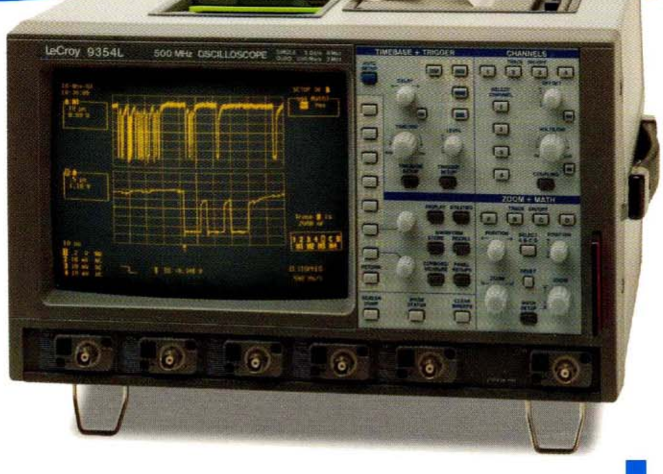
1994
Test & Measurement Catalog

30

YEARS OF INNOVATION IN INSTRUMENTATION



LeCroy

Innovators in Instrumentation

This catalog's cover celebrates LeCroy's 30th year as a leading edge instrumentation supplier. Our origins in High Energy Physics provided us with unique technologies for waveform acquisition and generation; technologies which we are now using to develop innovative tools for broader applications. In the process we have become the world's fastest-growing Test & Measurement supplier.

Back then, our customers were Nobel laureates who used our instrumentation for their prize-winning research. Today our customers are the big names in the electronics industry worldwide. Their development engineers use LeCroy instruments to gain a unique advantage in time-to-market, and their test engineers rely on us to increase throughput and repeatability. As a result, they are the leaders in their industries. And in getting there, they've helped us to define innovative new products.

This year, LeCroy is the third largest supplier of Digital Storage Oscilloscopes and the second largest supplier of Arbitrary Function Generators. We're growing faster than our competitors, and we're constantly adding newer, faster products. A few of those innovations are highlighted in the following pages. We hope you'll take a moment to look them over, and we look forward to showing them to you sometime soon.

In the meantime we wish you continued success.

Walter LeCroy

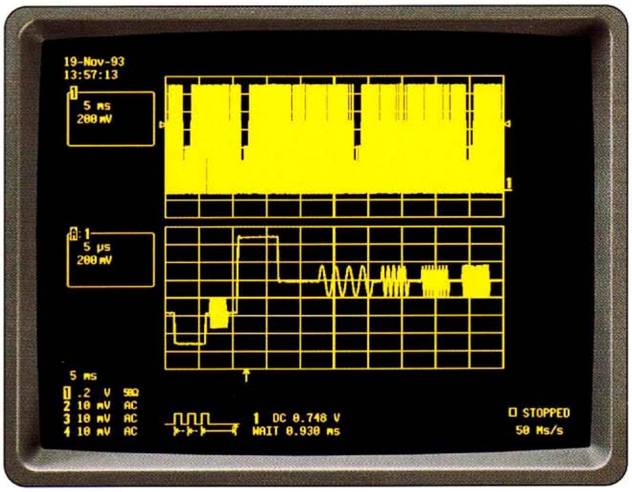
The Fastest, Deepest 500 MHz Scopes

The Latest Scopes in a Long Tradition of Innovative Instruments.

The 9350/9354 high performance Digital Oscilloscopes from LeCroy represent the very latest in DSO technology from the world's most innovative oscilloscope designers. Since the introduction of the 9400 series oscilloscopes in 1985, LeCroy has become the fastest growing manufacturer of digital scopes. Today, no other oscilloscope maker offers the high analog bandwidth, fast sample rate, and deep memories found in the 9350/54 digital scopes.

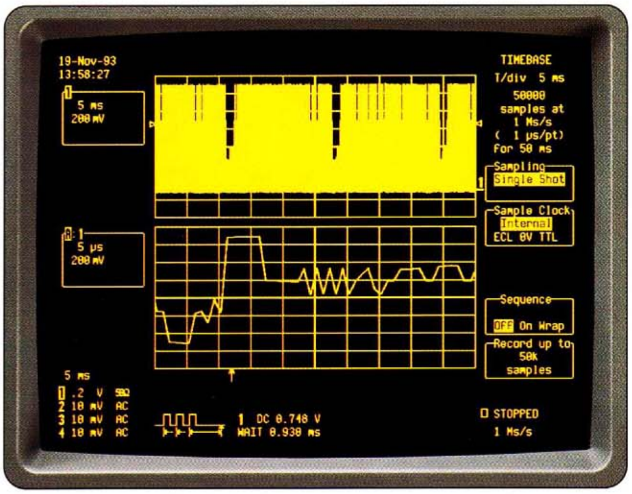
With the familiar user interface of our industry-standard 9310/14, the 9350/54 family offers unrivaled ease of use. And the widest range of processing, storage and interfacing options make these the most configurable as well as the most capable DSO's ever.

2 MBytes Acquisition Memory

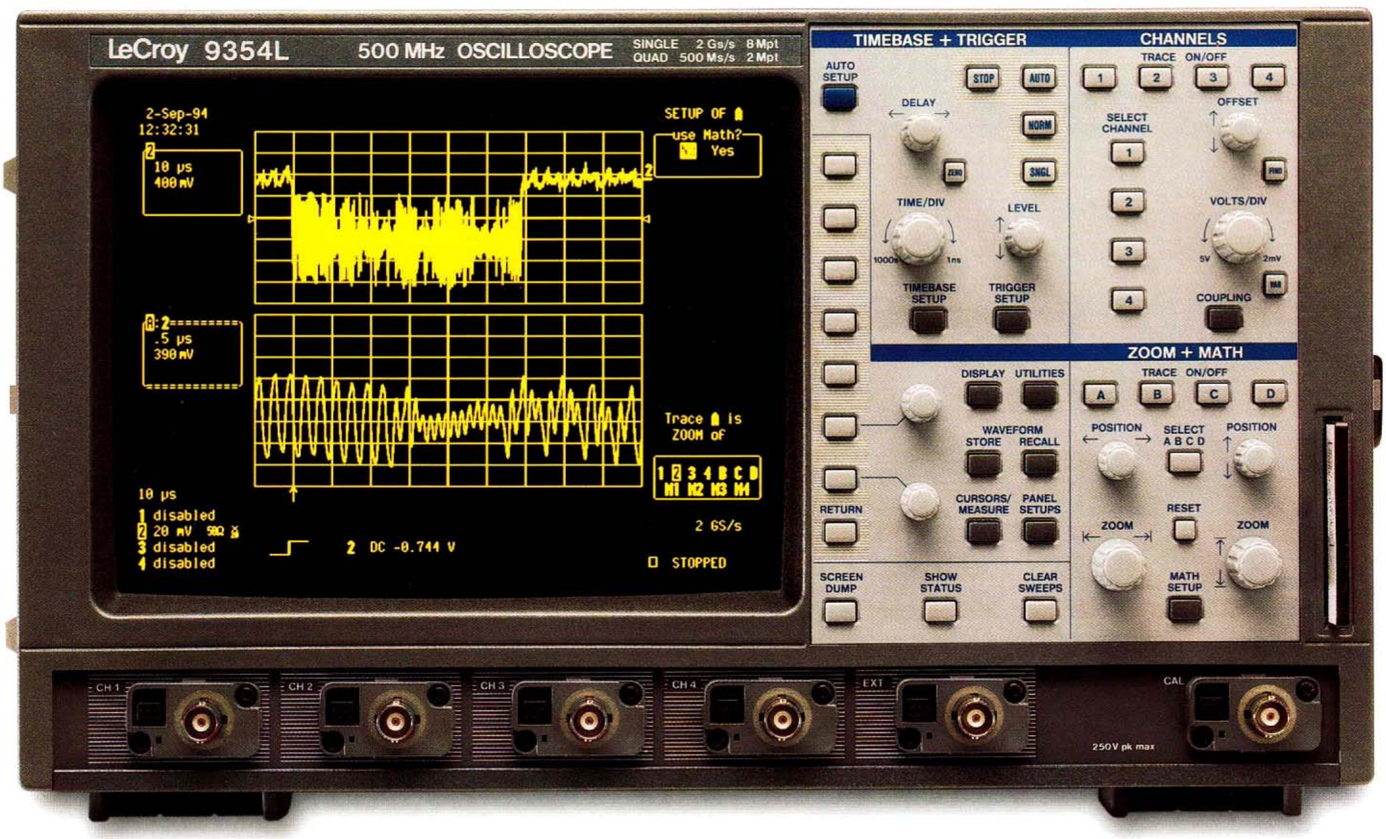


With 2 MBytes of memory, the expanded waveform shows the full detail of the original source.

50 KBytes Acquisition Memory



Expansion of the waveform (lower trace) clearly shows how the instrument with 50 KBytes of memory undersamples the signal.



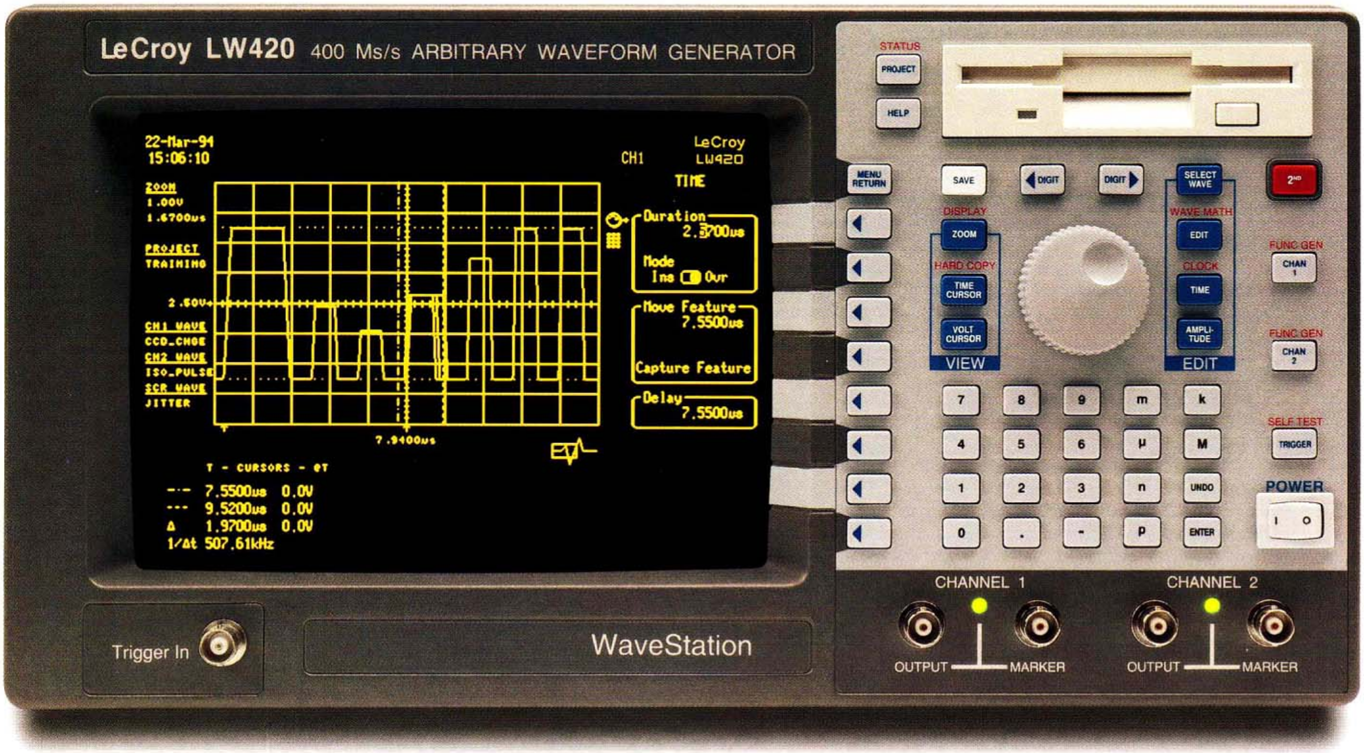
LeCroy's Super-Long Acquisition Memories are a perfect match for Data Communications and Disk Drive Testing

Information-rich signals pose some of the biggest challenges to Digital Storage Scopes. Long data streams may require several milliseconds acquisition, while their complex pulse-shapes demand high speed digitizing. Only LeCroy steps up to the challenge with 2 GS/s digitizing into 8 Mbytes of memory.

But raw performance is only half the story. LeCroy's unique memory management finds the real information in those megabytes of data. The whole acquisition is shown onscreen, together with zooms of the minutest waveform detail. And extensive Waveform processing puts the answers you need right at your fingertips.

For More Information, See Page 14

LeCroy's Most Powerful Arbitrary Waveform Generators

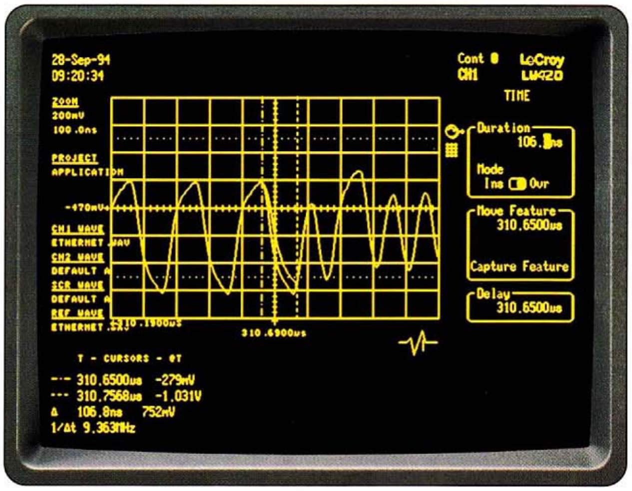


LW420 Offers Edge Placement to 100ps Resolution

LeCroy's WaveStation™ is a state of the art arbitrary waveform generator that redefines high performance AWGs and how they are used. WaveStation substantially increases functionality and ease of use while eliminating many of the traditional obstacles constraining previous AWGs. Move waveform features with 100 psec resolution, then add in multiple waveform sources and powerful on-screen cut and paste editing. Mix in 1 MByte memories for generating extra long waveforms and a 240 MByte hard drive for waveform storage. Combine it with powerful digital signal processing to assure artifact free waveform generation, and you have the formula for the next generation AWG.

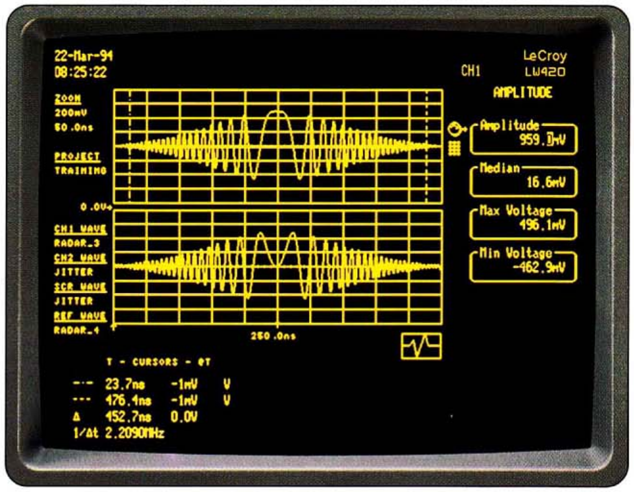
Communication Network Testing with WaveStation

Use the megabyte memory to create the most complex waveforms necessary to test your communication system. Grab an Ethernet packet off your network using your favorite digital oscilloscope, then download it to the LW420 and vary its parameters, move its features, change its amplitude, or stretch the timing between packets.



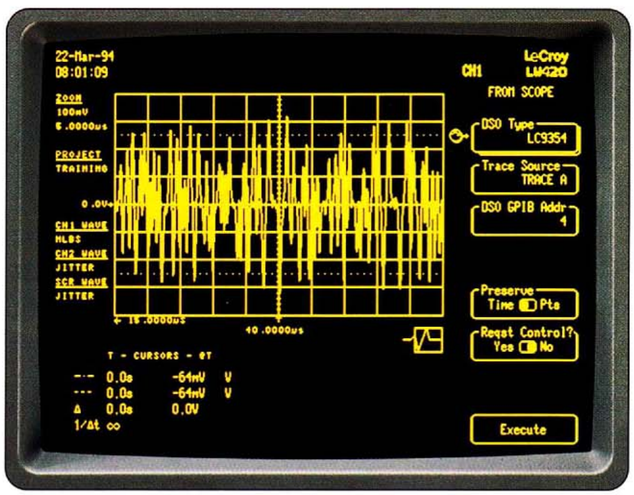
Radar, Sonar, Lidar and Ultrasound Simulation

Use two channels to make the I&Q signal for your RADAR application. Use the long memory to simulate the return echo from your RADAR, SONAR, LIDAR, or ULTRASOUND system. Vary the amplitude and location of the echo and check the decoding electronics.



Disk and Media Testing

Testing tomorrow's read channel requires advanced waveform generation capability. At right, a waveform has been captured on a LeCroy high speed DSO and downloaded to the LW420 for regeneration. This particular waveform exhibits significant nonlinear bit shift (NLBS) as determined by the measurement on a LeCroy DSO and can be used for studying the effects of an advanced read channel design.

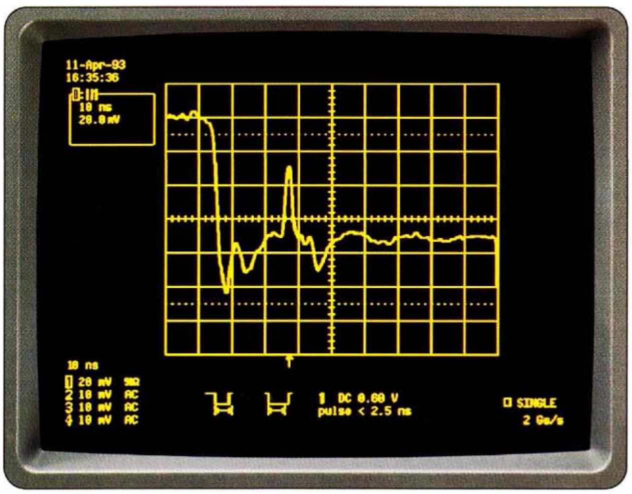


For More Information, See Page 73

The World's Most Powerful 400 MHz Digital Oscilloscopes

Internal Printer, Floppy Drive & Memory Cards: The Ultimate Documentation Capabilities

Internal high-speed printers and DOS compatible floppy drives are just the start. LeCroy also offers you fast high-density memory cards. Use them for automatically storing every acquisition, or make Pass/Fail test decisions in the scope, using limits defined and saved on a memory card. Combine all these benefits with the industry's most powerful set of automatic measurements, and get answers, not just data!

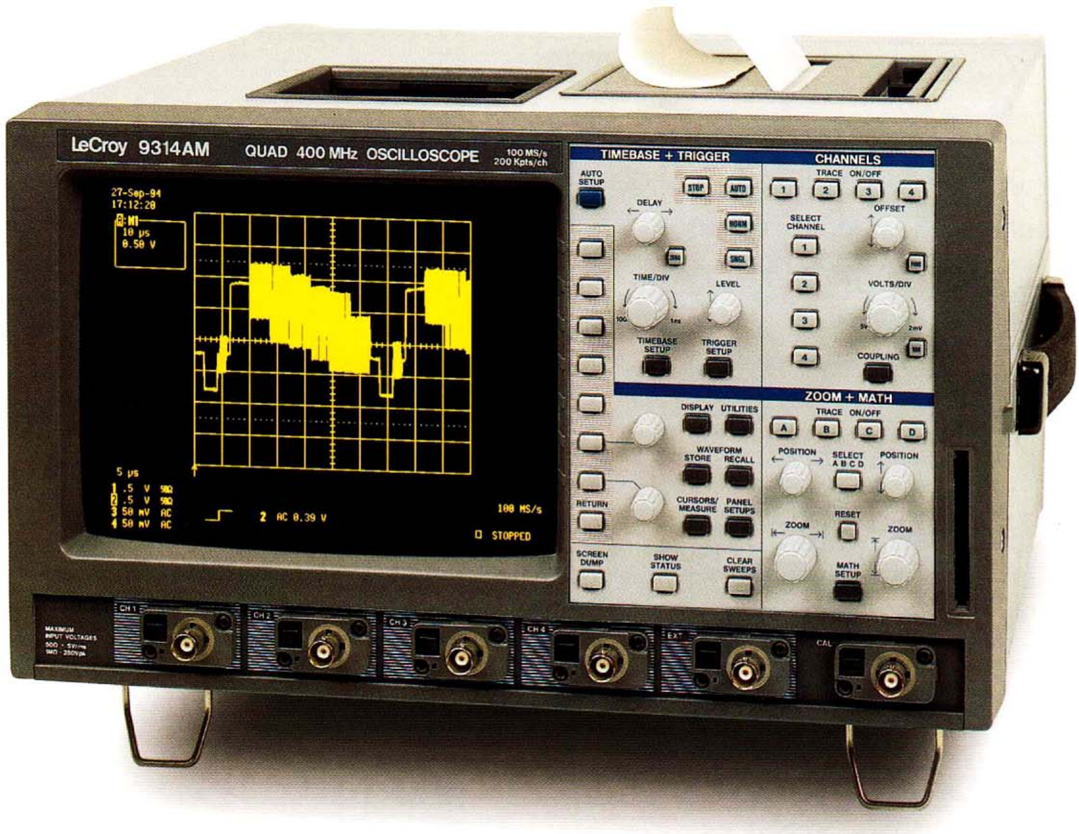


LeCroy's SMART TRIGGER™ The Most Extensive Trigger Features on Any Scope

Pulse width trigger captures glitches down to 1 nsec wide. Or use Peak Detect to see 2.5 nsec glitches even on slower timebases. The screen at left shows a glitch caused by reflections on a bus line, captured using Glitch Trigger.

The Newest, Most Complete Line of General Purpose DSOs

The 9310A family forms the ideal range of general-purpose digital oscilloscopes. They capture single-shot events at up to 100 MS/s, and repetitive signals at 10 GS/s. Record lengths up to 1M points provide high-quality horizontal resolution, and allow fast digitizing of long-duration events. Live waveforms may be viewed simultaneously with up to 3 expansions, showing all of the signal detail.



Highest Resolution Display in the Industry

LeCroy offers the largest displays with the highest resolution. 810 x 696 Pixels gives the 9300 series almost twice the resolution of competitive instruments. So you can view multiple waveforms in separate grids – ensuring the best utilization of your ADC's dynamic range.

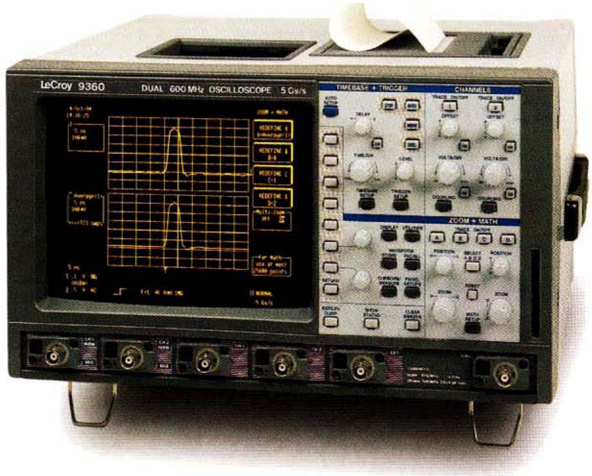
For More Information, See Page 5

The World's Fastest Sample Rate Single Shot DSOs

The 9360's 5 GS/s sample rate

makes it ideal for applications like digital design, which require high bandwidth Single-Shot acquisition. Its two independent digitizers are clocked simultaneously to make precise timing measurements.

Fast Single-Shot pulses can be characterized with 200 ps resolution. All acquisitions are Single-Shot, with no Repetitive Sampling used.

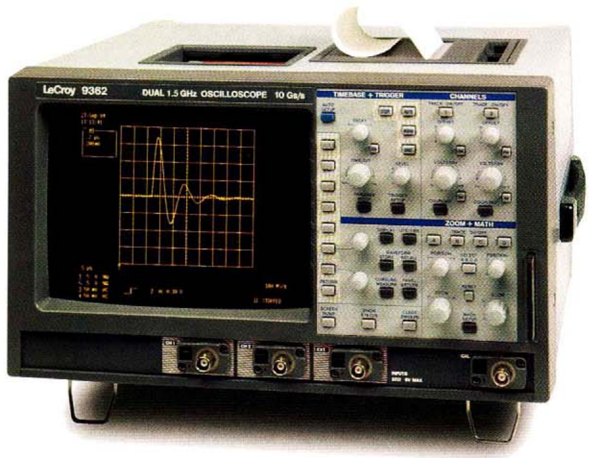


- **5 GS/s max per channel**
- **600 MHz Single-Shot Bandwidth**
- **Single-Shot acquisition on all timebases**

For More Information, See Page 17

Coming Soon!

The 9362's 1 GHz Single-Shot acquisitions with 10 GS/s maximum sample rate, provide 100 ps resolution or characterizing fast Single-Shot pulses. Dual channel Single-Shot acquisition can be made at 5 GS/s sample rate for detailed examination of clock and data timing and edge characterization.



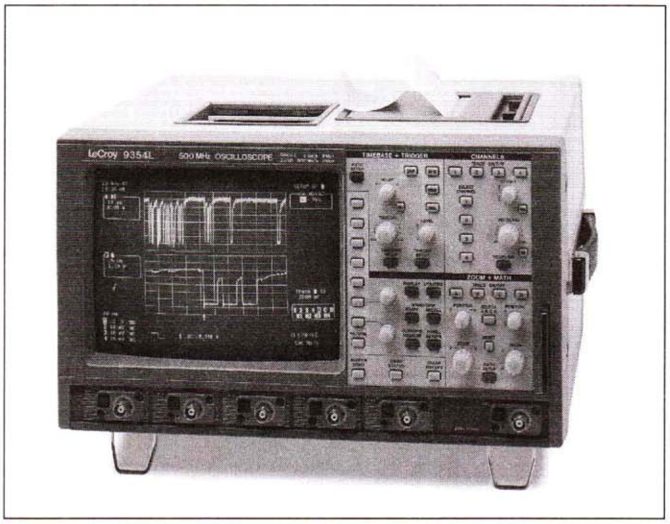
- **10 GS/s max sample rate**
- **Up to 1.5 GHz Analog Bandwidth for Repetitive Signals**
- **1 GHz Single-Shot Bandwidth**

Table of Contents

Table of Contents

9300 Series Portable Oscilloscopes Cover the Widest Range of Applications

Sampling rate, memory depth, and bandwidth. Choose the combination you need. The LeCroy 9300 family has it all! From the low cost quad 9304A to the high bandwidth 9324, the 9300 Series continues to expand with new configurations, all sharing an easy to use panel layout, programming command set, and memory card or floppy disk storage. Recently we have added the award winning 9360 which at 5 GS/s is the World's Fastest 2 channel DSO. The new 9350/54 series offers up to 2M of memory per channel for applications ranging from disk drive testing to communications design.



The Easiest DSO to Use

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

Choose the Memory Depth You Need

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

Floppy Disks and Memory Cards

Waveforms, templates, setups, or even Golden Waveforms are easy to save and become easily transportable from scope to computer, to data archives or to other scopes.

A Display You Can Watch All Day

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

Make The Measurements You Want

Calculate any of 32 standard measurements on any part of the waveform. Calculate rise time or glitch energy. Pass/Fail tells if a waveform is out of spec. You can measure parameters between two traces such as propagation delays between two different signals. Built in processing converts waveforms to the most useful format. View power traces or frequency spectra - live!

Advanced Trigger

Smart trigger circuitry allows you to lock onto the most complex signal or hard-to-find glitch or dropout.

Statistics

When measuring signal characteristics most users want to know the stability and worst case for risetime, propagation delay, etc. The statistics capability which is standard in every 9300 extends the usefulness of the DSO. Observe average, minimum, maximum and standard deviation values for 32 measurement parameters.

A Complete Instrument

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

OEM Kits Available

Designers of integrated test systems frequently require a good front end stage with amplifier/attenuator, fast analog to digital conversion , high speed memory and a processor to compute answers or handle data transfer to a higher level processor. The 9300 series OEM kits provide the basic PC boards and power supply to perform these operations. The kit versions remove the front panel, display, back panel, handle and enclosure which are normally part of a 9300 series scope. The manufacturer can then configure the basic PC boards inside his own enclosure to optimize space utilization. OEM kits are available for applications which will require 25 or more pieces annually.

Features and Benefits

TIME MEASUREMENT MADE EASY AND ACCURATE

Common applications in fields like digital electronics, computers, data communications, etc., require precise time interval measurements. The long memories in the 9350/54, 9310A/14A and 9304A allow for high sampling rate over the whole signal to give excellent time resolution. The 9360 with its 5 GS/s real time sampling rate specializes in precise capture of single shot events. Scope users who have repetitive signals will benefit from the 1 GHz bandwidth and two delayed timebases in the 9320/24 to capture signals at 20 GS/s equivalent time.

LECROY PROBUS INTELLIGENT PROBE SYSTEM

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

A TRIGGER FOR EVERY APPLICATION

Two levels of trigger make catching difficult signals an easy task for the 9300 user. The standard trigger functions such as pre- and post-trigger, level, slope, mode and coupling are all accessed with simple and direct controls. The touch of a button accesses further powerful trigger features (SMART trigger). Icon trigger graphics show the current setup at a glance.

SMART Trigger modes allow the acquisition of complex phenomena. Trigger techniques include Fastglitch mode for triggering on glitches down to 1 nsec. The ability to trigger on pulses greater than a particular length catches missing bits, timing shifts and runts. State and Edge qualified modes track timing problems including setup and hold violations. Most 9300 scopes also include video trigger and pattern trigger.

AUTOMATIC MEASUREMENTS

In addition to cursor measurements, the 9300 series performs fully automatic measurements. PASS/FAIL testing allows waveforms to be continually compared with a tolerance mask. (Masks may either be generated inside the instrument, or supplied on memory cards.) In addition, the scope can test any 5 waveform parameters from a list of 32, and compare them with user-defined limits. Any failure will cause preprogrammed actions such as Hardcopy, Save or GPIB SRQ. Basic statistics (low, high, average, and standard deviation) may also be calculated on these parameters.

DOS COMPATIBLE MASS STORAGE

The 9300 series offers two options (available together or separately) for built-in mass storage. Option FD01 provides a 3.5" 1.44 MB floppy disk drive, which stores waveforms and setups as DOS files. This may be used as a convenient way of transferring data to a PC. Option MC01 provides high-speed storage to industry-standard memory cards, which are also DOS compatible. Up to 8 MB of data (waveforms or setups) may be stored on a single card.

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

BUILT-IN PRINTER

As well as driving most printers and plotters via GPIB (IEEE-488.2), RS-232 and optional Centronics interfaces, the 9300 series also offers an optional internal printer. This high resolution graphics printer produces full size screen dumps in approximately 10 seconds.

FLEXIBLE INTERFACING

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

POWERFUL DISPLAY MODES

The 9300's high-resolution display shows from one to four independent waveform grids. Persistence display mode allows easy viewing of signal changes over time, and XY mode plots any two sources against one another. Cursors are usable in all display modes.

MULTIPLE-WAVEFORM ZOOM

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

EXTENSIVE WAVEFORM MATH

Built-in processing includes mathematics (add, subtract, multiply and divide, negation and identity) and summation averaging (up to 1000 sweeps). Option WP01 provides averaging (summed and continuous) and mathematics (including ABS, differentiation, identity, integration, log or exp (base e or base 10), negation, reciprocal, rescale, sin(x)/x, square and square root). Also included is enhanced resolution mode (up to 11 bits) and extrema mode for storage of peak positive and negative values. More information is available in the 9300 WP01 data sheet.

OPTIONAL FFT PACKAGE

Option WP02 provides comprehensive spectral analysis capabilities. These permit the system designer to identify characteristics which may not be apparent in the time domain. Option WP02 provides a wide selection of displayed projections (magnitude, phase, real, imaginary, power spectrum, power density) and windowing functions, as well as averaging in the frequency domain. For more information, see the 9300 WP02 data sheet.

LeCroy 9300 Series Portable Digital Oscilloscopes

LeCroy DSO Model Number	Max Transient Sample Rate	Max Repetitive Sample Rate	Analog BW (Minimum)	Number of Channels	Memory per Channel	Reference Memory (Waveform Storage)	See Page #
9304A	100 MS/s	10 GS/s	200 MHz	4	50k	200k	5
9304AM	100 MS/s	10 GS/s	200 MHz	4	200k	200k	5
9310A	100 MS/s	10 GS/s	400 MHz	2	50k	200k	8
9310AM	100 MS/s	10 GS/s	400 MHz	2	200k	200k	8
9310AL	100 MS/s	10 GS/s	400 MHz	2	1M	200k	8
9314A	100 MS/s	10 GS/s	400 MHz	4	50k	200k	8
9314AM	100 MS/s	10 GS/s	400 MHz	4	200k	200k	8
9314AL	100 MS/s	10 GS/s	400 MHz	4	1M	200k	8
9320	20 MS/s	20 GS/s	1 GHz	2	5k	20k	11
9324	20 MS/s	20 GS/s	1 GHz	4	5k	20k	11
9350	1 GS/s	10 GS/s	500 MHz	2	25k/2 Ch 50k/1 Ch	2M	14
9350M	1 GS/s	10 GS/s	500 MHz	2	100k/2 Ch 250k/1 Ch	8M	14
9350L	1 GS/s	10 GS/s	500 MHz	2	2M/2Ch 4M/1 Ch	16M	14
9354	2 GS/s	10 GS/s	500 MHz	4	25k/4 Ch 50k/2 Ch 100k/1 Ch	2M	14
9354M	2 GS/s	10 GS/s	500 MHz	4	100k/4 Ch 250k/2 Ch 500k/1 Ch	8M	14
9354L	2 GS/s	10 GS/s	500 MHz	4	2M/4 Ch 4M/2 Ch 8M/1 Ch	16M	14
9360	5 GS/s	N/A	600 MHz	2	500 - 25k	100k	17
9361	2.5 GS/s	N/A	300 MHz	2	500 - 25k	100k	17

9300 Series Ordering Information

Model:

9304A	4 Channel 200 MHz 100 MS/s 50k Memory/Channel Digital Oscilloscope
9304AM	4 Channel 200 MHz 100 MS/s 200k Memory/Channel Digital Oscilloscope
9310A	2 Channel 400 MHz 100 MS/s 50k Memory/Channel Digital Oscilloscope
9310AM	2 Channel 400 MHz 100 MS/s 200k Memory/Channel Digital Oscilloscope
9310AL	2 Channel 400 MHz 100 MS/s 1M Memory/Channel Digital Oscilloscope
9314A	4 Channel 400 MHz 100 MS/s 50k Memory/Channel Digital Oscilloscope
9314AM	4 Channel 400 MHz 100 MS/s 200k Memory/Channel Digital Oscilloscope
9314AL	4 Channel 400 MHz 100 MS/s 1M Memory/Channel Digital Oscilloscope
9320	2 Channel 1 GHz 20 GS/s Repetitive Sampling Digital Oscilloscope
9324	4 Channel 1 GHz 20 GS/s Repetitive Sampling Digital Oscilloscope
9350	2 Channel 500 MHz 500 MS/s 25k Memory/Channel Digital Oscilloscope
9350M	2 Channel 500 MHz 500 MS/s 100k Memory/Channel Digital Oscilloscope
9350L	2 Channel 500 MHz 500 MS/s 2 Meg Memory/Channel Digital Oscilloscope
9354	4 Channel 500 MHz 500 MS/s 25k Memory/Channel Digital Oscilloscope
9354M	4 Channel 500 MHz 500 MS/s 100k Memory/Channel Digital Oscilloscope
9354L	4 Channel 500 MHz 500 MS/s 2 Meg Memory/Channel Digital Oscilloscope
9360	2 Channel 600 MHz 5 GS/s Single Shot Real Time Digital Oscilloscope
9361	2 Channel 300 MHz 2.5 GS/s Single Shot Real Time Digital Oscilloscope

Options:

93XXWP01	9300 Series Waveform Processing Advanced Math
93XXWP02	9300 Series Spectrum Analysis
93XXWP01/02	9300 Series Waveform Math/FFT
93XX-MC01/04	Memory Card Reader with 512k Card
93XX-FD01	Floppy Disk Option
93XX-GP01	High Resolution Graphics Printer Option
93XX-FDGP	High Resolution Graphics Printer & Floppy Disk Options
93XX-MC-TC-1	Telecom Templates

Accessories:

93XX-TC1	Hard Transit Case
93XX-TC2	Soft Carrying Case
93XX-MC04	512k Memory Card
SM93XX	Service Manual
OM93XX	Extra Operators Manual
93XX-RM01	Rackmount Adapter
93XX-GPR10	Roll Paper for High Resolution Graphics Printer (10 Rolls)
PP091	9360 High Bandwidth Trigger Pickoff

Warranties/Calibrations:

93XX-W5	5 Year Repair Warranty
93XX-C5	5 NIST Traceable Calibrations (one at time of delivery and one each in years 2, 3, 4 and 5 of ownership.)
93XX-T5	5 Year Repair Warranty & 5 NIST Traceable Calibrations.
93XX-CC	NIST Traceable Calibration (at time of delivery.)

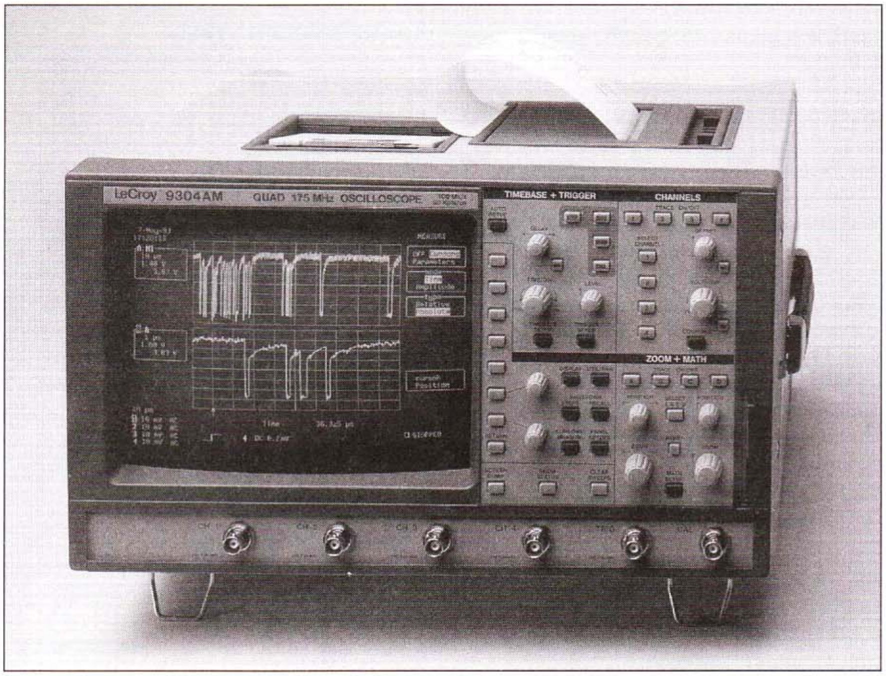
Probes:

P9011	10:1/1:1 (250/10 MHz) Scope Probe
PP011	100:1 (300 MHz) no sense ring
PP012	100:1 (300 MHz) for ProBus
P9010	10:1 (250 MHz) Scope Probe
P9010/2	10:1 (250 MHz) 2 m Scope Probe
PP001	10:1 350 MHz Scope Probe
PP002	10:1 350 MHz probe for ProBus
PP062	500 ohm, 1GHz probe for ProBus
AP003	x10 Active Probe, 1 GHz for 9304, 9310, 9314 (requires AP501)
AP020	x10 Active Probe, 1 GHz for ProBus
AP021	x5 Active Probe, 800 MHz for ProBus
AP030	15 MHz Differential Probe
AP501	Power Supply for AP003

9304A, 9304AM Digital Oscilloscopes 200 MHz Bandwidth, 100 MS/s

Main Features

- Four Channels
- 50k and 200k Point Records
- LeCroy ProBus Probe System
- Glitch, Window, Qualified, Interval, Dropout and TV Triggers
- 8-bit vertical resolution, 11 with ERES option
- Fully Programmable via GPIB and RS-232-C
- Automatic PASS/FAIL testing
- Persistence, XY and Roll Modes
- Advanced Signal Processing
- DOS Compatible Floppy Disk and Memory Card Options
- Internal High Resolution Graphics Printer Option



General

The 9304A and 9304AM are general purpose 200 MHz four channel digital oscilloscopes. They capture single-shot events at up to 100 MSamples/s, and repetitive signals at 10 GSamples/s. Record lengths up to 200k points provide excellent horizontal resolution, and allow fast digitizing of long-duration events. Memories can be segmented, for minimum dead time between acquisitions.

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

The LeCroy ProBus intelligent probe system allows automatic sensing of the probe type. For LeCroy's active FET probes it also provides variable offset at the probe tip; offset and coupling are controlled from the scope front panel.

SMART Trigger modes like Glitch, Window and Dropout allow you to capture precisely the events of interest. A comprehensive range of signal processing functions, on live or stored waveforms, allows waveform manipulation without destroying the underlying data.

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

DOS compatible floppy disk and memory card options store waveforms and test setups, and make transferring data to a PC easier than ever before. Hardcopies can be made on GPIB, RS-232-C or Centronics printers or plotters. An optional internal high resolution graphics printer is also available.

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

ACQUISITION SYSTEM

Bandwidth (-3 dB)
@ 50Ω: DC to 200 MHz
@ 1 MΩ DC: DC to 200 MHz typical at the probe tip.
No. of Channels: 4
No. of Digitizers: 4
Maximum Sample Rate: 100 MS/s simultaneously on each channel.
Acquisition memories, per channel:

9304A	50k
9304AM	200k

Sensitivity: 2 mV/div to 5 V/div, fully variable.
Scale factors: A wide choice of probe attenuation factors are selectable.
Offset Range:

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

DC Accuracy: ≤ ± 2% full scale (8 divisions) at 0 V offset.
Vertical Resolution: 8 bits.
Bandwidth Limiter: 30 MHz.
Input Coupling: AC, DC, GND.
Input Impedance: 1 MΩ//15 pF or 50Ω ± 1%.
Max Input:
1 MΩ: 250 V (DC+peak AC≤ 10 kHz)
50 Ω: ± 5 V DC (500 mW) or 5 V RMS

TIME BASE SYSTEM

Timebases: Main and up to 4 Zoom Traces.
Time/Div Range: 1 ns/div to 1000 s/div.
Clock Accuracy: ≤± 0.002 %.
Interpolator Resolution: 10 ps.
Roll Mode: Ranges 500 ms to 1,000 s/div. For > 50k points: 10 s to 1,000 s/div.
External Clock: ≤ 100 MHz on EXT input with ECL, TTL or zero crossing levels.

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single, Stop.
Trigger Sources: CH1, CH2, CH3, CH4, Line, Ext, Ext/10. Slope, Level and Coupling for each can be set independently.
Slope: Positive, Negative, Window (BiSlope).
Coupling: AC, DC, HF (up to 500 MHz), LFREJ, HFREJ.
Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% div increments).
Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).
Holdoff by time: 10 ns to 20 s.
Holdoff by events: 0 to 99,999,999 events.
Internal Trigger Sensitivity Range: ± 5 div.
EXT Trigger Max. Input:
1 MΩ//15 pF: 250 V (DC+peak AC≤ 10 kHz)
50 Ω ± 1%: ± 5 V DC (500 mW) or 5 V RMS
EXT Trigger Range: ±0.5V (±5V with Ext/10).
Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART TRIGGER TYPES

Signal Width: Trigger on width between two limits selectable from 2.5ns to 20s.
Signal Interval: Trigger on interval between two limits selectable from 10ns to 20s.
Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.
State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.
TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL, SECAM, NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 5 µs/div.
Single shot: for transient and repetitive signals from 50 ns/div.
Sequence: Stores multiple events in segmented acquisition memories.
Number of segments available:

9304A	2-200
9304AM	2-500

Dead Time between segments: ≤150 µs

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.
CRT: 12.5 x 17.5 cm (9" diagonal) raster.
Resolution: 810 x 696 points.
Modes: Normal, X-Y, Variable or Infinite Persistence.
Real-time Clock: Date, hours, minutes, seconds.
Graticules: Internally generated; separate intensity control for grids and waveforms.
Grids: 1, 2 or 4 grids.
Formats: YT, XY, and both together.
Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity).
Maximum Horizontal Zoom Factors:

9304A	1,000x
9304AM	5,000x

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4).
Processing Memory: Up to four 16-bit Waveform Processing Memories (A,B,C,D).
Setup Memory: Four non-volatile memories. Optional Memory Cards or Floppy Disks may also be used for high-capacity waveform and setup storage.

CURSOR MEASUREMENTS

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full-scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is displayed.
Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of full-scale in single-grid mode.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity and Summation Averaging.
Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 10^6 averages are possible with Option WP01.
Envelope*: Max, Min, or Max and Min values of from 1 to 10^6 waveforms.
ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.
Sampled data is always available, even when trace is turned off. Any of the above modes can be invoked without destroying the data.
FFT*: Spectral Analysis with four windowing functions and FFT averaging.
*Envelope and ERES modes are provided in Math Package WP01. FFT is in WP02.

AUTOMATIC MEASUREMENT

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

amplitude	falltime	peak to peak
area	f 80-20%	period
base	f@level (abs)	risetime
cycles	f@level (%)	r 20-80%
delay	frequency	r@level (abs)
Δdelay	maximum	r@level (%)
Δt at level (abs)	mean	RMS
Δt at level (%)	median	std dev
Δt at level (t=0,abs)	minimum	top
Δt at level (t=0,%)	overshoot +	width
duty cycle	overshoot -	

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

The parameters are based on ANSI/IEEE Std. 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". The terminology is derived from IEEE Std 194-1977 "Standard Pulse Terms and Definitions".

AUTOSETUP

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

PROBES

Model: One PP002 (10:1, 10 MΩ // 15 pF) probe supplied per channel.
The 9304A and 9304AM are fully compatible with LeCroy's range of FET Probes, which may be purchased separately.
Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω , frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical.
Alternatively, the Calibrator output can provide a trigger output or a PASS/FAIL test output.

INTERFACING

Remote Control: Of all front-panel controls, as well as all internal functions is possible by GPIB and RS-232-C.
RS-232-C Port: Asynchronous up to 19200 baud for computer/terminal control or printer/plotter connection.
GPIB Port: (IEEE-488.1) Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.
Centronics Port: Optional hardcopy parallel interface.
Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters. An optional internal high resolution graphics printer is also available.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.
Temperature: 5° to 40° C (41° to 104° F) rated 0° to 50° C (32° to 122° F) operating.
Humidity: < 80%.
Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.
Power: 90-250 V AC, 45-66 Hz, 150 W.
Battery Backup: Front-panel settings maintained for two years.
Dimensions: (HWD) 8.5"x14.5"x16.25", 210mm x 370mm x 410mm.
Weight: 12.5kg (27.5lbs) net, 18kg (40lbs) shipping.
Warranty: Two years.

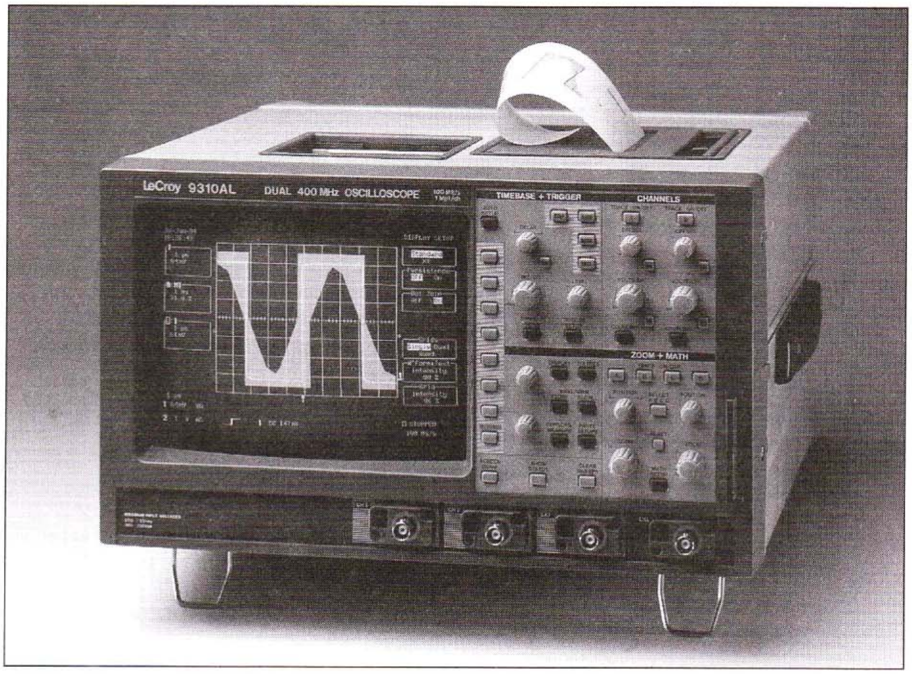
ORDERING INFORMATION

For Ordering Information see Page 4.

9310A Family Digital Oscilloscopes 400 MHz Bandwidth, 100 MS/s

Main Features

- Two and Four Channel Versions
- 50k, 200k and 1M Point Records
- LeCroy ProBus™ Probe System
- Glitch, Window, Qualified, Interval, Dropout and TV Triggers
- 8-bit vertical resolution, 11 with ERES option
- Fully Programmable via GPIB and RS-232-C
- Automatic PASS/FAIL testing
- Persistence, XY and Roll Modes
- Advanced Signal Processing
- DOS Compatible Floppy Disk and Memory Card Options
- Internal High Resolution Graphics Printer Option



General

The 9310A family offers two channel and four channel general-purpose 400 MHz digital oscilloscopes. They capture single-shot events at up to 100 MSamples/s, and repetitive signals at 10 GSamples/s. Record lengths up to 1M points provide outstanding horizontal resolution, and allow fast digitizing of long-duration events. Memories can be segmented, for minimum dead time between acquisitions.

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

The LeCroy ProBus intelligent probe system allows automatic sensing of the probe type. For LeCroy's active FET probes it also provides variable offset at the probe tip; offset and coupling are controlled from the scope front panel.

SMART Trigger modes like Glitch, Window and Dropout allow you to capture precisely the events of interest. A comprehensive range of signal processing functions, on live or stored waveforms, allows waveform manipulation without destroying the underlying data.

The 9310A family features the proven user-interface of LeCroy's portable scope family. A bright 9" CRT allows optimum waveform viewing on a high resolution 810 x 696 pixel screen.

Menus and text are arranged around the graticules - they never overwrite the waveforms. Each of the main control functions has a dedicated single knob, to keep the scope's performance at your fingertips.

DOS compatible floppy disk and memory card options store waveforms and test setups, and make transferring data to a PC easier than ever before. Hardcopies can be made on GPIB, RS-232-C or Centronics printers or plotters. An optional internal high resolution graphics printer is also available.

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

ACQUISITION SYSTEM

Bandwidth (-3 dB)
@ 50 Ω: DC to 400 MHz
Below 200 mV/div: 350 MHz
At 2mV/div: 300 MHz
@ 1 MΩ DC: DC to 250 MHz typical at the probe tip.
No. of Channels: 4 (9314A) or 2 (9310A)
No. of Digitizers: 4 (9314A) or 2 (9310A)
Maximum Sample Rate: 100 MS/s simultaneously on each channel.
Acquisition memories, per channel:

9310A, 9314A	50k
9310AM, 9314AM	200k
9310AL, 9314AL	1M

Sensitivity: 2 mV/div to 5 V/div, fully variable.
Scale factors: A wide choice of probe attenuation factors are selectable.
Offset Range:

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

DC Accuracy: ≤± 2% full scale (8 divisions) at 0 V offset.
Vertical Resolution: 8 bits.
Bandwidth Limiter: 30 MHz.
Input Coupling: AC, DC, GND.
Max Input:

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

TIME BASE SYSTEM

Timebases: Main and up to 4 Zoom Traces.
Time/Div Range: 1 ns/div to 1000 s/div.
Clock Accuracy: ≤±0.002 %.
Interpolator Resolution: 10 ps.
Roll Mode: Ranges 500 ms to 1,000 s/div. For > 50k points: 10 s to 1,000 s/div.
External Clock: ≤100 MHz on EXT input with ECL, TTL or zero crossing levels.

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single, Stop.
Trigger Sources: CH1, CH2, Line, Ext, Ext/10 (9314A: CH3, CH4). Slope, Level and Coupling for each can be set independently.
Slope: Positive, Negative, Window (BiSlope).
Coupling: AC, DC, HF (up to 500 MHz), LFREJ, HFREJ.
Pre-trigger recording: 0 to 100% of full scale (adjustable in 1% div increments).
Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).
Holdoff by time: 10 ns to 20 s.
Holdoff by events: 0 to 99,999,999 events.
Internal Trigger Sensitivity Range: ±5 div.
EXT Trigger Max. Input:
1 MΩ//15 pF: 250 V (DC+peak AC ≤10 KHz)
50 Ω ± 1%: ±5 V DC (500 mW) or 5 V RMS
EXT Trigger Range: ±0.5V (±5V with Ext/10).
Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART TRIGGER TYPES

Signal Width: Trigger on width between two limits selectable from 2.5ns to 20s.
Signal Interval: Trigger on interval between two limits selectable from 10ns to 20s.
Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.
State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.
TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL, SECAM, NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 10 µs/div.
Single shot: For transient and repetitive signals from 50 ns/div.
Sequence: Stores multiple events in segmented acquisition memories.
Number of segments available:

9310A-9314A	2-200
9310AM-9314AM	2-500
9310AL-9314AL	2-2,000

Dead Time between segments: ≤150 µs

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.
CRT: 12.5 x 17.5 cm (9" diagonal) raster.
Resolution: 810 x 696 points.
Modes: Normal, X-Y, Variable or Infinite Persistence.
Real-time Clock: Date, hours, minutes, seconds.
Graticules: Internally generated; separate intensity control for grids and waveforms.
Grids: 1, 2 or 4 grids.
Formats: YT, XY, and both together.
Vertical Zoom: Up to 5x Vertical Expansion (50x with averaging, up to 40 µV sensitivity).

Maximum Horizontal Zoom Factors:

9310A, 9314A	1,000x
9310AM, 9314AM	5,000x
9310AL, 9314AL	20,000x

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1, M2, M3, M4).
Processing Memory: Up to four 16-bit Waveform Processing Memories (A, B, C, D).
Setup Memory: Four non-volatile memories. Optional Memory Cards or Floppy Disks may also be used for high-capacity waveform and setup storage.

CURSOR MEASUREMENTS

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full-scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is displayed.
Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of full-scale in single-grid mode.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity and Summation Averaging.
Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 10^6 averages are possible with Option WP01.
Envelope*: Max, Min, or Max and Min values of from 1 to 10^6 waveforms.
ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.
Sampled data is always available, even when trace is turned off. Any of the above modes can be invoked without destroying the data.
FFT*: Spectral Analysis with four windowing functions and FFT averaging.
*Envelope and ERES modes are provided in Math Package WP01. FFT is in WP02.

AUTOMATIC MEASUREMENT

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

amplitude	falltime	peak to peak
area	f 80-20%	period
base	f@level (abs)	risetime
cycles	f@level (%)	r 20-80%
delay	frequency	r@level (abs)
Δdelay	maximum	r@level (%)
Δt at level (abs)	mean	RMS
Δt at level (%)	median	std dev
Δt at level (t=0,abs)	minimum	top
Δt at level (t=0,%)	overshoot +	width
duty cycle	overshoot -	

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

The parameters are based on ANSI/IEEE Std. 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". The terminology is derived from IEEE Std 194-1977 "Standard Pulse Terms and Definitions".

AUTOSETUP

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

PROBES

Model: One PP002 (10:1, 10 MΩ // 15 pF) probe supplied per channel.
The 9310A family is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.
Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50Ω , frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical. Alternatively, the Calibrator output can provide a trigger output or a PASS/FAIL test output.

INTERFACING

Remote Control: Of all front-panel controls, as well as all internal functions is possible by GPIB and RS-232-C.
RS-232-C Port: Asynchronous up to 19200 baud for computer/terminal control or printer/plotter connection.
GPIB Port: (IEEE-488.1) Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.
Centronics Port: Optional hardcopy parallel interface.
Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF and BMP formats are available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies: HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters. An optional internal high resolution graphics printer is also available.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.
Temperature: 5° to 40° C (41° to 104° F) rated, 0° to 50° C (32° to 122° F) operating.
Humidity: <80%.
Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.
Power: 90-250 V AC, 45-66 Hz, 150 W.
Battery Backup: Front-panel settings maintained for two years.
Dimensions: (HWD) 8.5"x14.5"x16.25", 210mm x 370mm x 410mm.
Weight: 12.5kg (27.5lbs) net, 18kg (40lbs) shipping.
Warranty: Two years.

