play functionality of these PXI digitizers provides ease of setup and use.

The PXD series digitizers include several software tools to help you quickly get started and develop test software in LabView, CVI, Visual C++ or Visual Basic. The PXD series software includes an IVI-scope-compliant instrument driver, ActiveX control and a custom LeCroy PXD Getting Started application program for interactive control.

The LeCroy PXD series provides a cost efficient, space efficient, high-performance digitizer solution for production test applications including:

- Analytical Instruments
- Disk Drive Testing
- Communications Test Systems
- Automotive
- Aerospace and Defense

Acquisition System

Model	PXD1022	PXD1021	PXD522	PXD514	PXD512	PXD214	PXD212	PXD114
Bandwidth	1 GHz	1 GHz	500 MHz	500 MHz	500 MHz	250 MHz	250 MHz	150 MHz
Maximum Single-Shot Sample Rate	2 GS/s	2 GS/s	2 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s	1 GS/s
Maximum Repetitive Sample Rate	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s	50 GS/s
Channels	2	1	2	4	2	4	2	4
3U PXI Slots	3	2	3	3	2	3	2	3
Acquisition Memory Standard	256 K	256 K	256 K	256 K	256 K	256 K	256 K	256 K
Acquisition Memory Option 1	4 M	4 M	4 M	4 M	4 M	4 M	4 M	4 M
Acquisition Memory Option 2	8 M	8 M	8 M	NA	NA	NA	NA	NA
Single-Shot Capture Window	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s	10 ns–10,000s
Repetitive Capture Window	2 ns–10 us	2 ns–10 us	2 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us	5 ns–10 us
Sequential Mode Max Segments	8192	8192	8192	4096	4096	4096	4096	4096

Bandwidth Limiter: 20 MHz and 200 MHz

Sensitivity: 5 mV/div to 1 V/div, fully variable (40 mV to 8 V full scale range)

Scale Factors (calibrated): 0.005, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0 Volts/div

Full Scale Range: 8 major divisions

Offset Range:
± 1 V (5 - 99 mV/div, 50 Ω only)
± 10 V (0.1 - 1.0 V/div, 50 Ω only)
± 1 V (5 – 100 mV/div, 1 MΩ only)
± 20 V (0.102 - 1 V/div, 1 MΩ only)

Variable Gain Range: 0.1 to 1.0 of full scale

Variable Gain Resolution: 0.1% of full scale

Input Coupling:
Z_{in} = 50 Ω DC, GND
Z_{in} = 1 MΩ AC, DC, GND

AC Coupled Lower Cutoff: <10 Hz, frequency -3 dB

Input Impedance:
Z_{in} = 50 Ω 50 Ω ± 1%
Z_{in} = 1 MΩ 1 MΩ ± 1% || 16 ± 2 pF

DC Accuracy: ±(2% full scale + 1.6% offset setting + 1 mV)

Vertical Resolution: 8 bits

Maximum Input Voltage:
Z_{in} = 50 Ω 5 V (rms, including DC)
Z_{in} = 1 MΩ 100 V (DC + pk AC, frequency ≤5kHz)

Input Connector(s): BNC (grounded)

Acquisition modes

Single Shot: For transient and repetitive signals. Maximum 2 GS/s (PXD1022/1021/522) or 1 GS/s (PXD514/512/214/212/114)

Random Interleaved Sampling (RIS): For repetitive signals up to 50 GS/s

Sequence: Stores multiple events, each of them time stamped (1 ns resolution) in segmented acquisition memory.

Maximum Dead Time between Segments: <7 us

Minimum Segment Length: 256 samples

Maximum Segment Length: 1 million samples

Timebase System

Capture Window at Maximum Sample Rate: Up to 4 ms

Clock Accuracy: 10 ppm

Trigger System

Modes: Normal, Auto, Single, and Stop

Slope: Positive, Negative

Coupling: DC, AC, LFREJ, HFREJ

AC Cutoff (low freq.): 7.5 Hz (typical)

HFREJ, LFREJ Cutoff: 50 kHz typical (6 dB/octave)

Pre-Trigger Recording: 0-100% of horizontal full scale (adjustable in 1% increments)

Post-Trigger Delay: 0-10,000 divisions (adjustable in 0.1 division increments)

Sources: All data channels, EXT (Slope, level and coupling are unique for each source. PXI triggering capabilities are described on the next page.)

External Trigger

Range: ± 0.5 V

Input Impedance: 50 Ω ± 3%, 1 MΩ ±1% || 16 pF

Maximum Input:

Z_{in} = 50 Ω 5 V (rms, including DC)
Z_{in} = 1 MΩ 100 V (DC + pk AC, f requency ≤5 kHz)

Input Connector: BNC

Trigger Outputs: PXI (see below)

Multi-Module Synchronization

The PXD digitizers support PXI extensions to the PCI bus for the following backplane clock and trigger capabilities:

1. External clock input for module synchronization to the 10 MHz TTL clock provided by the PXI backplane (PXI_CLK10).
2. Trigger inputs to support an asynchronous low skew (1-5 ns) trigger source broadcast on the PXI star trigger bus.
3. Asynchronous trigger I/O to support a single-line broadcast on the PXI trigger bus. The trigger input may come from an external source or from a digitizer module. Digitizer modules provide a tri-stated output to support this mode, with high impedance guaranteed on power-up.

Software Compatibility

The PXD hardware is compatible with the following software environments:

Operating Systems: Windows 95/98/NT4+

Supported Drivers:

- IVI-Scope Driver
- LeCroy PXD Getting Started Application Program
- ActiveX Control

Update Rate

Supports PCI Bus transfer rates up to 100 MB/s peak data rates.

General

Auto-Calibration: Ensures specified DC and timing accuracy.

Auto-Calibration Time: <500 ms

Recommended Factory Calibration Interval: One year

Temperature: 0° to 50° C (32° to 122° F) with an airflow typical of a PXI chassis. The PXD digitizers will function as specified during a maximum rate of temperature change that does not exceed 8° C/hour (15° F/hour).

Non-Operating Temperature: -40° C to 70° C (-40° F to 158° F)

Humidity: <80% non-condensing.

Altitude: Up to 4600 m (operating), 40° C

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

Mechanical Dimensions: PXD1021, PXD512 and PXD212 occupy 2 3U PXI slots. PXD1022, PXD522, PXD514, PXD214 and PXD114 occupy 3 3U PXI slots.

Service

LeCroy is committed to your success, whether you own one LeCroy instrument or hundreds. Call your local service representative to discuss your specific requirements. We offer:

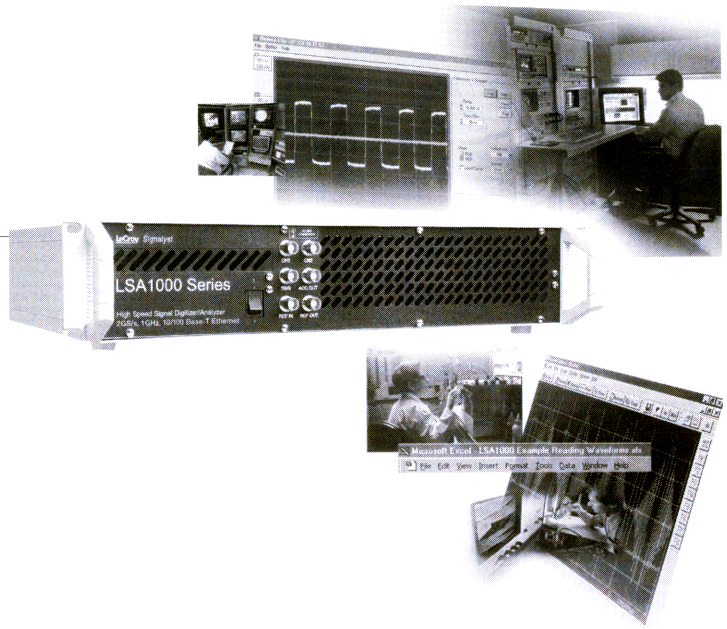
- Extended warranty packages
- Annual calibration maintenance
- Prompt, personalized warranty and nonwarranty repair at service offices

Ordering Information

PXI Digitizer	Product Code
1 GHz, 2 GS/s, 256k/ch, 2 Channel	PXD1022
1 GHz, 2 GS/s, 256k/ch, 1 Channel	PXD1021
500 MHz, 2 GS/s, 256k/ch, 2 Channel	PXD522
500 MHz, 1 GS/s, 256k/ch, 4 Channel	PXD514
500 MHz, 1 GS/s, 256k/ch, 2 Channel	PXD512
250 MHz, 1 GS/s, 256k/ch, 4 Channel	PXD214
250 MHz, 1 GS/s, 256k/ch, 2 Channel	PXD212
150 MHz, 1 GS/s, 256k/ch, 4 Channel	PXD114

Memory Options	
8 Mpts/Channel (only available for PXD1022, 1021, and 522)	PXD-XL
4 Mpts/Channel	PXD-L

High Throughput Digitizers LSA1000 Series



Main Features

- 1 GHz bandwidth
- 2 GS/s on one channel
- 1 GS/s on two channels
- 10/100 Base-T Ethernet interface for high throughput rate
- Acquisition memory to 8 Mpoints
- Easy-to-use software tools: ActiveX, LabVIEW, CVI drivers
- Optimized for OEM and system integration

LeCroy has a long tradition of technical leadership in high-speed, complex electronic signal acquisition and analysis. The company has made many breakthroughs over the years, including the industry's fastest digitizers and longest acquisition memories. LSA1000 has been designed 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.

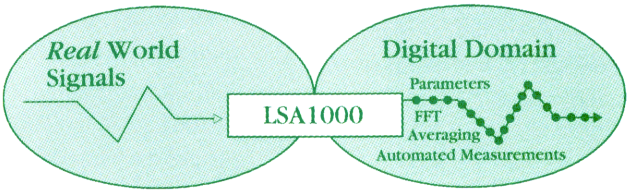
LeCroy's LSA1000 is a 2 GS/s waveform digitizer that brings the fidelity of LeCroy's digital scopes to embedded applications. Its onboard PowerPC processor maximizes measurement throughput and accelerates waveform analysis and computation. Acquired waveforms are transferred to the computer via 10/100 Base-T Fast Ethernet. LSA1000 maintains the integrity of your analog signals while digitizing and analyzing them in the shortest possible time.

LSA1000 provides:

- High Throughput
- Ease of Use
- Powerful Analysis

Solutions to Challenging Problems

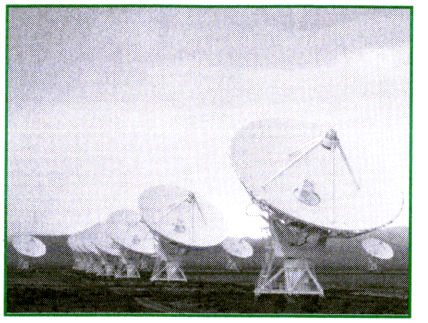
Today's system designers and test engineers face major challenges in high-speed signal acquisition and analysis. While real-world signals remain predominantly analog, signal acquisition and analysis must be performed in the digital domain. The process must be fast, accurate, and cost-effective. This 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.

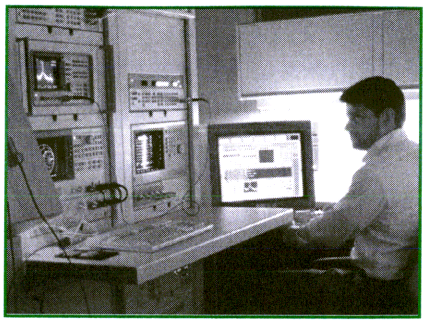


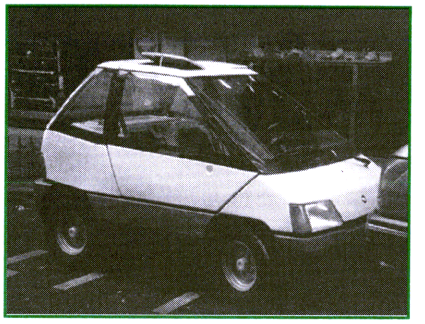
LeCroy's LSA1000 provides a high performance packaged solution at an unmatched price. The PowerPC processor maximizes throughput, while minimizing loading of your system's computer and busses. LSA1000's 19" rackmount form factor integrates easily into most environments and provides a cost-effective solution, even for low channel-count applications.

Applications

- Automatic Test Equipment: As mixed-signal testing becomes a key challenge, the LSA1000 provides fast and accurate digitization of your complex waveforms.
- Analytical Instruments: Whether you're in mass spectometry, ultrasonic testing, medical imaging, or other analytical instrument applications, the LSA1000 is easy to use and integrate into your system. The Ethernet interface facilitates integration with your system control computer.
- Disk Drive Testing: The LSA1000 is an ideal test instrument for disk drive manufacturing testing. Combined with LeCroy's powerful disk drive-specific software packages such as PRML and Disk Drive Measurement, the LSA1000 delivers unmatched performance in the shortest possible time.
- Communication Test Systems: Timing is everything. The Jitter and Timing Analysis (JTA) software package delivers high accuracy and full jitter analysis capability. Use JTA in the LSA1000 to make precise timing and jitter measurements.
- Automotive: The LSA1000 is ideal for high-speed transient measurements. You will appreciate the LSA1000's speed in testing ignition air bag, engine control, collision avoidance systems and powertrains.









- Aerospace/Defense: Mission-critical data cannot be missed. If you work with radar, lidar, or other high-speed data acquisition applications, the LSA1000's large memory of up to 8 Mbytes and its high sample rate guarantee that you capture the complete picture.

Optimized for High Throughput

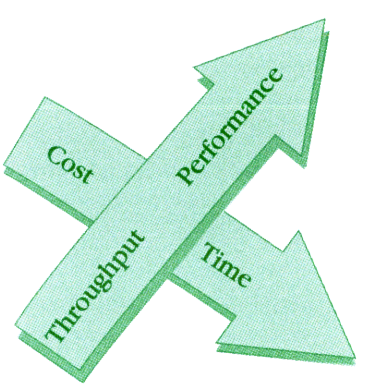
LSA1000 is optimized for high throughput in all phases of signal acquisition and analysis.

- Fast Data Acquisition: With up to 8 Mbytes on one channel, 1 GS/s sampling can be maintained for up to 8 ms of data. This maximizes waveform capture without costly interruptions.
- Onboard 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 LSA1000 gives you "answers," not just raw digitized data.
- Data Transfer over Ethernet: 10/100 Base-T Fast Ethernet interface ensures easy, standard connectivity to the computer with a faster data transfer rate than traditional GPIB.

Ease of Integration

The LSA1000 comes with several software tools to help you get started and to develop your own application-specific software quickly. All control commands are the same as LeCroy benchtop digital oscilloscopes to help preserve your software investment in other LeCroy products.

- Remote LSA provides a scope-like, live waveform display on your PC without any programming on your part. You can easily control LSA1000 settings through the soft panel. This means you can get visual feedback as you develop your own programs with the LSA1000.



- ActiveDSO™ is an ActiveX control for the LSA1000. ActiveDSO streamlines your programming in the Microsoft environment by taking care of the complicated PC-to-LSA1000 interfacing for you. Through ActiveDSO, a variety of Windows applications can control and exchange data with the LSA1000. Microsoft Office programs, Visual Basic, Visual C++, and MATLAB are a few of the many applications that support ActiveX controls.
- ScopeExplorer™ is another PC connectivity tool with a remote control terminal and virtual front panel for LSA1000. It also captures waveform images and converts and transfers waveform data.
- LabVIEW and LabWindows/CVI drivers are available for LSA1000.

Leverages Familiar Industry Standards

LSA1000 utilizes familiar industry standards, reducing its integration time into your system. Supported standards include:

- Ethernet Interface
- Windows NT/95 support

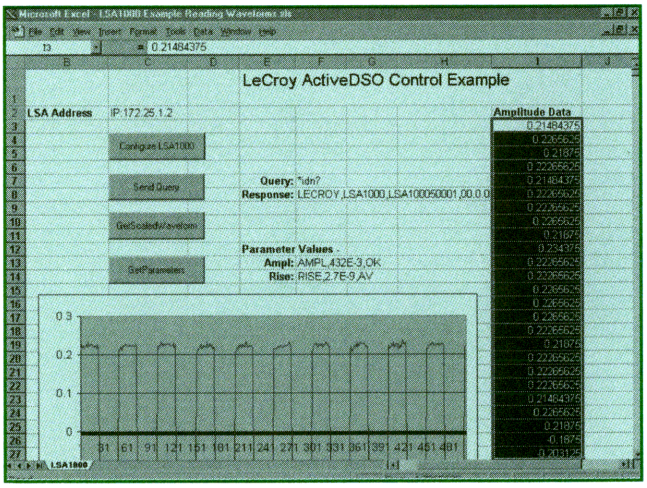
Powerful Analysis Tool

LSA1000 provides the same powerful waveform analysis capability as LeCroy digital oscilloscopes. Its onboard processor 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 jitter measurement and disk-drive analysis are also available.

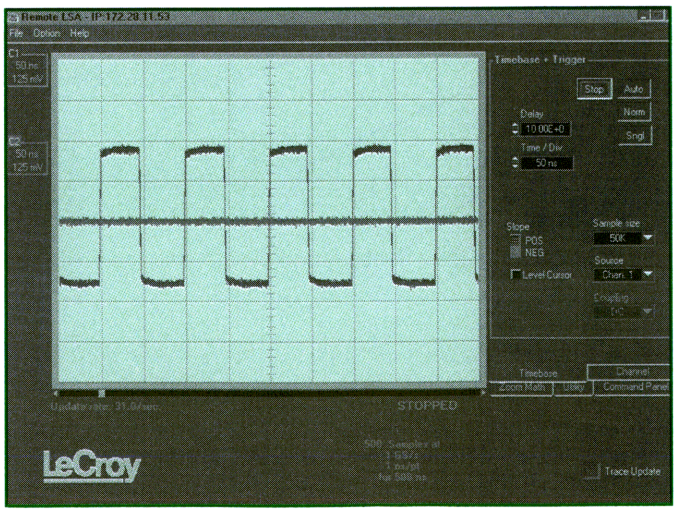
Customer Approval

LSA1000 has received many accolades from customers for its innovative design and superior performance. It has also received industry awards.

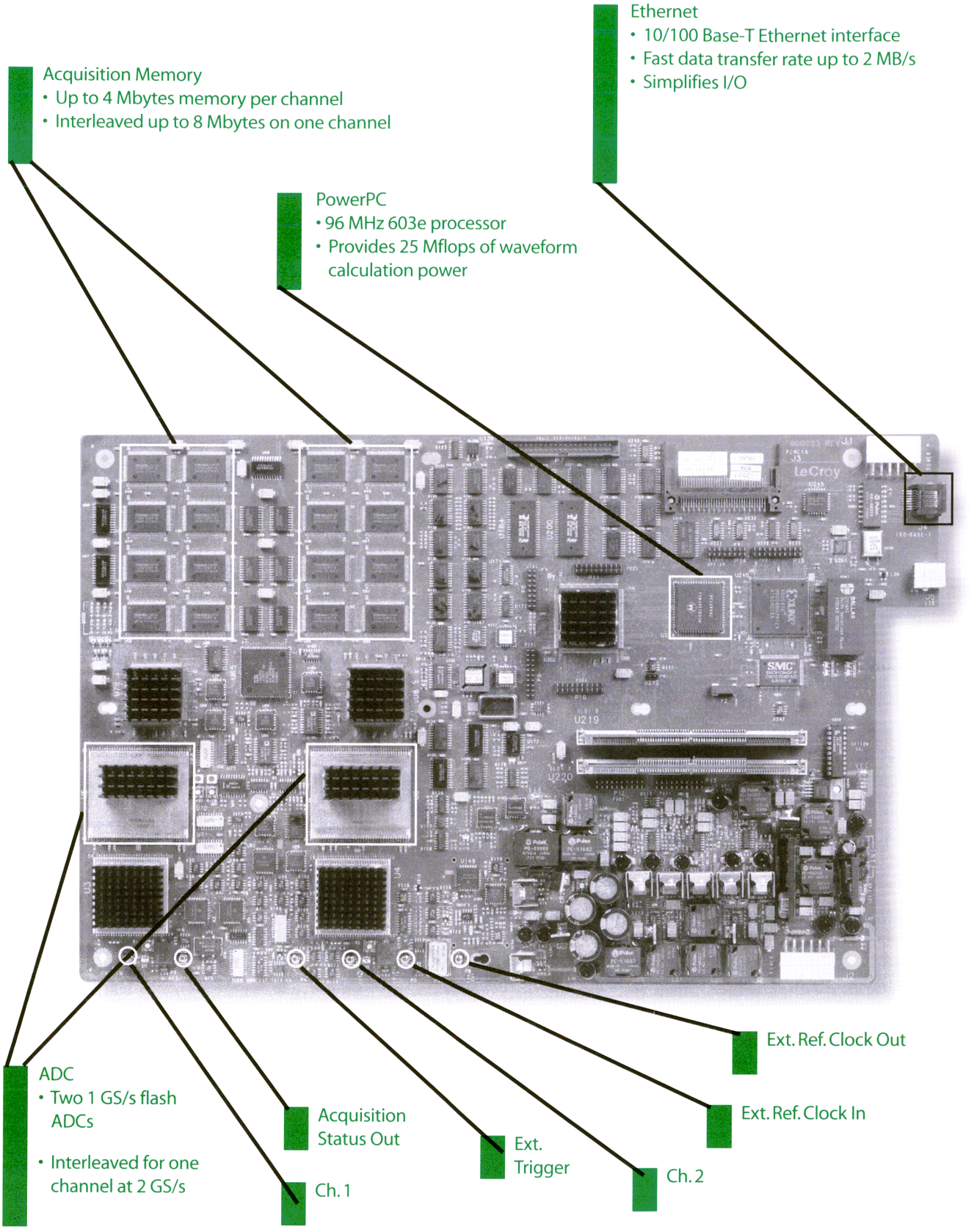




ActiveDSO gives you the power to build software applications quickly.



LSA1000 includes several software tools such as Remote LSA to help you get started quickly.


Ethernet
• 10/100 Base-T Ethernet interface
• Fast data transfer rate up to 2 MB/s
• Simplifies I/O
Acquisition Memory
• Up to 4 Mbytes memory per channel
• Interleaved up to 8 Mbytes on one channel
PowerPC
• 96 MHz 603e processor
• Provides 25 Mflops of waveform calculation power
Ext. Ref. Clock Out
Ext. Ref. Clock In
ADC
• Two 1 GS/s flash ADCs
• Interleaved for one channel at 2 GS/s
Acquisition Status Out
Ext. Trigger
Ch. 1
Ch. 2

Acquisition System

Bandwidth (-3dB): 1 GHz @ 50 Ω

No. of Channels: 2

No. of Digitizers: 2

Sampling Rate: Two channels in use: 1 MS/s to 1 GS/s; One channel in use: 2 MS/s to 2 GS/s

Sensitivity: 250 mV - 2.5 V or 100 mV - 1 V Full Scale Range (FSR), depending on model. 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 (up to 11 bits with Enhanced Resolution [ERES] with optional WP01 Advanced Waveform Math Package)

Bandwidth Limiters: 25 MHz, 200 MHz

Input Coupling: DC

Input Impedance: 50 Ω ±2%

Max Input Voltage: 2.5 V rms and ±5 V peak

Acquisition Modes

Single Shot: For transient and repetitive signals

Timebase System

Acquisition Memory Size:
100 kpts/ch on two active channels. 200 kpts on one active channel. Larger memory options available (L models: 4 Mpts/ch).

Capture Time Window:

Memory	@1 GS/s	@1 MS/s
100 k	0.1 ms	100 ms
500 k	0.5 ms	500 ms
2 M	2 ms	2 s
4 M	4 ms	4 s

Clock Accuracy: ≤10 ppm

Interpolator Resolution: 500 ps or sample size, whichever is larger.

External Reference:
Type: 10 MHz Square Wave
Coupling: AC
Impedance: 50 Ω
Level: 250 mV pk-pk min, 2V pk-pk max

Triggering System

Modes: Normal, Auto, Single, Stop

Sources: CH1, CH2, Ext

Slopes: Ch1, CH2: Positive, Negative Window; Ext: Positive, Negative

Coupling: DC

Pre-Trigger Recording: 0-100% of record size (adjustable in 1% increments)

Post-Trigger Delay: 0-1,000 times record size (adjustable in 1% increments)

Internal Trigger Range: ±FSR setting

Ext Trigger: ECL, TTL optional

Ext Trigger Max Input: ECL: 0.0 V to -4.0 V. TTL: 7.5 V to -11.5 V

Ext Trigger Range: ECL or TTL signal swing

Waveform Processing

Processing Functions: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging, and Sine x/x; four functions performable at one time.

Average: Summed averaging of up to 1000 waveforms in the basic instrument; up to 10^6 averages possible with optional WP01.

Extrema: Roof, Floor or Envelope values from 1 to 10^6 waveforms with WP01 Option.

ERES: Low-Pass digital filter provides up to 11 bits vertical resolution; sampled data always available even when trace turned off; any of above modes usable without destroying data with WP01 Option.

FFT: Spectral analysis with five windowing functions and FFT averaging, with optional WP02 Spectrum Analysis Package.

Histogramming and Trending: With optional WP03 Parameter Analysis Package, in-depth diagnostics on waveform parameters.

Internal Memory

Waveform Memory: Up to four 16-bit memories

Processing Memory: Up to four 16-bit waveform processing memories

System Memory: 16 Mbytes RAM; L models: 64 Mbytes RAM

Cursor Measurements

Relative Time: Provides time and voltage differences relative to each other

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

Interfacing

Remote Control: By Ethernet for all instrument controls, internal functions

Ethernet Port: 10/100 Base-T Ethernet

Ethernet Protocol: TCP/IP

Versatile Instrument Control Protocol (VICP): Allows Ethernet medium to emulate much of the GPIB behavior; remote command set conforms to the IEEE 488.2 standard to ensure compatibility with existing software.

General

Humidity: <80% RH (non-condensing)

Auto-Calibration: Ensures specified DC and timing accuracy; temperature: 5° to 40° C (41° to 104° F) rated accuracy, 0° to 45° C (32° to 113° F) operating

Power: 90-132 VAC or 180-250 VAC; 45-66 Hz; 200 W max

Altitude: Up to 4600 m (15,090 feet) operating, 40° C max

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

Dimensions: (HWD) 88 mm x 483 mm x 500 mm (3.24" x 19.0" x 19.7")

Warranty: Three years

CE Conformity

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

Safety: Conforms to EN61010-1: Protection Class 1, Installation (over-voltage) Category II, Pollution Degree 2

UL and cUL Listed: UL Standard: UL3111-1; cUL Canadian Standard: CSA-C22.2 No. 1010.1-9

Ordering Information

High-Speed Signal Analyzer	Product Code
1 GHz; 1 GS/s; 2 ch; 100 kpts/ch; Ethernet (250 mV - 2.5 V Full Scale Range, **Front** Panel BNCs)	LSA1000-01
1 GHz; 1 GS/s; 2 ch; 100 kpts/ch; Ethernet (250 mV - 2.5 V Full Scale Range, **Rear** Panel BNCs)	LSA1000-02
1 GHz; 1 GS/s; 2 ch; 100 kpts/ch; Ethernet (100 mV - 1 V Full Scale Range, **Rear** Panel BNCs)	LSA1000-09
1 GHz; 1 GS/s; 2 ch; 100 kpts/ch; Ethernet (100 mV - 1 V Full Scale Range, **Front** Panel BNCs)	LSA1000-12
1 GHz; 1 GS/s; 2 ch; 4 Mpts/ch; Ethernet (250 mV - 2.5 V Full Scale Range, **Front** Panel BNCs)	LSA1000-01L
1 GHz; 1 GS/s; 2 ch; 4 Mpts/ch; Ethernet (250 mV - 2.5 V Full Scale Range, **Rear** Panel BNCs)	LSA1000-02L
1 GHz; 1 GS/s; 2 ch; 4 Mpts/ch; Ethernet (100 mV - 1 V Full Scale Range, **Rear** Panel BNCs)	LSA1000-09L
1 GHz; 1 GS/s; 2 ch; 4 Mpts/ch; Ethernet (100 mV - 1 V Full Scale Range, **Front** Panel BNCs)	LSA1000-12L

Included with Standard Configuration	
Operator's Manual	LSA1000-OM
Remote Control Manual	LSA1000-RCM
Getting Started CD-ROM	LSA1000-GS
NIST Calibration Certificate	
Three-Year Warranty	

Hardware Options	
500 k memory/ch, 1 M memory/1 ch	LSA1000-M1*
1 M memory/ch, 2 M memory/1 ch	LSA1000-M2*
2 M memory/ch, 4 M memory/1 ch	LSA1000-M4*
TTL External Triggering	LSA1000-TTL
64 Mbyte System Memory (included in "L" models)	LSA1000-64MBSM

Software Options	
Advanced Waveform Math	WP01
FFT (Spectrum Analysis)	WP02
Parameter Analysis	WP03
PRML Analysis	PRML
Jitter and Timing Analysis	JTA
Basic Disk Drive Measurements (includes WP03)	DDM
Optical Recording Measurements	ORM
Disk Drive Failure Analysis	DDFA

Warranty & Calibration	
MIL STD Calibration	LSA1000-CCMIL
Five-Year Repair Warranty	LSA1000-W5
Five-Year Annual NIST Calibration Contract	LSA1000-C5
Five-Year Annual MILSTD Calibration Contract	LSA1000-CM5
Five-Year Warranty & NIST Calibration	LSA1000-T5

** These options are not applicable for "L" models, which have built-in 4 M memory/ch.*

LeCroy

3


TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
WAVE PILOT
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
LeCroy
Single Shot
Internal
Automatic
OFF
wavepro 960
ANALOG
PERSIST

LeCroy Analog Oscilloscopes

Some specific measurement problems are 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 overlaid signals**
- **Viewing signals requiring the fastest screen update rate**

To better serve customers, for these unique measurements, we have five high-performance analog oscilloscopes.

Analog oscilloscopes have display characteristics that provide specific visual information that is otherwise difficult to obtain.

Grey-scale and persistence analog displays show faster signals more faintly 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 overlaid 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 per second than a digital scope and can enable you to see waveform behavior in real time.

Ultra High Writing Speed with Variable Persistence

Based on a unique scan converter technology, LeCroy offers an analog variable persistence oscilloscope, the Model LA354, with a visual writing speed of 5 div/ns and a display update rate up to 1,000,000 times/sec. This is the fastest analog storage product available in today's market.

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 and particle detectors

Analog Oscilloscope Selection Guide

LeCroy Model Number	Analog BW (Minimum)	Number of Channels	Fastest Sweep Rate	Input Range
LA354	500 MHz	4 (2+2)	500 ps/div	2 mV/div - 5 V/div
LA314H	470 MHz	4 (2+2)	500 ps/div	2 mV/div - 5 V/div
LA314	400 MHz	4 (2+2)	500 ps/div	2 mV/div - 5 V/div
LA303	200 MHz	3 (2+1)	1 ns/div	2 mV/div - 5 V/div
LA302	100 MHz	3 (2+1)	2 ns/div	2 mV/div - 5 V/div

LA354 Analog Storage Scope



Main Features

- 500 MHz bandwidth
- 5.5" Color TFT LCD display
- Trigger and display update rate of one million per second
- Writing speed 5 div/ns
- Variable persistence storage
- Timebase dual delay
- Four channels
- High-speed auto setup
- Cursor measurements
- Event and burst trigger modes
- Full TV trigger with clamping
- Save and recall panel settings
- Frequency counter
- Wide input offset range
- High-intensity CRT
- Power for FET probes

With four channels and 500 MHz bandwidth, these leading-edge oscilloscopes offer the highest level of analog 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 color TFT-LCD screen, effectively displays and stores these "grey scaling" and "persistence" effects with up to 5 div/ns writing speed, 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 LA354 a truly universal oscilloscope.

Typical applications include:

- 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 and 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 its 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" color 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)

Risetime: 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; 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

Risetime: Approx. 700 ps

Input Coupling: AC, DC

Input RC: Direct: 1 MΩ ±1.5%// 16 pF + 2 pF

Maximum Input Voltage: ±400 V

Probe Sensors: 1:1, 1:10, 1:100 detection possible

Triggering

A Triggering

Sources: CH1, CH2, CH3, CH4, Line

Coupling: AC, DC, HFREJ, LFREJ

Polarity: Positive (dark)/negative (bright)

TV Sync - Line Selection:
NTSC: 1 - 525H
PAL (SECAM): 1 - 625H
HDTV: 1 - 1125H

B Triggering

Sources: CH1, CH2, CH3, CH4

Coupling: AC, DC, HFREJ, LFREJ

Polarity: Positive/Negative

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

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 ±0.1%

Output Voltage: 0.6 V ±1%

Power for FET probes

Voltage: Two each +12 V outlets for two FET probes, offset control available

Counter

Display Digits: Five 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 and ΔV can be measured simultaneously

Power

Voltage Range: AC 90 V - 250 V

Frequency Range: 48 Hz - 440 Hz

Power Consumption: 150 VA max.

Dimensions and Weight

Approx. (WDH) 320 mm x 160 mm x 420 mm

Weight: Approx. 8.5 kg (19.8 lbs)

Warranty: Three years

Ordering Information

Analog Oscilloscopes	Product Code
500 MHz, 4-Channel Color Storage	LA354

Included with Standard Configuration	
Two each 10:1 10 MΩ Passive Probes	PP005
Operators Manual	
Panel Cover	
Accessory Pouch	
Power Cable	
2 Fuses	

Accessories	
800 MHz FET Probe	SFP-4A
1 GHz FET Probe	SFP-5A
NIST Calibration	LAXXX-CCNIST
MIL Standard Calibration	LAXXX-CCMIL

LA314 & LA314H Analog Scopes



Main Features

- 400 & 470 MHz
- Four 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
- Wide input offset range
- High-intensity CRT
- Power for FET probes

The LA314 and LA314H analog oscilloscopes offer four channels and up to 470 MHz bandwidth.

The scopes' displays provide important clues that digital scopes cannot. And the LA314's meshless CRT displays "grey scaling" and "persistence" effects, with an ultrafast display update rate to let you see how waveforms behave in real time.

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

Visit our web site at: www.lecroy.com

Features

DC-470 MHz, 4 Ch

Four channels up to 470 MHz are available, with CH1 and CH2 boasting the widest frequency range and 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 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 two 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" 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):

Model LA314H
470 MHz (5 mV/div - 50mV/div)
440 MHz (2 mV/div, 100 mV/div - 5V/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; 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): 400 MHz

Risetime: Approx. 875 ps (bandwidth x risetime = 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

A Triggering

Sources: CH1, CH2, CH3, CH4

Coupling: AC, DC, HFREJ, LFREJ

Polarity: Positive (dark)/negative (bright)

TV Sync - Line Selection:
NTSC: 1 - 525H
PAL (SECAM): 1 - 625H
HDTV: 1 - 1125H

B Triggering

Sources: CH1, CH2, CH3, CH4

Coupling: AC, DC, HFREJ, LFREJ

Polarity: Positive/Negative

Event Delay:
Count: Setting range: 1 - 65535 (max 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

Mod 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

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 ±0.1%

Output Voltage: 0.6 V ±1%

Power for FET probes
Voltage: Two each +12 V outlets for two FET probes, offset control available

Counter
Display Digits: Five 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 and ΔV can be measured simultaneously

Power
Voltage Range: AC 90 V - 250 V

Frequency Range: 48 Hz - 440 Hz

Power Consumption: 150 VA max.

Dimensions and Weight
Approx. (WDH) 320 mm x 160 mm x 420 mm

Weight: Approx. 8.5 kg (19.8 lbs)

Warranty: Three years

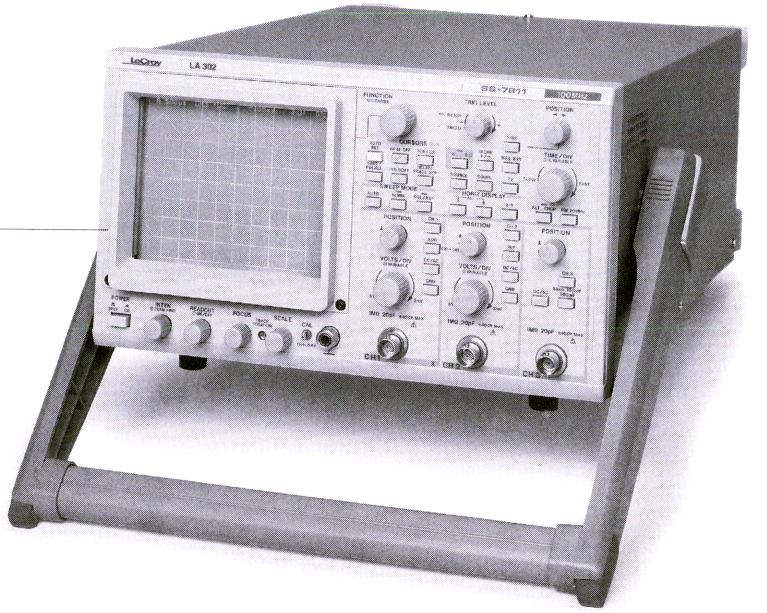
Ordering Information

Analog Oscilloscopes	Product Code
470 MHz, 4-Channel	LA314H
400 MHz, 4-Channel	LA314

Included with Standard Configuration:	
Two each 10:1 10 MΩ Passive Probes	PP005
Operator's Manual	
Panel Cover	
Accessory Pouch	
Power Cable	
Two Fuses	

Accessories	
800 MHz FET Probe	SFP-4A
1 GHz FET Probe	SFP-5A
Calibrator	IE-1066
NIST Calibration	LAXXX-CCNIST
MIL Standard Calibration	LAXXX-CCMIL

LA302 & LA303 Analog Scopes



Main Features

- 100 & 200 MHz
- 2 + 1 channels
- Sensitivity of 2 mV/div max
- Max sweep speed of 1 ns/div
- High-speed auto setup
- Cursor measurements
- Full TV trigger with field and line selection
- Save and recall panel settings
- Frequency counter
- High-intensity CRT

The LA302 and LA303 analog oscilloscopes offer three channels and up to 200 MHz bandwidth. They have high-level performance and low cost.

They are perfect instruments for service and educational applications. Equipped with extensive TV triggering, both scopes are excellent for video testing.

Like the other LeCroy analog scopes, their standard multipurpose trigger, five-digit counter, and comprehensive cursors make them useful and universal Instruments.

Features

Convenient Fine-Adjustment Mode
Pressing FINE and turning the knob enables slow scrolling of waveforms – a function comparable to a digital storage scope's roll mode.

Line Triggering Provided for AC Line Measurement
AC line-related measurement of various frequencies can be obtained.

Third-Channel Input
CH3 provides three sensitivity levels for a wider range of measurements.

Input with Probe Sensor Function
When using a probe, the range display is automatically calibrated by detecting 10:1 or 100:1 with the probe sensor.

Specifications

Display

CRT: 6-inch rectangular, internal graticule (8 x 10 div with scale illumination), meshless CRT

Accelerating Voltage: Nominal 16 kV

Vertical Deflection System

Mode: CH1, CH2, CH3, ADD, ALT, CHOP

Frequency Response:
Model LA302:
5 mV/div - 5 V/div, DC 100 MHz;
2 mV/div, DC 50 MHz

Model LA303:
5 mV/div - 5 V/div, DC 200 MHz;
2 mV/div, DC 50 MHz

Accuracy: ±2%

Bandwidth Limiter: 20 MHz

Risetime:
Model LA302: 3.5 ns or less
Model LA303: 1.75 ns or less

Signal Delay Time: At least 30 ns

Input RC Direct: 1 MΩ ±1.5% // 20 pF ±2 pF

Input RC with Probe: 10 MΩ ±3% // 12.5 pF ±2 pF

Max Input: Direct, ±400 V max, with 10:1 probe, ±600 V max

Polarity Switching: Possible only for CH2

Channel 1 & 2

Sensitivity: 2 mV/div - 5 V/div, 11 step (1-2-5); 2 mV/div - 12.5 V/div (with vernier)

Input Coupling: AC, DC, GND (The lowest usable frequency is 4 Hz with AC coupling.)

Channel 3

Sensitivity: 50 mV/div, 100 mV/div, 500 mV/div, ±2%

Input Coupling: AC, DC

A Triggering

Sources: CH1, CH2, CH3, LINE

Coupling: AC, DC, HFREJ, LFREJ

B Triggering

Sources: CH1, CH2, CH3

Coupling: AC, DC, HFREJ, LFREJ

TV Triggering: ODD, EVEN, BOTH, line selection, TV system (NTSC, PAL/SECAM — HDTV optional in LA302, standard in LA303)

Trigger Sensitivity
LA302: DC - 10 MHz, 0.4 div
10 - 100 MHz, 1.0 div

LA303: DC - 10 MHz, 0.4 div
10 - 100 MHz, 1.0 div
100 - 200 MHz, 1.5 div

B sweep

Sweep Time:
Model LA302: Fastest range, 20 ns/div; slowest range, 5 ms/div; accuracy A/B, ±2%

Model LA303: Fastest range, 10 ns/div (1-2-5 step); slowest range, 5 ms/div; accuracy A/B, ±2%

Magnifier: 10 times

Accuracy: ±3%

Fastest Range:
Model LA302: 2 ns/div
Model LA303: 1 ns/div

Delay Jitter: 1/20,000

Hold-Off Time: Variable (up to sweep length or longer)

Auto Setup

Input Channel: CH1, CH2

Frequency Response: 50 Hz – 50 MHz

CH2 Signal Output (factory option):
Model LA302: DC 50 MHz

Model LA303: DC 100 MHz

EXT Z-axis Input (factory option): 0.5 Vp-p

Utilities

Calibrator

Waveform: Square-wave, 1 kHz ±0.1%, 0.6 Vp-p ±1%

CTR Readout

Readout: Attenuator range, ADD, UNCAL, AC/DC/GND, vertical mode, CH2 polarity, A/B sweep range, x10 MAG, UNCAL, horizontal display mode, hold-off, trigger coupling, trigger source, trig slope, TV-field, TV-line, TV-system (NTSC, PAL/SECAM for both models — HDTV in the LA303)

Cursor Measurement

Time Difference: ΔT

Voltage Difference: ΔV

Division Calculation by ΔT: 1/ΔT

Frequency Counter

Display Digits: 5 digits, decimal

Accuracy: ±0.01%

Frequency Measurement range:
Model LA302: 2 Hz - 100 MHz (option six digit)

Model LA303: 2 Hz - 200 MHz, reciprocal (option six digit)

Save/Recall Function

Number of Panel Setups:
Model LA302 and LA303: 32 max

Model LA302: 255 in banks of 63

Backup: Battery back-up (approx. 30,000 hr)

Power Supply

Voltage Range: AC 90 V - 132 V/180 V - 250 V

Frequency Range: 48 Hz - 440 Hz

Power Consumption: 110 VA max

Dimensions and Weight

Dimensions: 272W x 152H x 410L

Weight: Approx. 7.5 kg (w/o access)

Environmental Conditions

Operating: 0° C – +40° C, 90% RH (40° C)

Performance Guarantee: +10° C – +35° C

Ordering Information

Analog Oscilloscopes	Product Code
100 MHz, 3-Channel	LA302
200 MHz, 3-Channel	LA303

Included with Standard Configuration	
Two each 10:1 10 MΩ Passive Probes	PP005
Operator's Manual	
Panel Cover	
Power Cable	
Two Fuses	

Accessories	
800 MHz FET Probe	SFP-4A
1 GHz FET Probe	SFP-5A
Calibrator	IE-1066
NIST Calibration	LAXXX-CCNIST
MIL Standard Calibration	LAXXX-CCMIL

Visit our web site at: www.lecroy.com

The Analog Advantage

The analog oscilloscope has inherent advantages for viewing complex signals. These include fast update rates and rearm times that allow viewing waveform changes in real time. Effects of adjustments on the device under test are immediately visible on the bright analog display. The ease of use and "alias-free" display afforded by analog scopes make them the ideal choice when you are making critical measurements, especially when setup time is limited.

Video Standards Summary

	Total Lines	Active Lines	Aspect Ratio	Frame Rate (Hz)
NTSC	525	484	4:3	29.94
PAL/SECAM	625	575	4:3	25

Video Triggers, Pedestal Clamping, Delayed Traces

Three major TV standards are presently in use: a) National Television Systems Committee (NTSC), b) Phase Alternation Line (PAL), and c) Sequential Couleur avec Memoire (SECAM). The differences between PAL, SECAM, and NTSC video systems are defined in their respective standards. Each system has a set of recommended test practices, which exploit the advantages of an analog scope equipped with TV trigger - such as the LeCroy analog scopes.

PAL, SECAM, and NTSC

All three systems use the same definition for luminance, but not for primary R, G, and B colors. The major differences between the systems are the number and frequency of horizontal lines.

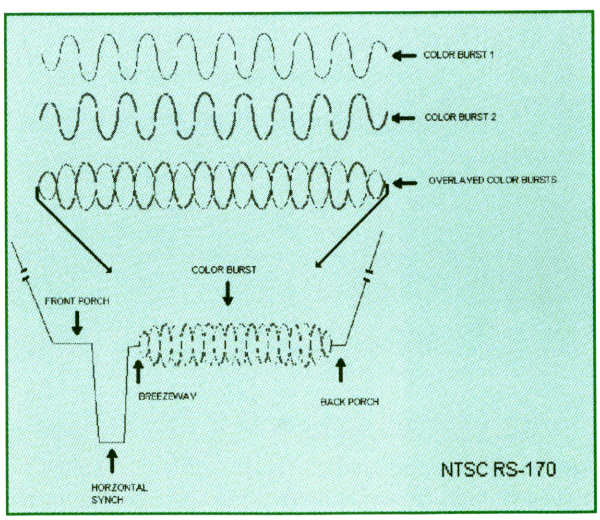
NTSC is mainly used in the United States and Japan. NTSC 525/60 refers to 525 lines at a 60 Hz rate (30 frames per second).

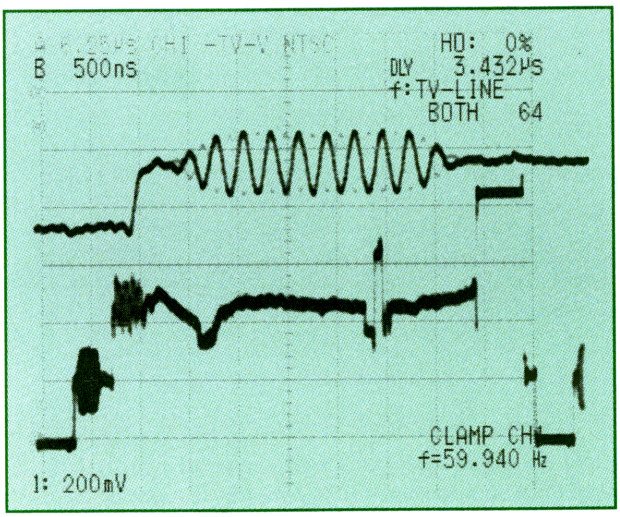
PAL is used in parts of Europe. PAL 625/50 refers to 625 lines at a 50 Hz rate (25 frames per second).