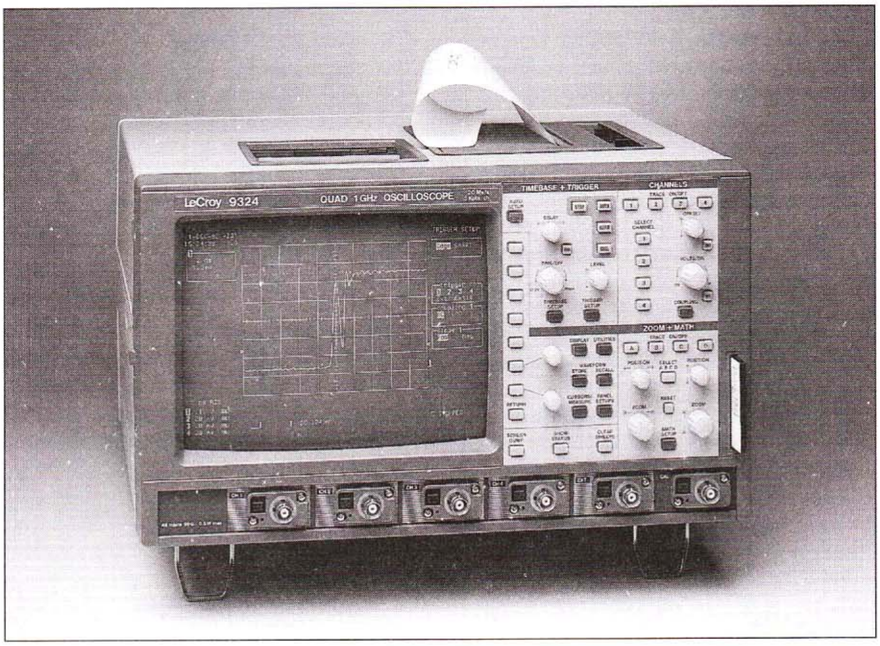
ORDERING INFORMATION

For Ordering Information see Page 4.

9320 and 9324, 1GHz Bandwidth Portable DIgital Oscilloscopes

Main Features

- Two or four channels
- Main and two delayed timebases for accurate time measurements
- LeCroy ProBus™ probe system
- Glitch, pattern, state and edge qualified triggers
- Automatic pass/fail testing
- Optional built-in printer
- DOS-compatible floppy disk and memory card options
- Persistence and XY modes
- Fully programmable via GPIB and RS-232



General

The 9320/24 are two and four channel instruments extending the power of digital oscilloscopes up to 1 GHz bandwidth. The oscilloscope is primarily intended for repetitive waveforms, which are sampled with an equivalent sampling rate of up to 20 GS/sec. Single shot events up to a few MHz may also be acquired with a single shot sampling rate of up to 20 MS/sec.

The digital technology used provides standard DSO features like pre-trigger view, hardcopy, full programmability, etc. The proven user interface of the 9300 oscilloscope family ensures ease of use and user efficiency.

The LeCroy ProBus intelligent probe system allows automatic sensing of the probe type. For LeCroy's active FET probes it also provides variable offset at the probe tip; offset and coupling are controlled from the scope front panel.

Up to two delayed timebases can be positioned on the main trace and displayed giving unrivaled resolution and precision in time measurements. Advanced triggering capabilities, which include glitch, pattern and state/edge qualified triggers, drastically simplify the testing and debugging of electronics systems.

DOS compatible floppy disk and memory card options store waveforms and test setups, and make transferring data to a PC easier than ever before. Hardcopies may be made on GPIB, RS-232 or Centronics printers or plotters. An optional built-in high resolution graphics printer is also available. Additional firmware packages extend the oscilloscope's processing capabilities in both time and frequency domains.

Analog oscilloscope users who have been using 350 - 400 MHz scopes to look at signals will find the higher bandwidth and digital measurement power of the 9320/24 gives them outstanding performance at a comparable price.

ACQUISITION SYSTEM

No. of channels: 2 (9320) and 4 (9324).
Bandwidth (-3 dB): DC to 1 GHz.
Rise time: < 350 psec.
Input impedance: 50 Ω ±1%.
Maximum input voltage: ±5 V DC (500 mW) or 5 V RMS.
Maximum Input Voltage: ± 5 V DC (500mW) or 5 V RMS.
Sensitivity range: 5 mV/div to 2 V/div in 1, 2, 5 sequence and continuously variable.
Random noise: < 500 µV RMS at 5 mV/div.
Probe calibrator: BNC connector, 250 mV into 50 Ω, generates rectangular pulses with 50% duty cycle; rise/fall times < 500 psec; flatness < 1%; zero offset; programmable frequency. The calibrator output can alternatively provide, under menu control, a trigger output or a PASS/FAIL output.
No. of digitizers: 2 or 4, one per channel.
Vertical resolution: 8 bits, all on screen (up to 12 bits with processing).
Sample rate: Up to 20 MS/sec for transients, up to 20 GS/sec for repetitive signals, simultaneously on all channels.
DC accuracy: ≤ ±2% full scale.
Vertical expansion: up to 5x normally, up to 50x with averaging.
Offset: 5 - 24.5 mV/div: ±0.8 V
25.0 - 124.9 mV/div: ±4.0 V
125 mV/div - 2 V/div: ±10.0 V

TIMEBASE SYSTEM

Timebases: Three, main and two delayed.
Main timebase range: 100 psec/div to 200 msec/div in 1, 2, 5 sequence.
Delayed timebase range: 100 psec/div to main timebase setting.
Clock accuracy: ≤ 0.002%.
Interpolator resolution: 10 psec.
Interpolator accuracy: < 15 psec.
Maximum record length: 5000 samples per channel.
Acquisition modes: Random interleaved sampling from 100 psec/div to 10 msec/div. Single shot from 0.1 msec/div to 200 msec/div.

TRIGGER SYSTEM

Pre-trigger time: Adjustable in 1% increments up to 100% full scale (grid width).
Post-trigger delay: Adjustable in 0.1 division increments up to 10,000 divisions.
Timing: Trigger date and time stored with each waveform.
External trigger input: 50 Ω ±1%.
External trigger voltage range: ±0.5 V in EXT, ±5 V in EXT/10.
Trigger rate: Up to 1.5 GHz on one channel only, (CH2 in 9320, CH4 in 9324) when HF coupling selected; 750 MHz for all other inputs.
Trigger jitter: < 10 psec RMS.
Trigger holdoff range: By time 12.5 nsec to 20 sec in steps of 12.5 nsec, by events 1 to 106, 100 MHz maximum rate.

STANDARD TRIGGER

Trigger sources: CHAN1, CHAN2, (CHAN1 to CHAN4 in 9324), Ext, Ext/10. CH1 to CH4 and EXT have independent trigger circuits allowing individual setting of slope, level and coupling.
Slope: Positive, negative.
Coupling: DC, AC-AUTOLEVEL, and HF (for one channel only).
Modes: Stop, auto, normal, single.

SMART TRIGGER™

Single source on any of CH1 to CH4 and EXT.
Pulse or pattern width < or >: 1 nsec to 1 msec in steps variable from 500 psec to 20 nsec.
Pattern: Trigger on the logic AND of the input channels (CH1 to CH4 in 9324, CH1 and CH2 in 9320), where each source can be defined as high (H), low (L) or don't care (X). The trigger can be selected at the beginning (entered) or at the end (exited) of the specified pattern. The pattern width can also be specified as above.
State/edge qualified: Triggers on any source (CH1 to CH4 + EXT) after the entering of a qualifying condition, edge or state, that can be defined on a single source or on a pattern of the input channels. The trigger can take place after (or within) a programmable delay ranging from 2 nsec to 1 msec in steps variable from 500 psec to 20 nsec. The state qualified trigger requires the continuing presence of the enabling pattern to trigger, while the edge qualified trigger does not.

DISPLAY

CRT: 12.5 x 17.5 cm (9" diagonal); raster.
Resolution: 810 x 696 pixels.
Graticules: Internally generated, separate intensity control for graticule and waveforms; single, dual and quad graticules.
Display modes: Normal, variable and infinite persistence, XY.

AUTOMATIC MEASUREMENT

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

amplitude	falltime	peak to peak
area	f 80-20%	period
base	f@level (abs)	risetime
cycles	f@level (%)	r 20-80%
delay	frequency	r@level (abs)
Δdelay	maximum	r@level (%)
Δt at level (abs)	mean	RMS
Δt at level (%)	median	std dev
Δt at level (t=0,abs)	minimum	top
Δt at level (t=0,%)	overshoot +	width
duty cycle	overshoot -	

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

The parameters are based on ANSI/IEEE Std. 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". The terminology is derived from IEEE Std 194-1977 "Standard Pulse Terms and Definitions".
Cursor measurements: Absolute and relative for voltage, time and frequency.
Cursor types: Horizontal bars for voltages, cursors riding on waveforms for times.

WAVEFORM PROCESSING

Waveform processing routines, up to four simultaneously, are called and set up via menus. These include arithmetic functions (add, subtract, multiply, divide, negate, identity), and summation averaging (up to 1000 sweeps).
Function memories: 4 x 5000 points, 16 bit.
Automatic testing: Up to five waveform parameters may be tested against selectable thresholds. Waveforms may also be tested against tolerance templates which can be generated inside the instrument.
Optional processing: Extra processing power can be added by installing LeCroy's waveform processing options.
Option WP01: Provides averaging, summation and continuous, extended mathematics including integration, differentiation, log, exp, absolute value, square, square root, etc; high resolution

mode, up to 11 bits; extrema mode for storage of extreme positive and negative values.
Option WP02: Provides FFT spectral analysis with a wide selection of displayed parameters.

AUTO-SETUP

Front panel button. Automatically scales timebase, trigger and sensitivity settings to correctly display repetitive signals with amplitudes between 10 mV and 5 V.
Auto-setup time: Approximately 2 sec, frequency above 50 Hz; duty cycle greater than 0.1%.
Vertical find: Individual per channel, automatically scales sensitivity and offset.

INTERFACING

Remote control: Of all front-panel controls, as well as all internal functions is possible by GPIB and RS-232.
RS-232 port: Asynchronous up to 19200 baud for computer/terminal control or printer/plotter connection.
GPIB port: (IEEE-488.1) Configurable as talker/listener for computer control and fast data transfer. Command language complies with requirements of IEEE-488.2.
Centronics: Optional parallel interface.
Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF format is available for importing to DTP programs. The following printers and plotters can be used to make hardcopies: HP ThinkJet, QuietJet, LaserJet, PaintJet (color), DeskJet (color) and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters.

STORAGE

Reference memories: 4 x 5000 points, 16 bits, usable to store acquired and processed waveforms.
Setups: Up to four stored in battery backed-up memories. Front-panel settings are maintained for two years.
Two DOS-compatible mass storage options: 1.44 MB, 3.5" floppy disk and/or up to 8 MB fast storage memory card, provide non-volatile mass storage of waveforms and/or front-panel setups.

SELF TESTS

Auto-calibration ensures specified DC and timing accuracy.

GENERAL

Temperature: 5°C to 40°C (41° to 104°F) rated, 0°C to 50°C (32° to 122°F) operating.
Humidity: < 80%.
Shock & vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.
Power: 90-250 V AC, 45-66 Hz, 150 Ω.
Battery backup: Front-panel settings maintained for two years.
Dimensions: (HWD) 8.5" x 14.5" x 16.25", 210 mm x 370 mm x 410 mm.
Weight: 10 kg (22 lbs) net, 15.5 kg (34 lbs) shipping.
Warranty: Two years.

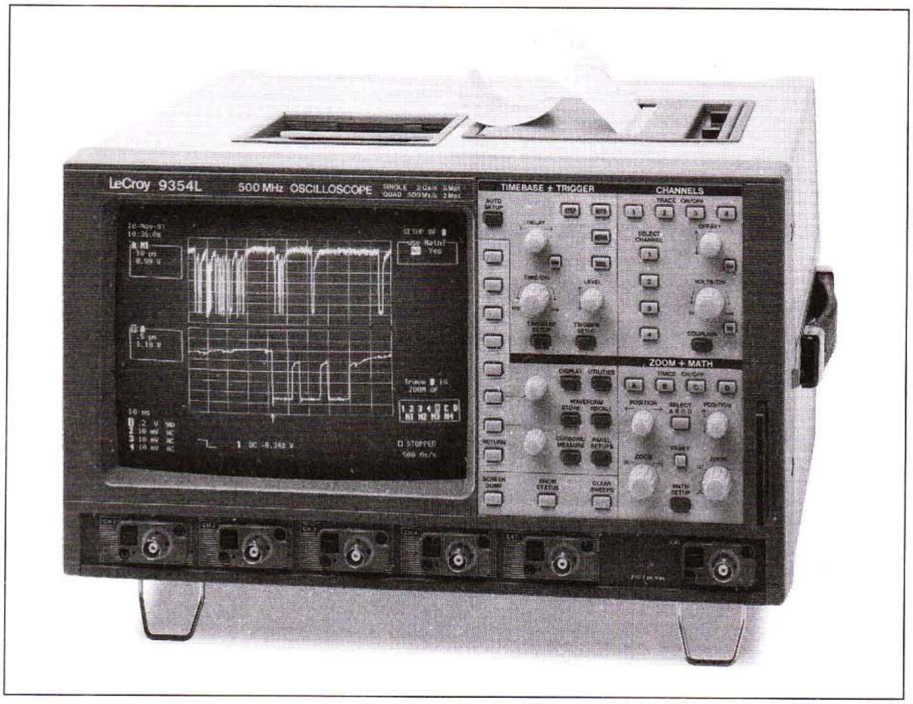
ORDERING INFORMATION

For Ordering Information see Page 4.

9350 Family Digital Oscilloscopes 500 MHz Bandwidth, 2 GS/s

Main Features

- Two and Four Channel versions
- Up to 8M Point record length
- Advanced Peak Detect Mode
- Glitch, Pattern, Qualified, Interval, Dropout and TV Triggers
- 8-bit vertical resolution, 11 with ERES option
- Fully programmable via GPIB and RS-232-C
- Automatic PASS/FAIL testing
- Advanced Signal Processing
- DOS Compatible Floppy Disk and Memory Card options
- Internal High Resolution Graphics Printer Option



General

High speed and long memory make this family the ideal 500 MHz general-purpose Digital Storage Oscilloscopes. Two and four channel simultaneous sampling at 500 MS/s meets demanding high-speed design applications. Even faster sampling may be achieved by combining channels, up to a maximum of 2 GS/s. Acquisition memories may also be combined, providing up to 8 M points of continuous or segmented waveform recording. Repetitive signals are digitized at up to 10 GS/s. These combined capabilities make the 9350 family the state-of-the-art in current DSO technology.

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

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

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

A comprehensive range of signal processing functions including FFT and Math on live or stored waveforms, allows extensive waveform manipulation. Up to 16 MBytes of RAM are available allowing high power processing including FFT's up to 1 Mpoint. DOS compatible floppy disk and memory card options store waveforms and test setups, and simplify data transfer to any PC. An optional high resolution graphics printer is also available.

ACQUISITION SYSTEM

Bandwidth (-3 dB): DC to 500 MHz
No. of Channels: 4 (9354) or 2 (9350)
No. of Digitizers: 4 (9354) or 2 (9350)
Maximum Sample Rate:
2 GS/s (9354) or 1 GS/s (9350)
Acquisition Memory: Up to 8 M (see table below)
Sensitivity: 2 mV/div to 5 V/div, fully variable.
Scale factors: A wide choice of over 12 probe attenuation factors are selectable.
Offset Range: 2.0 - 9.9 mV/div: ± 120 mV
10.0 - 199 mV/div: ± 1.2 V
0.2 - 5.0 V/div: ± 24 V
±20 V across the whole sensitivity range when using the AP 020 FET probe.
DC Accuracy: ≤±2% full scale.
Vertical Resolution: 8 bits.
Bandwidth Limiter: 30 MHz
Input Coupling: AC, DC, GND.
Input Impedance: 1 MΩ//15 pF or 50 Ω ± 1%.
Max Input:
1 MΩ: 250 V (DC+peak AC≤ 10 kHz)
50 Ω: ± 5 V DC (500 mW) or 5 V RMS

TIME BASE SYSTEM

Timebases: Main and up to 4 Zoom Traces.
Time/Div Range: 1 ns/div to 1000 s/div.
Clock Accuracy: ≤ 10 ppm
Interpolator resolution: 10 ps
Roll Mode: ranges 500 ms to 1,000 s/div. For > 50k points: 10 s to 1,000 s/div.
External Clock: ≤ 100 MHz on EXT input with ECL, TTL or zero crossing levels.

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single.
Trigger Sources: CH1, CH2, Line, Ext, Ext/10 (9354: CH3, CH4), Slope, Level and Coupling for each can be set independently.
Slope: Positive, Negative.
Coupling: AC, DC, HF, LFREJ, HFREJ.
Pre-trigger recording: 0 to 100% of full scale (adjustable in 0.1 div increments).
Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.01% increments).
Holdoff by time: 10 ns to 20 s.
Holdoff by events: 0 to 99,999,999 events.
Trigger Bandwidth: Up to 500 MHz using HF coupling.
Internal Trigger Sensitivity Range: ± 5 div.
EXT Trigger Max Input:
1 MΩ//15 pF: 250 V (DC+peak AC≤ 10 kHz)
50 Ω ± 1%: ± 5 V DC (500 mW) or 5 V RMS
EXT Trigger Range: ±0.5 V (±5 V with Ext/10)
Trigger Timing: Trigger Date and Time are listed in the Memory Status Menu.

SMART TRIGGER TYPES

Pattern: Trigger on the logic AND of 5 inputs - CH1, CH2, CH3, CH4, and EXT Trigger, (9350: 3 inputs - CH1, CH2, EXT) where each source can be defined as High, Low or Don't Care. The Trigger can be defined as the beginning or end of the specified pattern.
Signal or Pattern Width: Trigger on glitches as short as 1 nsec or on pulse widths between two limits selectable from < 2.5ns to 20s.
Signal or Pattern Interval: Trigger on an interval between two limits selectable from 10ns to 20s.
Dropout: Trigger if the input signal drops out for longer than a time-out from 25ns to 20s.
State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on another source. The delay between these events can be defined as a number of events on the trigger channel or as a time interval.
TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL, SECAM, NTSC or non-standard video.

ACQUISITION MODES

Random Interleaved Sampling (RIS): for repetitive signals from 1 ns/div to 2 µs/div (M,L versions: from 1 ns/div to 5 µs/div).
Single shot: for transient and repetitive signals from 10 ns/div (all channels active).
Peak detect: captures and displays 2.5 ns glitches or other high-speed events.
Sequence: Stores multiple events - *each of them time stamped* - in segmented acquisition memories.
Number of segments available:

9350-54	2-50
9350M-9354M	2-500
9350L-9354L	2-2,000

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots. Vectors may be switched off.
CRT: 12.5 x 17.5 cm (9" diagonal) raster.
Resolution: 810 x 696 points.
Modes: Normal, X-Y, Variable or Infinite Persistence.
Real-time Clock: Date, hours, minutes, seconds.
Graticules: Internally generated; separate intensity control for grids and waveforms.
Grids: 1, 2 or 4 grids.
Formats: YT, XY, and both together.

Channels Used	Maximum Sample Rate	Memory Per Channel 9350 9354	9350M 9354M	9350L 9354L	Notes
All, Peak Detect OFF	500 MS/s	25k	100k	2M	All channels active
All, Peak Detect ON	100 MS/s data 400 MS/s peak	10k data+ 10k peaks	50k data+ 50k peaks	1M data+ 1M peaks	All channels active 2.5 ns peak detect
Paired Peak Detect OFF	1 GS/s	50k	250k	4M	9350: CH1 9354: CH2 + CH3
Paired + PP092 Peak Detect OFF	2 GS/s	100k	500k	8M	9354 models only

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

Horizontal Zoom Factors:

9350-9354	500x
9350M-9354M	2,000x
9350L-9354L	40,000x

INTERNAL MEMORY

Waveform Memory: Up to four 16-bit Memories (M1,M2,M3,M4).
Processing Memory: Up to four 16-bit Waveform Processing Memories (A,B,C,D).
Setup Memory: Four non-volatile memories. Optional Cards or Disks may also be used for high-capacity waveform and setup storage.

CURSOR MEASUREMENTS

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full-scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is displayed.
Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of full-scale in single-grid mode.
Absolute Time: A cross-hair marker measures time relative to the trigger and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.

AUTOMATIC MEASUREMENTS

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

amplitude	falltime	peak to peak
area	f 80-20%	period
base	f@level (abs)	risetime
cycles	f@level (%)	r 20-80%
delay	frequency	r@level(abs)
Δdelay	maximum	r@level (%)
Δt at level (abs)	mean	RMS
Δt at level (%)	median	std dev
Δt at level (t=0,abs)	minimum	top
Δt at level (t=0,%)	overshoot +	width
duty cycle	overshoot -	

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

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Functions available are: Add, Subtract, Multiply, Divide, Negate, Identity and Summation Averaging.
Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to a million sweeps are possible with Option WP01.
Envelope*: Max, Min, or Max and Min values of up to one million sweeps.
ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.
Sampled data is always available, even when a trace is turned off. Any of the above modes can be invoked without destroying the data.
FFT*: Spectral Analysis with four windowing functions and FFT averaging.
*Envelope and ERES modes are provided in Math Package WP01. FFT is in WP02.

AUTOSETUP

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

PROBES

Model: One PP002 (X10, 10 MΩ // 15 pF) probe supplied per channel.
The 9350 family is fully compatible with LeCroy's range of FET Probes, which may be purchased separately.
Probe calibration: Max 1 V into 1 MΩ, 500 mV into 50 Ω, frequency and amplitude programmable, pulse or square wave selectable, rise and fall time 1 ns typical.
Alternatively, the Calibrator output can provide a trigger output or a PASS/FAIL test output.

INTERFACING

Remote Control: All front-panel controls, as well as all internal functions are possible by GPIB and RS-232-C.
RS-232-C Port (Standard): Asynchronous up to 19200 baud for computer/terminal control or printer/plotter connection.
GPIB Port (Standard): (IEEE-488.1) Configurable as talker/listener for computer control and fast data transfer. Command Language complies with requirements of IEEE-488.2.
Centronics Port: Optional hardcopy parallel interface.
Hardcopy: Screen dumps are activated by a front-panel button or via remote control. TIFF format is available for importing to Desktop Publishing programs. The following printers and plotters can be used to make hardcopies:
HP DeskJet (color or B&W), HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON printers. HP 7400 and 7500 series, or HPGL compatible plotters.
An optional internal high resolution graphics printer is also available.

GENERAL

Auto-calibration ensures specified DC and timing accuracy.
Temperature: 5° to 40° C (41° to 104° F) rated, 0° to 50° C (32° to 122° F) operating.
Humidity: < 80%.
Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications and MIL-T-28800C.
Power: 90-250 V AC, 45-66 Hz, 230 W.
Battery Backup: Front-panel settings maintained for two years.
Dimensions: (HWD) 8.5" x 14.5" x 16.25", 210mm x 370mm x 410mm.
Weight: 13 kg (28.6 lbs) net, 18.5 kg (40.7 lbs) shipping.
Warranty: 2 years.

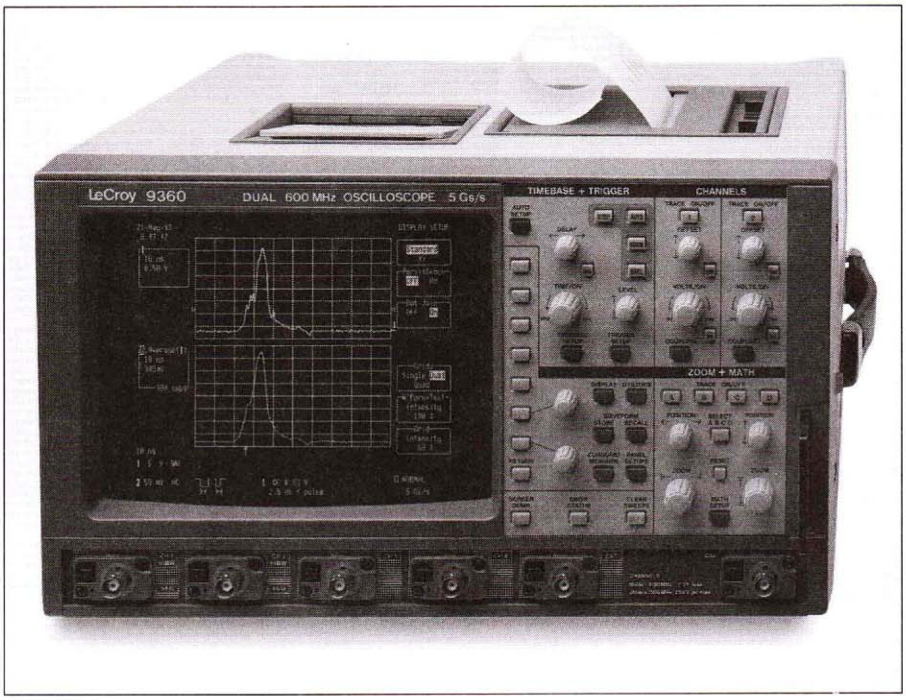
ORDERING INFORMATION

For Ordering Information see Page 4.

9360, 9361 Fast Digitizing Oscilloscopes

Main Features

- 5 GS/s max per channel on 9360
  2.5 GS/s on 9361
- 600 MHz single-shot bandwidth on 9360, 300 MHz on 9361
- Single-shot acquisition on all timebases
- 8-bit vertical resolution; 11 with ERES option
- Glitch, Interval, Window, Dropout, TV and State-Qualified Triggers
- Advanced signal processing
- Record length to 25,000 points
- Automatic PASS/FAIL testing
- 32 Automatic measurements
- Internal 3.5" floppy disk option
- Internal high resolution graphics printer option



Features

The 9360's 5 GS/s sample rate makes it ideal for applications like digital design, which require high bandwidth single-shot acquisition. Its two independent digitizers are clocked simultaneously to make precise timing measurements. Fast single-shot pulses can be characterized with 200 ps resolution. All acquisitions are real time, with no repetitive sampling used.

With 300 MHz and 600 MHz inputs, the 9361 and 9360 are also ideal for high-speed analog work. Optional FET probes ensure low loading and high bandwidth.

SMART Trigger modes like Glitch, Window and Dropout allow you to capture precisely the events of interest. Once signals are triggered, a range of signal processing functions, on live or stored waveforms, allows waveform manipulation without destroying the underlying data.

Menus and text are arranged around the waveform graticules - they never overwrite the waveforms. Each of the main control functions is dedicated to a single knob, to keep the 9360's performance at your fingertips.

The 9360 features the proven user-interface of LeCroy's portable scope family. A bright 9" CRT allows optimum waveform viewing on a high resolution 810 x 696 pixel screen.

Optional packages for FFT and extensive Waveform Processing (including Enhanced Resolution processing to 11 bits) are available.

DOS compatible memory card and floppy disk options store waveforms and test setups, and make transferring data to your PC easier than ever before. An optional high resolution graphics printer is also available.

ACQUISITION

No. of Channels: 2
No. of Digitizers: 2
Maximum Sample Rate: 5 GS/sec simultaneously on each channel for 9360, 2.5 GS/s for 9361.

VERTICAL SYSTEM

HiBW (600 MHz) Inputs: (9360 only). (Timebase Ranges 0.2 us/div to 1 ns/div).
Bandwidth (-3 dB): 600 MHz.
Sensitivity: 100 mV/div fixed.
Offset Range: ± 400 mV.
DC Accuracy: ± 3%.
Vertical Resolution: 8 bits.
Input Coupling: DC.
Input Impedance: 50Ω ± 1%.
Maximum Input: 5V RMS (500 mW).
Scale Factors: Probe attenuation is sensed automatically.
Note: The HiBW (600 MHz) inputs may be used as the trigger source with PP091 option.

NORMAL (300 MHz) Inputs (9360 & 9361):
Bandwidth (-3 dB): 300 MHz.
Sensitivity: 2 mV/div to 5 V/div, fully variable.
Offset Range:

2.0 - 9.9 mV/div:	± 120 mV
10.0 - 199 mV/div:	± 1.2 V
0.2 - 5.0 V/div:	± 24 V

DC Accuracy: ± 3%.
Vertical Resolution: 8 bits.
Analog Bandwidth Selections: 30 MHz and full.
Input Coupling: AC, DC, GND.
Input Impedance: 1 MΩ||15 pF or 50Ω ± 1%.
Max Input: 1 MΩ:250V (DC+peak AC<10KHz) 50Ω:± 5V DC (500 mW) or 5VRMS.
Scale Factors: Probe attenuation is sensed automatically.

WAVEFORM PROCESSING

Up to four processing functions may be performed simultaneously. Available functions are: Add, subtract, multiply, divide, negate, identity and the following:

Average: Summed averaging of up to 1,000 waveforms in the basic instrument. Up to 10^6 averages are possible with Option WP01.
Envelope*: Max, Min, or Max and Min values of from 1 to 10^6 waveforms are displayed.
ERES*: Low-Pass digital filter provides up to 11 bits vertical resolution.
Sample: Sample data is always available, even when trace is turned off. Any of the above modes can be invoked without destroying the sample data.
*Envelope and ERES modes are provided in Optional Math Package WP01.

TIME BASE SYSTEM

Timebases: Main and up to 4 Zoom Traces. Any 4 viewed simultaneously.
Time/Div Range: 1 ns/div to 1000 s/div.
Timebase Accuracy: ± 0.07%.
Record Length: 500 to 25,000 points (500 points for timebase settings from 500 ns/div to 1 ns/div).
Roll Mode: on ranges 500 ms to 1000 s/div.

TRIGGERING SYSTEM

Trigger Modes: Normal, Auto, Single, Stop.
Trigger Sources: CH1, CH2, Line, Ext, Ext/10 (Slope, Level and Coupling for each can be set independently.)
Slope: Positive, Negative, Window (BiSlope).
Coupling: AC, DC, LFREJ, HFREJ, HF.
Pre-trigger recording: 0 to 100% of full scale (0 to 75% at 10ns/div) adjustable in 1% steps.
Post-trigger delay: 0 to 10,000 divisions (adjustable in 0.1 div increments).
Holdoff by time: 25 ns to 20s.
Holdoff by events: 0 to 10^9 events.
Trigger Bandwidth: Up to 500 MHz using HF coupling.
Ext Trigger Input: 1 MΩ||15pF, 250V Max.
Ext Trigger Range: ± 500mV
± 5V with Ext/10
Trigger Timing: Trigger Date and Time are listed in the Waveform Status Menu.

SMART TRIGGER TYPES

Pulse Width: Trigger on pulse width between two limits selectable from less than 2.5ns to 20s. Typically triggers on glitches down to 1 ns.
Interval Width: Trigger on pulse spacing between two limits selectable from 2.5ns to 20s.
Dropout: Trigger if the input signal drops out for longer than a timeout from 25ns to 20s.
State/Edge Qualified: Trigger on any source only if a given state (or transition) has occurred on one of the other possible sources. The delay between these events can be defined as a number of events on the trigger channel.
TV: Allows selection of both line (up to 1500) and field number (up to 8) for PAL, SECAM, NTSC or non-standard video.

DISPLAY

Waveform style: Vectors connect the individual sample points, which are highlighted as dots.
CRT: 12.5x17.5 cm (9" diagonal) raster.
Resolution: 810x696 points.
Modes: Normal, X-Y, Persistence.
Real-time Clock: Date, hours, minutes, sec.
Graticules: Internally generated; separate intensity control for grids and waveforms.
Grids: 1, 2 or 4 grids.
Formats: YT, XY, and both together.
Persistence: Normal or Infinite.
Zoom: Up to 200x Horizontal and up to 5x Vertical Expansion (50x with averaging, up to 40 μV sensitivity).

AUTOMATIC MEASUREMENT

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

amplitude	falltime	peak to peak
area	f 80-20%	period
base	f@level (abs)	risetime
cycles	f@level (%)	r 20-80%
delay	frequency	r@level (abs)
Δdelay	maximum	r@level (%)
Δt at level (abs)	mean	RMS
Δt at level (%)	median	std dev
Δt at level (t=0,abs)	minimum	top
Δt at level (t=0,%)	overshoot +	width
duty cycle	overshoot -	

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

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

Δdelay provides time between midpoint transition of two sources, for making propagation delay measurements.
Δt at level allows the same measurement to be made at any specified level.

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

CURSOR MEASUREMENTS

Relative Time: Two cursors provide time measurements with resolution of ±0.05% full-scale for unexpanded traces; up to 10% of the sampling interval for expanded traces. The corresponding frequency value is also displayed.
Relative Voltage: Two horizontal bars measure voltage differences up to ±0.2% of full-scale in single-grid mode.
Absolute Time: A cross-hair marker measures time relative to the trigger, and voltage with respect to ground.
Absolute Voltage: A reference bar measures voltage with respect to ground.
Pass/Fail testing allows up to five of the above listed parameters to be tested against selectable thresholds. Waveform Limit Testing is performed using templates which may be defined inside the instrument.

INTERNAL MEMORY

Waveform Memory: Four 16-bit Reference Memories (M1,M2,M3,M4) for full 25k records.
Processing Memory: Four 16-bit Waveform Processing Memories (A,B,C,D) 25k each.
Setup Memory: Four non-volatile panel memories.

AUTOSETUP

Sets timebase, trigger and sensitivity to display a wide range of repetitive signals. (Amplitude 2mV to 40V; frequency above 50Hz; Duty Cycle > 0.1%). Not available on HiBW inputs.
Autosetup Time: Approximately 2 seconds.
Vertical Find: Automatically sets sensitivity & offset. Not available on HiBW inputs.

INTERFACING

Remote Control of all front-panel controls, as well as all internal functions, is possible by GPIB and RS-232.
RS-232 Port: Asynchronous up to 19200 baud for computer/terminal control or printer/plotter connection.
GPIB Port: (IEEE-488.2) Talker/listener for computer control and fast data transfer.
Hardcopy: Screendumps are activated by a front-panel button or via remote control. TIFF format is available for importing to DTP programs. The following printers and plotters can be used to make hardcopies: HP ThinkJet, QuietJet, LaserJet, PaintJet and EPSON compatible printers. HP 7400 and 7500 series, Philips 8151, Graphtek FP5301 and compatible plotters. An internal printer is also available.

MASS STORAGE OPTIONS

Optional 3.5" Floppy Disk drive and PCMCIA standard memory cards allow storage of traces, screen graphics, setups and Pass/Fail templates. For more detail see LeCroy's "9300 Series 3.5" Floppy, RAM Card, Printer" datasheet.

GENERAL

Temperature: 10° to 35° C (50° to 95° F) rated, 0° to 45° C (32° to 113° F) operating
Humidity: <80%
Shock & Vibration: Meets MIL-STD-810C modified to LeCroy design specifications, and MIL-T-28800C
Power: 90-250 V AC, 45-66 Hz, 150 W
Battery Backup: Front-panel settings maintained for two years
Dimensions: (HWD) 8.5"x14.5"x16.25" 210mm x 370mm x 410mm
Weight: 10kg (22lbs) net 15.5kg (34lbs) shipping
Warranty: Two years

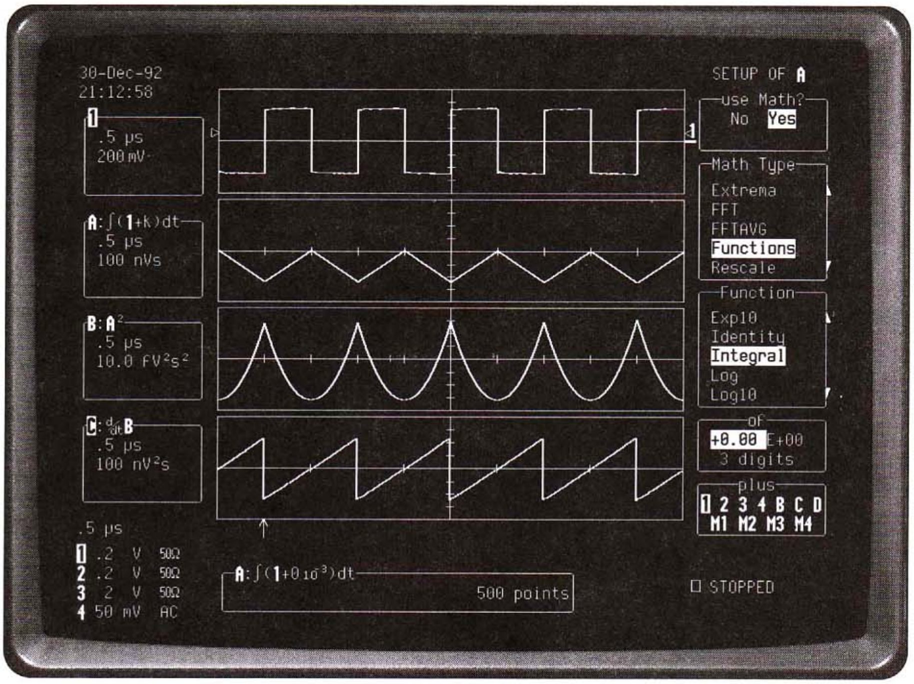
ORDERING INFORMATION

For Ordering Information see Page 4.

WP01 Waveform Processing Firmware for the 9300 Family of Digital Oscilloscopes

Main Features

- Averaging - summation up to 1 million sweeps and continuous
- Functions - including integration, differentiation, square root, square, reciprocal, logarithm (base 10 and e), exponential and sinx/x.
- Extrema mode - storage of extreme positive and negative values
- High resolution mode enhances vertical resolution with a choice of 6 digital filters



Added as a factory option or retrofitted in the field, the WP01 Waveform Processing Package adds high-speed averaging, filtering and mathematical capabilities to the 9300 family of digital oscilloscopes.

General

The LeCroy WP01 Waveform Processing package offers powerful routines that extend the processing capabilities of the 9300 family of digital oscilloscopes.

All processing is built-in to eliminate the need for external computers and controllers. High-speed microprocessors are used to ensure that computed waveforms are displayed instantly on the screen.

The package is fully programmable over GPIB or RS-232-C interfaces and hard copies can be directly made onto a wide range of printers.

Features and Benefits

EXTENSIVE SIGNAL AVERAGING

Two operation modes:

- Summation averaging up to 1,000,000 waveforms.
- Continuous averaging with weighting factors up to 1023.

Averaging speed up to 200,000 points/sec in summation averaging mode.

EXTREMA MODE

Keeps track of time and amplitude drift by storing extreme positive and negative values, such as glitches, over a programmable number of sweeps.

POWERFUL ARITHMETIC

Processes addition, subtraction, multiplication or division on any pair of waveforms.

MATHEMATICAL FUNCTIONS

Computes identity, negation, reciprocal, integration, differentiation, square, square root, absolute value, sinx/x, exponential and log on any waveform.

ENHANCED RESOLUTION

Allows filtering of the digitized signals, whether they are single-shot or repetitive, in order to increase the resolution of the displayed trace from 8 bits to 11 bits in steps of 0.5 bits. This feature is available on every timebase and can be applied to data without retriggering. The raw data is always preserved.

VERTICAL EXPANSION

Provides vertical scale expansion by a factor of up to 50.

CHAINING OF OPERATIONS

Automatically chains up to four operations. An indefinite number of operations can be performed sequentially, either manually or via remote control.

REMOTE CONTROL

Controls remotely all front-panel settings, as well as all waveform processing options via either GPIB or RS-232-C interfaces.

Functional Description

The WP01 waveform processing package can be implemented in any of the models of the 9300 family of digital oscilloscopes. This firmware is optimized for processing signals in real time. A powerful 68030/68020 microprocessor and a 68882/68881 co-processor enable rapid representation of results such as averages, integrations, exponentials and multiplications.*

Waveform operations can be performed on live, stored, processed or expanded waveforms. They are selected through simple menus that allow functions to be chained together allowing more complex computations. For example, it is possible to perform the integration of an averaged waveform or the multiplication of a differentiated waveform.

All processing occurs in function memories A, B, C and D which may be displayed on the screen by simply pressing the appropriate function button. All the necessary processing is automatically performed for all the functions selected.

The number of points used in the calculations is selectable from 50 to 2,000,000 points depending on scope model.

* All 9300 series scopes have a 68000 series processor and co-processor. This allows them to handle math operations faster than other scopes which lack a coprocessor.

SIGNAL AVERAGING

WP01 offers two powerful, high-speed averaging modes that can be used to reduce noise and improve the signal-to-noise ratio. Vertical resolution can be extended by several bits to improve dynamic range and increase the overall input sensitivity to as much as 50 μV/division.

Summed Averaging consists of the repeated addition (with equal weight) of recurrences of the selected source waveform. The number of acquisitions averaged can be selected up to 1,000,000 sweeps with the accumulation automatically stopping when the number is reached.

Continuous Averaging, sometimes called exponential averaging, is the repeated weighted average of the source waveform with the previous average. Averaging goes on indefinitely with each new acquisition and the effect of previous waveforms gradually tends to zero. Relative weighting factors can be chosen from 1:1 to 1:1023. The method is particularly useful for monitoring noisy signals which may change slowly over a period of time.

ENHANCED RESOLUTION

The WP01 package provides a selective filtering technique that improves vertical resolution for reduced bandwidth applications. By effectively removing high-frequency noise, with digital smoothing functions, waveforms can be analyzed with resolution from 8 to 11 bits. The technique can be used with both single-shot and repetitive signals and provides an ideal method for smoothing transient phenomena. This feature operates on all timebases and always preserves the raw data.

EXTREMA MODE

Tracking rare glitches or monitoring signals drifting in time and amplitude is made easy with Extrema mode. Extrema waveforms are produced by repeatedly comparing acquisitions of a source waveform with a stored waveform that contains previous maximum and/or minimum excursions. Whenever a given data point of a new acquisition exceeds the existing data point of the stored waveform, the old data point is replaced by the new. In this way the envelope of all waveforms is accumulated for up to a maximum of 1,000,000 sweeps.

ARITHMETIC

The 9300 family offers basic arithmetic operations such as addition, subtraction, division, multiplication and negation, even on the standard models. These arithmetic functions can be performed on any source waveform on a point by point basis. Different vertical gains and offsets of the source waveforms are automatically taken into account in the computed result.

MATHEMATICAL FUNCTIONS

Functions including differentiation, integration, absolute value, square, square root, logarithm (base 10 and e), exponential, reciprocal, and sinx/x interpolation may be performed on any source waveform. Arithmetical and mathematical functions can also be chained together to construct more complex processing routines.

Specifications

SUMMATION AVERAGING

Number of sweeps: 1 to 1,000,000.

Number of input points: 50 to 1,000,000 (depending on scope model).

Vertical expansion: 50X maximum.

Maximum sensitivity: 50 μV/div after vertical expansion.

Speed: up to 200,000 points/sec.

CONTINUOUS AVERAGING

Possible weighting factors: 1:1, 1:3, 1:7, 1:15, 1:31, 1:63, 1:127, 1:255, 1:511 and 1:1023.

Number of input points: 50 to 1,000,000 (depending on scope model).

Vertical expansion: 50X maximum.

Maximum sensitivity: 50 µV/div after vertical expansion.

ARITHMETIC

Addition, subtraction, multiplication, and ratio on any two waveforms.

Number of input points:
50 to 2,000,000 (depending on scope model).

Vertical expansion: 5X to 50X depending on the source waveforms.

FUNCTIONS

Identity, negation, integration, differentiation, square, square root, logarithm and exponential (base e and 10), sinx/x, reciprocal and absolute value of any source waveforms.

Number of input points:
50 to 2,000,000 (depending on scope model).

Vertical expansion: 5X to 50X depending on the source waveforms.

ENHANCED RESOLUTION

Choice of six low-pass filters for vertical resolution improvement from 8 to 11 bits at reduced bandwidth.

Vertical expansion: 50X maximum.

Maximum sensitivity: 50 µV/div after vertical expansion.

EXTREMA

Logs all extreme values of a waveform over a programmable number of sweeps. Maxima and minima can be displayed together, or separately by choosing ROOF or FLOOR traces. Glitches as short as 0.002% of the time base down to 10 nsec are displayed.

Number of sweeps: 1 to 1,000,000.

Number of input points:
50 to 2,000,000 (depending on scope model).

Vertical expansion: 5X maximum.

CHAINING OF OPERATIONS

Up to four functions can be automatically chained using Functions A, B, C and D. Using memories M1 to M4 for intermediate results, any number of operations can be chained manually or via remote control.

REMOTE CONTROL

All controls and waveform processing functions are fully programmable using the oscilloscope's GPIB or RS-232-C interfaces. Simple English-like commands are used.

STORED FRONT PANELS

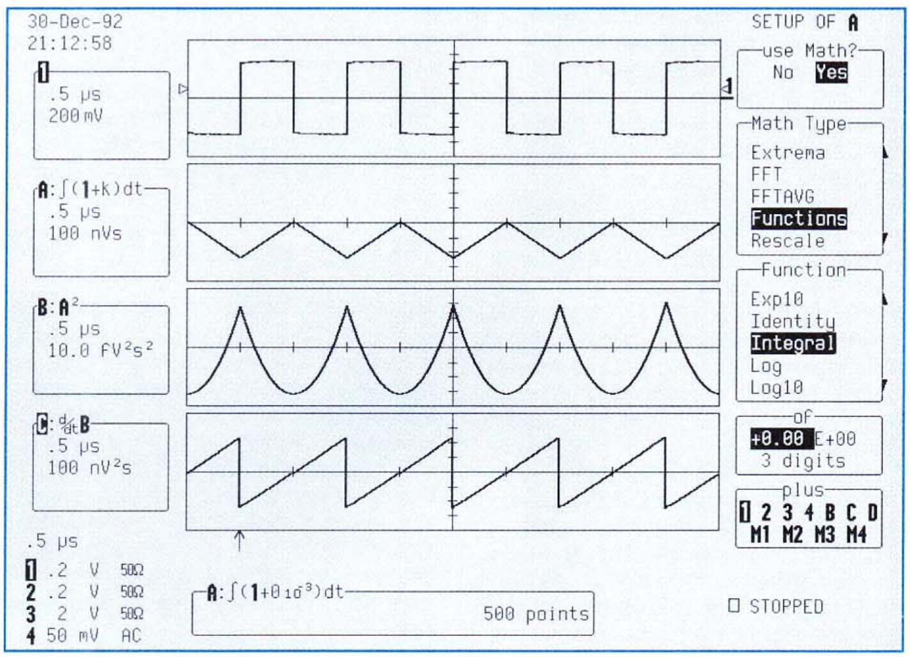
Up to four front-panel setups, including WP01 settings, can be stored in resident non-volatile memory and recalled using the menu buttons or via remote control.

WP01 INSTALLATION

The WP01 option may be retrofitted into an oscilloscope at any time or ordered as model 93XX-WP01 with any new 9300 series oscilloscope.

ORDERING INFORMATION

For Ordering Information see Page 4.

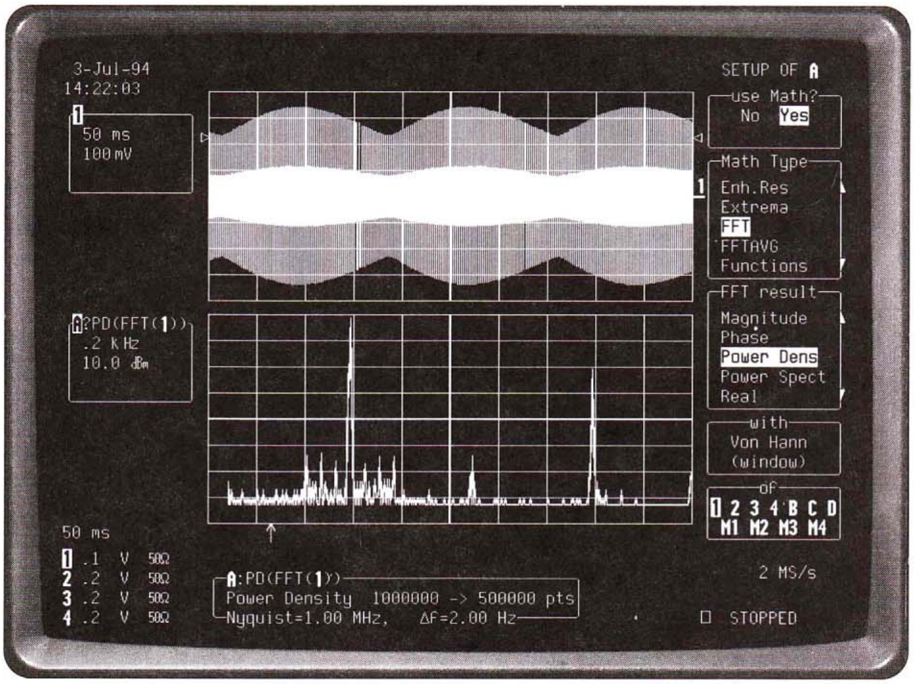


An example of the variety of math functions available in the 93XX-WP01. A square wave signal is integrated, squared, and differentiated. The math setup menu shows a partial list of available functions.

WP02 Spectrum Analysis Firmware for the 9300 Family of Digital Oscilloscopes

Main Features

- Up to 1,000,000-point FFTs over two or four channels simultaneously
- Frequency range from DC to to 1 GHz
- Frequency resolution down to 20 µHz
- Up to 20 GS/sec sampling rates
- Frequency domain averaging
- Wide selection of display formats and window functions
- 1,000-point FFTs in less than 0.5 sec



Adding the WP02 Spectrum Analysis Package to the 9300 family of digital oscilloscopes provides a fast and economical solution to users with frequency domain applications. Note 1,000,000 point FFT analysis shown here gives 2 Hz resolution.

General

The WP02 Spectrum Analysis Package extends the range of measurement capabilities of the 9300 Series of digital oscilloscopes. The package is fully programmable over GPIB and RS-232-C interfaces.

Fast Fourier Transforms (FFTs) rapidly convert time domain waveforms into frequency domain records to reveal valuable spectral information such as phase, magnitude and power.

Hardcopies can be directly made on a wide range of printers. The package is a firmware option installed inside the oscilloscope, eliminating the need for any external controller and is easy retrofit.

Features and Benefits

LONG RECORD TRANSFORMS

Long record FFTs up to 1,000,000 points, provide significant signal-to-noise ratio improvement.

WIDE-BAND FREQUENCY ANALYSIS

DC to up to 1 GHz bandwidth with high resolution.

HIGH SAMPLING RATES

Up to 20 GS/sec effectively eliminates aliasing errors.

BROAD SPECTRUM COVERAGE

Up to 500,000 spectral components.

MULTI-CHANNEL ANALYSIS

All input channels can be analyzed simultaneously to allow comparison of independent signals for common frequency-domain characteristics.

VERSATILE DISPLAY FORMATS

Frequency-domain data may be presented as magnitude, phase, real, imaginary, complex, log-power and log-PSD (Power Spectral Density). These display formats can all be selected via menu options.

FUNCTIONAL DESCRIPTION

The Spectrum Analysis package enhances the outstanding features of the LeCroy 9300 family. It provides high resolution and wide-band spectrum analysis together with sophisticated window functions and fast processing.

STANDARD WINDOW FUNCTIONS

Rectangular for transient signals; von Hann (Hanning) and Hamming for continuous waveform data; Flattop for accurate amplitude measurements; Blackman-Harris for maximum frequency resolution.

CALIBRATED VERTICAL SCALING

Flattop truncation window provides precisely calibrated vertical scaling for all spectral components.

FREQUENCY DOMAIN AVERAGING

Up to 50,000 FFT results may be averaged to reduce base-line noise and enable analysis of phase-incoherent signals or signals which cannot be triggered on.

TIME-DOMAIN AVERAGING

Averaging real-time signals prior to FFT execution can increase the dynamic range to up to 70 dB.

FREQUENCY CURSORS

Cursors give up to 0.004% frequency resolution (up to 0.002% for 10,000 point memory) and measure power or voltage differences to 0.2% of full scale.

CHAINING OF OPERATION

Up to four operations can be automatically chained, e.g., Function D = FFT of (CH1 X CH2). Any number of operations can be performed sequentially, either manually or via remote control.

FULL REMOTE CONTROL

All front-panel settings and waveform processing functions are programmable via GPIB or RS-232-C interfaces. Acquired and processed waveforms can be down-loaded to a computer and can later be retrieved and displayed on the oscilloscope.

HARDCOPIES

Provides hard copies of the screen using a wide range of printers.

PROCESSING OF EXPANSIONS

Up to four regions of the same waveform, or of different waveforms, can be expanded and processed simultaneously.

FFT ON SEGMENTED WAVEFORMS

Individual waveform segments can be expanded and then analyzed using FFT. Time and date information is automatically recorded for each segment.

FFT AND LECROY OSCILLOSCOPES

In FFT mode, LeCroy oscilloscopes perform spectral analysis on repetitive and single acquisitions. Users can obtain time and frequency values simultaneously and compare phases of the various frequency components with each other. Rather than the commonly used "power of two" record lengths, the routines used in the WP02 package feature decimal record lengths which can be selected in a 1, 2.5, 5 sequence. Resulting spectra are also calibrated in convenient decimal Hertz values.

The WP02 package is supported by the exceptional acquisition characteristics which are the hallmark of LeCroy oscilloscopes (±2% DC accuracy, high effective bits, improved resolution through averaging). Computations are made using 16-bit processing that allows high accuracy, stability and repeatability. With LeCroy oscilloscopes, signals may be acquired from up to four acquisition channels and processed simultaneously using up to four functions. This is particularly useful for network characterization or when looking for common frequency-domain characteristics on multiple signals.

IMPROVED RESOLUTION

Fast Fourier Transform calculates equally-spaced frequency components from DC to the full instrument bandwidth. By lowering the sampling rate, it is possible to make measurements with 20 μHz resolution up to 0.5 Hz (Nyquist). On the high bandwidth 9320 and 9324, the widest resolution becomes 2 MHz and the Nyquist frequency 10 GHz. This is comfortably above the highest frequency components recordable by the oscilloscope, and thus virtually eliminates aliasing effects.

MEMORIES

	9304A/10A/14A	9310AM/L and 9314M/AL
Acquisition memory/ch (8 bit)	50k points	200k/1M points
Reference memories (16 bit)	4 x 50k points	4 x 50k points
Function memories (16 bit)	4 x 50k points	4 x 50k points

FREQUENCY

		9304A/10A/14A	9310AM/L and 9314AM/L
Frequency resolution		20 μHz to 100 MHz	20 μHz to 100 MHz
Horizontal expansion		100 X	1000 X
Transform size	in	40 to 50,000 points	40 to 50,000 points
	out	20 to 25,000 points	20 to 25,000 points

Frequency range: DC to instrument bandwidth.
Nyquist frequency range: 0.5 Hz to 1/2 maximum instrument sampling rate.
Frequency scale factors: 0.05 Hz/div to 0.2 GHz/div in a 1, 2, 5 sequence.
Frequency accuracy: 0.01%.
Selection of the transform size: The number of points can be selected in a 1, 2.5, 5 sequence. The transform size defines the decimation applied to the signal after acquisition. It can be adjusted and optimized after signal acquisition and prior to FFT execution.

AMPLITUDE AND PHASE

Amplitude accuracy: Better than 2%. Amplitude accuracy may be modified by the window function (see the window functions table).
Signal overflow: A warning is provided at the top of the display when the input signal exceeds the ADC range.
Number of traces: Time domain and frequency domain data can be displayed simultaneously (up to 4 waveforms).
Phase range: -180° to +180°.
Phase accuracy: ±5 (for amplitude > 1.4 div).
Phase scale factor: 50°/division.
Zero base line: 0 div (center of screen).

SPECTRUM DISPLAY FORMATS AND SCALING

Frequency scale: Linear, real, imaginary or complex spectrum, in V/div, zero base line at 0 div (center of screen).
Power spectrum: in dBm (1 mW into 50 Ω).
Power spectral density: (PSD) in dBm.
Phase display: Linear.
Magnitude display: Linear. Power and PSD spectra displays have 160 dB range (20 dB/div), continuously expandable up to 0.5 dBm/div.

FREQUENCY DOMAIN POWER AVERAGING

Summation averaging of power, PSD or magnitude for up to 50,000 spectra.

VERTICAL EXPANSION

All spectral formats, up to 50 times, continuously.

DEFINITIONS

Filter bandwidth at -6 dB: Characterizes the frequency resolution of the filter.
Highest side lobe: Indicates the reduction in leakage of signal components into neighboring frequency bins.
Scallop loss: Maximum loss of an equivalent rectangular filter.

WINDOW FUNCTIONS

Rectangular, von Hann (Hanning), Hamming, Flattop and Blackman-Harris. The table below indicates the filter pass-band shape and the resolution.

CURSORS

Absolute (crosshair) and relative (arrow) cursors provide frequency and amplitude (phase, power, power density) measurements. Horizontal bars provide absolute and relative amplitude, (phase, power and power density measurements).

FFT EXECUTION TIME

100 points in less than 0.05 sec.
1000 points in less than 0.5 sec.
10000 points in less than 5.0 sec.

REMOTE CONTROL

All WP02 processing functions are fully programmable via the GPIB and RS-232-C interfaces. Simple English-like commands are used.

FILTER PASS BAND AND RESOLUTION

Window type	Filter bandwidth at -6 dB [freq. bins]	Highest side lobe [dB]	Scallop loss [dB]	Noise bandwidth [freq. bins]
Rectangular	1.21	-13	3.92	1.0
Von Hann	2.00	-32	1.42	1.5
Hamming	1.81	-43	1.78	1.36
Flattop	1.78	-44	0.01	2.96
Blackman-Harris	1.81	-67	1.13	1.71

REMOTE READ AND WRITE

All waveform formats including complex can be read by computer for storage or further processing. Externally generated waveforms can be written into Memories M1 to M4 for FFT or other processing.

STORED FRONT PANELS

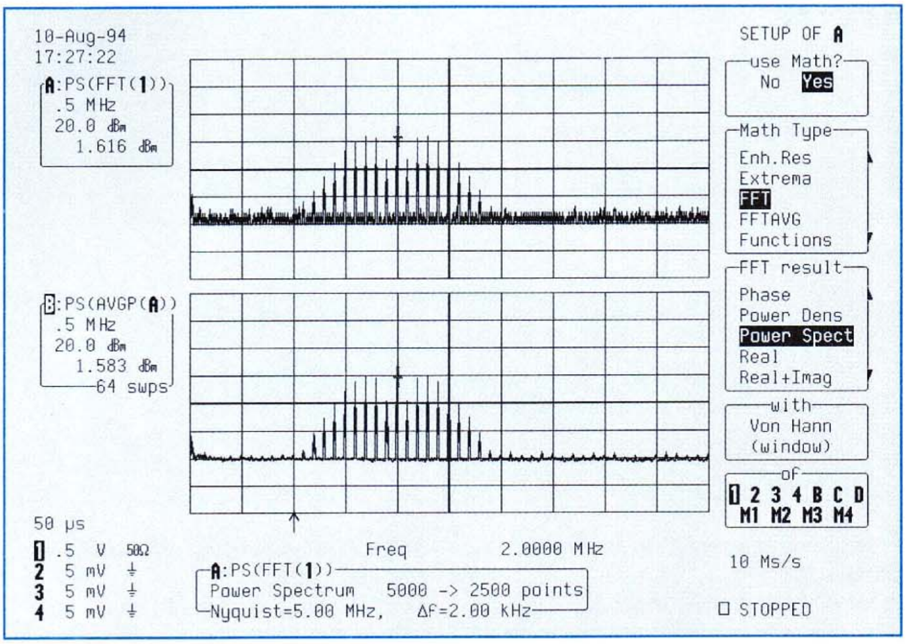
Up to 4 front-panel setups, including WP02 menu settings can be stored in non-volatile memory and recalled by the menu buttons at the left side of the screen.

WP02 INSTALLATION

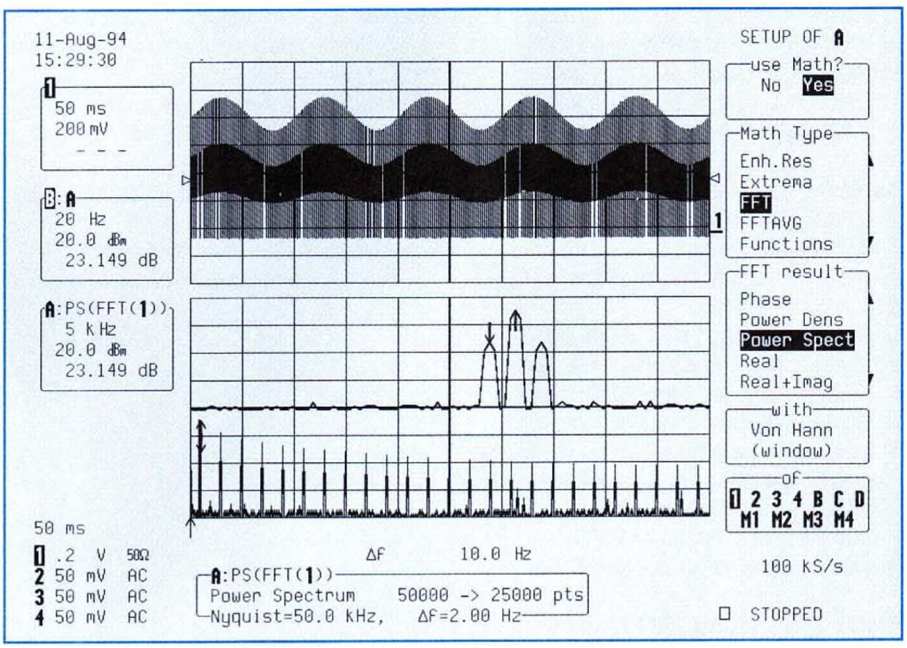
A WP02 package may be retrofitted at any time or ordered as model 93XX-WP02 with any new 9300 series oscilloscope.

ORDERING INFORMATION

For Ordering Information see Page 4.



Frequency modulated signal, 2 MHz carrier with 99 kHz modulation frequency, 4:1 frequency deviation, FFT shows modulation sidebands, FFT power average used to improve s/n ratio.

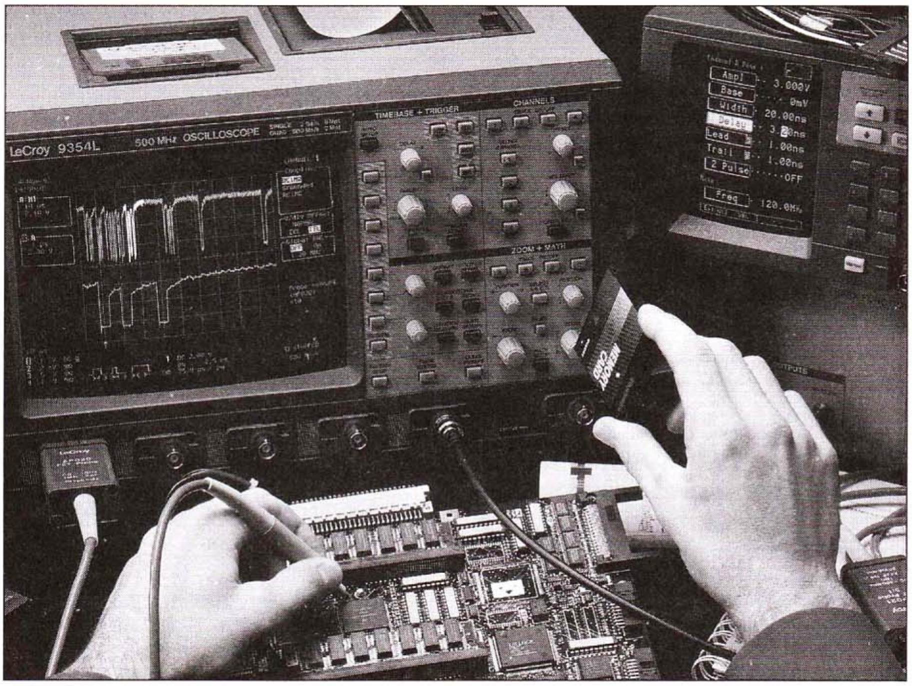


FFT analysis of 1 kHz square wave with 25% pulse amplitude modulation at 10 Hz. Long memory and 50 kpoint FFT show up to 51st harmonic, while expansion shows 10 Hz modulation sidebands.

9300 Series Built-in 3.5" Floppy Drive, RAM Card, Printer

Main Features

- 3.5" floppy drive, DOS format, affordable and convenient
- Ultra-fast RAM card, DOS format, ideal for PASS/FAIL testing
- High-resolution graphics printer, for fast, on-the-spot documentation
- Ideal for archiving test data for ISO 9000 requirements or saving screen images to document circuit performance.



3.5" FLOPPY

The floppy drive is a convenient storage medium, not only for saving and retrieving waveforms or instrument settings, but also for storing hardcopies that can be printed from a PC when desired. The floppy supports both 720k and 1.44M DOS formats so that it can be read back on any PC with a 3.5" drive, avoiding the need to interface the oscilloscope to your PC. As with the RAM-card option, the floppy system capabilities include automatic storage of data under pre-programmed conditions.

RAM CARD

The RAM card is a fast and compact storage medium for saving and retrieving waveforms or instrument settings. It is compatible with the PCMCIA/JEIDA standard, which has been adopted by the PC industry. With the special Autostore feature, waveforms can be automatically stored to the card after every acquisition, and played back when desired. With the scope's powerful PASS/FAIL feature; failure data can also be saved automatically to the RAM card.

PRINTER

The built-in high resolution graphics printer is an invaluable tool for instant, on-the-spot documentation. It generates a clear, crisp hardcopy of the screen in just a few seconds. The printout's 7" diagonal size combined with its high resolution provides you with an excellent document that matches the screen's superior quality even to the finest details. Because it frees you from the hassle of carrying and interfacing a bulky printer, it's the ideal solution for field measurements. Printouts can be expanded up to 200x in length to show every detail of a signal.

Mass-Storage Features and Benefits

LeCroy's mass storage capabilities provide a number of benefits:

- Easy data transfer to PCs
- Waveform logging
- Waveform archiving for future use
- Faster troubleshooting
- Faster, more reproducible testing
- Shared oscilloscope resources
- Document passing/failing parts
- Archive test results to floppy disks

EASY DATA TRANSFERS TO PCs

Because the 9300 Series oscilloscope uses DOS-formatted floppy disks and memory cards, transferring waveform data to a PC is a breeze. The removable storage allows transfers without cables, programming, or any knowledge of GPIB, RS-232, or other interfaces. And what's more, LeCroy provides, free of charge, a binary-to-ASCII format conversion program for the PC since some PC-based analysis packages such as spreadsheets, require ASCII format.

WAVEFORM LOGGING

By using glitch or dropout triggering in combination with the powerful Autostore mode, LeCroy oscilloscopes can monitor and log intermittent problems automatically. To store a waveform, the oscilloscope opens and names a DOS-compatible file and then stores the waveform data into the file. This logging feature requires no operator intervention and maintains data and the operational setup through power line failures. Logged waveforms can be selectively played back by trigger time/date or by sequence number, or can be scrolled through sequentially.

WAVEFORM ARCHIVING FOR FUTURE USE

- Recallable proof of performance
- Additional data analysis as needed
- Accurate trend or drift monitoring
- Calibration procedure verification

When storing waveforms, LeCroy DSOs also archive a header of setup information and the acquisition time/date. After recalling an archived waveform, the header ensures correct time and voltage scaling. When recalled into the oscilloscope, the waveform can be zoom expanded, compared, or analyzed just like a live waveform. The time/date offers proof of measurement authenticity and trend sequence.

FASTER FIELD MEASUREMENTS

Recallable reference waveforms and oscilloscope setups for each test point on a Device Under Test (DUT) can make fault troubleshooting faster and more accurate. A dedicated memory card or floppy disk can hold all of the correct test point waveforms and associated DSO setups for a particular DUT.

The technician can recall stored setups quickly and consistently, thereby avoiding incorrect measurement conditions. He can then compare actual waveforms to recalled reference waveforms taken from a known working system. So the technician needs less knowledge and skill to quickly probe a large number of test points and verify that the correct waveforms exist.

If a problem is found, the aberrant waveform may be saved. It can later be shown to laboratory-based engineers, for example, for problem-solving guidance or for improvement of DUT design. Memory cards, being rugged and shirt-pocket sized, are ideal for this application.

FASTER, MORE REPRODUCIBLE TESTING

LeCroy oscilloscopes can compare measured waveforms against upper and lower waveshape tolerances or against parameter limits, such as rise time, overshoot, or peak voltage, and make PASS/FAIL decisions. This PASS/FAIL testing decreases test times in GPIB-based ATE systems by reducing data transfers. It increases reproducibility and accuracy in manual tests by eliminating human errors.

Once defined, these tests may be saved by storing instrument setups which include the specified tolerances and/or reference waveforms. Different test personnel can easily share a common test library via PC network.

Waveshape test limits can be generated by capturing a "golden waveform" and by then selecting amplitude and timing limits (in fractions of screen graticule divisions). Or a user can create standard waveform limit templates on a computer (e.g., ANSI/CCITT telecommunication templates).

On LeCroy 9300 Series DSOs, specific parameter tolerance test procedures are created by selecting limits for any four out of 32 pulse parameters with Boolean AND or OR conditions between them. During testing, FAIL responses can include an audible beep, GPIB SRQ, hardcopy output, or store to memory card.

SHARED OSCILLOSCOPE RESOURCES

Tired of recovering your precious setup after someone else used your instrument? Just plug-in your *personal* RAM card or floppy and restore your setup in just seconds. Each individual user can keep his own preferred setups on his own floppy disk or RAM card.

Hardcopy Features and Benefits

The internal high resolution graphics printer adds a whole range of benefits to the LeCroy 9300 Series:

- Ultra fast printouts
- High resolution printing
- No-hassle interfacing
- No-hassle carrying

ULTRA-FAST PRINTOUTS

Measurement documentation is made easier - and faster - than ever since the internal printer produces a hardcopy in less than 10 seconds. What's more the document is date- and time-stamped: a real bonus for archiving those test results.

HIGH RESOLUTION PRINTING

With a resolution of 190 dots per inch, the internal printer matches the screen's superior quality, to document the captured traces down to their finest details. And the size of the printout is impressive for a built-in printer: a full 7" diagonal!

Floppy Drive, RAM Card and Printer Specifications

3.5" FLOPPY DRIVE

Type: 3.5 inch floppy drive, DOS format.

Supported disk formats: 720k, 1.44MB.

Maximum transfer rate: 15 kB/sec.

Typical waveform transfer speed:

Waveform file size: A channel-trace will use 1 byte per sample plus approximately 359 bytes of waveform descriptor.
A processed trace will use 2 bytes per sample.

Template size: Approximately 21 kbytes.

Panel setup size: Approximately 3 kbytes.

RAM CARD

Type: PCMCIA 1.0, JEIDA 3.0 & 4.0.

Supported card formats: SRAM for reading and writing, ROM, OTP and FLASH for reading, the driver software supports card sizes up to 8 MB.

Maximum transfer rate: 170 kB/sec.

Typical waveform transfer speed:

Waveform file size: Same as for the floppy.

Template size: Approximately 21 kbytes.

Panel setup size: Approximately 3 kbytes.

PRINTER

Type: Raster printer, thermal.

Resolution: 190 DPI.

Printout size: 126 mm x 90 mm.

Paper: Seiko or compatible thermal printer paper, 30 meter roll, 110 mm width.

Printing speed: Approximately 6 seconds for one screen.

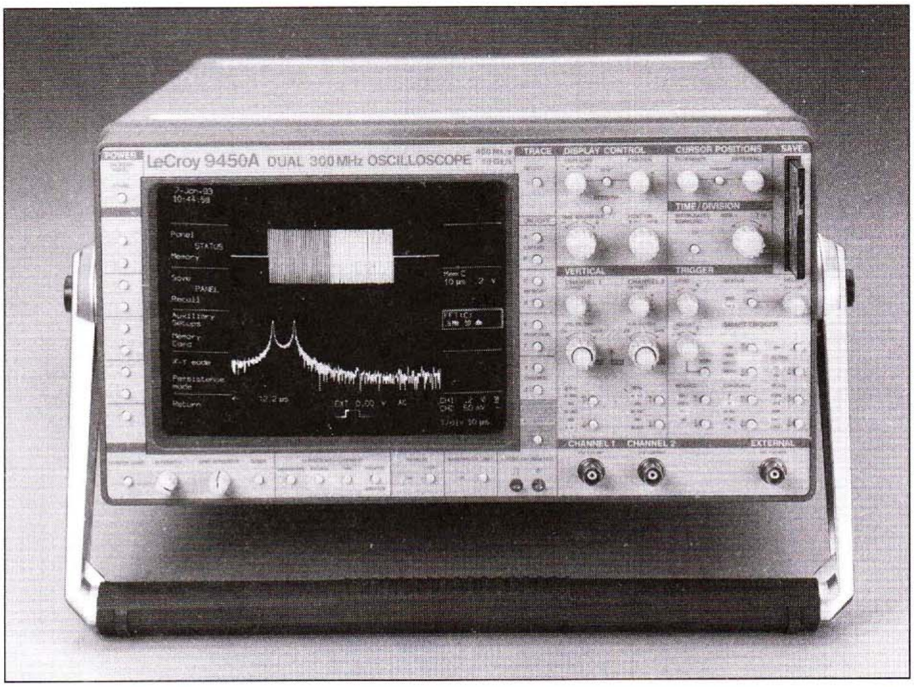
ORDERING INFORMATION

For Ordering Information see Page 4.

9400 Series Portable Digital Oscilloscopes

Main Features

- 8 to 10 bit resolution
- 150 to 350 MHz bandwidth
- 50k memory per channel
- Unmatched display quality with 4096 x 4096 pixels
- Automatic PASS/FAIL testing on templates and parameters
- Segmentable memories with trigger point time stamps
- Signal processing and FFT analysis options
- Optional high speed memory card



The 9450A is shown measuring a frequency shift keyed signal. The FFT of the waveform is shown in the lower trace, indicating peaks at 1 MHz and 1.5 MHz.

The LeCroy 9400 series combines high bandwidth, fast sampling rates, high fidelity, extensive trigger capabilities and signal processing. Aimed at meeting the demands of researchers and engineers working in fields as diverse as telecommunications, electronic design and test, lasers, computers, NDT, physics and defense, these scopes have become an indispensable measurement tool in any laboratory.

Like all LeCroy oscilloscopes, the 9424, 9430 and 9450A are designed to serve as a range of different instruments: oscilloscope, transient recorder, counter/timer, frequency meter, signal averager, data logger and digital voltmeter.

Functional Description

The LeCroy 9450A Dual-channel Digital Oscilloscope is a powerful high-resolution instrument for waveform recording and sophisticated analysis. It provides a bandwidth of 300 MHz, and sampling rates of up to 400 MS/sec for transients and 10 GS/sec for repetitive waveforms. The instrument features high-fidelity, 8-bit ADCs, 50k of non-volatile acquisition memory per channel, 200k of additional waveform storage memory, extensive pulse parameter analysis, and a highly sophisticated trigger system to capture the most complex signals, including spikes and glitches. It is fully programmable over GPIB or RS-232-C interfaces. Hard copies are made at the touch of a button on a wide range of digital plotters and printers.

The 9430 has a similar two channel architecture but offers high resolution 100 MS/s 10 bit ADCs and 150 MHz amplifiers. The 9424 rounds out the 9400 series with a 4 channel 350 MHz 8 bit oscilloscope. Each 9424 input has a 100 MS/s shot ADC which can capture repetitive signals at 10 GS/s equivalent time.

VERTICAL ANALOG SECTION FOR 9424/9450A

Bandwidth (-3 dB):
@ 50 Ω: DC to 350 MHz (9424)
DC to 300 MHz (9450A)

Input impedance: 1 MΩ//30 pF and 50 Ω ±1%.

Channels: Four (9420) or two (9450A) independent channels.

Sensitivity range:
5 mV/div to 2 V/div (9450A)
5 mV/div to 2.5 V/div (9424)

Vertical expansion: Up to 5 times (with averaging up to 10 times or 500 μV/div sensitivity).

Scale factors: Probe attenuation factors of X1, X10, X100, X1000 or X10000 may be selected and are remotely programmable.

Offset: ±12 times the fixed sensitivity setting in 0.02 division increments up to ±10 V max; ±24 div @ 10 mV/div; ±48 div @ 5 mV/div.

DC accuracy: ≤ ±2%.

Bandwidth limiter: 80 MHz (-3 dB) typical.

Maximum input voltage: 250 V (DC + peak AC) at 1 MΩ ±5 V DC (500 mW) or 5 V R.M.S. at 50 Ω.

VERTICAL ANALOG SECTION FOR 9430

Bandwidth (-3 dB): DC to 150MHz.

Input impedance: 1MΩ//25 pF and 50W±1%.

Channels: Two independent channels; standard BNC connector inputs.

Sensitivity range: 1 mV/div to 2.5 V/div; continuously variable from 1 to 2.5 times the fixed setting. Fixed settings range from 1 mV/div to 2 V/div (in a 1, 2, 5 sequence).

Vertical expansion: Up to 10 times (with averaging, up to 50 times or 20 μV/div sensitivity).

Scale factors: Probe attenuation factors of x1, x10, x100, x1000 and x10000 may be selected and are remotely programmable.

Offset: ±12 times the fixed sensitivity setting in 0.02 division increments up to ±12V max.; ±24 div @ 5 mV/div; ±60 div @ 2 mV/div; ±120 div @ 1 mV/div.

DC accuracy: ±1% full scale.

Bandwidth limiter: 15MHz (-3dB) typical.

Max. input voltage: 250V (DC + peak AC ≤10 kHz) at 1 MΩ, ±5V DC (500 mW) or 5V RMS at 50Ω.

VERTICAL DIGITAL SECTION

ADCs: One per channel, 8-bit Flash (9424) and 9450A. 10 bit flash (9430).

Conversion rate: Up to 100 MS/sec for transients (9424 and 9430); 400 MS/s (9450A), up to 10 GS/s for repetitive signals, simultaneously on all channels.

Aperture uncertainty: ±10 psec.

Acquisition memories, Channels 1, 2, (3 and 4): Non-volatile memories (battery backed for a minimum of 2 years) of 50 kilowords per channel can be segmented into 2, 5, 10, 20, 50, 100 or 200 blocks.

Reference memories, C and D: 50k, 16-bit word memories, each storing one acquired or processed waveform, or up to 200 segmented waveforms.

Function memories E and F: Two 50k, 16-bit word memories for waveform processing.

Peak and Glitch Detection

Minimum and maximum peaks as fast as 0.002% of the record length (minimum 10 nsec) are captured and displayed with 100% probability.

Using LeCroy's new FASTGLITCH trigger technique (see the trigger section below), glitches faster than 2.5 nsec can be detected on all time-base settings.

HORIZONTAL SECTION

Time Base

Range: 1 nsec/div to 5000 sec/div.

Clock accuracy: ≤ ±0.01%.

Interpolator resolution: 5 psec.

Sampling clock output: BNC connector on rear panel.

External clock input: BNC connector on rear panel.

Acquisition Modes

Random Interleaved Sampling (RIS): For repetitive signals from 1 nsec/div to 20 μsec/div.

Single shot: For transient signals and repetitive signals from 50 nsec/div to 200 msec/div.

Roll: For slowly-changing signals from 500 msec/div to 5000 sec/div.

Sequence mode: Divides the acquisition memory into 2, 5, 10, 20, 50, 100, or 200 segments.

Horizontal expansion: MULTI ZOOM mode allows different signals or different sections of the same signal to be expanded up to 1000 times.

TRIGGERING

Pre-trigger recording: Adjustable in 0.2% increments to 100% of full scale (grid width).

Post-trigger delay: Adjustable in 0.02 division increments up to 10,000 divisions.

Rate: Up to 500 MHz using HF trigger coupling.

Timing: Trigger timing (date and time) is listed in the memory status menu. The timing of subsequent triggers in sequence mode is measured with 0.1 sec absolute resolution, or nanosecond resolution relative to the time of the first trigger.

Trigger output: BNC connector on rear panel.

Trigger veto: BNC connector on rear panel.

Standard Trigger

Sources: CHAN1, CHAN2, CHAN4, LINE. CHAN1, CHAN2 and CHAN4 have independent trigger circuits allowing slope, coupling and level to be set individually for each source. (CHAN3 is used for TV trigger.)

Slope: Positive, negative.

Coupling: HF, AC, LF REJ, HF REJ, DC.

Modes:

Auto: Automatically re-arms after each sweep. If no trigger occurs, one is generated at an appropriate rate.

Normal: Re-arms after each sweep. If no trigger occurs after a reasonable length of time, the message "No or Slow Trigger" is displayed.

Single (hold): Holds display after a trigger occurs. Re-arms only when the "single" button is pressed again.

Sequence: Stores multiple events in segmented acquisition memories.

SMART Trigger

Single-source trigger operational modes:

Hold-off by time: 25 nsec to 20 sec.

Hold-off by events: 0 to 10^9 events.

Width-based trigger modes:

Pulse width < (FASTGLITCH): Triggers on opposite slopes of pulses narrower than a value in the range 2.5 nsec to 20 sec.

Pulse width >: Triggers on opposite slopes of pulses wider than a value in the range 2.5 nsec to 20 sec.

Interval width <: Triggers on similar slopes of signals narrower than a value in the range 10 nsec to 20 sec.

Interval width >: Triggers on similar slopes of signals wider than a value in the range 25 nsec to 20 sec.

TV: Allows stable triggering on TV signals that comply with PAL, SECAM or NTSC standards. Selection of both line and field number is possible. Active on CHAN3 only (9424).

Multi-source trigger operational modes:

Pattern: Triggers on the logical AND of CHAN1, CHAN2 and CHAN4 (9424), where each source can be defined as high (H), low (L) or don't care (X). The trigger can be selected at the beginning (entered) or at the end (exited) of the specified pattern.

Bi-level: This is a special condition of pattern trigger which allows triggering on any signal that exceeds a certain pre-set high or low trigger level. The signal must be connected simultaneously to two channels. The third trigger channel must be set to don't care (X).

State qualified: Trigger on any source (CHAN1, CHAN2 or EXT), while requiring that a certain pattern of the other two channels is present or absent. In addition, a delay by time or by number of events can be selected from the moment the pattern is valid.

Time/event qualified: Trigger on any source (CHAN1, CHAN2 or EXT), as soon as a certain pattern of the three channels is entered or exited. From the moment of validity, a delay can be defined in terms of time or number of events.

DISPLAY

CRT: 12.5 x 17.5 cm (9" diagonal); vector display.

Resolution: 4096x4096 points.

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

Grid: Internally generated; separate intensity control for grid and waveforms. Single, dual and pulse parameter measurement grid mode.

XY mode: Plots any two sources (Chan1, Chan2, Memory C or D, Function E or F and Expand A or B) against one another. Operates on live waveforms with cursor readout.

Hard copy: Single or multi-pen digital plotters as well as IBM, HP QuietJet, HP ThinkJet, HP LaserJet and EPSON printers can be used to make hard copies of the display. Screen dumps are activated by a front-panel button or via remote control. Plotters supported are: the HP 7400 and 7500 series, Philips PM 8151, Graphtek FP 5301, and compatible models. Plotting is done in parallel with normal operation.

Graphics: All waveforms and display information are presented using vector (linear) graphics. Expanded waveforms use LeCroy's DOT-LINEAR graphics that highlight actual data points and interpolate linearly between them.

Menus: Waveform storage; acquisition parameters; memory status; save/recall front-panel configurations; SMART trigger; waveform parameters; XY mode; RS-232-C configuration; hard copy setup and real-time clock setup; averaging; and arithmetic.

CURSORS

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

Relative voltage: Two horizontal bars measure voltage differences to ±0.1% of full scale.

Absolute time: A cross-hair marker measures absolute voltage versus signal ground, as well as the time relative to the trigger.

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

Pulse parameters: Two cross-hair cursors are used to define a region of interest for which pulse parameters will be calculated automatically.

AUTO-SETUP

Pressing the auto-setup button automatically scales the time-base, trigger and sensitivity settings to display a wide range of repetitive input signals.

Type of signals detected: Repetitive signals with amplitudes between 2 mV and 8 V, frequency above 50Hz and a duty cycle greater than 0.1%.

Auto-setup time: Approximately 1 sec.

WAVEFORM PROCESSING

Waveform processing routines are called and set up via menus. These include arithmetic functions (add, subtract and invert), and summation averaging (up to 1000 sweeps).

Pulse parameters: Based on ANSI/IEEE Std 181-1977 "Standard on Pulse Measurement and Analysis by Objective Techniques". The terminology is derived from IEEE Std 194-1977 "Standard Pulse Terms and Definitions".

Automatic measurements determine:

Maximum	Period
Minimum	Pulse Width
Mean	Rise Time
Standard Deviation	Fall Time
RMS	Delay

Sources: Chan1, Chan2, Memory C or D, Function E or F, Expand A or B.

Cursors define the measurement zone. When more than one pulse is present in the measurement zone, averaged results for period, width, rise time and fall time are presented.

REMOTE CONTROL

Front-panel controls, including variable gain, offset, position controls and cursors, as well as all internal functions are programmable.

RS-232-C port: For computer/terminal control or plotter connection. Asynchronous up to 19200 baud.

GPIB port: (IEEE-488) Configured as talker/listener for computer control and fast data transfer. Address switches on rear panel.

Local/remote: Remote control can be interrupted for local (manual) control at any time (except when in remote control with the lock-out state selected) by pushing a button on the front panel.

PROBES

Model: Two 94XX-P01 (x10,10 MΩ//15 pF) probes supplied.

Probe calibration: 1 kHz square wave, 1 V p-p.

Probe power: Two rear-panel power outlets for use with active probes provide ±15V, +5VDC.

SELF TESTS

Auto-calibration ensures specified DC and time accuracy.

GENERAL

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

Humidity: < 80%.

Power required: 110 or 220VAC, 45 to 440Hz, 150W.

Battery backup: Lithium batteries maintain front-panel settings and waveform data for 2years.

Dimensions: (HWD) 19.2x37x49.5cm, (7.5x14.5 x19.5 inch).

Weight: 15kg (33lbs)net, 20kg (44lb)shipping.

Warranty: 2 years.

ORDERING INFORMATION

For Ordering Information see Page 34.

LeCroy 9400 Series Portable Digital Oscilloscopes

Specifications	9450A	9430	9424
Bandwidth	300	150	350
Sampling Rate			
- Single Shot (MS/s)	400	100	100
- Repetitive (GS/s)	10	4	10
Vertical Sensitivity/Div.	5 mV - 2V	1 mV - 2.5 V	5 mV - 2.5 V
Number of Channels	2	2	4
Memory per Channel	50k	50k	50k
Triggers per Sweep	1 - 200	1 - 200	1 - 200
Vertical Resolution	8 bits	10 bits	8 bits
Enhanced Resolution	+3 bits (+5 bits with averaging)		
Mask/Parameter Testing	On pulse parameters and signal shape		
Cursor Delimited Parameters	Up to 20 selectable, live-updating		
Cursors	Absolute & relative, time & voltage with crystal precision		
Trigger Modes	Holdoff, glitch, pulse/interval width, TV, bilevel, dropout 3 input qualified		
Signal Processing	Add, subtract, invert, average 1,000 times		
Processing Options	Arithmetic functions, fast Fourier transforms (FFT)		
Page #	30	30	30

9400 Series Ordering Information

Model:

9424	4 Ch 350 MHz 100 MS/s DSO with 50k Memory/Channel and External Trigger
9430	2 Ch 150 MHz 10-Bit 100 MS/s DSO with 50k Memory/Channel
9450A	2 Ch 300 MHz 400 MS/s DSO with 50k Memory/Channel
9424-OM	9424 Operator's Manual Included with 9424
9424-SM	9424 Service Manual
9430-OM	9430 Operator's Manual Included with 9430
9430-SM	9430 Service Manual
9450A-OM	9450A Operator's Manual Included with 9450A
9450A-SM	9450A Service Manual

Options:

94XXWP01	9400 Series Waveform Processing Advanced Math Option
94XXWP01/02	9400 Series Waveform Math and FFT
94XXWP02	9400 Series Spectrum Analysis FFT Option
94XX-MC01/04	Memory Card Reader w/512k Card For 9400 Series
94XX-MC02	128k Memory Card
94XX-MC04	512k Memory Card
94XX-IA1/110	Isolation Amplifier (10x)
94XX-IA2/110	Isolation Amplifier (10x, 1x, 100x)

Accessories:

94XX-MC-TC1	Memory Card Telecom Template
OC9002	Oscilloscope Cart for 9300, 9400 and LS140 Series Compatible with FD/GP Option for 9300
RM9400-SERIES	Scope Rackmount Adapter 9400 Series - with front panel switch
SG9001	Overload Protector for High Voltage
TC9001	Hard Carrying Case for 9400 Series Scope
TC9002	Soft Carrying Case for 9400 Series Scope

Warranties/Calibrations:

94XX-CC	NIST Calibration on any 9400 Series Scope, at time of purchase
94XXC5	5 NIST Calibrations on any 9400 Series Scope
94XXCM5	5 MILSTD Calibrations on any 9400 Series Scope MILSTD 45662A Calibration
94XX-EW	1 Year Extended Warranty Includes NIST Calibration

ScopeStation 140 Portable Digital Oscilloscope 100 MHz Bandwidth, 200 MS/sec, 4 Channels

Main Connectivity Features

- Direct FAX output of waveforms, measurements and screen display (U.S. only)
- Ethernet compatibility
- Waveform and measurement data to spreadsheet and database files
- Standard RS-232C and Centronics interfaces
- Fully programmable over GPIB 488.2 interface
- SCPI command set compatible
- 3.5" floppy disk drive for DOS compatible file storage
- Direct hard copy output to a wide range of devices

Main Scope Platform Features

- Record lengths to 20,000 samples per channel
- Pass/fail testing and baby-sitting operations
- Optional internal 100 MByte hard disk for data storage/recall
- Cascade display up to 24 traces
- Smart Probe™ for remote operation from the probe
- Smart Trigger ™ for capturing and displaying complex signals
- Alias protect acquisition mode
- 2 year warranty

ScopeStation 140 . . . A New Measure In Connectivity

Setting a new standard for problem solving, this exciting new platform combines powerful connectivity features with a precision digital oscilloscope. Putting your measurement results to work has never been this easy and flexible. Now with the push of a button, you can transfer waveforms, measurements, and display information to fax, Ethernet Network, spreadsheet files, DOS-compatible floppy disks, or word processing documents.

The powerful connectivity features of the ScopeStation 140, integrated into a state-of-the-art digital oscilloscope, provides never before available solutions to your toughest testing, servicing, and remote monitoring tasks.

Data capture and archiving, statistical analysis, automated and semi-automated testing can be performed from a single instrument with repeatability and ease, improving throughput in manufacturing test. ScopeStation 140 is fully programmable over RS-232 or optional GPIB so it can become a powerful addition to your test systems.

ScopeStation provides test data in spread sheet files and is network compatible. Capture the data and transfer it to your network to develop a statistical data base to pinpoint opportunities to streamline your process and improve your cost of manufacturing.

For service applications in the lab and in the field, troubleshooting procedures can be sequenced through at the push of a button on the Smart Probe. Waveform or measurement data can be saved to disk, network, or faxed directly to other locations improving communication, reducing down time, and improving average time to repair.

In remote monitoring applications, ScopeStation's pass/fail testing combined with direct fax output provides the perfect solution to monitoring critical equipment at remote locations. When a failure occurs, ScopeStation will date and time stamp the data and automatically fax it. No more trips wasted or data missed. ScopeStation provides the critical information you need to make a decision, fast!

ScopeStation 140 opens the door to a revolution in problem solving never before available in a single instrument.

THE DIGITIZING ADVANTAGE

The ScopeStation 140 delivers capture and analysis capabilities for signals up to 100 MHz in frequency. Data is acquired through four channels with two precision 8-bit flash ADCs at rates up to 200 MS/sec for single shot events and up to 8 GS/sec for repetitive signals. The alias protect mode processes data from the ADCs at the full 200 MS/sec speed to provide alias protection for signals up to 100 MHz. Using alias protect mode, any glitch greater than 10 nsec can be displayed on any time/division range.

THE SETUP ADVANTAGE

Pressing the Auto Setup button automatically scales the timebase, trigger, and vertical sensitivity settings to provide a stable display for a wide range of repetitive input signals.

Setups can be easily saved and recalled from floppy disk allowing rapid setup. To make vertical setup easy for standard logic signals, there are built-in presets for TTL, ECL, and CMOS logic signals.

THE SMART TRIGGER™ ADVANTAGE

Using SMART Trigger you capture and see exactly what you want to see. SMART Trigger provides a glitch trigger to trigger on glitches as small as 10 ns. TV trigger provides triggering on NTSC, PAL, and SECAM signals. The SMART trigger hold-off mode allows the trigger to be held off either by time or by events.

THE DISPLAY ADVANTAGE

The bright 9" high resolution display makes measurements easy to read with display modes to suit your application. The cascade display illuminates timing problems and bit patterns by displaying up to 24 traces on one screen. A choice of single, dual, and quad grids makes separating channels and traces easy.

The XY display plots any two traces against each other. The persistence mode shows traces as they accumulate over time. A connection is even provided for an external VGA-compatible monitor.

THE PROCESSING ADVANTAGE

Waveform processing, which includes zoom, arithmetic functions (add, subtract, and invert), summation averaging, continuous averaging and smoothing is standard. Smoothing provides up to 11-bits of resolution. Summation and continuous averaging help reduce noise.

THE DATA OUTPUT ADVANTAGE

ScopeStation's connectivity features make putting your data to work simple. With direct fax output, you can fax waveform displays, measurement results and scope setup information anywhere in the world at the push of a button.

With Ethernet compatibility, ScopeStation becomes an integral part of your network. Now, in manufacturing test, you can download test procedures to ScopeStation from the network assuring version control and process integrity. Bidirectional file transfer provides waveform data, measurement results and scope setup files to the network disk, printer, or plotter.

The DOS compatible 3.5" floppy drive makes it easy to carry stored setups, waveforms, and measurements in your shirt pocket. There is no need to write a GPIB program to get data on to your PC. Just save the waveform on the floppy disk. Insert the disk in your PC and retrieve the data.

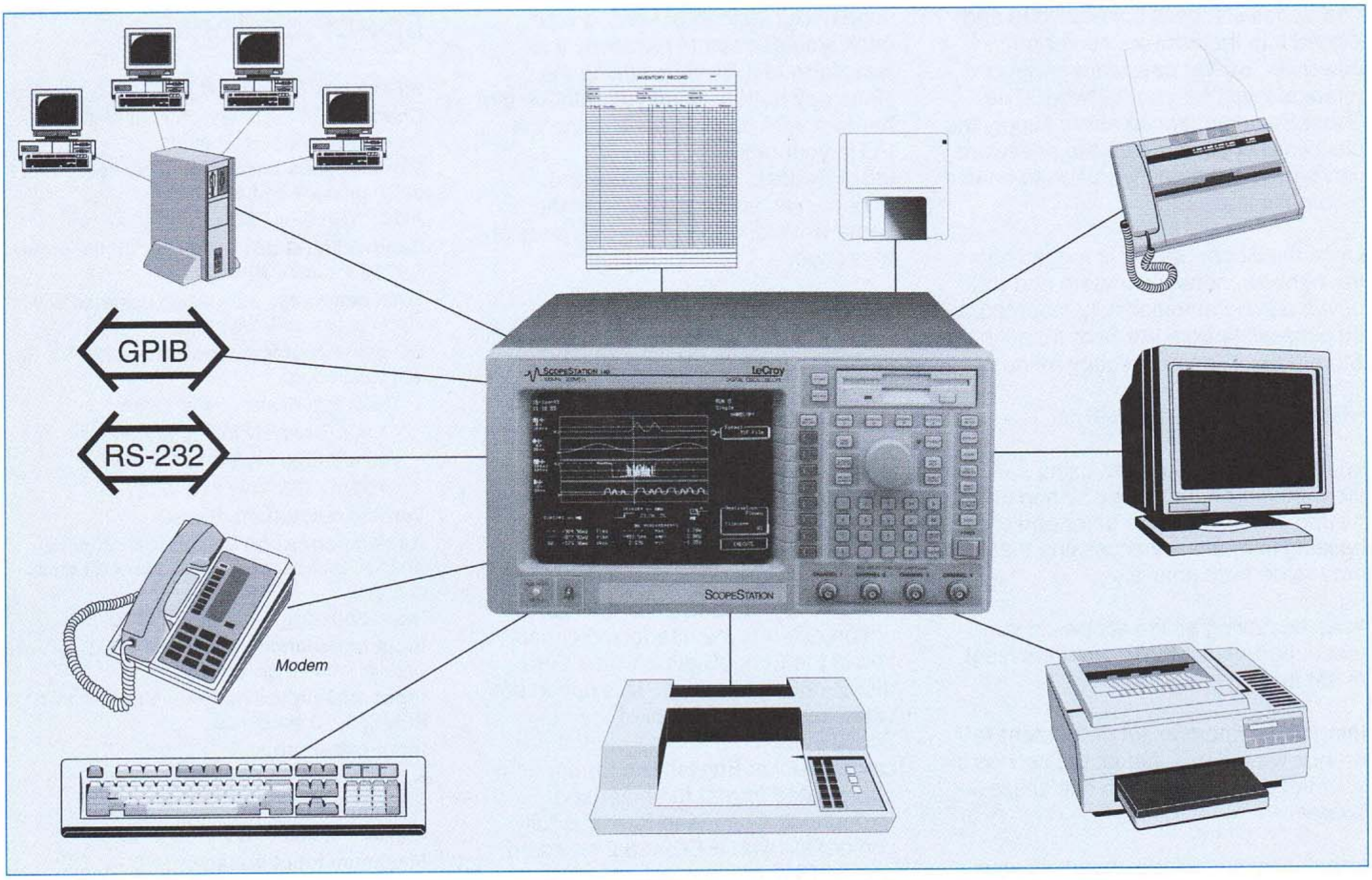
Data can be saved and communicated in a number of convenient formats. The formats allow easy data import into PC-based applications such as spreadsheets, database, desktop publishers, math packages, simulation tools, etc. The parallel, serial, and (optional) GPIB ports connect directly to printers, plotters, and computers for hardcopy and remote control.

THE MEASUREMENT ADVANTAGE

Eighteen waveform measurements are available for display and remote read out. Up to six of the measurements may be selected for live updates. The measurements may be calculated on live, stored, expanded, or processed waveforms. The measurements may be calculated on the entire record or on a region of the record gated by the cursors. Four cursor types are available for manual waveform measurements and marking regions of interest. To make analysis of standard logic signals easy there are built-in cursor thresholds for TTL, ECL, and CMOS logic levels.

THE SMART PROBE™ ADVANTAGE

SMART Probe provides finger tip control over common front panel operations. You never need to take your hands off the probe to change a setting, freeze the display, or plot a hard copy. Front panel operation can be tied to the SMART Probe for finger tip control.



ScopeStation's direct fax output, Ethernet compatibility, GPIB, and other connectivity features help you get the data out of your oscilloscope and working to solve your toughest testing, servicing, and monitoring tasks.

THE SMART PROBE ADVANTAGE

SMART Probe provides finger tip control over common front panel operations. You never need to take your hands off the probe to change a setting, freeze the display, or plot a hard copy. Front panel operation can be tied to the SMART Probe for finger tip control.

Ethernet Network Option

- Network store and recall of waveforms and setups.
- Hardcopy to network printers and plotters
- Store data from several ScopeStation scopes to a common net work drive making it easy to gather test results every station in the lab.
- Share waveforms and setups between ScopeStation scopes using the network disk.
- Keep "Golden" reference waveforms on the network that are accessible to all ScopeStation scopes.
- Change setup files once on the network to change the test setup used by all ScopeStation scopes.
- Share data between the ScopeStation and any PC on your network without writing a GPIB program or using a floppy disk.

The LeCroy ScopeStation-LS-NET option extends the interfacing capabilities of the ScopeStation with an Ethernet interface for Novell Networks. The LS-NET option provides bidirectional file transfer between the ScopeStation and the network server and ScopeStation access to network printers. The LS-NET configures the ScopeStation as a client on an Ethernet network with a Novell server allowing ScopeStation users to store and recall waveforms and setups using the network server. The network server disks are treated as if they were local disks within the ScopeStation.

The ScopeStation is connected to and logged into the network server on power up. Server password protection remains intact for your network. The ScopeStation user can either supply the password at power up or the password can be set in the configuration to enable automatic login.

Once the ScopeStation is logged into the network, network printers and disk drives can be automatically mounted to be accessible from the ScopeStation Store, Recall, and Hardcopy menus.

NETWORK APPLICATIONS

Imagine saving your data using the store button on the ScopeStation and having someone at the other end of the building immediately accessing that data to perform analysis.

Imagine having all the scopes in your test department access a common set of setups.

Imagine having one set of "golden" reference waveforms that all the scopes in your lab can access from one single source.

Imagine having all the scopes in your test department run semi-automated tests from a single set of test routines. There is never the chance that two scopes are running two different versions of the test.

Imagine upgrading the semi-automated test code for all the scopes in your lab by changing the code in only one place.

Imagine gathering data from all the scopes in your lab without ever writing a GPIB program or ever needing a floppy disk.

Imagine having your entire lab store test data to one area by simply pressing the ScopeStation front panel "Store" button.

Imagine having all the scopes in your lab use one printer and that printer is a laser printer. Never again share a GPIB printer between stations.

Imagine having a test technician call you to come look at a waveform on his scope. But instead of leaving your desk, you ask him to hardcopy the waveform to a file by pressing the Hardcopy button. Then you retrieve the hardcopy file and display it using the PC in your office. You never left your desk, never hung up the phone. Yet, you are looking at the same waveform the technician sees on his scope.

GPIB Option

- IEEE 488.2 compatible
- Full remote control
- Hardcopy to GPIB printers and plotters
- SCPI command set compatible

The LeCroy ScopeStation 140 GPIB option extends the interfacing capabilities of the ScopeStation with a GPIB (IEEE-488.2) interface. This option provides full remote control of the ScopeStation. All remote commands can be sent in English like format or in abbreviated format for increased throughput. Command format is fully compatible with IEEE-488.2 standard and SCPI command set. Commands control all aspects of the ScopeStation including all settings, acquisitions, processing, and measurements.

When using Remote Commands from the GPIB bus it is possible lock out the front panel operation to prevent accidental changes to settings or the front panel may remain fully active with front panel commands immediately removing the ScopeStation from Remote Mode.

Using the ScopeStation-GPIB option it is possible to perform hardcopies to GPIB printers and plotters. It is also possible to rapidly transfer data from the ScopeStation to a GPIB controller.

Because LeCroy understands it is often difficult to understand exactly what each Remote command does, a GPIB utility program is provided which allows the user to send commands and queries and receive answers and data using an IBM PC compatible computer without ever writing a single line of program

Specifications

SIGNAL ACQUISITION SYSTEM

Channels: 4 full channels in random interleaved sampling (RIS) mode.

Simultaneous channels: Channels 1 and 2 or Channels 3 and 4.

ADC: Two 8-bit Flash.

Bandwidth (-3 dB): 100 MHz (at the probe tip), 10 mV/div - 10 V/div.

Total accuracy: ±2% when operated within 10° C of last self-calibration.

DC gain accuracy: Specified within 10° of last calibration.

1% of Full Scale +1% of Offset
+1 mV (5 mV/div to 100 mV/div)
+10 mV (200 mV/div to 1 V/div)
+100 mV (2 V/div to 10 V/div)

Vertical resolution: 8 bits.

Analog bandwidth selections: 20 MHz and full. Independently selectable for each channel.

Input coupling: AC, DC, or GND.

Input impedance selections: 1 MΩ ±1% in parallel with 20 pF ±10%.

Input attenuation ranges: 5 mV/div to 10 V in 1, 2, 5, 10 sequence.

Input offset range:
> ±1 V from 5 mV/div to 100 mV/div
> ±10 V from 200 mV /div to 1 V/div
> ±100 V from 2 V/div to 10 V/div

Maximum input voltage: ± 400 V, DC + peak AC (maximum 10 kHz).

Channel isolation: > -40 dB at 25 MHz, for channels set to same V/div.

AC coupled low frequency limit: 10 Hz ± 1 Hz

ACQUISITION MODES

Alias protect: Alias protect acquisition, high frequency, and glitch capture. Captures glitches as small as 10 nsec on (real time) time/div settings.

Sample rate: Maximum real-time sample rate 200 MS/sec. In random interleaved sampling mode (RIS), 8 GS/sec maximum on 5 nsec to 0.1 µsec/div ranges. Disengages alias protect operation.

Envelope: See Waveform Processing.

Average: See Waveform Processing.

Smoothing: See Waveform Processing.

TIME BASE SYSTEM

Sampling rate: Single shot - 200 MS/sec. Repetitive - 8 GS/sec.

Time per division range: 5 nsec to 50 sec/div.

Timebase accuracy: < ±0.01%.

Record length: 2k samples per channel, 20k (Optional).

Pre-trigger selectable from: 0 to 100% of record length with sample point resolution.

Delay: 0 to 10,000 divisions with sample point resolution.

TRIGGER SYSTEM

Triggers: Edge or Smart Trigger.

Main trigger modes: Auto, normal, single.

Coupling: DC, DC bandwidth limit, AC, AC bandwidth limit, LF reject, LF reject bandwidth limit, HF reject.

SMART TRIGGER

Hold-off by time: 40 nsec to 80 sec (resolution of 20 nsec).

Hold-off by events: 1 to 10^9 (> 40 nsec apart).

TV trigger: Stable triggering on TV signals that comply with PAL, SECAM, NTSC standards. Selection on both line and field number.

Glitch and width: Trigger on pulse width > or < the operator set limit. Trigger on glitches as small as 10 nsec.

Width > (10 nsec to 20 sec).
Width < (10 nsec to 20 sec).
Resolution: ±1 ns +15% of setting.
Rearm time: 30 nsec.

Interval: Trigger on pulse distances < or > the operator set limit.

Interval > (30 nsec to 20 sec).
Interval < (10 nsec to 20 sec).
Resolution: ±1 ns + .05% of setting.
Rearm time: 30 nsec.

Dropout: Trigger whenever the input signal does not occur for longer than an operator selectable timeout.

Trigger on dropout: (30 nsec to 20 sec).
Resolution: ±1 ns +0.05% of setting.
Rearm time: 30 nsec.

DISPLAY

Waveform style: Dots, vectors, or infinite persistence.

Graticule style: Full, border, and crosshair.

Graticule type: Single, dual, quad, single and XY, full screen XY, up to 24 trace cascade.

Format: YT, XY, YT and XY simultaneously.

CURSOR MEASUREMENTS

Cursor types: Amplitude, time, attached, logic level.

Attached: Two cross-hair markers measure time relative to the trigger, time relative to each other. Absolute voltage relative to signal ground, and voltage relative to each other.

Time: Two vertical bars provide relative and absolute time and frequency measurements.

Amplitude: Two horizontal bars measure relative time and frequency.

Logic level: Four horizontal bars mark the levels for VIL, VIH, VOL, VOH. The logic cursors may be preset for: TTL, ECL, 5 V CMOS, 10 V CMOS, and 15 V CMOS logic.

AUTOMATIC MEASUREMENTS

Automatic measurements are based upon the ANSI/IEEE Standard. The following eighteen measurements are standard of which any six may be displayed in a live updating fashion.

Amplitude	Base
Delay	Duty Cycle
Fall Time	Frequency
Maximum	Mean
Minimum	Overshoot Positive
Overshoot Negative	Period
Peak-to-Peak	Rise Time
RMS	Top
Width Positive	Width Negative

WAVEFORM PROCESSING

Arithmetic operators: Add, subtract and invert.

Averaging: Summation averaging of waveform data selectable from 1 to 1,000 sweeps. Continuous averaging.

Smoothing: Adjacent sample averaging of data using windows of 3, 5, 7, 25, 49 or 55 samples.

Envelope: Capture and view glitches of 10 nsec or greater in duration with 100% confidence. Assures against display of aliased waveform.

Floor: MIN values acquired over 1 or more acquisitions.

Roof: MAX values acquired over 1 or more acquisitions.

Zoom: Zoom feature allows waveforms to be expanded, compressed, and positioned both horizontally and vertically.

HARDCOPY

Printers: Canon BubbleJet, Epson MX, Epson FX, Epson LQ, HP-ThinkJet, HP-DeskJet, HP-LaserJet.

Plotters: HPGL, HP74XX, 75XX, 7475A, ColorPro

Graphics formats: PCX, TIFF, BMP

Data formats: ASCII, MathCad™, PSPICE™, Spreadsheet.

STORAGE

Floppy disk: 3.5" 1.44 Mbyte DOS format used for storing setups, waveforms, and hardcopy output.

COMPUTER INTERFACES

Centronics parallel standard: Hardcopy.

RS-232C standard: Remote control of modes, settings, and measurements; hardcopy.

GPIB IEEE 488.2 (optional): Fully programmable talk and listen modes; full remote control; hardcopy.

POWER REQUIREMENTS

Line voltage range: 90-137 V rms or 180-265 V rms switchable.

Power consumption: 280 Watts maximum, 200 Watts (typical)

SCOPESTATION 140 INCLUDES

Four 10x Scope Probes
Operators Manual
Getting Started Guide
2 Year Warranty
Power Cord
One Install Disk

GPIB Option

HARDWARE SPECIFICATIONS

GPIB (IEEE-488.2) Compatible Interface Card. SCPI-compatible command set.

REMOTE CONTROL

GPIB port is configured as a Talker/Listener for computer control and fast data transfer. GPIB port is configured as a Talker Only for Hardcopy

REMOTE HARDCOPY

Hardcopy to any of the ScopeStation supported printers and plotters that have a GPIB interface.

Printers: HP-ThinkJet, HP-DeskJet, HP-LaserJet, Epson FX, Epson MX, Epson LQ.

Plotters: (HPGL), HP74XX, 75XX, 7475A, and ColorPro.

DATA TRANSFER

Formats: Binary, ASCII, TIFF, PCX, HPGL, Spreadsheet, P-Spice, MathCad, BMP.

Maximum block transfer speed: 200 kbytes/sec.

GPIB UTILITY SOFTWARE

GTALK Software for IBM PC compatible computers with National Instruments GPIB PC2, PC2A, or PC-AT GPIB Cards. This software utility sends and receives commands on the GPIB bus.

Ethernet Network Option

HARDWARE SPECIFICATIONS

Ethernet Interface Card configurable for 10Base5 (Thick Ethernet) or 10Base2 (Thin Ethernet) connections.

NETWORK REQUIREMENTS

Network server running Novell Netware version 2.XX or 3.XX.

NETWORK REMOTE CONTROL

The LS-NET option does not provide network remote control of the ScopeStation.

NETWORK HARDCOPY

Hardcopy to any of the ScopeStation supported printers and plotters over the network.

Printers: HP-ThinkJet, HP-DeskJet, HP-LaserJet, Epson FX, Epson MX, Epson LQ.

Plotters: (HPGL), HP74XX, 75XX, 7475A, and ColorPro.

NETWORK STORAGE

Waveforms can be stored or hardcopied to a file on a network drive. Storage and hardcopy to a network drive are treated as if the network drive were a built in hard disk. The drive and directory can be specified during the store or hardcopy to a file operations.

Storage formats: Binary, ASCII, TIFF, PCX, HPGL, Spreadsheet, P-Spice, MathCad, BMP.

NETWORK RECALL

Waveforms and setups may be recalled from a network drive. During recall the network drive appears as same as an internal disk drive. The network drive and directory can be specified during the recall operation.

Recall formats: Binary.

DISTRIBUTION DISKETTE FORMAT

All software supplied with the ScopeStation-Network1 interface is provided on 3 1/2" DOS formatted floppy disks.

ORDERING INFORMATION

Instrument Options

LS-FAX	Direct fax output (available in U.S. only)
LS-NET	Ethernet interface
LS-GPIB	GPIB interface
LS140-L1	Advanced Data Storage Option: Includes Hard Disk and 20,000 sample acquisition memory.
PP050	10:1 probe
PP051	SMART probe

Accessories

LS-RM	Rackmount kit
LS-OM	Operator's manual
LS-GS	Getting started guide
LS-SM	Service manual
LS-CART	Oscilloscope cart
LS-FC	Front cover
LS-TRANS	Transit case
LS-SOFT	Carrying bag
DC/GPIB	2 meter GPIB cable

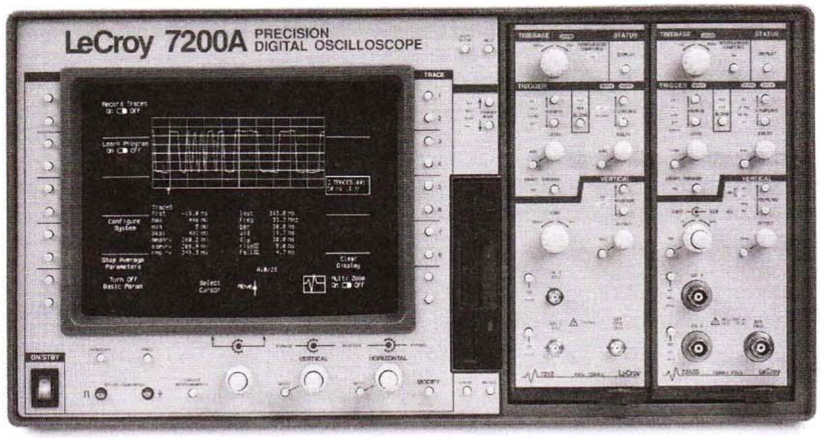
7200A Modular Digital Oscilloscopes System

Main Features

- Modular for flexibility
- True "multiple timebase" operation
- Internal hard disk for data logging
- Floppy disk for waveform storage
- Over 70 pulse parameters
- Over 40 processing functions
- Custom PASS/FAIL testing
- Spectrum analysis - up to 50K point live FFT's
- Statistics, including histograms and trends
- Up to eight "chainable" processing operations
- Instrument Control Language (ICL) for high speed, user customized internal processing and decision-making. Includes "learn" mode.
- High resolution color display

PERFORMANCE

The LeCroy 7200A Series is the most powerful and flexible digital oscilloscope available today. It has a modular architecture throughout. Through exchange of digitizing plug-ins, wide ranging acquisition performance is achieved. For instance, 2 GS/sec real time sampling rates are possible into memories as long as 1 megaword while at the same time the user can look at a repetitive signal with 4 GHz bandwidth. Similarly, 8 channels of real time data can be acquired simultaneously at 500 MHz bandwidth.



With the 7200A's internal command language (ICL), added to this, the 7200A becomes an advanced measurement workstation, providing answers and decisions, not just data and displays.

PERFORMANCE TO SUIT A HOST OF APPLICATIONS

With its straight-forward internal command language, the 7200A adapts to different measurement, automation and analysis tasks easily by just calling programs from the internal hard disk. A few examples of application benefits from this state of the art performance are:

Disk Drive Testing: Store and analyze complete tracks from hard disks.

Time of Flight Spectroscopy: Long drift times, high sampling rates, and fast averaging fit the demands of modern spectroscopy technology.

Electromagnetic Compatibility: Fast single events can be acquired and analyzed over multiple channels. Old signals can be retrieved from hard disk or floppy for comparison with current signals.

Communications: Modern LAN and PCM links run at several hundred megahertz speed.
Imaging and Displays: Full pictures can be stored in one record, facilitating CCD and plasma design and test.

Pulsed Echo Events: Radar, lidar, and ultrasonic testing benefit from high timing resolution over long durations.

THE 7200A - TARGETED FOR YOU...

Where customized measurements need be established and run automatically at high throughput rate;

Where internal processing, data archiving, and data transfer are crucial in conjunction with high speed measurements;

Where histogramming and trending are useful in addition to time and frequency domain analysis;

Where real time digitizing at rates of 1 GS/sec or more are required over time periods up to a millisecond.

7200A Series Digital Oscilloscopes

BASIC PARAMETER MEASUREMENTS

One of a digital oscilloscope's most powerful capabilities is its ability to make precision measurements on live, processed or stored waveforms. The LeCroy 7200A offers the most extensive set of measurements which can be accessed via on-screen displays, internal, or external control programs.