SECAM is used in France and many parts of the former Soviet Union. SECAM 625/50 refers to 625 lines at a 50 Hz rate (25 frames per second). PAL and SECAM differ in chroma modulation.

Measurements

Compositie video is typically monitored while triggering in line rate or horizontal sync rate. The line rate allows selection of Field 1 (ODD), Field 2 (EVEN), or Fields 1 and 2 sequentially (BOTH).





Figures 1a & 1b: Color burst and composite video line (single shot, triggered on both fields, line number 64, zoom on burst).

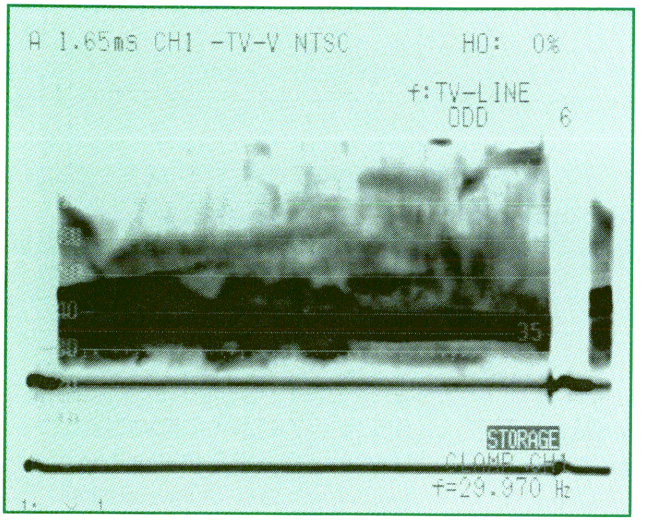


Figure 2: Composite Video; TV Line Trigger (Odd Field Line Number 6) displaying one full video frame.

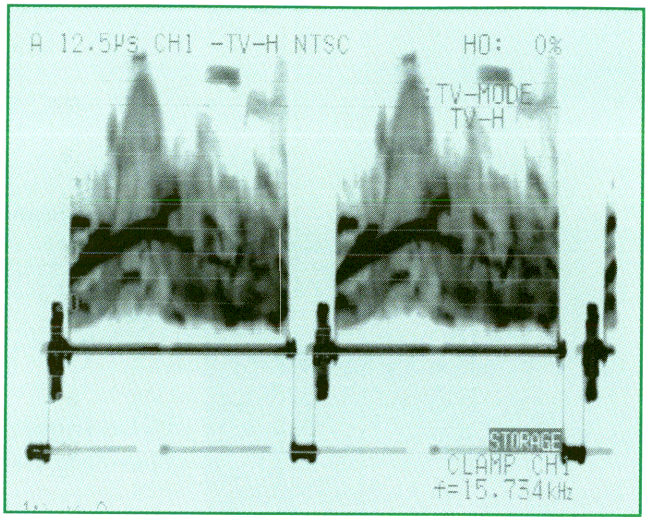


Figure 3: Composite Video 2H with EIA scales displayed on an LA354 analog storage scope.

NTSC Example Measurements

The screens in Figures 2 and 3 show the variable timebase triggering and EIA and CCIR scaling on the oscilloscope. The TV line trigger (TV-BOTH, ODD, EVEN) can be selected to view the signal with respect to line rate. Setting the timebase to 3.24 ms/div, the scope will display one full frame (two fields) of video (Figure 4). The delay function allows examination of one line while displaying the entire frame. This useful feature lets a user view one "pixel" while monitoring the full video frame.

The horizontal sync trigger (TV-H) is used to display two adjacent horizontal (2H Display) lines (Figure 5).

The scope's rear panel output lets the user measure video while outputting the same signal to a specialized device such as a vector scope, video monitor, or lower-impedance device that loads the device under test.

When using the scope to measure video, the variable timebase lets the scope perform specific video measurements that require timebase settings not achievable with scopes having fixed 1-2-5 time steps. The variable timebase is calibrated so that valid time per division and frequency measurements can be made while in variable mode. Amplitude can be adjusted in the same way. The amount of display compression is displayed on the screen when variable amplitude is invoked or changed. The highest performance analog scope, model LA354, even has the added feature of an IRE unit scale when in CCIR or EIA scales.

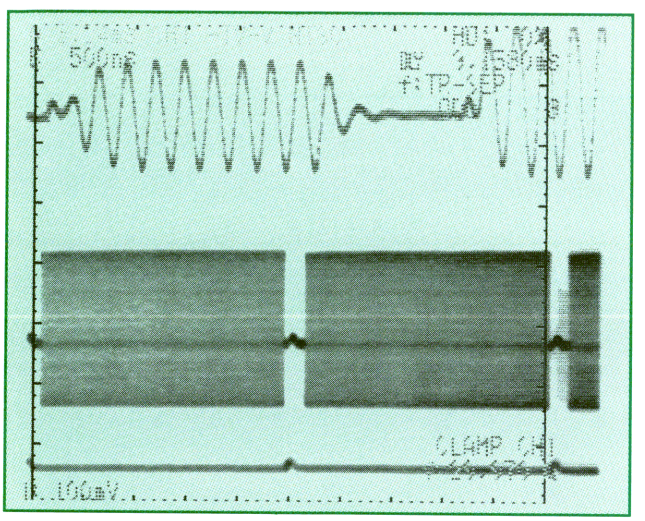


Figure 4: Examine color burst while viewing a frame. Line trigger (ODD 9) with Trace A 3.24 ms/div (32.4 ms duration); Trace B expanding one line to 500 ns/div (5 µs duration).

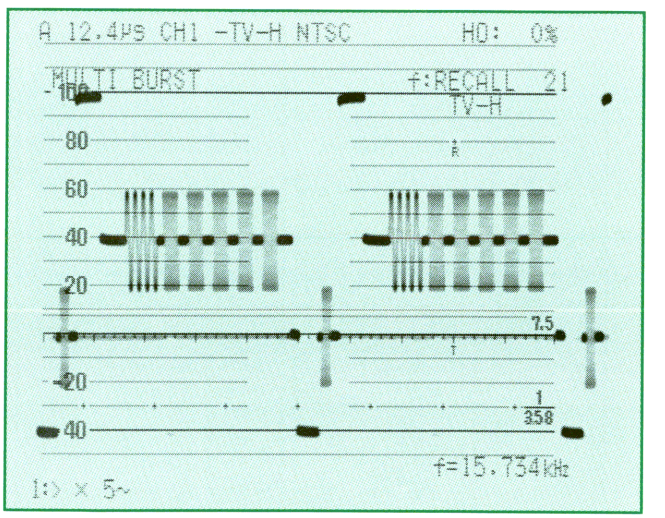


Figure 5: TV-H trigger with EIA scales with 2H displays of multiburst test pattern. Note that the frequency counter displays the trigger rate as horizontal sync frequency.

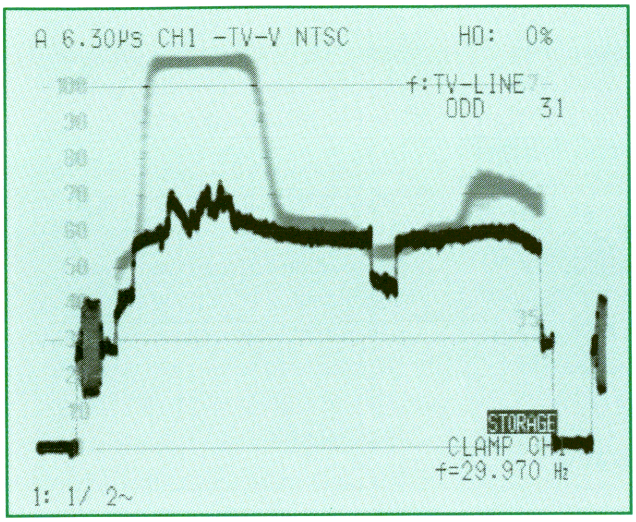


Figure 6: TV Line Trigger (ODD 31); Bottom trace is live feed, top trace is stored.

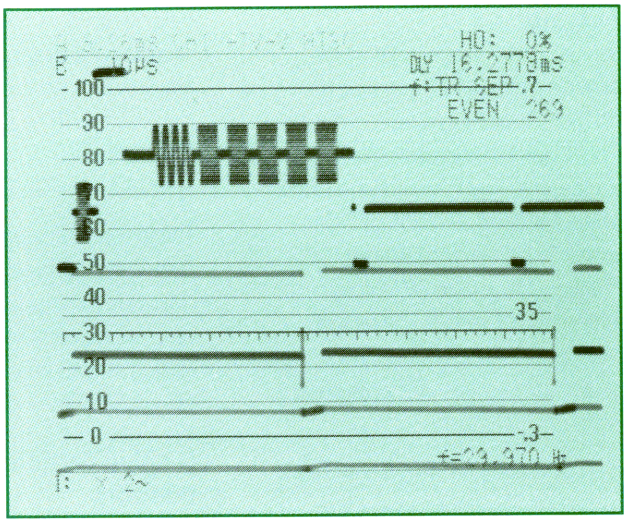


Figure 7: TV Line Trigger EVEN 269; Trace A 3.24 µs/div (32.4 µs duration). Trace B 10 µs/div (100 µs duration) displaying the only line in the field with multiburst pattern. All other lines are 100 IRE for 1/4 duration, then drop to 7.5 IRE.

Using the TV Trigger

These step-by-step descriptions walk you through the signal easy hookup and scope adjustments for triggering on video signals.

1. Input composite video signal of any format to CH 1 or CH 2.
2. Depress the TV Trigger key to select TV Trigger.
3. Depress AUTO SET. Observe the scope's SMART Trigger. Select the appropriate TV Trigger type triggering at the TV Horizontal rate (See Figure 5).

Selecting TV Trigger Type

Depressing the TV key selects the TV type. Each time the TV key is depressed the TV selection will toggle among:

a) TV-H (Horizontal Sync): The sweep is triggered by the horizontal synchronization pulse.

b) ODD (Odd Field Lines): The sweep is triggered by the selected horizontal synchronization signal in the odd-numbered field (See Figure 6).

c) EVEN (Even Field Lines): The sweep is triggered by the selected horizontal synchronization signal in the even-numbered field (See Figure 7).

d) BOTH (Odd or Even Lines): The sweep is triggered by the selected line number of a horizontal synchronization signal in the odd-numbered and even-numbered fields.

e) OFF (Non-TV Trigger)

TV CCIR and EIA Scales

When the CCIR or EIA scale is selected, the display changes the vertical axis to match that standard. Signal amplitudes can be measured from the display in standard units. For EIA, the input is scaled as 1 V = 140 IRE full scale. For the CCIR, the input is scaled as 1 V = 100 IRE full scale. When VARIABLE is selected, the voltage cursor (ΔV) measurement ΔV1/ΔV2 = IRE is displayed.

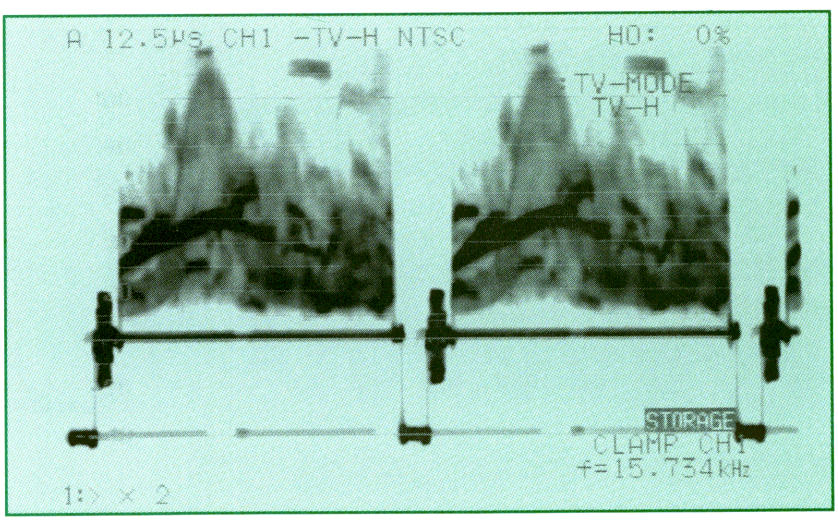


Figure 8: TV-H Trigger — 2H display with EIA scales. The white trace is a live field.

TV Clamp

When using the scope in TV mode, enable clamping by depressing the EVENT/TV CLAMP key. Clamping locks the back porch of composite signals to the reference level (ground level). This enables stable observation of DC-coupled TV signals without the fluctuation of average DC voltage resulting from changes in average picture level. The pedestal clamp trigger provides stable measurements on video signals.

Each time the EVENT/TV CLAMP key is depressed in TV trigger mode, the operation toggles: CLAMP CH1, or CLAMP CH2, or OFF. The selected clamp is displayed at the bottom right corner of the screen. Figure 1b (on page 13) shows an example of the position of the back porch and channel clamp display.

Using Dual Timebases in Video

All LeCroy analog scopes let you use delayed traces to show two timebases on a signal. This lets you examine a large section of the waveform in one timebase, while zooming on details in a faster timebase. In Figure 1b, one timebase displays a line of video, and the second timebase expands the color burst. Delay timebase provides more resolution on long duration signals. The LA354 has dual delay, which lets the user examine two sections of a larger waveform. These features are particularly useful when measuring VTR head switch points on an RF envelope, or Subcarrier to Horizontal Sync Phase for Gen-Lock.

The inherent analog fast update rate, responsive controls, crisp, alias-free display, fast retrigger rate, TV triggers, and ease-of-use combine to make LeCroy analog scopes an indispensable tool, especially to the video engineer.

Display Techniques and Benefits

In a digital storage oscilloscope (DSO), the display is an adjunct function to the instrument's data acquisition capability. In an analog oscilloscope, the CRT display is the heart of the scope and is integral to waveform capture. In fact, the vertical deflection amplifier and tube response characteristics dominate an analog scope's performance.

CRTs

LeCroy analog oscilloscopes feature a meshless, flat-scan expansion CRT and bright phosphor. The meshless design offers several advantages over traditional dome mesh CRTs. The meshless design means more brightness on the display due to fewer obstructions for the electrons to reach the phosphor. As a result, LeCroy analog CRTs are twice as bright as a domed mesh CRT with the same acceleration potential.

Additionally, LeCroy meshless CRTs are flat-expansion and are astigmatism free. The meshless CRT astigmatism is affected only by high-voltage power supply adjustments. Hence, there are no front-panel astigmatism adjustments for LeCroy analog scopes, and there are no changes in astigmatism with changes in sweep speed.

The other characteristics that determine brightness are:

1. CRT display dimensions
2. External CRT Filter
3. Ambient lighting
4. Halation

CRT display dimensions: The larger the viewing area (electron beam target area), the more the beam is dispersed. However, a larger viewing area enhances the viewing waveform details. Conversely, the smaller the viewing area, the brighter the display, but resolution is decreased.

External CRT filter and ambient lighting: Some scopes utilize a black matte external CRT filter. The filter enhances beam contrast by giving a black background but has a transparency

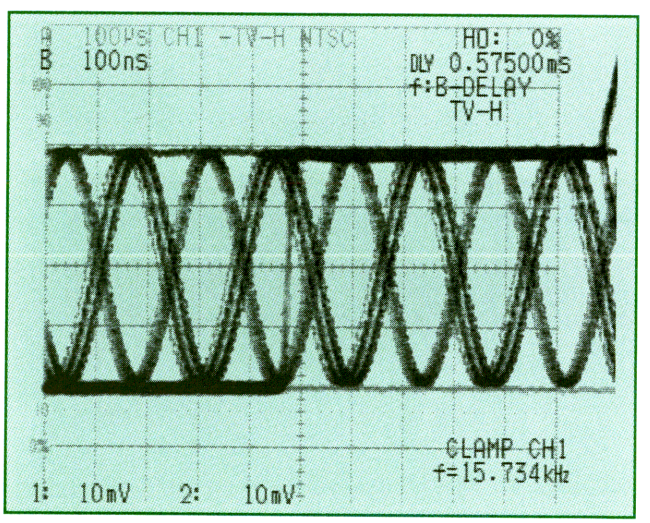


Figure 9: SCH Fine Adjust out of phase; the zero crossings and 50 percent point are separated.

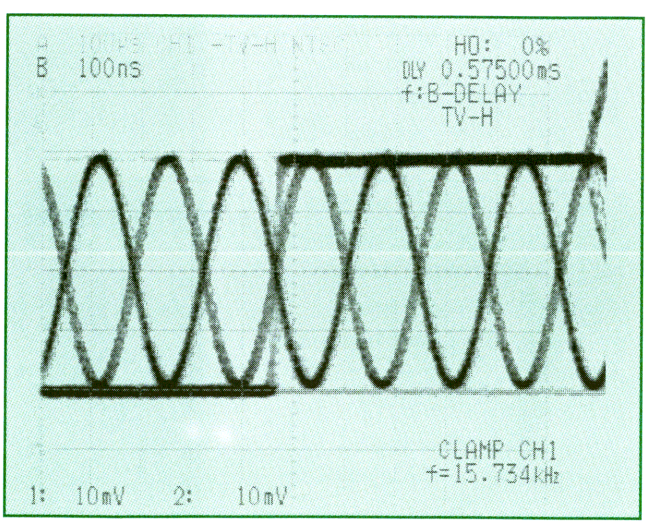


Figure 10: SCH Fine Adjust in phase, with crossing coincident.

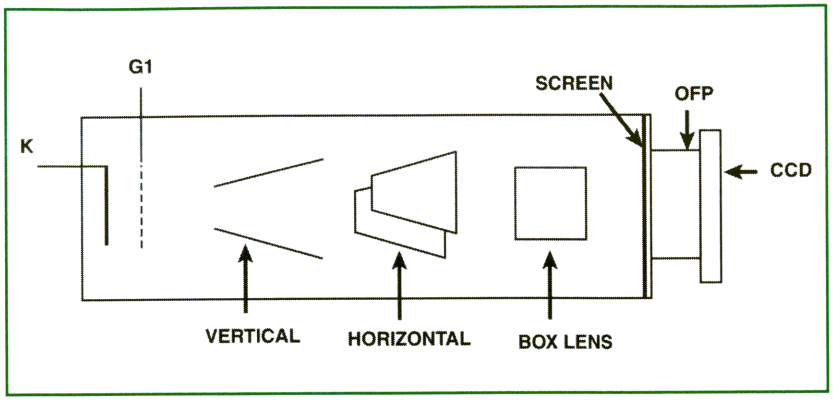


Figure 11: "Cutaway" view of scan converter tube.

loss of about 75 percent. Such filters are typically used in bright ambient lighting conditions where CRT glass and graticule reflections interfere with viewing.

Ambient lighting: The amount of ambient lighting affects the visibility of the signal on the screen. LeCroy scopes have a high-efficiency phosphor to ensure maximum brightness even for faint low rep rate signals.

Halation: Halation is the result of phosphor illumination caused by unwanted internal CRT electron beam reflections. Halation is usually the most pronounced when in horizontal magnify 10x operation at or near maximum brightness. The result is a poorly defined trace contrasted against a bright background. This is due to stray electrons from the main beam randomly illuminating the phosphor. Because LeCroy analog scopes have meshless CRTs, they are less susceptible to halation than are competitive scopes.

Combining Analog, Storage and Color Technologies

LeCroy analog oscilloscopes provide up to 500 MHz bandwidth signal capture. Using a unique scan converter technology, the LA354 provides an advanced combination of analog scope and digital scope technology to provide a low-cost color analog storage scope. Color lets you optimize the display for viewing waveforms by assigning persistence trace, scale, text, and background to different colors.

Scan Converter Tube

The design of LeCroy's analog storage scope is shown in Figure 11. In the LA354, the scan converter tube is the device used to convert the CRT trace into video format by means of a Charge Coupled Device. The scan converter tube consists of:

a) Meshless flat-expansion CRT with high-efficiency phosphor,

b) Optical Fiber Plate (OFP), and

c) Charge Coupled Device (CCD).

The CRT has approximately 20 kV acceleration potential applied between the cathode and the grid. The electron beam is deflected by VERTICAL and HORIZONTAL deflection plates during the active sweep time. The beam is expanded by the box lens and then projected onto the phosphor. The phosphor is excited by the applied beam and emits light.

The input waveform is displayed on CRT phosphor and captured by a CCD through the OFP.

The OFP is a bundle of many thin optical fibers. It provides electrical isolation from the CRT operating at 20 kV and the CCD at 0 V. It is also designed to maximize writing intensity on the scope.

Writing Speed for Seeing Glitches and Anomalies

Writing speed is the analog ability to visibly display a transition. The writing speed is similar to a DSO's single-shot bandwidth. Writing speed is expressed in divisions per unit of time. It represents the electron beam moving across the CRT and producing a visible trace. An additional benefit of the scan converter technique employed by the LA354 is a fast rearm and retrigger time. The reduction in CRT size correspondingly reduces the horizontal deflection voltage necessary to deflect the beam. As a result, the flyback, rearm and retrigger times are reduced, enabling the scope to rearm up to 1,000,000 times per second at 5 ns/div time setting.

LA354 Signal Capture — AUTO or NORM Sweep Speed

The waveform is displayed on the CRT phosphor, and the CCD captures the image. The CCD is similar to a video camera in RECORD mode. The CCD output video signal is input first to video RAM, then to both the display and the rear-panel composite video output BNC.

Sweep Modes

The analog storage scope LA354 can be operated with auto, normal and single sweep modes. The signal written to the CCD is updated to video RAM and displayed on the scope screen.

Example: Sweep rate 0.1 µs/div, total sweep period 1 µs.

The trigger signal evokes the sweep start and records to video RAM. After 1 µs, the CRT sweep stops, but recording to video RAM continues for approximately 66 ms. After stopping the sweep, the CRT-displayed waveform still remains on the screen, because the screen phosphor (P31) has a finite decay time.

Waveform Capture

The LA354 has only one scan converter tube. During multiple channel operation, the traces are sequentially captured from Channel 1 through Channel 4 in order. During delayed operation, the traces are captured in sequential order from CH 1, CH 1 delayed 1, CH 1 delayed 2, CH 2, CH 2 delayed 1, CH 2 delayed 2, etc.

The image in Figure 12 was taken using an LA354 in infinite persist mode. The signal was a ~500 ps risetime pulse edge. The persistence trace was used to capture pulse timing jitter.

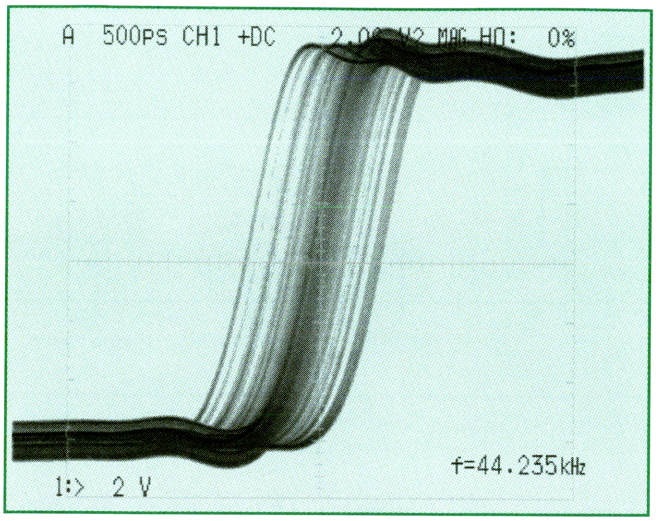


Figure 12. Fast rise pulse with persistence on.

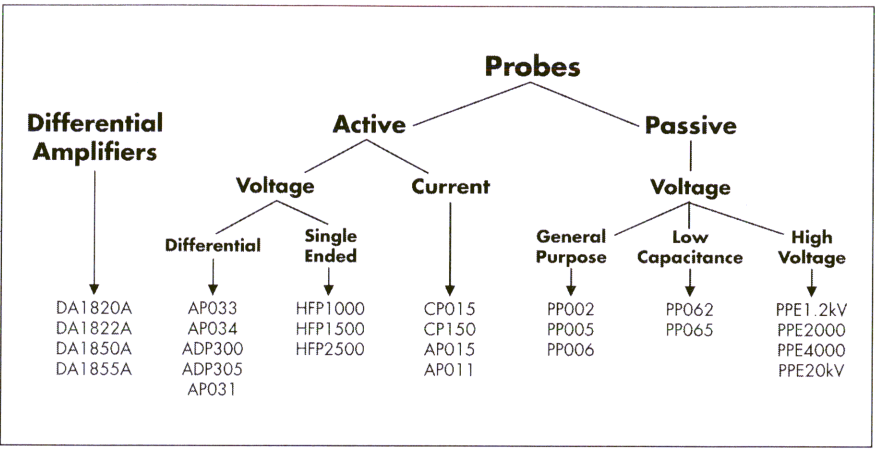
4


LeCroy
TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
Off On
Record up to
WAVE PILOT
ANALOG PERSIST
wavepro 960

Probes and Accessories

In This Section

- Passive Probes
- Active Voltage Probes
- Differential Probes
- Differential Amplifiers
- High Voltage Differential Probes
- High Voltage Passive Probes
- Current Probes
- General Purpose Accessories
- Instrument Carts
- Carrying Cases



Which Probe Is Right For You?

Selecting the right type of probe for an application is a large part of attaining a high quality measurement. There are a number of factors that need to be considered when choosing a probe including signal type, bandwidth, and the source impedance of the circuit.

The figure above depicts many different types of probes. In classifying oscilloscope probes, there are generally three types of signals: voltage, current and "other." Voltage signals are by far the most common signal type. They are found in applications ranging from circuit board testing to power devices. Current signals are commonly measured from power lines and other types of wire. Current probes measure the magnetic field surrounding a conductor, as opposed to voltage probes which touch the test point directly. "Other" signal types encompass all the other variants of measurable signals that are not voltage or current. These include thermal or optical measurements. LeCroy has an optical-to-electrical converter (OE-325) that can be found in Section 10, page 192.

Bandwidth and source impedance are closely related when choosing which probe to use. As the frequency of the measurement increases, the effect of the capacitance and impedance of the probe become more important. At high frequencies, attaching a probe to a circuit can have a negative effect on signal fidelity. This is why the probe's input impedance and capacitance are important. Probes with lower capacitance and higher impedance will cause less signal degradation at higher frequencies. Active probes are ideal for measuring high frequencies. LeCroy's HFP series probes have 0.7 pF input capacitance and 100 kohm impedance thereby providing minimal circuit loading for high frequency applications.

Passive probes are well suited to lower frequency measurements. A probe with 10 pF of input capacitance will be able to measure frequencies up to 300 MHz in most applications. Source impedance is not an issue at lower frequencies. In this case, high-impedance passive probes are commonly used.

Passive Probes – PP002, PP005, PP006, PP062, PP065, SS-082R, SS-0130R



Main Features

- **Bandwidth from 350 MHz to 1 GHz**
- **Probe encoding ring for automatic scale factor readout on LeCroy oscilloscopes**

High Impedance Passive Probes

Frequency compensation on high impedance probes is accomplished through the use of adjustment screws. All LeCroy digital oscilloscopes provide a calibration output on their front panel to enable this adjustment. The LeCroy WavePro, Waverunner and LC series oscilloscopes provide internal capability of adjusting both amplitude and frequency of the calibration output to suit user preferences. The output is applied to a front panel connector for easy access while adjusting the probes.

Low Capacitance Passive Probes

Low capacitance passive probes provide a better solution for higher frequency applications than high impedance passive probes. They are less expensive then high bandwidth active probes, however they only work on a 50 Ω input.

Compatibility:

1= LCxxx, 93xx, LA314, LA354
2= Waverunner scopes
3= 9304, LT224
4= LA303/314
5= LA302, LPxxx
6= WavePro

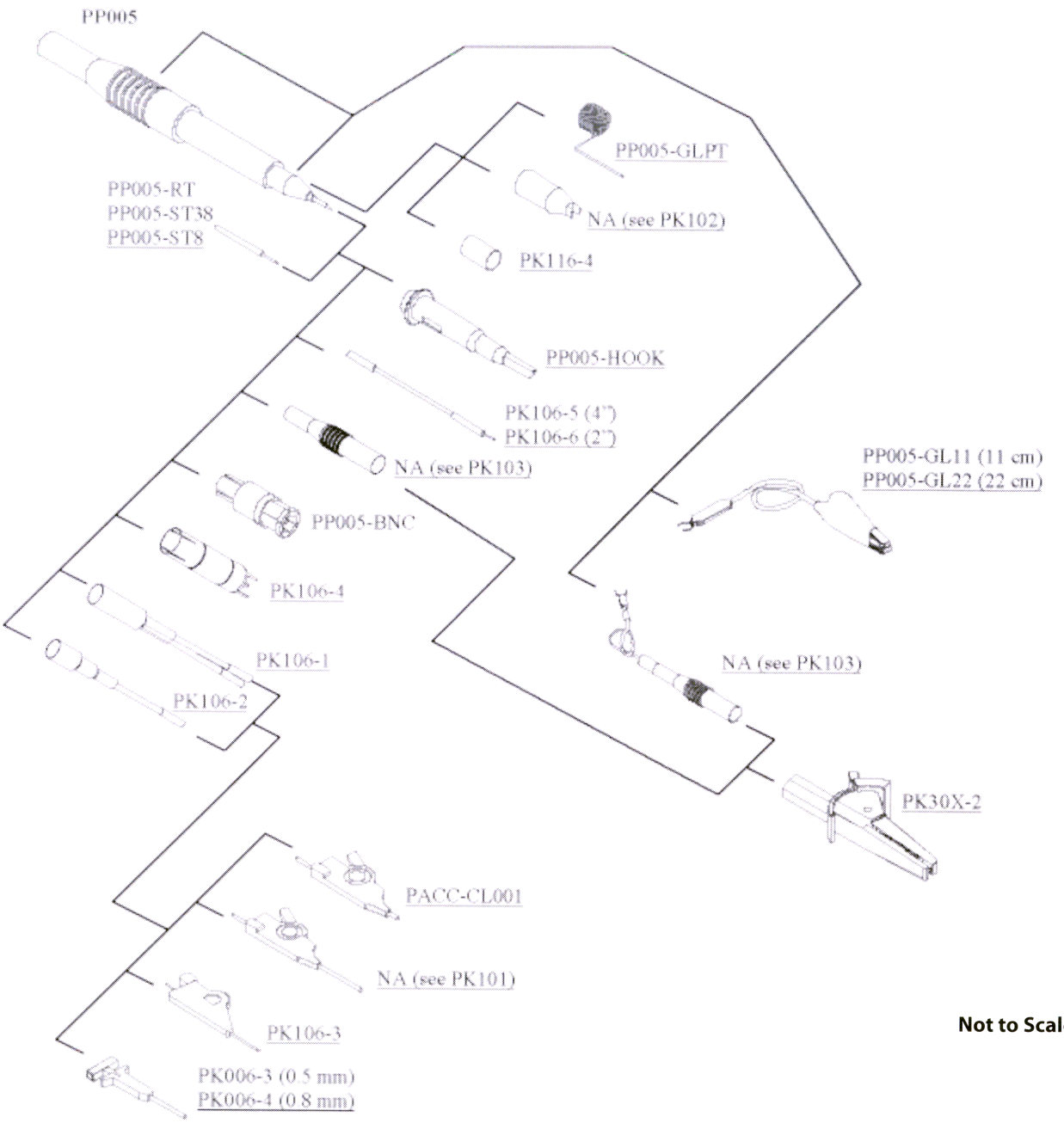
High Impedance Passive Probes

Model Number	Bandwidth	Input R	Input C	Attenuation	Maximum Voltage	Recommended Oscilloscope
PP002	350 MHz	10 M Ω	14.0 pF	÷10	500 V Cat I	3
PP005	500 MHz	10 M Ω	11.0 pF	÷10	500 V Cat I	1,6
PP006	500 MHz	10 M Ω	12.0 pF	÷10	600 V Cat II	2
SS-082R	400 MHz	10 M Ω	13.0 pF	÷10	600 V	4
SS-0130R	100 MHz	10 M Ω	12.5 pF	÷10	600 V	5

Low Impedance Passive Probes

Model Number	Bandwidth	Input R	Input C	Attenuation	Maximum Voltage	Recommended Oscilloscope
PP062	1,000 MHz	500 Ω	1.5 pF	÷10	22 V	1,2,6
PP065	1,000 MHz	5 k Ω	1.3 pF	÷100	30 V	1,2,6

PP005 – Recommended Accessory Diagram



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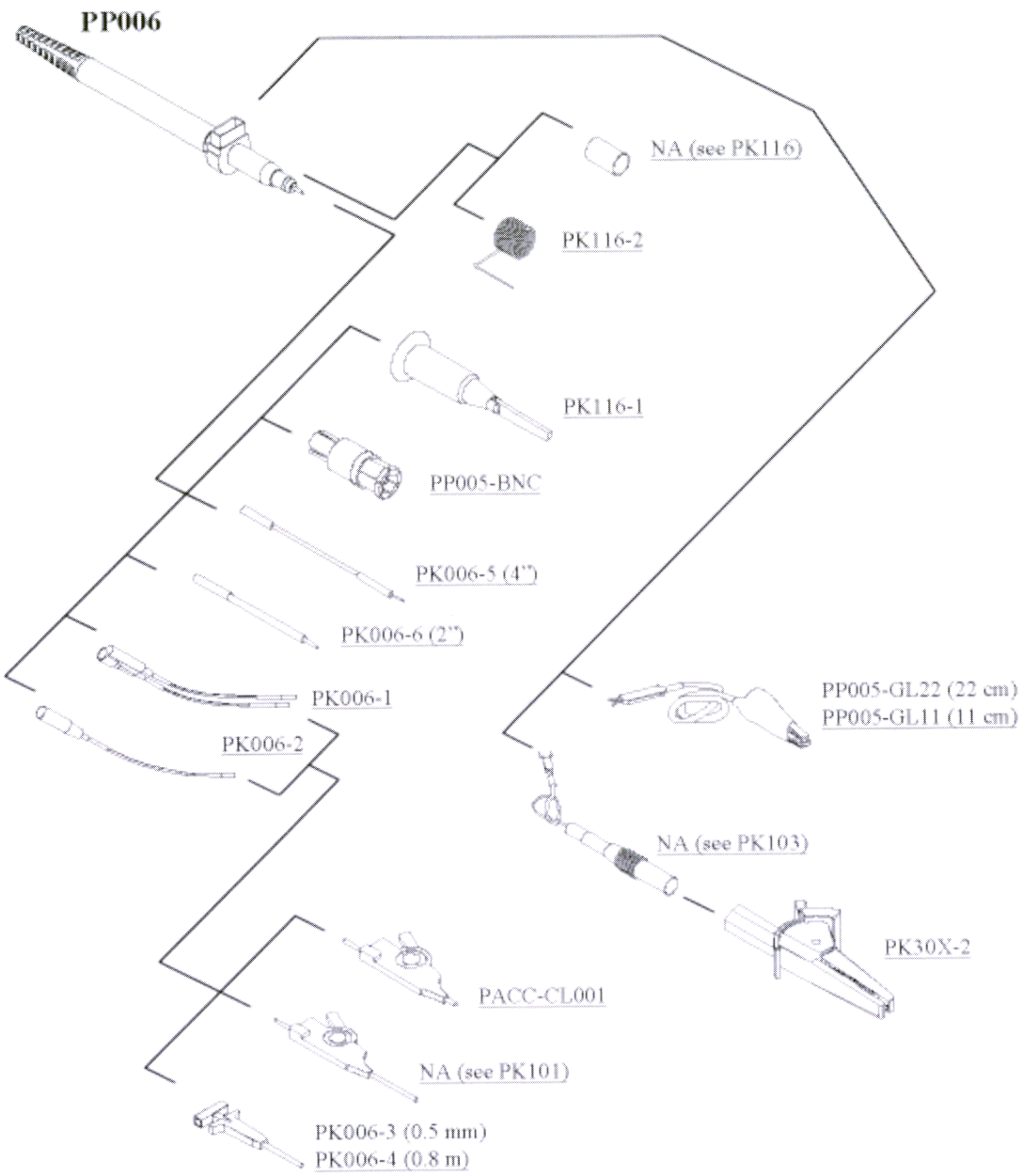
PP006 – Recommended Accessory Diagram



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Probes Kits and Accessories - PP002, PP005, PP006

PP002

PK001 - Probe accessories for PP002	
PP001/002-1	Ground lead PP001 & PP002
PP001/002-2	Probe tip to BNC adapter
PP001/002-3	Sprung hook PP001 & PP002
AP020/021-2	Ground Bayonet
NA	IC insulating tip
NA	Screw driver

PK006 - SMT accessories for AP020, PP006	
K006-1	Dual lead adapter PK006
PK006-2	Single lead adapter PK006
PK006-3	0.5 mm clip (black and red)
PK006-4	0.8 mm clip (black and red)
NA	M/F lead - long (4")
NA	M/F lead - short (2")

PP005

PK101 - Microclip accessories for PP005	
PK106-2	Single lead adapter
NA	QFPIC Clip (1300 mm 0.5 mm pitch)
PACC-CL001	QFPIC Clip (0.5 mm pitch)

PK102 - Probe accessories for PP005	
PP005-HOOK	Sprung hook (black)
PP005-ST38	Spring tip (0.38mm
PP005-ST8	Spring tip (0.8 mm)
PP005-RT	Rigid tip V2A
PP005-BNC	Prove tip to BNC adapter)
PP005-GL11	Ground lead (11 cm)
PP005-GL22	Ground lead (22 cm)
PP005-GLPT	Ground lead (short sp probe tip
NA	IC insulating tip
NA	Probe tip to banana plug adapter
NA	Screw driver

PK103 - Probe accessories for PPE1.2kV, PPE2kV	
PP005-HOOK	Sprung hook (red)
PP005-G22	Ground lead (22 cm)
PK30x-2	Crocodile clip
PP005-BNC	Probe tip to BNC adapter
NA	IC insulating tip
NA	Screw driver
NA	Probe tip to banana plug adapter
NA	Ground lead with banana plug
PP005-ST8	Spring tip (0.8 mm)
PP005-RT	Rigid tip V2A

PK106 - SMT accessories for PP005/65, PPExkV	
PK106-1	Dual lead adapter
PK106-2	Single lead adapter
PK106-3	0.5 mm clip (orange)
PK106-4	Probe tip to PCB adapter
PK106-5	M/F lead - long (4")
PK106-6	M/F lead - short (2")
PK106-8	0.5 mm clip (yellow)

Additional accessories	
PP001/002-1	Ground lead PP001 & PP002
PP001/002-2	Probe tip to BNC adapter
PK006-3	0.5 mm clip (black and red)
PK006-4	0.8 mm clip (black and red)

PP006

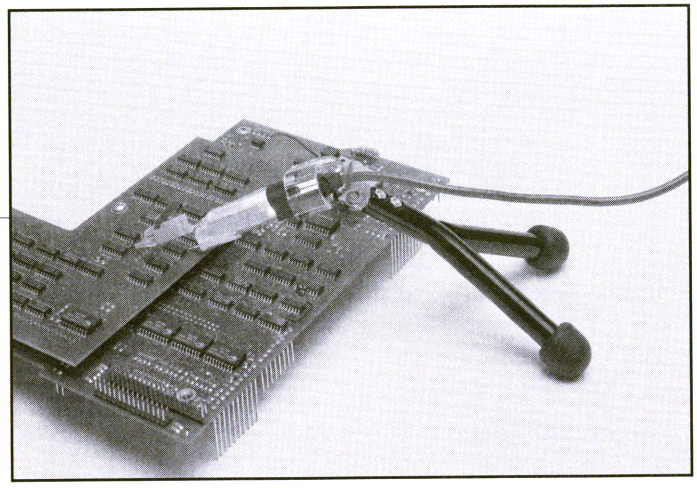
PK006 - SMT accessories for AP020, PP006	
PK006-1	Dual lead adapter PK006
PK006-2	Single lead adapter PK006
PK006-3	0.5 mm clip (black and red)
PK006-4	0.8 mm clip (black and red)
NA	M/F lead - long (4")
NA	M/F lead - short (2")

PK116 - Probe accessories for PP006	
PK116-1	Sprung hook
PK116-2	Ground lead
PK116-3	Ground pin
NA	Insulating tip
NA	Screw driver

Additional Accessories	
PP001/002-1	Ground lead
AP020/021-1	Probe tip to BNC adapter
AP020/021-2	Ground bayonet
PACC-CL001	QFPIC Clip (0.5 mm pitch)
PP005-BNC	Probe tip to BNC adapter
PP005-GL11	Ground lead (11 cm)
PP005-GL22	Ground lead (22 cm)
PP005-GLPT	Ground lead (short sp probe tip)
PK30x-2	Crocodile clip
PK106-3	0.5 mm clip (orange)
PK106-5	M/F lead - long (4")
PK106-6	M/F lead - short (2")

Visit our web site at: www.lecroy.com

Active Probes – HFP2500, HFP1500, HFP1000



Main Features

- 1 GHz to 2.5 GHz Bandwidth
- 0.7 pF Input Capacitance
- 100 kΩ input impedance
- ±8 V Dynamic Range
- ±12 V Offset Range
- 5 Interchangeable Tips for Probing a Variety of Test Points
- Replaceable Probe Tip Socket
- Hands-Free Probing with FreeHand Probe Holder
- AutoColor ID Feature Matches the Probe Color to the Trace Color

Engineers are using an ever-increasing variety of devices and test points in their designs. In order to access these test points conveniently, today's probing solutions need to be versatile, small and lightweight, while still maintaining a high bandwidth. LeCroy's new HFP series of probes is designed to meet these challenges.

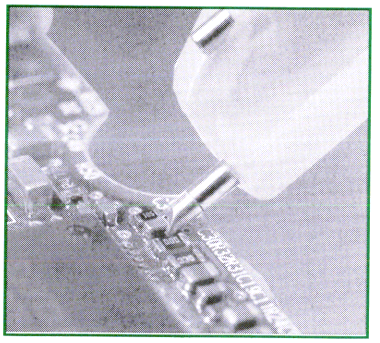
Convenient Hands-Free Probing

FreeHand is a revolutionary new probe holder that lets you focus on the oscilloscope screen instead of on maintaining contact to multiple test points. Besides being easy to use, *FreeHand* is versatile and reliable. Mathematically designed to keep most of the weight on the probe tip, *FreeHand* helps prevent lost contact when a bump to the table shakes your circuit under test, something spring tension probe holders can't do. *FreeHand* allows multiple probes to be used at once, so waveforms can be analyzed in real time instead of using stored waveforms. Additionally, the HFP probe can be mounted in *FreeHand* both vertically and horizontally, giving the added flexibility that may be required. All HFP model probes fit the *FreeHand* probe holder.

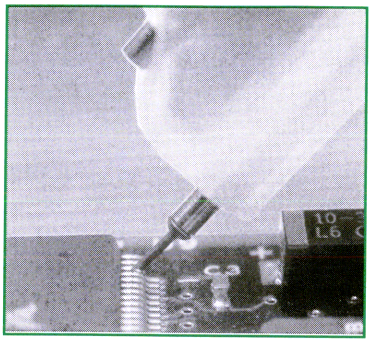
AutoColor ID

When the probe is connected to an oscilloscope channel, our patent-pending AutoColor ID feature automatically illuminates the probe head in that channel's factory default trace color. Thus, there is no longer a need to manually apply plastic rings or colored tape to determine which channel the probe is connected to.

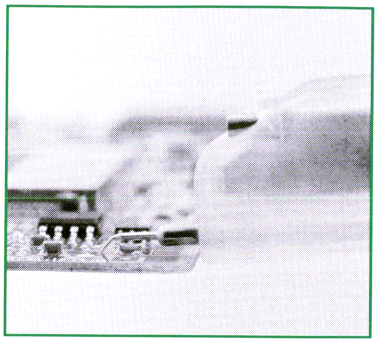
	HFP1000	HFP1500	HFP2500
Bandwidth	1.0 GHz	1.5 GHz	2.5 GHz
Attenuation	÷10	÷10	÷10
DC Attenuation Accuracy	± 1%	± 1%	± 1%
Output Zero	≤ ± 4 mV	≤ ± 4 mV	≤ ± 4 mV
Rise Time (probe only)	≤350 ps	≤233 ps	≤140 ps
Input Capacitance	0.7 pF	0.7 pF	0.7 pF
DC Input Resistance	100 kΩ	100 kΩ	100 kΩ
Dynamic Range	± 8 V	± 8 V	± 8 V
Offset Range	none	± 12 V	± 12 V



Discrete SMD Tip



IC Lead Tip



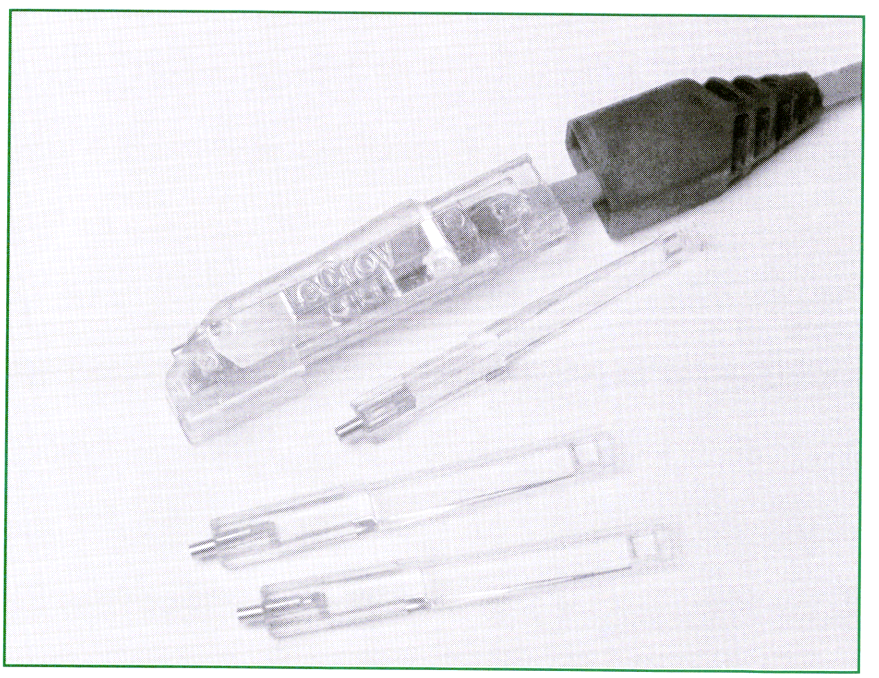
Bent Sharp Tip

Application Specific Tips

Five different styles of tips make probing easier than ever. In addition to a traditional Straight Tip, a Sharp Tip allows easier access to tightly-packed test points and circuit vias. The Bent Sharp Tip – made out of titanium – is ideal for making contact on devices that are spaced close together and prevent the probe from being oriented perpendicular to the circuit. The IC Lead Tip is covered insulation on all sides (except for a small wedge), and can be placed between small-geometry IC leads without shorting them together. It is one-size-fits-all, and will work with any IC lead pitch. The Discrete SMD Tip, with its crescent shape, is designed to fit tightly on surface mount capacitors, resistors and other components.