For time domain waveforms, the 7200A computes and displays the following 14 parameters for the section of the selected trace between the cursors:

first	maximum
minimum	peak-to-peak
mean	standard deviation
root mean square	last
frequency	period
width	delay
rise time	fall time

Figure 1 illustrates the display of measured parameters automatically positioned to not interfere with the waveform display.
For frequency domain waveforms, the 7200A computes and displays the following 6 parameters for the section of the selected trace between the cursors:

first	maximum
frequency at maximum	last
frequency at minimum	total power

For histogram waveforms, the 7200A computes and displays the following 13 parameters for the section of the selected trace between the cursors:

first	maximum
minimum	peak-to-peak
histogram standard	deviation
histogram root mean	square
full width at half max	last
mean	median
mode	total population
maximum population	

EXTENDED PARAMETERS

This measurement mode allows the operator to select up to 20 parameters out of a list of more than 69 and apply them to a user-selected combination of traces. This allows, for instance, the same parameter to be calculated for several traces as well as different parameters for each trace. See Figure 2.

The waveform parameters available are described below. The parameters are grouped according to the types of waveforms on which they operate: General (all types of waveforms), Time Domain, Frequency Domain, and Histogram parameters.

General Parameters

acquisition duration	data
date	first
last	points
time	

Time Domain Parameters

amplitude	area
base	cycles
delay	dnl
duty cycle	fall time
frequency	inl
local minimum	local pk-to-pk
local time between peaks	local time between troughs
local time at minimum	local time at maximum
local time-over-threshold	local time-under-threshold

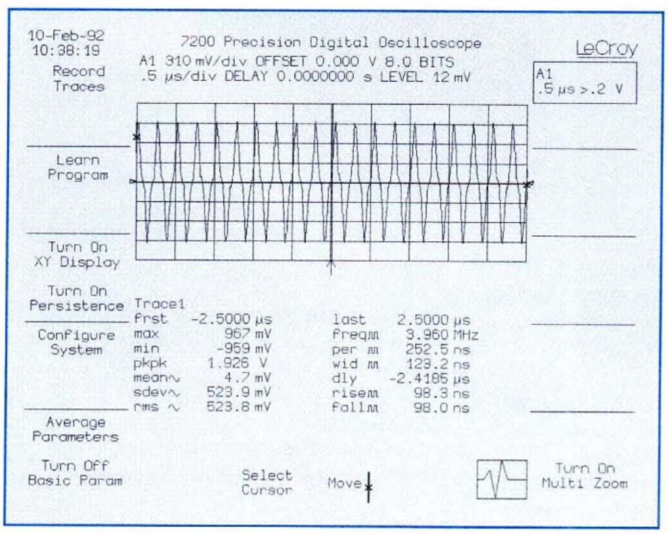


Figure 1

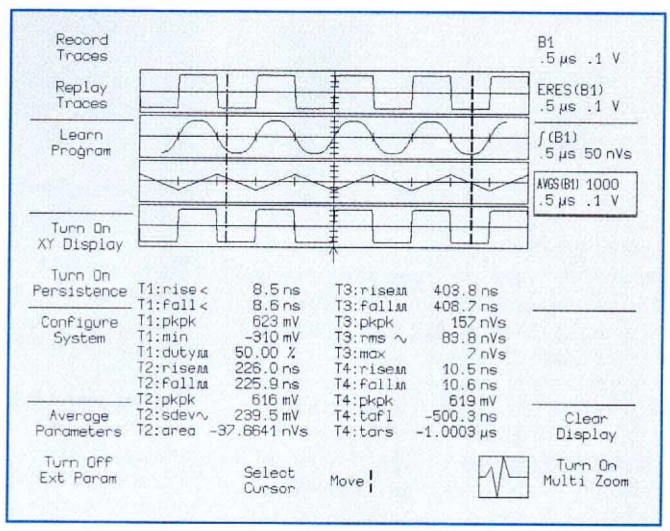


Figure 2

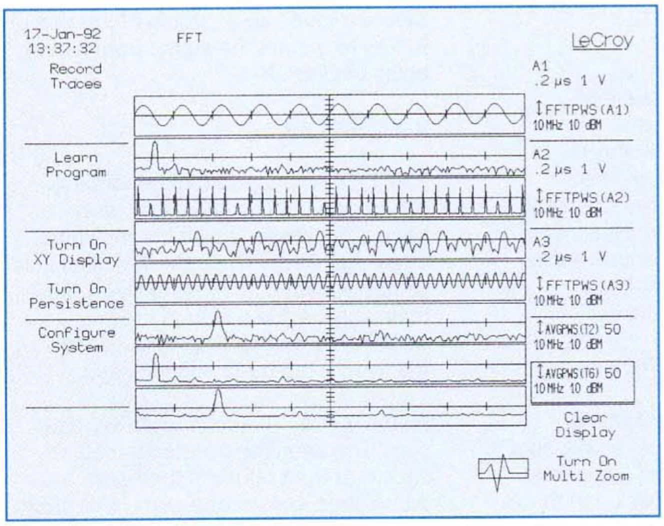


Figure 3

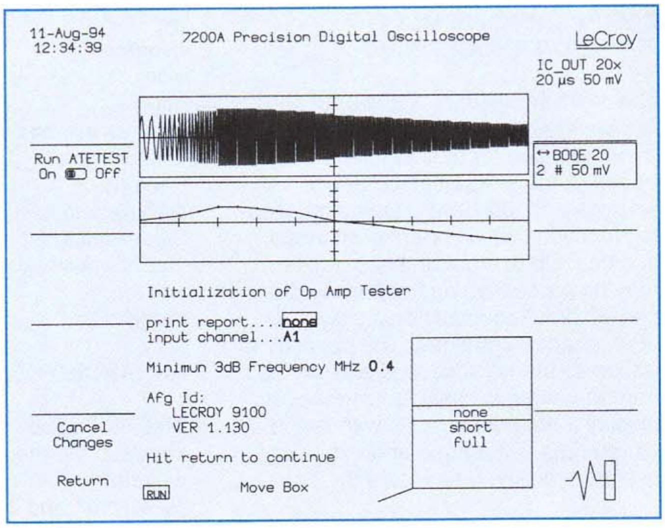


Figure 4

maximum	mean
median	minimum
mode	narrow-band phase
narrow-band power	overshoot negative
overshoot positive	peak-to-peak
period	rise time
root mean square	standard deviation
time at fall	time at maximum
time at minimum	time at rise
top	width

Frequency Domain Parameters

maximum	frequency at maximum
noise power	frequency at minimum
total power	

Histogram Parameters

amplitude	base
full width at half max	full width user-specified
maximum	maximum population
mean	median
minimum	mode
percentile	peak-to-peak
peaks	histogram root mean square
population	
top	histogram standard deviation
user-specified peak	

FREQUENCY DOMAIN PROCESSING

The 7200 series provides powerful Fast Fourier Transform (FFT) processing facilities for display and analysis of signals in the frequency domain from up to 8 sources.

Data sources may be up to 50,000 points from live inputs, traces stored on hard or floppy disk, or traces which have been processed by other functions. This capacity and flexibility gives the 7200A a unique capability for simultaneously displaying multiple signals in both the time and frequency domains. For instance, it is possible to display the time data simultaneously with its power spectrum (FFTPWS), the power spectrum of signal averaged or enhanced resolution time data, the average of the power spectrum (AVGPWS), FFTs with varied horizontal resolutions, FFTs with different window functions, the phase, and real or imaginary parts, etc.

HISTOGRAMMING AND TRENDING

A histogram is a graph of the number of occurrences of a measured parameter. The 7200 series can generate the histogram of any pulse parameter from either the basic or the extended pulse parameter sets.

Once a histogram is accumulated, basic measurement parameters may be applied to the histogram, just as this would to a time or frequency domain waveform.

TRENDS PERMIT STATISTICAL HISTORY TO BE EVALUATED

The 7200A allows the user to see and analyze "trends", i.e., the history of specific characteristics associated with waveform measurements. For instance, parameter values taken over time can be stored and displayed along a time axis. "Pulse parameters" can then be applied to this trend.

Figure 4 illustrates a swept frequency sine wave as the input to an operational amplifier and the trend of the amplitude has been developed (top trace). From this data the plot of amplitude versus frequency was computed (bottom trace) and thus the bode plot or the frequency response of the amplifier is shown. This is used to determine if the amplifier meets its bandwidth specification and is an example of how the 7200A can be used as a network analyzer.

COMPREHENSIVE MULTI-FUNCTION PROCESSING

The 7200 series uses a powerful and flexible mathematical format called a trace equation for defining up to 8 traces. A trace equation contains sources and, optionally, signal processing functions which operate on those sources. Up to eight of these traces may be processed and optionally displayed simultaneously on a single, dual, quad or octal grid. The capacity to define so many processed waveforms from the same or multiple sources and display them concurrently with live or stored data is a unique and extremely powerful facility. See Figure 5.

Processing functions that may be applied to the selected traces include the following.

absolute value	average magnitude
average power density	average power spectrum
average segments	continuous average
derivative	enhanced resolution
extrema	extrema sequence
FFT, power spectrum	FFT, power density
FFT, magnitude	FFT, phase
FFT, real part	FFT, imaginary part
FFT, real and imaginary part	floor
histogram	integral
inversion	limit
log	log 10
negation	roof
sign	sinx
square	square root
summed average	trend
time-of-flight analog	time-of-flight pulse count
window histogram	1 point smoothing
3 point smoothing	5 point smoothing
7 point smoothing	9 point smoothing
addition	subtraction
multiplication	division

ENHANCED RESOLUTION

The 7200A provides a facility to increase the resolution on single shot waveforms. This is called Enhanced Resolution and it provides up to three additional bits (i.e., to 11 bits or 1:2048) with a corresponding decrease in effective bandwidth.

Quite often the sampling rate of the 7200A is higher than is actually required for the bandwidth of the signal. In this case, a filter can be applied to increase the effective resolution. Regardless of the noise in the signal, this filtering improves the resolution of the input signal. This is a true increase in resolution which occurs whether or not the signal is noisy.

Enhanced resolution is implemented such that the phase, time position and gain (at low frequency) are maintained.

Figure 6 gives an example of the use of ERES to extract the signal from a very noisy background.

X-Y DISPLAY

The 7200A is capable of generating a plot of any trace against any other trace simultaneous with the individual display of each. Thus, the XY display is simply accessed by a softkey on the main screen. Selection of the two waveforms for this display is easily made with the trace section keys.

Figure 7 is an example of an x-y display. The two time domain traces shown at the bottom of the figure are the voltage across and current through a diode. When a plot of voltage versus current (x versus y) is generated the diode breakdown characteristic is the result. This is the display that is shown at the top of the figure.

VARIABLE PERSISTENCE

The 7200A's variable persistence mode is operable with either time, frequency, or statistical waveforms. It can be applied to live, archived, or processed data. The degree of persistence is user-selectable, giving the user control over the number of successive waveforms that will be overlaid to generate the display.

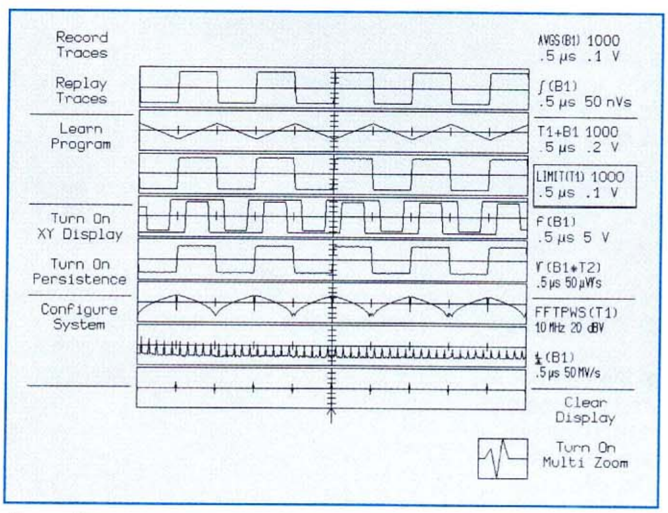


Figure 5

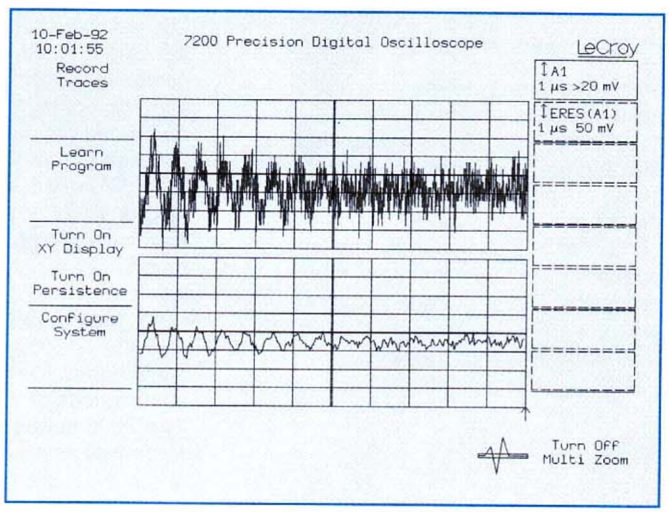


Figure 6

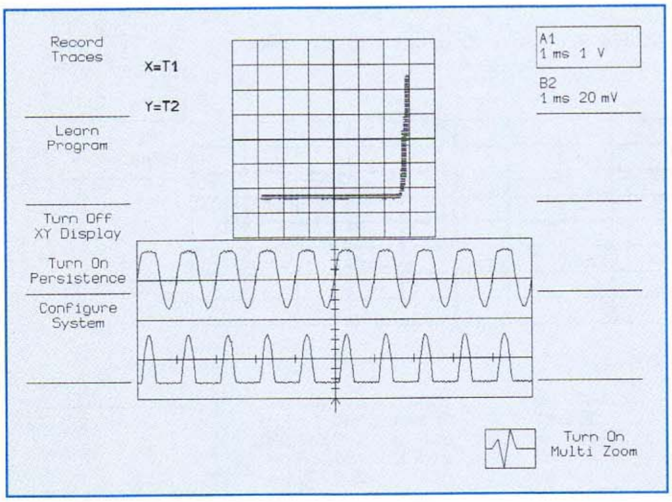


Figure 7

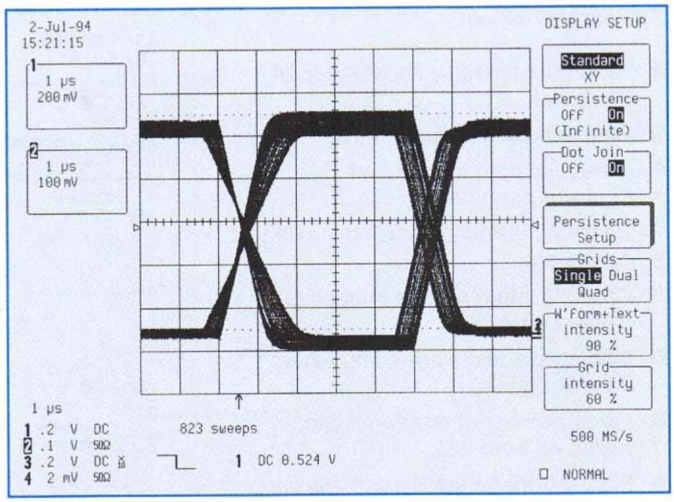


Figure 8

The variable persistence mode of the 7200A display system permits demanding logic design measurements. Jitter may be visualized and eye diagrams created such as the one shown in Figure 8. The degree of persistence is variable by simple menu selections. In addition to jitter, noise, drift and decay can all be characterized.

EXTENSIVE MASS STORAGE FACILITIES

The 7200A's extensive mass storage facilities have been designed to permit easy and flexible post processing of archived data. Besides the built-in floppy capacity of 1.44 Mbytes (2.88 Mbytes optional) per diskette, hard drives may be ordered with capacities up to 240 Mbytes.

Hard Disk: The 7200A's Record Mode automatically stores up to 60 Mpoints (e.g., 60,000 1k waveforms) in its internal hard disk simply by pressing the Record button on the side of the screen. No set up is required. All records are stamped with the time of acquisition.

At any time, the recorded traces can be replayed forward or backward in a scan or single step mode for viewing, processing or reprocessing.

Floppy: The 7200A can recall up to eight traces simultaneously every time the recall push-button is pressed. These recalled traces can be assigned to any of the 8 internal memories for processing and display.

The 7200A provides facilities for storing and recalling instrument set ups from either hard or floppy disk. Although they are often referred to as "panel settings" these files are really complete oscilloscope configurations and include set ups for the following:

- Traces
- Extended parameters
- Hardcopy
- Acquisition mode
- Waveform storage and recall
- Display annotation and controls
- Multizoom
- Communications
- Plug-in control settings
- Cursors
- Persistence display
- Disk utilities

This completeness enables the operator to totally change the operating conditions with one command and to be assured that previous set ups can be exactly recreated.

Disk archiving is fast and can store waveforms in under 100 msec. A table of storage times as a function of trace size for 1, 2, 4, and 8 traces may be found in the specifications.

ADVANCED ATE SYSTEM OPERATION

The 7200A is fully programmable from a computer with a GPIB port or from an RS-232C terminal. Bus commands can set up the instrument, control cursors, and readout data.

The fast GPIB data transfers and local data reduction cut overall testing time. The 7200A transfers data blocks at up to 400 kbytes per second over GPIB or up to 900 kbytes per second over the optional small computer systems interface (SCSI). Local processing and decision making provide for PASS/FAIL result readouts. The 7200A executes custom programs for conditional testing without a host computer connected.

7200A COMMAND LANGUAGE

The 7200A is capable of executing programs written in Internal Command Language (ICL), a programming language for customizing or automating the instrument's operation. Using ICL, the operator is able to write programs to create menus, issue operator prompts or information messages, collect and examine data, make decisions about the result, and generate reports or external control signals.

ICL features include:

- Control operation without external computer
- Simple basic-like statements
- Create custom menus and operator prompts
- Perform math and decision making operations
- Create custom reports to printer/ plotter/computers
- Generate audio alarms and external control signals
- Large number of programs can reside on hard disk
- Floppy transportability and archiving
- Uses same remote commands as GPIB and RS-232

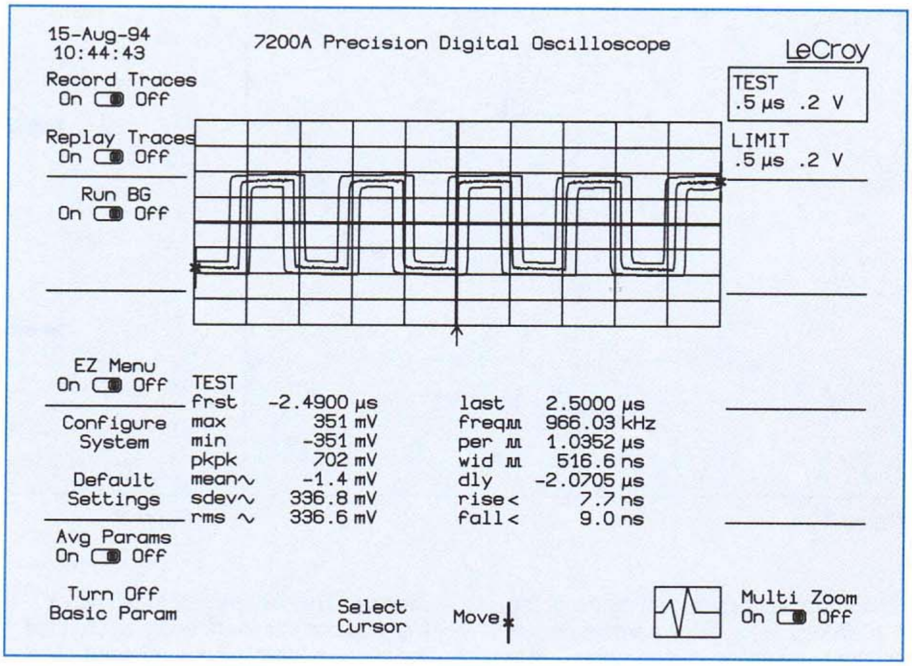


Figure 9

UNATTENDED MONITORING IS A BREEZE WITH THE 7200A

Whether the operation is controlled by ICL or by manually predefined triggering conditions, unattended operation is simple with the 7200A. In the example shown in Figure 9, both envelope and frequency limits were predefined for an incoming square wave to see if the phase or frequency of a clock circuit shifts over time. In this case, only the waveforms that violate the predefined requirements will be saved to hard disk. Such a technique is invaluable, for example, in searching for glitches or AC power line transient-related phenomena which occur at random.

LEARN MODE PROGRAMS

The 7200A is able to "learn" any sequence of key presses and knob changes. Once learned, the sequence or program can be executed repeatedly for fast or automatic operation. The program can also be stored and recalled to and from disk for later use.

Learn mode is enabled/disabled by depressing the Learn Program softkey. Once initiated, it keeps a record of all operations, including store or recall of waveforms or set ups, panel adjustments, running other programs, etc., a complete image of the operating session.

ON-LINE HELP

The 7200A's hard disk provides the capability for incorporating on-line help within the oscilloscope itself. The information, identical to the operator's manual, is comprehensive and complete. The facility is extraordinarily convenient and its ease of accessibility is welcomed by operators who otherwise shun written manuals.

On-line help contains information on the 7200A's keys, softkeys, knobs, and various other topics. Pressing the HELP key (above the floppy diskette drive at top of front panel) disables all control functions. The front panel keys and knobs can then be used to access the on-line HELP.

EASY GRAPHICS AND DATA TRANSFERS

The incorporation of an MS-DOS floppy disk enables communication to and from personal computers and other 7200As without complexity and the cost associated with cables, programming, GPIB, RS-232, or other interfaces.

Data may be saved in ASCII format for easy import into spreadsheets or word processing programs. Screen images may also be saved in file formats conducive to use in word processed or desktop publishing documents, such as the ones used in this introduction.

7200A Series Modular DSO Selection Guide

Specifications	with 7242B	with 7234	with 7262
Bandwidth (MHz) - minimum	500	500	4000
Sample Rate			
Single Shot (MS/s)	2000 single channel 1000 dual channel	200 single channel 200 four channel	40 single channel 40 dual channel
Repetitive (GS/s)	20	20	100
Number of Channels	2 (4 per mainframe)	4 (8 per mainframe)	2 (4 per mainframe)
Acquisition Memory Length	200k/channel	50k/4 ch, 100k/2 ch	20k/ch
Optional Memory Length	1M/channel	200k/4 ch 500k/2 ch, 1M/1 ch	N/A
Triggers per Sweep	1-4000	1-4000	1
Reference Memory (16 bits)	400k	400k	400k
Vertical Resolution	8 bits	8 bits	10 bits
Enhanced Res. (w/averaging)	11 (13) bits	11 (13) bits	13 (15) bits
Trigger Modes	Fast glitch, Interval, Pattern State & Time Qualified, Hold-off		
TV Trigger	Yes	No	No
Cursors	Time & Voltage	Time & Voltage	Time & Voltage
Cursor Delimited Parameters	> 60	> 60	> 60
DOS-Memory Storage	HD + Floppy	HD + Floppy	HD + Floppy
Mask/Parameter Testing	Yes + Custom	Yes + Custom	Yes + Custom
DSP, Math, Averaging, FFT	Yes	Yes	Yes
Instrument Control (ICL)	Yes	Yes	Yes
Page #	52	54	57

7200 Series Ordering Information

Model		
7200A	DSO Mainframe, High Speed CPU - Color Display	
7200AM	DSO Mainframe, Medium Speed CPU - Monochrome Display	
Plug-ins:		
7234	4 Channel 500 MHz 200 Ms/s	
7234-L1	Option L1 - Long Memory Version of 7234	50k Memory/Channel Plug-In
7242B	2 Channel 500 MHz 1 GS/s	200k Memory/Channel includes 7291 for 2 GS/s
7242B-L1	Option L1 - Long Memory Version of 7242B	1 Megabyte Memory/Channel
7262	2 Channel 4 GHz 100 GS/s	Sampling Front-nd Plug-in
Options:		
7200ARCLK	High Precision Internal Clock & Rear I/O	
7200A-DS1	Color DisplayIncludes 640x480 pixels, color CRT	
7200A-IF1	IEEE 488-1989 GPIB	Included in 7200A/7200AM
7200A-IF2	Small Computer Systems Interface (SCSI)	
7200A-KB	Computer Keyboard for 7200A	Included with 7200A
7200A-SW1	Time Domain DSP Package	Includes Internal Command Language
7200A-SW2	Statistical Domain DSP Package	Includes Extended Time Domain Parameters
7200A-SW3	Frequency Domain DSP Package	Includes Extended Freq Domain Parameters
7200A-SW5	Disk Drive Analysis Package	Requires SW1, SW2, SW3
Accessories:		
7200-OM	Operator's Manual	
7200-PM	Remote Programmer's Manual	
7200-RKMT	Rack Mount Slide Kit	
7200-SHIP	Rugged Shipping Case	
7200-SM	7200 Service & Calibration Manual	Covers Mainframe & Plug-ins
7200-SOFT	Padded Soft Carrying Case	
Probes:		
7200-P12/2Kit	2 each 300 MHz 10:1 Probe Kits	2 meters
7200-P21Kit	1 GHz 10:1 Passive Probe 500Ω Kit	
AP060	1 GHz 10:1 Active Probe	For 7200A
PP063	8 GHz 10:1 Passive Probe 500Ω	For 7262
Warranties/Calibrations:		
72XX-CC	NIST Calibration on any 7200 Series Product	
7200A-C5	5 NIST Calibrations on any 7200 Series Product	
7200A-T5	5 Year Warranty and 5 NIST Calibrations	Covers Mainframe and up to 2 Plug-ins
7200A-W5	5 Year Warranty on 7200 System	Covers Mainframe and up to 2 Plug-ins
7200-MIL	7200 Series MILSTD 45662A Calibration	On Any 7200 Series Product

Options Table

Option	7200AM	7200A
7200A-IF2 (SCSI)	Available	Available*
7200ARCLK	Available	Available*
7200A-DS1	Available	Included
7200A-KB	Available	Included
7200A-SW1	Available	Included
7200A-SW2	Available	Included
7200A-SW3	Available	Included
7200A-SW5**	Available	Available

* 7200A can have RCLK or IF2 Option but not both

** SW5 requires SW 1, 2 & 3

All 7200 Series Oscilloscopes Include the Following Features

1. Large crisp display.
2. Eight traces viewed simultaneously.
3. Standard RS-232, Centronics and GPIB ports.
4. Smart trigger.
5. Internal hard drive.
6. 8 meg RAM.
7. ISA Backplane.

Standard Mainframe Features Include

Model	7200 AM	7200A
Floppy Disk	1.44 MByte	2.88 Mbyte
Processing	386/33 MHz with VGA	486/33 MHz with VGA
Display	Monochrome	Color
Software	-	SW1/SW2/SW3/KB

Options:

7200A-SW1 (Time Domain Processing)

1. 55 Math Functions.
2. 70 Waveform Parameters.
3. Internal Pass/Fail Testing.
4. Customizable with Learn Mode & Internal Command Language.

7200A-SW3 (Frequency Domain Analysis Software)

1. 50 to 50,000 point FFT's.
2. Frequency range up to 500 MHz.
3. Frequency resolution from 100 MHz to 20 μHz.
4. Magnitude, phase, power spectrum, power density, real & imaginary displays.
5. Selectable window functions: Hamming, Hanning (Von Hann), Blackman-Harris, Flat-top, Rectangular.
6. Frequency domain averaging.

7200A-SW5 (Disk Drive Analysis Software)

1. Non-Linear bit shifts.
2. Signal to noise ratio based on Auto correlation.
3. Requires SW1, SW2 and SW3.

7200ARCLK (Reference and External Clock Option)

1. High Accuracy 10 MHz reference clock input.
2. External Clock input from DC to 1 GHz.

7200A-SW2 (Statistics Domain Software)

1. Histograms of any waveform parameter.
2. Trends of any waveform parameter.
3. Special cursor measurements to interpret statistics.
4. Advanced calculations for Time-of-Flight.
5. Parametric analysis for magnetic media evaluation.

7200A-IF2 (Small Computer Systems Interface (SCSI)

1. Continuous data transfer to appropriately equipped computer.
2. Data transfer rates to 900 kbytes/sec.

7200A-DS1 (Color Display)

640 x 480 Standard VGA Resolution.

7200A-KB (Keyboard)

85 Key full function keyboard.

MAINFRAME

Slots: 2, compatible with any 7200 Series digitizing plug-ins.

Timebases: Independent or locked.

Triggers: Independent or locked.

Time Reference: .001% accuracy standard (.00005% accuracy with 7200A-RCLK, option).

PROCESSORS

Processor speed can be selected, depending on measurement and analysis application.

7200A: Fast CPU and display processor.

7200AM: Medium speed CPU and display processor.

DISPLAY

7200A: Color 9 inch (23 cm) diagonal, raster type.

7200AM: Monochrome 9 inch (23 cm) diagonal, raster type.

Resolution: Standard VGA 640 x 480.

Grids: Single, dual, quad, octal, X-Y.

Single grid: 10 horizontal x 8 vertical divisions.

Traces: 1 - 8.

Waveform interpolation: Straight line or SIN (X)/X.

Waveform display: MIN/MAX compaction for large record lengths.

Annotation: Axis unit labels and trace annotation are user selectable and defined.

Persistence: Variable from 1 to infinity.

Auto setup: Automatically scales the timebase, trigger and gain setting for repetitive signals (signal limits: 20 mV-8 V pk-pk, 50 Hz, 0.1% duty cycle).

CURSORS

Marker: Reads absolute time, frequency and voltage.

Vertical: Reads absolute or delta relative amplitudes.

Horizontal: Reads delta time, frequency and voltage.

Basic parameters: A default set of 14 waveform parameters (defined by the trace data type) selected on a per trace basis.

MASS STORAGE

7200A	8 Mbyte RAM 2.88 Mbyte floppy disk, 100 Mbyte hard disk.
7200AM	8 Mbyte RAM 1.44 Mbyte floppy disk, 100 Mbyte hard disk.
Hard disk storage	Waveforms, record traces, system setups, ICL programs.
3.5" floppy disk storage	MS-DOS compatible data format; waveforms, system setups, ICL programs. Up to 8 waveforms may be archived simultaneously.

STANDARD EXTERNAL INTERFACES

RS-232-C

Communication: Asynchronous, bidirectional.

Baud rate: 110 to 19200.

Connector: DB-9 male (configured for DTE operation).

CENTRONICS

Communication: Output only.

Connector: DB-25 female.

488.2 GPIB

Communication: Talk/listen or talk only.

Address: Menu selectable.

OPTIONAL EXTERNAL INTERFACES

Option IF2: SCSI

Small Computer Systems Interface.

Printers supported: IBM, EPSON and compatibles, HP Laserjet.

Plotters supported: HP 7400 and 7500 Series, PHILIPS PM 8155, GRAPHTEC FP 5301 and compatibles.

Output types: Screen dump, waveform listing, program listing.

PROCESSING

Standard functions: Time and statistical domain functions, including: 1000 times summation averaging, add, subtract, multiply, negate and...

Waveform parameters:

First	Last	MAX.	MIN.
Freq	Period	Pk-Pk	Width
Mean	Delay	S-dev	RMS
Rise	Fall		

SW1 (supplied standard with 7200A):

Extended time domain waveform processing functions including: divide, absolute, 1M sweeps summation averaging, continuous averaging, sequential averaging, synchronous averaging, differentiate, integrate, enhanced resolution, exponent, exponent-pwr10, extrema (envelope) floor and roof, limit, log, 10log, sign, sinx/x, smooth 3/5/7/9, square, square root.

Internal command language: Includes Learn Mode and Program Mode.

Option SW2:

Statistical domain functions including: histogramming, limit testing, trending and...

Extended waveform parameters:

Periodic # of cycles, duty cycle, period, frequency.

Amplitude	Pulse amplitude, top, base, minimum, maximum, mean, median, most-occurring, overshoot, undershoot, peak-to-peak, root mean square, standard deviation.
Histogram	Amplitude, base, width at 1/2 max, width at specified, min, max, mean, median, most occurring, location of percentile, peak-to-peak, # of peaks, RMS, std deviation, total population, location of peak.
Acquisition	Date, time, duration.
Cursors	Date value, points between, position (left, right).
Local parameters	Amplitude max and min, number of phenomena, peak-to-peak, time between peaks and troughs, time at max. and min., time over/under threshold.

A total of twenty parameters may be uniquely defined across 8 traces simultaneously. (These parameters are described in detail in the 7200A Technical Reference Manual).

Option SW3

Frequency domain processing functions including: power spectrum, power spectrum density, magnitude, phase, real spectrum, imaginary spectrum, spectrum averaging

Extended frequency domain waveform parameters: Narrow band phase, narrow band power, noise power, total power, maximum value, frequency at max. and min.

AUTOMATIC UNITS OF MEASURE

-	dimensionless
%	percentage
dB	decibels
dBM	decibel milliwatt
dBV	decibel Volts
decade	decade
octave	octave
ppm	part per million
#	events
m	meters
K	degree Kelvin
°	degree
A	amps
Hz	Hertz
s	seconds
C	Coulombs
F	Farads
MHO	1/ohms
Ω	ohm
V	Volts
W	Watts
H	Henrys
WB	Webers
N	Newtons
J	Joules
POISE	Poise
g	grams
1/s	1/seconds
1/H	1/Henrys
PAL	Pascal
L	liter
T	Telsa
DIV	Division

MECHANICAL

Dimensions: 17 x 9.5" x 24" (435 mm x 240 mm x 610 mm).

Weight: 42 lbs (19 kg) without plug-ins.

ENVIRONMENTAL

Operating temperature: 4° to 50°C.

Non-operating temperature: -40° to 60°C.

Operating humidity: 20% to 80% relative humidity, non-condensing.

Non-operating humidity: 5% to 95% relative, non-condensing.

Vibration:
- 1.0 g max (10 to 100 Hz) operating.
- 0.75 g max (100 to 200 Hz) operating.
- 0.40 g max (200 to 600 Hz) operating.
- 2.0 g max (10 to 100 Hz) non-operating.

Shock:
- 5.0 g max operating.
- 60.0 g max non-operating.

Elevation:
- 10,000 feet (3.0 km) operating.
- 40,000 feet (12.2 km) non-operating.

POWER

Input: 47 to 63 Hz , 90 to 230 VAC (400 Hz operation optional).

Wattage: Mainframe only, 200 watts max.

Modules: Refer to module specification.

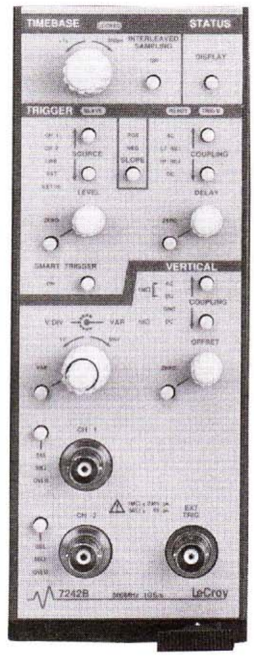
ORDERING INFORMATION

For Ordering Information see Page 48.

7242B Plug-In for the 7200 Series Modular Oscilloscope System

Main Features

- Up to 1 Mpoint/channel acquisition memory (optional), 200k/channel standard
- 2 independent channels, up to 4 channels per 7200 Series mainframe
- 2 GS/sec single shot sampling rate
- 20 GS/sec repetitive sampling rate
- System bandwidth DC to 500 MHz
- SMART Trigger™ including glitch, pattern, slope, time/event qualified, TV
- Roll mode



General

The LeCroy 7242B, 2 channel plug-in is a high bandwidth, long record length plug-in for the LeCroy 7200 Series Modular Oscilloscope System. With a second 7242B plug-in, the 7200 Series provides 4 channels of simultaneous 1 GS/s digitizing.

The 7242B records 200,000 sample points on each input channel (1,000,000 per channel optional). These long memories maintain full sample rate and usable bandwidth over a wide range of timebase settings.

By segmenting the memory, up to 4,000 waveforms/channel can be acquired at high trigger rates.

Smart Trigger lets the user trigger on complex waveforms like glitches or bit streams, so rare or subtle events can be observed.

The two input channels have flexible signal conditioning allowing the user to select 50 Ω or 1 MΩ input impedance with input sensitivities of 5 mV/div to 2.5 V/div.

VERTICAL

Channels: 2 independent channels.

Analog bandwidth (-3 dB):

Coupling	Bandwidth	Probe
50 Ω input	500 MHz	P21
DC 1 MΩ input	250 MHz	P12
AC 1 MΩ input	10 Hz - 250 MHz	P12

The system bandwidth values quoted above are valid for the entire analog path, i.e., from probe tip to the ADC output.

Bandwidth limit filter: 95 MHz.

Input impedance: 50 Ω ±2%; 1 MΩ ±2%//25 pF typical.

Resolution: 8 bits.

Enhanced resolution: Choice of low pass filters for vertical resolution improvement from 8 bits to 11 bits; adjustable in 0.5 bit increments.

Effective bits: Measured at 80% full scale.

Sine Wave Frequency	Effective Bits & Sample Rate	
	2 GS/sec	
	Guaranteed	Typical
400 MHz	5.0	5.5
50 MHz	6.0	6.5

Accuracy: ±2% at DC, full scale.

Input sensitivity: Fixed 5 mV/div to 1 V/div. Variable from x1 to x2.5 of fixed range in steps of 0.01.

Offset range: Minimum: ±10 div in .02 V/div steps. Maximum: ±4 V.

Maximum input voltage: ±5 V DC or 5 V RMS into 50 Ω, 250 V (DC + peak AC) into 1 MΩ input.

TIMEBASE

Single shot: ≥ 2 ns/div.

Repetitive: 200 ps/div to 200 nsec/div.

Sample clock:

Internal: 0.4 samples/sec to 2 GS/sec. Accuracy is equal to the mainframe reference.

External: 0 dBm to 10 dBm sine wave from 50 MHz to 1 GHz.

MEMORY

Acquisition memory selection: Selectable in 1, 2, 5 sequence from 1k to 200k points per channel. With option L1 installed, 500k and 1 Mpoint per channel are also provided.

Memory segmentation: Memory can be divided into segments. Each segment can be 50 to 200k points long and up to 4,000 segments can be selected. With option L1 installed, up to 500k and 1 Mpoint segments can be selected.

Minimum time between segment acquisitions: Sequence mode (segments the acquisition memories): 50 µsec for 50 point records.

Packed segment mode (segments the mainframe RAM memory): 500 µsec for 50 point records.

Waveform parameters: All waveform parameters will work on 1 Mpoint waveforms providing that there is enough system memory available.

XY display: With 8 Mbytes of system memory, XY mode is limited to 500 kpoint waveforms.

Fast averaging rate: Up to 2300 - 50 point records/second, up to 500,000 points/second for long records.

Synchronous averaging: Averages synchronous to trigger signal from 50 - 50k point record lengths.

TRIGGER

Trigger sources: CH1, CH2, EXT or line.

Trigger source settings: CH1, CH2 and EXT have independent slope, coupling and level settings.

Trigger slope: Positive or negative.

Trigger jitter: 20 psec RMS.

Trigger coupling: AC, DC, LF Rej, HF Rej, AC. Low freq. cutoff: 50 Hz ±10%. LF reject: 50 kHz ±10%. HF reject: 50 kHz ±10%.

Trigger level: ± full scale input range. Accuracy: ±3% of full scale (DC coupling only).

Trigger delay: -5X time per div. to 100,000X time per div. referenced to the center of the display.

Accuracy: Equal to the mainframe reference.

Timing: Trigger timing (date and time) is logged in the Display Trigger Times status screen. The timing of subsequent triggers in sequence mode is measured with 0.1 sec absolute time resolution, and nanosecond resolution relative to the time of the first trigger.

Maximum trigger rate: 400 MHz in HF Sync mode.

SMART TRIGGER

Single Source Modes

Source: CH1, CH2 or EXT.

Holdoff by time: 30 nsec to 680 sec.

Holdoff by events: 1 to 15,000,000 events.

Event rate: 125 MHz max.

Pulse Width:
Durations < specified limit or duration > specified limit.

Segment mode trigger rates:

Trigger Rate in "Maximize Trigger Rate" Mode

# of segments	pts./segment	trigger rate
100	2000	19 kHz
500	200	23 kHz
1000	100	23 kHz

Trigger Rate in "Maximize Points per Segment" Mode

# of segments	pts./segment	trigger rate
100	4000	97 Hz
500	1000	356 Hz
1000	400	767 Hz
2000	400	767 Hz
4000	200	1 kHz

Specified limit: 1 ns to 680 sec.

Interval width:
Durations < specified limit; 30 ns to 680 sec. Durations > specified limit: 30 ns to 680 sec.

Multi-Source Modes

Pattern: Trigger on entering or exiting a specified pattern (low, high, don't care) of CH1, CH2, and EXT.

Width: Trigger on pattern width or time between patterns less than or greater than specified limit of 1 nsec to 680 sec.

Interval: Trigger on pattern interval of less than or greater than specified limit of 30 nsec to 680 sec.

State qualified: Trigger on CH1, CH2 or EXT while a pattern of the other two sources is present or absent.

Holdoff by time: 30 nsec to 680 sec.

Before time: 10 nsec to 680 sec.

Events: Trigger on event 1 to 15,000,000.

Time qualified: Trigger on CH1, CH2 or EXT after entering or exiting a pattern of the three sources.

Holdoff by time: 30 nsec to 680 sec.

Before time: 10 nsec to 680 sec.

Events: Trigger on event 1 to 15,000,000.

TV: Allows stable triggering on TV signals that comply with PAL, SECAM or NTSC standards. Selection on both line (up to 1500) and field number (up to 8) is possible.

ORDERING INFORMATION

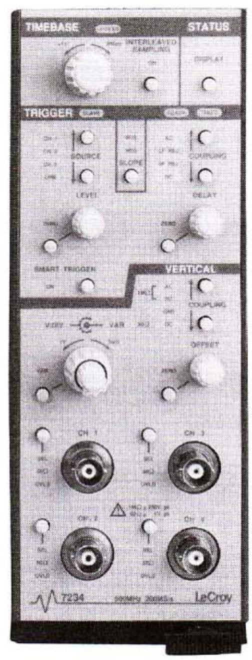
For Ordering Information see Page 48.

* The amount of system memory available is a function of the total memory as well as waveform functions being processed, parameters, persistence mode, xy mode, hardcopy, number of 1 Mpoint channels, etc.

7234 Plug-In for the 7200 Series Modular Oscilloscope System

Main Features

- Up to 1 Mpoint acquisition memory (optional), 50k/channel standard
- 4 independent channels, up to 8 channels per 7200A Series mainframe
- 200 MS/sec single shot sampling rate per channel
- 20 GS/sec repetitive sampling rate
- System bandwidth DC to 500 MHz
- SMART Trigger™ including glitch, pattern, slope, time/event qualified
- Roll mode



General

The LeCroy 7234, 4 channel plug-in is a high bandwidth, long record length plug-in for the LeCroy 7200 Series Modular Oscilloscope System. With a second 7234 plug-in, the 7200 Series provides 8 channels of simultaneous 200 MS/sec digitizing.

With option L1 installed, the 7234 records 1,000,000 sample points with 1 channel active, 500,000 sample points per channel with 2 channels active, or 200,000 sample points per channel with 4 channels active.

These long memories maintain full sample rate and usable bandwidth over a wide range of timebase settings. By segmenting the memory, up to 4,000 waveforms/channel can be acquired at high trigger rates.

Smart Trigger lets the user trigger on complex waveforms like glitches or bit streams, so rare or subtle events can be observed.

The four input channels have flexible signal conditioning allowing the user to select 50 Ω or 1 MΩ input impedance with input sensitivities of 5 mV/div to 2.5 V/div.

VERTICAL

Channels: 4 independent channels.

Analog bandwidth (-3 dB):

Coupling	Bandwidth	Probe
50 Ω input	500 MHz	P21
DC 1 MΩ input	250 MHz	P12
AC 1 MΩ input	10 Hz - 250 MHz	P12

The system bandwidth values quoted above are valid for the entire analog path, i.e., from probe tip to the ADC output.

Bandwidth limit filter: 95 MHz.

Input impedance: 50 Ω ±2%;
1 MΩ ±2%//25 pF typical.

Resolution: 8 bits.

Enhanced resolution: Choice of low pass filters for vertical resolution improvement from 8 bits to 11 bits; adjustable in 0.5 bit increments.

Resolution	Bandwidth Single Shot	Bandwidth Repetitive
8 bits	100 MHz*	500 MHz
9 bits	23 MHz	490 MHz
10 bits	6 MHz	300 MHz
11 bits	2 MHz	150 MHz

* Nyquist bandwidth

Total accuracy: ±2% full scale, DC.

Input sensitivity: Fixed 5 mV/div to 1 V/div. Variable from x1 to x2.5 of fixed range in steps of 0.01.

Offset range (minimum): ±10 div in .02 V/div steps.

Maximum input voltage: ±5 V DC or 5 V RMS into 50 Ω, 250 V (DC + peak AC) into 1 MΩ input.

TIMEBASE

Single shot: ≥ 10 ns/div.

Repetitive: 200 psec/div to 100 nsec/div.

Sample clock:

Internal: 0.1 samples/sec to 200 MS/sec. Accuracy is equal to the mainframe reference.

External: 0 dBm to 10 dBm sine wave from 50 MHz to 200 MHz.

MEMORY

Acquisition memory selection: Selectable in 1, 2, 5 sequence from 1k to 50k points per channel, up to 100k with 2 channels active, up to 200k with 1 channel active. With option L1 installed, 500k with 2 channels and 1 Mpoint with one channel active are also provided.

Memory segmentation: Memory can be divided into segments. Each segment can be 50 to 200k points long and up to 4,000 segments can be selected. With option L1 installed, up to 500k and 1 Mpoint segments can be selected.

Minimum time between segment acquisitions: Sequence mode (segments the acquisition memories) 50 µsec for 50 point records.

Packed segment mode (segments the mainframe RAM memory): 500 µsec for 50 point records.

SIGNAL PROCESSING AND DATA TRANSFER

All waveform processing, except those noted below, will work on 1 Mpoint waveforms providing that there is enough system memory available*. The tables show what processing functions are possible as a function of the number of channels and record length. It assumes 8 Mbyte of system RAM, XY and persistence off and no memories recalled.

Number of 1 MB traces that can be processed with one or two 7234-L1 plug-ins	
	1 channel only
Unary Functions	2
Binary Functions	2
FFTs	50k Max/Trace...
Summation Averaging & Extrema	0
Continuous Averaging /Limit Function	1

Number of 500 kB traces that can be processed with one or two 7234-L1 plug-ins		
	1 Ch	2 Ch
Unary Functions	4	4
Binary Functions	4	4
FFTs	50k Max/Trace...	
Summation Averaging & Extrema	1	1
Continuous Averaging /Limit Function	2	2

* The amount of system memory available is a function of the total memory as well as waveform functions being processed, parameters, persistence mode, xy mode, hardcopy, number of 1 Mpoint channels, etc.

Note: 1 Mbyte waveforms cannot be processed or transferred in the 7200 mainframe.

Waveform parameters: All waveform parameters will work on 1 Mpoint waveforms providing that there is enough system memory available*.

XY display: With 8 Mbytes of system memory, xy mode is limited to 500 kpoint waveforms.

Fast averaging rate: Up to 2300 - 50 point records/second, up to 500,000 points/second for long records.

Synchronous averaging: Averages synchronous to trigger signal from 50 - 50k point record lengths.

TRIGGER

Trigger sources: CH1, CH2, CH3 or line.

Trigger source settings: CH1, CH2 and CH3 have independent slope, coupling and level settings.

Trigger slope: Positive or negative.

Trigger jitter: 20 psec RMS.

Trigger coupling: AC, DC, LF Rej, HF Rej, AC. Low freq. cutoff: 50 Hz ±10%. LF reject: 50 kHz ±10%. HF reject: 50 kHz ±10%.

Trigger level: ± full scale input range. Accuracy: ±3% of full scale (DC coupling only).

Trigger delay: -5 X time per div. to 100,000 X time per division referenced to the center of the display.

Timing: Trigger timing (date and time) is logged in the Display Trigger Times status screen. The timing of subsequent triggers in sequence mode is measured with 0.1 sec absolute time resolution, and nanosecond resolution relative to the time of the first trigger.

Maximum trigger rate: 400 MHz in HF Sync mode.

Segment mode trigger rates:

Trigger Rate in "Maximize Trigger Rate" Mode

# of segments	pts./segment	trigger rate
100	2000	19 kHz
500	200	23 kHz
1000	100	23 kHz

Trigger Rate in "Maximize Points per Segment" Mode

# of segments	pts./segment	trigger rate
100	4000	97 Hz
500	1000	356 Hz
1000	400	767 Hz
2000	400	767 Hz
4000	200	1 kHz

SMART TRIGGER

Single Source Modes

Source: CH1, CH2 or CH3.

Holdoff by time: 30 nsec to 680 sec.

Holdoff by events: 1 to 15,000,000 events.

Event rate: 125 MHz max.

Fastglitch (pulse width): Durations < specified limit or duration > specified limit. Specified limit: 1 nsec to 680 sec.

Interval width:
Durations < specified limit: 30 ns to 680 sec. Durations > specified limit: 30 ns to 680 sec.

Multi-Source Modes

Pattern: Trigger on entering or exiting a specified pattern (low, high, don't care) of CH1, CH2, and CH3.

Width: Trigger on pattern width or time between patterns less than or greater than specified limit of 1 nsec to 680 sec.

Interval: Trigger on pattern interval of less than or greater than specified limit of 30 nsec to 680 sec.

State qualified: Trigger on CH1, CH2 or CH3 while a pattern of the other two sources is present or absent.

Holdoff by time: 30 nsec to 680 sec.

Before time: 10 nsec to 680 sec.

Events: Trigger on event: 1 to 15,000,000.

Time qualified: Trigger on CH1, CH2 or CH3 after entering or exiting a pattern of the three sources.

Holdoff by time: 30 nsec to 680 sec.

Before time: 10 nsec to 680 sec.

Events: Trigger on event: 1 to 15,000,000.

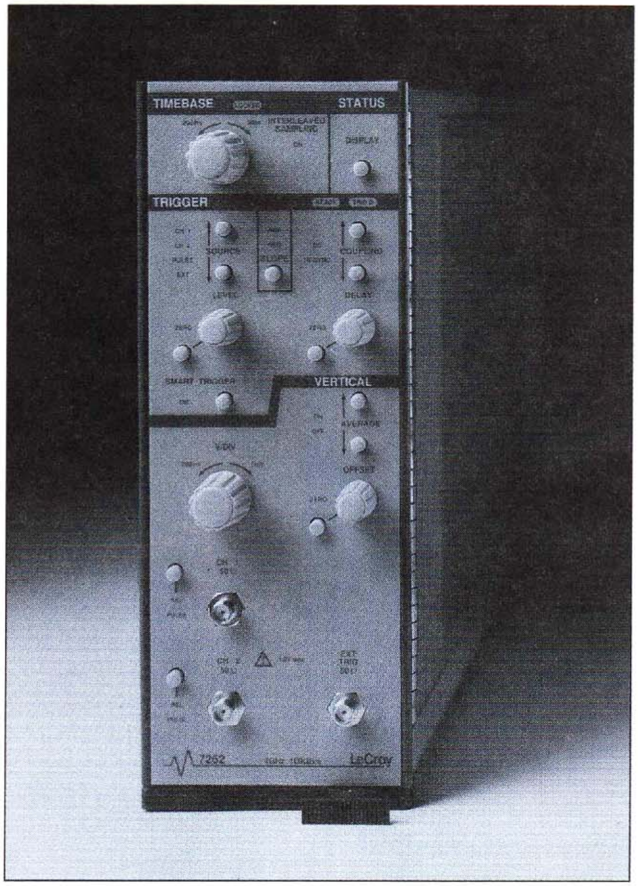
ORDERING INFORMATION

For Ordering Information see Page 48.

7262 Plug-In for the 7200 Series Modular Oscilloscope System

Main Features

- > 4 GHz Analog Bandwidth
- 100 GS/sec interleaved sampling for repetitive signals
- > 2.5 GHz Trigger Bandwidth
- Ultra Fast Pulse outputs for Time Domain Reflectometry
- Smart Trigger™ including glitch, pattern, slope, time/event qualified
- 10 bits dynamic range



General

The 7262 is a high bandwidth, repetitive sampling plug-in for the LeCroy 7200 Series Modular Digital Oscilloscope. The 7262 provides two channels of 100 Gigasample/ second repetitive sampling speed at 4 GHz bandwidth. The 7262 also provides a very long 20,000 point record for repetitive signals.

The two input channels provide 10 bits of dynamic range and flexible signal conditioning from 5 mV/div to 200 mV/div into 50Ω.

In addition, each channel has a variable frequency pulse output with <100 psec falltime to facilitate fast Time Domain Reflectometry (TDR). Dedicated software makes TDR especially simple to accomplish.

The 7262 may be used in conjunction with other 7200 series plug-ins to customize a data acquisition system to meet the users requirements. For example, a 7242B-L1 plug-in with 1 Megaword of memory per channel and high speed single shot sampling of 2 Gigasamples per second can be operated in a 7200 series mainframe simultaneously with the 7262. This provides an unprecedented combination of long record length, single shot sampling and ultra fast repetitive sampling that is simply unattainable from any other system available on the market today.

All of the extensive processing and parameter measurements indigenous to the 7200 series mainframes are available to analyze data acquired with the 7262. Additional new processing has been added to facilitate data reduction unique to 7262 applications. For example, infinite persistence, color eye diagrams (7200A) are quickly analyzed for jitter by a new processing function that eases the task of communication signal analysis.

The trigger bandwidth of the 7262 is a very high > 2.5 GHz with High Frequency Sync enabled. The LeCroy Smart Trigger™ lets the user trigger on complex waveforms with glitches, or permits triggering on patterns and logic states with hold-off by time or events so rare or subtle phenomena can be studied.

A high bandwidth 8 GHz passive probe and 1 GHz FET probe complement the 7262 plug-in and enhance its utility for accurately conditioning and acquiring very fast signals.

VERTICAL

Inputs: 2 SMA Connectors, 50Ω ±1%.

Bandwidth: > 4 GHz from 50 mV - 200 mV/div, >3 GHz from 5 mV - 20 mV/div

Risetime: 125 ps from 50 mV - 200 mV/div, 150 ps from 5 mV - 20 mV/div

Coupling: DC, 50Ω.

Input V/Div: 5mV/div - 200 mV/div, in a 1-2-5 sequence.

Maximum Input: ±2 volts.

Resolution: 10 Bits.

Accuracy: ±3% at DC

Isolation: Minimum of 60dB between channels @ 1GHz.

Delay Matching: Adjustable ±10ns in 10ps steps for each channel.

Pulse Out: Each channel.

V/Div	Fullscale Input	Offset Voltage Range	Pk to Pk Noise Typ.
200mV/div	8.0dbm	±800mV	40mV
100mV/div	2.0dbm	±800mV	40mV
50mV/div	-4.0dbm	±800mV	40mV
20mV/div	-12.0dbm	±80mV	5mV
10mV/div	-18.0dbm	±80mV	5mV
5mV/div	-24.0dbm	±80mV	5mV

TIMEBASE

Time/Div: 20 ps/div to 20µs/div RIS 50µs/div to 200ms/div Single Shot.

Time/Point: 10ps/pnt to 10ns/pnt RIS 25ns/pnt to 100µs/pnt Single Shot.

Accuracy: .001% Standard.

Memory Size: 500, 1k, 2k, 5k, and 20k samples.

TRIGGER

Sources: CH1, CH2, Pulse or Ext.

Slope: Positive or Negative.

Coupling: DC or HFSYNC.

Level: ± 800 mV from 50 mV/div - 200 mV/div., ± 80 mV from 5 mV/div - 20 mV/div

Accuracy : ± 5% of full scale range.

Minimum Signal:

DC: 100mV pk to pk at 50mV/div to 200mV/div and 10 mV pk to pk at 5mV/div to 20mV/div.

2GHz: 400mV pk to pk at 50mV/div to 200mV/div and 40mV pk to pk at 5mV/div to 20mV/div.

Trigger Rate:
100 MHz to > 2.5 GHz HFSYNC, 1GHz DC, 400MHz Smart Trigger™

Jitter: <5ps rms, <2ps rms smoothed (ERES10).

Delay Range: 10*t/div or 100ns minimum pretrigger to 2 seconds.

SMART TRIGGER™

Sources: CH1, CH2, EXT
Single Source and Pattern:

Holdoff by:
Time: 10ns to 100s.
Events: 1 to 15 million events.
Width: <1ns to 100s.
Interval: <10ns to 100s.
Window: In or Out, 10ns to 100s.

State Qualified:
Holdoff by time: 10ns to 100s.
Before time: 10ns to 100s.
Window: In or Out, 10ns to 100s.
Events: 1 to 15 million events.

Time Qualified:
Holdoff by time: 10ns to 100s.
Before time: 10ns to 100s.
Window: in or Out, 10ns to 100s.
Events: 1 to 15 million events.

PULSE OUT

Pulse Outputs: Independently selectable on CH1 and CH2.

Trigger: PULSE or channel trigger.

Amplitude: -400mV/div to GND.

Falltime: <100ps.

Duration: 200ns to 1s square wave period in a 1,2,5 sequence.

Aberrations: <±5% after 2ns.

MECHANICAL AND ENVIRONMENTAL

Temperature: 0 to +40°C at sea level, derated linearly to +34°C at 10,000 ft while operating and -40°C to 70°C non-operating.

Humidity: Up to 95% R.H. non-condensing while operating.

Vibration: 0.25g (maximum, 5 to 85Hz while operating. 2.0g (non operating)

Size: 3.0" (7.6mm) wide x 8.0" (203) high x 18.5" (470mm) deep.

Weight: 7.5 lbs. (3.63kg).

Power: Less than 100 watts or 4 amps at 24 volts DC.

ORDERING INFORMATION

For Ordering Information see Page 48.

7200A Frequency Domain Processing

- Display time and frequency domain waveforms simultaneously
- Number of points selectable to 50,000
- Operate on raw, stored, averaged, or processed waveforms
- -100 dbV noise floor
- Special frequency domain parameter measurements
- Up to 30 FFTs per second

The 7200A provides powerful Fast Fourier Transform (FFT) processing facilities for display and analysis of signals in the frequency domain (i.e., where the horizontal axis of the display is frequency instead of time). The advantage of an FFT over other frequency transformation methods (i.e., swept sine) is that it can operate on single shot or low repetition rate signals and can be performed rapidly on signals acquired as part of the scopes normal time domain recording functions.

FFT processing is selected via definition of trace equations and its possible to perform frequency domain processing from up to eight sources. Data sources include live inputs, traces stored on hard or floppy disk, or traces which have been processed by other functions. This capacity and flexibility gives the 7200A a unique capability for simultaneously displaying multiple signals in both the time and frequency domains. For instance, it is possible to display the time data simultaneously with its power spectrum (FFTPWS), the power spectrum of signal averaged or enhanced resolution time data, the average of the power spectrum (AVGPWS), FFT's with varied horizontal resolutions, FFTs with different window functions, the phase, and real or imaginary parts, etc. See Figure 1.

RESOLUTION AND BANDWIDTH

An FFT can be generated from a selectable number of points up to 50,000. This, in conjunction with the amplifier bandwidth and the sampling rate, determines the horizontal resolution in the frequency domain. The frequency resolution of an FFT is equal to {(sampling rate/number of points)}. As an example, with a sampling rate of 200 MS/sec and a 40,000 sample record length the frequency resolution would be 5 kHz.

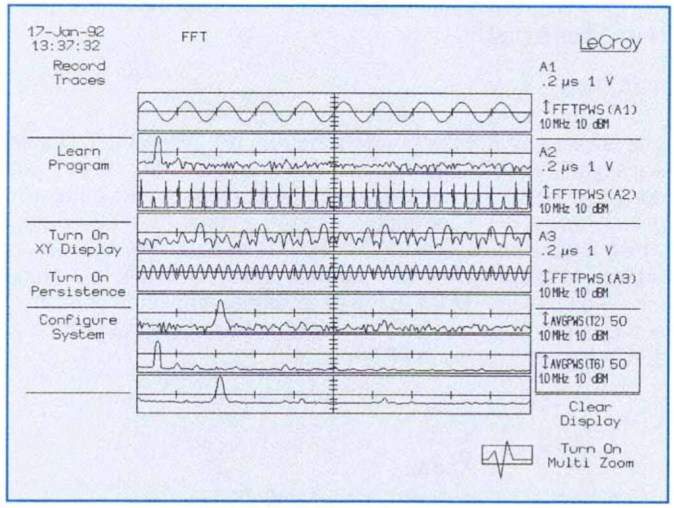


Figure 1

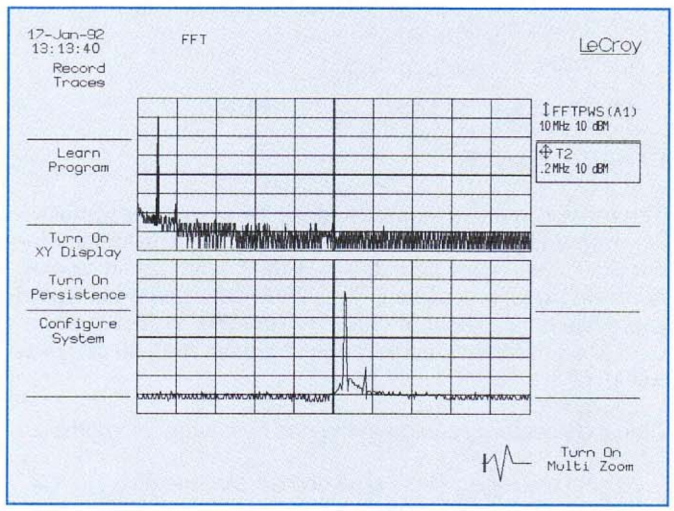


Figure 2

As shown in Figure 2, Trace 1 is a 100 MHz spectrum and Trace 2 is a display expansion showing full spectrum resolution.

The frequency range covered by an FFT is 1/2 the sampling rate or the amplifier bandwidth (500 MHz for the 7242B and the 7234) whichever is lower. The sampling rate is determined by the time base range selected. The long memory of the 7242B enables it to maintain minimum sampling rate over many time base ranges which provides maximum bandwidth processing. The bandwidth can be reduced to 95 MHz when the bandwidth limit filter is enabled or by using the Enhanced Resolution function.

SCALING

The vertical axis of the power spectrum (FFTPWS) and power density (FFTPWD) displays are Log amplitude. For 50 Ω input coupling, these displays are calibrated in logarithmic units of dBm where 0 dBm corresponds to the voltage (0.3162 Vpeak) which is equivalent to 1 mWatt. For 1 MΩ coupling, it is calibrated in dBV, where 0 dBV corresponds to 1 Vrms. In a magnitude display (FFTMAG), the peak signal amplitude is represented on a linear scale. The following table lists the calculation performed for each FFT format.

<u>50 Ω</u>

FFTMAG	V_{peak}
FFTPWS	10*Log ((V_{rms})2/50/.001)
FFTPWD	10*Log (((V_{rms})2/50/.001)/FFT RES)

<u>1 MΩ</u>

FFTMAG	V_{peak}
FFTPWS	20*Log (V_{rms})
FFTPWD	20*Log (V_{rms}/FFT RES)

DYNAMIC RANGE

The resolution and dynamic range in the frequency domain is governed by the system noise, the harmonic distortion of circuits in the analog path, the digitizer's quantization resolution, and signal processing. The 7200A series plug-ins typically provide a noise floor of -100 dBV (-80 dBV including spurious) and two tone dynamic range of greater than 40 dB (refer to Figure 3).

Signal detectability can be enhanced by several methods:

Signal averaging in the time domain for repetitive signal with a stable trigger point,

Enhanced Resolution or N-point smoothing filters in the time domain for transient signals, or

Averaging or smoothing in the frequency domain for repetitive signals without a stable trigger point.

or a combination of the above. In addition, the 7200A provides a variety of windowing functions which defines the bandwidth and shape of the equivalent filter associated with the FFT processing. These windows and their general characteristics are indicated in the table below. As an illustration of the use of window processing functions for continuous signals, Figure 3 was processed with a Hanning window and Figure 4 was processed with a Rectangular window.

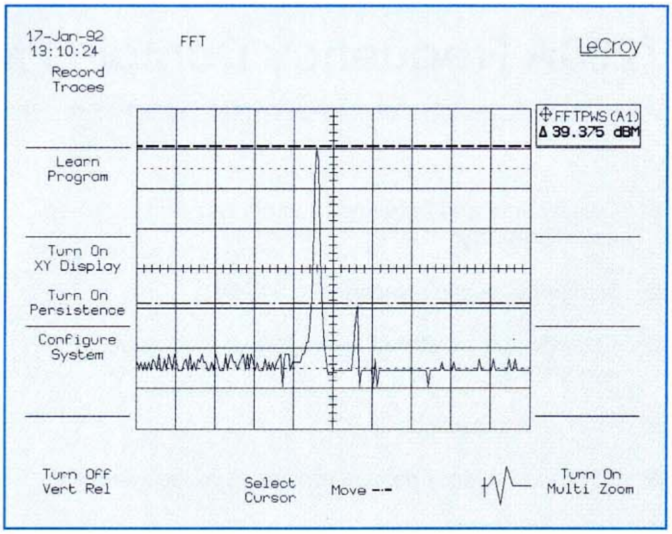


Figure 3

Window	Highest Sidelobe Level (dB)	Sidelobe Falloff (dB/oct)	3.0 dB BW (bins)	Scallop Loss (dB)
Rectangular	-13	-6	0.89	3.92
Hanning	-32	-18	1.44	1.42
Hamming	-43	-6	1.30	1.78
Blackman-Harris	-67	-6	1.66	1.13

CURSORS AND PARAMETERS

In addition to showing frequency content, FFTs provide a convenient way of determining phase information as a function of frequency. The Phase display is calibrated in degrees where zero corresponds to a sinewave whose minimum is at the left hand of the screen. Phase relative to the trigger may be determined by adjusting the trigger point on the screen with the delay control.

Other standard displays include the Real Part, Imaginary Part and the Real + Imaginary Part.

Measurements on frequency displays may be made with direct cursor measurements or waveform parameters. Cursors enable the operator to measure the difference hori-

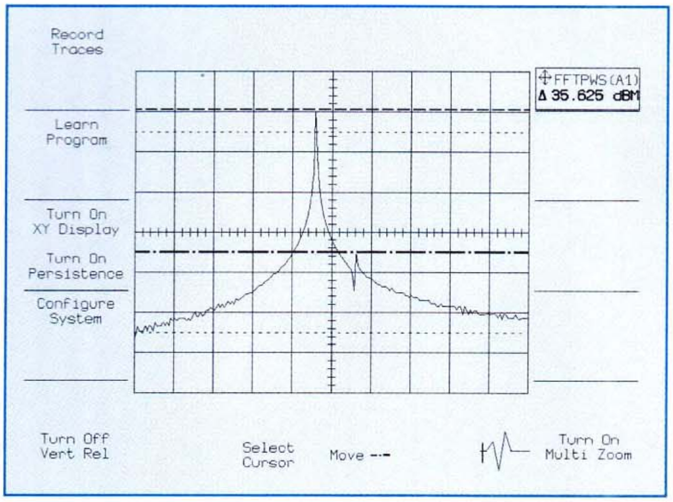


Figure 4

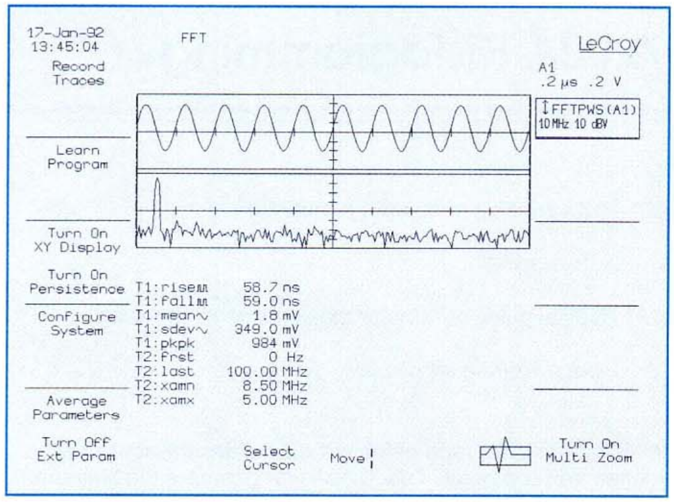


Figure 5

zontally or vertically between two points on the same or different waveforms, or display the absolute values at any point on a trace. Waveform parameter measurements are illustrated in Figure 5.

FIRST	Frequency at left edge of trace.
LAST	Frequency at right edge of trace.
Total Power	Area under the power density spectrum.
Noise Power	Total power less power in fundamental plus harmonics.
XMAX	Frequency at maximum amplitude.
XMAN	Frequency at minimum amplitude.

Two frequency parameters are also available for time domain waveforms as shown in Figure 6.

Narrow-band Phase: The phase in degrees relative to the left cursor for a user-specified frequency.

Narrow-band Power: The power in dBv for a user-specified frequency.

These parameters offer the facility to make up to 20 phase and power measurements directly from the time domain without having to define a FFT trace. These measurements are also faster than performing an entire FFT.

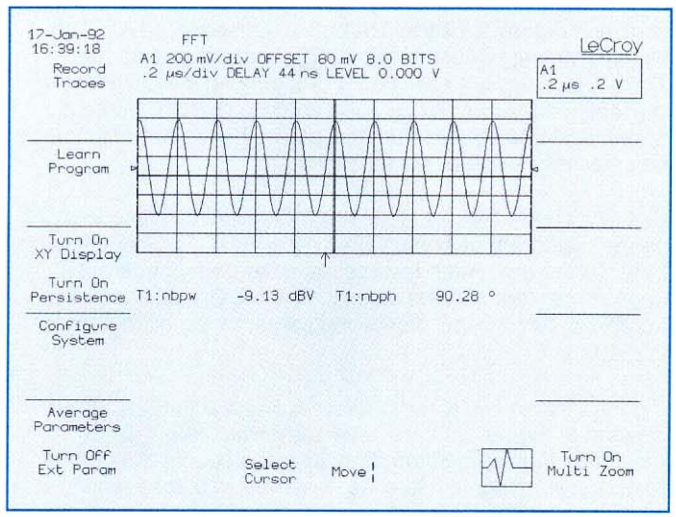


Figure 6

7200A Histogramming

- Plots the # vs measured parameter
- Auto scaling
- Special pulse parameter measurements provided
- Range filtering for display

A histogram is a graph of the number of occurrences of a measured parameter. The 7200A can generate the histogram of any pulse parameter from either the basic or the extended pulse parameter sets.

Suppose one wants to study the fall time of the pulse shown in Figure 1. Notice Trace 1 is defined to be A1. The histogramming feature of the 7200A is accessed via the Trace Setup screen selection. For example, if MODIFY is pressed followed by Trace 2 the setup screen for Trace 2 appears. Pressing Add Function allows histogramming to be selected as one of the functions.

Figure 2 shows the setup screen for assigning Trace 2 to be the histogram of Trace 1, i.e., T2 = HIST(1). The softkey Find Center and Width insures the histogram of interest appears centered on the display. The fall time of Trace 2 is approximately 2 nsec. Notice the center of the histogram is 2.2513 nsec.

Figure 3 shows basic parameters applied to the histogram. Several of the parameters have somewhat different meanings than in the time domain and a couple are unique to histogramming. In this case, a symbol is placed next to the parameter name indicating that the parameter was calculated on a histogram or FFT. For instance, mode gives the value of the bin containing the most points of the histogram. This indicates that the fall time of 2.21 nsec was most frequently observed. The maximum population, MAXP, indicates that this particular fall time was observed 344 times out of the total number of observations of 1,000. For this particular distribution, the largest fall time measured had a value of 2.31 nsec and the minimum value measured is 1.71 nsec giving the peak-to-peak in the distribution of 500 psec. First and last have the meaning of the value of the first cursor and the last cursor.

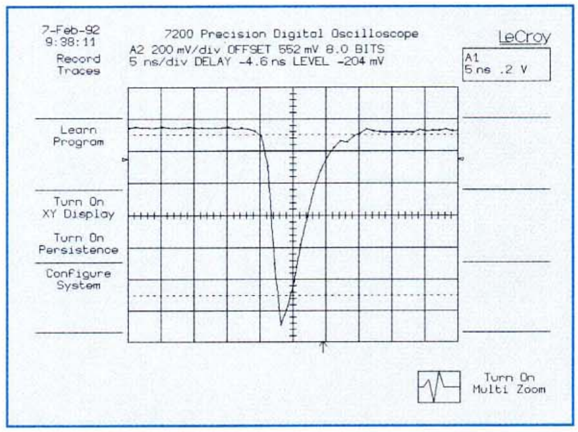


Figure 1

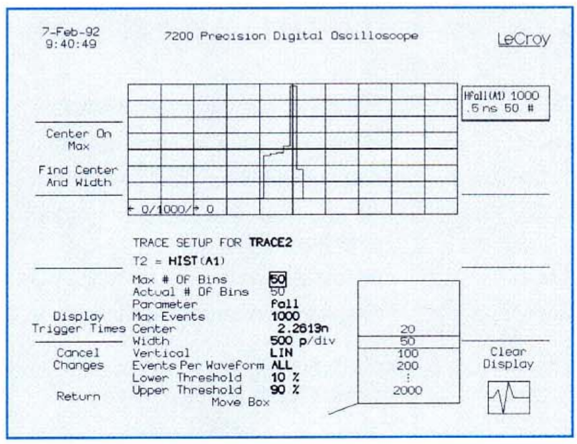


Figure 2

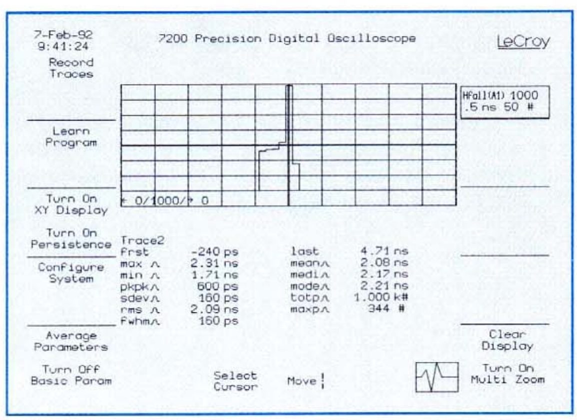


Figure 3

7200A Trending

- Trend up to 20,000 points
- Single or average measurements
- Auto scaling
- Range filtering for display

There are many times when the operator may not be interested in the details of a specific waveform but in the history of some aspect of the waveform. For example, suppose the task is to measure the output energy from a pulsed accelerator and determine if there is any degradation over a long period of time. The operator is confronted with the task of taking perhaps hundreds of "shots', computing the energy in each pulse and plotting the energy versus shot number. This class of measurement can now be automated with the 7200A.

Another example is taken from the world of nature: a dolphin "click". Suppose a dolphin is swimming around and we hang out our microphone and record the sound the dolphin makes (called a click by dolphin researchers). Figure 1 is a dolphin click in the time domain. Now suppose the task is to monitor the frequency content of the sound coming from our dolphin while a 2nd dolphin is introduced into the pool. Thus, we wish to generate the TREND of the frequency of the dolphin click.

Trending is accessed via the "modify trace" and "add a function" setup screen selection.

Figure 2 shows the setup screen for Trace 2 = trend of Trace 1 (T2 = TREND(T1)). The parameter to be trended is selected using the Parameter field which appears when TREND is chosen. Starting from the left side of the screen the frequency is seen to increase when the new dolphin is introduced into the pool and then gradually returns to normal. The center frequency is 18.737 kHz and the vertical scale is 200 Hz per division while the horizontal axis is 5 seconds per division indicating the observation was taken over a 50 second interval.
Figure 3 shows pulse parameters applied to the trend. Notice that the meaning of the pulse parameters do not change even though their units might. For example, MAX is always the maximum vertical value of the trace between the cursors. In this case, since the trend is of the frequency, the vertical value is in the units of frequency. The max frequency observed between the cursors (which are positioned at 20.7 sec and 30.7 sec into the observation interval) is 19.048 kHz while the minimum frequency observed is 18.002 kHz.

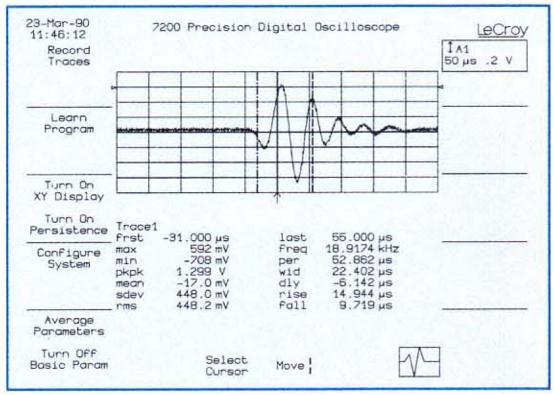


Figure 1

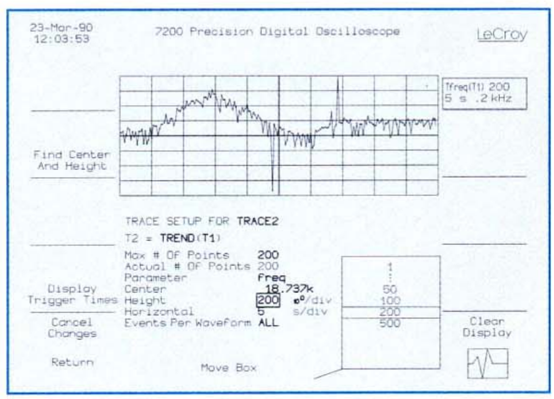


Figure 2

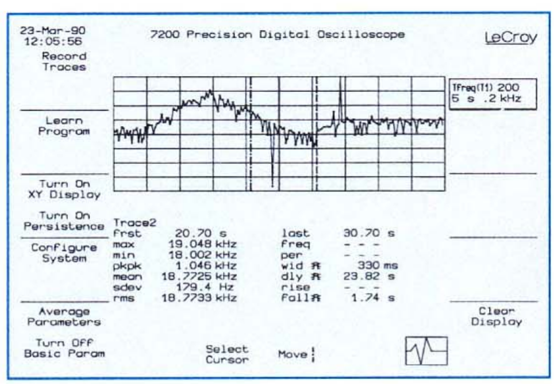


Figure 3

Digital Oscilloscope Probes

Main Features

- Bandwidths from 10 MHz to 8 GHz
- Attenuation from 1X to 100X
- Input rise times as low as 58 psec
- New "SMART" probes now available

General

LeCroy digital oscilloscopes are provided with one probe for each input measurement channel. Each probe comes high frequency compensated to match the oscilloscope with which it is supplied.

ADJUSTMENTS

Low frequency compensation on the high impedance probes is accomplished through the use of adjustment screws on the probe heads. All LeCroy digital oscilloscopes provide a calibration output on their front panel for this adjustment. LeCroy 9400 and 7200 Series scopes provide a 1 V square wave of 1 kHz frequency for this purpose. The LeCroy 9300 Series provides internal capability of adjusting both the amplitude and frequency of the calibration output to suit user preferences. The output is applied to a front panel BNC, and a BNC-to-probe tip adapter is supplied in each probe kit.

THE SMART PROBE

The ScopeStation 140 oscilloscope includes three passive probes and one "SMART" probe. The SMART probe provides fingertip control over common front-panel operations. You never need to take your hands off the probe to change a setting, freeze the display, or plot a hard copy. This utility helps create a "cascade" display on the DSO, whereby different probe points measured in this fashion represent individual traces on a common display. In this way, digital troubleshooting measurements that normally require multiple channels of a scope or logic analyzer can be accomplished with one input and one probe.

SELECTION GUIDE

PASSIVE PROBES

LeCroy Digital Oscilloscopes are provided with a complete set of passive probes. In order to provide the best possible pulse and frequency response, each passive probe is adjusted to match a specific oscilloscope.

1 Smart Probe: Allows up to three separate action to be controlled right from the probe.
2 Equipped with SMA connector
3 Mini Probe: The ideal probing tool for fine pitch integrated circuits.

Compatibility:
1= 9310/04/14
2= 9320/24
3= 9360/61
4= 9350/54, 930xA/931xA
5= 94xx
6= 7200/7200A
7= LS140
8= 9310A/04A/14A

The following selection tables provide basic specifications for the range of probes and the oscilloscope model with which they are to be used.

Types	Bandwidth MHz	Input Z Ω	Input C pF	Attenuation	Maximum Voltage VDC + Peak AC	Probe Ring	Compatibility
PP 001	350	10 M	14	10:01	600	NO	1; 5
PP 002	350	10 M	14	10:01	600	YES	3; 4; 8
PP 011	300	10 M	4	100:1	1000	NO	1; 5
PP 012	300	10 M	4	100:1	1000	YES	3; 4; 6; 8
PP 050	150	10 M	18	10:01	600	YES	7
PP 051[1]	150	10 M	18	10:01	600	YES	7
PP 061	1000	500	1.5	10:01	22	NO	1; 5
PP 062	1000	500	1.5	10:01	22	YES	2; 3; 4; 6; 8
PP 063[2]	8000	500	< 0.5	10:01	10	NO	2; 3; 4; 6; 8
PP 064	1000	5 K	1.3	100:1	30	YES	2; 3; 4; 6; 8
7200-P 12	350	10 M	14	10:01	600	YES	6
PMM 502[3]	500	10 M	< 6	10:01	600	YES	1; 3; 4; 8

THE LeCroy ProBus SYSTEM

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

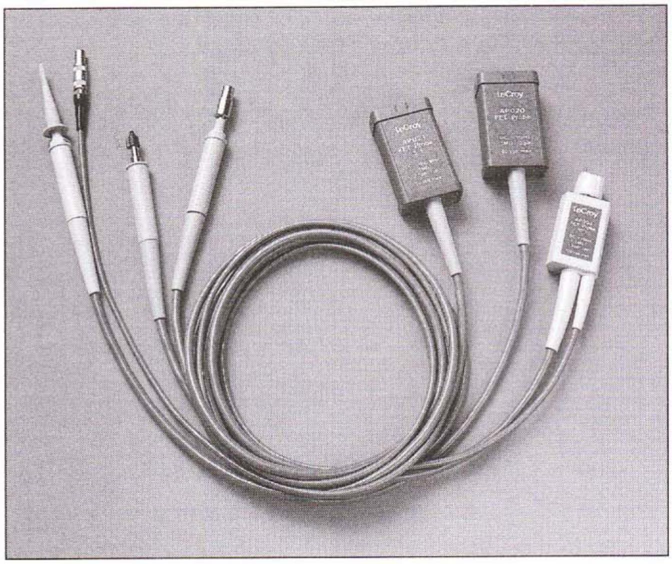
Communications between oscilloscope and probe are provided by a 6 pin connector carrying I^2C protocol.

Application specific devices such as attenuators, amplifiers, impedance adapters etc. can also be integrated into the ProBus concept. Attenuation or amplification factors are automatically taken into account by the oscilloscope so the user is protected against measurement errors.

ACTIVE PROBES

FET Probes

FET probes extend the measurement capabilities of any oscilloscope. They provide higher resistance and lower capacitance than passive probes. The reduced load on the circuit being probed results in more accurate measurements. FET probes are the ideal tool for working on sensitive or high-speed electronics.



Model Number	Bandwidth MHz	Input Z MΩ	Input C pF	Attenuation	Dynamic Range V	DC Offset Range V	ProBus	Compatibility
AP 003 AP 060	DC to 1000	1	1.9	10:1 ±2%	±7	N/A	NO	9304/10/14 94xx/LS140 7200/7200A
AP 020	DC to 1000	1	1.8	10:1 ±2%	±5	±20	YES	9304A/9310A 9314A/9320/9324 9350/9354 9360/9361
AP 021	DC TO 800	1	2.7	5:1 ±2%	±2.5	±10	YES	9304/9310A 9314A 9320/9324 9350/9354 9360/9361

Probes & Accessories

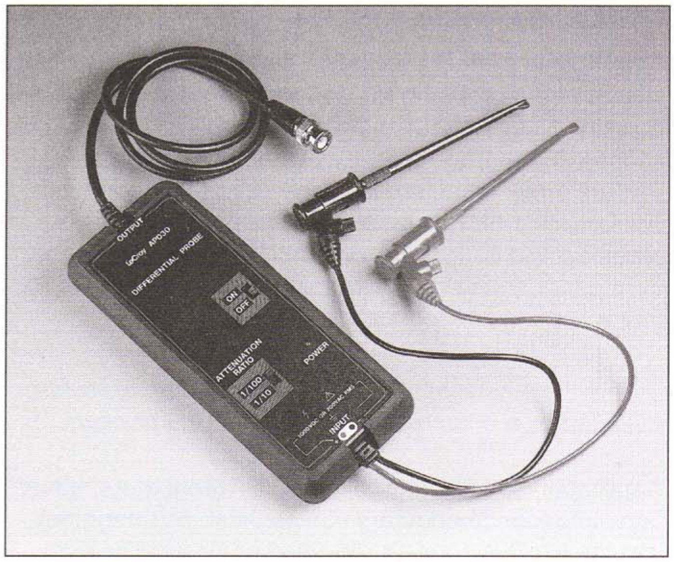
Differential Probes

The AP030, SI 9000 and SI 9000A are active differential probes. The differential techniques employed permit measurements to be taken at two points in a circuit without reference to ground.

This allows the oscilloscope to be safely grounded without the use of opto isolators or isolating transformers.

The two signals are processed in the probe and the resultant output is fed to a single channel of the oscilloscope. The output from the probe is a coaxial cable equipped with a standard BNC connector.

The probes are compatible with all 1 MΩ input oscilloscopes.



The following table gives key specifications for LeCroy differential probes. Further information is provided in the technical data sheets.

Model	Bandwidth MHz	Input Z MΩ	Common Mode Rejection Ratio 50 Hz	Common Mode Rejection Ratio 1 MHz	Attenuation	Maximum Input Voltage DC + Peak AC Diff. V	Com.mode V	Abs.max V
AP 030	DC to 15	2	-90	-53	10:1 100:1	±40 ±400	420 420	1000 1000
SI 9000	DC to 15	2	-80	-45	20:1 20:1	±70 ±700	700 700	1000 1000
SI 9000A	DC to 15	2	-80	-45	50:1 500:1	±100 ±1000	1000 1000	1000 1000

PROBE ACCESSORIES

General Purpose

D 901x: 10:1 High Impedance Dividers

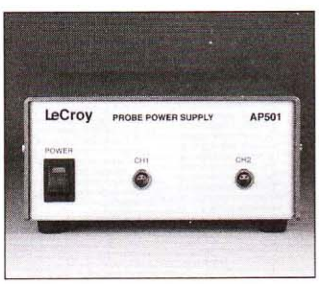
The D 901x plugs directly onto the input BNC of the scope in 1MΩ configuration, and is compatible with the models listed below. Most DSO attenuation factors include a setting for 10000:1, making it possible to use the D 901x and a suitable 1000:1 probe at sensitivities of over 10,000 volts/division.

Model	Oscilloscope Model Compatibility
D 9010	9420, 9424, 9450, 7200's
D 9011	9410, 9414, 9430
D 9012	9450A
D 9013	931x, 935x, 9360, 9361

SG 9001: Overvoltage Input Protector

Assembled in a BNC feedthrough housing, Model SG 9001 protects the high impedance scope input circuitry from voltage signals exceeding 230V. It is a spark gap protection device, which adds negligible capacitance to the input, thus ensuring clean signal measurement.

AP 501: Probe Power Supply



Provides external power for LeCroy's AP 003 FET Probe. It is not required for AP 020 or AP 021, which are powered directly via ProBus.

PP 093: Probe Tip

Probe tip replacement for PP 063 10:1 8 GHz passive probe.

ProBus

PP 090: 75 to 50 ohm ProBus Adapter

Used with any ProBus-compatible scope input, provides 75Ω input impedance. Gain compensation is performed automatically by the oscilloscope. Primary applications include telecommunications and video.
Input Impedance : 75 Ω ± 1% Atten. : 2:1 ± 1%
Max. Input Voltage : ± 8.66 V DC (1 W)
VSWR : (DC to 1 GHz), <1.1 typical.

PP 091: Trigger Pickoff for Model 9360

A ProBus adapter providing a low capacitance pick-off of the analog signal for use with the external trigger of Model 9360, 5 GS/s Digitizing Oscilloscope. Model PP 091 is recommended when using the high bandwidth input of Model 9360.
Insertion loss : 1dB at 600 MHz

PP 092: 2GS/s Adapter for Model 9354

The PP 092 Adapter transforms Model 9354 into a single channel, 2GS/s Digital Oscilloscope.

PB 001: ProBus Kit

For users requiring their own custom circuit, the ProBus kit offers a ProBus case, input and output BNC connectors, ProBus connector for ±12V and ground connections, a breadboarding PCB and a set of screws. Mechanical drawings and pin assignments are provided in the kit.

PROBE KITS

Probe accessories are supplied as kits for the various probe models and may be purchased separately.

AK 062: Accessory Kit for 7262

SMA Female Terminator
SMA Male Terminator
SMA Female Short Circuit
SMA Male Short Circuit
SMA Attenuator 3 dB
SMA Attenuator 6 dB
SMA Attenuator 20 dB
Adapter SMA Male to BNC Female
Adapter BNC Male to SMA Female.

This table lists the contents of each kit and the probes with which it is compatible.

LeCroy ORDERING No.	PK 001	PK 002	PK 003	PK 004	PK 005
PROBE COMPATIBILITY	PP 001 PP 002	PP 011 PP012	PP 061 PP 062 PP064	AP 020 AP021	AP 060
RETRACTABLE PINCHER TIP	PF 059	PF 004	PF 059	PF 135	PF 135
GROUND LEAD	PF 061	PF 060	PF 061	PF 060	PF 060
BNC ADAPTER	PF 017	PF 010	PF 017	PF 095	PF 095
GROUND BAYONET	PF 015 (3X)	PF 0008 (3X)	PF 015 (3X)	PF 015 (3X)	PF 015
IC TIP	PF 016	PF 009	PF 016	PF 016	PF 016
MINI PINCHER LEAD				PF 063	
MINI PINCHER (RED)				PF 082	
MINI PINCHER LEAD GND					PF 099
MINI PINCHER (BLACK)					PF 080
COLOR TAG ORANGE	PF 001 (2X)	PF 001 (2X)	PF 001 (2X)		
COLOR TAG WHITE	PF 003 (2X)	PF 003 (2X)	PF 003(2X)		
SCREW DRIVER	PF 094	PF 094			

SCOPE CART

Oscilloscopes can be easily transported around the laboratory on oscilloscope carts which roll on large locking castors.

Shown: OC9002

OC9002:
For 9400 or 9300 Series & LeCroy ScopeStation.

TRANSIT CASES

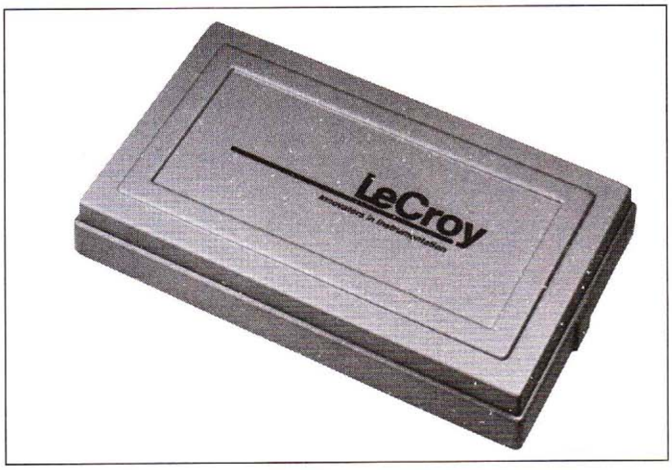
LeCroy transit cases are made of a heavy duty reinforced aluminum. Light weight and measuring approximately 30 x 50 x 60 cm (size given for 9400 Series), these cases are ideal for transporting oscilloscopes by air, road or sea.

TC9001:	For 9400 Series.
93XX-TC1:	For 9300 Series.
7200-SHIP:	For 7200 Series Mainframe.
LS-TRANS:	For LeCroy ScopeStation.

CARRYING CASE

These soft cloth carry bags have an internal pouch for instruction manuals and accessories. Designed for customers who use their oscilloscope in several different locations, the carry bag also acts as a protective cover.

TC9002:	For 9400 Series.
93XX-TC2:	For 9300 Series.
7200-SOFT:	For 7200 Series.
LS-SOFT:	For LeCroy ScopeStation.



PROTECTIVE FRONT COVERS

93XX-FC:	Cover for 9300 Series.
94XX-FC:	Cover for 9400 Series.
7290-FC:	Cover for 7200 Series.
LS-FC:	Cover for LeCroy ScopeStation.

About Arbitrary Waveform Generators

What is an Arbitrary Waveform Generator?

The Arbitrary Waveform Generator (AWG) is a signal source that uses digital techniques to produce user specified custom analog waveforms. You might think of it as a digital oscilloscope operating in reverse. The shape, pattern, and harmonic content of the waveform to be generated are defined by a sequence of numeric values loaded into a high speed waveform memory. Each successive memory location contains a value proportional to the amplitude of the waveform point to be generated. A high precision programmable time base is used to clock the memory address counter which loads the next value to be output into a digital-to-analog converter (DAC). This produces an analog equivalent to the numeric waveform description. Like other digitally synthesized signal sources, it is characterized by high accuracy, stability, repeatability, and ease of control. The distinctive benefit of an arbitrary function generator is the ability to produce structurally complex waveforms as well as standard sine, square, and triangle waves.

GENERATES MULTIPLE PERIODIC WAVEFORMS

Many users, like the telecommunications industry, need to generate waveforms which use multiple periodic waveforms with accurately controlled harmonic amplitude and phasing. These complex waveforms are readily generated using the AWG.

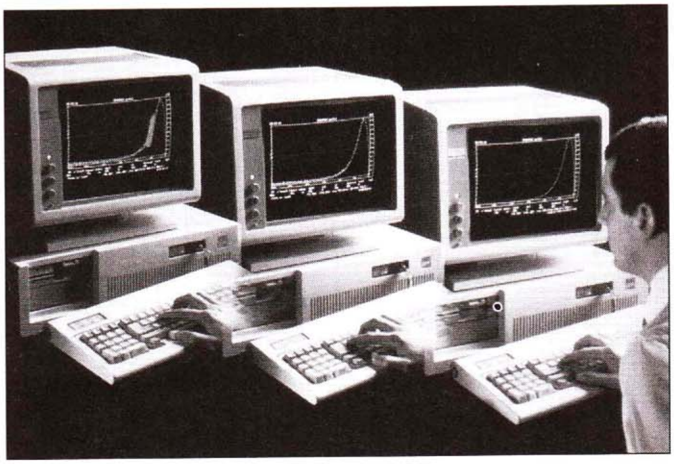
SIMULATES RANDOM OR INFREQUENT SIGNALS

Another class of applications involves duplicating signals upon demand, that are the results of random or infrequent events. Electromagnetic pulse (EMP) susceptibility testing and power line transient testing are common examples. Such transient events can be specified by equation or captured using a digital oscilloscope or digitizer. Once the waveform file describing the transient waveform is generated, it can be used when and where needed.

PRECISELY CONTROLS AMPLITUDE AND PHASE

Other applications make use of the AWG's precise control of amplitude or phase. Radar, sonar, and radio navigation test signals are all phase sensitive. Arbitrary waveform generators with dual outputs are especially well suited for producing outputs with controllable phase differences. AWG's with synchronous digital outputs provide phased digital inputs directly to radar signal processing circuits at high, operational data rates. Magnetic peripherals like disk and tape drive testing require selective control of signal amplitude or timing a specific point within the waveform. Dual channel outputs can be added or subtracted to produce amplitude or timing variations at the desired points within the waveform for tolerance and margin testing.

SIGNAL SOURCES



Should You Be Using An AWG?

The examples cited are samples of a broader range of applications which would benefit from the use of an AWG as a test source. You should consider an AWG if your test signal requirements fall into any of the following categories:

- You're using "hot mock-ups", "golden reference" assemblies, or custom designed generators to supply real signals.
- You must test with signals that occur rarely, or unpredictably.
- You have to supply signals that originate in parts of a system that are unavailable or are hard to control.
- You have to supply multiple waveform types that would require many different signal sources.
- You need mixed analog and digital test signals.

When Choosing an AWG, Be Sure to Consider the Following:

EASE OF WAVEFORM CREATION

As the use of AWGs is a relatively new concept, it is extremely important to choose one that offers convenient user interaction. The LW400 series allows users to create and control waveforms "live" by turning knobs on the front panel while viewing the signal on a built-in 9" CRT. For the 9100 series, LeCroy's EASYWAVE waveform creation software (IBM PC compatible) is used to create and transfer waveforms to the AWG via GPIB. Its features include very easy waveform creation methods, file management, waveform transfer from LeCroy's digital scopes, and operation of the AWG.

SUFFICIENT AND NON-VOLATILE WAVEFORM STORAGE MEMORY

Recalling stored waveforms from memory is faster than recreating them from equations or externally downloading them when you want to change output waveforms. In LeCroy AWGs, non-volatile memory stores waveform data, setup files, and macro-command sequence files, which are all used for quick, automated AWG operations. The 9100 AWGs come with 512 kbytes of memory standard. Configurations of up to 2 million bytes are offered.

DC ACCURACY

DC accuracy is a measure of how precisely an AWG can provide the fundamental output voltage upon which all other smaller dynamic inaccuracies piggyback. It is important to focus on this attribute, and then analyze the overshoot, ringing, rise time, settling time, and harmonic distortions that can adversely affect the fidelity of your waveforms. LeCroy AWGs emphasize this specification, offering a range of 2% to 0.3% DC accuracy on its AWGs.

PRECISE SIGNAL CONTROL AND CONDITIONING

One of the most important characteristics of an AWG is the ability to make precise, controlled shifts in waveform timing and amplitude. An outstanding benefit of the LW400 series design is the EASY way in which the user can control signal edge and feature placement in 100ps increments. Output signal conditioning is optimized through an amplifier/attenuator/filter section that provides the signal you need without complex programming. Competitive instruments force the user to set waveform lengths in 32 point increments, but in the LW400 the customer gets what he wants - single point resolution.

DUAL CHANNEL OPERATION

In some AWGs, two independent channels operate from a common timebase, providing precise phase synchronization as well as simultaneous, dual-function operation. You can use the two channels to generate different but time-related signals, or you can sum the signals from both channels into one output.

Signal Source Ordering Information

Model		
LW410	Single Channel 400 Ms/s Arbitrary Waveform Generator	
LW410-ME2	1 Megasample memory	1 Channel
LW420	Dual Channel 400Ms/s Arbitrary Waveform Generator	
LW420-ME2	1 Megasample memory	2 Channels
LS-RM	Rackmount Adapter for LW410/420	
LS-SOFT	Soft Carrying Case for LW410/420	
LS-TRANS	Transit Case For LW410/420	
LW400-HD1	240 MByte Hard Disk Drive	
LW400-OM	Operators Manual for LW410/420	Included with LW410/420
LW400-RPG	Remote Programming Manual for LW410/420	Included with LW410/420
LW400-SM	Service Manual for LW410/420	
LW400-09	Digital Output	Channel 1 Only
9100	Arbitrary Function Generator	8-bit 200 Ms/s 2 Ch 512k Memory
9100/CP	9100 Control Panel	
9100/EC	Control Panel Extender Cable	6 ft (1 supplied with 9100/CP)
9100-EW	1 Year Extended Warranty	
9100GPIB2	GPIB Interface Card/Software	National Instruments PC2/GPIB-P
9100/MM	Memory Expansion to 512k	Standard in newer units
9100/MM1	1 MByte Memory Expansion	
9100/MM2	2 MByte Memory Expansion	
9100-OM	Extra 91XX Operator's Manual	Included with 91XX
9100/RT	Real Time Sequencing	
9100-SM	9100 Service Manual	Covers 9100/9101/9109
9100/SW	EasyWave™ Software	
9101	Single Channel Arbitrary Function Generator	8-bit 200 Ms/s 512k Memory
9101-EW	1 Year Extended Warranty	
9109	AFG with Digital Word Output	8-bit 200 Ms/s 512k Memory 2 Ch
9109-EW	1 Year Extended Warranty	
9112	Arbitrary Function Generator	12-bit 50 Ms/s 512k Memory 2 Ch
9112-EW	1 Year Extended Warranty	
9112-OM	9112 Operator's Manual	Included with 9112
Filter/36MHz	External 36 MHz Low Pass Filter	Included with 9112
9210	300 MHz Modular Pulse Generator	Accommodates 2 output modules
9211	250 MHz Output Module	With complementary outputs
9213	50 MHz Output Module	With variable transition times
9214	300 MHz Output Module	
9210-OM	9210 Operator's Manual	Included with 9210
9210-2-50/M1	9210 W/2 9213 plus MOD1	x10 better delay resolution
9210/RM	9210 Rack Mount Assembly	For 9210 Mainframe
9210/SC	Soft Carrying Case for 9210	
9210-SM	9210 Service Manual	Covers all 92XX modules

SIGNAL SOURCES

LeCroy WaveStation
LW410/LW420 Arbitrary Waveform Generator
400 MHz Sample Clock

Main Features

- 100 ps feature placement resolution
- 400 MS/s maximum sample clock per channel
- 1 and 2 channel versions
- Live update of waveform output
- Built-in display
- Stand Alone Design, no PC required
- 8 bits of vertical resolution
- Up to 1 MByte of playback waveform memory per channel
- Internal 130 MByte hard disk drive for project, sequence, and waveform storage (240 MByte optional)
- Built-in Floppy Disk Drive for waveform and sequence file transfer and storage
- Digital Outputs optional

Features and Benefits

The WaveStation, LW420, is a dual channel, 400 MS/s arbitrary waveform generator (AWG) that redefines what high performance AWG's are, and how they will be used. WaveStation offers more than just improved technical specifications, it substantially increases functionality and ease of use, eliminating many of the traditional obstacles constraining previous AWG's. Building on over 7 years of experience in the design and manufacture of high performance signal sources, the LW420 combines innovative signal processing, high speed electronic design, and human factors engineering to provide a truly intuitive and highly interactive arbitrary waveform generator.

SPECIFY THE WAVEFORM, LET THE LW420 WORRY ABOUT THE DETAILS

The WaveStation does not require the user to be aware of the sample clock period or the particular reconstruction filter being used. All the LW420 needs to know is your waveform in terms of voltage and time. No matter which of the many available tools you use to specify the waveform, the LW420 will generate the output using the optimum combination of sample clock rate and filter bandwidth. The filters used will assure that aliasing does not take place and that all the timing relationships within the waveform will be precisely maintained.

LIVE WAVEFORM MANIPULATION LET'S YOU CONTROL THE WAVESHAPE QUICKLY AND INTERACTIVELY WHILE BEING DISPLAYED ON THE INTERNAL CRT DISPLAY

Select a section of the waveform using the time cursors, then select one of a set of waveform manipulation operations (e.g. move feature, delay, amplitude,...) and turn the knob! That is how easy it is to continuously modify all or part of a waveform. Time shifts, as small as 100 ps, amplitude variations on a peak, or changes in signal duration are instantly reflected in the output signal. Margin testing or characterization, with the most complex waveforms, has never been so simple.

WAVEFORM CREATION HAS NEVER BEEN EASIER

Waveforms can be selected from libraries of traditional function generator waveforms. They can also be created using equations or imported from external sources such as oscilloscopes or other computer programs. Waveforms, once created or captured, can be further manipulated using the internal waveform (array) math processing. The waveform math functions include basic arithmetic operations, smoothing, integration, differentiation, and convolution.

A highly developed waveform editing capability uses advanced signal processing to provide bandlimited cut, paste, insert and offset operations with minimum editing artifacts. Single sample resolution eliminates the constraint found in other AWGs that waveforms be multiples of 8 samples further simplifying the waveform creation process.

PULL WAVEFORMS DIRECTLY FROM MOST DIGITAL SCOPES

Connect a GPIB cable between the LW420 and your digital oscilloscope. Select your scope from a list of commonly available scopes and begin importing waveforms. Once in the WaveStation all the manipulation, editing and math tools can be used to put the waveform in the shape you need for your task.

400 MS/S MAXIMUM CLOCK RATE, 1 MBYTE WAVEFORM LENGTH, SYNTHESIZER TIMEBASE MEANS BETTER PERFORMANCE

A maximum sample rate of 400 MS/s combined with up to 1 MByte of waveform memory gives you the raw performance you need to generate the most demanding, complex stimuli. The timebase combining 3 ppm accuracy and 1ppm/year stability assures that the waveforms you test your systems with next year will be the same as the ones you use today. Low single sideband phase noise of less than -110 dBc/Hz @ 10 KHz from a 10MHz carrier and a 1 Hz frequency resolution mean that the LW420 can be used to generate even the most demanding communications waveforms.

FULLY INTEGRATED AWG INCLUDES HIGH PERFORMANCE PROCESSOR, INTERNAL HARD DISK DRIVE, AND BUILT-IN 9 INCH CRT

WaveStation provides all the power needed to work with long and complex waveforms. A built-in 130 MByte hard disk drive, a 33 MHz 486 processor, up to 20 MByte of RAM, and an internal monochrome VGA display make the LW420 a fast and responsive instrument ideally suited for interactive graphical operations required in a high performance AWG.

PERFORMANCE SPECIFICATIONS

GENERATOR MODE

Standard Function Waveforms

- Sine, 1 Hz - 100 MHz
- Square, 1 Hz - 50 MHz
- Triangle, 1 Hz - 25 MHz
- Ramp, 1 Hz - 25 MHz
- Pulse, (period)10 ns - max. memory
- DC

Frequency Sweep Linear / Log
Multitone, 1-10 tones, 1 Hz - 100 MHz

ARBITRARY FUNCTIONS:

Waveform Creation
Interactive Graphical editor on Internal 9" CRT

Standard Functions
Sine, Square, Triangle, Ramp, Pulse, DC

Equation Editor
Waveform (array) Math
Waveform Import From
Digital Oscilloscope
Floppy Disk

Waveform Feature Time Resolution: 100 ps
Available memory: 256k/ch. standard, 1 Mpoint optional
Minimum segment length: 64 points
Maximum segment length: Up to available memory (1Mpoint when optional memory installed)
Segment length resolution: 1 point
Number of links: 512 for 256k memory 2048 for 1M memory
Noise: Independent pseudo random white noise generator with Gaussian distribution and 2^{32} states

WAVEFORM OUTPUT CHARACTERISTICS

Output channels: LW410 - 1 Channel
LW420 - 2 Channel
Output Impedance: 50 Ω, ± 5%
DC Accuracy: 2% of setting + 40 mV
Vertical resolution: 8 bits
Minimum output voltage: 10 mV p-p into 50 Ω
Maximum output voltage: 10 V p-p into 50 Ω
Offset voltage range: ± 5 V into 50 Ω. The output voltage (signal + offset) must be in the range ± 5 V into 50 Ω. Offset limited for smaller amplitudes as follows:

Output V p-p	Offset Range
10 → 0.5	5V
0.5 → 0.1	1V
0.1 → 0.01	0.2V

Offset voltage resolution: 0.05% of full scale
Output bandwidth: 100 MHz (-3dB) (widest bandwidth)
Total harmonic distortion: <5 V p-p
<-45 dBc (-50 dBc typical) for sinusoidal output <=1MHz
<-35dbc for sinusoidal output 1 MHz to 20 MHz (<-45 dBc typical)
<-25 dBc to 50 MHz (<-40 dBc typical) (predominantly 2nd harmonic)
Spurious & non-harmonic distortion: <-60 dBc for frequencies <=1 MHz for output
Signal-to-noise ratio: >40 dB (-45 typical) for output amplitudes >100 mV @ 0 offset
Transition times: <6 ns 10%- 90% @ widest bandwidth
Overshoot and ringing: <8% of step size max. 3% typical
Settling time: <50 ns to within 2% of step size @ widest bandwidth
Inter-channel crosstalk: <1%
Ch 1 to Ch 2 skew: <1 ns for identical waveforms in each channel (widest bw)
Output protection: ± 20 V

SIGNAL SOURCES

Output filtering: The following filter cutoff frequencies are available;
100 MHz Gaussian, 10 MHz Gaussian,
1 MHz Gaussian, 100 kHz Gaussian,
10 kHz Gaussian
Sample clock characteristics:
(with internal 10 MHz reference)
Maximum sample rate: 400 MS/second
Accuracy: <3 ppm over operating temperature range
Stability: aging <1 ppm/year
SSB Phase Noise: <-110 (-115 typical) dBc/Hz @ 10 KHz offset for a 10 MHz sine wave at the output
Resolution: 1 Hz

TRIGGERING CHARACTERISTICS

Trigger slope: Positive or Negative
Trigger input impedance: 50 Ω ± 5%
Threshold range: ± 2.5V
Threshold resolution: 20 mV
Threshold accuracy: 100 mV
Threshold sensitivity: 50 mV p-p
Minimum pulse width: 5 ns
Protection: ± 5 V

TRIGGER MODES

Continuous: Runs continuously
Single: Outputs 1 repetition of the waveform for each trigger received. Triggers received while the waveform is still running are ignored.
Burst: Outputs the selected waveform a programmable number of times in response to a trigger. The maximum number of repetitions for a burst is 4,095. Triggers received while the burst is running are ignored.
Gated: The waveform starts on the leading edge of the gate signal and stops on completion of the waveform cycle occurring at the trailing edge of the gate signal.

TRIGGER DELAY

Minimum delay time: 35 ns ±3.5 ns +5 sample clocks
Maximum delay time: (2^{32}-1) sample clocks
Delay resolution: 1 sample clock. The delay will be programmed in units of seconds. When operating from the front panel the resolution (sample clock period) will be shown to the user and the delay will change in increments of that value.
Delay accuracy: Same as sample clock + minimum delay time
Delay jitter: 1 sample clock

TRIGGER SOURCES

Manual: Front panel pushbutton
External: Front panel BNC connector
GPIB: A trigger command may be issued over the GPIB bus

AUXILIARY INPUTS

External: 10 MHz reference A rear panel input is provided that allows an external reference clock to be input. 400 mV p-p to 5 V p-p into 50 Ω.

AUXILIARY OUTPUTS

10 MHz reference output
Timing marker: 1 bit of memory up to 128 transitions definable
Output levels: ECL or TTL levels
Protection: Outputs are protected to ± 5 V
Digital Output: (optional) Channel 1 only, 8 bits and clock available from rear panel. TTL/ECL/PECL logic levels simultaneously.
Noise In/Out: From rear panel BNC Connectors

HARD COPY OUTPUTS

Supported Printers include:
- Epson MX/FX
- Epson LQ
- HP LaserJet II
- HP ThinkJet

PROGRAMMABILITY

GPIB IEEE 488.2 compatible. Compliant with SCPI programming language. Capable of initiating and controlling waveform transfer from digital oscilloscopes by simply connecting a GPIB cable (no computer required).

MECHANICAL

Dimensions: 14.92" W x 7.67" H x 19.58" D (37.9 cm x 19.5 cm x 49.7 cm)
Weight: 27.6 lbs (12.5 kilograms)

ENVIRONMENTAL

Temperature: 5° to 35° full specifications; 0° to 40° C operating; -20° to 70° C non-operating.
Humidity: 10% to 90% relative, non-condensing
Power: 90 - 132/180-250 V AC
47 - 63 Hz
4 amps @ 115 V AC (20 amps cold start surge)
2 amps @ 230 V AC (40 amps cold start surge)

ORDERING INFORMATION

For Ordering Information see Page 75.

9100 Series
Arbitrary Function Generators

Main Features

- Custom waveforms from 5 nsec per point
- Analog outputs of 8- and 12-bit resolution
- High-speed waveform memory lengths to 2 MBytes (512 kbytes standard)
- Waveform linking and looping with real time dynamic simulation options
- Six standard waveforms
- 10 V p-p waveform outputs (50 Ω)
- Dual or single channel versions
- GPIB interface
- EASYWAVE® waveform creation software (optional)
- Easy waveform capture from digital oscilloscopes

Generates Custom or Standard Waveforms

The LeCroy 9100 Series of Arbitrary Function Generators (AFGs) are high performance ATE or benchtop instruments which can generate either standard or user defined, complex waveforms with fine point-to-point time resolution. They are fully programmable via either GPIB or RS-232. Waveform generation and editing software is offered for PC-DOS compatible computers. Applications include: scientific research, medical instrumentation, disk drive testing, communication link testing, radar and sonar testing, ultra-sound testing and video testing.

HIGH SPEED WAVEFORMS

Custom waveform outputs using digital generation techniques can now be created from amplitude points separated by as little as 5 nsec. Wide-band amplifiers coupled with high-speed DACs yield fast rise times and settling times. Built-in filters eliminate point-to-point steps to present smooth output shapes at your option. Analog signals to 100 MHz can be created.

DUAL CHANNEL OPERATION

In the dual output versions, each channel has independent amplitude, offset, and phase delay, providing the ability to simultaneously generate two different signals. Also, generating the same signal on both channels and inverting one results in differential output signals. The excellent phase match between channels permits the generation of precise, phase related signals for use in such applications as testing logic set up times or synchro resolvers. It is especially suited for mixed signal automated testing for products such as digital filters, A/D converters, D/A converters, video systems, and data communications circuits.

INTERNAL CHANNEL SUMMING

With the 8-bit Model 9109, internally summing the two channels together makes it possible to combine two waveforms and control the amplitude of one portion of the resultant composite waveform independently of the rest of it. This also provides expanded dynamic range because one portion of the waveform can be attenuated relative to the rest without losing resolution (bits). Also, by setting the amplitude range of each channel to half the desired total amplitude and summing, a resolution of 9 bits can be achieved.

STANDARD AND ARBITRARY FUNCTIONS

In addition to the primary function of arbitrary function generation, the Series 9100 units also provide both standard function generation and pulse generation capabilities. Sine, square, triangular, ramp, pulse and DC-waveform functions are built-in standards. Function selection and parameter manipulation can be implemented from the control panel or via the GPIB or RS-232-C interface.

DIGITAL AS WELL AS ANALOG OUTPUTS

Both dual channel models of Series 9100 generate custom or standard waveforms and their equivalent digital data patterns. Their high speeds up to 200 Mpoints/sec make it possible to produce "real world" custom waveforms for testing digital filters, RADAR and SONAR signal processing systems, disk drives, A/D-D/A converters, video systems, and data communications systems.

VERSATILE MEMORIES FOR WAVEFORM GENERATION AND NON-VOLATILE STORAGE

The AFGs use a high-speed waveform memory (512 kbytes, expandable to 2 MBytes) to generate waveforms. This memory can be down-loaded with a variety of different waveform files or segments. Waveform elements can be repeated and linked together to create larger composite waveforms. There is no dead time between linked segments. Each custom waveform can be repeated up to 65,535 times.

FLEXIBLE OPERATION AND TRIGGER MODES

Waveforms can be output as a single shot, as a triggered burst of up to 64k cycles, as an auto-triggered recurrent waveform with programmed delays between cycles, as a continuous waveform, or gated under control of an external signal. Triggering can be manual, bus operated, or external, with selectable slope, polarity, level, and delay. Timemark, sync'd, waveform start, and clock outputs provide flexible timing reference for synchronized operation.