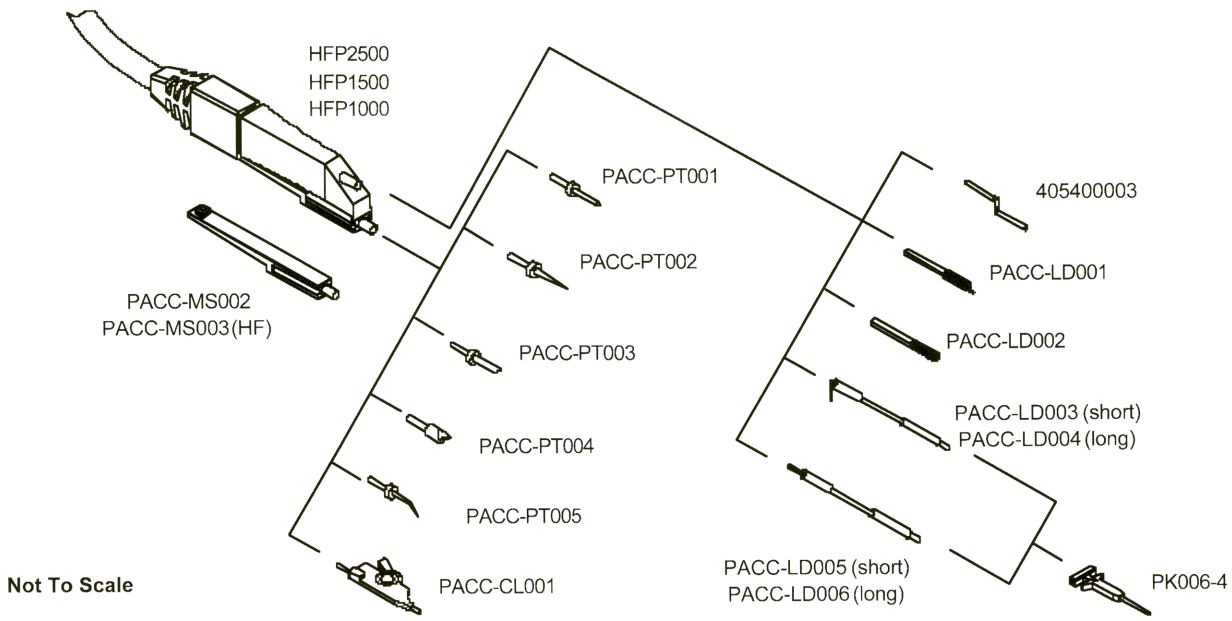
Use on Non-LeCroy Instruments

The HFP series active probes are compatible with the optional ADPPS power supply, and so can be used on any instrument with BNC connection. When used with the ADPPS power supply, AutoColor ID will not function, there will be no internal probe offset and the bandwidth is limited to approximately 1 GHz. On LeCroy oscilloscopes with firmware earlier than 8.7.0, AutoColor ID will not function and there will be no internal offset.



Replaceable Cartridges

There is no need to buy a new probe if your tip socket gets damaged because the HFP series active probe has a removable tip socket cartridge. In addition to being able to replace damaged tip sockets, HFP probes also have the ability to use either the normal cartridge with a selection of probe tips or the high frequency cartridge. By having a fixed tip, which plugs directly onto test point square pins, the high frequency cartridge is able to increase accuracy during high frequency measurements.



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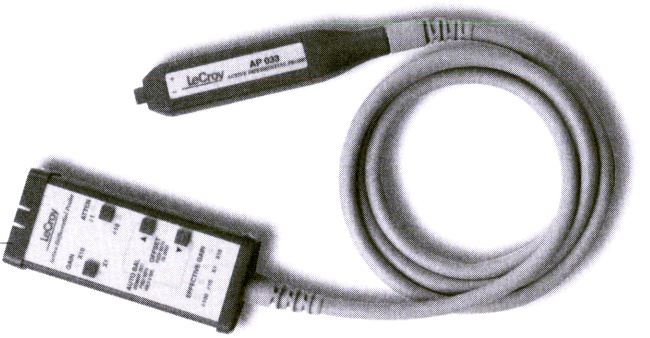
		Accessories Included with Probes		
Part Number	**Description**	**HFP2500**	**HFP1500**	**HFP1000**
HFP2500	2.5 GHz Active Probe			
HFP1500	1.5 GHz Active Probe			
HFP1000	1 GHz Active Probe			
PACC-PT001	Straight Tip	4	4	4
PACC-PT002	Sharp Tip	4	4	4
PACC-PT003	IC Lead Tip	4	4	0
PACC-PT004	SMD Discrete Tip	4	4	0
PACC-PT005	Bent Sharp Tip	4	4	0
PACC-CL001	Micro Clip	2	0	0
PK006-4	0.8 mm Clip	2	2	2
PACC-LD001	Ground Spring Hook	1	1	0
PACC-LD002	Square Pin Ground Spring	1	1	1
40540003	Offset Pin	2	2	2
PACC-LD003	Short Right Angle Lead	2	2	1
PACC-LD004	Long Right Angle Lead	2	2	1
PACC-LD005	Short Single Lead	2	2	1
PACC-LD006	Long Single Lead	2	2	1
PACC-MS001	*FreeHand* Probe Holder	1	1	0
PACC-MS002	Replaceable Cartridge	1	1	1
PACC-MS003	High Frequency Cartridge	1	0	0
SAC-01	Soft Accessory Case	1	1	0
HFP1000-OM-E	HFP1000 Instruction Manual, English	0	0	1
HFP1500-OM-E	HFP1500 Instruction Manual, English	0	1	0
HFP2500-OM-E	HFP2500 Instruction Manual, English	1	0	0

Active Differential Probes – AP033, AP034



Main Features

- 500 MHz bandwidth (AP033)
- 1 GHz bandwidth (AP034)
- X10 gain to ÷10 attenuation range (AP033)
- 10,000:1 DC CMRR
- Low 9 µV/√Hz noise(AP033)
- 1.5 pF/side input C (AP034)
- 200 µV/div - 10 V/div (AP0033)
- Input ESD protection
- Autobalance feature

The AP033 and AP034 are high-performance active differential probes. High bandwidth, excellent common-mode rejection ratio (CMRR), and low noise make these probes ideal for applications such as disk drive design and failure analysis, as well as wireless and data communication design.

Fully Integrated

With the ProBus interface, the AP033 and AP034 become an integral part of the oscilloscope. The probe offset can be controlled from the oscilloscope front panel or by using the remote control commands (GPIB or RS-232). Sensitivity, offset, input capacitance, and common-mode range are displayed on the scope screen. When used with a LeCroy digital oscilloscope, no external power supply is required.

Wide Dynamic Range

The AP033 probe provides a range of sensitivities from x10 gain to ÷10 attenuation (even ÷100 with plug-on attenuator) for diverse signals. The sensitivity can be adjusted continuously from 200 µV/div to 1 V/div when used with a LeCroy oscilloscope (10 V/div with plug-on attenuator).

The AP034 probe provides a range of sensitivities from X1 gain to ÷10 and ÷20 attenuation (with plug-on attenuators) for diverse signals. The sensitivity can be adjusted continuously from 2 mV /div to 2 V/div (2 V/div is achieved with plug-on attenuator) when used with a LeCroy oscilloscope.

Autobalance

Autobalance can be invoked from the oscilloscope front panel when the input is disconnected from the test circuit. This provides the highest measurement accuracy by removing any residual DC offset from the probe.

Use with Other Instruments

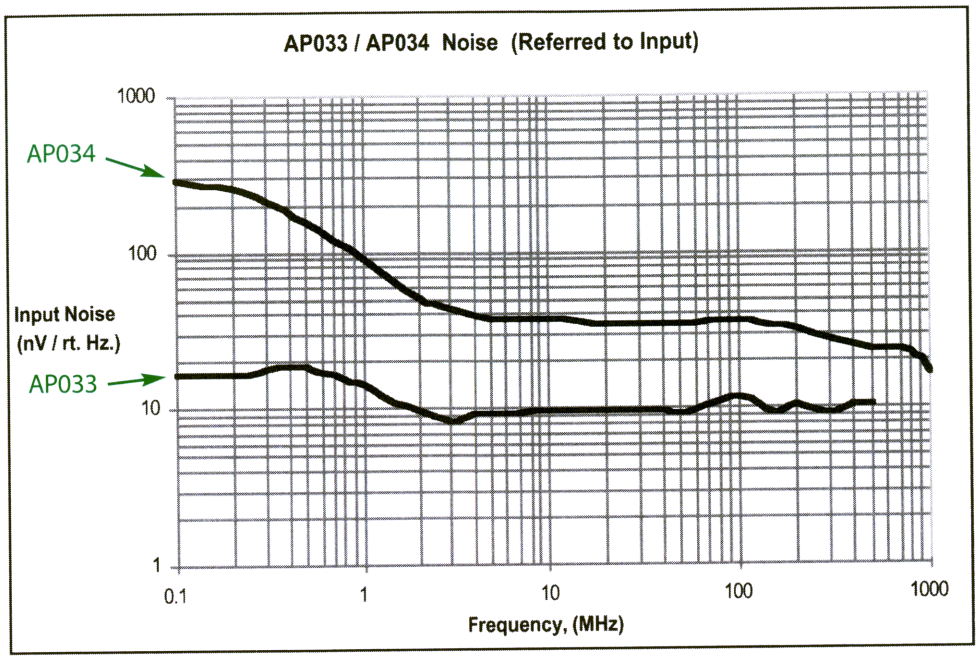
Instruments with 50 Ω inputs, such as spectrum and network analyzers, time interval analyzers, and others, pose a challenge when the signal to be measured is differential or high-impedance. Low noise and high bandwidth make the AP033/AP034 probes an ideal signal conditioner to solve these problems.

The optional ADPPS Power Supply provides power to the AP034 and converts the output to a conventional male BNC connector.

Common Mode Sensing and Input Protection (AP033)

It is not uncommon for a differential amplifier to be connected to a signal whose common-mode voltage exceeds the amplifier's common-mode range. Faulty readings, including total loss of signal, can result. The AP033 senses when signals exceed ±5.5 V and switches its input attenuator into the signal path. The oscilloscope shows the new deflection factor, and the probe continues to work.

The same mechanism protects the probe from damage due to large input signals. The probe amplifier is protected from large, fast-rising signals until the input attenuator can provide permanent protection.



Specifications (AP033)

Bandwidth: 500 MHz

Gain Range: x10, x1, ÷10 (÷100 with plug-on ÷10 attenuator)

DC Accuracy: 1% in x1 without external attenuator

Input Resistance: 1 MΩ (each input to ground), 2 MΩ differential (between inputs)

Input Capacitance:

3 pF (each input to ground) (÷10)
6 pF (each input to ground) (÷1)
1.6 pF differential (between inputs) (÷10)
3.1 pF differential (betwee inputs) (÷1)

Input Voltage
Differential Mode Range:

±40 V	(÷100)
±4 V	(÷10)
±400 mV	(x1)
±40 mV	(x10)

Offset Range:

±400 mV	(x1, x10)
±4 V	(÷10)
±40 V	(÷100)

Common-Mode Range: ±42 V peak (÷10), ±4.2 V peak (÷1)

CMRR:

70 Hz	10.000:1	(80 dB)
100 kHz	10.000:1	(80 dB)
1 MHz	1.000:1	(60 dB)
10 MHz	100:1	(40 dB)
250 MHz	5:1	(14 dB)

Specifications (AP034)

Bandwidth: 1 GHz

Gain: x1 (÷10 and ÷20 with plug on attenuators)

DC Accuracy: 2% typical (probe only)

Input Impedance:

2 MΩ || 0.85 pF between inputs
1 MΩ || 1.5 pF each input to ground

Differential Mode Range:

±400 mV	(x1)
±4 V	(÷10)
±8 V	(÷20)

Offset Range:

±1.6 V	(x1)
±16 V	(÷10)
±32 V	(÷20)

Common-Mode Range:

±16 V	(x1)
±42 V	(÷10)
±42 V	(÷20)

CMRR:

70 Hz	10,000:1	(80 dB)
1 MHz	100:1	(40 dB)
100 MHz	18:1	(25 dB)
500 MHz	9:1	(19 dB)

Specifications (AP033 and AP034)

Max Nondestruct Voltage: ±200 V DC continuous

Cable Length: 1.2 m

Operating Temperature: 0°C to 50°C

Standard Accessories:

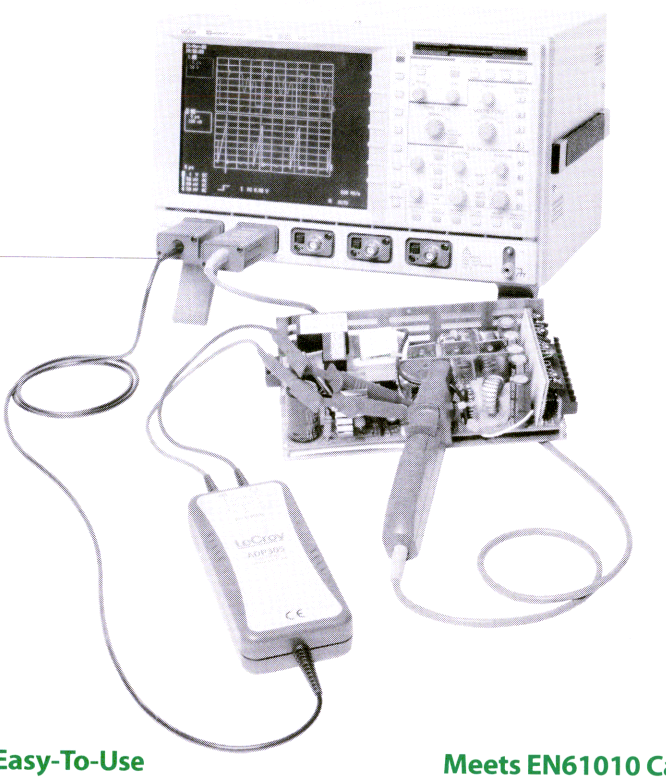
÷10 Plug-on Attenuator
÷20 Plug-on Attenuator (AP034 only)
Plug-On AC Coupler
Probe Connection Accessory Kit:
- Flex Lead Set (1)
- Input "Y" Lead (1)
- Mini Clip, 0.8 mm (3)
- Mini Clip, 0.5 mm (2)
- Ground Lead (1)
- Offset Pins, Round (4)
- Square Pin Header Strip (1)

Warranty: Three years

High Voltage Differential Probes – ADP300, ADP305

Main Features

- 20 MHz and 100 MHz bandwidth
- 1,000 V_{RMS} common mode voltage
- 1,400 V_{peak} differential voltage
- EN61010 CAT III
- 80dB CMRR at 50/60 Hz
- ProBus system
- Full remote control



ADP30X high-voltage active differential probes are safe, easy-to-use probes ideally suited for measuring power electronics. The ADP300 is good for troubleshooting low-frequency power devices and other circuits where the reference potential is elevated from the ground or the location of ground is unknown. The ADP305 is designed for measuring the high-speed floating voltages found in today's high-speed power electronics.

Easy-To-Use

With the ProBus interface, the ADP30X becomes an integral part of the oscilloscope. The attenuation, offset, and bandwidth limit are all controlled from the oscilloscope front panel or by using the remote control commands. This means the complete measurement setup can be saved and recalled by the oscilloscope, and all measurement values will be correct. The oscilloscope provides power to the probe, so there is no need to worry about a separate power supply or changing batteries.

Autozero

The ADP30X offset can be easily set to zero by pushing a button in the oscilloscope's coupling menu, even when connected to live circuits. This makes it easy to get accurate measurements.

Meets EN61010 Category III Requirements

Safety is the top priority when you work around high-voltage signals. The ADP300 and ADP305 are both designed to the standards required for Installation Category III. This means that in addition to being used on appliances and portable equipment (CAT II), they can be used in fixed-installation environments.

Electrical Characteristics

Bandwidth:
ADP300 20 MHz
ADP305 100 MHz

Differential Voltage: 1,400 Vpeak

Common Mode Voltage: 1,000 V_{RMS} CAT III

Low-Frequency Accuracy (probe only): 1% of reading

CMRR:
50/60 Hz 80 dB (10,000:1)
100 kHz 50 dB (300:1)

Max. Slew Rate (referenced to input):
ADP300 60,000 V/µs
ADP305 300,000 V/µs

AC Noise (referenced to input):
50 mVRMS

Attenuation: ÷100/÷1000 (automatically selected by scope)

Input Impedance:
Between inputs 8 MΩ, 6 pF
Each input to ground 4 MΩ, 1 pF

Sensitivity:
ADP300 1 V/div to 350 V/div
ADP305 200 mV/div to 350 V/div

General Characteristics

Overall Length: 2 meters

Input Connectors: 4 mm shrouded banana plug

Operating Temperature: 0°C to 50°C

Warranty: One year

Standard Accessories (ADP300)

Instruction Manual
Certification of Calibration
Plunger Hook Clip (1-Red, 1-Blue)
Straps for Holding Probe

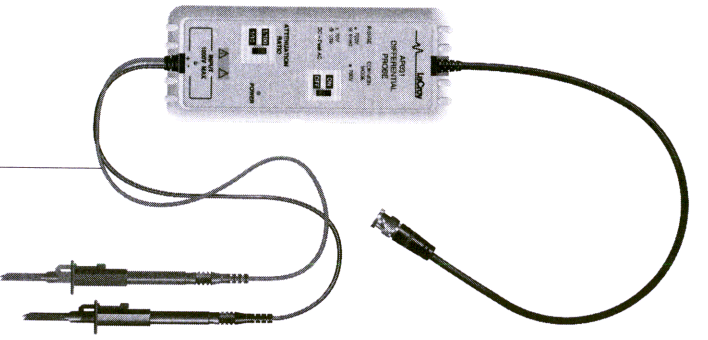
(ADP305)

All ADP300 Accessories
Safety Spade (1- Red, 1-Blue)
Plunger Clamp Clip (1- Red, 1-Blue)
Plunger Jaw Clip (1- Red, 1-Blue)
Safe Alligator Clip (1-Red, 1-Blue)
Soft Accessory Case

Differential Probes – AP031

Main Features

- **Safe floating measurements**
- **15 MHz bandwidth**
- **700 V maximum input voltage**
- **Works with any 1 MΩ input oscilloscope**



The AP031 is an active differential probe. The differential techniques employed permit measurements to be taken at two points in a circuit without references to ground.

This allows the oscilloscope to be safely grounded without the use of opto-isolators or isolating transformers.

The two-input signals are processed in the probe, and the resulting output is fed into a single channel of the oscilloscope. The probe's output is a coaxial cable equipped with a standard BNC connector.

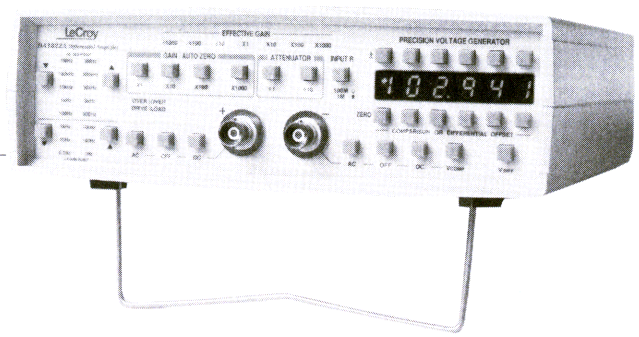
The probes are compatible with all 1 MΩ input oscilloscopes. Optional 4 mm banana plug accessories include plunger neck clip (PK30X-1), safe alligator clip (PK30X-2), plunger clamp clip (PK30x-3), plunger jaw clip (PK30X-4), safety spade (PK30X-5).

Warranty: One year

Differential Probes

			Common Mode Rejection Ratio		Maximum Input Voltage DC + Peak AC		
Model	**Bandwidth (MHz)**	**Input R (MΩ)**	**50 Hz**	**200 kHz**	**Attenuation**	**Diff.V**	**Com. mode V**
AP031	15	4	-86	-56	÷10	±70	±700
					÷100	±700	±700

Differential Amplifiers – DA1820A, DA1822A



Main Features

- **Full control from oscilloscope through ProBus interface**
- **DC to 10 MHz bandwidth**
- **100,000: 1 CMRR**
- **Gain of 1, 10, 100 & 1000**
- **Selectable upper and lower bandwidth limits**
- **Precision voltage generator (1822A only)**
- **Ideal for automotive and medical electronics**

The DA1820A/1822A are stand-alone, high-performance 10 MHz differential amplifiers. They are intended to act as signal conditioning preamplifiers for oscilloscopes, 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 DA1820A/DA1822A can extend the sensitivity of a LeCroy oscilloscope to 2 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 dynamic ranges in proportion to their attention ratio, but not exceeding the probe's maximum input voltage rating. Effective gain of the DA1822A, including probe attenuation, amplifier gain and attenuator settings, is automatically displayed on the front panel.

When connected to a LeCroy oscilloscope through ProBus, the DA1820A/1822A and the oscilloscope become and integrated system. All of the differential amplifier controls can be accessed through the oscilloscope user interface or remote control bus (GPIB, RS-232C). The system provides an automatic gain control mode, where the proper combination of oscilloscope scale factor, differential amplifier gain, and attenuation are automatically selected through the volts/div knob. The oscilloscope offset knob controls the precision voltage generator (DA1822A), maintaining maximum usable dynamic range of the system. The effective gain of the differential amplifier, including the attenuation of DXC series probes, is communicated to the scope through ProBus to correctly display the scale factor.

A wide range of high-performance DXC series differential probes is available for use with the DA1820A/1822A.

Precision Voltage Generator (DA1822A only)

The DA1822A features a built-in Precision Voltage Generator (PVG) that can be set for any voltage between ±15.5 volts (±10 volts in Differential Offset) with 5 1/2 digit resolution. The generator's temperature-controlled oven provides high accuracy. 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.

Note: The DA1820A, which does not have the Precision Voltage Generator, will only allow the waveform's ground reference to be centered on screen.

Comparator Mode

The DA1822A becomes a differential comparator when the internal Precision Voltage General (PVG) output is selected as the amplifier's inverting (-) input. In this mode, the DA1822A can be used to accurately measure relatively small signals that are riding on large components. The DA1822A can make voltage arrangements that are much more accurate than the oscilloscope is capable of by itself. The operator can use the PVG as an accurate position or offset control to compare to the PVG's value with any point on the "+" Input signal.

The DA1820A also functions as a differential comparator when an external voltage source is supplied.

True Differential Offset Mode

The DA1822A's built-in PVG 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 ±50,000 divisions. This mode facilitates making measurements such as changes to a transistor's base to emitter voltage caused by variations in temperature and/or current.

Autozero

Pressing Autozero in the coupling menu adjusts the amplifiers DC balance to remove any offset drift.

Two-Channel Option

The DA18xxA-PR2 series are two-channel versions of the DA1820A and DA1822A, high performance differential amplifiers. Each amplifier channel operates independently from the other channel, but shares a common power cable and power switch. The package depth is extended to allow most oscilloscopes to sit on top of the amplifiers, making optimum usage of bench space.

The DA18xxA-PR2 series amplifiers are fully compatible with the LeCroy DXC series of differential probes.

Rackmount Option

A rackmount adapter is available for the all DA18xxA series amplifiers, including the two-channel PR2 option.

DA18xxA-RM or DA18xxA-PR2-RM are the ordering options.

Specifications

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

Common Mode Rejection Ratio: 100,000:1 @ 70 Hz

Input Resistance:
(÷1 attenuator): 1 MΩ or 100 MΩ
(÷10 attenuator and/or with attenuating probe attached): 1 MΩ

Input Capacitance: 20 pF

Bandwidth Limit Filters
Upper: 3 MHz, 1 MHz, 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 Protection: Protected to ±250 V, automatic input disconnect with manual reset.

Dynamic Ranges*

Max Differential Mode Range:

X1000 gain, ÷1 attenuator	±5 mV
X100 gain, ÷1 attenuator	±50 mV
X10 gain, ÷1 attenuator	±0.5 V
X1 gain, ÷1 attenuator	±5 V
X1000 gain, ÷10 attenuator	±50 mV
X100 gain, ÷10 attenuator	±0.5 V
X10 gain, ÷10 attenuator	±5 V
X1 gain, ÷10 attenuator	±50 V

Max Common Mode Input:

÷1 attenuator	±15.5 V
÷10 attenuator	±155 V

Differential Offset Range (V DIFF Mode):

X10, X100, X1000 gain, ÷1attenuator	±1 V
X1 gain, ÷1 attenuator	±10 V
X10, X100, X1000 gain, ÷10 attenuator	±10 V
X1 gain. ÷10 attenuator	±100 V

Comparison Offset Range (V COMP Mode):

÷1 attenuator	±15.5 V
÷10 attenuator	±155 V

**Voltages are referenced to amplifier input. Multiply by probe attenuation factor to obtain value referenced to probe input.*

Precision Voltage Source (DA1822A only)

Output Range: ±15.5 V

DC Accuracy: 0.05% of reading + 500 µV (15° to 45°C)

Resolution: 100 µV (5 1/2 digit)

Temperature Coefficient: Typically <5 ppm/°C of full scale

Type: Oven stabilized buried zener.

Output: Applied to inverting input and available at rear panel.

Power Requirements

Line Voltage Requirement: 100 to 250 V AC

Line Frequency Range: 48 - 66 Hz

Power Consumption

Single Channel Models: approximately 36 W, approximately 36 V A

Two Channel Models: approximtely 52 W, approximately 72 V A

Environmental Characteristics

Temperature Operating Range: 0° to 50°C

Temperature Nonoperating: -40° to 71°C

Physical Characteristics

Single Channel Models

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)

Two Channel Models

Height: 8.75 cm (3.4")

Width: 43.9 cm (17.3")

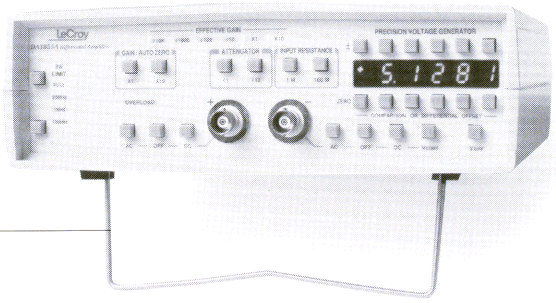
Depth: 42.5 cm (16.7")

Weight: 9.5 kg (21 lb)

Shipping Weight: 11.3 kg (25 lb)

Warranty: Three years

Differential Amplifiers – DA1850A, DA1855A



Main Features

- **Full control from oscilloscope through ProBus interface**
- **DC to 100 MHz bandwidth**
- **100,000: 1 CMRR**
- **Gain of ÷1 or ÷10**
- **State-of-the-art overdrive recovery**
- **Low Noise**

The DA1850A/1855A are stand-alone, high-performance 100 MHz differential amplifiers. They are intended to act as signal conditioning preamplifiers for oscilloscopes, network and spectrum analyzers, providing differential measurement capability to instruments having only a single-ended input.

Amplifier gain can be set to 1 or 10. A built-in 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 DA1855A, including probe attenuation, amplifier gain and attenuator settings, is automatically displayed on the front panel.

When connected to a LeCroy oscilloscope through ProBus, the DA1850A/DA1855A and the oscilloscope become an integrated system. All of the differential amplifier controls can be accessed through the oscilloscope user interface or remote control bus (GPIB, RS-232C). The system provides an automatic gain control mode, where the proper combination of oscilloscope scale factor, differential amplifier gain, and attenuation are automatically selected through the volts/div knob. The oscilloscope offset knob controls the precision voltage generator, maintaining maximum usable dynamic range of the system. The effective gain of the differential amplifier, including the attenuation of DXC series probes, is communicated to the scope through ProBus to correctly display the scale factor.

The DA1855A has a bandwidth of 100 MHz, but any one of the three bandwidth limit filters can be selected to reduce bandwidth to 10 MHz, 1 MHz, or 100 kHz.

A wide range of high-performance DXC series differential probes is available for use with the DA1850A/1855A.

Overdrive Recovery

The DA1850A/1855A contains special input circuitry to keep the amplifier in its linear range during input overdrive conditions. In addition, the amplifier output is carefully limited to 500 mV, preventing the oscilloscope input from being overloaded. These two features provide extremely fast system overdrive recovery. In X10 gain, the differential amplifier will typically settle in less than 100 ns to within 1 mV referred to input after a 4 V (8000 %) overdrive.

Fast overdrive recovery is essential when measuring small signals after a large step change. Typical applications where this capability is required include measuring dynamic saturation voltage in power supply switching transistors, and amplifier or D/A converter settling times.

Precision Voltage Generator (DA1855A only)

The DA1855A features a built-in Precision Voltage Generator (PVG) that can be set for any voltage between ±15.5 volts (±10 volts in Differential Offset) with 5 1/2 digit resolution. The generator's temperature-controlled oven provides high accuracy. 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.

Note: The DA1850A, which does not have the Precision Voltage Generator, will only allow the waveform's ground reference to be centered on screen.

Comparator Mode

The DA1855A becomes a differential comparator when the internal Precision Voltage General (PVG) output is selected as the amplifier's inverting (-) input. In

this mode, the DA1855A can be used to accurately measure relatively small signals that are riding on large components. The DA1855A can make voltage arrangements that are much more accurate than the oscilloscope is capable of by itself. The operator can use the PVG as an accurate position or offset control to compare to the PVG's value with any point on the "+" Input signal.

The DA1850A also functions as a differential comparator when an external voltage source is supplied.

True Differential Offset Mode

The DA1855A'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 ±50,000 divisions. This mode facilitates making measurements such as changes to a transistor's base to emitter voltage caused by variations in temperature and/or current.

Autozero

Pressing Autozero in the coupling menu adjusts the amplifier's DC balance to remove any output offset drift.

Two-Channel Option

The DA18xxA-PR2 series includes two-channel versions of the DA1850A and DA1855A high-performance differential amplifiers. Each amplifier channel operates independently from the other channel, but shares a common power cable and power switch. The package depth is extended to allow most oscilloscopes to sit on top of the amplifiers, making optimum usage of bench space.

The DA18xxA-PR2 series amplifiers are fully compatible with the LeCroy DXC series of differential probes.

Rackmount Option

A rackmount adapter is available for the all DA18xxA series amplifiers, including the two-channel PR2 option.

DA18xxA-RM or DA18xxA-PR2-RM are the ordering options.

Specifications

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 ±0.5 V into 50 Ω

Input Attenuation: ÷1 or ÷10

Typical Input Noise (x10 GAIN):
4 nV/sqrt Hz @ 1 MHz

Common-Mode Rejection Ratio:
>100,000:1 @ 70 Hz
>100,000:1 @ 100 kHz
>316:1 @ 10 MHz

Input Resistance:
(÷1 Attenuator): 1 MΩ or 100 MΩ
(÷10 Attenuator): 1 MΩ

Input Capacitance: 20 pF

Bandwidth Limit Filters: (DA1855A only) 10 MHz, 1 MHz and 100kHz

Filter Characteristics: (DA1855A only) 18 dB/octave (3-pole Bessel)

Input Protection: Protected to ±250 V, automatic input disconnect with manual reset.

Dynamic Ranges*

Max. Differential Mode Range:

X10 gain, ÷1 attenuator	±50 mV
X1 gain, ÷1 attenuator	±0.5 V
X10 gain, ÷10 attenuator	±0.5 V
X1 gain, ÷10 attenuator	±5 V

Max Input Slew Rate:

÷1 attenuator	±0.15 V/ns
÷10 attenuator	±1.5 V/ns

Max Common Mode Input:

÷1 attenuator	±15.5 V
÷10 attenuator	±155 V

Differential Offset Range (VDIFF Mode):

X10 gain, ÷1 attenuator	±1 V
X1 gain, ÷1 attenuator	±10 V
X10 gain, ÷10 attenuator	±10 V
X1 gain, ÷10 attenuator	±100 V

**Voltages are referenced to amplifier input. Multiply by probe attenuation factor to obtain value referenced to probe input.*

Comparison Offset Range (VCOMP Mode):

÷1 attenuator	±15.5 V
÷10 attenuator	±155 V

Precision Voltage Source (DA1855A only)

Output Range: ±15.5 V

DC Accuracy: 0.05% of reading ±500 µV (15° to 45°C)

Resolution: 100 µV (5 1/2 digit)

Temperature Coefficient: Typically <5 ppm/°C of full scale.

Type: Oven stabilized buried zener

Output: Applied to inverting input and available at rear panel.

Power Requirements

Line Voltage Requirement: 100 to 250 V AC

Line Frequency Range: 48 - 66 Hz

Power Consumption

Single Channel Models: approximately 28 W, approximately 39 V A

Two Channel Models: approximately 56 W, approximately 78 V A

Environmental Characteristics

Operating Range: 0° to 50°C

Non-Operating: -40° to 71°C

Physical Characteristics

Single Channel Models

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)

Two Channel Models

Height: 8.75 cm (3.4")

Width: 43.9 cm (17.3")

Depth: 42.5 cm (16.7")

Weight: 9.5 kg (21 ib)

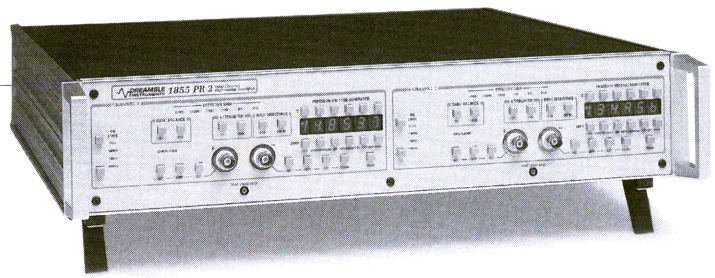
Shipping Weight: 11.3 kg (25 lb)

Warranty: Three years

Differential Amplifiers – DA1820A-PR2, DA1822A-PR2, DA1850A-PR2, DA1855A-PR2

Main Features

- **Two-channel versions of DA1800A series differential amplifiers**
- **Benchtop or rackmount configurations**



The DA1800A-PR2 series includes two-channel versions of the DA1820A, DA1822A, DA1850A and DA1855A high-performance differential amplifiers. Each channel amplifier operates independently from the other channel, but shares a common power cord and power switch. The package depth is extended to allow most oscilloscopes to sit on top of the amplifiers, making optimum use of bench space.

The DA1800A-PR2 series amplifiers are fully compatible with the LeCroy DXC series of differential probes.

Rackmount Option

A rackmount adapter is available for DA18XXA-PR2, size 2U.

Differential Probe Pairs – DXC100A

Main Features

- **DC to 100 MHz bandwidth with DA1850A/DA1855A**
- **Max input voltage 500 V**
- **Selectable ÷10 or ÷100 attenuation factor**
- **1.2 meter cable length**



The DXC100A is a high-performance, passive, matched, differential probe pair designed for use with DA18xxA 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 ÷10 and ÷100. When used with the DA18xxA series differential amplifiers, the probe's attenuation factor is automatically incorporated into the effective gain display, and the scale factor on the LeCroy oscilloscope. When used with a differential amplifier, the DXC100A allows for precise adjustment and matching of 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 DA1850A/DA1855A): 100 MHz

System Risetime (with DA1850A/DA1855A): 3.5 ns

Input Resistance: 1 MΩ ±1%

Input Capacitance: 10.5 pF ±0.5 pF

Max Nondestructive Input Voltage: 500 V DC + peak AC

Length: 1.2 meter

Environmental Characteristics

Operating Range: 0° to 50°C

Non-Operating: -40° to 71°C

Physical Characteristics

Weight: 0.18 kg (6.4 oz)

Shipping Weight: 0.45 kg (1 lb)

Warranty: One year

Differential Probe Pairs – DXC200

Main Features

- DC to 100 MHz bandwidth with DA1850A/DA1855A
- 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 while still maintaining practical probe-to-circuit attachment. Full DA18xxA series gain and Common Mode Rejection Ratio (CMRR) are maintained. The DXC200 allows the user to take advantage of the DA18xxA series' 100 MΩ input resistance setting.

Specifications

Attenuation factor: 1

Capacitance: 30 pF

Max Nondestructive Input Voltage: 500 V DC + peak AC

Length: 0.7 meter

DXC200 & DA1850A/DA1855A System Specifications

Risetime: 7 ns

Bandwidth (-3 dB): 50 MHz

Input Resistance (selectable): 1 or 100 MΩ

Input Capacitance: 50 pF

Max Input Voltage: 1x attenuator 15.5 volts, 10x attenuator 155 volts

Environmental Characteristics

Operating Range: 0° to 50°C

Non-Operating: -4° to 75°C

Physical Characteristics

Weight: 0.14 kg (5 oz)

Shipping Weight: 0.45 kg (1 lb)

Warranty: One year

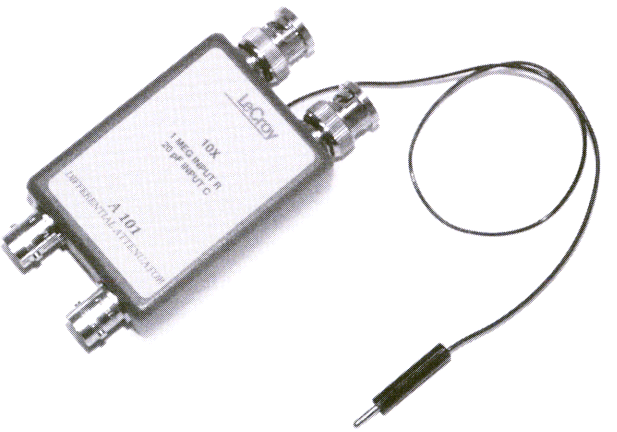
High Voltage Differential Probe Pairs
DXC5100 and DA101

Main Features

- **Max input voltage 2500 V to ground**
- **÷100 attenuation**
- **DC to 100 MHz bandwidth with DA1850A/DA1855A**
- **<2.75 pF input capacitance**



The DXC5100 is a passive, high voltage, differential probe pair for use with DA18xxA series differential amplifiers. When used with the DA101 ÷10 passive external attenuator, up to 5000 volts of differential mode range can be attained, provided that the common mode voltage of 2500 V to ground for each probe is not exceeded. Without the DA101, the DXC5100 maximum differential input voltage is 500 volts.



DXC5100 Specifications

Attenuation factor: ÷100, ±1.75%

Bandwidth (-3 dB): DC to 250 MHz

Max Input Voltage: 2500 V (DC + peak AC)

Input Resistance: 10 MΩ

Input Capacitance: <2.75 pF

Cable Length: 3.1 meter

Weight: 275 g (10 oz)

Shipping Weight: 0.5 kg (1 lb 1.6 oz)

Warranty: One year

DA101 Specifications

Attenuation factor: ÷10

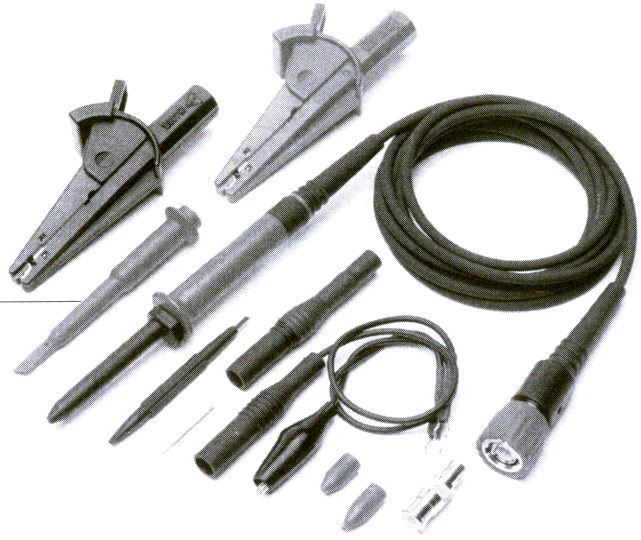
Weight: 0.10 kg (3.5 oz)

Shipping Weight: 0.41 kg (0.9 lb)

High-Voltage Passive Probes – PPE1.2kV, PPE2000, PPE4000, PPE20kV

Main Features

- **Suitable for safe, accurate high-voltage measurements**
- **1.2 kV to 20 kV**



The PPE series consists of three fixed attenuation probes with 2 kV, 4 kV and 20 kV maximum voltage inputs. There is also one switchable probe that provides ÷10 and ÷100 switchable attenuation for maximum voltage inputs up to 600 and 1.2 kV respectively.

Both fixed-attenuation, standard probes automatically re-scale any LeCroy Waverunner™, Wavepro™, LC series or 9300C attenuation factor of the probe.

The PPE1.2kV, PPE2000, and PPE4000 probes are best used on higher frequency applications. PPE20kV is best used on moderate frequency signals with voltages between 4 kV and 20 kV.

The accessories included with the PPE family of probes (excluding the PPE20kV) are: two crocodile clips, a sprung hook, probe tip to banana plug adapter, ground lead with banana plug adapter, BNC adapter, IC insulating tip, insulating tip, ground lead, replacement tip, and a screw driver. The PPE20 kV comes with a ground lead and a hook.

Warranty: One year

High-Voltage Probes Selection Guide

Types Length	Bandwidth (MHz)	Input R (Ω)	Input C (pF)	Attenuation	Maximum Voltage (Cat I)	Probe Encoding	Cable
PPE1.2kV	400	50 M	<6	÷10, ÷100	600 V/1.2 kV	No	2 m
PPE2000	350	50 M	<6	÷100	2 kV	Yes	2 m
PPE4000	300	50 M	<7.5	÷100	4 kV	Yes	2 m
PPE20kV	100	50 M	<2	÷1000	20 kV(40 kV peak)	Yes	3 m

Current Probes – CP015, CP150



Main Features

CP015

- **15 A peak**
- **50 MHz bandwidth**
- **Measure pulses up to 50 A peak**

CP150

- **150 A RMS**
- **10 MHz bandwidth**
- **Measure pulses up to 500 A peak**
- **ProBus compatible**

Measure AC and DC Currents

Measuring AC, DC, and impulse currents is easier with the CP015 and CP150 probes. Based on a combination of Hall effect and transformer technology, these current probes are ideal for making accurate power measurements. There is no longer a need to own an AC and a DC current probe, because the CP015 and CP150 can measure both.

Small Form Factor

Insulated wires aren't always easily accessible, which is why a small form factor solution will greatly simplify measuring. However, while retaining a small form factor, the CP015 and CP150 have a large jaw size, enabling most common insulated wires (in the current range of the respective probes) to be measurable.

ProBus Interface

The degauss function, measurement units, and scale factors are all controlled from the oscilloscope's front panel. This means all measurements and units will be correct without the need to compensate for attenuation differences between the probe and the oscilloscope. In addition, the oscilloscope provides power to the probe, so there is no hassling with an external power supply or changing batteries.

Degauss and Autozero

When using the CP015 and CP150 probes, the measurement system offsets can be easily set to zero by pushing a button in the oscilloscope's coupling menu. This makes it easy to get accurate measurements.

The CP015 and CP150 can be used with LeCroy oscilloscopes with firmware version 8.6.0 or later.

Electrical Characteristics

Max Continuous Input Current:
CP015 15 A
CP150 150 A

Bandwidth (probe only):
CP015 50 MHz
CP150 10 MHz

Max Peak Current (at pulse width):
CP015 50 A (≤10 µs)
CP150 500 A (≤30 µs)

Max In-Phase Current (across all oscilloscope channels):
CP150 500 A

Low-Frequency Accuracy (probe only at 23 +3˚C):
CP015 1%
CP150 1%

Maximum Insulated Wire Voltage:
CP015 300 V CAT I
CP150 600 V CAT II
300 V CAT II

Risetime:
CP015 ≤7 ns
CP150 ≤35 ns

AC Noise (referenced to input):
CP015 ≤2.5 mA
CP150 ≤25 mA

Insertion Impedance:
CP015 0.5 Ω at 5 MHz
CP150 0.1 Ω at 5 MHz

Minimum Sensitivity:
CP015 20 mA/div
CP150 200 mA/div

Coupling: DC and ground

General Characteristics

Max Conductor Size (diameter):
CP015 5 mm (0.2")
CP150 20 mm (0.79")

Cable Length: 2 meters

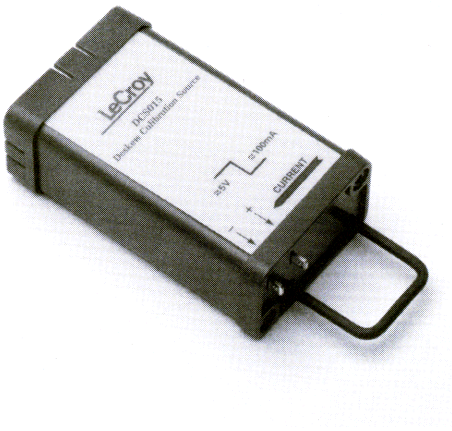
Weight (probe only):
CP015 230 g (8.1 oz)
CP150 500 g (17.6 oz)

Usage Environment: Indoor

Operating Temperature: 0˚C to 40˚C

Interface: ProBus, 1 MΩ only

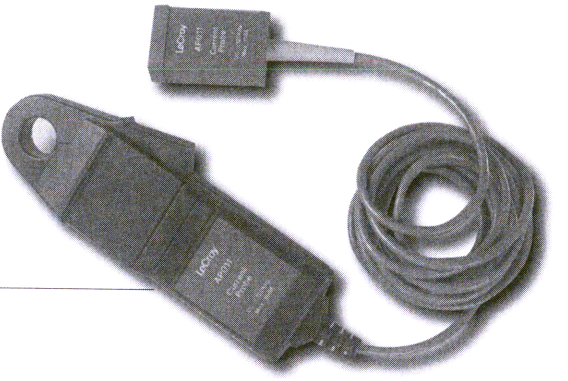
Warranty: One year



DCS015 – Deskew Calibration Source

To make an accurate instantaneous power measurement, you must align your voltage and current waveforms in time. The DCS015 allows you to calibrate your voltage and current probes so that you can achieve matching delays. Using the resample function on a ProBus compatible oscilloscope, you are able to align the edges of the voltage and current square waves, which aligns your probes in time allowing precise instantaneous power measurements. The DCS015 has both voltage (approximately 5 V) and current (approximately 100 mA) time aligned outputs. The CP015, AP015, along with any compatible voltage probe are designed to work with the DCS015.