WAVEFORM AND COMMAND SEQUENCING SPEED TEST SETUP AND THROUGHPUT

LeCroy arbitrary function generators let you store hundreds of waveform generation commands in a single "Sequence File". By activating just one sequence file, the most complex waveforms can be output easily and automatically.

OPTIONAL HAND-HELD CONTROL PANEL

An optional hand-held control panel allows test technicians full access to stored waveforms and permits flexible manipulation of these waveforms without the use of a computer.

WAVEFORM CREATION SOFTWARE

LeCroy's optional EASYWAVE software simplifies creation of custom waveforms or digital data patterns. With EASYWAVE you can easily and quickly create almost any conceivable "real world" waveform required for comprehensive and realistic testing of your circuits.

Waveforms can be created directly from the mathematical equation which describes the waveform. Or, it may be easier to simply select the needed shapes from EASYWAVE's library of simple waveform elements, link them together, and then stretch them to desired amplitudes and time durations. A spreadsheet-like array editor is used for point-by-point waveform or pattern entry in decimal or hexadecimal form. Waveforms may also be captured using any of LeCroy's digital oscilloscopes, digitizers, or transient recorders, and transferred to the AFGs.

Custom waveforms can be captured by a digital scope or digitizer, and then edited and regenerated with the Series 9100 AFGs. Or, they can be created from scratch from simple elements or equations with our user-friendly EASYWAVE® software.

9100 Series Models	
Model 9101	Single-channel, 200 Mpoints/sec, 8-bit analog outputs.
Model 9109	Dual-channel, 200 Mpoints/sec, 8-bit analog outputs, 8-bit digital outputs.
Model 9112	Dual-channel, 50 Mpoints/sec, two 12-bit analog outputs, two 16-bit digital outputs.

Specifications	9101	9109	9112
Ouput Channels	1	2	2
Maximum Sample Rate	200 MS/sec	200 MS/sec	50 MS/sec
Analog Bandwidth	100 MHz	100 MHz	25 MHz
Waveform Memory Standard	512 kpoints	512 kpoints	256 kpoints
Maximum Waveform Memory Optional	2 Mpoints	2 Mpoints	1 Mpoint
Digital Outputs	None	Dual 8 bit	Dual 16 bit
External Sum Input	Yes	Yes	No
Internal Summing	No	Yes	No
Output Impedance	50Ω ±0.5 Ω	50Ω ±0.5 Ω	50Ω ±0.5 Ω
DC Accuracy	The greater of 1% of level or 1% of full scale amplitude or 20 mV	The greater of 1% of level or 1% of full scale amplitude or 20 mV	0.5% of full scale amplitude into 50Ω for amplitude ≥ 500 mV
Vertical Resolution	8 bits	8 bits	12 bits
Minimum Full Scale Ouput Voltage	5 mV p-p into 50Ω 10 mV p-p into high-Z	5 mV p-p into 50Ω 10 mV p-p into high-Z	100 µV p-p into 50 Ω 200 µV p-p into high-Z
Maximum Full Scale Output Voltage	10 V p-p into 50 Ω (-5 V to +5 V) 20 V p-p into high-Z	10 V p-p into 50 Ω (-5 V to +5 V) 20 V p-p into high-Z	10 V p-p into 50 Ω (-5 V to + 5 V) 20 V p-p into high-Z
Offset Voltage Range	±5 V p-p into 50 Ω ±10 V p-p into high-Z	±5 V p-p into 50 Ω ±10 V p-p into high-Z	± full scale amplitude (must be within output voltage range)
Offset Voltage Resolution	< 6 mV steps	< 6 mV steps	0.05% of full scale amplitude
Total Harmonic Distortion	< -50 dBc for sinusoidal output at frequencies ≤ 1 MHz	< -50 dBc for sinusoidal output at frequencies ≤ 1 MHz	< -65 dBc for sinusoidal output at frequencies ≤ 200 kHz
Spurious and Non-Harmonic Distortion	< -65 dBc for frequencies ≤ 1 MHz, excluding band within 1 kHz of carrier	< -65 dBc for frequencies ≤ 1 MHz, excluding band within 1 kHz of carrier	<-65 dBc for frequencies ≤ 1 MHz, excluding band within 1 kHz of carrier
Signal-to-Noise Ratio	≥ 45 dB for full scale amplitudes ≥ 75 mV 0V offset	≥ 45 dB for full scale amplitudes ≥ 75 mV 0V offset, sum off	> 70 dB RMS (p-p noise ≤ 0.1% of full scale amplitude +2 mV excluding glitch energy of 50 pV•sec amplitude
Transition Times	< 5 nsec, 10% - 90%, filters off	< 5 nsec, 10% - 90%, filters off	<8 nsec , 10% - 90%(5.5 nsec typ)
Overshoot and Ringing	5% of full scale amplitude max, 3% typical	5% of full scale amplitude max, 3% typical	5% of full scale amplitude max, 2% typical
Settling Time	< 20 nsec to 3% of amplitude change for 5 V transition, including rise time (filter off)	< 20 nsec to 3% of amplitude change for 5 V transition, including rise time (filter off)	< 50 nsec to 1% of amplitude change, 20 nsec typical
Crosstalk Between Channels	N/A	< 1%	<0,05% with both channels set for 10 V amplitude
Channel 1 to Channel 2 Phase Accuracy	N/A	±1nsec, dual mode, ±0.5 nsec, channels summed	±1 nsec
Output Protection	±40 V	±40 V	±40 V
Page #	79	79	79

OUTPUT CHARACTERISTICS

Output smoothing (filtering): The 9101 and 9109 have built-in 18 dB/octave (3 pole Bessel) filters for each channel with independently programmable cutoff frequencies of 100 MHz, 30 MHz, 10 MHz, 3 MHz or 1 MHz. Filters may also be turned off. The 9112 is provided with one external 8-pole Butterworth low-pass filter. Cutoff frequency (-3 dB point) 36 MHz, rolloff ≈ 48 dB/octave. Additional filter for 2nd channel optional.

OUTPUT CLOCKING CHARACTERISTICS

Clock resolution: 0.035% (350 ppm).

Clock accuracy: < 5.0 ppm at achievable set points, at 23°C, 115 VAC/60 Hz, after a 30 minute warm-up period.

Clock stability: < 0.5 ppm/°C.

Clock jitter: 0.05% max., 0.0125% typical.

Interval range:

	9101	9109	9112
Maximum Output Rate	200 Mpoints/sec	200 Mpoints/sec	50 Mpoints/sec
Single Channel	5 nsec - 10 sec/pt	5 nsec - 10 sec/pt	20 nsec - 40 sec/pt
Dual Channel	N/A	10 nsec - 20 sec/pt per channel	20 nsec - 40 sec/pt per channel

External clocking: Output point rate may also be controlled by an external clock source. When external clocking is selected, the internal clock is bypassed and the waveform is generated using the external clock. The External Clocking Performance table describes the relationship between the external clock frequency and the output point rate in various configurations.

External clock input impedance: 50 Ω.

External clock threshold: Variable over the range of ±2.5 V. Resolution < 20 mV.

TRIGGERING CHARACTERISTICS

Trigger Modes

Continuous: The generator runs continuously at the selected frequency.

Recurrent: The waveform is cycled with a programmable delay between cycles. The number of waveforms per cycle is programmable up to 65,535.

Single: Upon receipt of a trigger, the selected waveform is generated only once. The start of the waveform can be programmed to delayed from the trigger point.

Burst: Upon receipt of a trigger, the selected waveform is generated a programmable number of times, up to 65,535. The start of the burst can be programmed to delay from the trigger point.

Gated: The waveform is triggered by the leading edge of the gate signal, and stops at the completion of the waveform cycle occurring during the trailing edge of the gate signal.

Trigger delay: Programmable; limits depend on generator model and single or dual channel operation. The limits are given in the Trigger Delay Limits table. In the table, the term "point" indicates one sample interval's duration.

Trigger arming sources:

Auto: Generator automatically rearms itself at the end of the waveform.

Bus: Generator is rearmed only via command from the GPIB, RS-232 or the 9100/CP Hand-held Control Panel.

Triggering sources:

Manual: Front panel push-button.

External: External trigger applied via a front panel BNC.

Bus: Trigger from GPIB of RS-232.

Control Panel: Trigger key.

External trigger input:

Impedance: 50 Ω.

Slope: Positive or negative threshold.

Range: ±2.5 V.

Threshold resolution: < 20 mV.

External Clocking Performance

	9109, 9109 Single Channel Mode	9109 in Dual Channel Mode	9112 in Single Channel Mode	9112 in Dual Channel Mode
Maximum External Clock Frequency	200 MHz	200 MHz	200 MHz	100 MHz
Clock Divider	None	÷2	÷4	÷2
Maximum Ouput Sample Rate	200 Mpoints/sec	100 Mpoints/sec per channel	50 Mpoints/sec	50 Mpoints/sec per channel

This table describes the relationship between the external clock frequency and the output point rate in various configurations.

Trigger Delay Limits

	9101, 9109 Single Channel Mode	9109 in Dual Channel Mode	9112 in Single Channel Mode	9112 in Dual Channel Mode (min).
Minimum	4 points	2 points	2 point	1 point
Maximum	1 Mpoint	500 kpoints	500 kpoints	250 kpoints

WAVEFORM MEMORY CHARACTERISTICS

All LeCroy 9100 Series Arbitrary Function Generators (AFGs) have 512 kbytes of high speed waveform memory as a standard feature.

Waveform memory may optionally be extended to 1 MByte with the /MM1 option or 2 MBytes with the /MM2 option.

The 9101 and the 9109 use one high speed memory byte per waveform point. The 9112 uses 2 bytes per point. Therefore, with the 9112 the standard configuration provides 256 kpoints, the /MM1 option provides 512 kpoints and the /MM2 option provides 1 Mpoint.

Individual waveform files, or segments, may be linked to create larger composite waveforms. There is no dead time between linked segments.

The maximum number of links in a composite waveform is 2048. Each linked segment can be repeated up to 4095 times before advancing to the next linked segment. Regardless of how many times a given linked segment is used in a composite waveform, it appears in high-speed memory only once. The Memory Segment Length Requirements table describes segment length requirements.

REAL-TIME OPERATING MODE

The 9100/RT option allows immediate, interactive access to any waveform file in the AFG's high-speed waveform memory. This gives the user the ability to change the output waveform "on the fly", in a smooth and continuous fashion. The option consists of a First-In, First-Out (FIFO) memory and support hardware. Data written to the FIFO is used instead of the contents of the generator's Control Memory, which normally controls the sequencing of output waveforms.

Compatibility: This option is fully compatible with all LeCroy 9100 Series AFGs.

Maximum real-time waveform selection rate: 2.77 MHz, for 72 point single-channel waveforms at 200 MHz sample rate in 9101 and 9109, or for 18 point dual-channel waveforms at 50 MHz sample rate in 9112. **Fetch time for waveform change instruction:** 72 sample clock periods.

Throughput delay: (from rising edge of write to output change) 121 sample clock periods + 120 nsec, relative to the end of the waveform currently being output.

DIGITAL OUTPUT CHARACTERISTICS

Two digital output channels are standard features of LeCroy's 9109 and 9112 Arbitrary Function Generators. Each of the two channels has both a digital and an analog output port. This allows users to utilize data in both the digital and analog domains. This feature is useful in mixed signal test and development applications.

The 9212 uses a 16-bit memory architecture. The four least significant bits of each of the 9112's data words are not delivered to their respective DACs, and may therefore contain time-correlated data which do not affect the analog waveform generated by that channel. (The Digital Output feature is unavailable in Model 9101.)

AUXILIARY INPUTS AND OUTPUTS

Outputs: All of the AFGs in LeCroy's 9100 Series feature five timing outputs which may be used to help synchronize other devices in your test system to the AFG's output. Two Sample Clock outputs (located on the rear panel) are provided, as well as three timing pulse outputs (located on the front panel).

Timing outputs: The Time Marker, Sync Trigger and Waveform Start Outputs are described below.

Time marker output: Occurs at a programmable time after the trigger. Limits are the same as for Trigger Delay (see the table in the Trigger Characteristics section of this Specification).

Sync trigger output: Occurs at the next sample clock edge after receiving a Trigger.

Waveform start output: Occurs at the start of the waveform. This is the only timing output available in Continuous trigger mode.

Output impedance: 50 Ω.

Output levels: TTL into a high impedance, 1.5 V into 50 Ω. Outputs are positive-going pulses of approximately 75 nsec duration.

Output protection: Externally applied voltages should not exceed -0.5 V or +5.0 V.

Clock outputs: These outputs are squarewaves at the sample frequency for single channel waveforms in the 9101 and 9109, at twice the sample frequency for dual channel waveforms in the 9109 and for single channel waveforms in the 9112, or at 4 times the clock frequency for dual channel waveforms in the 9112.

Clock Out 1: Present in all modes including Ext. Clock. Active even if no waveform is being generated.

SIGNAL SOURCES

Memory Segment Length Requirements

	9101, 9109 Single Channel Mode	9109 in Dual Channel Mode	9112 in Single Channel Mode	9112 in Dual Channel Mode
Minimum Linkable Segment Length	72 points	36 pts/ch	36 points	18 pts/ch
Maximum Segment Length	65,536 points	32,768 pts/ch	32,768 points	16,384 pts/ch
Segment Length Resolution	8 points blocks	4 pts/ch blocks	4 points blocks	2 pts/ch blocks

9109 and 9112 Digital Output Specifications

	9109 ECL*	9109 TTL*	9112
Maximum Data Rate	200 MBytes/sec	80 MBytes/sec	50 Mwords/sec
$V_{out\ high}$ (min)	-1.0 V	+2.7 V @ +1 mA	+2.7 V @ 1 mA
$V_{out\ low}$ (max)	-1.55 V	+0.75 V @ -3.2 mA	+0.75 V @ -3.2 mA
Maximum Safe External Voltage	+0.5 V -2.0 V	+5.5 V -0.5 V	+5.5 V -0.5 V
Output Word Length	Two 8-bit words or one 16-bit word	Two 8-bit words or one 16-bit word	Two 16-bit words or one 32-bit word
Digital Clock Output	differential	single-ended	single-ended

** Each channel individually configurable for ECL or TTL output by internal jumper selection.*

Clock Out 2: Active only when waveform is being generated. Quiescent during trigger delay, re-arm interval, etc. Used as Master clock for Master-Slave operation.

Output impedance: 50 Ω.

Output levels: NIM logic levels (0 to -0.8 V) into 50 Ω. Can be configured at factory for ECL levels into 50 Ω.

Output protection: Externally applied voltages should not exceed ±2.5 V.

Inputs: The following characteristics apply to the inputs of LeCroy's 9100 Series Arbitrary Function Generators.

Protection: The maximum input voltage level for all inputs should not exceed ±5 V.

External trigger/gate input: Input impedance 50 Ω. Threshold level ±2.5 V, < 20 mV resolution. See Triggering Characteristics section for more detail.

External clock input: Input impedance 50 Ω. Threshold level ±2.5 V, < 20 mV resolution. See Output Clocking Characteristics section for more detail.

Sum input: (not available on 9112)

Impedance: 50 Ω.

Gain: x1, ±5% for > 350 mV full scale output ranges.

Bandwidth: > 80 MHz at 3 dB.

Hand-held keypad (control panel) input: A DIN connector is provided for attaching the optional hand held control panel and display.

STANDARD FUNCTIONS

Any member of LeCroy's 9100 Series of AFGs can be operated as a standard function generator, a pulse generator, or a precision DC source, as well as an arbitrary function generator.

Standard Function Mode

The user selects the desired function (sine, square, ramp or triangle), and frequency. The AFG uses these selections to calculate the data file and sample rate most suitable for generation of the requested output signal, in a manner transparent to the user. In the dual-channel generators (9109 and 9112), the phase of the signal on Channel 2 is independently programmable. The Standard Function Frequencies table describes the frequencies obtainable for the various standard functions in each generator type.

Pulse Generator Mode

The user specifies the repetition rate, delay and width of the desired pulse output, and the AFG calculates the best sample rate and data pattern to meet those characteristics. Note that the Pulse function is only available in Single Channel mode (i.e., even in the 2-channel generators, pulses will only be output on Channel 1). The table below gives the pulse parameter limits.

DC Mode

Allows the AFG to operate as a source of precise DC voltages. Any DC output voltage within the range of ±10 V into 50 Ω (±20 V into a high-Z) may be programmed.

PROGRAMMABILITY

All of LeCroy's 9100 Series Arbitrary Function Generators feature both GPIB (IEEE-488) and RS-232 interfaces as standard equipment. **GPIB:** IEEE 488-1978 compatible.

Implemented interface functions are SH1, AH1, T5, TE0, L3, LE0, SR1, RL1, PP0, DC1, DT1, and C0

DMA rates: Typically ≥ 200 kbytes/sec.

Data formats:

9101 & 9109:

Waveforms:

#A Binary or #L ASCII HEX "00" to "FF" (double the length of internally stored binary data files).

Other Files:

#I Arbitrary length ASCII

9112:

Waveforms:

#9 Binary or #L ASCII HEX "0000" to "FFFF" (double the length of internally stored binary data files).

Other Files:

#0 Arbitrary length ASCII

RS-232: Implemented as Data Communications Equipment (DCE).

Baud rates: 300, 1200, 2400, 4800, or 9600.

Data bits: 7 or 8.

Stop bits: 1 or 2.

Parity: None, even, or odd.

Protocol: Full duplex, Xon/Xoff (DC1/DC3) handshake.

Commands: Full conversational, same as GPIB plus: RS_SRQ, Define character equivalent to SRQ in GPIB (default is "Bell"), ESC commands, ECHO on/off, Trig remote/local.

ENVIRONMENTAL & GENERAL CHARACTERISTICS

Temperature range: 15°C. to 35°C, full specification; 0°C to 40°C, operating.

Humidity: 40°C, 10% to 95% relative, non-condensing.

Power: 115/220 VAC, ±20%, 47-63 Hz. Approximately 147 W. For 440 Hz operation, contact factory.

Size: 5.25" H x 19" W x 15" D.

Weight: 26 lbs. (approximately).

WAVEFORM DEVELOPMENT SOFTWARE

LeCroy currently offers the EasyWave software package to support our arbitrary function generator products. EASYWAVE is a menu-driven system designed to get new AFG users "up to speed" on their new tool quickly and easily.

ORDERING INFORMATION

For Ordering Information see Page 75.

Standard Function Frequencies

	9101	9109	9112
Sine	0.01 Hz to 25 MHz	0.01 Hz to 25 MHz	0.01 Hz to 6.25 MHz
Triangle	0.01 Hz to 25 MHz	0.01 Hz to 25 MHz	0.01 Hz to 6.25 MHz
Square*	0.01 Hz to 100 MHz	0.01 Hz to 100 MHz	0.01 Hz to 25 MHz
Ramp**	40 nsec to 100 sec	40 nsec to 100 sec	160 nsec to 100 sec

** In the 9101 and 9109, frequencies up to 100 MHz may be programmed, but 5 nsec rise and fall time limits still apply.*

*** Ramp orientation may be positive- or negative-going.*

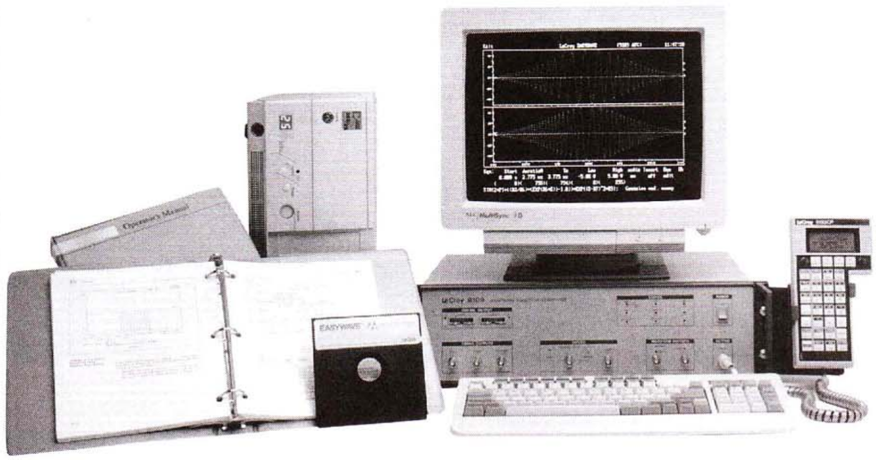
Pulse Parameters

	9101	9109	9112	Comments
Period	40 nsec to 10 sec	40 nsec to 10 sec	160 nsec to 10 sec	—
Width	5 nsec to 10 sec	5 nsec to 10 sec	20 nsec to 10 sec	Width + Delay must be < Period
Delay	25 nsec to 5 msec	25 nsec to 5 msec	35 nsec to 5 msec	Width + Delay must be < Period

SIGNAL SOURCES

9100/SW EASYWAVE® Software

The LeCroy EASYWAVE® software package converts your IBM PC compatible into a powerful, menu-driven tool for the generation of customized arbitrary waveforms. EASYWAVE can be used independent of the AFG for waveform creation and editing. Coupled with your LeCroy arbitrary function generator you can develop waveforms and download them to the AFG's non-volatile high speed waveform memory.



EASYWAVE creates waveforms with push-button ease from a library of common waveforms, from algebraic equations, or tabular point-by-point data entry. Waveforms, captured with an IEEE 488.2 compatible digital oscilloscope, or one of LeCroy's many modular digitizers or transient recorders, may be transferred to EASYWAVE for editing or processing. During waveform creation and editing the waveform is always visible.

As a control program, it provides simple and intuitive control of every 9100 Series feature using either direct manual control, or automatic command sequence files.

Main Features

SIMPLE ELEMENTS

Resident in EASYWAVE are nine commonly used waveforms... sine, DC/step, square, ramp, triangle, exponential, Gaussian pulse, damped sine, and frequency sweep. Selecting any of these waveforms requires just one keystroke.

As an example, a damped sine wave can be created by simply entering an "M". Capitalized letters designate each of the particular simple elements.

The next screen menu allows you to enter the parameters of the damped sine; that is, the frequency or period, vertical scaling, starting phase, and exponential time constant. By keying in the desired values, EASYWAVE calculates the waveform and displays it on the monitor. Other simple elements are created in the same manner. Waveforms created from simple elements or by other methods can be stored in computer memory, recalled for future editing, or downloaded to the non-volatile memory in the AFG. When stored in the AFG, waveforms are instantly available for file transfer to the high speed waveform memory by simply entering the file name.

ORDERING INFORMATION

For Ordering Information see Page 75.

Plug-in Modularity

The 9210's pulse output characteristics are determined by the selection of one of three available output modules. The mainframe performs all timing, triggering, interface, and control functions. In this way, the 9210 can meet a wide range of pulse generation applications... from the large amplitude requirements of analog device characterization to the sub-nanosecond transition times required by today's fast digital IC's.

Straightforward, Versatile Controls

1. **Display:** Large blue keys select the display of pulse, triggering, or control parameters for adjustment.
2. **Select:** The touch-screen CRT selects individual parameters (like pulse width) for adjustment.
3. **Enter:** Parameter values can be quickly entered using the numeric keypad, the 1-2-5 sequence rotary ring, or the fine analog rotary control knob.

Highest Precision and Accuracy

The 9210 uses a 12-bit ADC and a high resolution TDC to make nearly 1000 calibration measurements to guarantee timing accuracies of <0.5% and edge placement resolution to 10 psec.

Automatic Load Compensation

Test fixtures and jigs can often introduce slight variations in load impedance. The load compensation capability of the 9210 delivers the programmed pulse level to any load from 47Ω to 1 MΩ.

Constant Phase Mode

Constant Phase Mode on the 9210 maintains a constant phase relationship between two channels, even when varying the repetition rate during simultaneous clock and data simulation.

GPIB Programmable

Fully GPIB (IEEE 488.2) compatible with an easy-to-understand, plain English command set and syntax. A built-in GPIB command monitor aids in rapid debugging of automated test programs.

5 Year Warranty, By Design

The 9210 Pulse Generator has a unique five year warranty. It's not an extended warranty... it's the standard warranty. The 9210 is guaranteed to meet its specs, continuously and reliably, for five full years.

This type of warranty is made possible by designing in plenty of margin in the 9210's components and specifications. Component and connector counts are low, cooling is generously provided, and automated testing routines are extensive.

9200 Series, 300 MHz Programmable Pulse Generator

Main Features

Modular Architecture - Achieves an exceptionally wide range of pulse characteristics. Output modules can be mixed in any combination within the mainframe, making future upgrades as simple as plugging in a new module. Plug-in modules provide:

- Variable edge pulses (1 nsec to 1 msec) at rates to 250 MHz
- Fast 300 psec edges to 300 MHz
- Wide output swings to 32 V at pulse rates to 50 MHz

Unparalleled Accuracy and Precision
The 9210 features 10 psec resolution with ±(0.5% + 200 psec) timing accuracy. DC amplitude accuracy is 1%. Accuracy is guaranteed by the built-in calibration system. Automatic load compensation delivers true programmed amplitudes even with non 50 Ω loads.

Easy, Intuitive Operation - Setting the operating parameters couldn't be easier! A bright CRT display shows all related settings at a glance. Pulse parameters and trigger settings are accessible with a single keystroke. Individual parameters are selectable from on-screen system or front-panel select keys. Displays automatically match installed modules. An on-screen graphical icon shows the pulse parameter being affected and setting conflicts are highlighted to prevent setup errors. Up to 16 setup configurations can be stored and recalled from non-volatile memory.

Control Without Compromise -
Choose the data entry method you prefer, digital or analog. Use the full-featured keypad to enter parameter values with digital precision and speed.

Use the concentric knob if you prefer the interactive analog feel. The analog knob provides both coarse range selection and vernier control, with key-selectable vernier sensitivity.

The 9210 is also fully GPIB compatible, with an easy-to-understand command set and syntax. A built-in command monitor aids in rapid debugging of your test programs.

All this at a Price You Can Afford -
Compare the cost of the Model 9210 with that of comparable instruments. Even with all its innovative features and high performance, the Model 9210 is significantly more affordable than its competition.

Model 9211

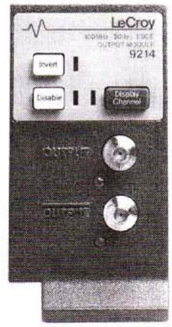
250 MHz, 1 nsec output module

- 250 MHz, 1nsec output module
- Variable edged... 1nsec to 1 msec
- 5 volt swing into 50 Ohms
- Complementary outputs

Model 9213

50 MHz, 16 volt output module

- 50 MHz pulse repetition rate
- Variable edges... 6.5 nsec to 95 msec
- 16 volt p-p output into 50 Ohms
- 32 volts into high impedance



Model 9214

300 MHz, 300 ps output module

- 300 MHz pulse repetition rate
- 300 psec leading edge
- 5 volt swing into 50 Ohms
- Complementary outputs

Functional Description

The LeCroy Series 9210 Pulse Generator is a high performance programmable pulse generator which uses a flexible modular architecture. The system can be performance matched to a wide range of pulse generator applications by the selection of the appropriate plug-in output modules. The modular architecture allows the pulse generator to be re-configured to match changing needs at minimum cost. The following three output modules are available, offering picosecond edges, high output swings, and wide rise time variability.

Model 9211 - 250 MHz Variable Edge Output Module

Model 9213 - 50 MHz Variable Edge Output Module

Model 9214 - 300 MHz 300 psec Edge Output Module

Plug-ins can be used in any combination and changed easily at any time. Pulse parameters for each output module, including delay, width, and transition times, are independently adjustable. The modules share a common timebase and trigger mode.

The timebase in the 9210 mainframe offers six operating modes including: normal (free run) mode; four triggered modes including single, burst, gated, and external width; and double pulse mode.

The unit can be triggered by an external signal, front panel manual push-button, or via GPIB. External trigger threshold is user-programmable either manually or with an automatic trigger level adjustment. In externally triggered modes the external trigger frequency is measured by an internal frequency counter and displayed on the CRT.

An output trigger pulse, with programmable or preset TTL or ECL compatible levels, is available for synchronization.

The 9210 Series sets a new standard for accuracy and precision. It achieves 5 mV amplitude resolution with 1% DC accuracy. Its time resolution is 10 psec with a timebase accuracy of ±(0.5% + 200 psec). Internal self-calibration using a built-in frequency counter and 12-bit analog-to-digital converter are combined with other accuracy related features, such as load compensation, to obtain these high levels of accuracy.

The front panel operation of the 9210 has been designed for intuitive error free setup. The friendly user interface is centered on a bright CRT display which shows all related setup parameters at a glance. The menu based display adapts automatically to match the installed output modules. A graphical icon is included to show the parameter being adjusted. Settings conflicts are highlighted and help messages appear on screen. Settings are changed by means of either a numeric keypad for precise numeric entry or by means of an analog knob for continuous variation of parameters.

CRT touch-screen response allows the user to set and change parameters through the use of optical soft keys.

For added operational convenience, alternate settings formats can be selected. These include: duty cycle or pulse width, frequency or period, delay or phase, amplitude/median and amplitude/offset or Vhigh/Vlow, slew rate or rise time – all key selectable.

Fully programmable via GPIB, the 9210 pulse generator complies with the IEEE-488.2 interface standard. It uses a self-documenting, English-language based command set and features high-speed command execution.

Important Note: At least one output module (9211, 9213, or 9214) must be installed in the 9210 Pulse Generator Mainframe in order to obtain a pulse output.

TIMING CHARACTERISTICS

Defined at 50% amplitude points and minimum transition times.

NOTE: The minimum values listed below refer to the mainframe only, and may not be achievable with all output modules.

Pulse period: 3.33 nsec to 450 msec.

Resolution: The greater of 0.1% of value or 10 psec.

Accuracy: ±(0.5% of value + 0.2 nsec) from 3.33 nsec to 450 msec.

RMS jitter: ≤ 0.035% (350 ppm) of value + 35 psec.

Temperature coefficient: < 250 ppm/°C typical with temperature compensation ON.

Frequency: Alternate format for period. Settable from 300 MHz to 2.2 Hz with 0.1% resolution.

Pulse width: 1.0 nsec to 450 msec.

For period setting ≤ 8.0 nsec; max. width = period -0.8 nsec.

For period setting > 8.0 nsec; max. width = period -2.9 nsec.

Resolution: The greater of 0.1% of value or 10 psec.

Accuracy: ±(0.5% of value + 0.3 nsec transition time error) from 1.6 nsec to 450 msec (see output module data for transition time accuracy specifications).

RMS jitter: ≤ 0.035% of value + 35 psec.

Temperature coefficient: < 250 ppm/°C typical with temperature compensation ON.

Duty cycle: Alternate format for width. Settable from 1% to 99% in 0.01% steps. In this format, width is controlled as a percentage of period.

Pulse delay: 0 nsec to 450 msec, measured from leading edge of trigger out to *beginning* of leading edge of pulse output (relative to fixed offset).

For period setting ≤ 8.0 nsec; max. delay = period -2.6 nsec.

For period setting > 8.0 nsec; max. delay = period -4.7 nsec.

Resolution: The greater of 0.1% of value or 10 psec.

Accuracy: ±(0.5% of value + 1.0 nsec).

RMS jitter: ≤ 0.035% of value + 35 psec.

Temperature coefficient: < (250 ppm + 50 psec)/°C typical with temperature compensation ON.

Match between output modules of the same type: 1.2 nsec.

Phase: Alternate format for delay. Settable from 0° to 359.9° with 0.1° resolution. In this format, delay = phase/360 x period.

Double pulse delay: 4 nsec to 450 msec.

Resolution: The greater of 0.1% of value or 10 psec.

Accuracy: ±(0.5% of value + 0.3 nsec).

RMS jitter: ≤0.035% of value + 35 psec.

Temperature coefficient: < 250 ppm/°C typical with temperature compensation ON.

INPUTS AND OUTPUTS

External Input

Input impedance: 10 kΩ or 50 Ω ±5%, selectable.

Input range: ±5 V into 50 Ω or ±20 V into 10 kΩ.

Minimum detectable amplitude: 200 mV.

Threshold range and resolution: ±2.5 V adjustable in 20 mV steps.

Threshold level accuracy: ±100 mV.

Max. input frequency: 300 MHz.

Min. pulse width: 1.5 nsec.

Min. input slew rate: 10 V/sec.

Edge selection: Positive, negative, neither edge (disabled).

Trigger Output

Output levels: Nominal 1 V negative swing from base level into 50 Ω. Base level adjustable over ±1.5 V range with 20 mV resolution. (Into Hi-Z: amplitude = -2 V. Base level of ±3 V, 40 mV resolution.)

Output impedance: 50 Ω ±5%.

Protection: Protected against application of ±10 V.

Delay from trigger input: 21 nsec typical.

Width: Dependent on trigger mode.

Normal mode:

Period ≤ 7.2 nsec:
Width = 1.8 nsec typical.
7.2 nsec < period < 50 nsec:
3.6 nsec ≤ width ≤ 7.2 nsec:

Period ≥ 50 nsec:
Width = 25 nsec typical.

Single mode:

Pulse width setting ≤ 40 nsec:
Trigger output width = 1.8 nsec typical.

Pulse width setting > 40 nsec:
Trigger output width = 25 nsec typical.

Burst mode:

Width = period x (burst count - 1).

Gate and ext. width modes:

Trigger output width ≈ trigger input width.

PROGRAMMABILITY

All generator functions are programmable over GPIB. Command set conforms with IEEE 488.2-1987.

TRIGGERING MODES

Normal: Continuous pulse stream. Trigger output for each pulse output.

Single: Each external trigger input generates a single output pulse. One trigger output for each trigger.

Gated: Signal at external input enables period generator. The first output pulse is synchronized with the gate's leading edge. Last pulse is allowed to complete. One trigger output for each gate input; 20 nsec retrigger (dead) time between gate inputs.

Burst: Each external trigger input generates a pre-programmed number of pulses (3 to 4095). Minimum time between two bursts is 50 nsec. One trigger output for each trigger.

External width: The signal at the external input is reproduced with programmable transition times and output levels. Trigger output for each external trigger.

OPERATING FEATURES

Manual trigger: Front panel push-button generates an external trigger input. Each push provides one trigger pulse in single and burst modes. Output remains active as long as button is pressed in gate and external width modes.

Double pulse mode: When double pulse is set to ON, two pulses are produced for each trigger. The first pulse begins as soon as possible after the trigger (approximately the minimum pulse delay time). The delay parameter now specifies the time from the leading edge of the first pulse to the leading edge of the second pulse. One trigger output occurs for each pulse pair. Compatible with all trigger modes except external width.

ADDITIONAL CAPABILITIES

Limit: When enabled, the maximum high and low level settability of the pulse outputs is limited to protect the device under test.

Setups: 16 setup configurations can be stored and recalled using the store and recall keys on the front panel.

Change format: Enables the alternate representation of a parameter or enables an alternate mode of operation. Examples are amplitude/base or amplitude/median in lieu of Vhigh/Vlow, duty cycle instead of width, phase instead of delay, frequency instead of period, slew rate as opposed to transition time.

ENVIRONMENTAL

The following specifications apply to the 9210 mainframe and to all output modules (9211, 9213 and 9214).

Storage temperature: -40°C to 70°C (temp above 40°C may degrade battery life).

Operating temperature: 5°C to 40°C at rated specifications, operational from 0°C to 50°C.

Temperature & self-calibration: Generator and output modules will meet specifications over a ±5°C range without repeating self-calibration.

Humidity range: < 95% R.H from 5°C to 40°C.

POWER

115/220 VAC ±20%; 48 - 448 Hz, 300 Watts max. (180 typical).

MISCELLANEOUS

Battery backup life: 10 years typical.

The following specifications apply to the 9210 mainframe and to all output modules (9211, 9213 and 9214).

Recalibration interval: 1 year.

Warm-up time (to meet specs): 15 min, after which a new self-calibration must be performed.

MAINFRAME

Weight: 23 lbs. net, 34 lbs. shipping.

Dimensions: (HWD) 5 x 17 x 21 inches.

OUTPUT MODULES

Weight: 2 lbs. net, 4 lbs. shipping.

Dimensions: (HWD) 4.6 x 2.4 x 14.7 inches.

OPTIONS

9210/SM	Service manual
9210/RM	Rackmount kit

ORDERING INFORMATION

For Ordering Information see Page 75.

9211 - 250 MHz Output Module Specifications

TIMING CHARACTERISTICS

Maximum rep rate: ≥ 250 MHz.

Minimum pulse width: ≤ 2.0 nsec.

Fixed delay from trigger out: 13 nsec ±4 nsec.

OUTPUT CHARACTERISTICS

Specified with both outputs terminated in 50.00 Ω. (Ratings in { } are when driving an open circuit.)

Outputs: Normal and complementary polarity.

Short circuit output current: ±260 mA.

DC output source impedance: 50 ±1.0 Ω.

Output protection: Protected against application of ≤ ±15 V.

OUTPUT LEVELS

High level: -4.95 V to +5.00 V {-9.90 V to +10.00 V}

Low level: -5.00 V to +4.95 V {-10.00 V to +9.90 V}

Output voltage range: ±5 Volts {±10 Volts}; max. amplitude of 5 V {10 V}; min. amplitude of 50 mV {100 mV}.

Resolution: 5 mV {10 mV}.

Level Accuracy

Normal output: ±(1% of programmed value +1% of amplitude +40 mV) into 50.00 Ω.

Accuracy with load comp: The same accuracy as stated above will be maintained for user supplied load of 47 Ω to 1 MΩ when load compensation feature is enabled.

Complementary output: ±(1% of programmed value +3% of amplitude +40 mV) into 50.00 Ω.

Accuracy with load comp: ±(3% of setting times the ratio of the load on the complemented output to the load on the normal output). Measurements for the load compensating correction factors are made on the normal output.

PULSE PERFORMANCE

Variable transition times (10% to 90%):

Leading edge: ≤ 1.2 nsec min (1 nsec typical) to 10 msec.

Trailing edge: ≤ 1.2 nsec min (1 nsec typical) to 10 msec.

Ranges: 7 ranges of 25:1. Minimum lead to trail dynamic range = 2.5:1, except 2:1 at first range break (see graph below).

Resolution: The greater of 1% or 100 psec.

Accuracy: ±(10% of value + 300 psec).

Linearity: ±3% typical (10 - 90%) for transition times > 50 nsec.

Slew rate mode: Settable down to 0.1 V/msec with 0.1% resolution and ±10% accuracy (separately settable for leading and trailing edge). Max. rate determined by amplitude setting & transition time limits stated above.

Overshoot and ringing: The greater of ±8% of amplitude or ±10 mV.

Settling time: ≤ 10 nsec to 2% of amplitude change at fastest transition times.

Normal to complementary output skew: 200 psec max at fastest transition times (50 psec typical).

MODULE CONTROLS

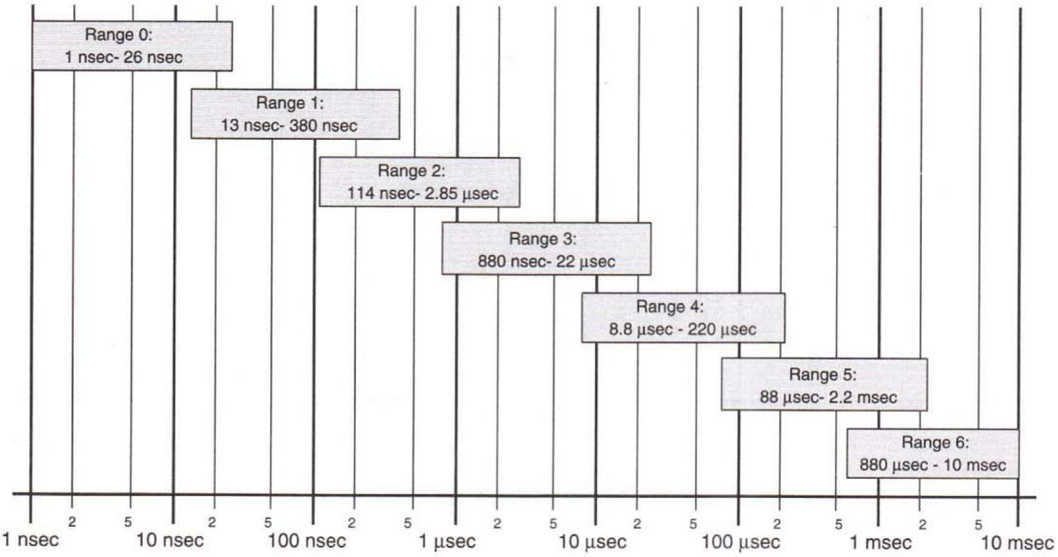
The following controls are located on the front panel of the output module.

Invert: Inverts normal output pulse levels. Quiescent and active levels exchanged.

Disable: Output circuitry is disconnected via relay.

Display channel: Instructs mainframe to select and display the settings parameters for this module.

SIGNAL



9211 Transition Time Ranges

9213 - 50 MHz, 16 V Output Module Specifications

TIMING CHARACTERISTICS

Maximum rep rate: ≥ 50 MHz.

Minimum pulse width: ≤ 10.0 nsec.

Fixed delay from trigger out: 13 nsec ±4 nsec.

OUTPUT CHARACTERISTICS

Specified with output terminated in 50.00 Ω. (Ratings in { } are when driving an open circuit.)

Output: Normal polarity.

Short circuit output current: ±200 mA.

DC output source impedance: 50 ±2.0 Ω.

Output protection: Protected against application of ≤ ±40 V.

OUTPUT LEVELS

High level: -7.98 V to +8.00 V {-15.96 V to +16.00 V}

Low level: -8.00 V to +7.98 V {-16.00 V to +15.96 V}

Output voltage range: ±8 Volts {±16 Volts}; max. amplitude of 16 V {32 V}; min. amplitude of 20 mV {40 mV}.

Resolution: 5 mV {10 mV}.

Level accuracy: ±(1% of programmed value +1% of amplitude +40 mV) into 50.00 Ω.

Accuracy with load comp: The same accuracy as stated above will be maintained for user supplied load of 47 Ω to 1 MΩ when load compensation feature is enabled.

PULSE PERFORMANCE

Variable transition times (10% to 90%):

Leading edge: ≤ 6.5 nsec to 95 msec.

Trailing edge: ≤ 6.5 nsec to 95 msec.

Ranges: 8 ranges of 25:1. Minimum lead to trail dynamic range = 2.5:1 (except for lowest range, see graph below).

Resolution: The greater of 1% or 100 psec.

Accuracy: ±(10% of value + 300 psec).

Linearity: ±3% typical (10-90%) for transition times > 100 nsec.

Slew rate mode: Settable down to 0.1 V/msec with 0.1% resolution and ±10% accuracy (separately settable for leading and trailing edge). Max. rate determined by amplitude setting and transition time limits stated above.

Overshoot and ringing: The greater of ±8% of amplitude or ±10 mV.

Settling time: < 50 nsec to 2% of amplitude change for amplitudes ≤ 10 V or to 3% of amplitude change for amplitudes > 10 V (at fastest transition times).

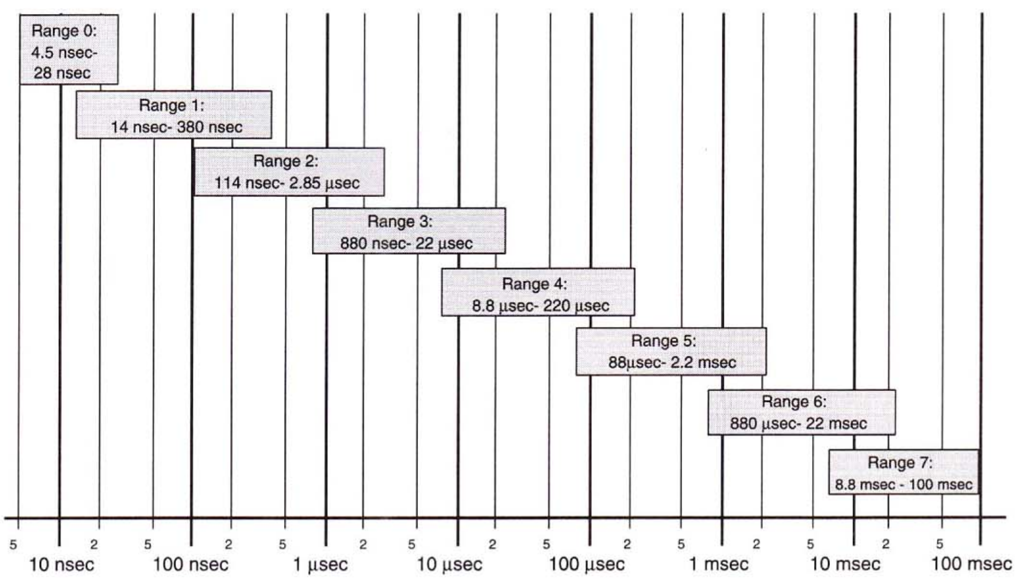
MODULE CONTROLS

The following controls are located on the front panel of the output module.

Invert: Inverts normal output pulse levels. Quiescent and active levels exchanged.

Disable: Output circuitry is disconnected via relay.

Display channel: Instructs mainframe to select and display the settings parameters for this module.



9213 Transition Time Ranges

9214 - 300 MHz, 300 psec Output Module Specifications

TIMING CHARACTERISTICS

Maximum rep rate: ≥ 300 MHz.

Minimum pulse width: ≤ 1.2 nsec .

Maximum pulse width:
For period setting ≤ 8.0 nsec;
max. width = period -1.4 nsec.
For period setting > 8.0 nsec;
max. width = period -3.5 nsec.

Fixed delay from trigger out: 13 nsec ±4 nsec.

OUTPUT CHARACTERISTICS

Specified with both outputs terminated in 50.00 Ω. (Ratings in { } are when driving an open circuit.)

Outputs: Normal and complementary polarity.

Short circuit output current: ±240 mA.

DC output source impedance: 50 ±1.0 Ω.

Output protection: Protected against application of ≤ ±6 V.

OUTPUT LEVELS

High level: -4.50 V to +5.00 V
{-4.00 V to +5.00 V}

Low level: -5.00 V to +4.50 V
{-5.00 V to +4.00 V}

Output voltage range: ±5 Volts {±5 Volts} (amplitude will double into a high impedance up to the 5 V level limit). Max. amplitude of 5 V {10 V}. Min. amplitude of 500 mV {1 V}.

Resolution: 5 mV {10 mV}.

Level Accuracy

Normal output: ±(1% of programmed value +1% of amplitude +40 mV) into 50.00 Ω.

Accuracy with load comp: The same accuracy as stated above will be maintained for user supplied load of 47 Ω to 1 MΩ when load compensation feature is enabled.

Complementary output: ±(1% of programmed value +3% of amplitude +40 mV) into 50.00 Ω.

Accuracy with load comp: ±(3% of setting times the ratio of the load on the complemented output to the load on the normal output). Measurements for the load compensating correction factors are made on the normal output.

PULSE PERFORMANCE

Minimum transition time: ≤ 300 psec guaranteed (20% - 80%).

Overshoot and ringing: The greater of ±10% of amplitude or ±10 mV.

Settling time: ≤ 10 nsec to 2% of amplitude change.

Normal to complemented output skew: 100 psec max. (25 psec typical).

MODULE CONTROLS

These controls are located on the front panel of the output module.

Invert: Inverts normal output pulse levels. Quiescent and active levels exchanged.

Disable: Output circuitry is disconnected via relay.

Display channel: Instructs mainframe to select and display the settings parameters for this module.

SIGNAL SOURCES

Models 9211, 9213 and 9214 plug-ins.

Fundamentals of Digital Oscilloscopes and Waveform Digitizing

INTRODUCTION

Digital oscilloscopes and waveform digitizers sample signals using a fast analog-to-digital converter (ADC). At evenly spaced intervals, the ADC measures the voltage level and stores the digitized value in high-speed dedicated memory. The shorter the intervals, the faster the digitizing rate, and the higher the signal frequency which can be recorded. The greater the resolution of the ADC, the better the sensitivity to small voltage changes. The more memory, the longer the recording time.

What are the benefits of this digital technology? Multiple signals associated with intermittent and infrequent events can be captured and analyzed instantly. Complex problems can be quickly identified by viewing waveform data which precedes a failure condition (pretrigger data). Captured waveforms can be expanded to reveal minute details such as fast glitches, overshoot on pulses, and noise. These captured waveforms can be analyzed in either the time or frequency domains.

Most digital oscilloscopes provide:

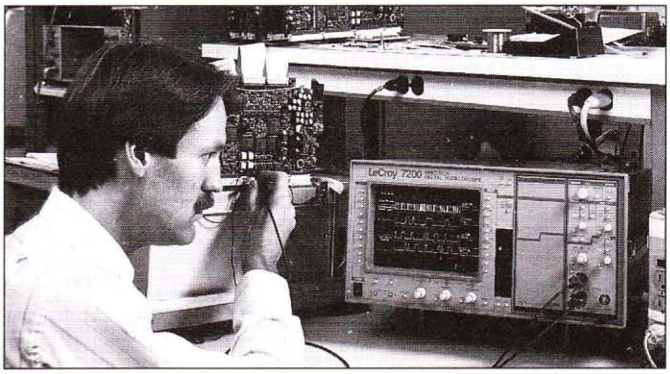
- Capture of transient events
- Internally adjustable pretrigger viewing
- Superior measurement accuracy
- Fast measurements with cursors and automatic parametric readouts
- Quick hardcopies on printers and plotters
- Archives for later comparison or analysis
- Waveform mathematics and spectral analysis
- Complete programmability and automatic setups

GETTING TO AN INSTRUMENT SOLUTION

The instrument purchaser needs to understand basic digitizer specifications and architectures to get the right digitizer for the application. For analog oscilloscopes, the primary specifications are simply bandwidth, voltage sensitivity, and accuracy. For digital oscilloscopes, the basic specifications also include sample rate, vertical resolution, and waveform memory length. Some digitizer architectures are optimized for transient signal capture, while others only record repetitive signals.

KNOW YOUR WAVEFORM

Before you evaluate digitizers, evaluate your signals. Answering these questions regarding your signal and the



types of measurements needed will help you choose the right instrument. This preparation will save time and money in the long run.

1. Are the signals ever transient in nature (intermittent, single-shot, random, modulating, drifting quickly, or occurring slower than 100 times per second)?
2. What is the signal bandwidth?
3. How small are the details you need to resolve relative to the peak-to-peak voltage?
4. How accurately do you want to measure voltages and times on the waveforms?
5. How long a waveform portion do you want to capture?
6. What conditions do you need to trigger on?
7. How often should the display update with new waveforms and analyzed results?
8. What kinds of analysis do you want?
9. How often will you change set ups?
10. Do you want to automate tests?
11. Do you want to store and recall waveforms?

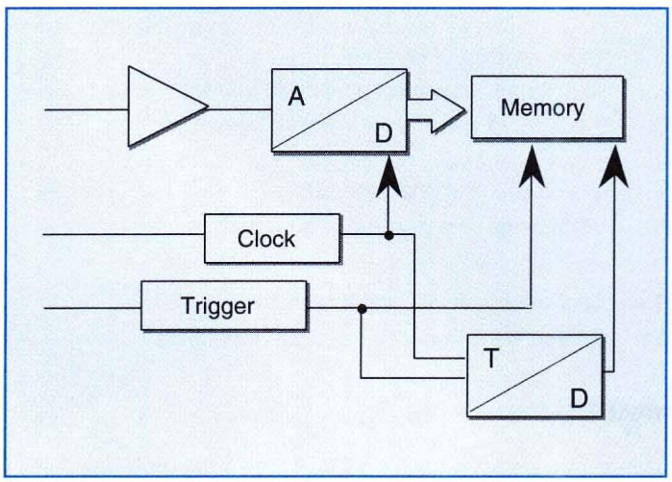
TRANSIENT CAPTURE

Most analog scopes have a difficult time displaying transient events. In contrast, many digital oscilloscopes are designed for transient capture. Three basic digitizer architectures exist. Transient digitizers and Random Interleaved Sampling (RIS) digitizers can capture transient signals; sampling digitizers cannot. All three types can record repetitive signals. Only transient and RIS digitizers record pre-trigger waveform information; sampling digitizers cannot.

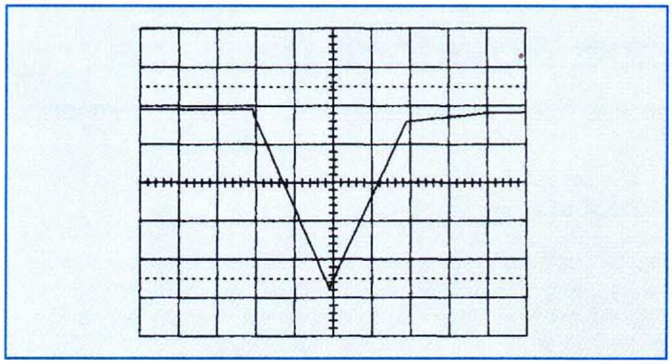
Transient digitizers contain an analog-to-digital converter (ADC) and waveform memory. Once "armed", the ADC digitizes the signal continuously and feeds the samples into the memory using circular addressing. After the last memory location is filled, the system overwrites the stored data, starting at the beginning of memory. After a trigger is generated, memory continues to fill with a user-selected number of post-trigger samples. Then the ADC stops feeding the memory. If the user had selected 100% pre-trigger data, then the ADC would stop sending data as soon as the trigger arrived. If the user selected 100% post-trigger, then the system would fill every memory location one more time and stop. Memory would contain waveform data which occurred after the trigger.

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

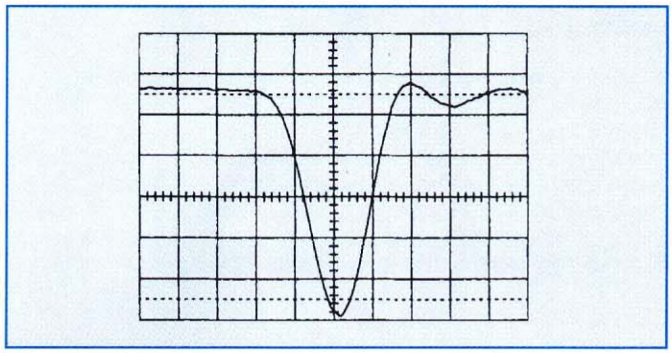
Since the digitizer has no way of knowing when the trigger will arrive, the sample clock and the trigger point are asynchronous. Therefore, the time between the trigger and the very next sample clock randomly varies from waveform acquisition to acquisition. The RIS architecture uses a time-to-digital converter (TDC) to measure this relationship and accurately interleave successive waveform acquisitions. The TDC has much better timing resolution than the sample interval, so RIS reconstructions can reveal details that the transient digitizer alone misses. Yet the RIS digitizer provides user-selectable pretrigger recording, just like the transient digitizer.



RIS digitizer block diagram

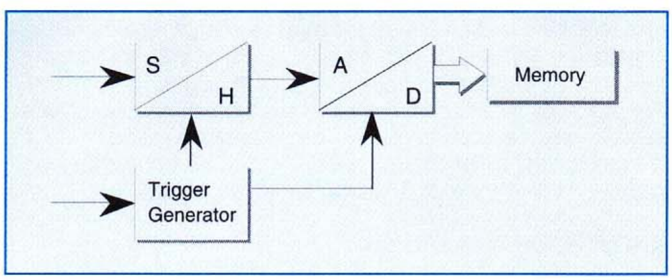


100 MS/sec digitizing of 5 nsec wide pulse

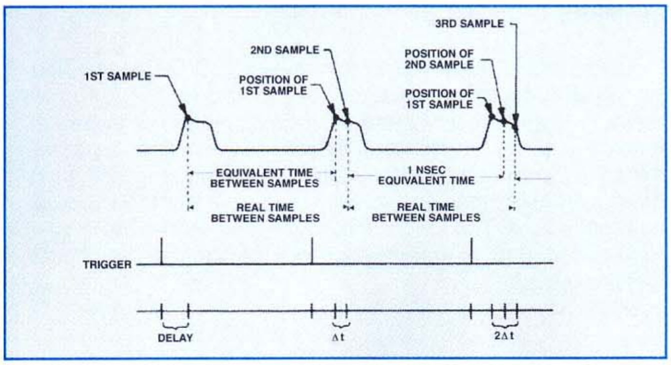


5 GS/sec RIS digitizing of 5 nsec wide pulse

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/sec, the first sample point would be at the trigger point, the second delayed by 1 nsec, the third delayed by 2 nsec, and so on. Since the sample points are delayed from the trigger point, sampling digitizers cannot record pre-trigger information.



Sampling digitizer block diagram



Equivalent Time Sampling with sampling digitizer.

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.

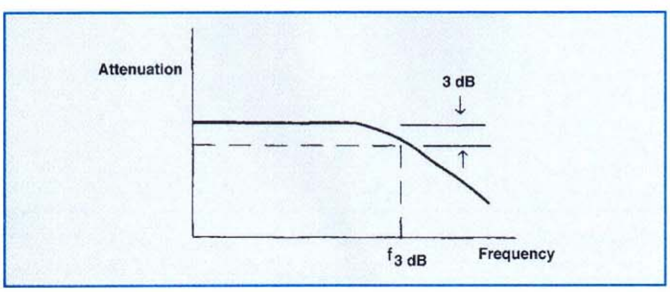
BANDWIDTH AND SAMPLE RATE

Bandwidth is an important specification for digitizers, just like analog scopes. The digitizer's input amplifiers and its filters determine the bandwidth. Fast pulse edges and sharp waveform peaks contain high frequency signal components. To accurately record these edges and peaks, the digitizer must have adequate bandwidth to pass these high frequency signal components with minimal attenuation.