Current Probes – AP011



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 LeCroy 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.

Autozero 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.

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).

Electrical Characteristics

Probe Bandwidth: DC to 120 kHz

Measuring Range: 0 to ±150 A

Max. Overload Current: 1500 A

Offset Range: ±150 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.

Maximum Insulated Wire Voltage: 300 V CAT II

Delay Time: <1 µs

General Characteristics

Operating Temperature: 0°C to 50°C

Max Conductor Size: 19 mm

Cable Length: 2 m

Interface: ProBus

Weight: 300 g

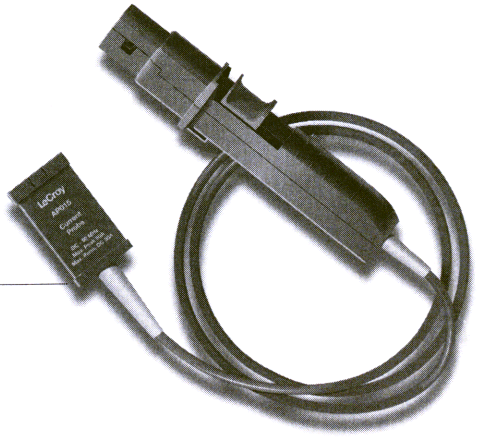
Max Altitude: 2000 m

Max Relative Humidity: 80% (max. 31°C)

Warranty: One year

** Note: Accuracy is specified for probe operating in fixed orientation with respect to earth's magnetic field following an auto-zero operation.*

Current Probes – AP015



Main Features

- DC - 50 MHz bandwidth
- ±30 A max DC current
- ±50 A peak pulse current
- 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.

Autozero & Degauss Functions

Temperature changes and continuous exposure to DC currents can magnetize the core and create offsets in all AD/DC current probes. The AP015 includes a degauss feature to remove residual magnetic fields from the core, and an autotzero feature to eliminate output offset. These features can be conveniently accessed through the coupling menu, and by using remote control commands.

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.

All functions and measurements recognize ampere vertical scales and adjust the resulting waveform or calculation units, including mixed-unit conversions.

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.



DCS015 – Deskew Calibration Source

To make an accurate instantaneous power measurement, you must align your voltage and current waveforms in time. The DCS015 allows you to calibrate your voltage and current probes so that you can achieve matching delays. Using the resample function on a ProBus compatible oscilloscope, you are able to align the edges of the voltage and current square waves, which aligns your probes in time allowing precise instantaneous power measurements. The DCS015 has both voltage (approximately 5 V) and current (approximately 100 mA) time aligned outputs. The CP015, AP015, along with any compatible voltage probe are designed to work with the DCS015.

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

Maximum Insulated Wire Voltage:

300 V	CAT I
150 V	CAT II

Rise Time: < 7 ns

Insertion Impedance: < 0.06 Ω at 5 MHz

**Note depends on the oscilloscope used.*

General Characteristics

Max Conductor Size: 5 mm

Operating Temperature: 0˚C to 40˚C

Max Conductor Size: 5 mm

Cable Length: 2 m

Interface: ProBus, 1 MW only

Weight: 300 gr

Usage Environment: Indoor

Maximum Altitude: 2000 m

General Purpose Accessories

Main Features

- High-impedance divider
- ProBus kit
- ProBus adapter
- Overvoltage input protector
- ADPPS power supply
- Printer paper

GPR10 - Printer Paper

Graphic printer paper for internal oscilloscope printers. Box of 10 rolls.

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.

ADPPS Power Supply

Provides power to the AP33/34 and HFP series active probes; allows the probe's output to be connected to other non-ProBus test equipment. Probe bandwidth limited to 1 GHz. Possible test equipment include: spectrum analyzers and network analyzers.

PP090: 75 to 50 Ω Adapter

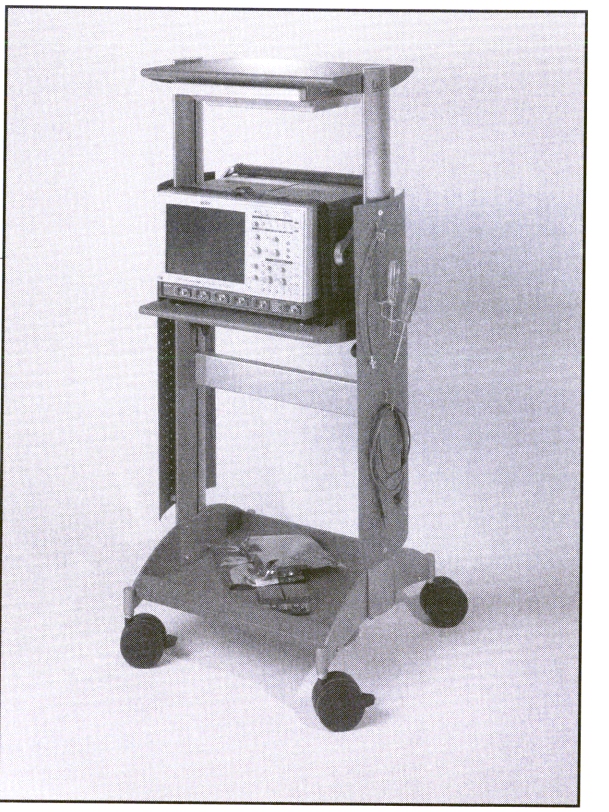
Used with the ProBus compatible scope input, the adapter provides 75 Ω input impedance. Gain compensation is performed automatically by the oscilloscope. Primary applications include telecommunications and video.

SG9001: Overvoltage Input Protector

Assembled in a BNC feedthrough housing, model SG9001 protests 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.

Instrument Carts –
OCPro, OCRunner



OCPro Scope Cart

Both the OCPro and the OCRunner will fit WavePro, Waverunner, LC and 9300C series oscilloscopes. Designed to be as functional as they are stylish, these new carts will change what you expect an oscilloscope cart to do.

The OCPro has standard spaced pegboard holes on its sides. This allows probes, cables, screwdrivers and other tools to be mounted on the side of the cart using standard pegboard hooks. There is also a second shelf with a drawer that is ideal for storing manuals and other documentation.

The OCRunner does not have pegboard walls or the top shelf.

Large, high quality locking casters are used on both models to make transportation as smooth as possible. In addition, the oscilloscope shelf is both height and angle adjustable (angle adjustable using knobs).

Carrying Cases

Main Features

- Soft accessory case
- Carrying cases
- Transit cases

Soft Accessory Case
SAC - 01

The soft accessory case is an ideal way to store a probe with all its manuals and accessories. It can be attached to the top of an instrument using velcro strips. With a pocket on the inside flap meant for the storage of manuals, as well as an interior with enough room for a probe and its many accessories, you will never be hunting for a part again.



Orderable part number:
SAC-01

Carrying Case

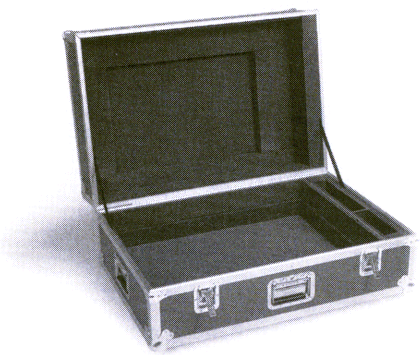
These soft cloth carry bags have an internal pouch for the instruction manuals and accessories. Designed for customers who use their oscilloscope in several different locations: the carry bag also acts as a protective cover.



Orderable part numbers:
LTxxx-TC2
LCxxx-SCC

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.



Orderable part number:
LCxxx-TC1 Transit Case
LCxxx-TC1/RC Removable casters

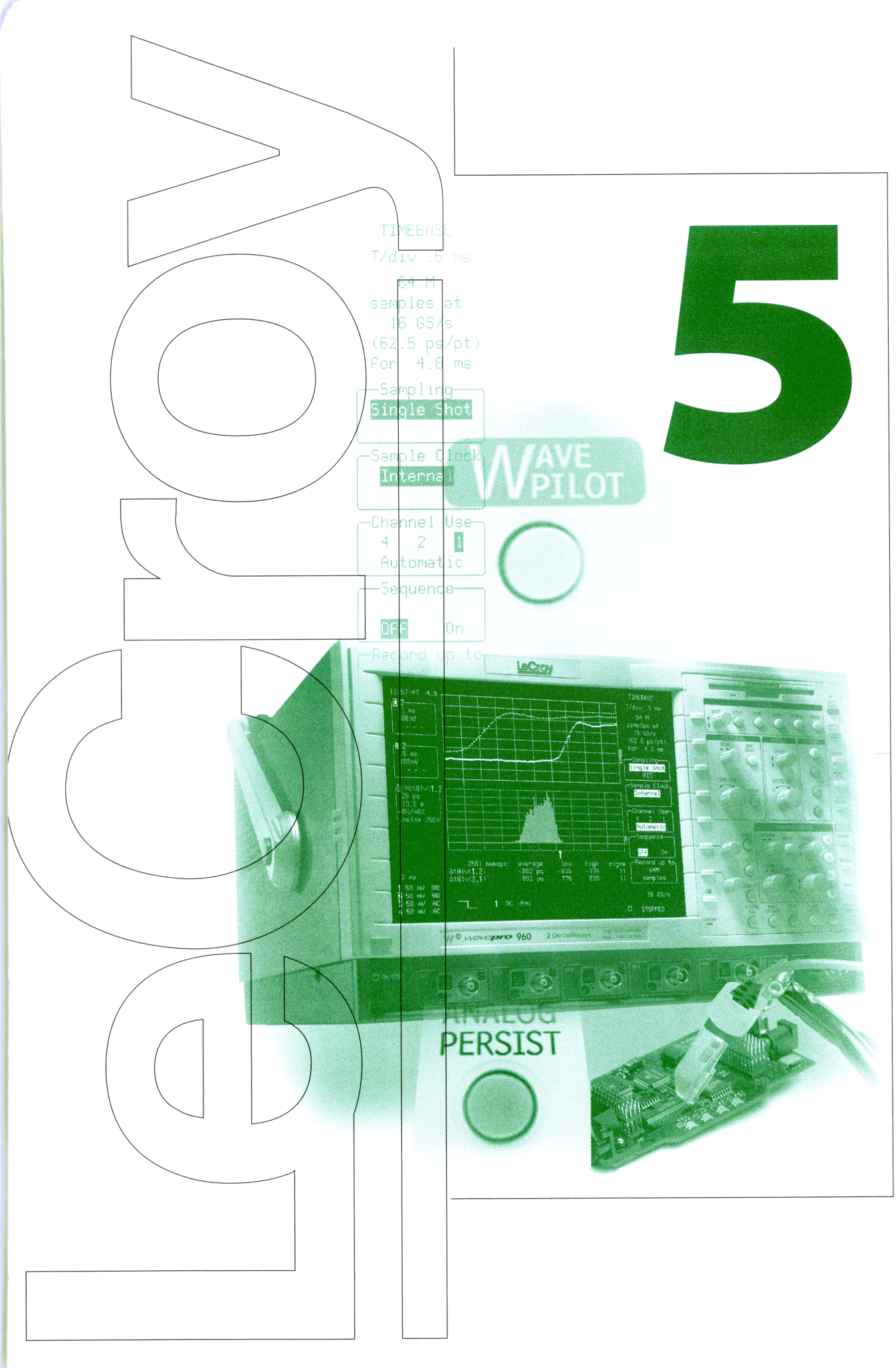
Ordering Information

Probes	Product Code
Active Probes	
20 MHz, 1400 V Differential Probe	ADP300
100 MHz, 1400 V Differential Probe	ADP305
1.0 GHz, 1.8 pF FET Probe	AP020
2.5 GHz, 0.6 pF	AP022
15 MHz High Voltage Differential Probe	AP031
500 MHz Differential Probe	AP033
1 GHz Differential Probe	AP034
1.0 GHz, 0.7 pF	HFP1000
1.5 GHz, 0.7 pF	HFP1500
2.5 GHz, 0.7 pF	HFP2500
Optical to Electrical Converter	OE-325
Current Probes	
150 Amp, 120 kHz	AP011
30 Amp, 50 MHz	AP015
AP015 with 8 meter cable	AP015-8M
15 Amp, 50 MHz	CP015
150 Amp, 10 MHz	CP150
Passive Probes	
÷10, 1 GHz, 500Ω Passive Probe	PP062
÷10, 350 MHz, 10 MΩ Passive Probe	PP002
÷10, 350 MHz, 10 MΩ Passive Probe	PP006
÷10, 500 MHz, 10 MΩ Passive Probe	PP005
÷10/÷100, 600 V/1.2 kV max voltage, 200/300 MHz	PPE1.2kV
÷100, 1 GHz, 5 kΩ Passive Probe	PP065
÷100, 2 kV DC + peak AC pulse, 400 MHz	PPE2000
÷100, 4 kV DC + peak AC pulse, 400 MHz	PPE4000
÷1000, 20 kV DC + peak AC pulse, 100 MHz	PPE20kV
2 GS/s Adapter for 9354/M/L or LC334 Series	PP092
2 GS/s Adapter for 9354/M/L or LC334 Series	PP094
2 GS/s Adapter for 9374/M/L or LC534 Series	PP093
HFP series Accessories	
Micro Clip	PACC-CL001
Ground Spring Hook	PACC-LD001
Square Pin Ground Spring	PACC-LD002
Short Right Angle Lead	PACC-LD003
Long Right Angle Lead	PACC-LD004
Short Single Lead	PACC-LD005
Long Single Lead	PACC-LD006
FreeHand Probe Holder	PACC-MS001
Replaceable Cartridge	PACC-MS002
Low C Cartridge	PACC-MS003
Straight Tip	PACC-PT001
Sharp Tip	PACC-PT002
IC Lead Tip	PACC-PT003
SMD Discrete Tip	PACC-PT004
Bent Sharp Tip	PACC-PT005
0.8 mm Clip	PK006-4
Offset Pin	405400003

Ordering Information (cont.)

Probes	Product Code
Probe Accessory Kits	
Probe Accessory Kit for PP001/2	PK001
Probe Accessory Kit for PP061/62/64	PK003
Probe Accessory Kit for AP020/21	PK004
SMT Probe Kit for AP020	PK006
SMT Probe Kit for AP022	PK022
Microclip Accessories for PP005	PK101
Standard Accessories for PP005	PK102
Probe Accessory Kit for PPE1.2kV, PPE2/4/5/6kV	PK103
Probe Accessory Kit for PPE20kV	PK104
SMT Probe Kit for PP005	PK106
Probe Accessory Kit for PP006	PK116
Differential Amplifiers and Accessories	
÷10 1 MΩ Passive Attenuator (use with DXC 5100)	DA101
10 MHz Differential Amplifier	DA1820A
Two Channel DA1820A	DA1820A-PR2
DA1820A-PR2 with rackmount	DA1820A-PR2-RM
DA1820A with rackmount	DA1820A-RM
10 MHz Differential Amplifier with Precision Voltage Generator	DA1822A
Two Channel DA1822A	DA1822A-PR2
DA1822A-PR2 with rackmount	DA1822A-PR2-RM
DA1822A with rackmount	DA1822A-RM
100 MHz Differential Amplifier	DA1850A
Two Channel DA1850A	DA1850A-PR2
DA1850A-PR2 with rackmount	DA1850A-PR2-RM
DA1850A with rackmount	DA1850A-RM
100 MHz Differential Amplifier with Precision Voltage Generator	DA1855A
Two Channel DA1855A	DA1855A-PR2
DA1855A-PR2 with rackmount	DA1855A-PR2-RM
DA1855A with rackmount	DA1855A-RM
÷100 or ÷10 Selectable 250 MHz Passive Differential Probe Pair	DXC100A
÷1000 50 MHz Passive Differential Probe Pair	DXC200
÷100 250 MHz, 2.5 kV Passive Differential Probe Pair	DXC5100
Miscellaneous Accessories	
Protective Front Cover 9300 Series	93XX-FC
Rackmount Adapter for 9300 Series	DSO93XX-RM01
Soft Carrying Case for 9300 Series	DSO93XX-TC2
Hard Carrying Case for 9300 Series	DSO93XX-TCI
ProBus to BNC and Power Adapter for AP03X and HFPXXXX probes	ADPPS
Two-Meter GPIB Cable (IEEE488)	DC/GPIB
Deskew source for CP015 and AP015	DCS015
Graphic Printer Paper /10 rolls	GPR10
128k Memory Carrd for 9300 Series	MC02
512k Memory Card for 9300 Series	MC04
Oscilloscope cart, with pegboard sides, for WavePro, Waverunner, LC series	OCPro
Oscilloscope cart for WavePro, Waverunner, LC series	OCRunner
Overload Protector for High Voltage	SG9001
Oscilloscope cart for Waverunner and LA series scopes	SK-2101

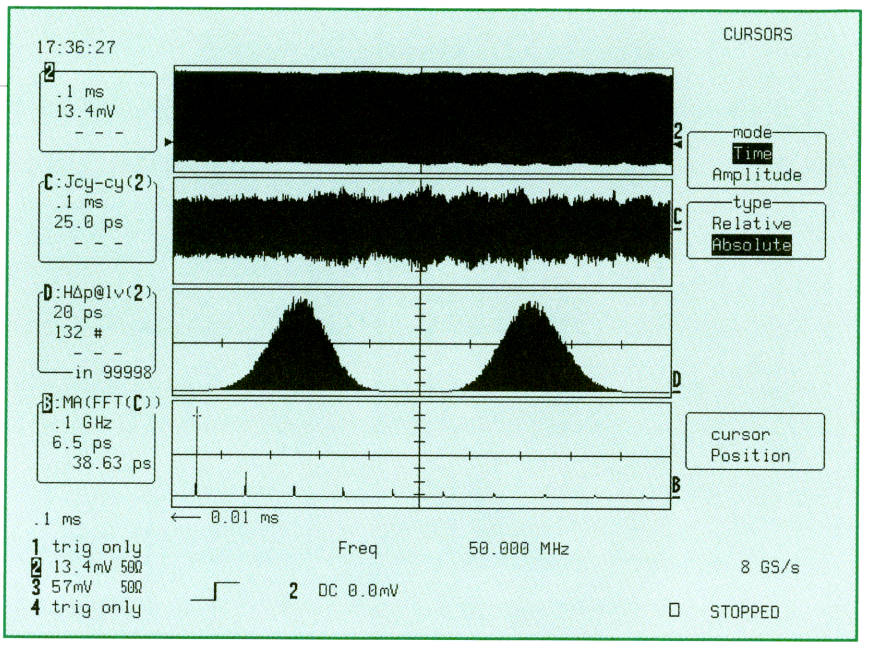
5


LeCroy
TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
PERSIST
wavepro 960

Jitter and Timing Analysis

Main Features

- **JitterPro — high-speed clock and data jitter analysis package**
- **Three views of jitter, including JitterTrack**
- **A rich set of timing measurements for clock, clock-to-data, and data stream analysis**
- **Rambus-specified module for DRCG clock validation**
- **High-accuracy, peak-to-peak jitter measurements**
- **Ease of operation – through JitterWizard**
- **Flexibility of operation – to do exactly what you need**
- **Application-specific solutions**



LeCroy provides the most complete and useful solutions available today for characterizing, validating, and debugging signal jitter and timing. In combination with the right scope, these tools provide fast answers with a high confidence level.

The long memory and high-performance processing power in a LeCroy scope enable you to achieve accurate answers with high statistical confidence.

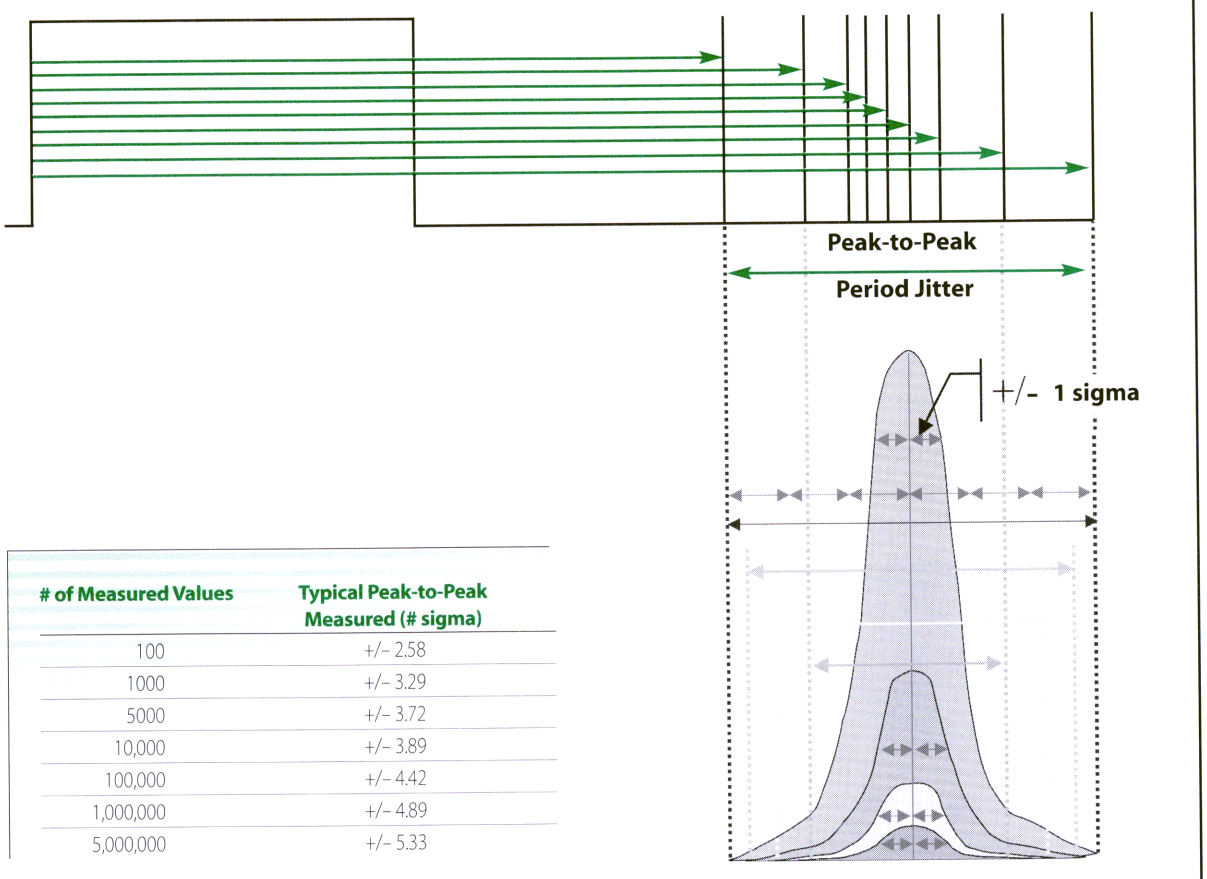
Additionally, while other test instruments provide only "numbers," LeCroy also provides three "views" of signal jitter to give you insight into the causes of timing instabilities. These "views" in the time, statistical, and frequency domains allow you to troubleshoot circuit problems or perform component characterization much more quickly.

Three Views of Jitter

1 – Statistical View: The Key to Measurement Accuracy

LeCroy's statistical view of jitter gives insight by providing a view of the distribution of jitter. As with any noise-based phenomena, the peak-to-peak value grows as more values are measured. Therefore, anyone interested in determining worst-case timing and jitter values needs to consider the number of measurements taken in making this determination. More is better.

One type of jitter commonly measured is the variation in a clock period as diagrammed below. Consider each arrow as one measurement of period and the difference between the shortest and longest durations as the peak-to-peak jitter. In most designs, it is the worst case jitter occurences that cause problems, so finding them is crucial.



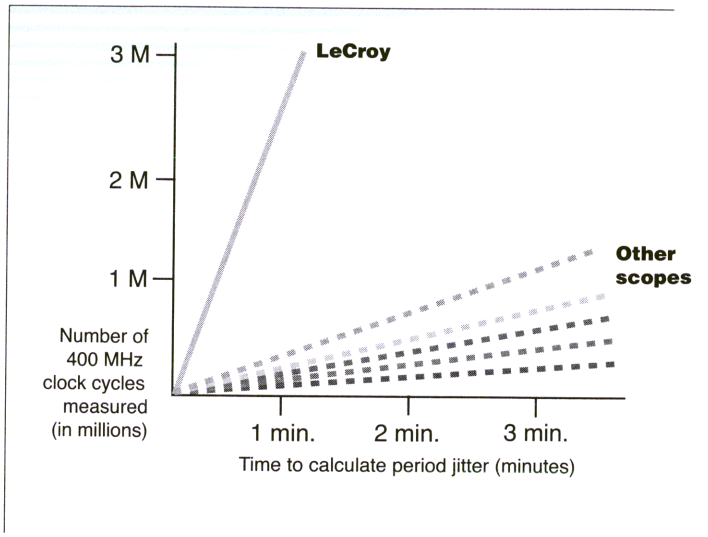
# of Measured Values	Typical Peak-to-Peak Measured (# sigma)
100	+/- 2.58
1000	+/- 3.29
5000	+/- 3.72
10,000	+/- 3.89
100,000	+/- 4.42
1,000,000	+/- 4.89
5,000,000	+/- 5.33

As can be seen above, hundreds of thousands and even millions of timing measurement values are necessary for accurate peak-to-peak measurements. ***More measurements mean higher accuracy!***

As more individual measurements are accumulated, their distribution can be displayed in a histogram. **The peak-to-peak value grows statistically as more measurements are made.**

Processing Performance and Accuracy

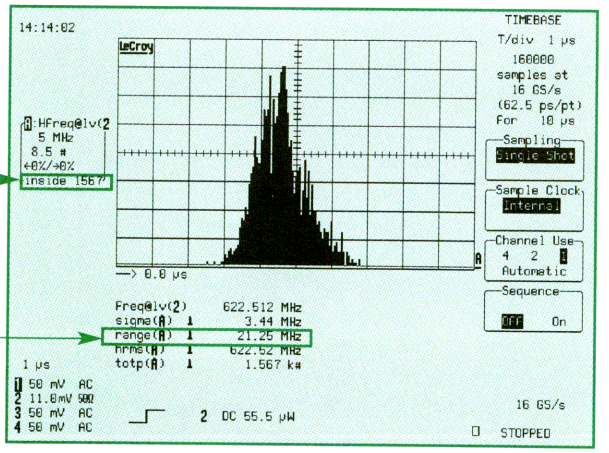
Component selection and clock system validation require that tens of thousands, if not hundreds of thousands, of peak-to-peak jitter measurements be made. LeCroy's ultra-fast processing can provide statistically meaningful peak-to-peak measurements in seconds, unlike other oscilloscopes that are orders of magnitude slower.



Capture Duration and Measurement Accuracy

Some measurements, such as n-cycle jitter measurements, can only be performed on a single acquisition. Acquisition duration is key to peak-to-peak measurement accuracy! LeCroy scopes can capture and analyze hundreds of thousands — even millions — of clock cycles in a single acquistion with zero dead time!

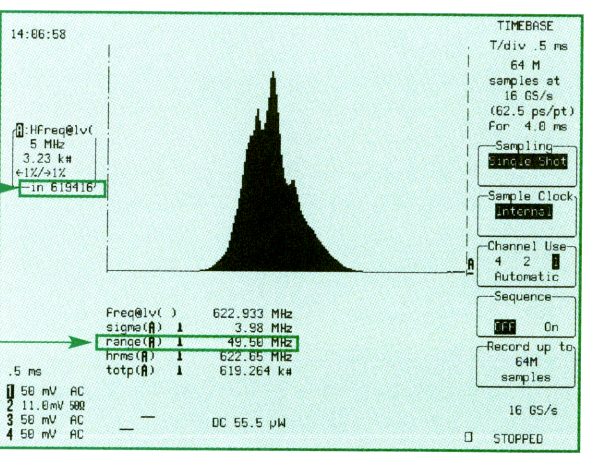
160 kpoints Capture



160 kpoints Captured/Analyzed

Shown above is a frequency jitter measurement for a high-speed clock using a capture duration of 160 kpoints of acquisition memory (typically available on non-LeCroy scopes). Due to the short capture duration, the histogram has only 1,567 measurement values in its distribution. Note that the frequency jitter value range (D) is 21.25 MHz. Is this the peak-to-peak jitter your system actually sees?

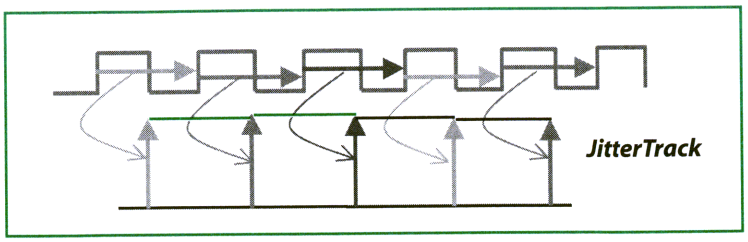
64 Mpoints Capture



64 Mpoints Captured/Analyzed

Shown above is the same measurement as on the left, using the 64 Mpoint capture duration available in LeCroy scopes. Note that the histogram distribution is now very clear. Also note that the peak-to-peak measurement range (D) is considerably higher and more accurate now because 395 times more measurement values (a total of 619,418) can be included to determine the peak-to-peak range of jitter. The more accurate range of frequency jitter is 49.5 MHz.

2 – Time View of Jitter: JitterTrack
The key to understanding and debugging jitter



What is JitterTrack?

JitterTrack is a patent-pending feature from LeCroy that displays how a jitter/timing measurement varies with time.

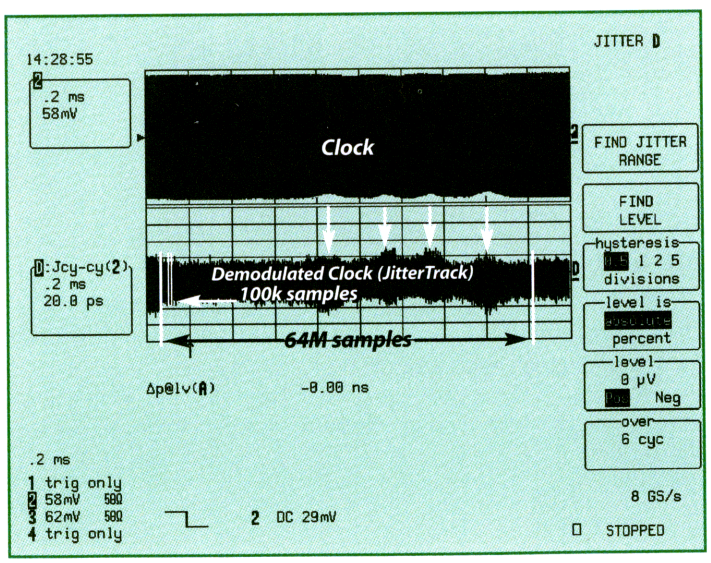
Imagine that each clock period is represented by an arrow, as shown above. Variations in time of the period are not clear at all. Now imagine that each of these arrows is flipped perpendicularly and placed time-synchronized to the individual periods they represent. The amplitude of each arrow represents the time duration of each period. By connecting the tops of those arrows, you now can see how a particular jitter measurement varies over time, perfectly synchronized in time to the signal being measured.

Unique JitterTrack Feature for Debugging Jitter

The most useful jitter debugging tool available today!

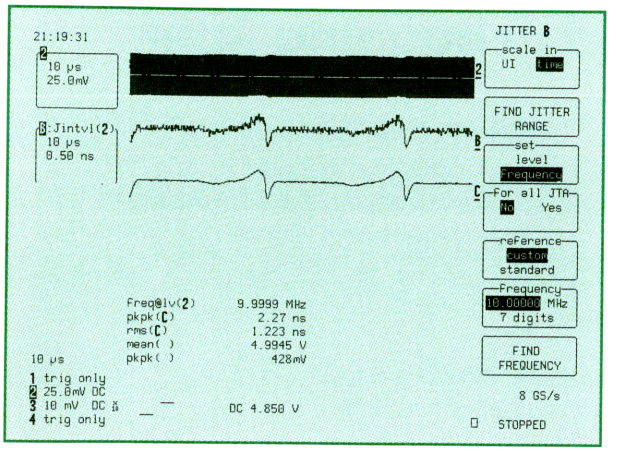
The key to debugging jitter is the ability to correlate jitter events to other device, board, or system signal events. Only LeCroy's JitterTrack function offers this capability by providing a display of jitter that is synchronized in time with the display of captured scope signals.

Jitter Bursts



Shown in the upper trace is a 2 ms capture of a 400 MHz differential clock. The lower trace is the JitterTrack display of the clock's cycle-to-cycle jitter, synchronized in time with the clock signal. The JitterTrack signal shows clear bursts of higher jitter. The times of these bursts correspond directly to times when the clock signal has a slight reduction in amplitude. A clear relationship between the two events, amplitude variation and jitter bursts, is thereby easily determined. Also note that a scope with a short capture duration, or limited analysis window of only 100k samples would be incapable of identifying this phenomena.

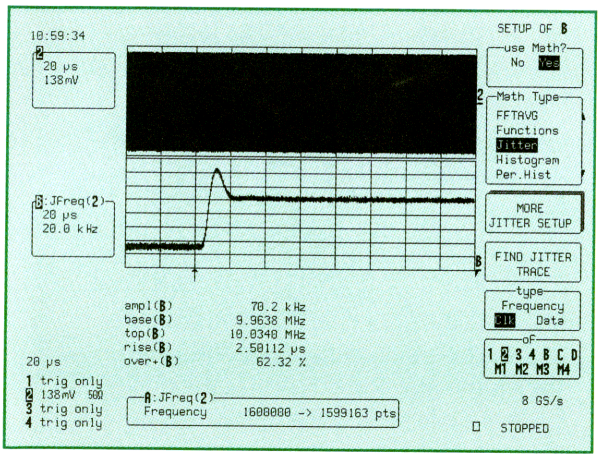
Power Spikes



Power quality problems are the most common source of excessive jitter, but how do you know if this is the case for your circuit? With JitterTrack! The upper trace is a clock signal. The middle trace is a Time-Interval-Error JitterTrack of the clock signal. The bottom trace shows the power signal to the clock chip. Notice that the JitterTrack display shows spikes of jitter occurring simultaneously with the power spikes. A clear understanding of the impact of power spikes to jitter can be made here only because the JitterTrack function is synchronized in time with all other captured signals and because LeCroy scopes have long acquisition duration.

JitterTrack for Characterization

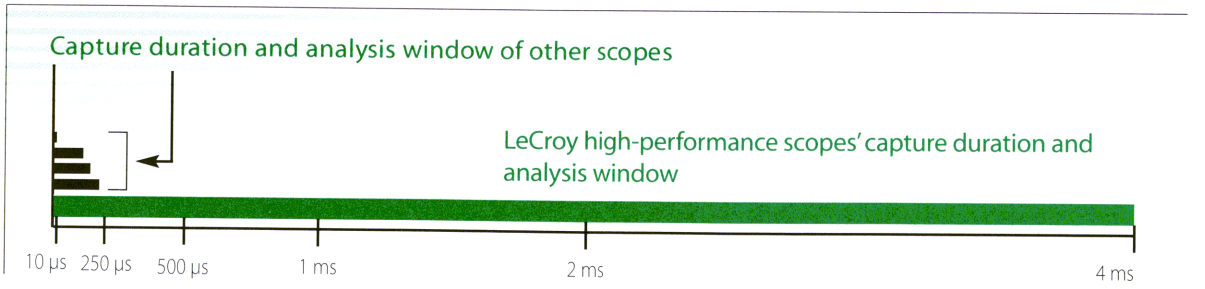
PLL Step Response



The upper trace shows a PLL whose reference frequency is being stepped. The lower trace shows the JitterTrack of the PLL's output frequency. The PLL step response is clearly seen in the JitterTrack display, including frequency overshoot. In addition, a range of measurements is performed directly on the JitterTrack display to numerically characterize the frequency step response. LeCroy's JitterTrack capability combined with the flexibility of the LeCroy interface allows this analysis to be easily performed.

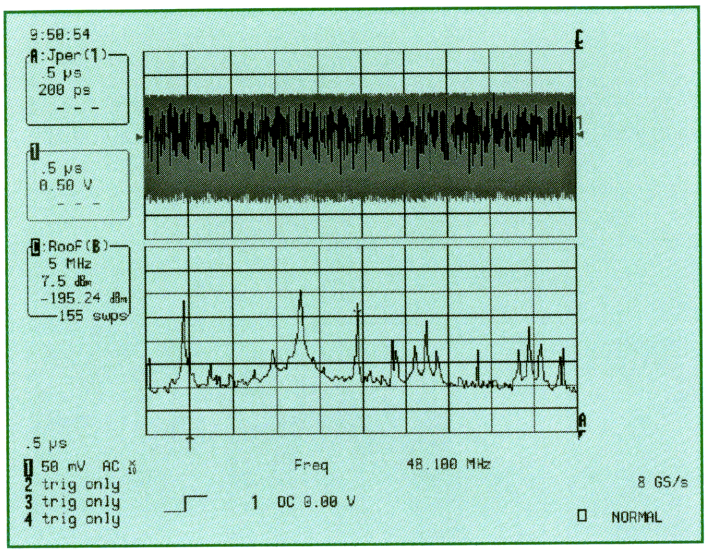
Acquisition Duration is Crucial to Jitter Debug and Characterization

Many phenomena that impact jitter and timing, such as power glitches, clock modulation, PLL step response, etc., take hundreds of microseconds or even milliseconds to occur. Only with the combination of LeCroy's long-capture duration and the JitterTrack function can these events be detected and analyzed. Don't get stuck without the right tools to do your job!



3 – Spectral View of Jitter

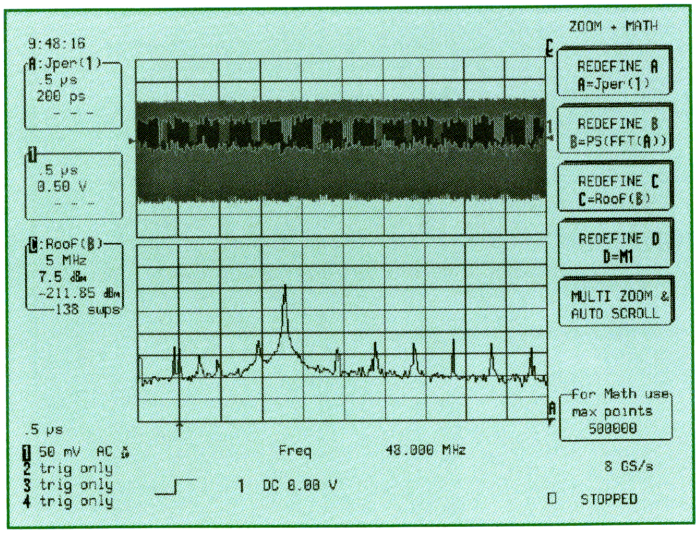
Because jitter may have various frequency components, it is important that a spectral view of jitter be available. This view often reveals critical insights into the sources of jitter. LeCroy provides a direct view of these frequency components as an FFT of jitter. Unlike FFT's of a clock signal, this provides a spectral view that is purely of the timing measurement variations.



Crosstalk in Integrated Circuits
The JitterTrack option is a useful tool for troubleshooting problems such as crosstalk. The screen shot (left) is an example of a 40 MHz clock with a high jitter component. Channel 1 (upper trace) is a 50 µs acquisition of the clock signal at 8 GS/s sampling rate and Trace A (super-imposed on the top grid) is the JitterTrack of the clock period. Trace B (not shown) is the Jitter FFT and Trace C (lower grid) is the roof of 155 acquistions of the Jitter FFT spectrum. This trace shows a spike at 48.1 MHz.

Data stream Time Interval Error (TIE) Measurements

For telecom, datacom, data storage, and other applications employing clock recovery circuitry, serial data stream jitter measurement is an absolute necessity. LeCroy's advanced jitter measurement algorithms provide this capability. Several data stream measurements, including the very important Time Interval Error (TIE), are provided. For TIE measurements, high clock stability and long acquisition duration are essential. LeCroy's industry leading acquisition duration and high-stability sampling clock make them the only scopes to use for TIE measurements.



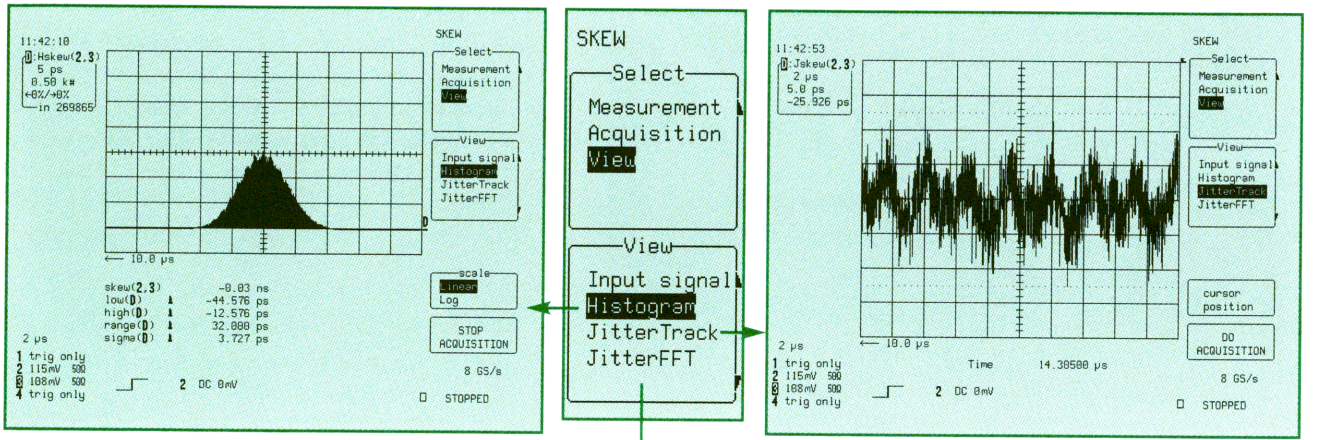
Shown is a non-standard data stream signal (upper trace) and the corresponding Time Interval Error JitterTrack (lower trace). The variations of data stream jitter in time are easily seen. As with clock signals, all three views of jitter can be selected for data stream signals. In addition, data stream signals based on telecom standards can be easily configured using the "standard" menu selection.

LeCroy Jitter & Timing Products

JitterPro Software Package

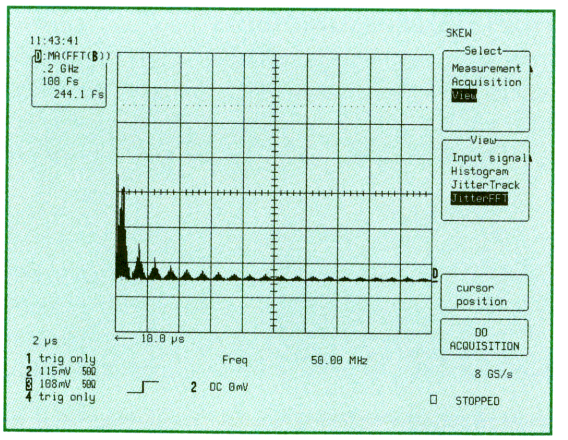
JitterPro is LeCroy's newest, most powerful and complete jitter measurement and analysis package. It is available for the WavePro, LC684D and LC584 series of high-end oscilloscopes. JitterPro features:

- A full set of jitter measurements and the JitterTrack function, including skew, setup, hold, and N-Cycle analysis with start cycle selection
- The JitterWizard function which turns your LeCroy DSO into a dedicated jitter analyzer
- For incredible ease of operation, combined with unparalledled jitter analysis capabilitiies. All three views of jitter are automatically set up and displayed through a simple menu selection.



Statistical View – Histograms characterize the range and distribution of jitter

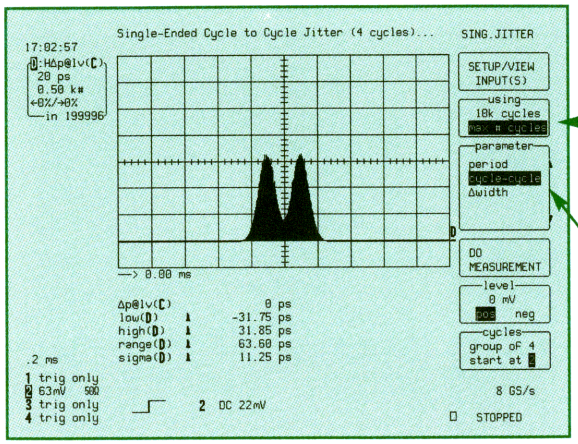
Time View – JitterTrack reveals modulation effects and allows intermittent jitter events to be correlated with the signal.



Spectral View – The Jitter FFT gives insight to jitter sources using the frequency domain view.

Clock Certification & Test Module (CCTM)
Rambus-Specified Jitter Measurement

LeCroy's CCTM package is specified by Rambus Inc. as the first approved tool for compliance testing of DRCG (Direct Rambus® Clock Generator) jitter. All jitter measurements as required by Rambus are automatically configured and easily performed through the CCTM wizard.



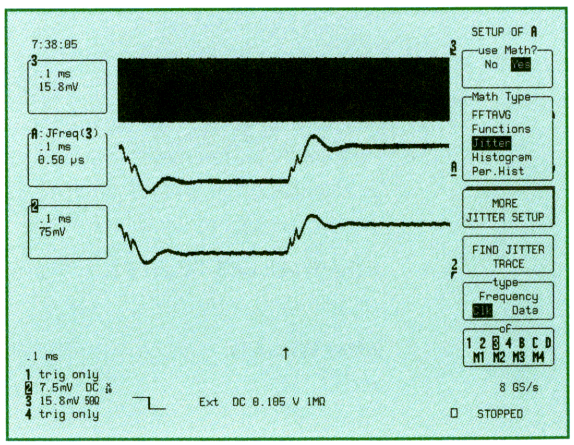
Rambus specifies that measurements be performed over the same acquisition. Select "10 k" clock cycles for a very rapid snapshot of jitter. Or choose "maximum number" of cycles to apply the power of LeCroy's unparalleled capture length and achieve maximum peak-to-peak measurement accuracy.

Selection between different measurement choices results in display of jitter measurement distributions and peak-to-peak values using data from the same acquisition.

N-Cycle jitter measurement results are often dependent on the specific clock cycle the measurement is initiated on. To account for this dependency, CCTM provides the ability to select each possible start cycle (i.e., 0-3 for a 4-cycle measurement) and see how the jitter measurements vary for each of these — all on the same acquisition. Shown above is a four-cycle measurement with a start cycle of two.

Jitter and Timing Analysis (JTA) Package

JTA is a moderately priced jitter and timing analysis solution for design and test engineers working with lower performance signals or who only occasionally need to perform jitter and timing measurements. It has broad application from high-speed clock measurements to lower-speed digital electronics or mechanically related measurements. You can measure a wide variety of timing parameters: cycle-to-cycle, period, frequency, time interval, duty cycle, and width.



For VCOs, linearity of response of output frequency to input voltage is a key characteristic. JTA's JitterTrack feature, combined with the flexibility of LeCroy's user interface, makes VCO linearity easy to determine. The top trace is the output of the VCO. The center trace is a JitterTrack of the VCO output frequency. The bottom trace is the reference voltage for the VCO. The linearity of response of the VCO is clearly evident, thanks to JitterTrack's time synchronization to other scope signals.

Jitter Measurement Specifications

Available Measurements

Single-Shot Measurements	JitterPro	JTA	CCTM
Clock			
Cycle-to-Cycle	√	√	√
N-Cycle	√	√	√
N-Cycle w/Start Selection	√		√
Frequency	√	√	
Period	√	√	
Width	√	√	
Duty-Cycle Error			√
Time Interval Error	√	√	
Data stream			
Cycle-to-Cycle	√	√	
Frequency	√	√	
Period	√	√	
TIE (Time Interval Error)	√	√	
Two-Signal Measurements			
Skew	√	√	
Setup	√		
Hold	√		
Troubleshooting Tools			
JitterTrack	√	√	√
Jitter FFT	√	√	√
Histogram	√	√	√
Jitter Wizard	√		√

Jitter Noise Floor: The jitter noise floor specification represents the lowest value of timing jitter which can be observed. The noise floor is determined usng an extremely stable pulse generator such as an HP8133 operating at 50 MHz. The signal must be measured in a low noise environment with high quality cables. The jitter noise floor of JTA and JitterPro when used with a WavePro or LC series scope is 2 ps rms.

Maximum Clock Stability: 1-2 ppm typical, 10 ppm max. Better than 1 ppm with external reference clock option.

Capture Duration: Up to 4 ms at 16 GS/s for WavePro 960.

Processing Performance: Capture, measure, and view histogram of a 400 MHz clock:

1.6 million measurements per trigger with 16 GS/s resolution for 4 msec. with a WavePro 960 using the XL memory option

800,000 measurements with 8 GS/s resolution for 2 msec. for LC684DXL or LC584AXL

800,000 measurements with 4 GS/s resolution for 2 msec. for a Waverunner-2 model LT374 with "L" memory option

Number of Jitter Measurements that can be Displayed: Four traces of JitterTrack, FFT, or histogram can be displayed simultaneously with a choice of any five parameter measurements. Parameter measurements include average, max, min, and standard deviation of parameter values.

JitterTrack and JitterFFT: Available with JitterPro and JTA.

Jitter Wizards: Available with JitterPro and CCTM.

Jitter Analysis Packages

Ordering Information

Software Options	Product Code
JitterPro	JPRO
JitterPro Field Retrofit	RK-JPRO
JitterPro Upgrade for JTA Owners	RK-UPG-JPRO
Jitter and Timing Analysis Package	JTA (includes WP03 Statistical Analysis)
JTA Field Retrofit	RK-JTA (includes WP03 Statistical Analysis)
JTA Upgrade for WP03 Owners	RK-UPG-JTA
Clock Certification & Test Module	CCTM
Clock Certification & Test Module Field Retrofit	RK-CCTM

An Introduction to Timing and Jitter Measurements for Phase-Lock Loops and Oscillators

Because today's products involve faster signals with tighter timing budgets, it is important that engineers have accurate instruments to verify the timing accuracy of crucial signals — and the best trouble-shooting tools for fixing problems so that new products can get to market. New digital scope features have added considerably to their accuracy and problem-solving capabilities. Standard features such as a large display, long memory, and high bandwidth and sampling rate are good starters. But there is more to look for beyond these basic features.

The Basics — Capture, View, Analyze

In general, a digital oscilloscope's task is to let the user capture, view, and analyze a variety of signals — and provide troubleshooting tools in case the view/measurements show the circuit under test is faulty. When making timing measurements, factors to consider in capturing the signal are the trigger capabilities, bandwidth, sampling rate, and acquisition memory length. Many high-performance scopes offer triggers that can isolate problems with slew rates (the speed of signal edges), glitches, and runts. If you are working with high-speed signals, look for a scope with the capability to trigger on fast events. The fastest trigger circuits can be set with a resolution of 100 ps to capture slew rates, runts, and glitches down to 600 ps in length. If you don't have any idea what sort of problem a circuit has, several vendors offer scopes that simply trigger very quickly and put all the data into a persistence map on the screen. You can then look for the types of events that might be causing trouble and set up a trigger to catch them. Alternatively, if you know what a normal signal should look like, some scopes will allow you to NOT trigger on those events — just trigger when the signal has an abnormal timing characteristic. This is sometimes called "exclusion trigger" because the triggering conditions exclude the usual signal and trigger only on abnormal events. For example, if a normal clock signal has a certain period and risetime, it is possible to set the trigger condition to ignore the normal clock pulses and trigger only if the period is too short or too long — or if the risetime is too fast or too slow.

Scope bandwidth and sampling rate are also important in accurate signal capture. For timing measurements, sampling rate is usually the more important of these two factors. As a general rule, a digital scope should capture at least eight samples per signal cycle to make reasonably accurate timing measurements. Precision measurements may require an even better ratio. The front end amplifier's bandwidth needs to be sufficient to track the highest bandwidth component of the signal for which the user is interested in measuring the timing characteristics. An engineer working on a circuit with risetimes of 350 ps may be quite happy using a 1 GHz scope, which has amplifiers with an intrinsic risetime of 400 ps. The scope will slow the risetime of all the clock edges equally without changing their relative timing. Of course, if the user wants to measure the effects of very high-frequency noise (above 1 GHz), then a higher-bandwidth instrument should be used. But scope users should be careful of the two-edged effect of higher bandwidth. Granted, risetimes will be more accurate and the scope will accurately portray wide bandwidth noise on the signal. But suppose the microprocessor clock is driving an input to high-speed RAM devices and that these chips will respond to the clock edge but not to high-frequency noise. In this case, circuit response is bandwidth limited and ignores the very high-frequency noise. If the measuring instrument has too much bandwidth, it can lead the user to an incorrect conclusion. As an example, wideband vertical noise can be a major contributor to edge jitter. But one should not overestimate the effect of vertical noise by including what is beyond the bandwidth responsiveness of the circuit under test. Also, as a general rule, the wideband noise of an amplifier increases with the bandwidth's square root, so one must be careful that the test instrument does not add substantially to the signal's noise/jitter. High-performance scopes are available in the 500 MHz to multi-gigahertz bandwidth range that have intrinsic jitter of a few picoseconds.

If you are measuring the timing for a single occurrence of simple signals such as the propagation delay through a gate or setup and hold times, the length of acquisition memory in the scope is of little importance. But many engineers work with more complex circuits that require analysis of clock stability or checking the timing of complex data streams. Such applications include the design of microprocessor-based devices, peripherals, video, and all types of datacom and telecom products. In these cases, a scope should be selected that includes enough memory to maintain the maximum sampling rate of the ADC

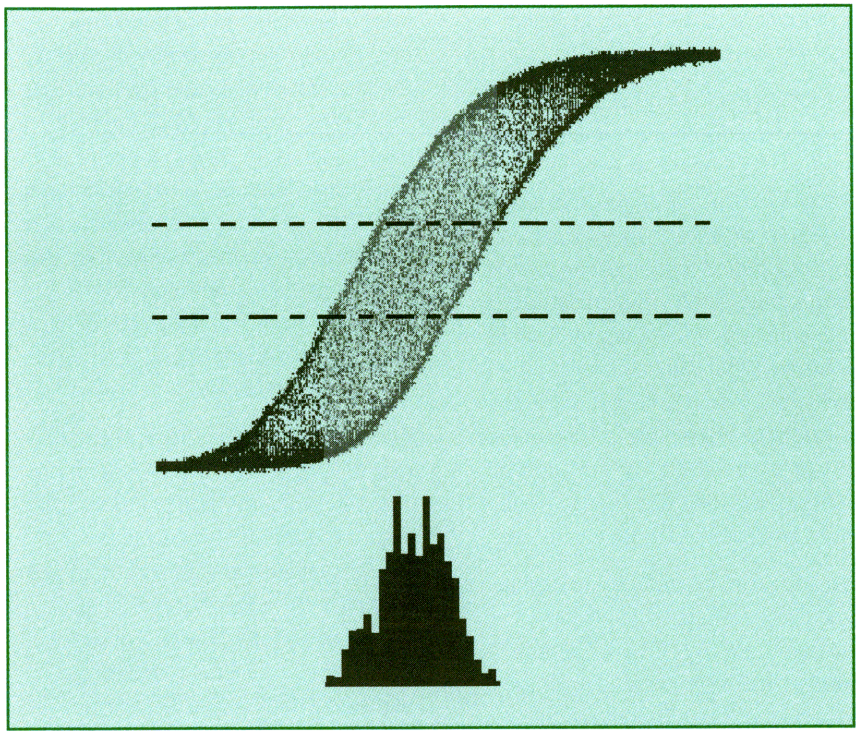


Figure 1: A digital scope user can set "cuts" (the horizontal bars) that define an area of interest in a signal. If the signal is acquired many times and mapped onto a persistence representation, the data that is inside the "cuts" can be displayed — for example, the spread of signal edge arrival times.

throughout the data record. If the memory length is insufficient, the user has the undesirable choice of either slowing the sampling rate of the ADC to capture the whole signal or keeping the sample rate at maximum by not recording the whole pulse train. As an example, a Rambus clock stability test requires capturing a minimum of 10,000 consecutive cycles. For a 400 MHz clock, a sampling rate of 4 GS/s would be a good match (this would give 10 samples per 2.5 ns clock period). To capture 25 ms of clock data at this sampling rate, 100,000 data samples are required — a modest memory length but beyond the capability of many scopes. However, this protocol also requires testing of groups of "n cycles" with n ranges as high as six. To get measurements of 10,000 consecutive groups of six cycles requires an acquisition memory of at least 600,000 samples. In addition, the scope needs a processor that can handle that amount of data and enough RAM to support calculations on long data arrays. Some scopes have as much as 64 Mbytes of RAM and can handle math operations fairly quickly even when long data records are captured on multiple channels.

Also keep in mind that many types of timing measurements need a statistically valid data set. You can't measure clock period jitter by measuring the cycle-to-cycle change one time. The table on page 135 shows the number of measurements you need to perform in order to attain reasonable certainty that you have measured the distribution range of a parameter whose values have a Gaussian distribution. This would include many types of timing measurement in which the variation of the signal timing is dominated by wideband noise.

If you measure the value of a parameter like duty cycle error 1000 times, you will most likely get a distribution that spans a range of ±2.9 sigma. Capturing 1,000,000 measurements extends the range of values to about 9 sigma (±4.6 sigma). This gives users much more confidence that they have accurately characterized worst-case circuit performance. Some scopes will capture just one value of a parameter per trigger (usually from the first period on the screen) even if a long memory length is captured, while others can capture one million or more cycles of a high-speed clock in a single trigger and measure them all. CPU speed and RAM size vary considerably from model to model and are not necessarily related to price. Some low-price scopes have powerful processing, while some high-priced units are quite slow. Also, some scopes have dedicated DSPs to perform certain computations quickly but run like molasses on other types of calculations. So if you are looking for a scope, the best advice is to try it on the types of measurements you want to make.

Troubleshooting

If your capture, view, and analysis proves that your product is meeting all its timing criteria, congratulations! If not,

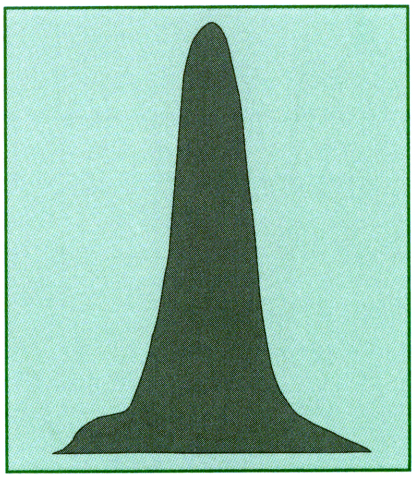


Figure 2: Histograms that have "shoulders" or multiple peaks are excellent troubleshooting tools. In this case, the parameter distribution clearly has a contribution from noise determining the width of the basic peak, but there is also a "shoulder" on the left side indicating a non-random and reasonably common shift in the parameter value.

the next step is troubleshooting. Some advances have brought more power to bear on locating the source of timing/jitter problems. The first is the ability for several brands of scopes to go into modes that trigger very quickly and display a persistence map of the data. This lets you "eyeball" a large number of events in order to spot anomalies visually. Some scopes can also take this persistence map data and draw vector traces that show an envelope that is ± 3 sigma (or any other value of "sigmas") while others can give a statistical representation of the data values. The statistical representation can be a simple set of four numbers that characterize multiple acquisitions of an edge by displaying the earliest, latest, average, and sigma for the arrival of that edge. Also, some scopes will plot a histogram that shows the times of arrival of all the edges (Figure 1). This is a useful feature, because it allows you to see the effects of noise (usually a Gaussian distribution) and of competing processes (a multi-peaked histogram or one with "shoulders," such as Figure 2, indicates there are more contributions to the timing problem than simple noise).

In addition to plotting histograms showing the distribution of the raw signal, some scopes can also plot histograms of signal parameters such as cycle-to-cycle jitter, changes in duty cycle from one period to the next (required for constructing Rambus systems), the distribution of pulse amplitudes, etc. The set of parameters that can be histogrammed varies from model to model, so be aware of which parameters are important for your product and choose a scope that gives you the tools you need to troubleshoot instabilities in those parameters.

In many cases, it is desirable to maintain a time-related record of parameter measurements. A LeCroy scope with JitterPro or JTA can draw a JitterTrack trace on the screen that shows the consecutive values of timing parameters such as period, width, cycle-to-cycle, and frequency using the same timebase as for data acquisition. This trace tracks the timing variations of the signal "live" along with the trace of the raw data (Figure 3). If there are changes in the period (or frequency or duty cycle, etc.) of a signal, the JitterTrack trace will show a line that tracks those changes. While statistical data is useful for verifying that a system is within specifications, a jitter tracking trace on a scope provides an excellent tool for troubleshooting circuits when they have problems. The engineer can quickly identify the location of the offending part of the signal under test and zoom in on the cause of the failure.

If you are like most engineers, next month's project will involve faster, more complex problems than last month. And you can count on next year to bring circuits that are even faster, as the desire continuously grows to move larger chunks of data (audio, video, graphics, etc.). So the final factor in choosing a scope is to think ahead. Get a faster trigger, more memory, and more parameter analysis capabilities than you need now. Alternatively, LeCroy scope architectures have been designed to allow upgrades for adding analysis packages, and some allow the owner to add more acquisition memory and more RAM at a future date.

When choosing a scope for making timing and jitter measurements, make sure you understand as much as possible about the circuit characteristics you will need to measure. Check the technical specifications of available models to narrow down your choice, then get a few samples from different vendors to try. Once you "drive" the scope, try making real-world measurements with it, and do some troubleshooting. You will have used your time in a way that assures your own future circuit timing is more accurate.

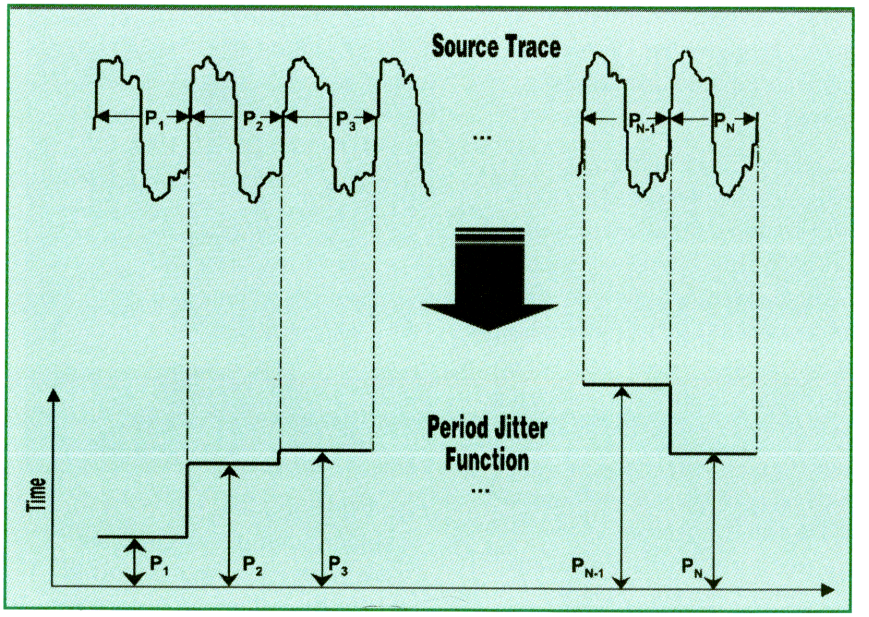


Figure 3: This diagram shows how an oscilloscope can draw a trace representing signal jitter. In this example, each value of the signal period is measured. The period jitter trace will have "peaks" when the period of the raw signal is higher than usual and has "valleys" indicating short period.

Basic Timing Measurements

Oscilloscopes have always served as visually oriented instruments that allowed an engineer to spot troublesome performance in a circuit or to verify the signal was correct. In recent years, digital scopes have begun offering the ability to make numerical measure-

ments of key signal characteristics. A very basic timing measurement is shown in Figure 4. Here, the jitter in arrival time of an edge is measured to have a range of 440 ps. A measurement such as this one is made by triggering the scope on a signal and examining the variation in timing of another signal one millisecond later. This type of measurement makes few demands on the scope; it must be able to hold off recording data for one millisecond after the trigger and have sufficient bandwidth and sampling rate to capture the edge that is of interest. It is helpful if the scope can histogram the data and provide statistical measurements of the histogram. However, little acquisition memory is required to capture this short signal, and the math operations are elementary.

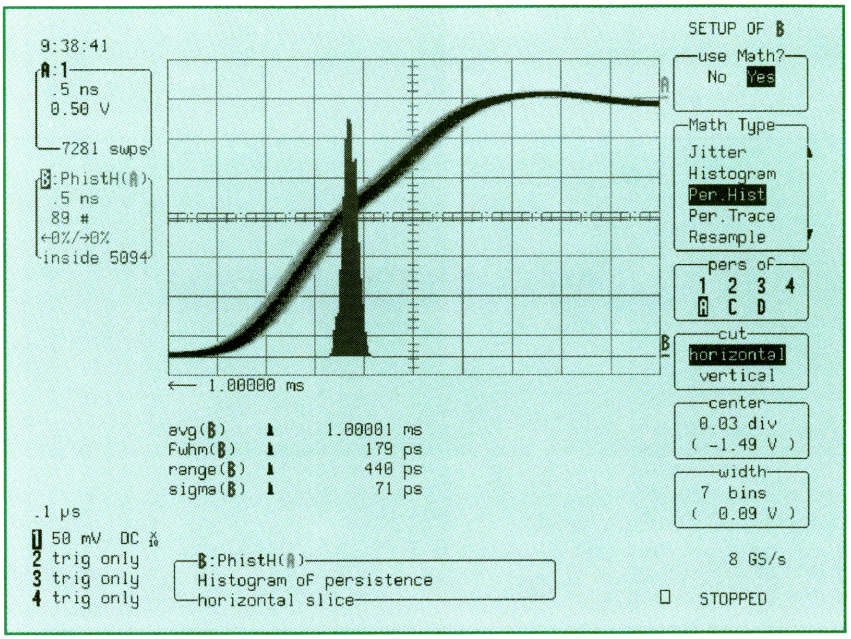


Figure 4: A basic jitter measurement of the time of a signal edge arrival. Horizontal bars define an area of interest, and the histogram shows the distribution of data within that area.

This method has several disadvantages, most of which stem from the fact that nearly all of the signal information is lost. This is because the oscilloscope's trigger rate is slow compared to the signal frequency. Even a very fast trigger rate of 1 million times per second is still slow compared to the clock frequency. In the case of a 200 MHz clock, a scope that triggers one million times per second and analyzes only one pulse per trigger can capture only one out of every 200 cycles. Also, each time the scope triggers, there is "trigger jitter," which is due to uncertainty in the timing of the trigger point relative to the acquired data. This is caused by small instabilities in the trigger level, vertical noise on the trigger signal, and internal delays inside the scope. Thus a "Short-Term Jitter Measurement" is made using only a small fraction of the available signal, and each acquisition is affected by trigger jitter.

New Methods of Tracking Timing Characteristics

Several new methods are available for measuring the timing performance of PLLs, oscillators, and other signals using digital scopes. These methods are more accurate than the basic timing measurement discussed above and also give more insight into circuit behavior. This can be useful in troubleshooting timing/jitter-related problems. Figure 4 shows a histogram of raw signal data (the density of signal occurrence). But newer scopes can draw histograms of the values that occur for signal parameters such as the amplitude, risetime, period, frequency, and cycle-to-cycle timing differences. These parameter histograms give much more insight into signal behavior than looking at the raw data. And they allow the user to verify that a circuit is meeting the performance standards for these parameters. For example, is the amplitude always within the allowed range? Is cycle-to-cycle jitter within the permitted bounds?

Figure 3 (on the previous page) shows a new method for locating the exact portions of a signal where timing problems are occurring. The JitterTrack trace uses the same horizontal timebase as the raw signal. But its vertical scale is in units of time rather than volts. This trace tracks the measured changes in timing characteristics of a signal. In Figure 3, each period of a signal is measured. The user could also choose to measure pulse widths, frequency, cycle-to-cycle change, duty cycle error, and other timing parameters. The value of the parameter measured for each individual cycle is put into the JitterTrack trace using a number of data points equal to the number of data samples captured by the scope for that signal's period. This means that you can expand or contract the raw signal and the JitterTrack signal simultaneously. The user can easily spot trends in the JitterTrack waveform due to modulation riding on the signal or see spikes in the JitterTrack that correspond to sudden shifts in the period of the signal under test. It is easy to zoom in on the aberration, measure the change, and look for what caused it.

Examples of JitterTrack for Troubleshooting

Figure 5 shows a practical example of the process diagrammed in Figure 3. The upper trace is the raw signal from a crystal oscillator while the lower trace

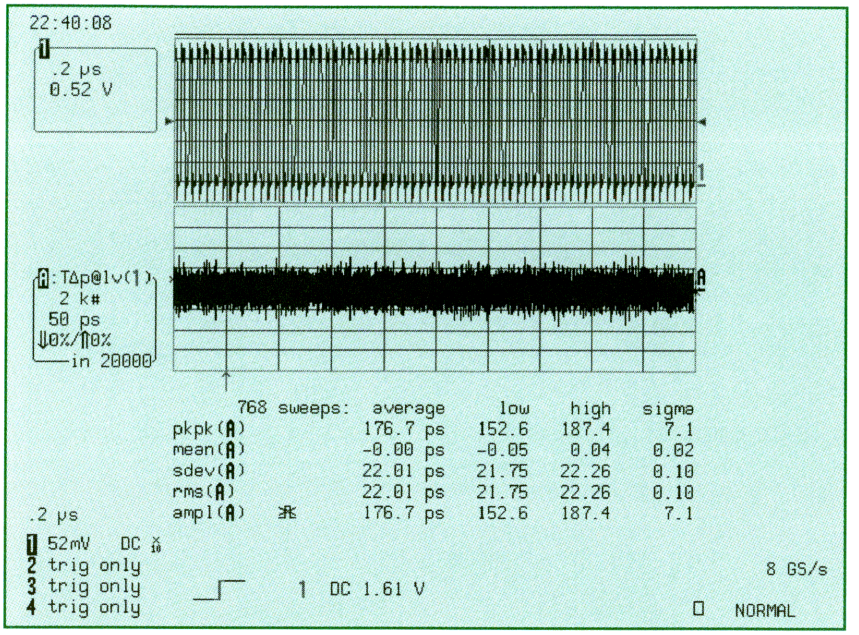


Figure 5: The raw signal from a crystal oscillator and the JitterTrack trace showing changes in pulse period.

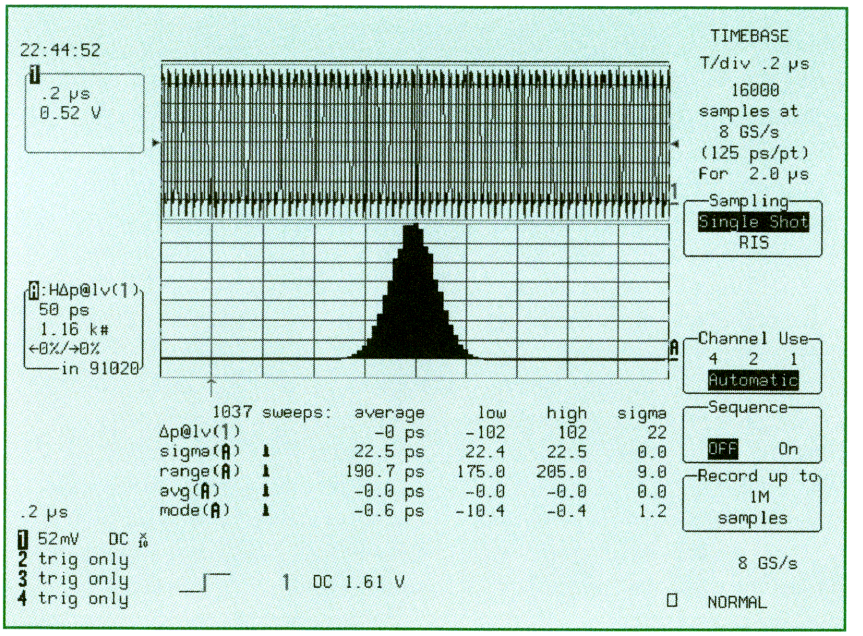


Figure 6: The same oscillator signal as shown in Figure 5. The lower trace is a histogram showing the distribution of changes in the signal period. The Gaussian shape indicates noise pickup as the source of period instability.

shows the JitterTrack of changes in the signal period. In this case, 20,000 consecutive cycles of the oscillator have been captured (2k per horizontal division of the screen), and the value of the changes in period are plotted using a vertical scale of 50 ps per division. A total of 768 sweeps were acquired, with 20,000 values in each sweep. The parameters in the lower portion of the screen reveal that the peak-to-peak difference in period between the shortest and longest periods in a typical set of 20,000 oscillator cycles is 176 ps, with a worst case change of 187 ps that was observed in at least one of the 768 data sets. Figure 6 examines the same signal, but depicts the measurements of period changes in a histogram rather than a JitterTrack. It is even possible to view the raw signal, JitterTrack trace, and histogram of parameter values simultaneously. The JitterTrack trace in Figure 5 resembles a trace of wideband noise. This correlates with the Gaussian shape of the histogram in Figure 6. Such a shape often indicates that system noise is the dominant contributor to signal jitter. In general, when a circuit is working properly, the residual timing jitter is due to noise and will display the characteristics of Figures 5 and 6.

Figure 7 shows the startup of a PLL (phase-locked loop), which is a component commonly used in wireless devices. In this case, the device under test is a pager. Proper data transmission depends on steady, accurate performance of the PLL. The JitterTrack trace makes it easy to see there are instabilities in the PLL period during startup.

Figure 7 shows 10 ms of signal (at 1 ms per division) from a PLL as it "wakes up" when the user turns on a pager. The upper trace is the full 10 ms of the signal captured by a digital scope with long data acquisition memory, while the lower trace is a JitterTrack view showing how the PLL period changes during startup.

In Figure 8, the timebase of the scope has been changed to look at the first two milliseconds of data after startup. The PLL signal is stored in Trace D of the scope (but not displayed), and the user is examining the JitterTrack of the PLL period (upper trace) and cycle-to-cycle change of the period (lower trace). It can been seen from this figure that the PLL period gradually decreases and has large swings that result in substantial changes in period from one cycle to the next. These changes gradually diminish over the course of approximately 1.2 ms.

In the previous discussion, a problem was revealed in the PLL startup. The next step

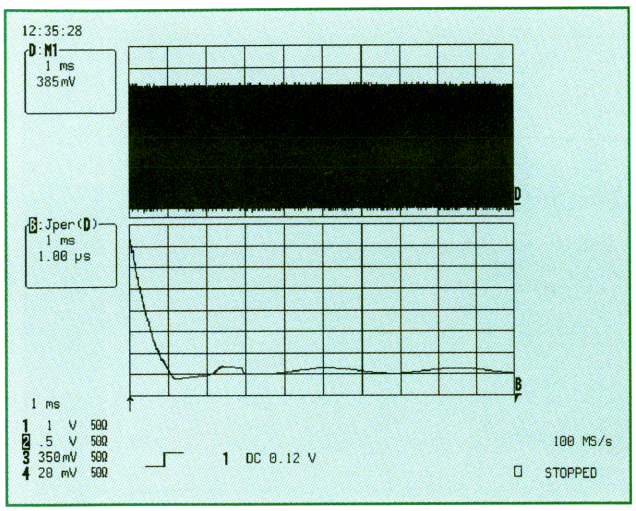


Figure 7: The top trace shows 10 ms of data from startup of a PLL. The JitterTrack trace of period below reveals the period starts at a high value, which gradually stabilizes.

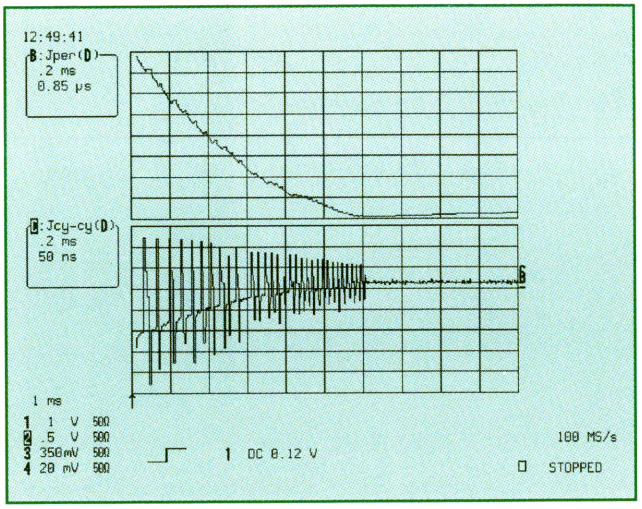


Figure 8: Two JitterTrack views of PLL startup. The upper trace tracks the first two milliseconds of signal period during startup. The lower trace is a JitterTrack view of cycle-to-cycle period variations during this time.

would be to identify the worst-case instabilities, verify that they are within operating tolerances, and troubleshoot the source of the problem if the jitter was too large. New tools in digital scopes make it possible for these instruments to measure timing instabilities (as was often done in the past with time interval analyzers or jitter analyzers) and to trace the source of timing problems directly to the portion of the signal where they occurred.

Because the problem with the PLL has been identified as occurring during startup, the next step is to examine the first two milliseconds of data more closely. Figure 8 shows the JitterTrack view of the PLL pulse periods. The vertical scale is 0.85 µs per division, while the horizontal scale is exactly the same as the raw data (0.2 ms per division). The JitterTrack view reveals that the PLL pulse width drops by about 6 µs during the first millisecond of operation after startup.

In addition to revealing jitter in pulse widths or cycle-to-cycle changes, JitterTrack traces can monitor variations in signal frequency, time over threshold, duty cycle, or the difference between observed signal period and a reference frequency. In each case, an unlimited number of signal periods can be measured, and there is exact time correlation between the JitterTrack trace and the signal trace. This powerful tool can be used to spot timing and jitter irregularities in master clocks or all sorts of data streams. The next step in troubleshooting this timing instability is to look for factors within the product under test that could be causing these symptoms. One of the most frequent sources of timing jitter is power quality problems. Figure 9 shows how JitterTrack can be used to look at the sensitivity of clock stability to power supply voltage. The clock interval jitter in the second trace correlates exactly to fluctuations in power supply voltage to the clock chip as shown on the lower trace.

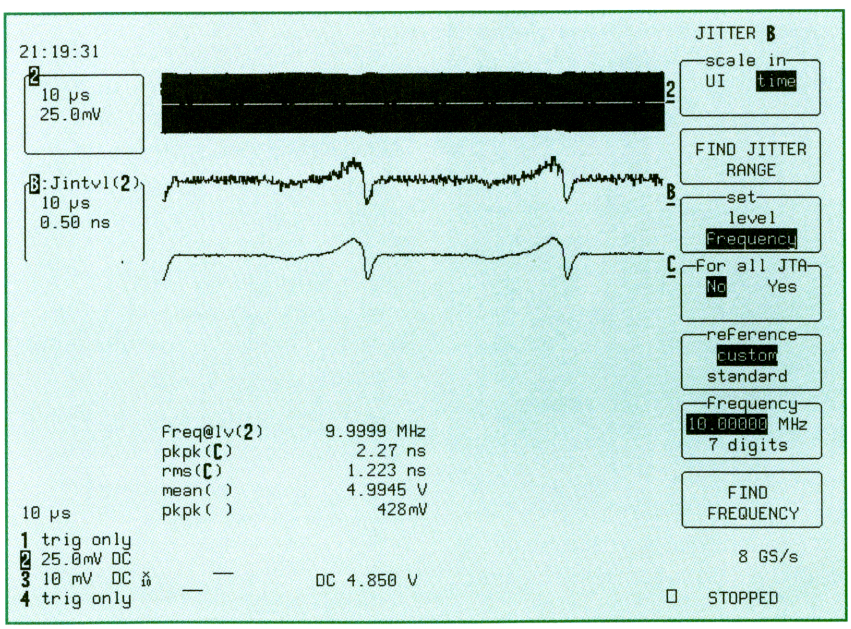


Figure 9: Clock interval jitter (middle trace) is clearly associated with power supply spikes (lower trace).

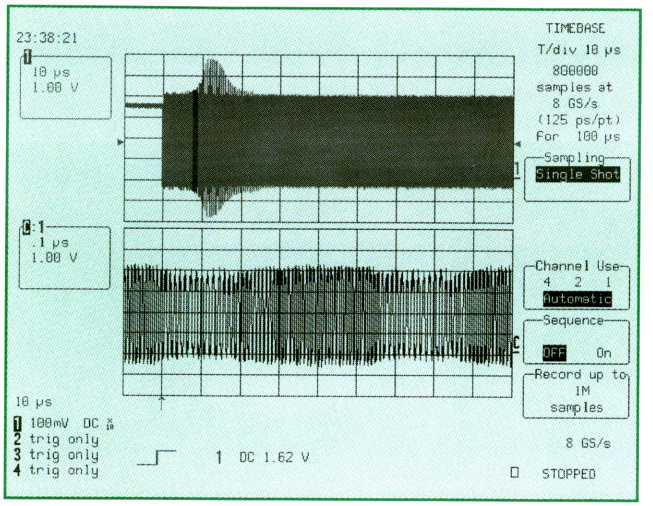


Figure 10: The top trace shows 100 µs of data from turn on of a PLL. The lower trace zooms in on a portion of the data showing a "breathing" effect that occurs about 10 µs after start up.

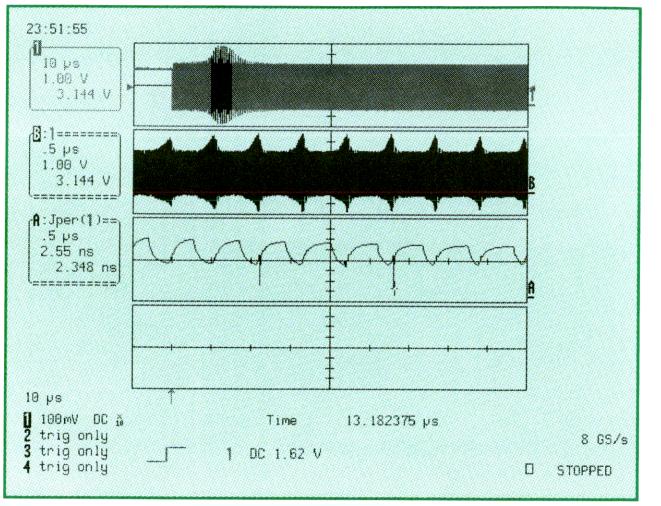


Figure 11: The third trace above tracks the PLL period. It is easy to spot two very low values. The second one is marked with a cursor at 13.18 µs. At this point, the period is only 2.348 ns.

Figures 10 and 11 show signals from a PLL circuit in a DSL modem. This device also suffers from unstable operation during the startup, but the symptoms are much different from the previous example. In this case, an amplitude modulation effect is related to a modulation of the PLL period. However, there are also two "catastrophic" PLL periods that are much lower than all other values. By knowing the exact timing of these failures, the engineer can look for their source by using the scope to zero in on other circuit aberrations.

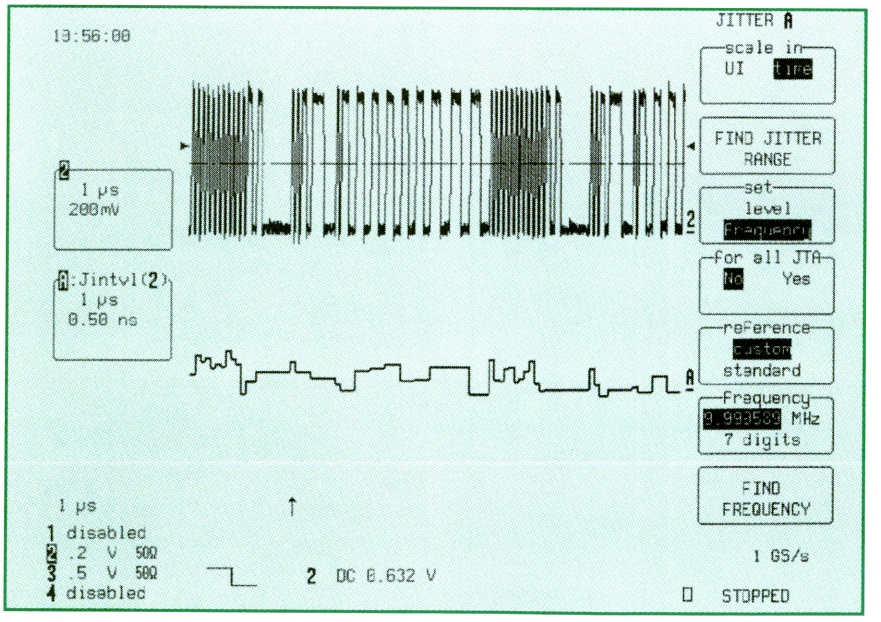


Figure 12: It is also possible to extract the clock frequency from a data stream automatically and then measure timing errors of the data stream edges against the clock timing.

Characterizing Timing Jitter in Data Streams

A common challenge in many types of telecommunications and data communications is the need to pack more information into shorter periods of transmission time. When data transmission occurred at a more leisurely rate, little thought was given to the timing jitter of signal edges or to variations in pulse widths from one cycle to the next. Now such considerations are becoming critical to signal integrity. Figure 12 shows an example of a data stream being tested. The clock frequency can be extracted and the actual edges of the data signal compared to the location where they should have appeared.

Acknowledgements

The PLL signal discussed above was provided from a Flex Pager, courtesy of Motorola.

Part of this LeCroy article appeared in the September 1999 issue of Electronic Products Magazine and is reprinted with the permission of the publishers.

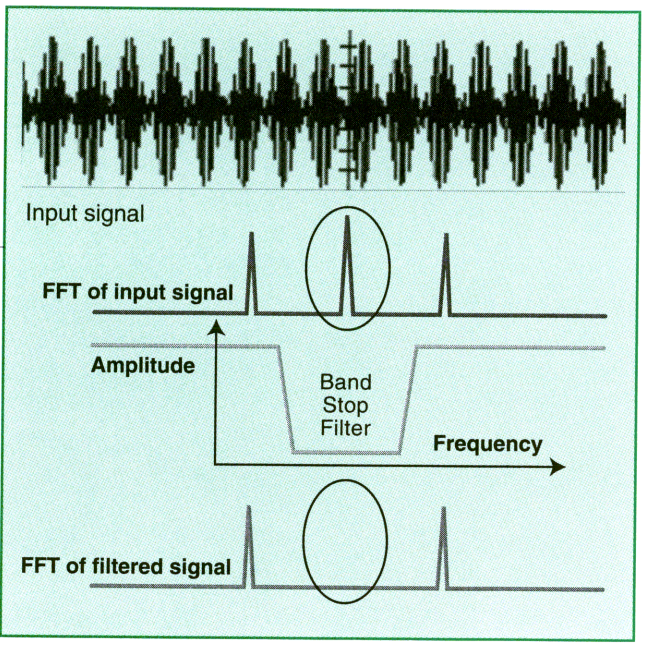
6

LeCroy
TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
PERSIST
STOPPED

Digital Filter Package (DFP)

DFP implements a set of linear-phase Finite Impulse Response (FIR) filters. The package enhances your ability to examine important signal components by filtering out undesired spectral components such as noise.

Use a digital filter design or math package such as MATLAB® or Mathcad® to design a custom filter, then download the filter coefficients into a LeCroy DSO with the DSO-Filter utility.



Design your own filters with DFP

Filters include:

- Low Pass
- High Pass
- Band Pass
- Band Stop
- Raised Cosine
- Raised Root Cosine
- Gaussian
- Custom

Up to 4 filters can be cascaded

Ordering Information

DFP	Digital Filter Package available on all LC, WavePro and Waverunner oscilloscopes, and on Disk Drive Analyzers.
RK-DFP	Retrofit Kit
DFP-OM-E	Operator's Manual

WAVA – WaveAnalyzer Software Option

- **Enhancements to averaging and FFT capabilities**
- **Histogramming and trending of signal parameters**
- **Additional math functions**
- **For use with WavePro, Waverunner-2 or Waverunner series instruments**

Extended Averaging

Summed, average of up to one million waveforms; Continuous average

Extended FFT

Fast Fourier Transform of up to 10 million points (depending on DSO model); FFT Average; Power Averaging, Power Density, Real, Real + Imaginary

Histograms

Graphical analysis with histograms of up to 1 billion values and histogram analysis parameters

Trending

Plot a parameter vs. time or vs. another parameter

Math Functions

Absolute Value, Derivative, Exp (base e), Exp (base 10), Integral, Log (base e), Log (base 10), Reciprocal (1/x), Square, Square Root

Parameter Measurements

cmedian	Cyclic median; The average of base and top values over an integral number of cycles
csdev	Cyclic standard deviation
Δc2d±	Δ clock to data ± (setup and hold time)
Δt@lv	The transition time between selected levels on a single trace or between two traces
first	Indicates value of horizontal axis at left cursor
last	Time from trigger to last (rightmost) cursor
median	The average of base and top values
r@level	Risetime between selected voltage levels
Points	Number of points in the waveform between the cursors
t@level	Time from trigger (t=0) to crossing at a level
f@level	Falltime between selected voltage levels
dur	The time between triggers in segment or other history modes

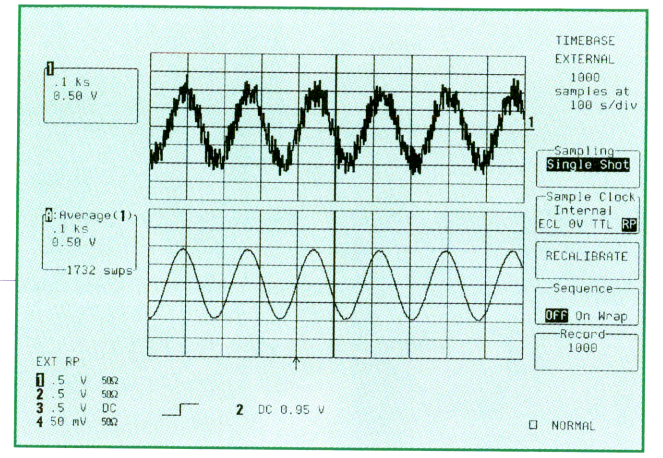
Ordering Information

Option	Product Code
WaveAnalyzer Software Option	WAVA

CKTRIG
External Clock and Trigger Output Option

Main Features

- **High-speed 500 MHz external clock input**
- **10 MHz external clock reference input**
- **Edge trigger comparator output**
- **BNC, rear-panel mounted connectors**



This figure shows how synchronous sampling can eliminate interfering signals.

External Clock

This feature allows the 9354C 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, sampling data at specified frequencies can be required.

The 9354C 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. Waverunner scopes offer external clocking up to 500 MS/s (200 MS/s for LT322 and LT224) as a standard feature.

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

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, 50Ω, series-terminated.

Note: This feature does not operate in SMART Trigger mode.

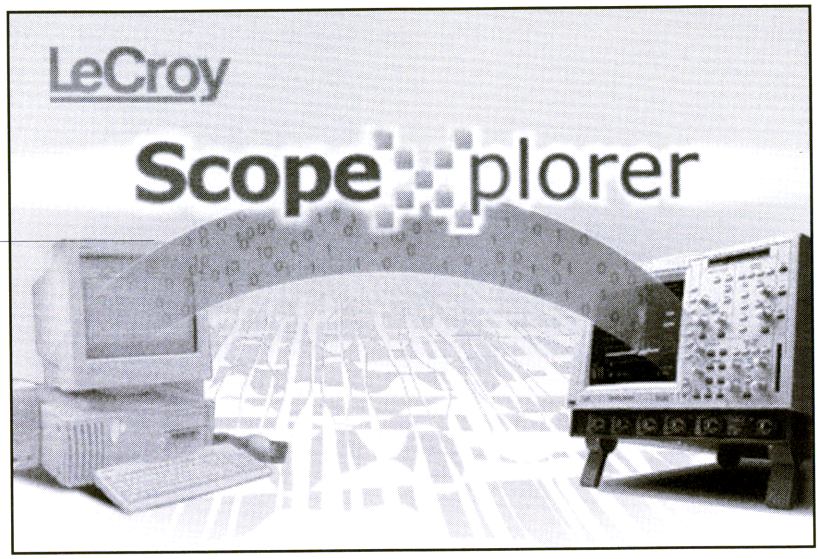
Ordering Information

CKTRIG	93XX Series External Clock, Reference Clock	
LC684-CKTRIG	DC-500 MHz Ext. Clock, 10 MHz Ref. In, Trig Out	For use in LC684 Series
LC584-CKTRIG	DC-500 MHz Ext. Clock, 10 MHz Ref. In, Trig Out	For use in LC584 Series
LC574-CKTRIG	50-500 MHz Ext. Clock, 10 MHz Ref. In, Trig Out	For use in LC574 Series 0-100 MHz ext. clock standard
LC564-CKTRIG	DC-500 MHz Ext. Clock, 10 MHz Ref. In, Trig Out	For use in LC564 Series

ScopeExplorer™

Main Features

- **Windows user interface for DSO control**
- **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 free by visiting our web site and following the simple download instructions at http://www.LeCroy.com/ScopeExplorer.

ScopeExplorer is a free PC-based connectivity tool that integrates a LeCroy DSO with the Windows 95/98/2000 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.