But how much bandwidth is enough? To accurately indicate signal peak amplitudes, the digitizer bandwidth should exceed the signal bandwidth. So first determine the signal bandwidth by estimating the fastest pulse rise time in your signal. Assuming a single pole system response, the signal bandwidth is as follows:

$$\text{Signal Bandwidth} \approx 0.35/(10\%\text{-}90\% \text{ rise time})$$

The digitizer bandwidth indicates the frequency at which the signal is attenuated by 3 dB (29%). This attenuation occurs gradually, starting at a much lower frequency. Therefore, choose a digitizer with higher bandwidth than the signal.



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

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

Sample Rate Effects on Usable Bandwidth

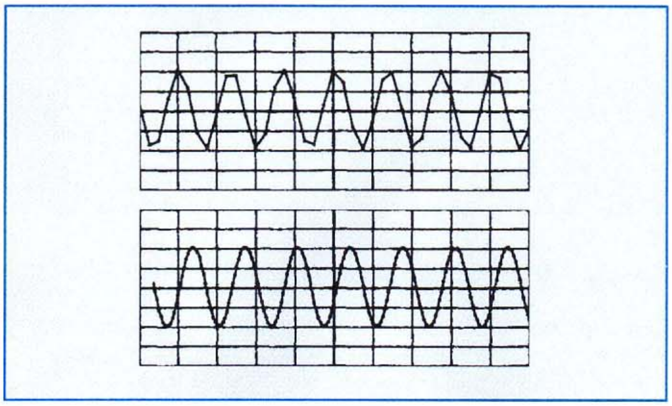
The digitizer sample rate can degrade the usable bandwidth. To ensure adequate sampling, obtain 4 samples per cycle with sin(X)/X interpolation, or 10 samples per cycle with straight line interpolation. If your signal is transient, then look at the single shot sample rate specification; if repetitive, then the faster equivalent time sample rate can be used.

Given an ideal the digitizer with no noise and given a bandwidth limited signal, Nyquist criterion holds true. Nyquist states that at least two samples must be taken for each cycle of the highest input frequency. In other 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. Since noise exists in real signals and digitizers, sin(X)/X should be used cautiously, especially with only 2 samples per cycle.

Sin(x)/x algorithms can also create undesirable overshoot and preshoot on fast edges. At least 2 data samples are required on the fastest edge in a signal. It is important that the user be able to examine the number of raw data points acquired in any scope using Sin(x)/x display.

For more accurate waveform representations, the digitizer should record at least four sample points per cycle of the highest frequency sine component. The additional sample points effectively enhance the signal-to-noise ratio for sin(X)/X interpolation. For example, a 1 GS/sec (gigasample per second) sample rate could capture the waveshape of signals up to 250 MHz.

Straight line interpolation can deliver accurate waveform representations without the noise amplification caused by curve fitting. For best results, it requires 10 or more samples per cycle.



Sine wave digitized at 5 and 25 samples/cycle respectively, with straight line interpolation applied.

Maintaining Usable Bandwidth

Long memory allows the scope to maintain the fastest specified sample rate on more timebase settings than a shorter memory scope. Memory determines the maximum possible sample rate at a particular timebase setting as follows:

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

For example, if the digitizer contained 50,000 points of memory and 10 CRT display divisions and the timebase was set to 5 µsec/division, then the sample rate could be as high as 1 GS/sec and still fill the screen.

As the timebase is reduced (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.

BENEFITS OF LONG MEMORIES IN DIGITAL OSCILLOSCOPES

Increasing the memory length of digital storage oscilloscopes brings many advantages, not all of them obvious. Among these are:

- No missed details on waveforms, thanks to higher effective sampling rate.
- Permanent glitch capture, without waveform distortion.
- Better time and frequency resolution.
- Reliable capture of events which are unpredictable in time.
- No dead time between acquired events.

NO MISSED DETAILS

Figures 1 and 2 show the same waveform (a 50 msec video signal) acquired by two different oscilloscopes configured with memory lengths of 2.5M and 50k 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.

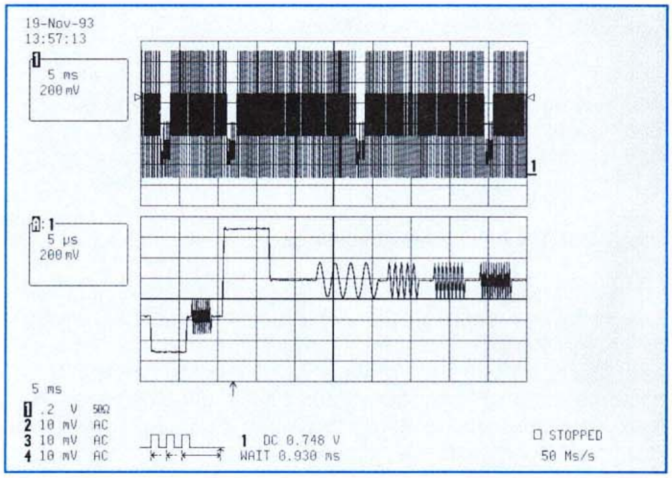


Figure 1: The 9354L always shows the maximum record length on screen, and sampling is always optimal. Note that the original trace and its expansion can be displayed simultaneously.

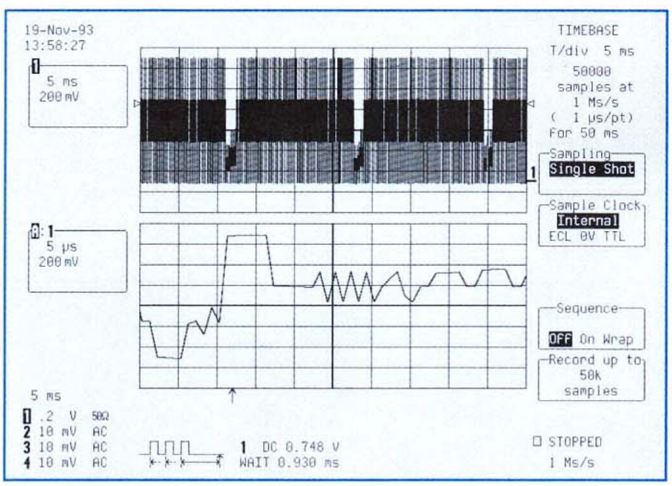


Figure 2: The same signal captured by a 50k memory scope. The trace is undersampled as shown in the expansion below the main trace.

This example illustrates the effect of record length upon sampling rate. Both scopes are displaying 50 msec of data (10 divisions at 5 msec/div). Thus the 50k point scope is digitizing at:

50 msec/50,000 = 1 µsec per point
= 1 MS/s

while the 2,500,000 point scope is digitizing at:

50 msec/2,500,000 = 20 nsec per point
= 50 MS/sec

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 the thereby give greater usable bandwidth for longer signals.

A word about default setups. In LeCroy oscilloscopes, the easiest to use default setup automatically digitizes the signal at a memory length and sampling rate optimized to yield the highest sampling rate possible for that time base 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 will then have 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 in the same way. Some display only a small portion of their long memory on screen, and window or scroll the display to show the rest of the data. LeCroy scopes represent all measured points on-screen in such a way that a live waveform can be displayed together with up to three expanded views. This is done using a proprietary compaction algorithm, and ensures that any glitch, representing as little as 1/8,000,000th of the displayed waveform, will always be captured accurately and displayed.

Compare this with scopes that rely on peak detection to capture glitches. While peak-detected data acquired may be useful to look at, it will no longer yield accurate parametric or cursor measurements, since all the time information has been randomly skewed.

Some DSO's have a special "Peak Detect" mode in which the ADC runs at its fastest sampling rate but only the maximum and minimum signal values are stored in memory. The time at which these peaks occur is not well known. An advantage of LeCroy's long memory is that half the memory can be used to store peak detected values while the other half can store a normally digitized picture of the signal.

BETTER TIME AND FREQUENCY RESOLUTION

Comparing the different scopes in Figures 1 and 2, the first scope offers 50 times more horizontal points, and thus has better horizontal resolution by a factor of 50:1. Better horizontal resolution will improve the accuracy of any time-related measurement. It will also result in improved frequency domain (i.e., Fourier Transformed) displays, since the number of points displayed in an FFT is equal to the number of points in the original record (only half are displayed; the other half represent negative frequency).

RELIABLE CAPTURE OF UNPREDICTABLE EVENTS

The occurrence of some events may be so unpredictable that they are difficult to trigger on reliably. The easiest way to acquire this type of event is with a long memory oscilloscope. The entire pulse train may be captured and expanded for examination. Once the nature of the failure is understood, LeCroy's SMART Trigger may be used to trigger on this particular type of event.

NO DEAD TIME BETWEEN ACQUIRED EVENTS

There is a finite period of time after an acquisition has been made before any scope is ready to make another acquisition. During this period the scope performs various processing and display routines. This dead time, typically several milliseconds, creates problems when sequential events are being acquired. An example is the sequence of bursts shown in Figure 3. Displaying this accurately requires a high sampling rate over a relatively long period of time.

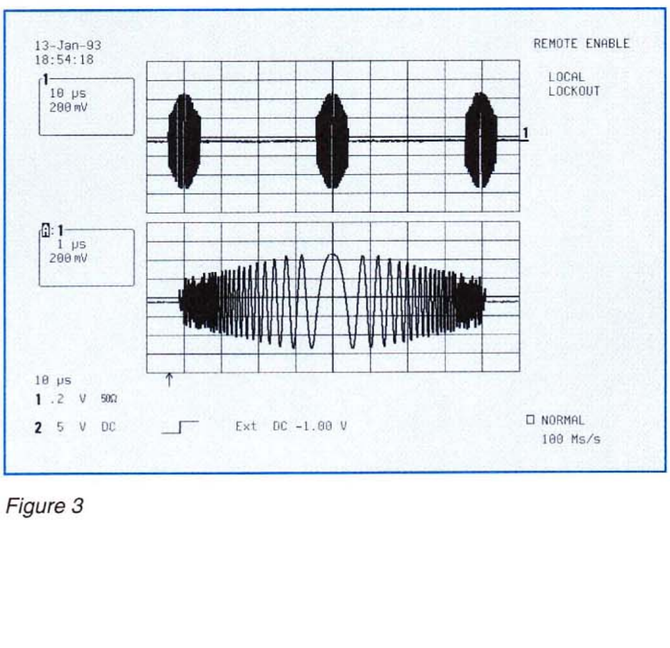


Figure 3

Figure 4 shows a similar signal, with longer "quiet time" between bursts. One way to acquire such bursts is to segment the scope's acquisition memory into many shorter memories. Using this technique will reduce the measurement dead time from milliseconds to less than 100 microseconds. Thus the bursts in our illustration could be stored into 50 separate, time-stamped memories of 1k each. The time stamp for each trigger is important since users often want to know the time when each event occurred. Scopes from some manufactures will store multiple events without any time stamp information.

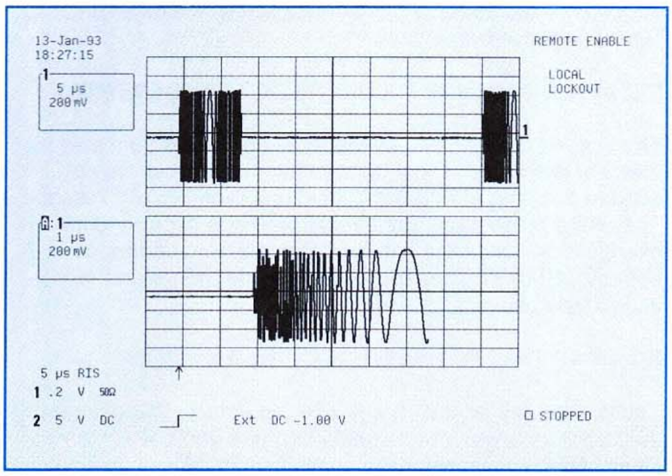


Figure 4

TRIGGERING

The power of a digital oscilloscope in any given application depends on a combination of several features including the ability to trigger on the event of interest.

An important criterion when choosing a digital oscilloscope is the flexibility and sophistication of the trigger. To capture rare phenomena such as glitches or spikes, logic states, missing bits, timing jitter, microprocessor crashes, network hang-ups or bus contention problems, the user needs a much more sophisticated trigger system than 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 price scopes. LeCroy believes all scope users at every bandwidth want both a simple standard trigger and the power of a SMART Trigger to capture difficult events.

The Standard Trigger Mode

The standard mode resembles that of a conventional analog oscilloscope, and is directly controlled using the front-panel controls. The following controls and modes are available:

Trigger source: Channel 1, Channel 2, (Channel 3, Channel 4), Line, Ext, Ext/10.
Trigger coupling: AC, LF Reject, HF Reject, DC, HF.
Trigger slope: Positive, negative.
Trigger level: Channel 1, 2, 3 or 4.
Ext: Adjustable to ±2 V.
Ext/10: Adjustable to ±20 V.
Line: Not adjustable.
Trigger mode: Single event, normal, automatic, sequence.

The trigger delay can be adjusted between 1,000 screen widths after the trigger, and one screen width before the trigger. Together with large memories, this enables the user to see events which occur much later or much earlier than the trigger itself.

A very distinctive feature of the LeCroy triggers is that coupling, slope and level can be adjusted separately for each trigger source, allowing ultimate trigger flexibility.

Figure 5 shows a typical LeCroy scope display. The trigger level is indicated by the small arrows at the left edge of the grid and the trigger timing position by the arrow under the grid. At the bottom of the screen, a trigger summary, including LeCroy's trigger graphics, gives an overview of the trigger conditions. Figure 6 shows the data acquisition menu which is available at the touch of a button. The trigger conditions, as well as the acquisition conditions, are fully specified here.

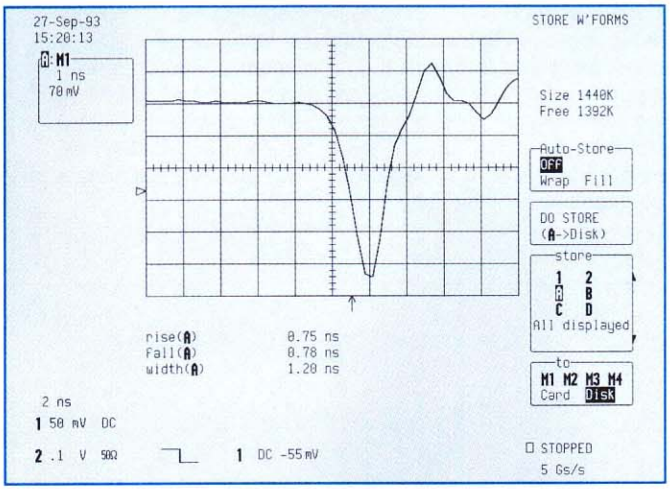


Figure 5: A typical 9354 display. Note the trigger level and source identified below the grid. The left-side and bottom arrows give a visual indicator of trigger level and time.

Another important feature of the LeCroy triggers is Sequence Mode, which divides the long acquisition memories into as many as 4,000 segments. The instrument can then acquire as many events as the defined number of segments, and record each new event in successive segments.

Sequence Mode Acquisition is explained in detail in the previous section (Figures 3 & 4). A substantial benefit found in LeCroy scopes that is not available in some competitive instruments is the ability to timestamp each trigger so the user knows the time of occurrence for each event.

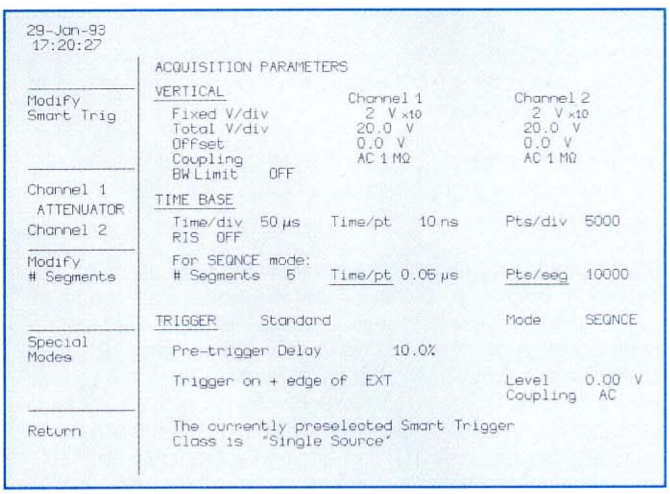


Figure 6: The acquisition parameter menu of the 9354 shows a summary of both the data acquisition and trigger conditions.

THE SMART TRIGGER

A push-button control switches between standard and SMART trigger. With the SMART trigger the user has access to a variety of sophisticated trigger modes based on two important facilities.

1. The ability to preset the logic state of the trigger sources, Ch1, Ch2, Ch3, Ch4, Ext, and Ext/10.
2. A presettable counter, which can be used to count a number of events between 1 and 10^9 or to measure time intervals from 2.5 nsec up to 20 sec in steps of 1% of the time scale.

Combining these two facilities opens the door to such a large variety of trigger conditions that the oscilloscope could potentially become cumbersome and difficult to use. However, great care has been taken to make the SMART trigger mode user-friendly without loss of versatility. On the screen, special trigger graphics illustrate the trigger conditions for every trigger mode. Examples of these graphics can be found below the grid in all the screen figures. The SMART trigger has several principal modes of operation:

- Single source trigger with hold-off
- Width triggers (+ glitch)
- Pattern trigger
- Dropout Trigger
- State-qualified trigger
- Edge-qualified trigger
- TV trigger

Single Source Trigger - Hold-off

Using this trigger mode, the user can select the desired source and its coupling, level and slope. A hold-off can be set when the waveform contains bursts or patterns and can be specified as a hold-off by time or number of events.

Hold-off by time: Many oscilloscope measurements require the ability to acquire a complex waveform which lacks any unique features to trigger on. Examples of these types of waveforms include data packets from local area networks, disk drive data streams, and outputs from charge coupled devices. These signals, which are clocked and generally of fixed length, are easily synchronized by using trigger hold-off by time or event.

Consider the Ethernet packet in Figure 7. Normal edge trigger cannot be used because there are many signal transitions that satisfy the trigger requirements. Since they occur at a much higher rate than the overall signal duration, the signal display is not stable. By using trigger hold-off, with a hold-off time

TECHNICAL TUTORIALS

equal to the signal duration, all intermediate triggers are ignored and the displayed trace is synchronized.

Hold-off by events: Consider the need to synchronize the acquisition of a pseudo random noise generator output. The data offers no distinctive trigger points and the only available timing signal is the generator's clock signal. Knowing the length of the pseudo random sequence, 4095 states in the example shown in Figures 8 & 9, allows the use of hold-off by events. The clock signal, with a hold-off by 4094 events, is used as the trigger source.

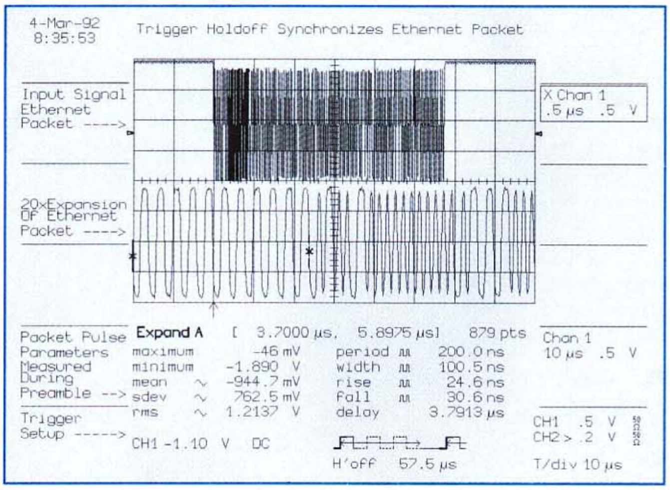


Figure 7: Trigger hold-off by time allows the above Ethernet signal to be displayed in its entirety as a stable trace despite repeated occurrences of valid trigger conditions. The 20:1 expansion in the lower trace and automatic pulse parameters characterize the packet's preamble.

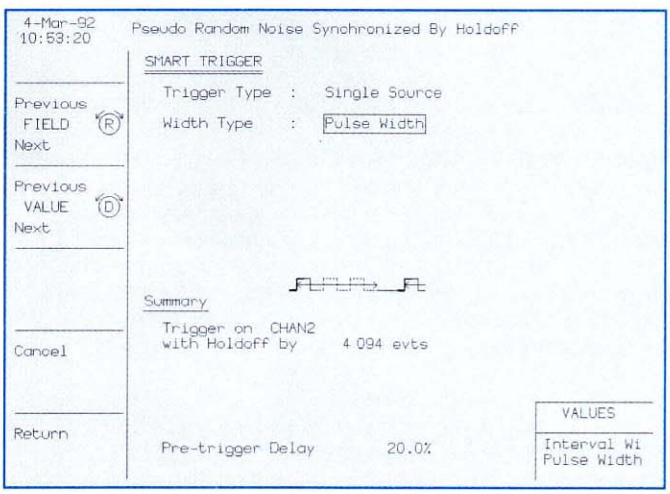


Figure 8

Trigger hold-off is setup using the LeCroy SMART Trigger setup menu. In this application the single source trigger was used, as shown in Figure 8. The number of events is set to trigger on the 4095th clock synchronizing the acquisition with the pseudo random sequence repetition period. The resulting display, shown in Figure 9, synchronizes the oscilloscope acquisition with the generator's output allowing each state to be examined easily.

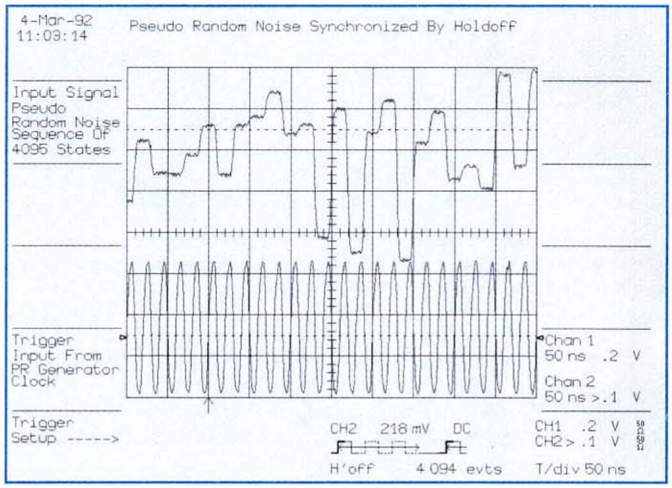


Figure 9

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, ATE, EMI, telecommunications, and magnetic media studies. Catching elusive glitches becomes very easy. In digital electronics, where the circuit under test normally uses an internal clock, a glitch can be theoretically defined as any pulse narrower than the clock period (or half period). The oscilloscope can selectively trigger only on those events, as shown in Figure 10.

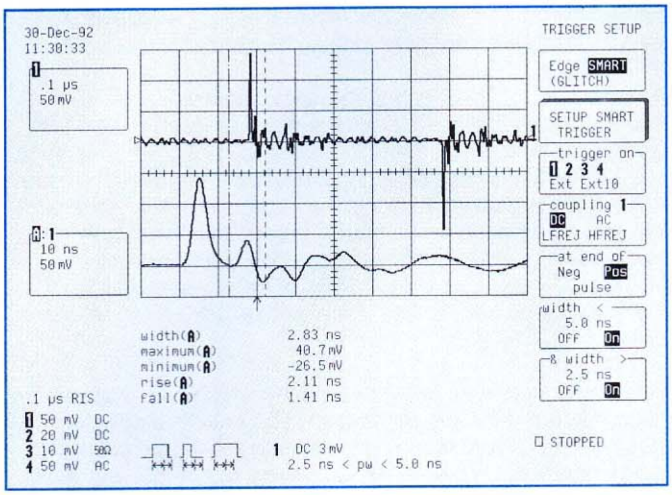


Figure 10: Selective trigger on a 2.83 nsec glitch. The DSO has been set to trigger on any pulse narrower than 5.0 nsec and wider than 2.5 nsec. Pulse parameters are used to characterize this phenomenon after expansion in the bottom trace.

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

Besides triggering on short widths (glitches) there is another substantial benefit of the "Width" trigger. In cases where jitter or other timing problems cause a pulse to be too wide, the user can trigger on long widths (trigger condition width > XX). Triggering on a wide pulse is also useful in many communications protocols where a wide pulse occurs at the beginning of a datastream. In some cases, the user wants to trigger the scope based on the time elapsed between two rising or falling edges. An example of this "interval width" trigger is shown in figure 11.

Dropout Trigger

The dropout trigger allows the user to trigger when a signal stops occurring. Common applications are microprocessor crashes, network hangups and bus contention problems. The user connects the signals of interest to the oscilloscope and specifies a time period for one of them. If that signal becomes quiescent the scope triggers and data is displayed from all input channels. An example of dropout trigger used in power supply testing is shown on Page 125.

Multi-Source Triggers - Pattern

The pattern trigger is based on the logic state of the several input channels, CH1, CH2 (CH3, CH4) and EXT. Here the user can set the coupling and trigger level of each channel. He then chooses the required logic state for each input and decides whether the scope should trigger at the beginning of the defined pattern or at the end, i.e., when the pattern is "entered" or "exited". This type of trigger is present in 7200, 9400 and some 9300 series DSOs.

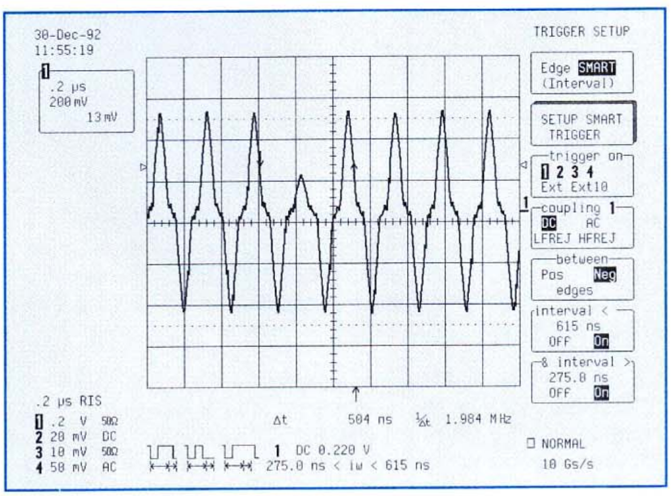


Figure 11: Triggering on a missing bit when reading a magnetic disk. A missing bit can be interpreted as a pulse wider than the period of the pulses, or a pulse separation greater than the pulse period. The "interval width >" is used to trigger on this condition.

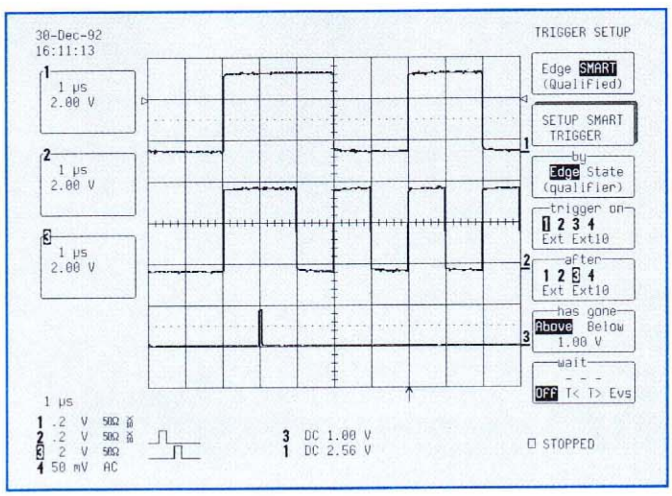


Figure 12: Logic Qualified (Pattern) Trigger: In this figure, acquisition is triggered on Channel 1's trigger conditions only after the signal on Channel 3 meets its own, independent set of trigger conditions. The trigger setup menu shows setup options, including delay (wait) by user-entered time or number of trigger events.

The width and time-separation trigger capabilities described above can be combined with pattern trigger, enabling the user to compare the duration of the pattern, or the interval between patterns, with a reference time. This type of trigger will be greatly appreciated whenever complex logic has to be tested. Examples are: setup and hold times on IC's, computer or microprocessor debugging; high energy physics where a physical event is identified by several events occurring simultaneously; and debugging of data transmission buses in telecommunications. Figure 12 shows an example of pattern trigger with no constraints apart from the occurrence of the required logic combination.

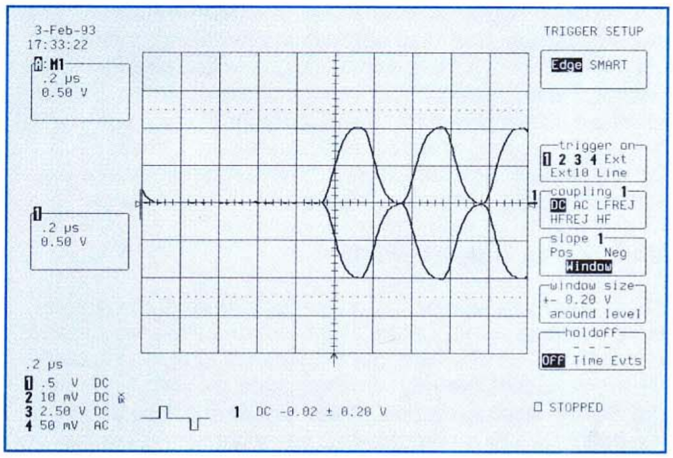


Figure 13: Example of bi-level trigger. The pattern trigger is set so that the scope can trigger on both the upper as well as the lower trace. While the lower trace shows Channel 1, the upper trace shows a previous event stored in memory M1. The arrow at the bottom of the screen shows the trigger time in both cases.

The pattern trigger is the logic AND of two to five defined input logic states. However, applying de Morgan's laws, the pattern trigger becomes much more general. To demonstrate this, let's look at an example which is of particular importance, that is a bi-level trigger (see Figure 13). Bi-level trigger means that the user wants the scope to trigger on a single-shot signal of unknown polarity and of roughly known amplitude.

This can be done by connecting the signal source to two inputs, for instance CH1 and CH2. Let's imagine setting the threshold of CH1 to +100 mV and the threshold of CH2 to -100 mV. Bi-level triggering occurs if the scope triggers on CH1 for any pulse greater than +100 mV OR on CH2 for any pulse more negative than -100 mV.

In Boolean notation we can write:

Trigger = CH1 + CH2 (when entering the pattern).

By deMorgan's law this is equivalent to:

Trigger = $\overline{\text{CH1}} \bullet \overline{\text{CH2}}$

i.e., trigger on CH1 = low AND CH2 = high when exiting the pattern. This last configuration can be easily programmed.

The possibility of setting the threshold individually for each channel extends this method to a more general window trigger. In this case, to trigger the DSO the input pulse amplitude must lie within or outside a given window. Another important aspect of the pattern trigger is that all the features of the single-source trigger mode can also be applied. That is, the user again has the choice of imposing a hold-off by time or by number of events, or alternatively, of detecting durations or intervals which are greater or smaller than a time fixed by the user.

A warning should be given here about which time interval is compared to the reference time. The pattern trigger is designed to let the user always choose the trigger point. So if, for instance, LHX-entering is chosen, the trigger will occur

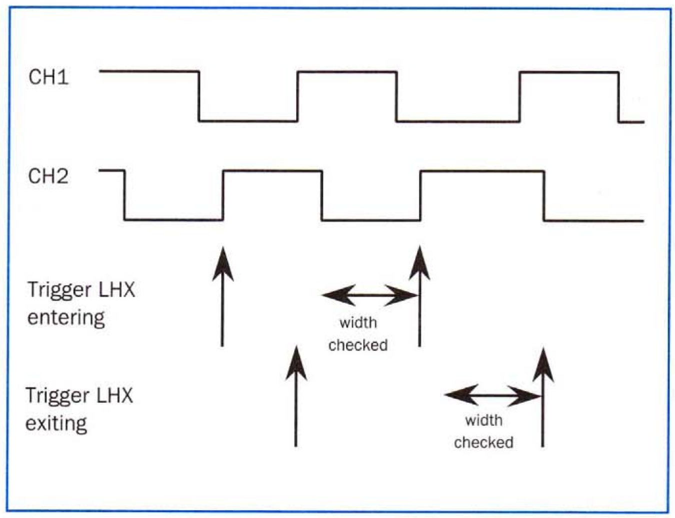


Figure 14: Timing diagram of the pattern trigger.

as soon as the pattern LHX becomes true. If we now add the condition pattern width < reference time, the width which is compared to the reference time is the width of the pattern LHX complement preceding the trigger point. Therefore, this trigger mode checks the repetition time of the pattern.

On the contrary, if LHX-exiting, pattern width < reference time is chosen, then the duration of the LHX state will be compared to the reference time and the scope will trigger when LHX becomes false (A timing diagram is shown in Figure 14 and an example in Figure 15).

Multi-Source Trigger - State-Qualified

This trigger enables the oscilloscope to trigger on one source, CH1, CH2 or EXT, as soon as a selected logic condition of the other two sources exists. *The qualifying state must be held until the oscilloscope triggers.* The user sets

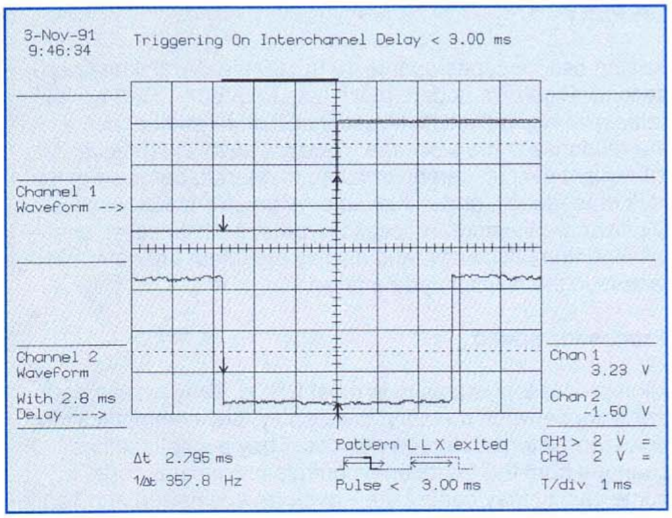


Figure 15: Example of triggering on the delay between two waveforms using pattern trigger. The DSO is triggered on a delay of less than 3 msec between Channel 1 and Channel 2. Pattern trigger has been set for triggering when Channel 1 and Channel 2 are both more negative than the trigger threshold levels for pulses narrower than 3 msec. Triggering will occur on exiting the pattern.

the required logic pattern on two sources and uses this condition as an enable or a disable for the third source. Different coupling, slope and trigger level settings can be chosen for each channel.

It is also possible to choose a delay by time or number of events which starts as soon as the logic pattern is valid, as illustrated in the timing diagram shown in Figure 16. Typical

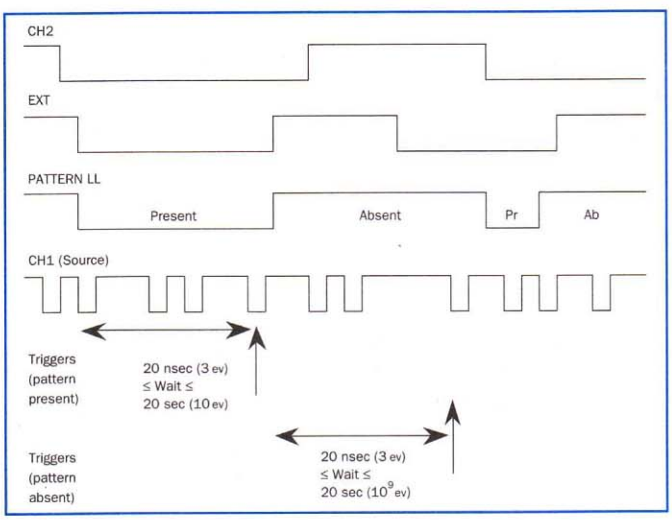


Figure 16: Timing diagram of the state-qualified trigger.

applications for this trigger can be found wherever time violations occur, for instance in microprocessor debugging or in telecommunications.

Multi-Source Trigger - Time/Event (or Edge) Qualified

This is another conditional trigger requiring a trigger source, CH1, CH2 or EXT, and a given logic state to occur on the three inputs. This trigger, unlike the state-qualified trigger, *does not require that the qualifying logic state be maintained until the trigger occurs.* From the moment that this logic state is present or absent, a delay can be defined in terms of time or number of events. When the delay has elapsed, triggering is enabled as shown in Figure 17. This feature provides a solution to applications which involve systems with long firing jitter time, e.g., lasers and magnetic discs. Other applications can be found in telecommunications or microprocessors for debugging of asynchronous data buses.

As an example of an edge-qualified trigger application, a DSO is set up to trigger off of the 5th pulse out of an optical shaft encoder. This pulse represents a 1.75° rotation of the shaft, where 1024 pulses represent a full rotation. The index pulse, the 0° reference, is applied to the DSO's CH2 input and the output pulses are applied to CH1. The edge-qualified SMART trigger is used with the positive-going edge of the index pulse, enabling the trigger on the positive-going edge of the signal on CH1. Hold-off by event is set to trigger after four trigger events. Thus, the oscilloscope triggers on the desired fifth positive-going edge. See Figure 18.

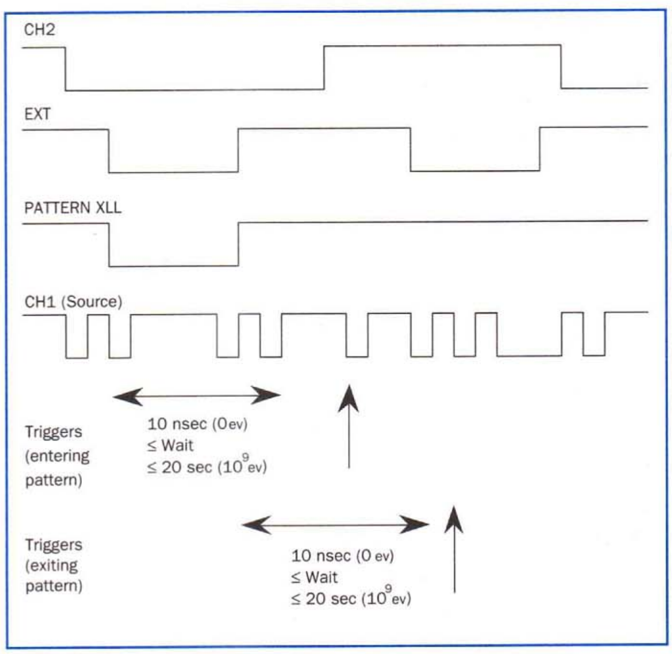


Figure 17: Timing diagram of the edge qualified trigger.

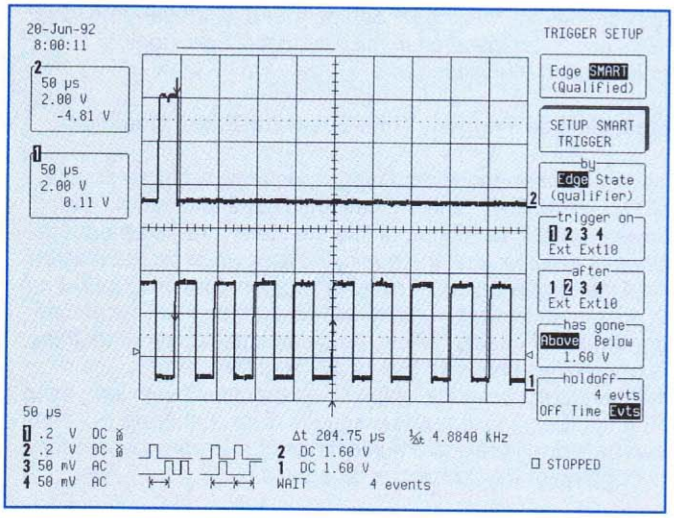


Figure 18: Example of edge-qualified trigger to find the 5th pulse after occurrence of fiducial event.

TV Trigger

The user can decide whether he wants to trigger on every field, on either odd or even fields, or, when working with color TV signals, he can trigger on one of the four or eight color fields. This can be done for TV standards such as NTSC, PAL-M, PAL and SECAM-625.

Once the field has been selected, the user can selectively trigger on any line within the field.

When it comes to TV applications, LeCroy digital oscilloscopes offer many advantages over traditional test equipment. By combining pre- and post-trigger viewing capabilities, long acquisition memories (up to 2 Mword per channel) and very high sampling rates, the oscilloscopes enable measurements with improved timing accuracy and provide better analytical capabilities. For example, waveforms are easily stored and overlaid allowing rapid comparisons for measurements such as K ratings. Expansion (up to 1,000 times) can be used to reveal glitches and discontinuities that affect picture quality and stability. Timing measurements on sync width, burst width, front-porch and horizontal blanking width can all be made with greater precision even on single-shot acquisitions. And, an optional FFT (Fast Fourier Transform) Spectral Analysis package is available so that frequency, power and phase information can be revealed at the touch of a button.

CONCLUSION

The LeCroy DSO series' offer the most comprehensive trigger systems available in an oscilloscope. Versatility has been combined with user friendliness to provide instruments with exceptionally powerful triggers.

DISPLAY

Analog oscilloscopes update 10 to 100 thousand times per second. Digitizers update much less frequently. Fast update rates give digitizers a "live response", or an analog feel. If the response is too slow, the digitizer can miss changing or infrequent events, can be irritating to operate because of the lack of feedback, and can even provide erroneous results. Digitizer architecture, processor type(s) and speed(s), analysis algorithm efficiency, and display algorithm are determining factors in the display update rate.

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 settings changes from the front panel controls or from the ports. In some cases, they control the waveform acquisition and configure advanced trigger settings. Their efficiency at manipulating data tremendously effects display update rates.

Use of multiple, fast-clocked, 32-bit processors plus dedicated digital signal processors can cause a digitizer to approach real-time update rates, even when extensive signal processing, such as FFT, is applied to the signal. Digitizer designs using a single, slow-clocked, 8-bit processor are less expensive, but can also make the instrument slow to operate.

Display Algorithm

Use of dedicated display processors and simple long-memory compression techniques increases the display update rate. For example, if the CRT can display 2000 waveform points horizontally and memory holds 50,000 points, then only one out of each 25 points can be displayed. A simple display data reduction algorithm is to take every 25th point and display it. Although fast, this technique can miss important signal peaks and glitches. LeCroy's proprietary "compaction" algorithm shows all the details and takes only slightly longer to run. High speed 32-bit processors minimize the effect of the additional calculations. Other display algorithms, such as smoothing or sin(X)/X interpolation, require many calculations and, therefore, processing time.

DYNAMIC ACCURACY

Accuracy consists of resolution, precision, and repeatability. Resolution indicates uncertainty associated with any reading. Precision indicates how well the reading matches the actual voltage. Repeatability indicates how often the same reading occurs for the same input.

All digitizers contain numerous measurement error sources which limit precision and repeatability. These errors include:

- Harmonic distortion
- Spurious response
- Differential non-linearity
- Noise (both amplitude and aperture jitter)
- Phase shift with frequency
- Amplitude and offset response with frequency

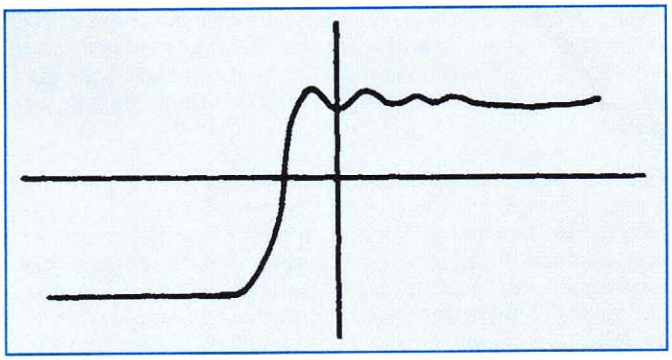
DC errors indicate how accurately the digitizer will measure static or slow moving signals. The input amplifier, not the ADC, determines DC accuracy. Analog oscilloscopes typically have 3% DC accuracy which matches the display errors. Digitizers can deliver better measurement accuracy, and thus should have better DC accuracy (typically 1-2%).

Dynamic accuracy represents DC accuracy plus numerous other error sources as well. Amplitude non-linearities result in harmonic distortion. These include static (DC) non-linearity, sometimes called integral non-linearity. Dynamic non-linearities, as can be induced by slew-limiting, contribute to harmonic distortion. All of these factors introduce spectral components into the digitized waveform data, at integral multiples of the input frequency. For example, for a 5 MHz sine input, 2nd and 3rd harmonic distortion adds 10 MHz and 15 MHz components to the original signal. Typically, dynamic non-linearities become larger for higher input signal frequencies and levels.

Differential non-linearity is a measure of the uniformity in the spacing of adjacent quantizing levels for a digitizer. For an N-bit digitizer, 2 to Nth power minus one quantizing levels exist. For example, an 8-bit digitizer has 255 quantizing levels. For each digitizer code, the bin-width is defined as the difference between its upper and lower quantizing levels. An ideal digitizer has perfectly uniform, nominal spacing between all quantizing levels. The differential non-linearity is defined as the worst-case variation, expressed as a percentage, from this nominal bin-width. For example, if the LSB voltage is 2 mV and the worst case bin is 3 mV, then the differential non-linearity is 50%. A "missing code" has equal adjacent quantizing levels, or zero bin-width, precluding the possibility of the correct code being output at that input level. Differential non-linearity typically causes significant errors only for small signals since the error is usually only one count of the ADC.

Phase distortion means the digitizing system phase shifts the input signal different amounts at different input frequencies. Square pulse edges are composed of a spectrum of frequencies. The pulse waveshape is maintained only if the phase of all the sine components remains constant. Therefore, phase distortion induces erroneous overshoots and rise times on edges.

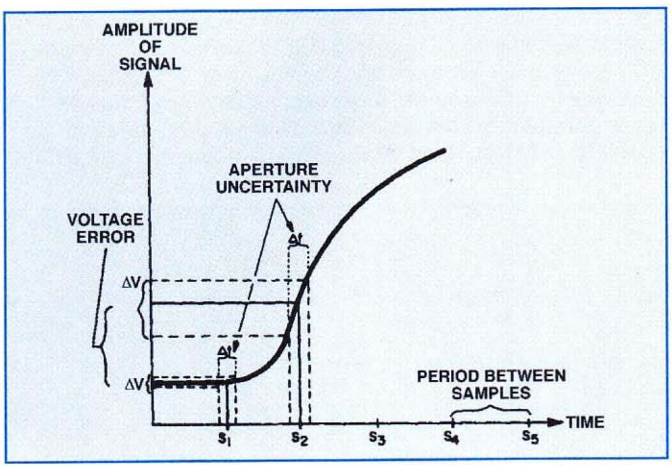
Amplitude noise is random or uncorrelated to the input signal. The amplifier associated with the digitizer generates noise into the digitizing process. Noise can mask subtle input signal variations on transient events. For repetitive signals, noise can be reduced by averaging several waveform acquisitions.



Phase distortion can cause pulse overshoot.

A high resolution FFT plot of a digitized sine input indicates noise distribution, but it also indicates quantization noise. Even an ideal digitizer will have an FFT noise floor because of the quantization noise caused by the finite resolution (e.g., an ideal 8-bit digitizer has a -75 dB noise floor).

Aperture uncertainty represents sampling time noise, or jitter on the clock. The amplitude noise induced by clock jitter equals the time error multiplied by the slope of the input signal. The amplitude error increases for fast signal transitions, such as pulse edges or high frequency sine waves. Thus, aperture uncertainty affects timing measurements such as rise time, fall time, and pulse width. Aperture uncertainty has little effect on low frequency signals.



Aperture uncertainty causes errors on fast edges.

Effective Bits

A figure of merit called "effective bits" provides a simple means of comparing the accuracy of two digitizers. It indicates dynamic performance. The effective bits measurement includes errors from harmonic distortion, differential non-linearity, aperture uncertainty, amplitude noise, and slewing. The effective bits measurement compares the digitizer under test to an ideal digitizer of identical range and resolution.

Effective bits as a performance indicator has many drawbacks. Effective bits measurements change with input frequency and amplitude. Since the effects of harmonic distortion, aperture uncertainty, and slewing increase at higher signal frequencies and amplitudes, the effective bit values decrease. To represent overall performance under a wide variety of conditions, effective bits should be plotted for various frequencies and amplitudes.

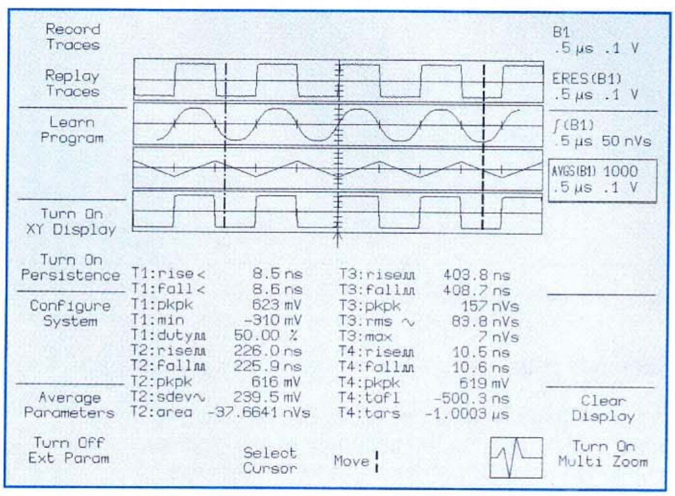
The effective bits indicator is calculated using sine wave inputs. Therefore, it does not include phase, gain, or offset errors which vary with frequency. It poorly represents worst case errors. It does not indicate which error source contributed most.

ANALYSIS

One of the greatest advantages of digitizing is the ability to analyze the data. Since the digitizer has converted the analog signal into digital data, either an external computer or the internal digitizer processor can analyze the data. Most digitizers now have a wide spectrum of analysis built in. For additional analysis, PC software packages simplify custom array processing. Let's consider some of the available analysis.

Pulse Parameters

Cursor readouts allow a user to use the full resolution of the ADC to measure absolute and relative times and amplitudes on a waveform. However, most users commonly measure the same parameters on a waveform. These parameters include rise time, fall time, 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.



Automatic pulse parameter readout in a 7200A

Waveform Math and Engineering Units

Waveform math allows the user to display final answers, rather than raw data. For example, inputs from voltage and current transformers can be multiplied together to display power. LeCroy scopes have a very important feature which is the ability to daisy chain math functions. For example, the power trace can be integrated to display energy (Figure 19).

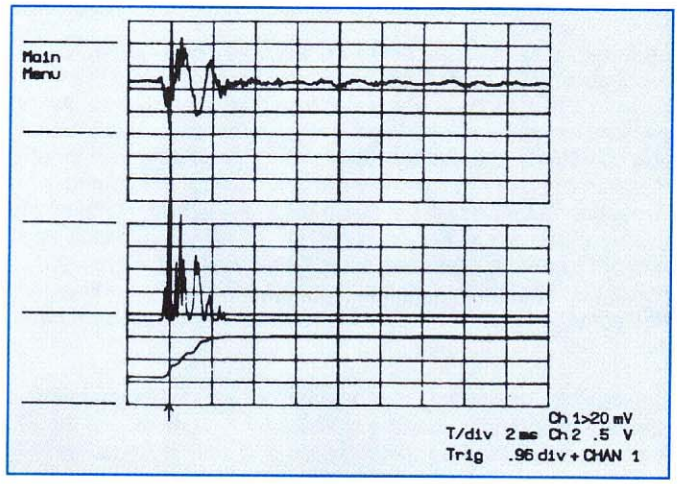


Figure 19: Current and voltage waveforms multiplied and integrated to display total energy.

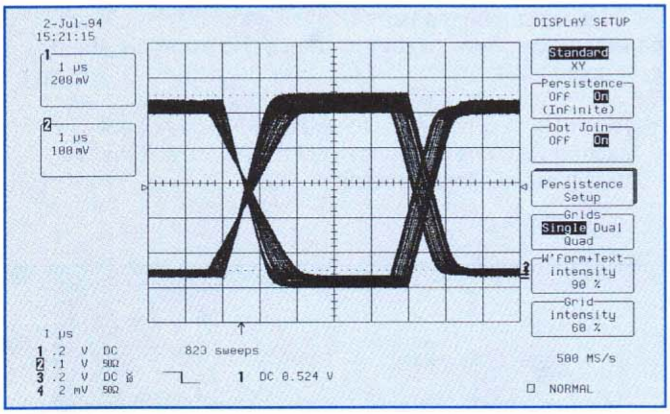
Signal Variation

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.

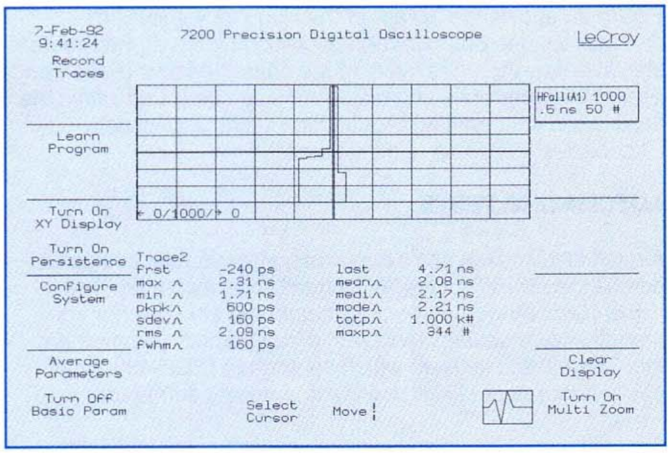
Frequency Domain

The Fourier transform converts sampled waveform information into a unique set of sine wave components. The data is usually plotted as frequency vs. amplitude. Two algorithms are common: the discrete Fourier transform (DFT) and the fast Fourier transform (FFT). Practical implementations use the FFT since it is many times faster to calculate. The FFT can expose information not easily visible in the time domain

TECHNICAL TUTORIALS



Persistence mode displays a user-selected number of sequential measurements.



The figure above shows a histogram of a repetitive "fall time" measurement. The parameters shown below the screen characterize the detail of the histogram itself. Such parameters can be automatically applied to histograms and trends as well as time and frequency data.

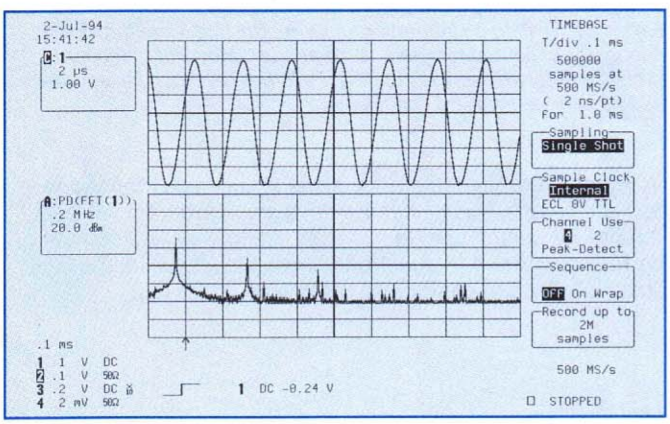
(time vs. amplitude). Ideal uses for FFT analysis include measuring frequency components of communication signals, monitoring drift in a oscillation, etc. The frequency resolution of an FFT is directly proportional to the number of time domain points the FFT algorithm can handle. Some companies make scopes with 50k points but their FFT algorithm can accept only 10k. Those scopes have 1% as much resolution as a LeCroy scope which can perform 1 million point FFT's.

Statistical Domain

The existence of measured waveforms in digital representations permits convenient utilization of the data inherent in those measurements. Besides analysis of signals in the frequency domain and the ability to perform mathematical operations and signal averaging upon the data, one can also determine trends and analyze histograms of the data.

Histograms: A histogram is a graph of the number of occurrences of a measured parameter. For instance, one might want to measure the risetime of a repetitive signal. If all the measurements were exactly equal, a resultant histogram would be a straight vertical line with no breadth. However, variations in the risetimes create a plot with some horizontal structure, implying variations in the measurements. Certain LeCroy oscilloscopes not only create such histograms but also allow measurement of their own characteristics.

Trends: There are many times when an operator may not be interested in the details of a specific waveform but in the history of some aspect of the waveform. For example, suppose the task is to measure the output energy from a pulsed accelerator and determine if there is any degradation over time. The operator is confronted with the task of taking several shots, computing the energy in each pulse and plotting the energy versus shot number. This class of measurements can now be automated with certain digital scopes, such as LeCroy's Series 7200.



FFT of sine wave shows harmonics not visible in time domain.

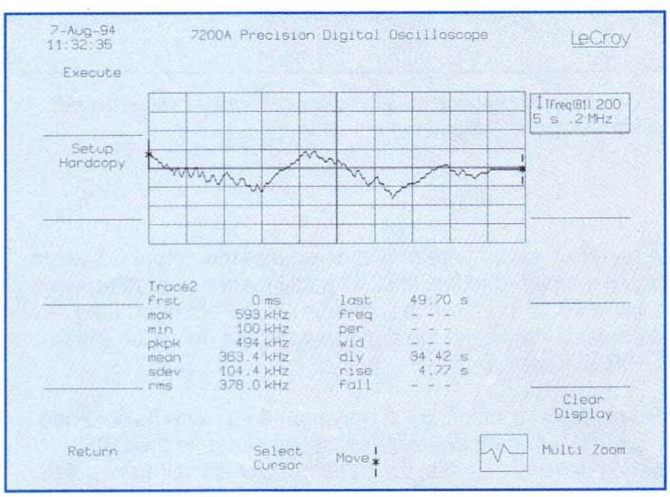


Figure 20: Trend of frequency measurements in time.

Figure 20 shows the "trend" of the frequency spectrum of a microphone output over a 50 second interval. Parameters shown below the trace indicate the characteristics of the trend itself. More on trends and histograms can be found within the application note entitled "Advanced Digital Oscilloscope Capabilities" available upon request.