ScopeExplorer coupled with the LAN option available on WavePro and Waverunner/Waverunner-2 oscilloscopes provides a networked Windows user interface for print/file sharing and complete remote control.

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.

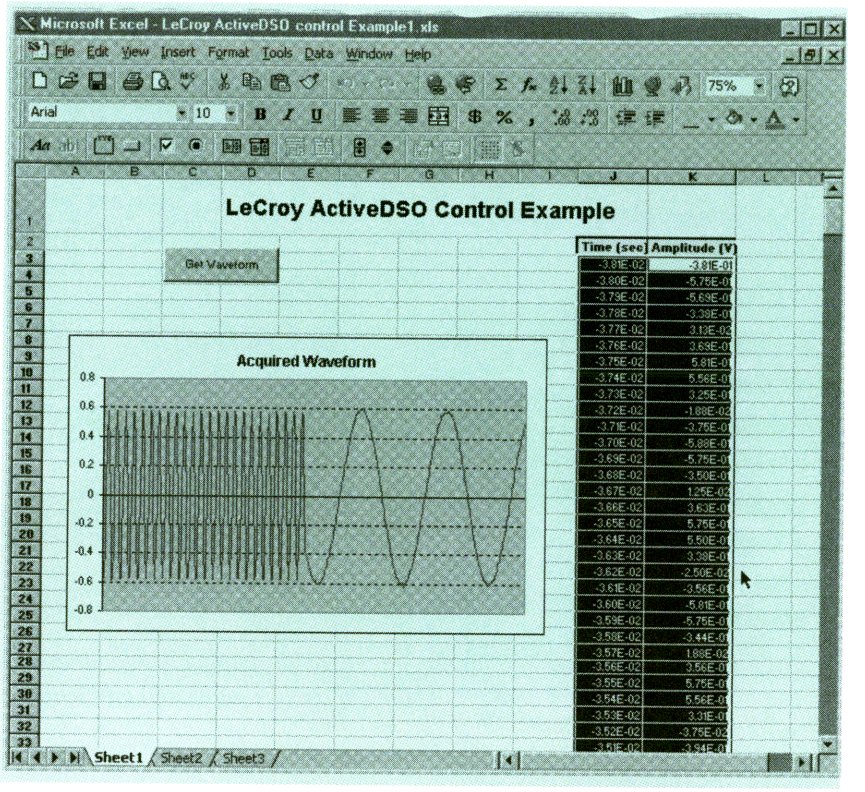
ScopeExplorer provides the following new powerful features:

- Store and annotate screen shots.
- Virtual front panel to allow full control of remote DSOs.
- Windows based Binary-to-ASCII waveform converter (replaces the DOS-based WaveTran utility).
- Support control of the LSA1000 via TCP/IP.
- Automatic refresh of the scope's display image.
- Multiple windows containing the scope's display are now permitted.
- More intelligent color display inversion algorithm retains trace while inverting background.
- Display image inversion is now remembered when the display is refreshed.
- Redirection to file is now permitted from macros.
- Edit and run "CustomDSO" files from LeCroy.
- Display and access files on storage media that are inserted in a DSO.

ActiveDSO™

Main Features

- **Generate reports**
- **Analyze waveforms in MathCad**
- **Archive measurements on the fly**
- **Automate tests**



ActiveDSO is an ActiveX control that enables LeCroy oscilloscopes and the LSA-1000 series embedded signal analyzers to be controlled by (and exchange data with) a variety of Windows applications that support the ActiveX standard. MS Office programs, Internet Explorer, Visual Basic, Visual C++, Visual Java, and Matlab (v5.3) are a few of the many applications that support ActiveX controls.

The ActiveDSO control can be used as a program and as an embedded control. Software designers can create instances of the ActiveDSO control within their programs, and use the control's Methods and Properties for instrument communications, setup, and data transfer. With ActiveDSO, all details of the interface bus used to connect to the LeCroy instrument are encapsulated within the ActiveDSO control. The intricacies of programming for each of these interfaces is hidden from the user, allowing the software developer to focus on his or her application and to avoid the complexities of the lower-level interface calls.

The ActiveDSO control can also be embedded visually in any OLE automation compatible client. Include ActiveDSO in you Microsoft Word document or PowerPoint presentation and easily transfer the bitmap image of the instrument display into your document. No floppy disk required!

Whether you are using the control as a program or as an embedded object, ActiveDSO helps integrate your oscilloscope data with your application:

- Generate a report by importing scope data right into Excel or Word.
- Analyze your waveforms by bringing them directly into MathCad.
- Archive measurement results on the fly in a Microsoft Access Database.
- Automate tests using Visual Basic, Java, C++, Excel (VBA).

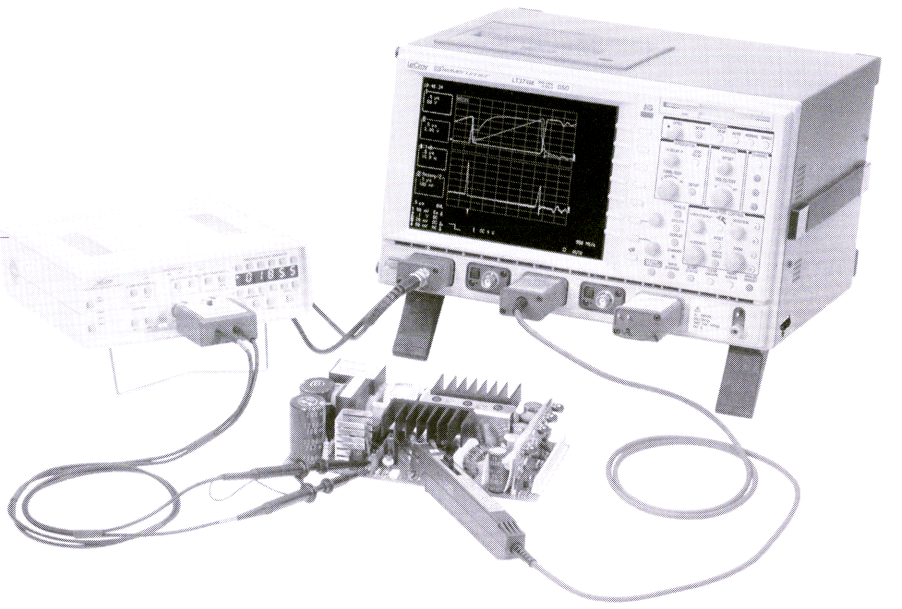
To download your **free** copy of ActiveDSO, visit the LeCroy web site at www.lecroy.com/software.

Visit our web site at: www.lecroy.com

7

TIMEBASE
T/div .5 ms
64 M
samples at
15 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
PERSIST
LeCroy
wavepro 960
STOPPED

LeCroy's PowerMeasure™ System – Power Measurements Made Easy!



Complete. Very Complete.

Affordable, too!

It will do virtually everything you want to do... with just the push of a few buttons!

The LeCroy PowerMeasure System is all you need to start and complete your power conversion design safely and with confidence.

The LeCroy PowerMeasure System sets a new standard of affordability while providing an unequalled level of performance and completeness. It no longer makes economic sense to use unsafe and questionable measurement practices when the highest level of measurement integrity is available affordably.

The LeCroy PowerMeasure System not only makes your routine power measurements simple, it makes easy work of even your most complex, difficult measurements.

No more crossing your fingers and hoping your power supply or motor drive won't fail. No more trial and error – or expensive, over-designed systems. Now you can focus on what's important in power design – confident that the testing is accurate and exhaustive. You won't have to worry about product failures or recalls.

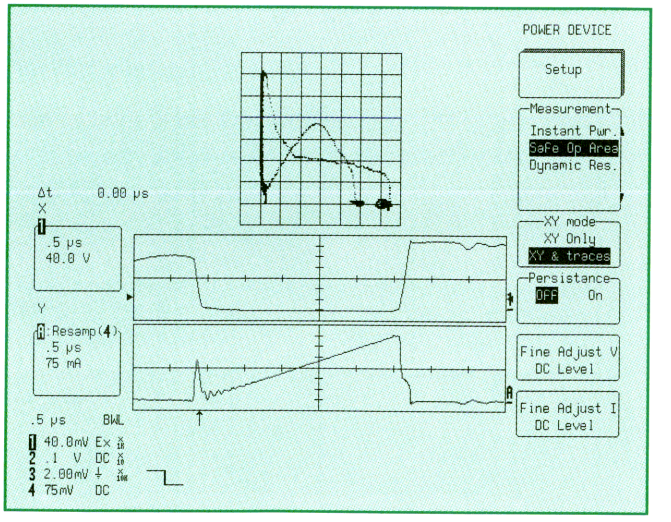
The PowerMeasure System is the most complete high-performance design system available for the power conversion engineer. It includes an easy-to-use, high-performance, full-featured digital storage oscilloscope (DSO); high-performance current and differential voltage measurement capabilities; and powerful software for your key measurements.

You will quickly find this system indispensible. Its accuracy, precision, and reliability will improve your production and let you feel "hard-wired" to the power conversion product you are creating.

The PowerMeasure System performs these vital measurements:

Power Device Analysis
Measures power device saturation voltage, instantaneous power loss, safe operating area (SOA), and dynamic on-resistance while the device is operating in circuit.

Modulation Analysis
Provides time domain display and analysis of feedback control loop response, including modulation.



Measure power device characteristics – in circuit.

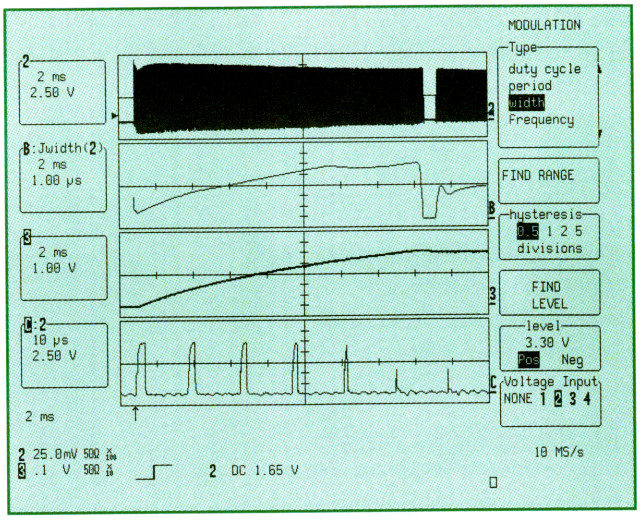
Line Power Analysis
Analyzes voltage current, real power, apparent power, power factor, and line current harmonics for compliance under EN61000-3-2 for CE qualification.

The PowerMeasure System

The following components make up the PowerMeasure System — the most complete solution available for making power measurements.

The *Waverunner™ DSO* captures the fine details, such as turn-on and turn-off, in each switching cycle of long events — load change response or startup. SMART Trigger makes it easy to capture waveforms during complex power transitions. The system performs mathematical analysis of live or stored waveforms and performs waveform math and math-on-math for detailed live analysis of the circuit and its components.

The **PowerMeasure Analysis (PMA1)** software's dedicated menus and shortcuts let you quickly and easily set up the scope to acquire, view, and analyze power signals. A "Setup Helper" is built in to support users step-by-step, ensuring correct and accurate measurements. The dedicated manual that comes with PMA1 details the best way to optimize the scope and probe setups for voltage, current, power, and energy measurements.



Use modulation analysis to determine step response and soft start performance.

The **DA1855A** is a standalone, high-performance 100 MHz differential amplifier that acts as a fully integrated signal conditioning preamplifier. It provides unequalled common mode rejection ratio (CMRR) and overdrive recovery performance. 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, extending the gain between 200 µV/div and 100 V/div, and common mode dynamic range limited only by the voltage rating of the probes.

Equipped with the ProBus interface, the DA1855A becomes an integral part of the oscilloscope. The amplifier can be fully controlled from the oscilloscope's front panel, the amplifier's front panel, or by using remote commands (GPIB or RS-232-C).

The **DXC100A** is a high-performance, passive, matched differential probe pair designed for use with the DA1855A. It increases the maximum input signal and common mode ranges in proportion to their attenuation ratio, up to a ±500 V voltage rating.

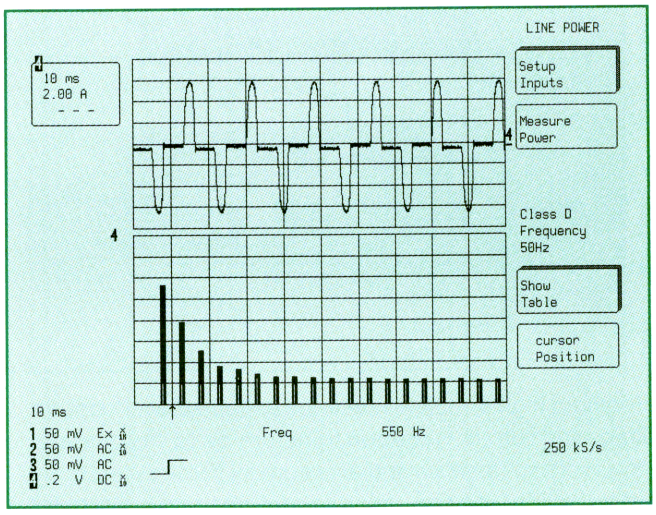
The **AP015 current probe** measures the current flowing through a conductor. The probe is based on a combination of Hall effect and transformer technology that allows measurements to be made on DC, AC, and impulse currents. Its rugged design uses a split-core transformer that allows the probe head to be clamped around a conductor that remains in circuit.

The AP015 is a wideband DC-coupled current probe. It is the ideal tool for making accurate measurements in high-efficiency switch mode power supplies and other applications requiring high bandwidth.

The **DCS015** provides time-coincident voltage and current signals that are used as references for deskewing current and voltage measuring systems.

Protect Your Investment!

Maybe you already own a LeCroy DSO, or you've already invested thousands of dollars in another vendor's probes. No problem! The PowerMeasure System software works on any LeCroy oscilloscope, and other manufacturers' current and voltage probe settings are integrated into the setup menus. Waveforms are displayed showing the proper units (watts, joules, VA, etc.), even with other manufacturers' non-ProBus accessories. Not only do you protect your investment, you get superior performance and analysis capabilities.



Analyze power factor and line current harmonics.

Power Device Analysis

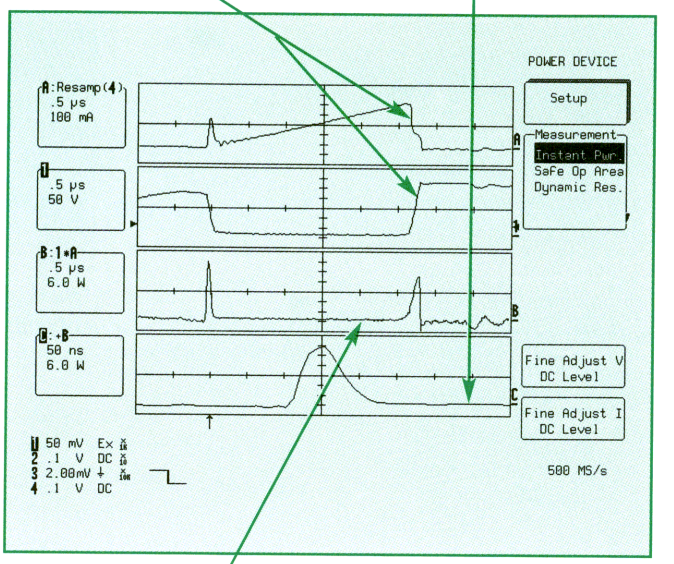
LeCroy's PowerMeasure System includes the capability to analyze power devices' performance while they are operating in circuit. Tests formerly reserved for the test fixture and which requires specially designed clipping circuits can now be routinely made on these devices while they operate in their designed environment. This requires a unique combination of capabilities not previously available in a single system.

The PowerMeasure System combines the required current and differential voltage measuring capability with unequalled DSO triggering, long record capture, and waveform math to make these difficult measurements as simple as the push of a few buttons.

Instantaneous Power

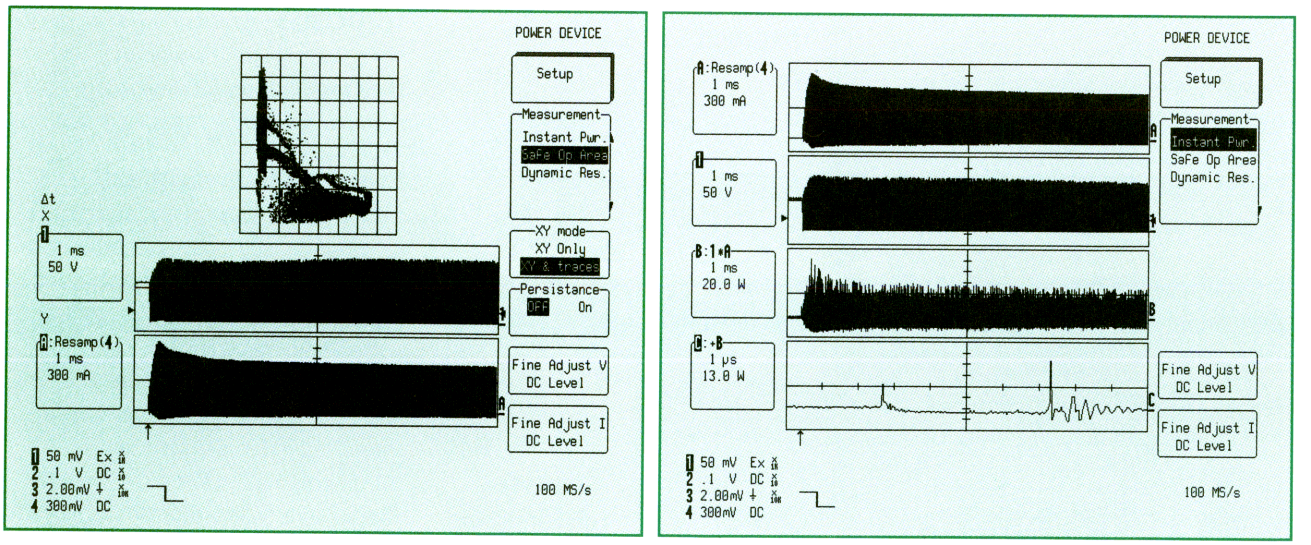
Power Device Analysis captures the device's current waveform and displays it properly time-deskewed in relationship to the voltage waveform.

A zoom trace is provided that allows the user to expand the power waveform for detailed analysis. Other waveforms or math functions can be substituted for the zoom trace. For instance, the DSO's MATH TOOLS can be used to display an energy waveform (joules). The



Each acquired point on the current waveform is multiplied by its corresponding point on the voltage waveform. The resulting Instantaneous Power waveform is displayed using the proper units (watts).

Waverunner oscilloscope's full range of standard measure tools, such as waveform parameters and math tools, is also available.



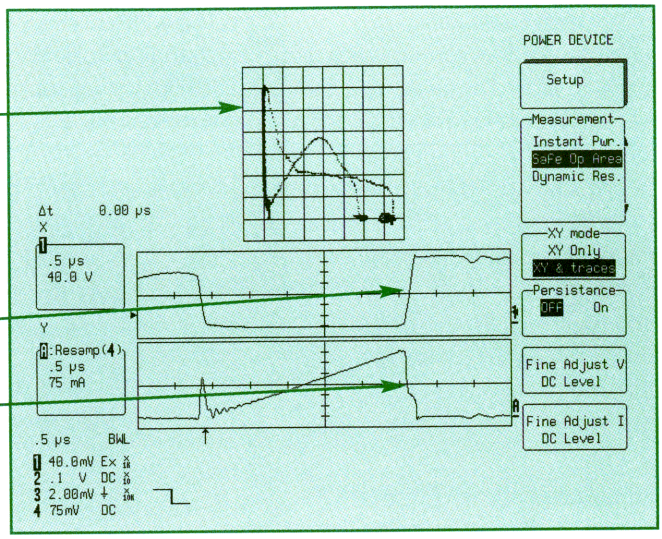
The Waverunner LT344L DSO's 1 Mpoint/channel allows the required high sampling rate to be sustained over enough time to enable the user to acquire a switching transistor's voltage and current waveform from turn-on to steady state. This allows the Safe Operating Area and Instantaneous Power waveforms for each and every one of these cycles to be captured and observed at your leisure. There's no need to destroy multiple devices trying to capture that elusive glitch.

Safe Operating Area

LeCroy's PowerMeasure System displays the device's Safe Operating Area in the proper XY format; Voltage on the X-axis and Current on the Y-axis.

The DA1855A/DXC100A differential amplifier and probes have unique capabilities to allow a power FET's drain-source voltage to be safely acquired while the device operates in a power supply's line-referenced primary circuit.

A precision AC/DC current probe, such as the AP015, acquires the power device's drain current waveform, and Power Device Analysis displays it properly time-deskewed in relationship to the voltage waveform.



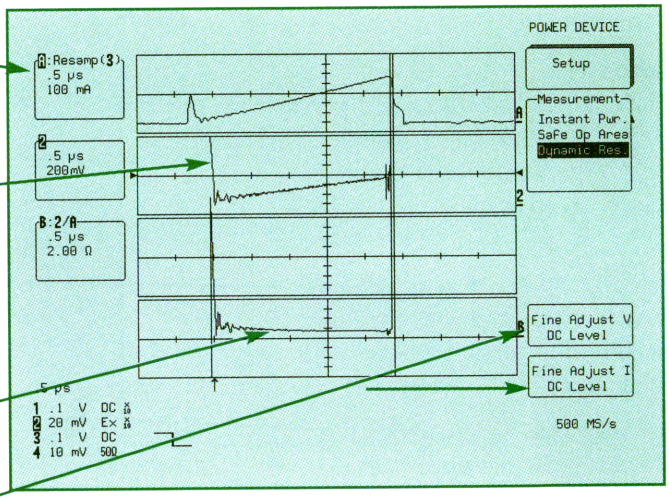
Dynamic On-Resistance

The power device's current waveform is acquired using an AP015 AC/DC current probe, time-deskewed and displayed in proper time relationship to the voltage waveform.

The DA1855A differential amplifier's fast recovery from overdrive and the DXC100A differential probe's 250 ppm flatness capability combine to accurately acquire the power device's saturation voltage waveform – while the device is operating in circuit.

The voltage waveform is divided by the current waveform, and the device's dynamic on-resistance is displayed.

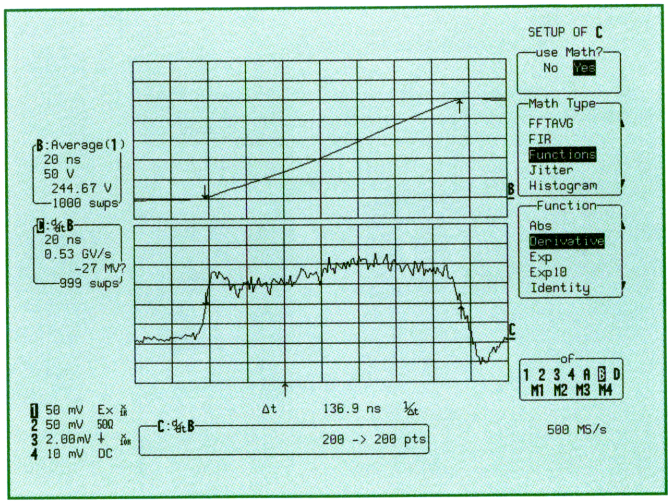
Adjustment is provided to allow the user to remove any residual DC offset in both the current and voltage waveform without removing the probes from the circuit.



Drain-Source Voltage dv/dt

The PowerMeasure System's Math functions measure and display the dv/dt of a power transistor's drain-source turn-off voltage waveform.

Cursors allow the dv/dt value to be read at any point on the waveform.

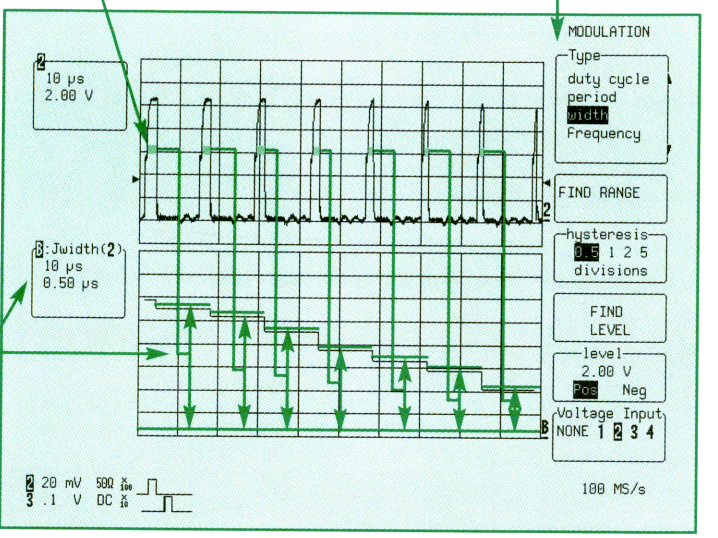


Modulation Analysis

A switchmode power conversion circuit's output is controlled by transferring the proper amount of energy from an unregulated source to the output on a cycle-by-cycle basis. Power conversion design engineers can learn a great deal about the circuits they design by analyzing the information contained in the modulation of this energy transfer. Modulation Analysis provides the engineer with tools to view this information in a very clear and concise way.

The width of every pulse in a rapidly changing Pulse Width Modulated (PWM) power supply's control circuit is measured.

Modulation Analysis is provided for duty cycle, period, width, and frequency modulation.



The time value of each pulse is displayed on the vertical axis.

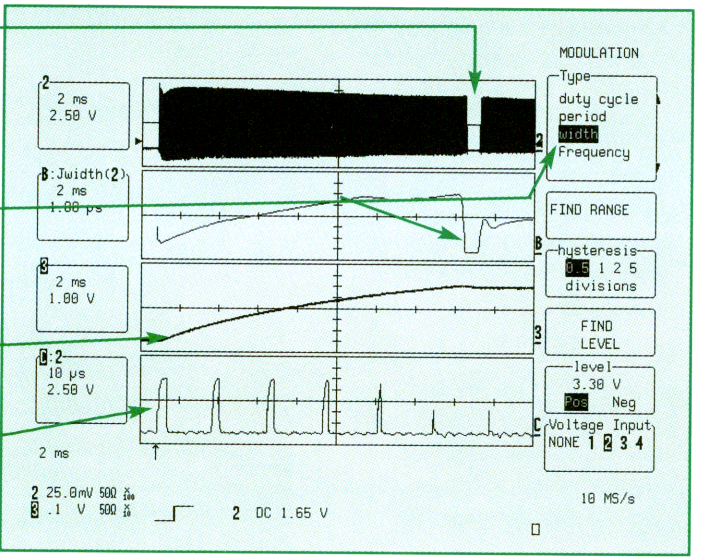
Startup

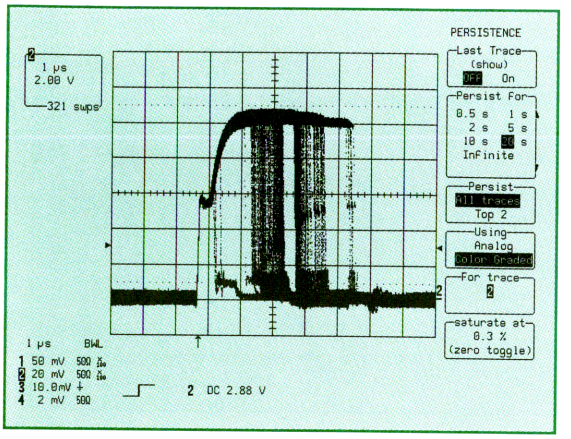
In this example, the *Waverunner* LT344L DSO acquires a 20 ms record of every gate drive pulse from the time a power supply is turned on until it reaches steady state.

Modulation Analysis displays the width value of every pulse on the vertical axis as it occurs. The soft start circuit's performance is readily observed.

The 5 volt supply is monitored as it increases from 0 volts to a regulated +5 volt level.

The zoom feature allows each gate drive pulse to be individually examined.





Color-graded persistence reveals many details about the change in a power supply's gate drive signal during a large load change. Color variation indicates the relative distribution of the various pulse widths and the change in waveform shape.

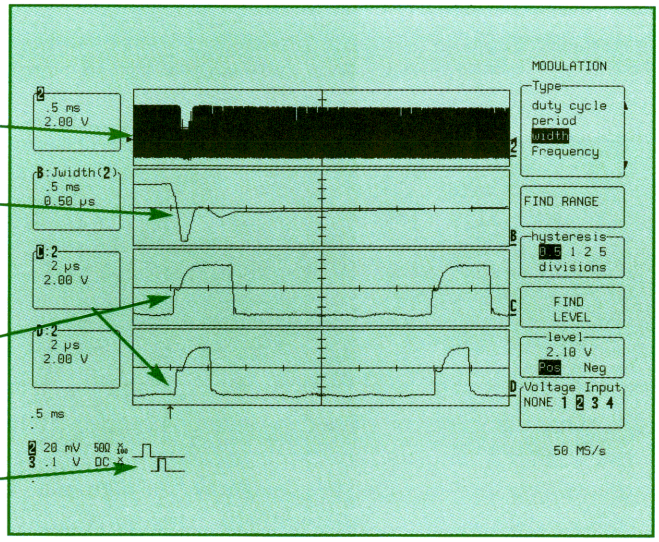
Step Response

The Waverunner LT344L DSO examines the change in gate drive pulse widths as a power supply's load steps from full to minimum.

Modulation Analysis displays the width value in time of every pulse on the vertical axis as it occurs. The circuit's response to a step change can be observed.

The two zoom traces allow individual gate drive pulses to be observed before and after a large load change.

SMART Trigger allows the gate drive signal acquisition to start on the first gate drive pulse that occurs after the load changes from maximum to minimum.



Line Power Analysis

The PowerMeasure System provides design engineers with an easy-to-use method of measuring the line power harmonics of their circuits. EN61000-3-2 precompliance testing avoids expensive and time-consuming trips to a third-party qualification laboratory.

Line Power Analysis easily measures a power supply's power factor and power consumption (watts and VA), as well as its line voltage and current rms values. Line harmonic measurements for class A, B, C, and D equipment are read out in both graphical and tabular format.

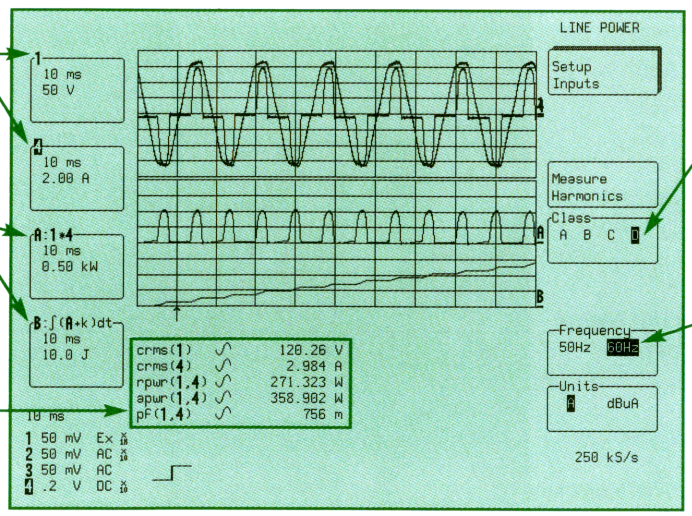
The PowerMeasure System measures line voltage up to +/-500 volts and current up to 30 amps. Higher voltage and currents are accommodated through the use of optional probes. Proper units and scale factors are easily set by the PowerMeasure software.

Live line power voltage and current waveforms are displayed.

Live power and energy waveforms are displayed.

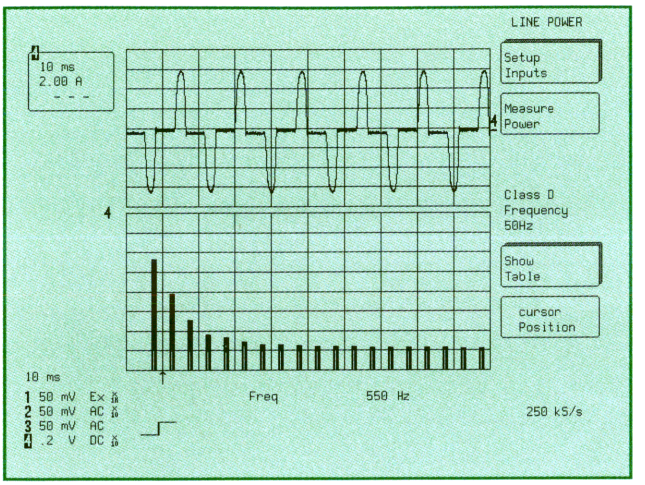
All on "live" waveforms:

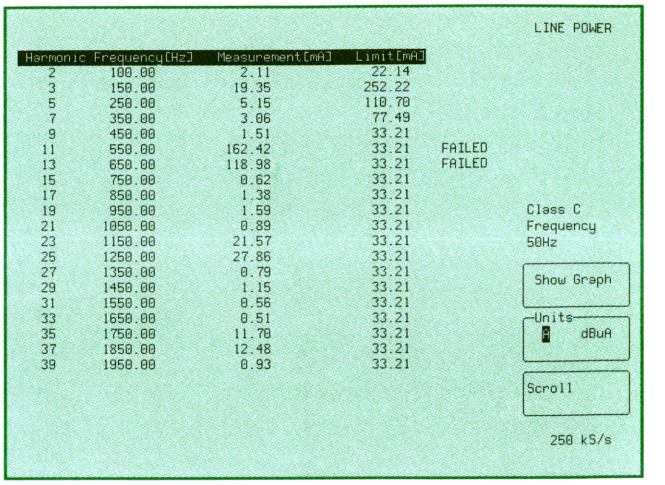
rms Line Voltage
rms Line Current
Real Power
Apparent Power
Power Factor



Select EN61000-3-2 Class A, B, C, or D.

Select 50 or 60 Hz line frequency.





Line current harmonics can be viewed in either graphical or tabular format. The proper template for the selected class and line frequency is calculated and displayed as each current waveform is acquired. Each harmonic's value is displayed on the graph. A cursor is provided to select individual harmonics. Out-of-limit harmonics are shown extending beyond the template. In tabular format, the value of each harmonic is displayed along with its frequency and magnitude limit. Harmonics exceeding their limits are shown as "FAILED" on the table.

PowerMeasure Systems Selection Guide

Specifications	PS374/M/L	PS344L	PS344	PS322	PS264/M	PS224
Channels	4	4	4	2	4	4
Points per Channel	250 k/1 M/4 Mpt	1 Mpt	250 kpts	100 kpts	250 k/1 Mpt	100 kpts
Bandwidth	500 MHz	500 MHz	500 MHz	500 MHz	350 Mhz	200 MHz
Sample Rate	2-4 GS/s	500 MS/s	500 MS/s	200 MS/s	1 GS/s	200 MS/s
Maximum Voltage†	500 V	500 V	500 V	500 V	500 V	500 V
Power Device Analysis						
Power Device Saturation	Yes	Yes	Yes	Yes	Yes	Yes
Upper Gate Drive	Yes	Yes	Yes	Yes	Yes	Yes
Dynamic On-Resistance	Yes	Yes	Yes	Yes	Yes	Yes
Instantaneous Power						
up to 1 ms window acquisition*	Yes	Yes	Yes	Yes	Yes	Yes
up to 10 ms window acquisition*	No/Yes/Yes	Yes	No	No	No/Yes	No
Safe Operating Area						
up to 1 ms window acquisition*	Yes	Yes	Yes	Yes	Yes	Yes
up to 10 ms window acquisition*	No/Yes/Yes	Yes	No	No	No/Yes	No
Modulation Analysis						
Load Change, Turn-On, Turn-Off, Soft Start						
up to 2 ms window acquisition**	Yes	Yes	Yes	Yes	Yes	Yes
up to 20 ms window acquisition**	No/Yes/Yes	Yes	No	No	Yes	No
SINGLE Phase Power Line Analysis						
Harmonics Analysis (EN61000-3-2)	Yes	Yes	Yes	Yes		Yes
Real Power, Apparent Power, Power Factor	Yes	Yes	Yes	Yes		Yes

† ±500 V to ground, 500 V differential. Up to 2.5 kV with the optional DXC5100 and DA101, passive differential matched pair of 1:100 probes and external ÷10 attenuator.
* at 100 MS/s
** at 50 MS/s

Visit our web site at: www.lecroy.com

Recommended System Components

APPLICATIONS	Differential		Current		Time	DSO with PMA1 Optional Software					
	DA1855A	ADP305	CP015 or AP015	CP150	DCS015	LT374/M/L 4 Ch	LT344L 4 Ch	LT344 4 Ch	LT264/M 4 Ch	LT224 4 Ch	LT322 2 Ch
(up to 500 V)	w/DXC100A										
or											
(up to 2500 V)	w/DXC5100 + DA101										
Power Device Analysis											
Power Device Saturation	R[1]	No	N/R	N/R	N/R	Yes	Yes	Yes	Yes	Yes	Yes
Upper Gate Drive	R	No	N/R	N/R	N/R	Yes	Yes	Yes	Yes	Yes	Yes
Dynamic On-Resistance	R[1]	No	Yes	N/R	R	Yes	Yes	Yes	Yes	Yes	Yes
Instantaneous Power											
up to 1 ms window acquisition*	Yes	Yes	Yes	No	R	Yes/Yes/Yes	Yes	Yes	Yes	Yes	Yes
up to 10 ms window acquisition*	Yes	Yes	Yes	No	R	No/Yes/Yes	Yes	No	No/Yes	No	No
Safe Operating Area											
up to 1 ms window acquisition*	Yes	Yes	Yes	No	R	Yes/Yes/Yes	Yes	Yes	Yes	Yes	Yes
up to 10 ms window acquisition*	Yes	Yes	Yes	No	R	No/Yes/Yes	Yes	No	Yes	No	No
Modulation Analysis											
Load Change, Turn-On, Turn-Off, Soft start											
up to 2 ms window acquisition**	Yes	Yes	Yes	No	N/R	Yes	Yes	Yes	Yes	Yes	Yes
up to 20 ms window acquisition**	Yes	Yes	Yes	No	N/R	Yes	Yes	Yes	No/Yes	No	No
SINGLE Phase Power Line Analysis											
Harmonics Analysis (EN61000-3-2)	Yes	Yes	Yes	Yes	N/R	Yes	Yes	Yes	Yes	Yes	Yes
Real Power, Apparent Power, Power Factor	Yes	Yes	Yes	Yes	N/R	Yes	Yes	Yes	Yes	Yes	Yes

R means required
N/R means not required
Yes means appropriate
No means not applicable

* at 100 MS/s
** at 50 MS/s
[1] DA1855A and DXC100A required for this measurement.

Additional DSO Accessories for Power Measurements

Active Differential Voltage Probes

AP031	15 MHz; 10:1, 100:1 attenuation; 700 V
ADP300	20 MHz; 1.4 kV
ADP305	100 MHz; 1.4 kV
AP033	500 MHz x 10, 1:1, 10:1, 100.1 (with adapter)

Active Current Probes

AP011	120 kHz; 150 amps DC
AP015	50 MHz; 30 amps DC, 50 amps peak
CP150	10 MHz; 150 amps, 500 amps peak
CP015	50 MHz; 15 amps, 50 amps peak

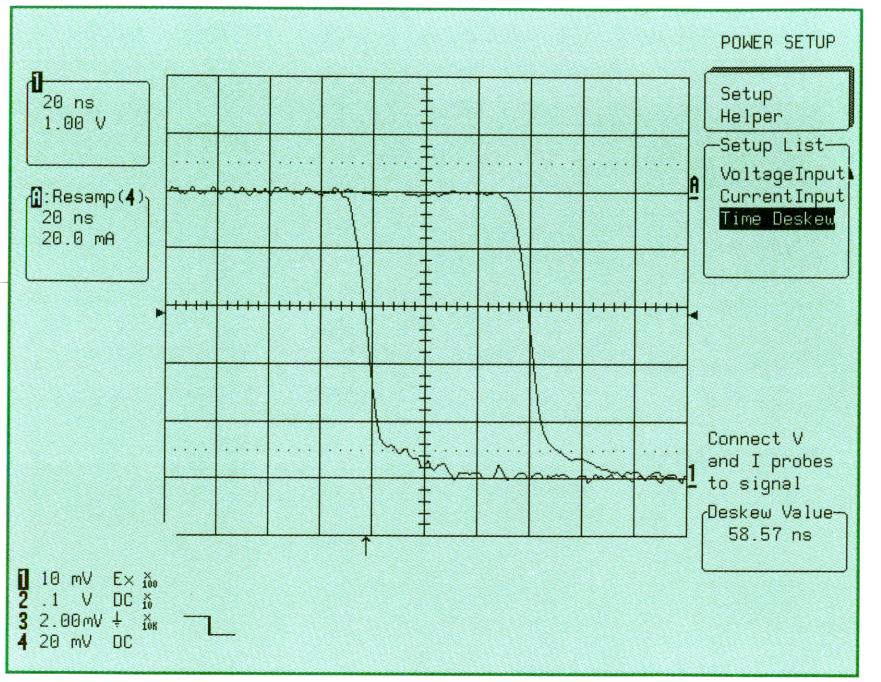
Passive High Voltage Probes

PPE1.2kV	50 MΩ with 600 V/1.2 kV max voltage
PPE2000	50 MΩ with 2 kV max voltage DC + peak AC
PPE4000	50 MΩ with 4 kV max voltage DC + peak AC
PPE20kV	50 MΩ with 20 kV (40 kV peak) max voltage DC + peak AC

PMA1
PowerMeasure Analysis Software

Main Features

- **Makes difficult, error-prone measurements easy**
- **Guided "Setup Helper" streamlines setup process**
- **Supports LeCroy and other vendors' voltage and current probes**



±2 µs channel-to-channel time deskew (10 ps resolution)

PowerMeasure Analysis Software

The PowerMeasure Analysis (PMA1) software provides unique tools for power conversion engineers using switching techniques. This software adds dedicated menus and shortcuts allowing the user to set up the oscilloscope quickly and easily to be able to view and analyze signals from power supply, electronic motor drives, or high-efficiency lighting designs. A "Setup Helper" is built in to support users step-by-step, ensuring correct and accurate measurements.

A detailed manual gives expert advice on how to optimize the oscilloscope and probe setup for voltage, current, power, and energy measurement. Full remote control is possible over GPIB or RS-232-C interfaces.

PowerMeasure Analysis software is also available as an upgrade for WavePro, Waverunner-2 , Waverunner, or LC series LeCroy oscilloscopes.

General Specifications

- Analysis on up to 8 million points with the PS374L, 1 million points with the PS344L, up to 250 kpoints with the PS344, and up to 100 kpoints with the PS322 and PS224.
  Analysis is also available on the full memory length of Waverunner-2 series scopes.
- Deskew range is ±2 µs with a resolution of 10 ps.
- Scale factor from x100 to 1:10,000 provided for non-ProBus voltage and current probes.
- Fine voltage and current DC offset adjustment.
- Proper units displayed for non-ProBus voltage and current probes.

PMA1 software consists of three analysis areas:

Power Device Analysis

- Instantaneous Power
- Safe Operating Area (SOA)
- Saturation Voltage and Dynamic Turn-on Resistance
- dv/dt measurements

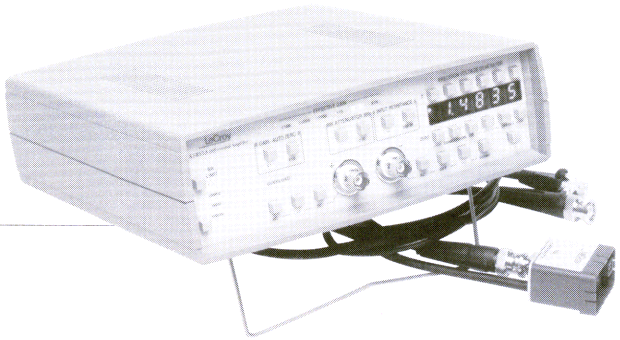
Modulation Analysis

- Signal width (PWM), duty cycle, period, or frequency modulation
- Full control of hysteresis (0.5, 1, 2, 5 div) and level (Pos and Neg)
- Analysis for an unlimited number of events or cycles

Line Power Analysis

- Real power, apparent power, power factor, rms voltage, and rms current parameters
- 50 Hz and 60 Hz
- Automatic Pass/Fail test for precompliance harmonics testing (EN-61000-3-2)
- Standard templates for Class A, B, C, and D
- Up to 40th harmonics
- Graph or tabular display

Differential Voltage Measurements



Main Features

- **ProBus compatible**
- **State-of-the-art overdrive recovery**
- **Very low noise**

Technical Specifications

The DA1855A differential amplifier, when combined with the DXC series differential probes, provides the user with the capability of accurately acquiring virtually any signal in a power conversion circuit without concern for the signal degradation normally associated with these measurements. The Common Mode Voltage Range is limited only by the voltage rating of the probes. The amplifier's signal clipping capability and high Common Mode Rejection Ratio (CMRR) allow you to make such difficult measurements as device saturation voltage and high-side gate drive—while the device is operating in its line primary voltage environment.

DDA1855A

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 ±0.5 V into 50 Ω

Input Attenuation: ÷1 or ÷10

Typical Input Noise (x10 GAIN): <4 nV/sqrt Hz, @ 1 MHz

Common-Mode Rejection Ratio:
>100,000:1 @ 70 Hz
>50,000:1 @ 100 kHz
>1,000:1 @ 10 MHz

Input Resistance:
(÷1 ATTENUATOR): 1 MΩ or 100 MΩ
(÷10 ATTENUATOR): 1 MΩ

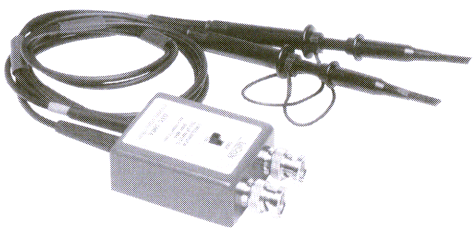
Input Capacitance: 20 pF

Bandwidth Limit Filters: (DA1855A only) 10 MHz, 1.0 MHz and 100 kHz

Offset Range

Max Differential Mode Range:

X10 gain, ÷1 attenuator	±50 mV
X1 gain, ÷1 attenuator	±0.5 V
X10 gain, ÷10 attenuator	±0.5 V
X1 gain, ÷10 attenuator	±5 V



Comparison Offset Range (V_{COMP} Mode):

÷1 attenuator	±15.5 V
÷10 attenuator	±155 V

DXC100A

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

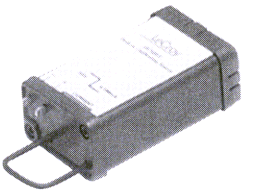
Max Nondestructive Input Voltage: 500 V DC + peak AC

Length: 1.2 meter

A choice of additional differential probe pairs is available for the DA1800A series, with inputs up to ±2500 V (see page 116).

Current Measurements and Channel Delay Matching





Main Features

- ProBus compatible
- 30 Amp
- DC to 50 MHz bandwidth

AP015

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 250 C): ±1% of reading to 15 A, ±2% of reading to 30 A

Risetime: < 7 ns

di/dt Tracking: > 1.6 A/ns

External Field Rejection: 75 dB at DC

Insertion Impedance: < 0.06 Ω at 5 MHz

**Depends on the oscilloscope used.*

DCS015

Time Correlation: ±1 ns

Voltage Output: ~0 to 5 V

Current Output: ~ -100 to 0 mA

Repetition Rate: ~8 kHz

RiseTime: ~8 ns

The DCS015's time coincident voltage and current waveform edges and the PMA1 Software deskew function can be used to match delay differences up to ±2 µs with 10 ps resolution.
This is sufficient for large current and voltage probes with greatly differing cable lengths.

Ordering Information

PowerMeasure Systems with Waverunner-2 Oscilloscopes	Product Code
LT374 Four-Channel 500 MHz DSO with 250 kpt mem/ch DA1855A, DXC100A, DCS015, AP015 and PMA1 software (option M of 1 Mpt/ch and L of 4 Mpt/ch memory are available)	PS374
LT264 Four-Channel 350 MHz DSO with 250 kpt mem/ch DA1855A, DXC100A, DCS015, AP015 and PMA1 software (option M of 1 Mpt/ch memory is available)	PS264

PowerMeasure Systems with Waverunner Oscilloscopes	
LT344L Four-Channel 500 MHz DSO with 1 Mpt mem/ch DA1855A, DXC100A, DCS015, AP015, and PMA1 software	PS344L
LT344 Four-Channel 500 MHz DSO with 250 kpts mem/ch DA1855A, DXC100A, DCS015, AP015, and PMA1 software	PS344
LT322 Two-Channel 500 MHz DSO with 100 kpts mem/ch DA1855A, DXC100A, DCS015, AP015, and PMA1 software	PS322
LT224 Four-Channel 200 MHz DSO with 100 kpts mem/ch DA1855A, DXC100A, DCS015, AP015, and PMA1 software	PS224

PowerMeasure Analysis Software	PMA1

Differential Amplifiers – ProBus Compatible	
100 MHz Differential Amplifier with Precision Offset and 100 kHz, 1 MHz, and 20 MHz BW filters	DA1855A

Differential Passive Probes	
250 MHz ÷10/÷100 Differential Probe Pair	DXC100A
250 MHz ÷100 High-Impedance Differential Probe Pair	DXC350A
50 MHz ÷1 Differential Probe	DXC200
250 MHz ÷100 2.5 kV High-Voltage Probe Pair	DXC5100
1 MΩ ÷10 Passive Attenuator (for use with DXC5100)	DA101

Differential Active Probes	
100 MHz; 1.4 kV	ADP305
20 MHz; 1.4 kV	ADP300
15 MHz ÷10/÷100 700 V Differential Active Probe	AP031

Current Active Probes	
50 MHz; 15 amps, 50 amps peak	CP015
50 MHz 30 Amp AC/DC Current Probe	AP015
10 MHz; 150 amps, 500 amps peak	CP150
120 kHz 150 Amp AC/DC Current Probe	AP011

Accessories	
Deskew Calibration Source (for AP015 and CP015)	DCS015

Accurate Instantaneous Power Measurements

Almost all electronic equipment utilizes a power conversion circuit to convert the AC line voltage to the regulated DC voltages required by the electronics.

Power transistors used in these circuits can dissipate more power during turn-on and turn-off transitions than they do during saturation, so it is important to know the instantaneous power loss during this period. Accurate measurement of instantaneous power loss in power switching transistors requires very sophisticated instrumentation to acquire data, as well as software tools to analyze that data.

One approach is to use a Digital Storage Oscilloscope (DSO) with waveform math processing that can acquire and display the power loss. It does this by multiplying the data points that make up the collector (or drain) current and voltage waveforms.

Before the DSO can accurately perform the required waveform math, both the current through the device and the voltage across it need to be accurately measured. Additionally, some method must be used to remove time-delay differences between the voltage and current measuring channels.

Measurement Methodology

The most useful information about a device's power loss is obtained while it is operating in its normal operating environment. This often means the measurements need to be made on transistors located in a line-referenced power supply's primary circuit. Therefore, the instruments must be able to safely measure signals riding at line voltage levels, without adding common-mode voltage signal corruption.

It is therefore necessary to use high-performance current and differential voltage acquisition systems to acquire the voltage current waveforms of the power-switching transistor. Both the current and voltage channels should have upper-bandwidth capabilities beyond the highest frequency contained in signals being measured.

Dividing 0.35 by the risetime of the fastest voltage waveform to be measured will give a good estimate of its bandwidth. The instrumentation should exceed this bandwidth by a factor of three. Equally important is the ability to measure DC levels of the current and voltage signals.

The waveform measurements described here were made using a LeCroy DA1855 DC-100 MHz differential amplifier, a LeCroy AP015 DC-50 MHz current probe, and a LeCroy *Waverunner*™ LT344L DC-500 MHz digital oscilloscope. All these instruments have sufficient upper-bandwidth capabilities to make these power supply measurements.

The DA1855 differential amplifier and its matched differential voltage probes can accurately and safely measure various power supply signals located in the primary circuit, while minimizing circuit loading. The AP015 current probe provides the DC reference required for the current measurement, while also providing circuit isolation.

After the current and voltage waveforms are acquired, the *Waverunner* scope performs a multiplication function (I x V) to yield a waveform that represents power. To accomplish this, *Waverunner* multiplies the value of each acquired point on the voltage waveform by the value of the current waveform that it acquired at the same time.

Due to differences in the voltage and current signal path lengths and to delays introduced by the current probe and differential amplifier, the current waveform data can be time-skewed in relation to the voltage waveform. When this occurs, the scope does not multiply time-coincident data pairs; therefore, the resulting power waveform is incorrect.

Small time differences can result in substantial errors in the instantaneous power waveform. For this reason, the measurement system must provide some method for correcting this time skew problem.

Deskew

If the voltage and current probes' bandwidths are higher than the highest frequency of interest in the signals they acquire, the difference in the data points can be treated as a simple time skew.

Few DSOs provide a method to deskew the time differences between channels. Those that do use different methods and offer differing amounts of deskew range. The deskew feature in some oscilloscopes is intended for digital timing measurements and can lock the range necessary for instantaneous power measurements.

Resample Function

The LeCroy *Waverunner* oscilloscope used for these measurements uses a deskew method in which the data points in an acquired waveform are "resampled" and displayed as a standard math function called "resample" with delay correction set

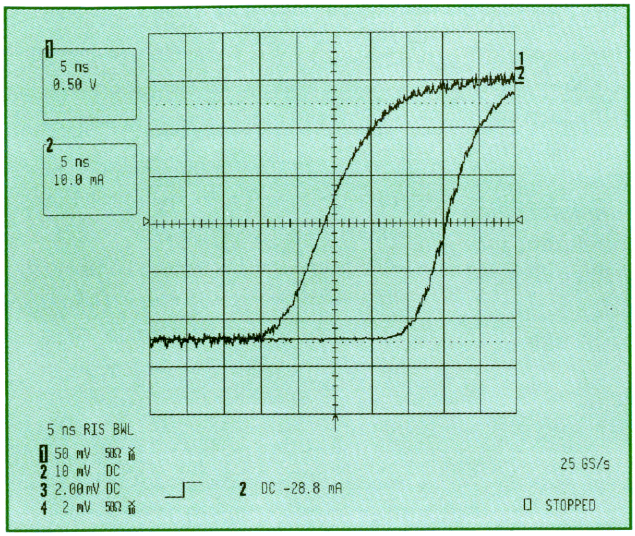


Figure 1: Measurement of the same signal indicates about an 18 ns delay difference between the current and voltage channels.

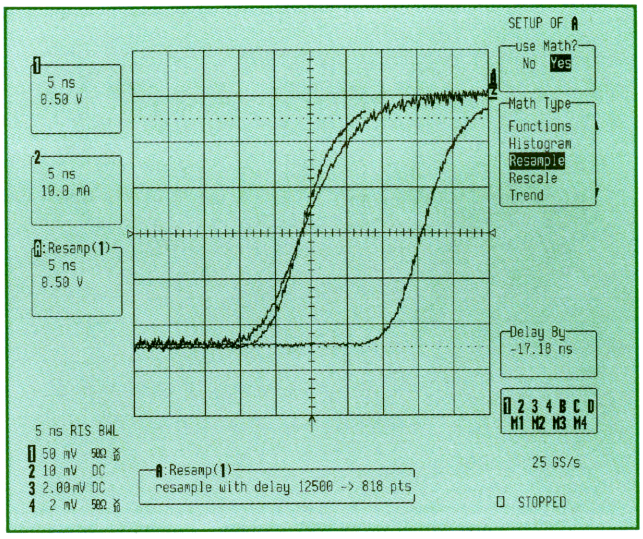


Figure 2: The resample function is used to correct the current and voltage channels' 17.18 ns delay difference. In this case, the slower waveform (voltage) is moved forward in time by entering a negative delay.

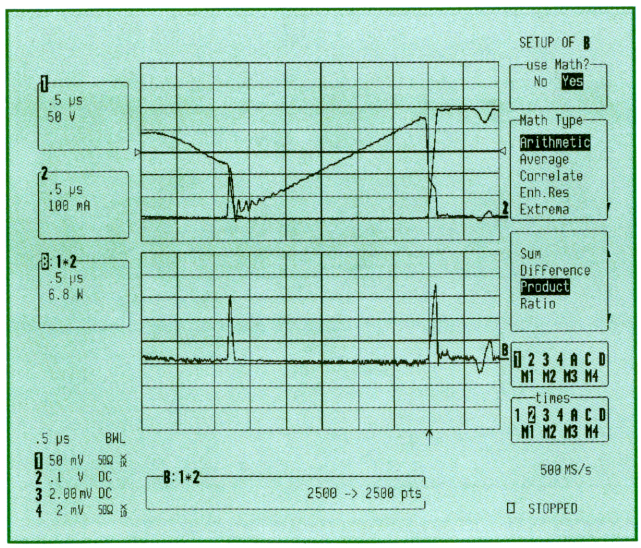
by the user. The time relationship between the acquired and resampled waveforms can be skewed up to plus and minus 2 µs with 0.01 ns resolution. This is more than adequate to handle the time skew introduced by a wide range of current and voltage probes.

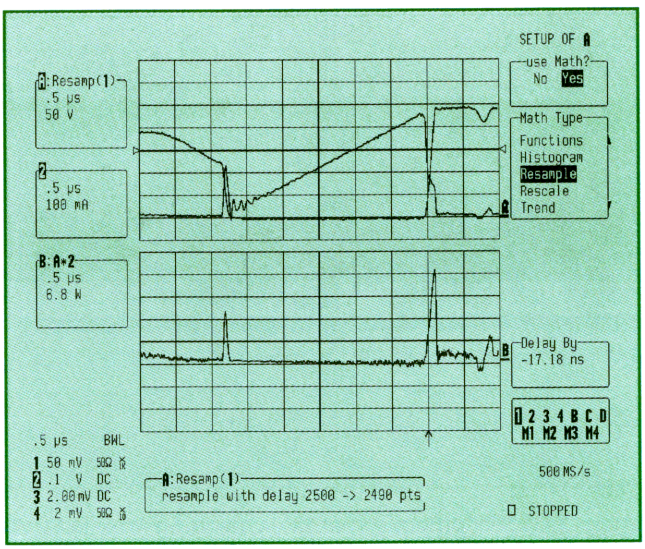
After any time skew has been compensated for, the data points in the resampled (deskewed) current waveform are multiplied by the voltage waveform to yield an accurate representation of the instantaneous power waveform.

To determine the amount of deskew required, the user must calibrate the system. Both the current and voltage probes are connected to the same high-speed test signal. This signal's risetime should be much faster than the device voltage and current waveforms to be measured.

Figure 1 shows the current and voltage waveforms measured at the output of a pulse generator with a 50 Ω load. This measurement indicates that the voltage signal is delayed by about 18 ns with respect to the current signal. In this particular setup, this delay difference is caused by the length of coaxial cable used to connect the external DA1855 differential amplifier to the input of the *Waverunner* or Waverunner-2 oscilloscope.

To correct for the time skew difference between the current and voltage channels, we used *Waverunner's* resample function to adjust the delay of the voltage probe waveform to match that of the current probe. The resample function creates a new waveform that is a "resampled" version of the voltage probe waveform.





Figures 3A & 3B: Comparison of instantaneous power measurements before and after channel time skew correction.

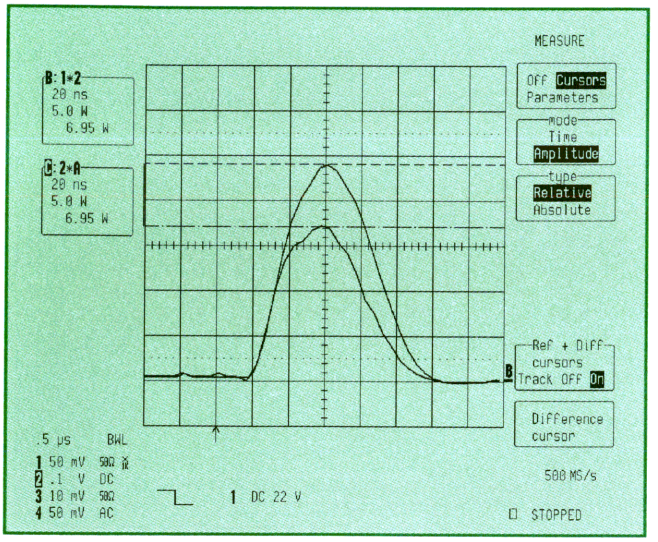


Figure 4: Cursors indicate an error of 6.95 W peak in the turn-on instantaneous power waveform when the current and voltage channel delay is not corrected.

This new waveform differs from the original live waveform only by the amount of delay set in the resample control. Adjusting the amount of resample delay matches the voltage channel delay to that of the current channel (Figure 2) for any acquisitions done with this system (the oscilloscope plus the differential and current probes).

After the two waveforms are matched, the scope's "delay" parameter indicates that the time-delay difference between the current and voltage channels is 17.18 ns. Using the resample function to delay the current waveform by this amount, we can now make accurate measurements that depend on the voltage and current samples corresponding. Two such power circuit measurements are instantaneous switching power losses and safe operating area (SOA) measurements.

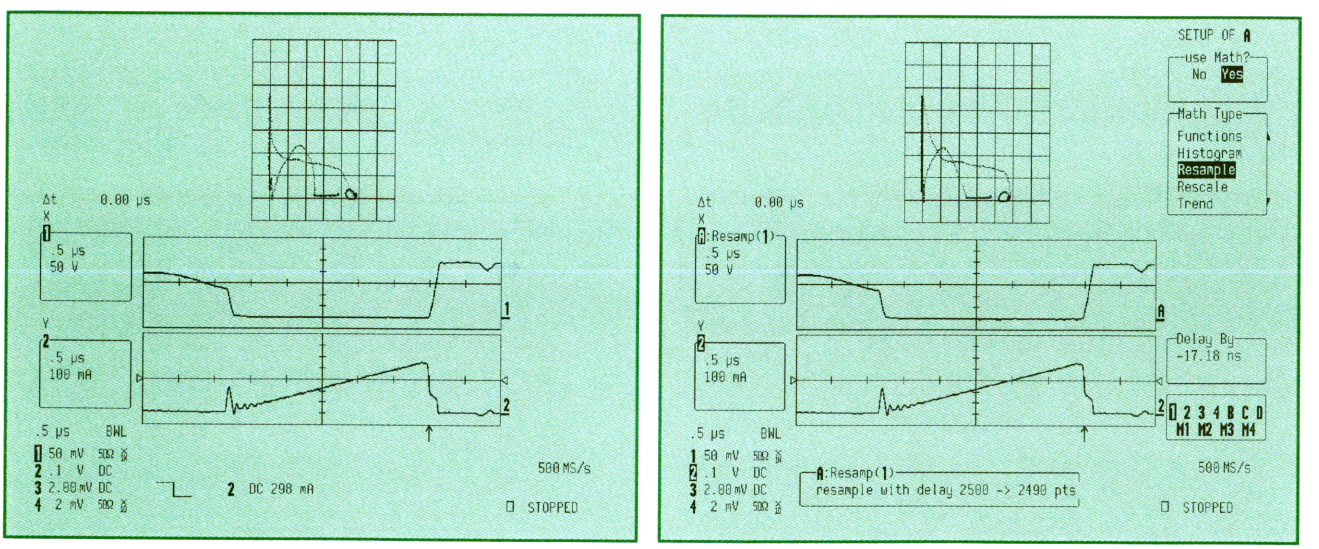
To illustrate the importance of signal deskew when designing snubber circuits, look at the current and voltage waveforms associated with the switching FET in a 25 W off-line flyback power supply. The snubber circuits are added to decrease radiated EMI by slowing the FET's turn-off dv/dt. The challenge is to design a snubber circuit that allows the power supply to meet EMI requirements while introducing minimal power losses.

Figure 3A shows the FET's voltage (CH 1) and current (CH 2) waveforms and the instantaneous power waveform that results from multiplying CH 1 and CH2.

In Figure 3B the resample function is used to correct the 17.18 ns time-delay difference between the current and voltage channels. When we compare the resulting power waveforms in Figures 3A and 3B, we can see the difference in the indicated amount of instantaneous power dissipation.

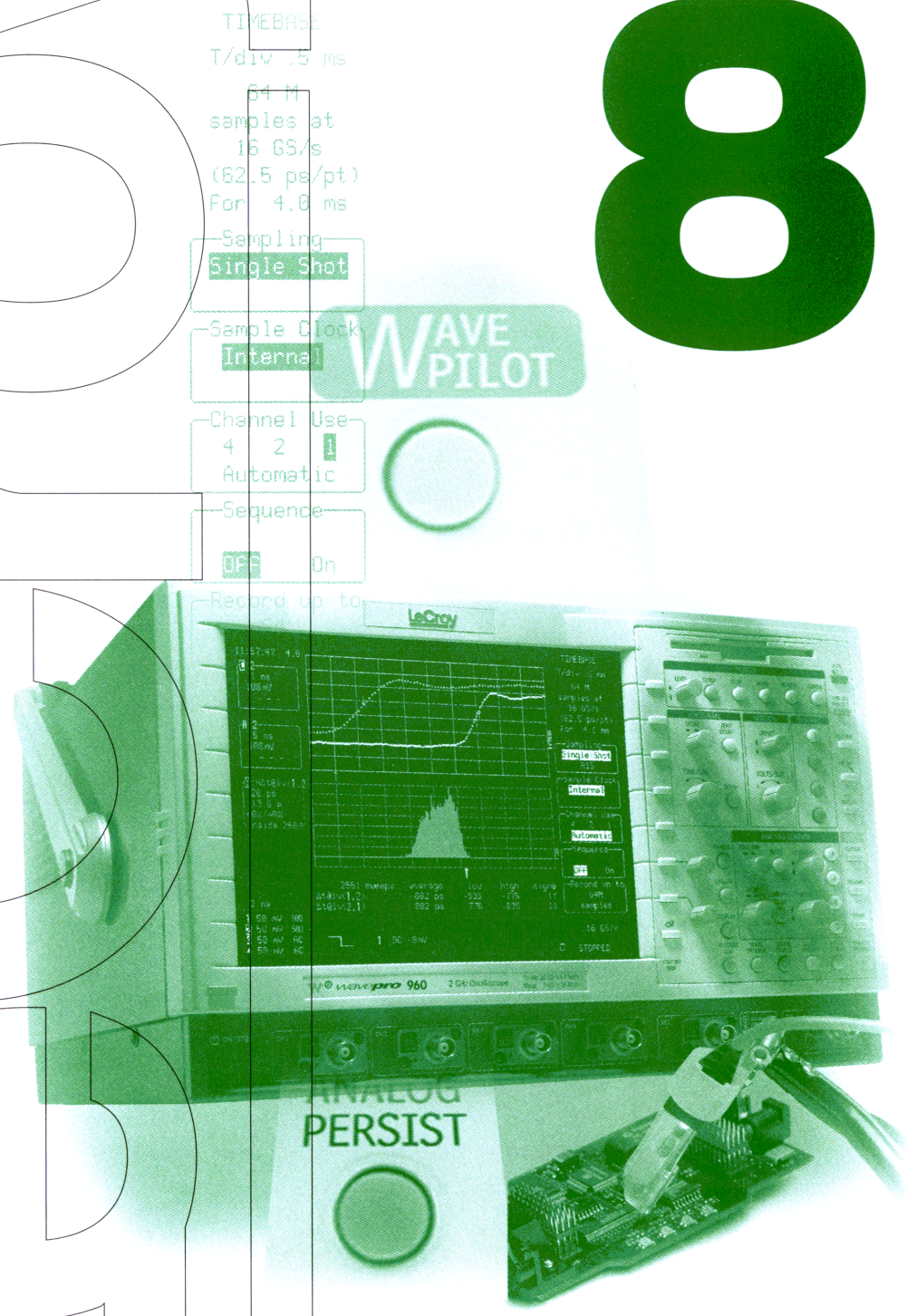
In Figure 4, the two instantaneous power waveforms are shown expanded around the transistor's turn-on time. Using *Waverunner's* cursors, we can see there is a substantial error in the non-deskewed instantaneous power waveform.

After the snubber circuits are designed, the power transistor's SOA can be accurately checked using the oscilloscope's XY function. The accuracy of SOA measurements also depends on the plotted current and voltage points being time-correlated. To obtain accurate results, it is necessary to use the resampled (deskewed) form of the voltage waveform. Figures 5A and 5B compare the same SOA measurement, with and without correcting the delay difference between the voltage and current channels.

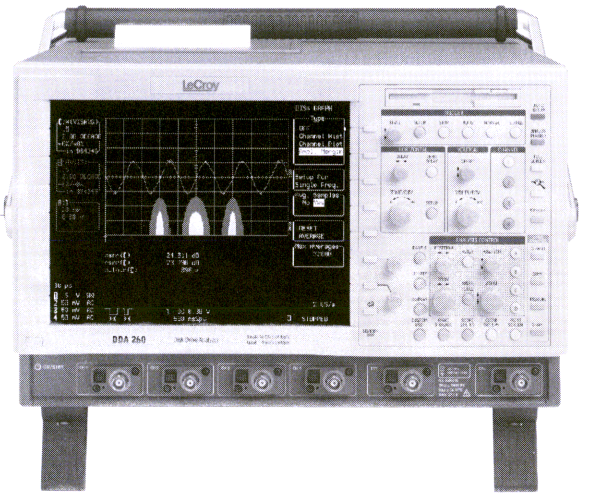


Figures 5A & 5B: Comparison of Safe Operating Area (SOA) measurements before and after channel time-skew correction.

8


TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
LeCroy
wavepro 960
ANALOG
PERSIST

DDA 260
Powered For Drive Analysis



The power to get your job done quickly and easily, and with all the insight you could want. LeCroy Disk Drive Analyzers have performance specifications, capture and analysis features, and a drive-oriented user interface that all provide maximum value to the disk drive engineer.

Drive Analysis



- Special front-panel keys provide easy access to a powerful set of drive analysis capabilities
- Analyze your channel from head signal through PRML channel emulation
- Analyze servo wedges and position error signal for insights into positioning errors
- View drive-specific graphical analysis such as PRML dot plots, SAM histograms, and media noise analysis measurements

Performance

- Up to 16 GS/s on a single channel
- Up to 64 Mpts on a single channel
- 2 GHz Bandwidth
- 256 Mbyte processing memory
- 500 MHz external clock input

Drive-Specific Triggers

Only in the DDA series will you find disk drive triggers defined in disk drive terminology.



Customized triggering is available for selecting the nth servo gate or triggering on every servo gate after the index pulse. The Read Gate Trigger can be customized to select pulses from 100 ns to 50 ms. The PES Trigger will activate signal acquisition when the Position Error Signal exceeds threshold. Finally, the Sector Pulse Trigger allows selection of any particular sector.

Disk Drive Noise Analysis

Characterize head and media noise. Separate media noise from electronics noise.

PRML Analysis

Channel emulation of PR4, EPR4, E2PR4, and other head signals. You can compute NLTS, ACSN, or view maximum likelihood markers indicating ideal sampling points for a PRML signal.

Basic Disk Drive Measurements

The DDM package includes a wide range of basic measurements: TAA, PW50, Overwrite, Resolution, and others. It also offers many local parameters such as local minimum, maximum, time under threshold, and base.

Internal Graphics Printer

A high-resolution internal graphics printer comes standard with the DDA 260. Get hard-copy output in less than 10 seconds, or use the strip chart mode to view all the details in a long, complex signal.

Visit our web site at: www.lecroy.com

Probing Solutions

LeCroy Active Differential Probes have low noise and high performance:

AP033 – 500 MHz Active Differential Probe

AP034 – 1 GHz Active Differential Probe

HFP series – The HFP series of "Little Feet" probes are low-mass, hands-free probes with bandwidths to 2.5 GHz. These probes offer a choice of clip-on tips for probing surface mount devices and circuit vias.

CustomDSO

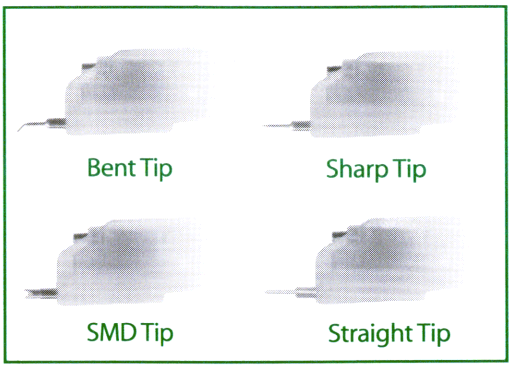
Customize your DDA 260 with shortcut keys, or create application-specific tests and menus.

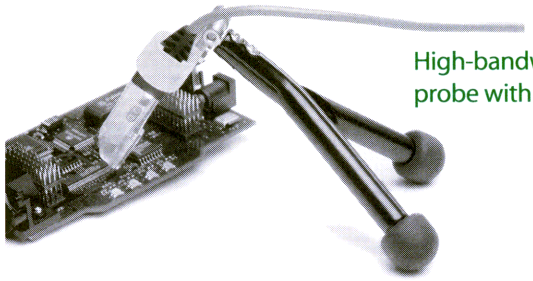
External Interfaces Standard

Built-in printer, GPIB, Floppy, PCMCIA hard drive, PCMCIA memory card, and VGA port. Bidirectional RS-232-C and Centronics ports are also provided.

Ethernet Port (optional)

10 Base-T, TCP/IP protocol



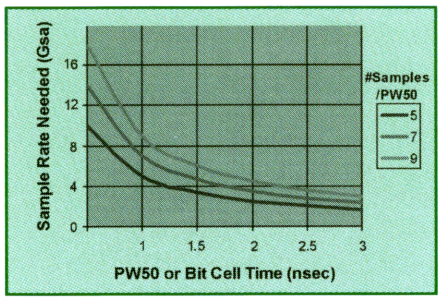


High-bandwidth HFP probe with AutoColor ID

Acquire Drive Signals

Have Confidence in Your Design & Testing

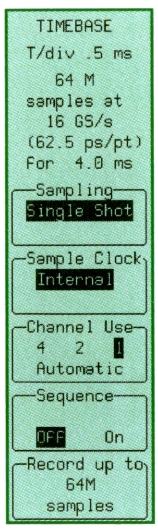
With the DDA 260, you have the sample rate, bandwidth and capture window necessary for precisely capturing head signals. The outstanding capture and analysis capabilities provide excellent design tools and ensure long usable lifetime of your capital investment.

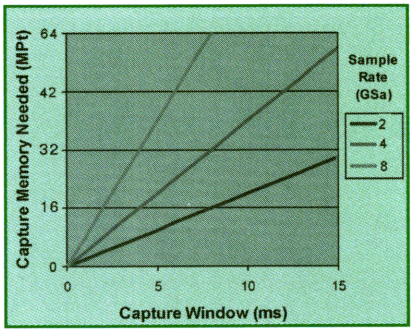


Sample Rate	
1 Channel	16 GS/s
4 Channels	4 GS/s
Capture Memory	
1 Channel	64 Mpts
4 Channels	16 Mpts
Bandwidth	
2 GHz	

Sample Rate

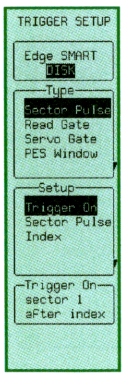
The number of samples per PW50 or per bit-cell-time determines your signal analysis accuracy. It is recommended to use a minimum of 5 or more samples per PW50 for head signal measurements or per bit-cell-time for channel emulation.





Capture Window

The DDA 260 provides up to 64 Mpts capture memory on a single channel to acquire 16 ms of continuous data at 4 GS/s, or over 150 40-µs servo bursts at 1 GS/s.



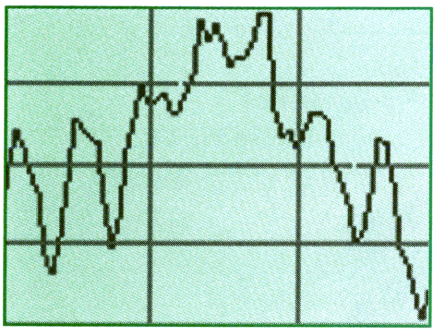
Drive Triggers

The LeCroy DDA 260 has powerful triggering features for capturing disk drive signals of interest. You can rapidly set up triggers using familiar disk drive terminology.

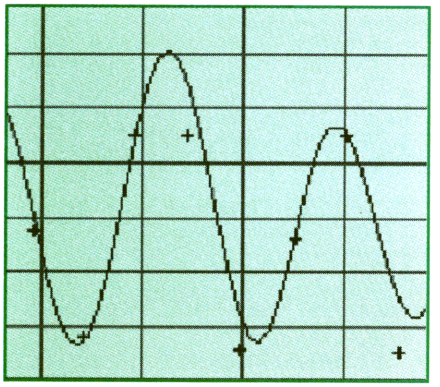
See Signals from the Complete Channel

Use Insightful Display Capabilities

Through the DDA 260's powerful PRML channel emulation, you can view a channel starting from the raw head signal to the output of the Viterbi Detector.



Noisy head signal



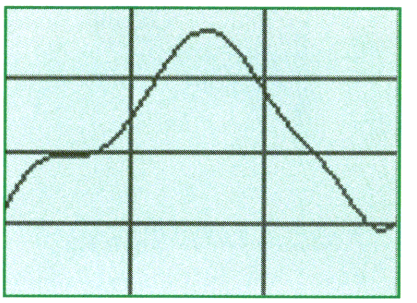
Equalized head signal and Viterbi sample targets ('+')

Head Signal Filtering

A 7-pole, continuously-selectable cutoff frequency filter emulator is available to remove head signal noise.

Byte Number

No more guessing which part of a PRML head signal you are viewing. View the byte number of the head signal at the center of the display.

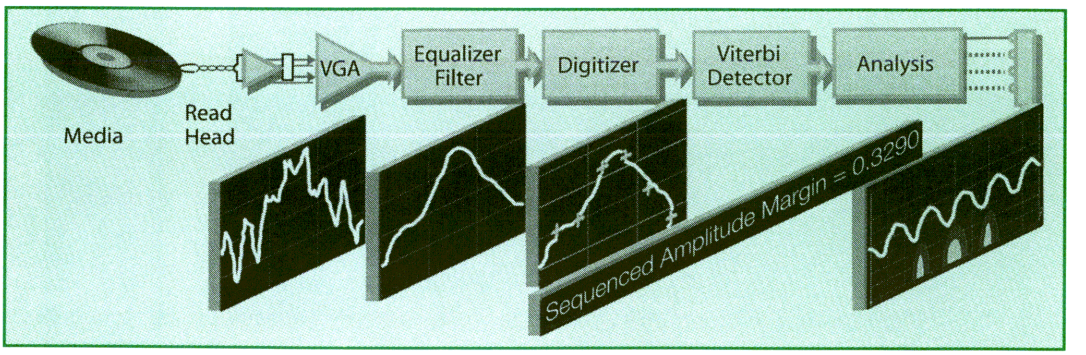


Same signal with 95 MHz 3 dB cutoff selected

PRML Channel Insight

View your head signal from a PRML channel's point of view. The DDA displays the head signal equalized, based on the selected PRML target levels (PR4, EPR4, E2PR4) or others (PRI,PR2) via the user-defined trellis (UDT) capability. The DDA 260 also provides PRML sample targets ('+' signs) indicating where the ideal PRML sample points are. Visual comparison of the equalized head signal and PRML targets gives a rapid visual indication of head signal quality from a PRML viewpoint. In addition, the DDA 260 provides the channel emulation quality metric Sequenced Amplitude Margin (SAM) for the 100 head-signal samples with the poorest SAM.

PRML Signal Processing Made Easy



The DDA's channel emulation takes the mystery out of complex PRML signal processing. See the PRML head signal and —through channel emulation — the PRML signal as it gets processed through the equalizer, sampler, and Viterbi Detector. Quality metrics such as SAM histograms and media noise can then be viewed.

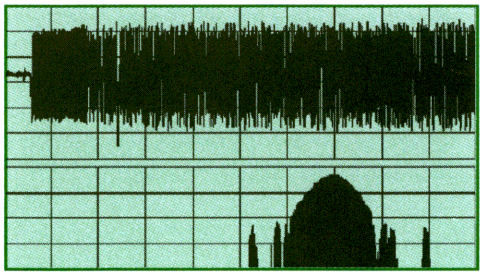
Get Rapid Insights into Drive Problems

Eliminate Guesswork

Today's sophisticated disk drives need sophisticated measurement tools — with simple interfaces. Determining what is going on with your drive using general-purpose measurement equipment is often a guessing game. Many design engineers are forced to draw conclusions from visual inspection or generic processing functions. The DDA 260's drive-specific processing functions take the guesswork out of analysis by directly providing the information you need.

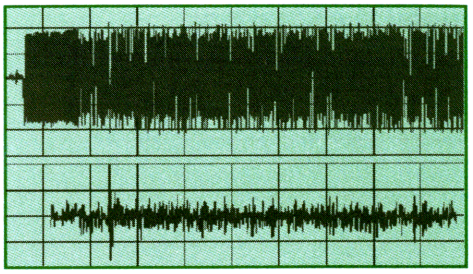
Head Signal Quality Distributions

How do you determine the quality of your PRML signal? SAM histograms provide a direct indication of how much margin you have, what the noise contribution to signal quality is, and whether there are anomalous events. Shown below is a SAM histogram of a noisy PR4 signal (top) with distinct non-noise anomalies indicated by the histogram (bottom). The center of the display indicates a 0 SAM value.



Head Signal Quality Line Graphs

Easily observe how head-signal quality varies over a PRML signal. Shown below is a PRML head signal (top) and a trace of how the head signal quality (SAM) varies from nominal (bottom). The signal spike shown is a clear indication of a PRML signal quality problem and its location.

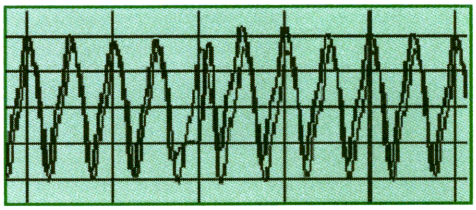


Rapidly Locate PRML Signal Quality Problems

If you do not know the exact location of a PRML error, or if you want to locate signal areas with poorest margins from a PRML channel viewpoint, use the DDA 260's powerful channel tools. Simply turn a knob, and the DDA 260 will display your head signal in order of signal locations with worst SAM. Also displayed will be the corresponding SAM value for each location.

PES Runout Analysis

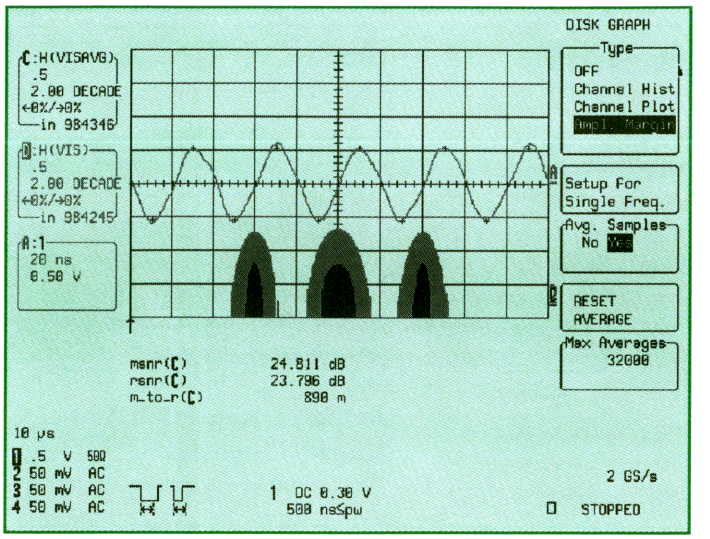
See the values for the Position Error Signal (PES) runout contributors for each wedge around a track. Values provided include Repetitive Runout, Non-Repetitive Runout, and Instantaneous Runout.



Pinpoint the Source of Noise

Media vs. Electronic

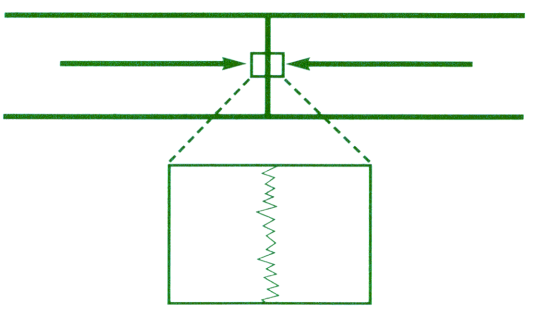
Media noise is becoming a major factor in today's disk drives. The DDA 260 provides simple ways to measure the total noise, as well as determine how much is media noise versus electronics noise.



Trace A is a portion of a captured disk drive sector. Trace C is a histogram of the averaged Viterbi input samples. There are three distributions due to the peak locations, zero crossings, and trough locations. Trace D is a histogram of the actual Viterbi input samples. Measurements performed on Trace C are Media Signal-to-Noise (msnr), Residual Signal-to-Noise (rsnr), and the ratio of Media Noise to Residual Noise (m_ to_r).

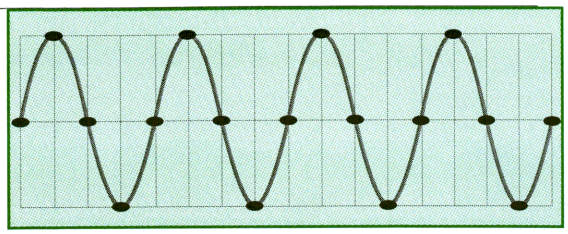
Media Noise

Media signal-to-noise (msnr) automatically measures repetitive noise that has been recorded on the media. Residual signal-to-noise (rsnr) automatically measures the non-repetitive noise, which is often referred to as electronics noise. Media noise to residual noise (m_to_r) automatically measures the ratio of media noise to residual noise. If this ratio is greater than 1.00, the signal is media noise–dominated. If not, the signal is electronics noise–dominated. In the example (the screen shot above), msnr = 24.811 dB, while rsnr = 23.796 dB. There is less media noise (better signal-to-noise ratio) than electronics noise. The noise is dominated by the residual noise and the m_to_r ratio is less than one (.896).



This figure represents a single recorded magnetic transition. An ideal transition is a straight line. However, granuality in the media produces zigzag transitions. The zigzag locations change from write to write, producing variability in the read-back signal or media noise.

Granularity in magnetic media produces zigzag transitions. The exact location of the zigzags changes from write to write, causing media noise (also known as transition noise or zigzag noise). During a read, the read head effectively averages across the track, the location of all of the zigzags. If the recorded track width is wide, there are many zigzags and very little variability in the averaged transition location. If the track width is narrow, there are fewer zigzags, and the variability in the averaged transition location increases.



For this analysis, sector-based data is required. The signal structure must contain a single frequency preamble, an address mark field, and a data field. The data needs to be a single frequency pattern. The ideal "data" pattern is a single 2T pattern or equivalent. By utilizing a single frequency data pattern, any hardware channel can be used — PR4, EPR4, E2PR4, or even modified PRML.

Media Noise vs. Electronics Noise

Distinguish Between Them

Head signal amplitude is approximately proportional to track width. Media noise is approximately proportional to the square root of the track width. Therefore, the ratio of the head signal to the media noise (msnr) is proportional to the square root of the track width. As disk drive manufacturers continue to increase disk drive capacity by reducing track width, msnr will get worse. Although advanced head technology (i.e., MR and GMR) can increase the head signal output for a given track width, the effect of media noise on the head signal is also increased, so there is no improvement in msnr.

Media noise can affect a disk drive signal in a number of different ways. It can distort the pulse width and amplitude. It can cause either early or late timing transitions and partial erasure.

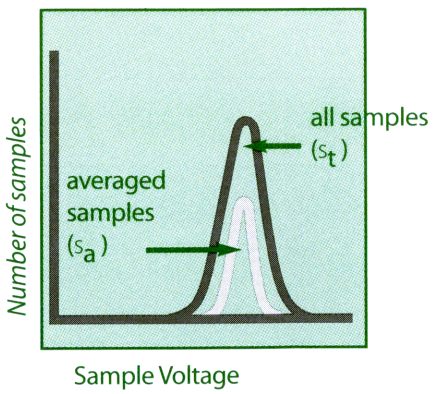
The trend is clear: msnr continues to get worse, and as a result, the industry is shifting from designs that were electronics noise-dominated to designs that are media noise-dominated. LeCroy offers new, simple tools to help determine if your system is electronics or media noise-dominated. One of the key attributes of media noise is that once it is recorded on the media, it is the same on every read. Thus, media noise is repeated noise.

With the DDA 260, you can optimize your product by identifying the amount of media noise and electronics noise.

Noise Distributions

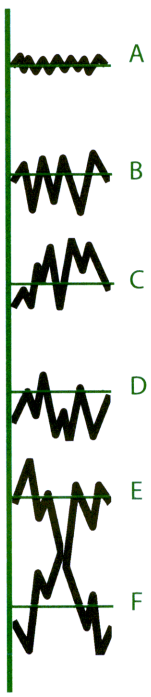
$s_t^2 = s_m^2 + s_r^2$
(always true)

For large n:
$s_m^2 = s_a^2$
$s_a^2 = s_t^2 - s_a^2$



The squared sigma of the total noise distribution is the sum of the squared sigmas of the media noise and the residual noise distributions. After multiple acquisitions, residual noise averages away, yielding the media noise.

Media Noise Transition Distortions

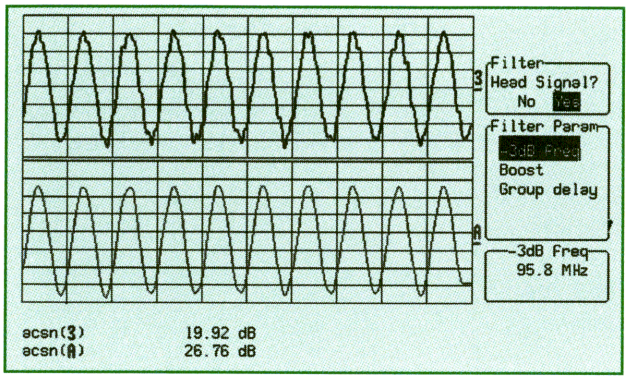


Examples of how media noise can distort the actual transition. Transition A vs. Transition B is an example of pulse width and amplitude distortion. Transitions C and D are examples of timing distortions. Transitions E and F are examples of partial erasure.

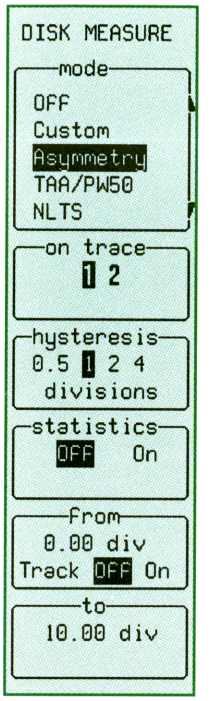
Measure Drive Signals with Confidence

Rapid Access to Drive-Specific Measurements

LeCroy provides a rich set of drive measurements that are considered the industry standard. Measurements such as TAA asymmetry and local period are provided in the Disk Drive Analyzers. Setup of the most common drive measurement parameters is rapidly accessed through the DDA 260's special MEASURE front- panel key.



Determine head-signal noise using the DDA 260's ACSN measurement parameter. Use the continuously-selectable frequency cutoff filter to ensure ACSN is measuring only the noise components your channel will see.



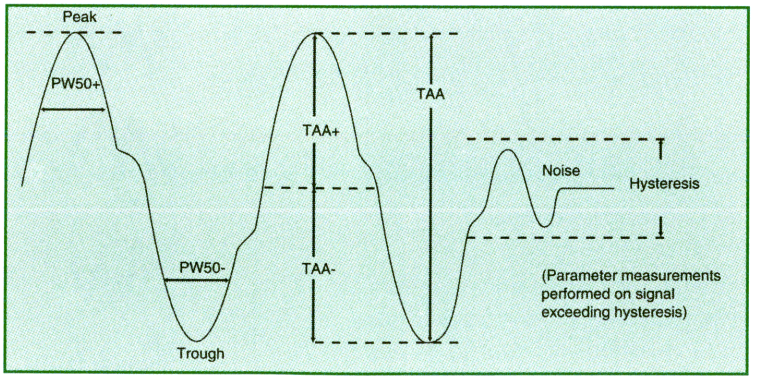
Frequency Domain Parameters

The DDA 260 can calculate narrow band phase (nbph) in degrees relative to the start of the waveform and narrow band power (nbpw) in dBm.

These parameters provide a rapid technique to extract the amplitude and phase of single frequencies from complex waveforms. The parameters are more efficient than using an FFT for specific frequencies of interest.

The nbpw frequency domain parameters provide an easy method for measuring non-linear distortion using fifth harmonic elimination.

Peak/Trough Measurements



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 parameter histogram display, a statistical description of the waveform can be calculated.

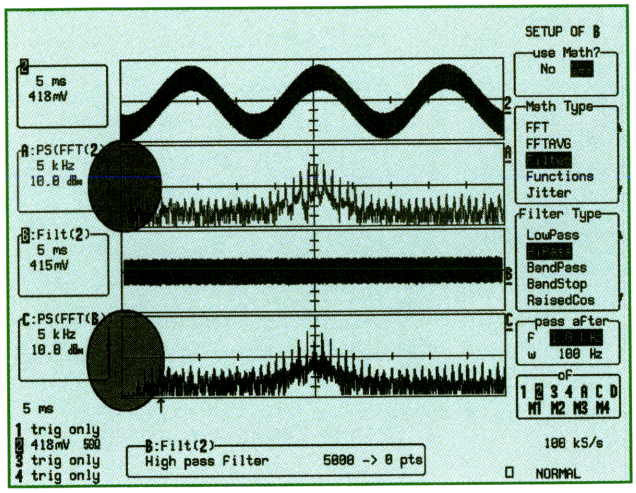
Software Options for Specific Applications

LeCroy offers a wide variety of software options targeted to the solution of specific types of measurement problems. One popular option for the DDA series is the Advanced Optical Recording Package (AORM), for testing CD-ROM, DVD, and magneto-optical drives. Other very powerful additions offered for the DDA 260 are jitter and timing analysis packages (JTA or the more advanced JitterPro). The DDA 260 can measure signal jitter, modulation effects, and other types of timing problems precisely and can present the results in the time, frequency, or statistical domains.

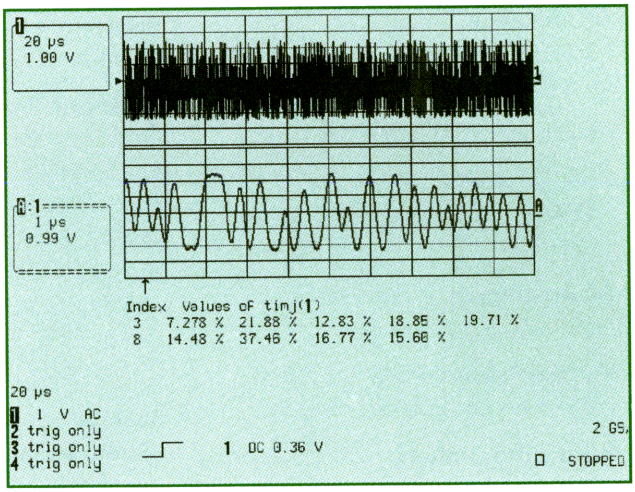
Two additions to the suite of available software options are the Digital Filter Package (DFP) and PolyMask. DFP allows you to create a variety of filters including low pass, high pass, band pass, band stop, Gaussian, raised cosine, raised root cosine, and user-defined (up to 1,000 elements). The PolyMask option is intended for applications requiring pass/fail testing.

PolyMask includes a PC utility — MaskMaker — for creating pass/fail test templates and the ability to download these templates into a LeCroy DDA 260. Incoming waveforms can be compared to the test masks, and a variety of actions can be initiated if the signal fails the test.

For applications requiring measurement of the performance of power devices, LeCroy offers a complete PowerMeasure system including a differential amplifier, current probe, timing deskew, calibration source and PMA1 software. With this system, you can measure in-rush current during turn-on, determine power dissipation, check the Safe Operating Area (SOA) of power devices, verify emitted and conducted EMI, and more.



LeCroy's Digital Filter Package (DFP) offers additional filtering capability. It implements a set of linear-phase Finite Impulse Response (FIR) filters. It enhances your ability to examine important signal components by filtering out undesired spectral components such as noise. With the custom design feature, you can reconstruct corrupted signals by applying matched (mirror) filters to compensate for known distortions.



AORM can create a list by nT display of Timing Jitter (timj) measurements of a CD-ROM Data waveform with separate values displayed for each nT mark/space width.

Visit our web site at: www.lecroy.com

Specifications

Signal Capture

Bandwidth (-3 dB): @ 50 Ω: DC to 2 GHz * ; @ 1 MΩ: Bandwidth depends on probe used

Number of Channels: 4

Sample Rate and Acquisition Memory: See table below

Active Channels	Max Sampling Rate	Max Record Length
4	4 GS/s	16 M
2	8 GS/s	32 M
1	16 GS/s	64 M

Sensitivity: 50 Ω: 1mV - 1 V/div fully variable; 1 MΩ, 1mV - 2 V/div fully variable

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

Offset Range

50 Ω or 1 MΩ: 1 mV - 4.99 mV/div: +400 mV

50 Ω: 5 mV - 99 mV/div: +1 V; 0.1 - 1V/div: +10 V

1MΩ: 5 mV - 100 mV/div: +1 V; 0.101 V - 2 V/div: +20 V

DC Accuracy: (±) 2.0% full scale + 1.5% offset value @ gain >10 mV

Vertical Resolution: 8 bits, up to 11 bits with enhanced resolution (ERES)

Bandwidth Limiters: 20 MHz, 200 MHz

Input Coupling: 1 MΩ: AC, DC, GND; 50 Ω: DC, GND

Input Impedance: 50 Ω: ±1.5%; 10 MΩ // 11 pF typical (using PP005 probe)

Max Input Voltage: 50 Ω: ±5 V DC (500 mW) or 5 Vrms; 1 MΩ: 100 Vmax (peak AC <5 kHz + DC)

Acquisition Modes

Random Interleaved Sampling (RIS): 50 GS/s. For repetitive signals from 200 ps/div – 1 µs/div

Single-Shot: For transient and repetitive signals from 200 ps/div – 1000 s/div

Sequence: Stores multiple events — each of them time stamped (1 ns resolution) — in segmented acquisition memories

Sequence Mode Dead Time: Typically 30 µs

Number of Segments Available: 2 – 8000

Timebase System

Timebases: Main and up to four zoom traces

Time/Div Range: 200 ps/div – 1000 s/div

Rapid Signal Processing

Microprocessor: Motorola PowerPC 603e

System Memory Configuration: 256 Mbytes

Video Memory: 1 Mbyte

Persistence Data Map Memory: 16 bits per displayed pixel (64k levels)

Waveform Processing: Up to four processing functions can be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity, Summation Averaging, Sine x/x, Integral, Derivative, Square Root, Ratio, Absolute Value, Resample (deskew), Rescale Exp Log, and the advanced functions listed below

Average

Summation: Up to 10^6 averages possible.

Continuous: Weighting factors from 1:1 to 1:1023

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 five windowing functions (Rectangular, Von Hann, Hamming, Flat Top, Blackman-Harris) and FFT averaging

Statistical Diagnostics: The parameter analysis package permits in-depth diagnostics on waveform parameters. Live histogramming and trending of any waveform parameter measurement is possible. The histogram can be autoscaled to display the center and width of the distribution.

Histogramming: Generate history of waveform parameter calculations.

Trending: Generate trend sequence of waveform parameter calculations.

Correlation: Calculate the normalized correlation coefficient between two signals.

Head Filter/Equalizer Emulation

Type: Utilizes a seven-pole, two-zero equiripple filter. Values for –3 dB frequency, boost and group delay can be independently adjusted

Boost: 0 to 13 dB

FC: 10 MHz – 200 MHz

Group Delay: –30% to 30%

In addition, DDA can autotrain on a PRML signal using a 2D search of fc and Boost to automatically set fc and Boost. A 21–tap FIR (Finite Impulse Response) filter — settable through GPIB control — is also available for channel emulation. Filter tap weights can be asymmetric to minimize delay through the filter.

Channel Emulation: Channel emulation capability is provided to analyze PR4, EPR4, E2PR4, and user-defined trellis PRML head signal quality. The channel emulator includes a resampling ADC, PLL, Automatic Gain Control (AGC) and Viterbi detector. Maximum likelihood levels are independently controlled and can adjust for MR head asymmetries.

** for sampling rates > 4 GS/s*

SAM Histograms: Histograms of SAM values can be automatically displayed for the head signal SAM values determined in channel emulation. SAM histograms give an overall view of the distribution of SAM and, thereby, overall head signal quality, noise contribution, and quality outliers from a PRML channel perspective.

Plot of SAM Values: A sequential graph of SAM values can be displayed along with the PRML head signal. The plot of SAM values provides a rapid visual indication of the location of PRML signal problems.

PES Runout Analysis: Provides a table of runout values for PES (Position Error Signal) for each servo wedge captured; includes Repetitive Runout, Instantaneous Runout, Maximum IRO, Minimum IRO, and Sigma.

Analog Compare: Provides automatic comparison of a stored reference head signal and acquired head signals, with automatic adjustment for spindle speed variations. Differences between head signals are calculated using a 3–byte sliding window, and a calculation of the Mean-Square-Distance (MSD) is computed.

Cursor Measurements

Relative Time	A pair of arrow cursors measures 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	duty	lper	period	std dev
area	delay	fall	maximum	peak-to-peak	t@level
base	Δc2d- (hold)	f 80-20%	mean	phase	top
cmean	Δc2d+ (setup)	f@level	median	rise	width
cmedian	Δdelay	first	minimum	r 20-80%	
crms	Δt@level	frequency	overshoot+	r@level	
csdev	duration	last	overshoot-	rms	

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	msnr	rsnr	m_to_r	nbph	nbpw

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 items (parameters and/or masks) to be tested against selectable thresholds. Waveform Limit Testing is performed using Masks that may be defined either inside the instrument or by downloading templates created with MaskMaker — a utility that is part of the PolyMask option. Any failure will cause preprogrammed actions such as Stop, Hardcopy, Save to Internal Memory, Save to mass storage device (card or disk), GPIB SRQ, or Pulse Out.

Viterbi Input Samples Plot: Provides a rapid and easy means for viewing traditional "dot plots" of PRML signal samples. No external clock signal is required. The PRML signal samples are obtained through the DDA's channel emulation sampler. The sampled values can be displayed in a persistence display mode.

Viterbi Input Samples Histogram: Provides an automatic histogram of PRML sample values obtained through the DDA's channel emulation sampler. The histogram provides the ability to easily view whether sample value crossover is due to excessive noise or signal anomalies.

Internal Waveform Memory

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

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 Storage

Front Panel and Instrument Status: Four non-volatile memories and floppy drive are standard. Hard drive and memory card are optional.

Macro Storage: Customize and access scope settings with up to five custom DSO macros stored in internal non-volatile memory.

Color Waveform Display

Type: VGA Color 10.4" flat panel TFT LCD

Resolution: VGA 640 x 480 pixels

Screen Saver: Display blanks after 10 minutes (when screen saver is on).

Real Time Clock: Date, hours, minutes, and seconds displayed with waveform

Number of Traces: Display a maximum of eight traces. Simultaneously display channel, zoom, memory, and math traces.

Grid Styles: Single, Dual, Quad, Octal, XY, Single+XY, Dual+XY; Full Screen gives enlarged view of each style

Intensity Controls: Separate intensity control for grids and waveforms

Waveform Styles: Sample dots joined or dots only; regular or bold sample point highlighting

Trace Overlap Display: Select opaque or transparent mode with automatic waveform overlap management.

Analog Persistence Display

Analog & Color-Graded Persistence: Variable saturation levels. Store each trace's persistence data in memory.

Persistence Trace Selection: Activate Analog Persistence on a selected trace, top two traces, or all traces.

Persistence Aging Time: Select from 500 ms to infinite.

Trace Display: Opaque or transparent overlap

Sweeps Displayed: All accumulated or all accumulated with last trace highlight

Zoom Expansion Traces

Display up to four zooms

Vertical Zoom: Up to 5x expansion, 50x with averaging

Horizontal Zoom: Expand to 2 pts/div, magnify to 50,000x

Auto Scroll: Automatically scan and display any zoom or math trace

Real-time Clock: Dates, hours, minutes, seconds, and time stamp trigger to 1 ns resolution

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 and out)

Coupling: DC, AC (> 10 Hz), HF, LFREJ (>50 kHz), HFREJ (<50 kHz)

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: 500 MHz (AC,DC); 2GHz (HF)

Max Ext Trigger Input at 50 Ω: ±5 V DC or 5 V rms

Max Ext Input at 1 MΩ: 100 volts max (DC + peak AC <5 kHz)

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

Auto Setup

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

Vertical Find: Automatically sets sensitivity and offset for selected channel

Probes

Model PP005: 10:1, 10 MΩ with autodetect (one per channel)

Probe System (ProBus®): Automatically detects and supports a wide variety of differential amplifiers; active, high-voltage, current, and differential probes

Scale Factors: Up to 12 automatically or manually selected

Interfacing

Remote Control: All front-panel controls and internal functions possible via GPIB, RS–232–C, or Ethernet

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 (Standard): Hard copy parallel interface

Ethernet (optional): 10 Base-T ethernet interface

Floppy Drive: Internal, DOS–format, 3.5" high-density

PC Card Slot (optional): Supports memory and hard drive cards

External Monitor Port: 15-pin D-type VGA compatible

Internal Graphics Printer (Standard): Provides hard-copy output in <10 seconds, or stripchart printout up to 200 cm/div

Pass/Fail and Trigger Output: Front panel Cal BNC output provides choice of Cal signal, pass/fail condition, trigger ready or trigger out signals

Hard copy

Print screen is activated by a front-panel button or via remote control. Store screen image files or print to external printers.

Trigger Name	Trigger Description
Basic Triggers	
Edge/Slope/Window/Line	Triggers when signal meets slope and level condition
SMART Triggers®	
State or Edge Qualified	Triggers on any input source only if a defined state or edge occurred on another input source. Delay between sources is selectable by time or events.
Dropout	Triggers if signal drops out for longer than selected time between 2 ns and 20 s
Pattern	Logic combination of 5 inputs (4 channels and external trigger input). Each source can be High, Low, or Don't Care; trigger at start or end of the pattern.
SMART Triggers with Exclusion Technology	
Signal or Pattern Width	Triggers on glitches or on pulse widths selectable from 600 ps to 20 s or on intermittent faults
Signal or Pattern Interval	Triggers on intervals selectable between 2 ns and 20 s
Slew Rate	Trigger on edge rates. Select limits for dV, dt, and slope. Select dt from 600 ps to 20 s.
Runt	Positive or negative runts defined by two voltage limits and two time limits selectable between 600 ps and 20 ns
Drive Triggers	
Sector	Trigger on the n'th sector pulse after index. Index and sector pulse can be individually defined as positive or : neg ative polarity. Sector pulse number can be selected from 1 to 500.
Servo Gate	Trigger on the n'th servo gate after Index and every m'th thereafter. Index and servo gate can be individually defined : as positive or negative polarity. On most drives, this makes it possible to use sequence mode acquisition to trigger on : every servo gate starting with a specific one after the index (m = 1).
PES Trigger	Trigger on Position Error Signal (PES) exceeding a selected voltage window. User can select whether to use the servo : gate as an additional criterion before a PES window trigger can occur.
Read Gate Trigger	Trigger on any read gate that is longer than a specified Sector ID field length. The Sector ID field length is adjustable : from 100 ns to 50 µs.

Supported Printers

B/W: LaserJet, DeskJet, Epson

Color: DeskJet 550C, Epson Stylus, Canon 200/600/800 series

An internal high-resolution graphics printer is standard for screen dumps; stripchart output formats capable of up to 200 cm/div.

Hard-Copy Formats: TIFF b/w, TIFF color, BMP color, and BMP compressed

Waveform Output

Store waveforms to floppy disk or optional PC-Card hard drives and memory cards. Select any trace and request auto-store to automatically store the waveform after each trigger.

Output Formats: The ASCII waveform output is compatible with spreadsheets, MATLAB, Mathcad, etc. Binary output is also available for reduced file size.

Documentation

Operating Manual: Hard copy

Remote Programming Manual: Hard copy

CD-ROM: PDF formatted manuals plus software utilities including ScopeExplorer and ActiveDSO™

General

Auto-Calibration: Ensures specified DC, and timing accuracy is maintained for one year minimum.

Auto-Calibration Time: <500 ms

Power Requirements

Voltage: 90 – 132 VAC; 180 – 250 VAC

Frequency: 45 – 440 Hz; 45 – 66 Hz

Max. Power Dissipation: 350 VA

Battery Backup: Front panel settings retained for two years minimum

Warranty and Calibration: Three years. Calibration recommended yearly

Environmental and Safety

Operating Conditions

Temperature:

5 to 40° C rated accuracy (41 to 104° F)
0 to 45° C operating
–20 to 60° C non-operating

Humidity: 75% max RH (non-condensing) up to 35° C; 50% max RH (non-condensing) at 35 – 45° C:

Altitude:

3 000 meters (10 000 feet) operating at 25 °C
4 500 meters (15 000 feet) non-operating

CE Approved

EMC: EMC Directive 89/336/EEC; EN 61326–1 Emissions and Immunity

Safety: Low Voltage Directive 73/23/EEC; EN 61010–1 Product Safety (Installation Category II, Pollution Degree 2)

UL and cUL approval

UL Standard UL 3111–1
cUL Standard CSA-C22.2 No. 1010.1

Physical Dimensions

Dimensions (HWD): 264 mm x 397 mm x 453 mm; 10.4"x 15.65"x 17.85" (height excludes unit's feet)

Weight: 14 kg; 31 lbs

Shipping Weight: 22.2 kg; 49 lbs

Service

LeCroy service programs include unique upgrades for LeCroy oscilloscopes and analyzers, metrology modules customized for your : company, and more. Whether you own one LeCroy instrument or hundreds, whether you need prompt attention from our service offices or an on-site service contract, LeCroy is committed to your success. Call your LeCroy service representative to discuss your : company's specific requirements.

DDA 260 Ordering Information

Disk Drive Analyzers		Product Code
2 GHz, 4 GS/s per channel, 16 Mpts/Ch, 4 channel Disk Drive Analyzer/DSO	16 GS/s, 64 Mpoints/1 Channel	DDA 260

Included with Standard Configuration (DDA 260):	
10:1 10 MΩ Passive Probe (1 per channel)	PP005
User's Guide	DDA-UG
Remote Control Manual	DDA-RCM
Reference Manual	DDA-REF
Disk Drive Noise Analysis Package	DDNA
Disk Drive Measurements	DDM
Supplementary Disk Drive Measurements	PRML
Extended Math and Measurement Package	EMM
Internal Graphics Printer	GP02
WaveAnalyzer Package (including Histograms)	WAVA
Floppy Disk Drive	
Protective Front Cover	
Performance Certificate	
Three-Year Warranty	

Selected Probes & Accessories	
1 GHz Active Probe	HFP1000
1.5 GHz Active Probe	HFP1500
2.5 GHz Active Probe	HFP2500
1 GHz Active Differential Probe	AP034
1 GHz, 10:1, 500 Ω Passive Probe	PP062
ProBus 75 to 50 Ω Adapter	PP090
SMD Kit for PP005 Probe	PK106
Graphic Printer Paper/10 Rolls	GPR10
Oscilloscope Cart with Drawer and Printer Shelf	OC-PRO
PC Card Slot and 520 Mbyte Portable Hard Drive	HDD

Software Options	
Jitter and Timing Analysis Package	JTA
JitterPro Package	JPRO
Clock Certification Timing Module (requires JitterPro)	CCTM
Advanced Optical Recording Measurements	AORM
Digital Filter Package	DFP
PowerMeasure Analysis	PMA1
PolyMask Mask Testing Software	PMSK

Warranty & Calibration	
NIST Calibration Certificate	DDA-CCNIST
MIL STD Calibration	DDA-CCMIL
Swiss OFMET Standard	DDA-CCOFMET
5–Year Repair Warranty	DDA-W5
5–Year NIST Calibration Contract	DDA-C5
5–Year Warranty & NIST Calibration	DDA-T5

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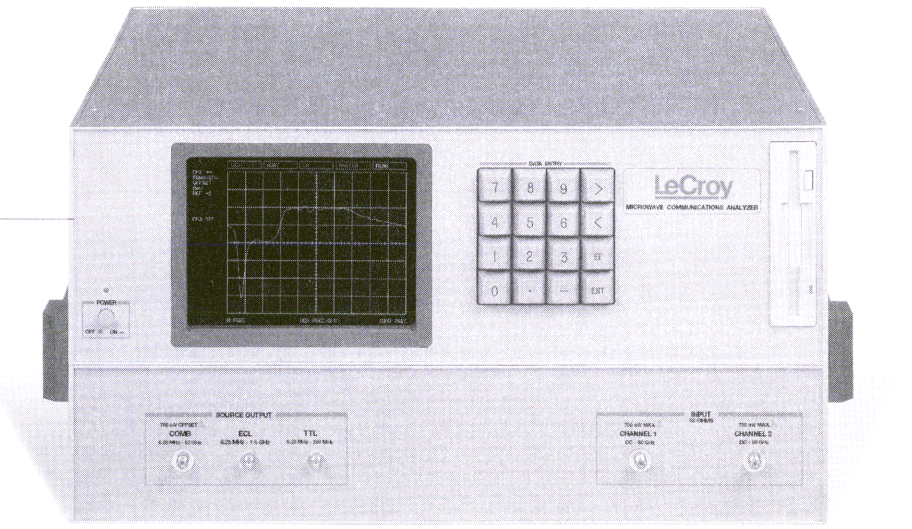
LeCroy
TIMEBASE
T/div .5 ns
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ns
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
PERSIST
STOPPED

MC1060
Microwave Communications Analyzer

Preliminary
Data Sheet

Leading Specifications

- 60 GHz Bandwidth
- Measure and display waveshapes; quantify amplitude, pulse width, rise and fall times, overshoots etc. See time delays with sub-picosecond resolution.
- Display pseudo random patterns and eye diagrams.
- Use as a vector network analyzer to measure group delay, transmission and reflection, both amplitude and phase. Fully corrected high-speed calibration
- Use as a synchronous spectrum analyzer
- Broadband TDR capability
- Built in frequency synthesizers with resolution of up to 1.4 µHz



Model MCA1060 is a complete test set capable of characterizing microwave systems and components in both the time and frequency domain.

The LeCroy MCA1060 Microwave Communications Analyzer is a self-contained system for measuring and characterizing microwave systems and components in the time and frequency domains. The measurement system consists of three synthesized sources and a two-channel receiver. The sources include an impulse generator with high spectral content to 60 GHz. Each receiver channel has an innovative very high bandwidth, low noise sampler and a digitizer with 14 bits of resolution. The sources and samplers are driven by independent very low jitter synthesizers with micro Hertz frequency resolution.

Automatic calibration provides the system with flat gain and phase response to 60 GHz. The MCA 1060 uses synchronous sampling in the time domain to characterize the device under test, and can display either time or frequency domain responses. The low noise floor of –70 dBm is ideal for characterizing microwave fiber optic receivers and transmitters, as well as components such as mixers, filters, amplifiers and very high-speed logic.

Flexible display modes include Smith chart, rectangular and polar displays. Optional accessories provide expanded capability such as picosecond resolution TDR, and eye diagram analysis using a synchronized pseudo-random bit stream.

Model MCA1060 Specifications

Input Channel A and Channel B Connectors: 1.85 mm "V" - 50 ohms
Response
DC –60 GHz

Full Scale Input:
CW: –20 dBm
Pulse: +/–0.25 volts

Absolute Maximum Input:
+/–0.5 volts

Noise Floor: –70 dBm in the frequency domain, without averaging

DC Drift: Typically 2 mv/degree C

System Phase Noise: <1 psec rms typical (without averaging)

Channel Display Modes:
Channel A: Channel B; Channel A and Channel B: Ratio, Sum, Difference, X vs. Y

Vertical Readout:
Voltage, dB, dBm, degrees, delay

Horizontal Readout:
Time Domain: 0.1 psec to 16 nsec/div.
Frequency Domain: linear 6.25 MHz to 100 GHz User-controlled frequency start, stop, and step size

Frequency Resolution:
1.4 µHz between 6.25 MHz and 1600 MHz, 52.5 µHz at 60 GHz

Source Synthesizer Output:
Output 1
Impulse Rate: 6.25 MHz - 1600 MHz; 60 GHz spectral content
2.5 volts / 50 ohms
Connector 1.85 mm "V"

Output 2
ECL: 6.25 MHz - 1600 MHz
Typical rise and fall time 225 psec
Connector SMA

Output 3
TTL: 6.25 MHz - 200 MHz
2.5 volts
Connector SMA

Measurement Modes
Time domain
Frequency domain
TDR (requires model RV or RK TDR adapter)

Display Modes
Linear (Time domain and TDR)
Log Magnitude (Frequency domain)
Smith (Frequency domain)
Polar (Frequency domain)
Group Delay (Frequency domain)
Eye Diagram (Time domain)

Averaging
0 to 100 (Frequency domain mode only)

Noise Reduction Filter
User-selected filter reduces the noise floor to –80 dBm

Acquisition Memory
Selectable from 256 to 64K points

Display
Color TFT Active Matrix 6.4"

Markers (2) and Delta
Readout, volts; dB; dBm; degrees; delay; frequency; complex impedance

Reference Clock
Allows synchronization of external sources
Output: 10 MHz, +10 dBm
Input: 10 MHz, 0 dBm
Connectors: BNC

External Monitor Output
Color VGA
Connector D15

I/O
GPIB/IEEE 488
3.5" Floppy Drive
File formats: SPICE - PWL Stimulus and Circuit File
S Parameter output data for Touchstone and Eagleware
.CKT file for Eagleware

Printer Output
Connector: D37
Drivers for: HP LaserJet, Epson Stylus Color

Physical
Power: specify 100-130 VAC or 220-240 VAC; 50/60 Hz, 250 watts
Size: width 18", depth 17.5", height 8.75"
Weight: 35 pounds

Ordering Information

Microwave Communications Analyzer	Product Code
60 GHz Microwave Communications Analyzer	MCA 1060

Visit our web site at: www.lecroy.com

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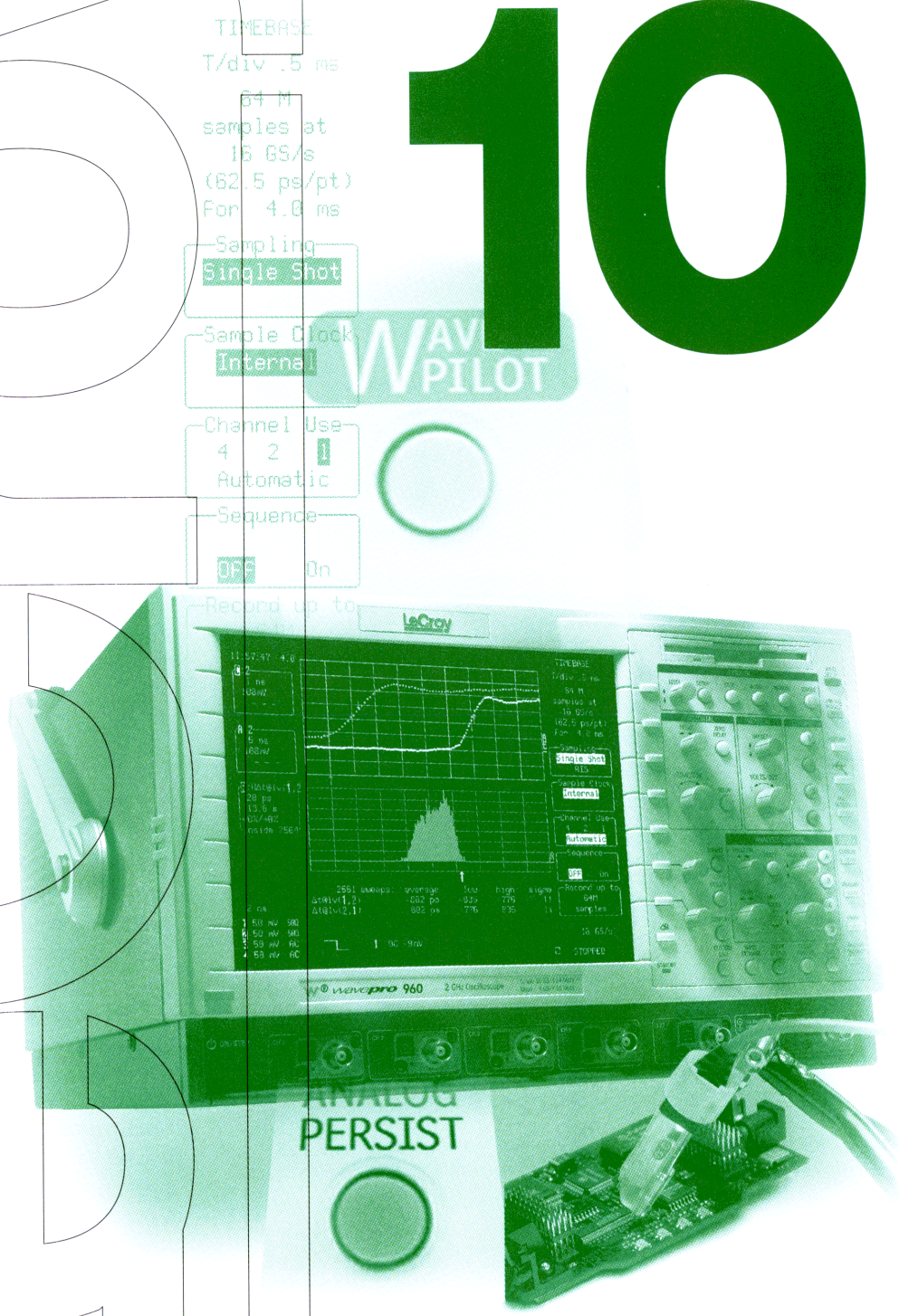
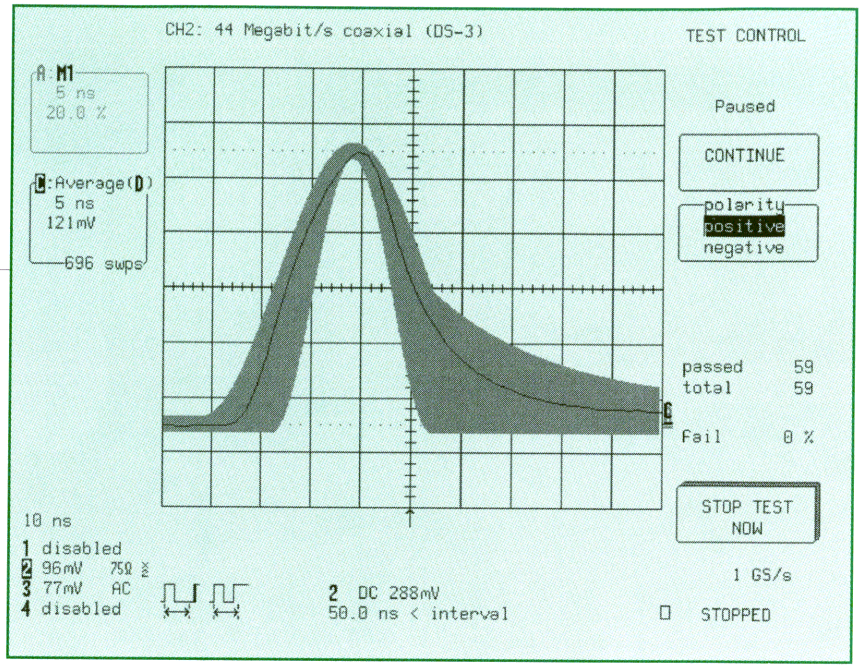

TIMEBASE
T/div .5 ms
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVPILOT
LeCroy
wavepro 960
ANALOG
PERSIST

Telecom Testing
MT01, MT02 and MT03



Main Features

- **Easy to use**
- **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**
- **Test electrical or optical telecom signals**

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 controls 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.
- MT03 optical test package for OC3 and OC12 includes reference receiver.

Dedicated Mask Tester

With the MT01, MT02, or MT03 Mask Tester, your LeCroy digital oscilloscope becomes a powerful, dedicated mask-testing instrument.

Power and 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.

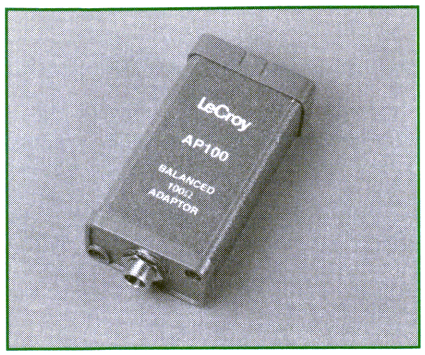
Capturing and aligning certain telecom signals can be tricky. But Finder uses pattern recognition. Pulse isolation can be performed at all bit rates, on any random-bit stream, eliminating the need for sophisticated pattern generators. Some CMI encoded signals (STS-3E, STM-1E, 140 Mb/s) tolerate a limited 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.



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")

MT03: STM-1/OC3 (155.52 Mb/s) "0" and "1"; STM-4/OC12 (622.08 Mb/s) "0" and "1"

Note: Testing of E4, STM-1E and STS-3 signals require a scope with 350 MHz or greater bandwidth and a sampling rate of 1 GS/s. These test masks are not supplied with lower speed scopes. Also, use of the MT03 package requires an oscilloscope with at least 1 GHz bandwidth.

Signal Adapters

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.

MT03: FC female to SC female adapter, FC female to ST female adapter

Features

MT01:

- Automatic signal to mask alignment
- Cable attenuation compensation
- Four 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

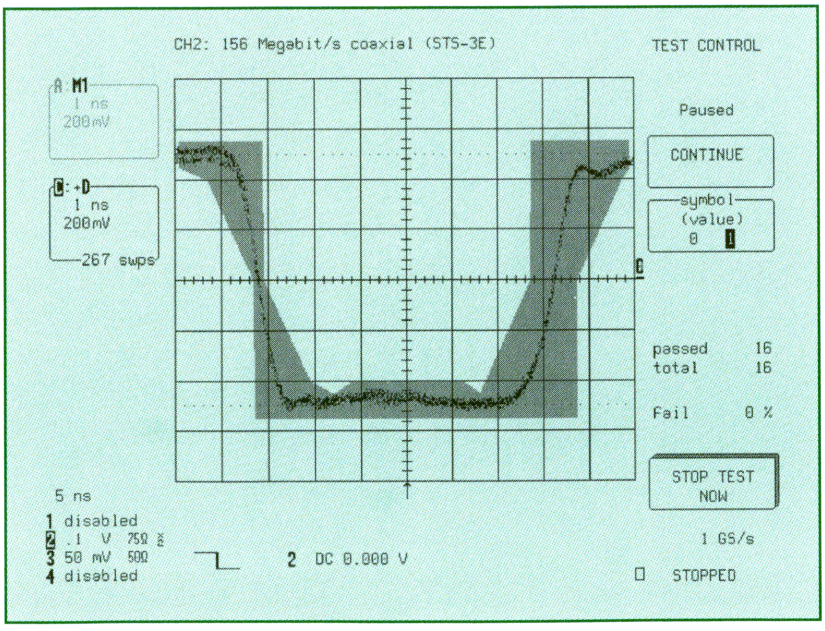
MT02:

- Exclusive, "Isolated pulse" extraction on random-bit stream following ANSI T1.102 requirements
- Four 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

MT03:

- ITU G.957 compliant test system
- Automatic signal-to-mask alignment
- Automatic signal power compensation
- Reference receiver
- Four selectable Pass/Fail actions: Stop, Hardcopy, Store, Beep
- Automatic test and manual test operation modes
- Automatic measurements
- Wavelength coverage: 950 - 1600 nm
- Bandwidth: 1.5 GHz
- Conversion gain: >500 mC/mW
- Max average input optical power (nondestruct): 4 dBm (2.5 mW)
- Max peak input optical power (nondestruct): 7 dBm
- Sensitivity: -23 dBm min
- Typical probe sensitivity: -26 typ
- Dynamic range: -35 dB - 0 dBm
- Type: single mode

Warranty: Three years



Testing the 155 Mb/s SONET/SDH electrical signal. Notice how the "1" pattern is cleanly isolated in this PRBS stream.

Ordering Information

Software Options	Product Code
Automatic Mask Tester and Adapters for ITU G.703	MT01
Automatic Mask Tester and Adapters for ANSI T1.102	MT02
Automatic Mask Tester Kit with O/E and reference receiver for ITU G.957 STM-1 and STM-4	MT03
Automatic Mask Tester and Adapters for ITU G.703 and ANSI T1.102	MT01/02
Automatic Mask Testers and Adapters for ITU G.957, ITU G.703, and ANSI T1.102	MT01/02/03
Optical to Electrical Converter, 1.5 GHz, 950–1650 nm, single mode fiber	OE-325

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LeCroy
TIMEBASE
T/div .5 ns
64 M
samples at
16 GS/s
(62.5 ps/pt)
For 4.0 ms
Sampling
Single Shot
Sample Clock
Internal
Channel Use
4 2 1
Automatic
Sequence
OFF On
Record up to
WAVE PILOT
ANALOG PERSIST
WavePro 960

Sales and Service

- **Scope upgrades**
- **Instrument calibration**
- **Warranty service**
- **Repair service**
- **Parts and accessories**
- **Technical expertise**
- **Customer satisfaction**
- **Customized service**
- **Performance assurance**
- **Cost-effective maintenance**

The LeCroy Service Department is comprised of skilled people with more than 200 years of combined service experience, over 100 total years with LeCroy. Our technicians are not only well known for friendliness and accessibility, but also for their participation in metrology consortiums and conferences worldwide. Working with a solid mastery of industry standards, many of which they wrote themselves, they administer an incredibly rigorous 3,000 tests on all oscilloscopes, both new and installed, three to six times more often than other manufacturers or calibration houses. And they provide documentation on this excellent calibration service as a standard item, at not cost, to all customers.

These high standards, plus advanced tools and techniques developed only at LeCroy, are applied equally to new LeCroy products and to instruments purchased three, five, or ten years ago. You can be assured that your LeCroy scope will be maintained at peak performance for many years to come.

For companies with in-house metrology departments, LeCroy conducts training modules that allow this same high standard of calibration to be maintained on-site for all LeCroy oscilloscopes.

An initial purchase decision is usually based on product performance, quality and price. At LeCroy, our high percentage of repeat oscilloscope customers testifies to superior after-sale support — the quick response, high-level expertise, and flexibility of our service staff in meeting customer requirements. Our dedication to solving your test and measurement needs will result in increased productivity and confidence when using your oscilloscope and superior performance in your specific applications. Expert guidance from our service technicians will help you to reduce time and cost in your design work.

Just as LeCroy instruments serve customer needs in innovative ways, so LeCroy Service is tailored to the needs of customers. LeCroy service products include unique upgrades for LeCroy oscilloscopes, metrology modules customized for your company, and more. Whether you own one LeCroy instrument or hundreds, whether you need prompt attention from our Service offices or an on-site service contract, LeCroy is committed to your success. Call your LeCroy service representative to discuss your company's specific requirements.

LeCroy Service provides:

- Retrofit/upgrade service for LeCroy scopes
- Annual calibration maintenance
- Extended warranty packages
- On-site service contracts
- Metrology training module for on-site calibration maintenance
- Prompt, personalized warranty and nonwarranty repair at service offices
- Cost-effective subassembly repair
- Full range of parts in stock
- Full line of accessories for LeCroy instruments

LeCroy products can always be upgraded. No one else in the industry offers this. When you purchase an oscilloscope from LeCroy, you are assured of the ability to add on any of the original options at any time, in most cases for the same price you would have paid at time of purchase.

LeCroy always endeavors to make new features retrofittable into previous designs. This means that as LeCroy innovations are introduced, you can order them for your existing LeCroy scope, making it virtually obsolescence-proof. Even the acquisition memory and processing RAM in most oscilloscopes can be upgraded. This upgrade support is unique to LeCroy and is not available from any other company.

We specialize in retrofits. You can request hardware or software upgrades at the time of your yearly calibration or at any time.

We recommend yearly calibration of scopes to maintain the original high-performance levels of these instruments. Your scope will be rigorously tested and recalibrated by one of the most exacting service departments in the industry.

Calibration service can be arranged through LeCroy field offices anywhere in the world, from our factory service headquarters in New York or from our European service headquarters in Switzerland.

All scopes returned to LeCroy for repair or calibration receive high-priority firmware and hardware ECO upgrades at no charge.

LeCroy instruments repaired under warranty are calibrated as an integral part of that warranty service, at no extra charge. Copies of test data and traceable certificates for NIST/OFMET or MIL-STD quality standards are available for a reasonable service fee.

In addition to testing for the usual bandwidth, DC accuracy, and timebase, our calibration service also checks for flatness, linearity, overload time, variable gain, noise, dynamic accuracy (sinefits), trigger, risetime overshoot, and more.

For customers with multiple scopes, we recommend an annual calibration and preventive maintenance contract for on-site service. Your service representative can work out a schedule to suit your particular requirements.

Our extended maintenance contracts assure that your instruments are secure for their lifetime of use. The lifetime cost of the instrument, often depreciated over five years, can be set in one lump sum to include maintenance. No purchase order is needed, then, for future repair or calibration, and you don't have to worry about budgeting for maintenance. Maintenance options include:

- W5 – Five-year extended warranty
- C5 – Five-year annual calibration maintenance
- T5 – Five-year total coverage, repair and calibration

The five-year total coverage package is the most cost-effective option, providing complete confidence for your high-performance equipment.

For customers who have multiple LeCroy instruments and/or their own metrology departments, the Service Department offers on-site calibration, preventive maintenance, and repair contracts, as well as a metrology training module. On-site contracts work best in combination with T5 calibration and maintenance agreements, providing your company complete on-site service for the best possible price. Call your service representative to discuss this option.

LeCroy Service staff respect the LeCroy instruments they service and enjoy direct customer contact. Our customers get fast, personal service, along with uniquely rigorous calibration on every item received for repair or upgrade.

Typical turnaround time to repair a portable scope is seven days. Standard prices allow for quick and easy turnaround. Plus, you will usually know the price of a repair before you even send in an item. Copies of test data and calibration certificates are available at a nominal fee.

Parts

A wide range of repair parts and accessories is kept in inventory and can be shipped promptly upon request. Our service staff will be happy to help you determine the correct part numbers.

Accessories

LeCroy offers a wide variety of world-class probes and amplifiers. The list includes the new HFP series of high frequency active probes, DA1800A series of differential amplifiers and probes, the 1 GHz AP034 differential probe, the PPE series of six high-voltage probes, and a large selection of active and passive probes. In addition, there are probe kits, SMT kits, software utilities for PCs, transit and carrying cases, and instrument carts, as well as a series of current probes. For a complete listing, see the Probes and Accessories section of this catalog, starting on page 97.

The LeCroy 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. All other instruments are warranted 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 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. You can:

- Copy software for backup or modification purposes to support 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.

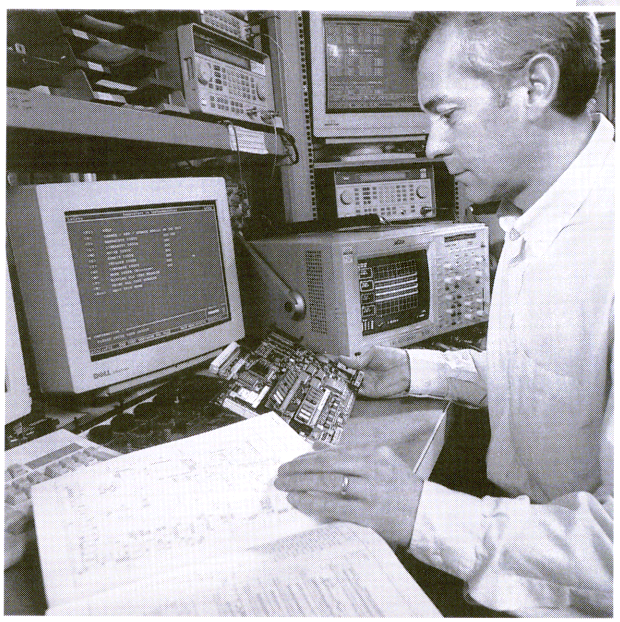
Enhance Your Scope's Capabilities with Unique Software Innovations

Another LeCroy exclusive innovation is simple, automatic software installation by telephone, using key codes. For complete, up-to-the-minute availability of new upgradable software capabilities, contact your local LeCroy office.

LeCroy Specializes in Service







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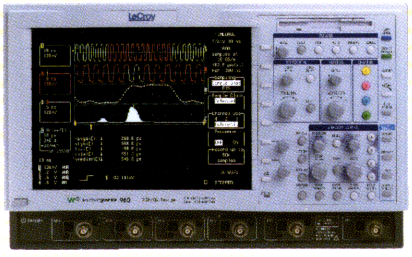
Scope Selection Guide

Digital Oscilloscopes

WavePro

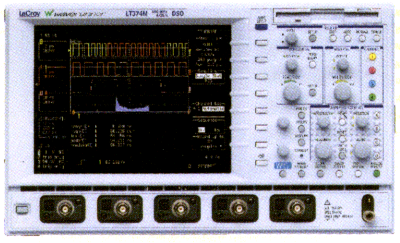


LeCroy DSO Model Number	Number of Channels	Bandwidth	Sample Rate per Channel/1 Ch	Memory per Channel/1 Ch	Display
960	4	2 GHz	4-16 GS/s	250 k/1 M	10.4" TFT
950	4	1 GHz	4-16 GS/s	250 k/1 M	10.4" TFT
940	4	500 MHz	4- 8 GS/s	250 k/1 M	10.4" TFT

Memory Options

M	1 Mpt/ch	4 Mpt maximum
L	4 Mpt/ch	16 Mpt Maximum
VL	8 Mpt/ch	32 Mpt Maximum
XL	16 Mpt/ch	64 Mpt Maximum (Model 960 only)

Waverunner - 2

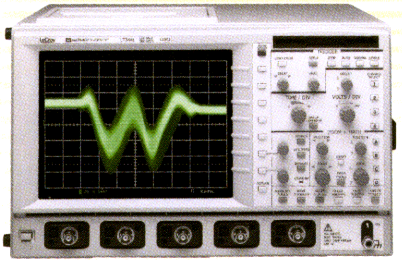


LT374	4	500 MHz	2-4 GS/s	250 k/500k	8.4" TFT
LT372	2	500 MHz	2-4 GS/s	250 k/500k	8.4" TFT
LT264	4	350 MHz	1 GS/s	100k	8.4" TFT
LT262	2	350 MHz	1 GS/s	100k	8.4" TFT

Memory Options

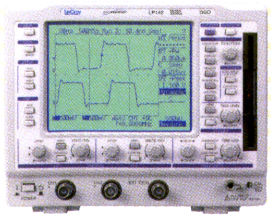
M	1 Mpt/ch; (Models 374 and 264)
L	4 Mpt/ch; (Model 374 only)

Waverunner



LT364	4	500 MHz	500 MS/s -1GS/s	250 k/500k	8.4" TFT
LT364L	4	500 MHz	500 MS/s -1GS/s	1 M/2 Mpts	8.4" TFT
LT344	4	500 MHz	500 MS/s	250 k	8.4" TFT
LT344L	4	500 MHz	500 MS/s	1 M	8.4" TFT
LT342	2	500 MHz	500 MS/s	250 k	8.4" TFT
LT342L	2	500 MHz	500 MS/s	1 M	8.4" TFT
LT322	2	500 MHz	200 MS/s	100 k	8.4" TFT
LT224	4	200 MHz	200 MS/s	100 k	8.4" TFT

Literunner



LP142	2	100 MHz	500 MS/s	100 k	5.7" LCD

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