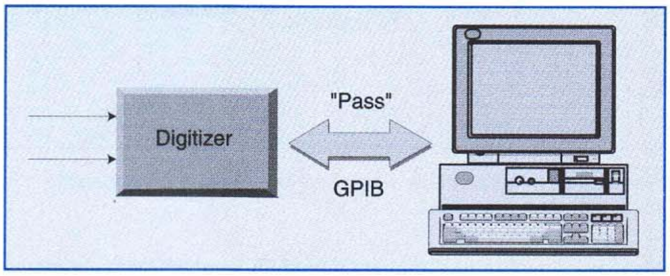
AUTOMATING TESTS

Almost all digitizers can be controlled from a host computer across the GPIB (IEEE-488 Standard Interface bus). The IEEE-488.2 Standard specifies command structure for common digitizers settings, such as voltage range, sample rate, etc. Therefore, digitizers which conform to IEEE-488.2 have easily understood, English-like, mnemonic commands.

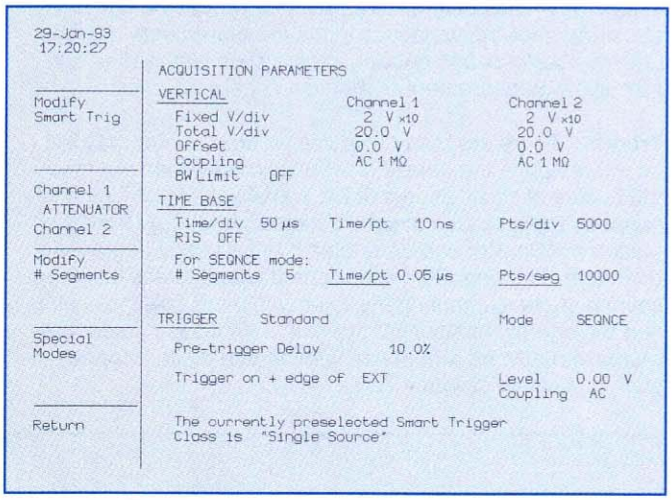
One of the problems associated with high-accuracy digitizers in a GPIB-based automated test system is the transfer time and storage requirements of long waveform data blocks. Local data analysis within the digitizer allows for transfer of answers, not extensive data blocks. This analysis can be as simple as calculating pulse parameters. Or it could actually consist of PASS/FAIL testing.

parameters can be measured on the acquired data. Each parameter can have its own tolerance. For example, the digitizer could act if:

> Rise time exceeds a 5% tolerance **AND** overshoot exceeds 2% **OR** frequency varies by 0.5% **OR** the third harmonic is larger than -42 dB.



Local analysis reduces data transfer time.



Non-volatile storage and recall of complete configurations simplify setup changes.

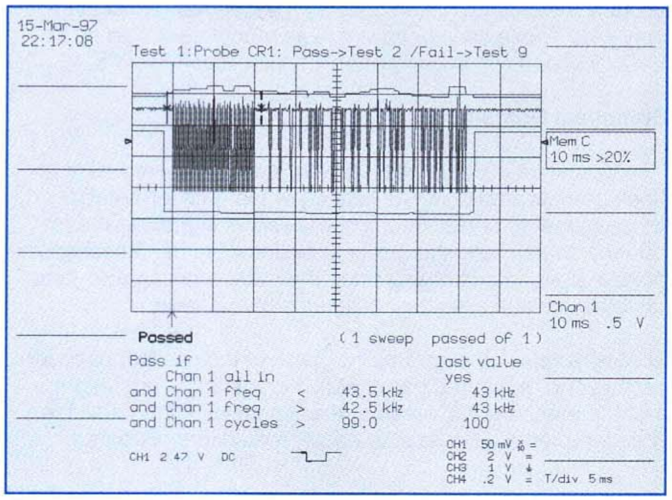


Figure 21: Testing an infra-red remote control unit. Note the simultaneous use of both parameters, such as frequency and number of cycles, and tolerance mask testing. Pass/Fail tests can incorporate up to 5 user-defined test conditions.

A "save-on-delta" type of test compares the actual waveform against a high and low limit. The limits are set as tolerances compared to a reference waveform. If the acquired data passes outside the limits, the digitizer can take an action (beep, GPIB SRQ, etc.).

Some digital oscilloscopes may contain a more flexible and powerful test than envelope limits checking. In the 9300 series or 7200A series, for instance, several different pulse

In Figure 21, both a tolerance mask and waveform parameters are established to test the drive signal from an infrared remote TV control unit. In this case, frequency and number of cycles as well as the upper and lower amplitude versus time limits are used to pass or fail the device under test.

The test conditions are completely programmable, and therefore completely flexible. The actions taken can include printing the data, printing a report, saving the waveform to disk, polling the GPIB SRQ line, modifying its own setup and taking a different measurement, beeping, turning on an external device, etc.

STORING & RECALLING WAVEFORMS & PARAMETERS

A few digital oscilloscopes have built-in mass storage for storing large numbers of waveforms. The capability is powerful and time saving. An internal floppy drive and hard disk can store and recall waveforms, setups, measured parameters, and test programs, or 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 and RAM memory cards, all in DOS-compatible format. After storing waveforms, the memory card or diskette can be removed from the oscilloscope and transferred to a PC for further storage, manipulation, or network transfer, or can be carried over to or copied for other test, field service, or R&D stations. Absolute consistency can be maintained in testing via this method, as all locations share the same waveform files.

Most digital oscilloscopes have GPIB or RS-232C output as standard or optional. Direct fax connections are available on others. File formats are becoming increasingly PC-software compatible, with the LeCroy DSO ScopeStation Series outputting measurements in formats directly importable into word

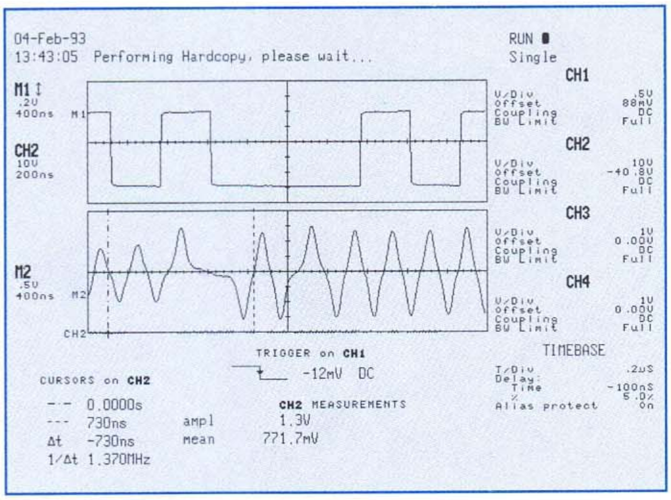


Figure 22

processor, spreadsheet, database, math package, and design simulation software. Figure 22 shows the result of a screen printout to a .PCX format file. Note that the main settings for each channel are given to the right of the screen.

Besides storage and transfer to memory devices, LeCroy digital scopes offer push-button transfer of waveforms and settings to LW400 and 9100 series Arbitrary Waveform Generator products. This facility enables reference waveform, for instance, to be captured from a known good device and be used as a test stimulus applied to other devices.

DSO Applications in High Speed Electronics

INTRODUCTION

Analog designers have long battled against high-frequency effects such as reflections, noise, capacitive loading and power supply transients. They address these problems with tools like Transmission Line theory and Network Analysis. Until recently, digital designers have been unaffected by such "analog" phenomena. But today's hardware designer, *analog or digital*, ignores them at his or her peril.

With microprocessor clock speeds now routinely exceeding 50 MHz, and the corresponding reduction in transition times and propagation delays, digital circuits are exhibiting increasingly non-digital behavior. The old simplifying assumptions (perfectly square pulses, clean edges, all signals either High or Low) are no longer valid. At the same time, fewer systems are 100% analog or digital; many are "mixed signal", imposing analog *and* digital design disciplines.

Fortunately, help is at hand. New design tools are better able to theoretically model such effects. At the same time, new Digital Storage Oscilloscopes provide the capability to investigate real-world performance. This Application Note introduces the different types of DSO available for high-speed work, and discusses their relative merits and applications.

Sample rate considerations

Most scope users realize that the bandwidth of the front end amplifier sets a limit on the ability to examine high speed signals. A DSO's sample rate also limits the fastest signal that it can capture. To avoid aliasing (which completely distorts displayed waveforms) the sample rate must be at least twice as fast as the highest frequencies present in the signal (Nyquist criterion). In order to make precise measurements, however, the sample rate should be approximately 10 times faster than the frequencies measured.

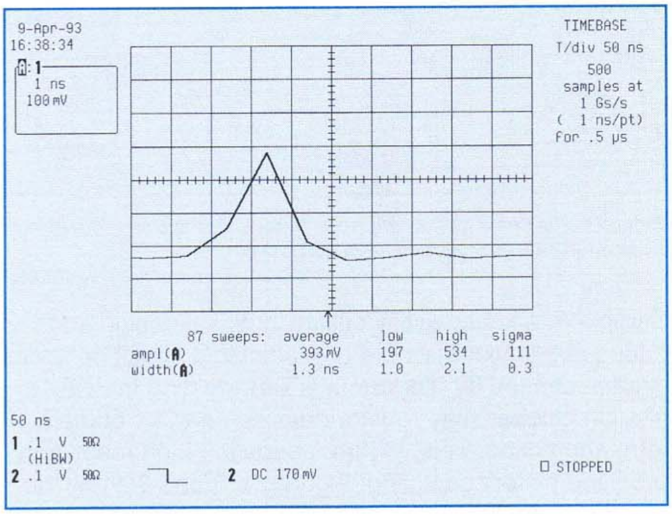


Figure 1. 1 ns glitch digitized at 1 GS/s. It is impossible to accurately determine amplitude or width.

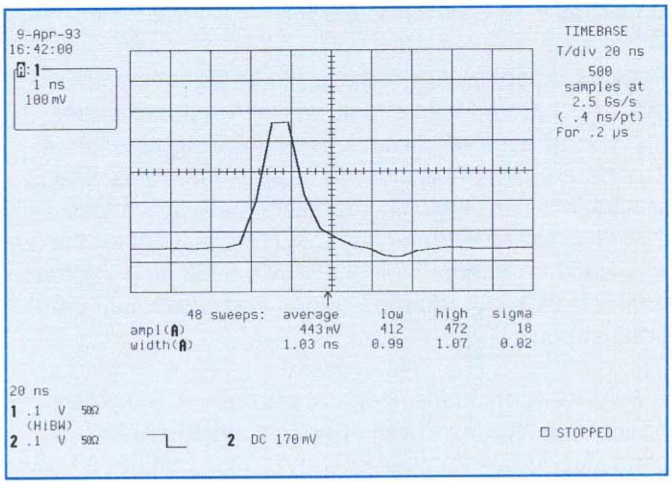


Figure 2. The glitch of figure 6 sampled at 2.5 GS/s. Width is measurable, but peak amplitude information is missing.

SELECTED APPLICATIONS

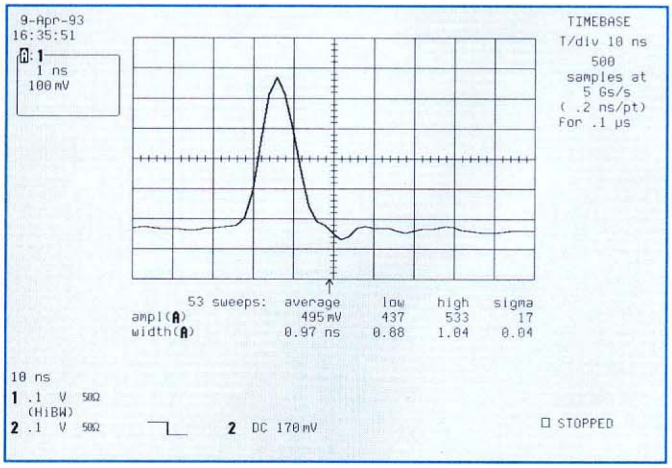


Figure 3. The same glitch sampled at 5 GS/s. Both pulse width and peak amplitude may be measured accurately.

Sample rate is especially critical in digital design and debug applications, where unpredictable circuit behavior is often caused by fast glitches. Determining the cause of such glitches may require detailed analysis of their form and timing. This, in turn, needs the high resolution provided by fast sampling. Figures 1, 2 and 3 show the effect of sampling a 1 nanosecond glitch at 1, 2.5 and 5 GigaSamples per second.

Single-shot capture is particularly important when looking for intermittent faults, so a single-shot DSO should be used for debugging and troubleshooting new designs. The fastest single-shot DSO currently available is LeCroy's 10 GigaSample 9362.

Repetitive scopes may be used to troubleshoot an already characterized circuit, where the board under test will be compared with known good signal shapes. The parameters measured (e.g. phase margins, timing values, etc.) are typically repetitive. LeCroy's 1 GHz 9324 is a low-cost repetitive DSO and is ideal for such applications. Alternatively, LeCroy's 7262 plug-in offers 4 GHz bandwidth for applications such as device characterization.

A third category is the "general-purpose" DSO, which offers both high bandwidth and fast single-shot sampling. A good example is LeCroy's 9354, with 500 MHz bandwidth and 2 Gs/s single-shot digitizing. This family also offers the longest-memory DSOs currently available, with up to 8 MegaBytes of acquisition memory.

Longer Memory means higher Effective Bandwidth

Any DSO's maximum sample rate is just that - the fastest it can possibly sample. But at most timebases, DSOs sample far slower than maximum speed. This is because they must fill their acquisition memory in exactly the time specified by the timebase. So when you set the time per division, you are also specifying the sample rate. But the more memory a scope has, the faster it can sample during that time. So the longer your memory, the faster you can sample.

This is particularly important in debugging microprocessor based systems. Any circuits with asynchronous events are easier to debug with fast digitizing over long time windows. Figure 4 is a typical example. The top trace shows a burst of communication pulses between a microprocessor and a peripheral device. This was acquired at a relatively slow timebase, showing a complete 2 millisecond burst. The waveform has also been expanded (lower trace) in order to make measurements on the individual pulses. The 2 Megabyte memory of the 9354L allows the signal to be acquired at 500 MS/s, even over the long time-window required.

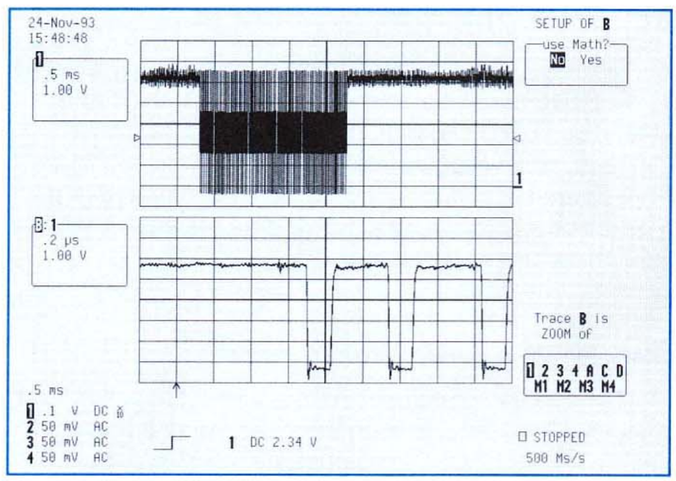


Figure 4. A burst of microprocessor communications activity. The expansion (lower trace) shows individual pulses in the train.

TYPICAL MEASUREMENT PROBLEMS

Measuring in the presence of noise

It is sometimes necessary to characterize a circuit in noisy conditions. This may occur early in the product design, before shielding and layout issues are finalized. Alternatively, circuit layout may make good probe grounding difficult. In either case, the noise present can dramatically mask the measurement, as illustrated by Figure 5.

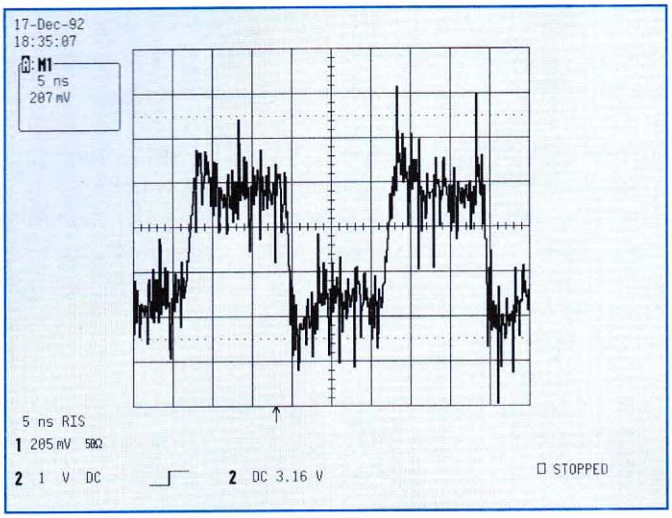


Figure 5. Pulses masked by noise.

A common approach to the noise problem is to filter the signal. This, however, 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. Thus, 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 like overshoot on large signals. Figure 6 shows the effect of averaging the noisy waveform shown above.

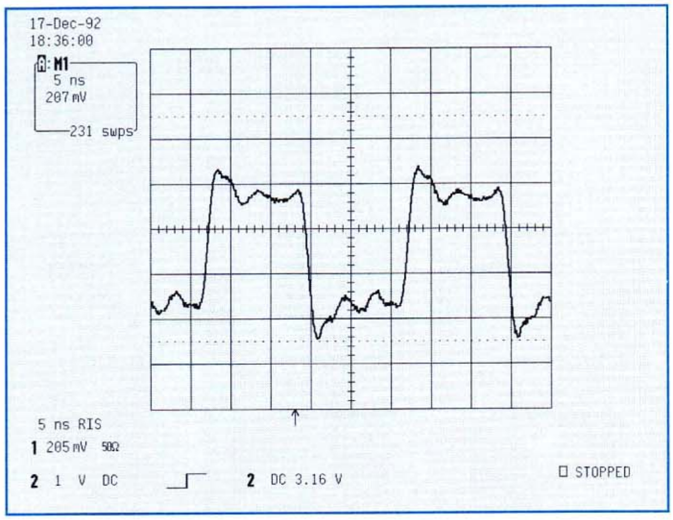
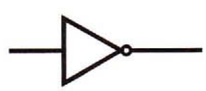


Figure 6. Noise removed by averaging

Inter-Channel measurements

Most timing measurements are made between two or more different signals. For example, it may be necessary to test a BiCMOS buffer like the one below:



t_{PLH}		
MIN	TYP	MAX
2	4.5	6

Figure 7. BiCMOS buffer, with typical specs for propagation delay (low to high transition).

The propagation delay (time from an input transition to an output transition) for this part is nominally 4.5 ns. The DSO (a LeCroy 9360) is used to measure the time from CH1 (input) to CH2 (output). This delay is shown by the Δdelay parameter. In addition, statistics show the highest, lowest and average values, and the standard deviation. Alternatively, Pass/Fail testing could be used to verify that all acquisitions fall within the specified limits.

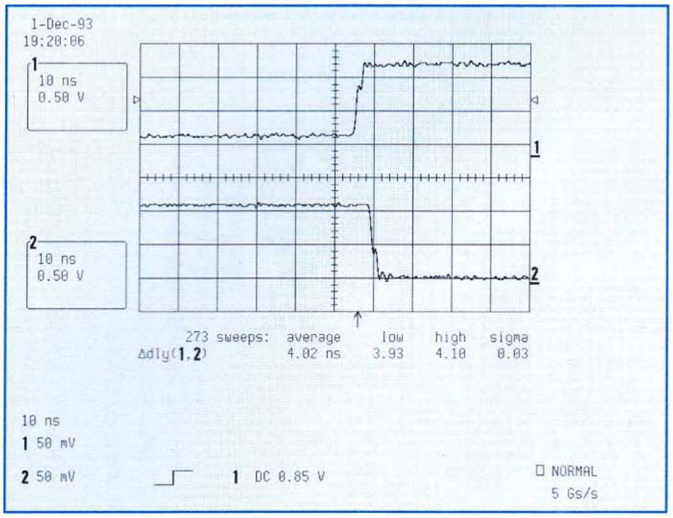


Figure 8. Propagation delay measurement.

In the above example, timing is measured from the 50% point of the input edge to the 50% point of the output edge. This is typical for propagation delay measurements, although LeCroy DSOs allow the user to specify other signal levels, either in percentages or in volts. An engineer using this buffer in a circuit would probably test it with a general purpose DSO. The IC manufacturer is more likely to use a high bandwidth (repetitive) scope with a test circuit set up to cycle the chip repetitively.

Choice of level for edge measurements

The risetime of a signal will be accurately measured as long as the DSO has sufficient bandwidth. Risetimes are typically measured from the 10% to the 90% point on the waveform to include the signal's full voltage swing. In very fast circuits, it is more common to measure the 20% to 80% risetime. This makes the risetime specification insensitive to inflections near the top of the pulse. LeCroy DSOs allow the user to measure risetime at these or any other levels.

Crosstalk

Parasitic capacitance between PCB tracks can cause the fast edges of high-speed logic to propagate from one signal line to another. This crosstalk can have catastrophic effects, producing glitches large enough to cross logic thresholds. Glitches may cause unpredictable failures such as unwanted logic pulses in a data path or even timing errors that result in device misfiring. Detection of glitches, and accurate measurements of their amplitudes and widths, is therefore of major importance in identifying sources of crosstalk. A DSO with glitch trigger capability is extremely useful for such applications.

Microprocessor crashes

During the final phase of many designs, microprocessor crashes or lockups are common. These may be due to hardware problems, software bugs, or unpredicted interaction between hardware and software.

In investigating such crashes, the designer is interested in the sequence of events leading up to the failure. Therefore it is particularly helpful to have a DSO which can trigger on the crash itself, with a large amount of pre-trigger data stored in memory. If the system successfully restarts, it is also useful to trigger on the restart condition.

One convenient way to trigger on microprocessor lockup is LeCroy's unique DROPOUT trigger mode. Any busy processor line may be monitored, and a timeout period specified. Whenever the processor is quiet for longer than the timeout, the DSO will trigger. Using a 4-channel scope with long pre-trigger memory will allow several signals to be observed for milliseconds or even seconds before the crash.

Triggering on a successful restart is possible with LeCroy's unique EDGE QUALIFIED trigger. Typically, the DSO monitors a Reset line and a data signal. The trigger conditions can be set so that the first event on the data line will cause a trigger, but only if a Reset has first been asserted for a specified period of time. (The signal monitored might in fact be a dedicated Watchdog Timer output).

Clock skew

Timing problems may be caused by skew between clock signals delivered to different parts of the circuit. It is therefore important to identify any skew or jitter present on clock edges. In order to measure accurately, the user must first eliminate any skew due to the DSO and probes used, particularly if the probes are not identical. To do this with a LeCroy DSO, connect both probes to the same test point and set the DSO to its fastest timebase. If any inter-channel skew is seen, use the zoom function to create copies of the main traces, and the zoom position control to eliminate the skew.

Jitter measurements may be made by using the DSO in Infinite Persistence display mode. Any changes in the signal's performance will be "painted" onto the display, so that the total jitter on a clock edge may be viewed.

Metastability

The data input to a flip-flop should be stable for a given period of time before and after the clock pulse. This period is known as the device's setup and hold time. If the data changes during the setup and hold time, the flip-flop's output may not change cleanly, but go to an intermediate level between high and low. While it remains in this indeterminate state, the signal is said to be metastable.

Figure 9 shows the output of such a flip-flop, with many successive acquisitions overlaid in Infinite Persistence display mode. A region of metastability is clearly visible during the 5 nanoseconds following the low-to-high transition.

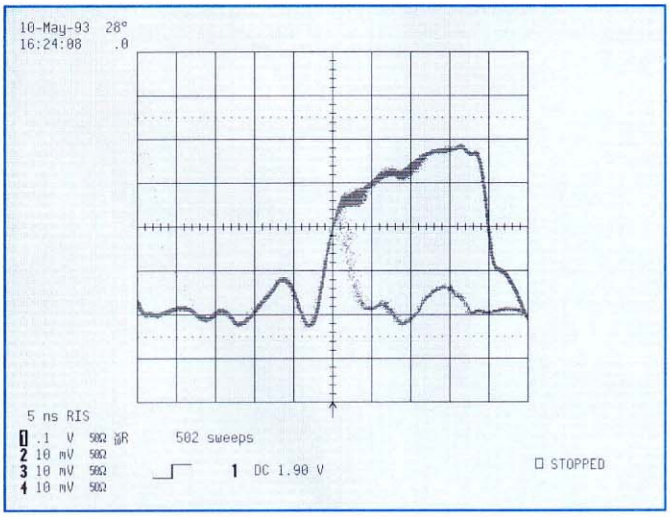


Figure 9. Flip-flop output exhibiting metastability.

PROBES AND PROBING

The simple act of probing a high-frequency circuit can significantly alter its performance. The proper use of probes is therefore crucial. It is important to choose the right probe for each measurement and also to use good grounding technique. Ground leads should be kept as short as possible and, whenever possible, a spring clip ground pin should be used.

There are three factors which are important when selecting a probe: bandwidth, resistance and capacitance. The effects of low probe bandwidth are obvious: the composite oscilloscope/probe bandwidth is degraded.

Low impedance passive probes offer very high bandwidth (typically several GHz). They also feature very low capacitance. Due to their low impedance, however, (typically 500 Ω) they present a significant load to the circuit under test. This resistive loading results in loss of signal amplitude. This may be a problem when using TTL with 1 kΩ pull-up resistors, or CMOS which is not capable of sourcing the current required. It is usually not a problem when using ECL.

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 would 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. These have bipolar or field-effect transistors in the probe tip which act as the input stage of a buffer amplifier. These active probes provide high bandwidth, high impedance and low capacitance but they are more expensive, and may be sensitive to damage due to overvoltage abuse.

For more details on probes and probing, request Application Note ITI016B.

Benefits of DSOs in Communications

INTRODUCTION

The rapid evolution of communications poses new and challenging technical problems and a need for improved instrumentation. Despite the variety of communications media, there are many similarities in the problems encountered when developing, testing and debugging communication links. Testing is typically performed by transmitting and receiving known patterns of data which are most often repetitive, whereas real-life conditions often require single-shot capabilities due to the unpredictable nature of the data.

Because of their ability to display single-shot as well as repetitive events, digital oscilloscopes are ideal for the communications field. Advanced digital oscilloscopes also offer a wealth of features including sophisticated triggering, processing of data, computer control, etc. These features can be invaluable to engineers faced with the problem of capturing and analyzing communications signals.

This note presents typical applications and shows how particular features of LeCroy oscilloscopes can be beneficial.

DIGITAL OSCILLOSCOPE OVERVIEW

The transition from analog to digital technology in oscilloscopes brings several advantages which include:

- Capture of single-shot as well as repetitive events.
- Steady, non-volatile display of waveforms.
- Event archiving (computer storage and paper hardcopy).
- Viewing of pre- and post-trigger data.
- Digital control of the acquisition conditions.

While the above features are common to most digital oscilloscopes, LeCroy oscilloscopes also provide innovative and unique features particularly valuable in communications. These are:

- Long memory per channel, 10 kword to 1 Mword, allow viewing of long-lasting events with very high time resolution.
- Simultaneous sampling on all channels to ensure correct phase analysis of complex waveforms.
- XY display with dedicated cursors for relative phase and amplitude measurements.
- External clock input to sample the input waveform synchronously with a user-defined clock (particularly useful for constellation displays).
- A wide choice of signal processing options, including Fast Fourier Transform (FFT) which allows the oscilloscope to act as a spectrum analyzer.
- Variable and infinite persistence display modes, for eye diagram display.
- PASS/FAIL testing with "template" waveforms and parameter limits representing popular telecom standards.
- Time-qualified trigger, where the distance between the arming condition and the actual trigger is defined in terms of time.
- State-qualified trigger, where the presence of a particular logic state, for instance on Channel 2 and/or External, is a condition for Channel 1 to trigger.

The following examples highlight some applications of these features.

PHASE SHIFT KEYING

Phase Shift Keying (PSK) is a popular way of transmitting digital data through modems and telephone lines. It is based on the phase modulation of a continuous sine wave. While the structure of these signals is quite simple, oscilloscopes with just a threshold trigger have difficulty displaying them. The continuous change of phase results in a display with excessive jitter. A trigger which operates only when the oscilloscope senses a variation in the phase of the signal is much more effective.

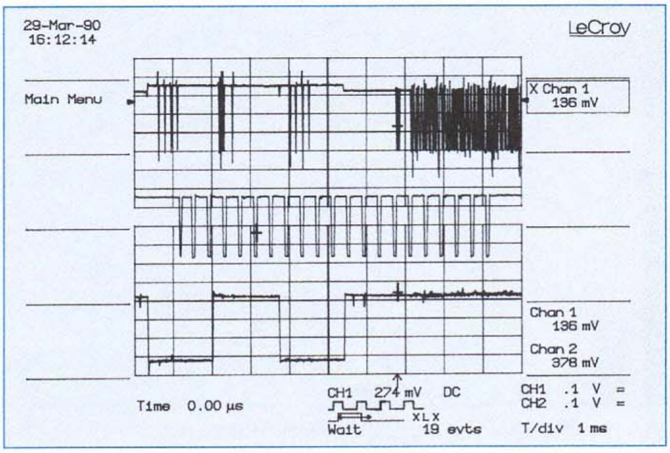


Figure 1: Interval trigger provides a stable trigger on a Phase Shift Keyed signal.

LeCroy oscilloscopes are capable of sensing the width of the input pulses or, alternatively, the time distance separating successive pulses. A change of phase in a continuous sine wave can be detected as a sudden variation of the period.

Figure 1 shows such an example. The trigger occurs on Channel 2 (lower trace). The requirement is that the separation between two cycles must be smaller than the sine wave period (Interval smaller than 258 μsec). The trigger position in time is indicated by the small arrow at the bottom of the screen. As can be seen, the trigger takes place after a 180° phase change.

CONSTELLATION DISPLAY

The two waveforms in Figure 1 are the I (In-phase) and Q (Quadrature) components of a transmitted PSK waveform, acquired simultaneously. An XY display of these two waveforms shows their phase trajectory (Figure 2).

A constellation display can be generated by clocking the I and Q components with the system clock and showing an XY display of the sampled values. This can be easily done since LeCroy oscilloscopes can be used with an external clock.

Figure 3 shows the constellation display obtained by the two waveforms of Figure 1. The slight spread of the points in the constellation display indicates a small phase jitter between the I and Q signals.

The phase jitter can be measured exactly by locating the cross-hair cursor at the two extremes of a spot, as shown in Figures 3 and 4. The difference of the two angles seen on the right-hand side of the XY display gives the amount of jitter. In this case, $\Delta\phi = 50.8° - 46.3° = 4.5°$.

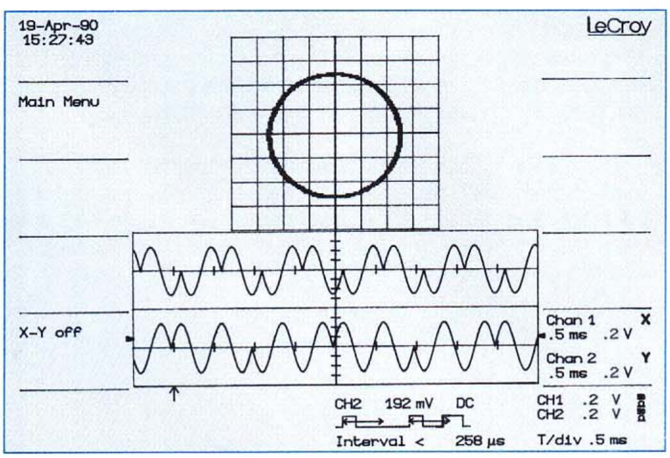


Figure 2: The phase trajectory of the I and Q components of a PSK signal.

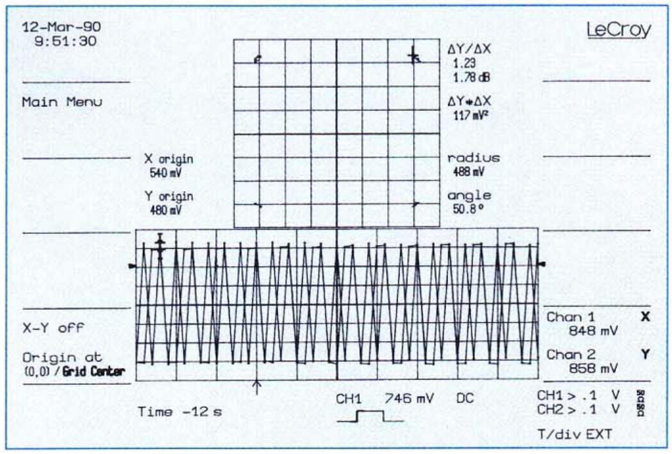


Figure 3: Constellation diagram of a PSK signal.

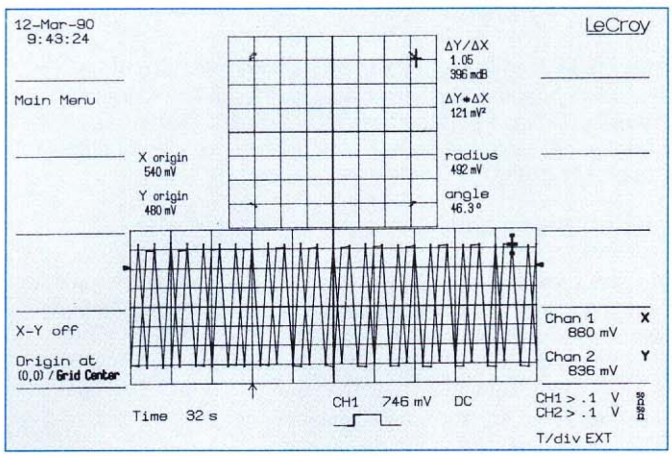


Figure 4: The same constellation diagram of a PSK signal as in Figure 3, with the crosshair cursor used to measure the phase jitter.

FREQUENCY SHIFT KEYING

Frequency Shift Keying (FSK) is another common way of transmitting digital data. It's based on modulation frequency of a carrier.

The upper waveform in Figure 5 shows an example of a binary frequency modulation. This is a relatively simple signal, but very difficult to trigger on without resulting in a jittering display. Any one of the pulses composing the waveform can be a potential trigger. The signal in Figure 5 was captured with a LeCroy oscilloscope by setting the instrument to trigger only when a change takes place in the carrier period (pulse width less than 3 μsec). The trigger position is indicated by the arrow at the bottom of the grid.

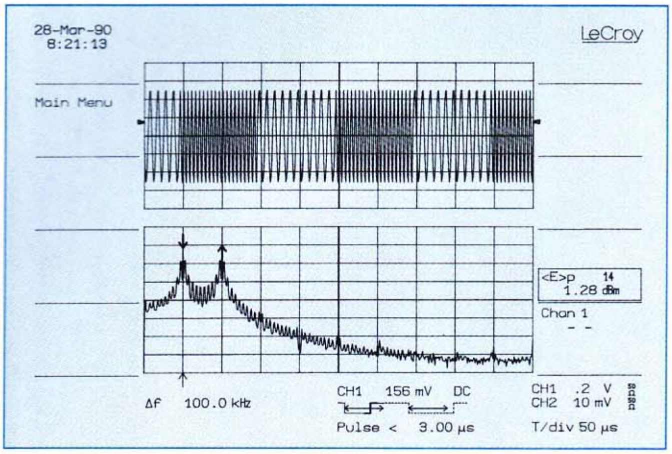


Figure 5: An FSK signal and its frequency spectrum.

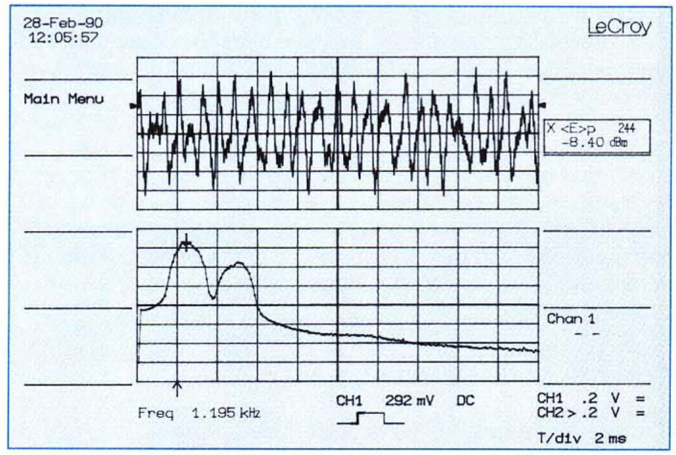


Figure 6: Signal captured on a full duplex line and its corresponding frequency spectrum.

The lower trace in Figure 5 shows another feature of LeCroy oscilloscopes; the ability to calculate the FFT of the input waveform. Two frequency peaks are clearly visible. The two cursors, set on the two peaks, measure a frequency difference of 100 kHz.

FULL DUPLEX LINE

A full duplex line is a two-way link between two communication terminals, where transmission occurs in both directions simultaneously. In order to distinguish the direction of the data, carriers at two different frequencies are normally used. Each terminal isolates the carrier bringing data from the other terminal, by applying a suitable filter to the signal.

The upper trace in Figure 6 shows the data flow in a full duplex line. The bottom trace shows the FFT Power Spectrum of the same waveform. The two carriers are clearly visible. The cross-hair cursor measures the peak frequency of the first carrier (1.195 kHz) and the associated power (-8.40 dBm).

One more feature is used to provide the frequency spectrum in Figure 6. The time domain waveform is quite noisy and the FFT of a single waveform would provide a noisy FFT spectrum. This would reduce the chances of clearly identifying the two carriers. In Figure 6, the FFT spectrum shown was obtained by averaging individual spectra (244 times). Random noise effects are dramatically reduced, making the two frequency components clearly visible.

GAUSSIAN MINIMUM SHIFT KEYING

Gaussian Minimum Shift Keying (GMSK) is a type of modulation typically used in digital mobile telephones. The upper trace in Figure 7 shows one of the components of a GMSK signal. Again, the sophisticated trigger capabilities of the LeCroy oscilloscopes are employed. Triggering at the beginning of individual data streams can be obtained by requiring a pulse separation greater than the longest separation expected in the data stream (150 µsec in this case). The deep acquisition memory (up to 2 MBytes/channel) also allows the user to catch a long data stream and to zoom in to see the fine details of the waveform. The lower trace in Figure 7 is a 20 times expansion of the upper trace.

The two waveforms at the bottom of Figure 8 are the I and Q components of a GMSK signal taken with a LeCroy oscilloscope, simultaneously acquired as they came out from a transmitter. The XY display at the top shows the corresponding phase trajectory. The asymmetry in the circle at the point of the upward arrow is indicative of a saturation effect. This effect is also visible in the time domain on the Q component (lower trace), but not as clearly as in the XY display. The possibility of positioning a cursor in the XY display, as well as on the waveform in the time domain, facilitates the use of the XY display to identify the problem in the time domain.

In Figure 9 the GMSK signal has been transmitted, then received and decomposed again into its I and Q components (lower two traces). The XY display clearly shows the degradation of the signal due to noise and to the non-ideal characteristics of the receiver.

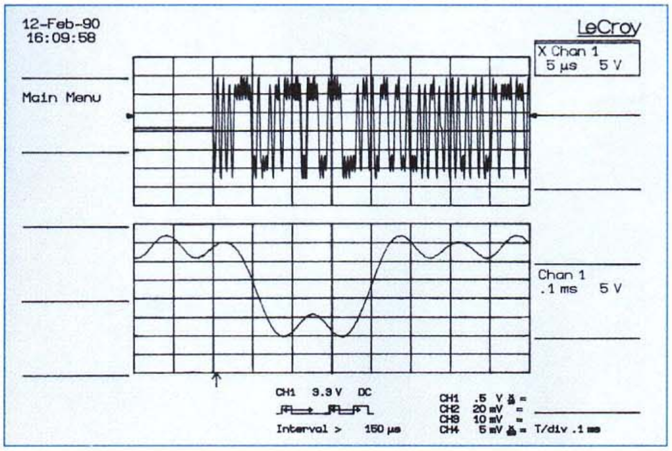


Figure 7: Interval trigger used to capture a GMSK signal.

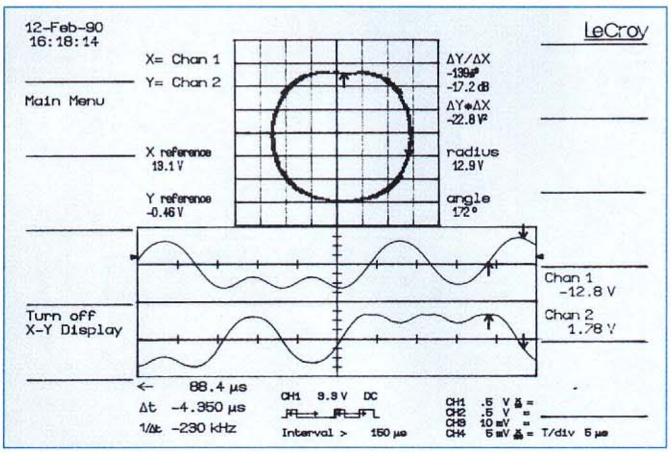


Figure 8: Phase trajectory of the I and Q components of a transmitted GMSK signal.

QUADRATURE AMPLITUDE MODULATION

Quadrature Amplitude Modulation (QAM) is another well-known modulation technique for achieving more efficient use of the available bandwidth. It consists of two amplitude-modulated carriers summed in quadrature and, therefore, it can also be viewed as a combination of amplitude and phase modulation. If, for instance, the amplitude of each carrier is allowed to have four different states, each carrier will transmit two bits per baud. The total waveform will, therefore, carry a total of four bits and the constellation diagram would then contain 16 points arranged in a rectangular constellation (16-QAM). This is exactly what can be seen in Figure 10 showing the XY display of the I and Q components of a 16-QAM signal. The two signals have been simultaneously sampled by the system clock sent to the external clock input of the oscilloscope.

The 16 possible states are clearly shown. By using voltage cursors (not shown) it is possible to verify the symmetry of the states. The cross-hair cursor shown provides the relative phase of the I and Q signals (45.1 degrees), the distance from the center of the grid (1.416 V), and the ratio of the I and Q amplitudes (in this case equal to 1).

VARIABLE PERSISTENCE

The variable persistence feature allows accumulation of successive events on display, so that the user can estimate the evolution in time of a given phenomenon. In communications this feature is useful to build up eye diagrams, showing the time or amplitude jitter in a given bit stream.

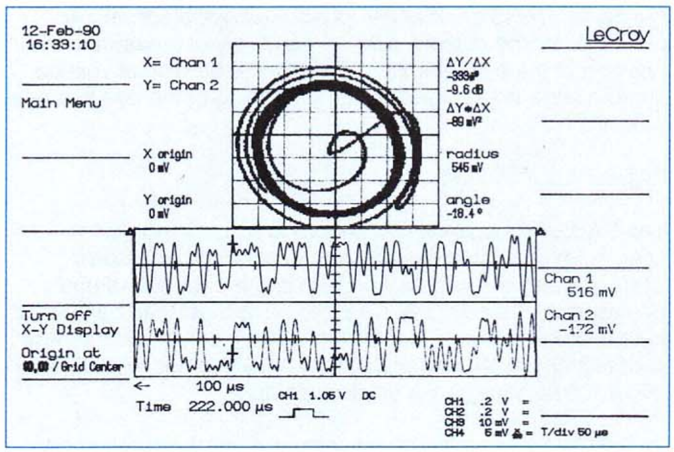


Figure 9: Phase trajectory of the I and Q components of a received GMSK signal.

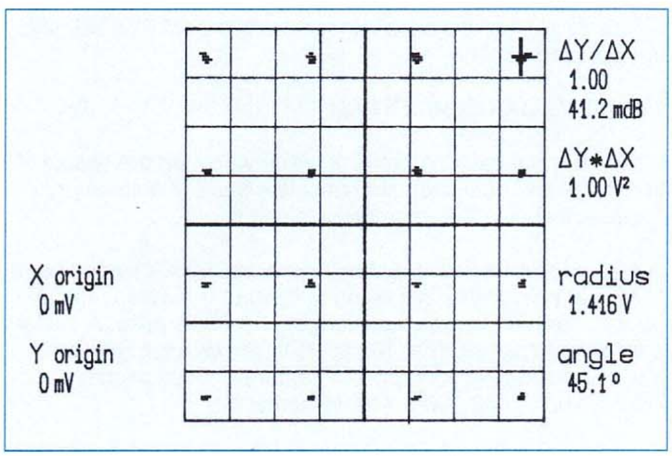


Figure 10: Constellation display of a 16-QAM signal.

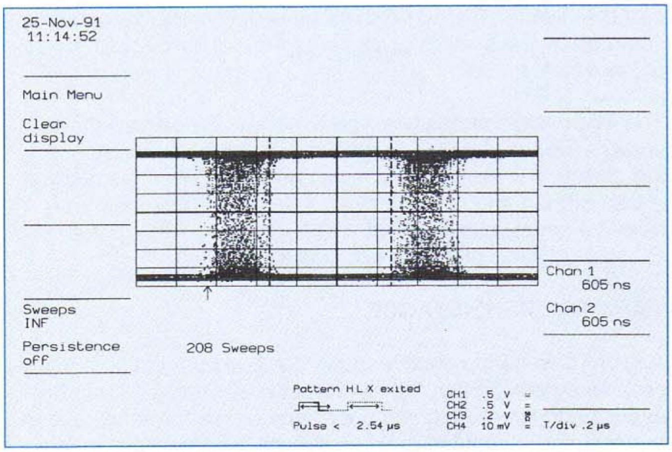


Figure 11: Example of an eye diagram using variable persistence.

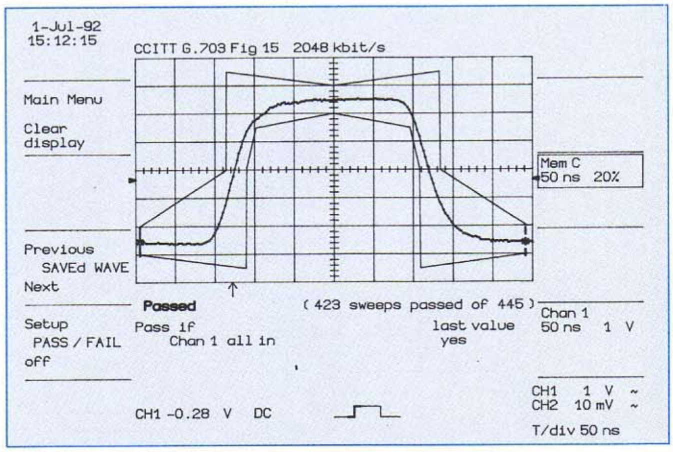


Figure 12: Automatic PASS/FAIL testing against a telecom template.

Figure 11 shows an example of such an eye diagram: the two vertical time cursors offer an easy way of measuring the opening of the eye over time. Two similar horizontal voltage cursors allow measurement of the opening of the eye in amplitude.

PASS/FAIL TESTING

The PASS/FAIL package, standard in all LeCroy oscilloscopes, permits multiple tests on an acquired waveform. The tests can be executed both on pulse parameters and/or against a tolerance mask. The tolerance mask can be defined by the user, or down-loaded from either the optional memory card (9300 and 9400 families) or the build-in floppy disk (7200 and 9300 families) or an external computer.

LeCroy offers an optional memory card which is preloaded with 23 telecom templates taken from the following standards: ANSI T1.102, ANSI T1.403, CCITT G.703, and CCITT1.430 (ISDN).

Figure 12 shows one such telecom template PASS/FAIL test being executed.

TESTING AN ETHERNET LAN

Ethernet is a local area network which works on the assumption that each local user can sense the state of a common broadcast line before attempting to use it.

A data packet can have a maximum size of 1526 bytes, that is 12,208 bits. With a bit lasting 100 nsec, this means that a packet can have a maximum length of 1,220.8 µsec. A digital oscilloscope sampling at 100 MS/sec allows capture of the individual 100 nsec long bit, but capture of a full packet requires up to 122,080 words of memory.

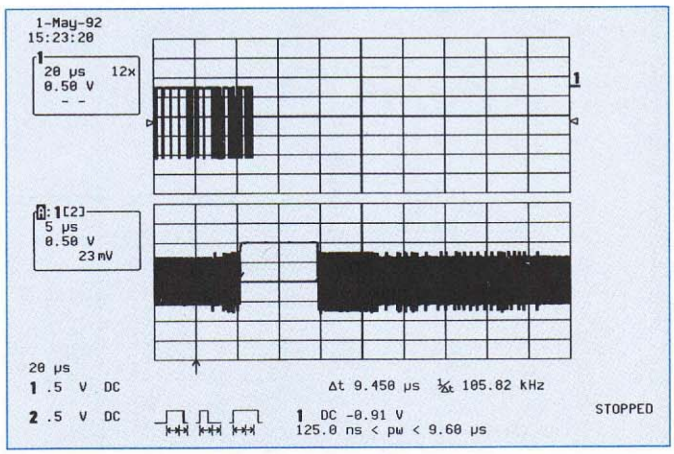


Figure 13: Capture of collisions on an Ethernet bus.

The 9300 series scopes offer models with up to 2 Mword of memory per channel.

The 2 Mword memory can also be sliced in segments (up to 2,000) and each segment can be used to acquire a new event. Figure 13 shows this feature applied to the unattended monitoring of "collisions" happening on the Ethernet bus. The upper trace shows a compacted display of a sequence of 12 such collisions.
A collision is defined at the trigger level by requesting a separation between two successive packets varying between 125 nsec and 9.6 µsec (the trigger conditions at the bottom of the display). The lower trace is the expanded view of one of these events, where the "illegal" gap between two packets is visible. The two cursor arrows measure a gap width of 9.45 µsec.

Figure 14 shows the time stamps associated with each individual collision. The instrument provides both the absolute trigger time, with resolution of one second, and the time relative to the first trigger, with nanosecond resolution.

Acknowledgments: We wish to thank Prof. J. Sloziar and Prof. C. Kunze of the Engineering School, Yverdon, Switzerland, for their help in the preparation of this document.

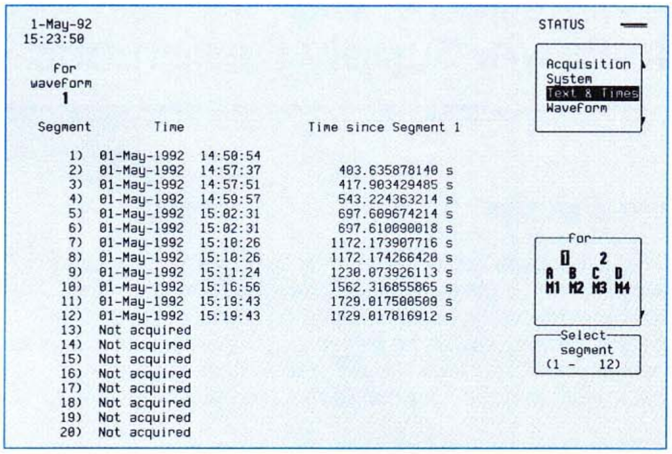


Figure 14: Time stamps associated with the collisions of Figure 13.

SELECTED APPLICATIONS

Benefits of Digital Oscilloscopes in Power Supply Design and Test

INTRODUCTION

The last decade has seen dramatic improvements in power supplies, and particularly in switch-mode power supplies. Due to improvements in power MOSFETs, in regulators and in control circuitry, switching power supplies are becoming smaller with power densities already greater than one watt per cubic inch, and with efficiencies reaching 90%.

As with many other technologies, the product life cycle is shortening rapidly, and manufacturer competition is becoming tougher. When the designs are very similar, a shorter time-to-market (for a new product), or a shorter production cycle, can make the winning difference. Test time, for instance, can now be reduced by using the latest developments in digital oscilloscopes. In the following we will describe a number of applications where digital oscilloscopes can considerably shorten design and test times.

BENEFITS OF DSOs

As with analog oscilloscopes, the primary job of a digital oscilloscope is to display the input waveforms. Unlike analog oscilloscopes, the technique used to achieve this is to sample the input waveforms at regular intervals. The sampled analog values are then converted into digital numbers which in turn are stored into an internal memory. An input waveform is stored in the scope as a sequence of numbers, as many as the memory length. The waveform display is done by retrieving these numbers and representing them on the screen.

The use of this digital technology has many implications. Those which affect power supply testing include the following:

- **Multi-channel single-shot capture:** A DSO can capture single shot phenomena like power ON/OFF or failure conditions synchronously on up to four channels at the same time.

- **Waveform processing:** Since the DSO internally uses a microprocessor, it can also perform various types of processing on the acquired waveform.

For example, automatic calculation of pulse parameters and basic waveform mathematics (sum, difference, product, ratio) are standard features of all LeCroy oscilloscopes. Options are available for the 9300 and 9400 scope families to perform more complex mathematics like integral, derivative, exponential, logarithm, extended averaging, digital filtering, extreme values, Fast Fourier Transform and more.

- **Data storage and archiving:** LeCroy DSOs have built-in memories which can store reference waveforms. They also offer DOS-compatible memory card and floppy-disk options for non-volatile mass storage. The scopes can be easily interfaced to a large variety of plotters and printers for high quality hardcopies. The user can download the data and screen graphics as TIFF files directly into WordPerfect or other publishing software.

- **More trigger possibilities:** DSOs also offer a wealth of trigger capabilities not found in analog oscilloscopes. For instance it is possible to trigger on faulty conditions and look at pre-trigger data to understand the history leading to the fault.

- **Stored test sequences:** All LeCroy oscilloscopes offer the facility to store entire instrument setups in internal non-volatile memories. Many more setups can be stored onto memory cards or floppy disks, depending on what mass storage option is installed. These setups can be easily recalled either manually or under computer control. The user can then recall these predefined setups as part of a fully automatic (or semi-automatic) test sequence, eliminating the need for time consuming manual adjustments.

- **Automatic PASS/FAIL testing:** LeCroy DSOs provide two kinds of automatic testing. The user can define a mask waveform and specify that any input waveform must be contained within the mask. Alternatively, the user can select a set of waveform parameters, which will be automatically calculated, and compare them to predetermined limits. If the waveform or the parameters fall outside the desired limits, a number of actions can be taken, including: freezing of the display (for visual inspection); screen-dump to a printer or waveform storage to disk or memory card; send an interrupt to a computer; produce an audible alarm. The DSO tracks the statistics of passing and failing events.

MONITORING AT POWER-ON

Figure 1 shows the Power-On transitions in a multi-voltage power supply. The simultaneous monitoring of all these transitions is useful to verify that any phase shifts are within acceptable limits. In fact, any voltage imbalances could be damaging to the load circuits. The switching time can also be automatically calculated, as shown in the figure.

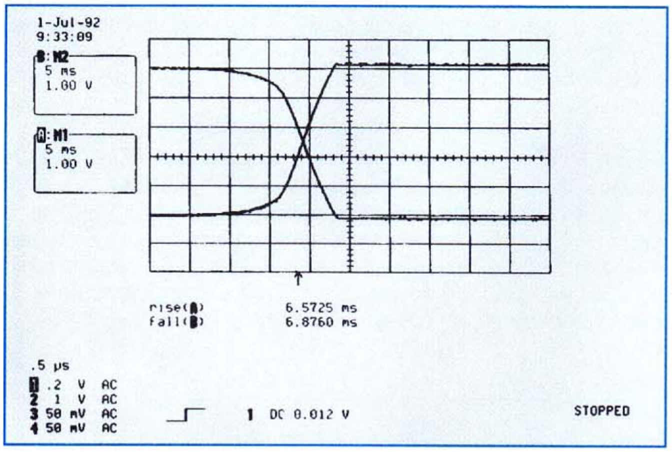


Figure 1: Switch-on transition of a dual output power supply (+5 V and -5 V). Symmetric behavior of the two voltages is often required. The automatic calculation of pulse parameters (rise and fall times in this case) simplify this test.

HOLD-UP TIME

The hold-up time is the time for which the output voltage remains stable, at full load, after the loss of AC power. A digital oscilloscope is the ideal instrument for measuring this because of both the powerful trigger system and the single shot capture capability. (An oscilloscope with deep memory is normally required.)

Figure 2 shows such a hold-up time. The trigger condition used is LeCroy's "Dropout" trigger. As shown at the bottom of the display, the scope triggers when the pulse train on channel C (the AC line) disappears for longer than 25 msec. The trigger conditions are also shown on the trigger setup menu, at the right of the display. The cursors positioned on the waveforms measure a hold-up time of about 70 msec.

IN-RUSH CURRENT

At power-on, the input current absorbed by the power supply has a spike which should not exceed the maximum allowable input current. The upper trace in Figure 3 shows an example of In-Rush current. The lower trace shows the simultaneously acquired input voltage.

The oscilloscope used, a Model 9314M, utilizes a bi-slope trigger, as shown in the trigger icon, at the bottom of the screen. That is, the oscilloscope would trigger on Channel 1 for whatever slope of the input pulse, provided it exceeds +0.5 V. The oscilloscope can test the In-Rush current automatically and in two different ways. It can calculate the current peak value and verify that it is smaller than a preset limit.

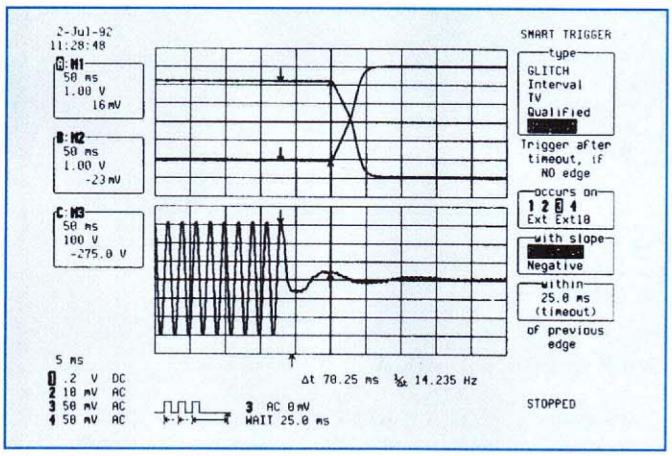


Figure 2: Measurement of the hold-up time. LeCroy's "Dropout" trigger mode is used, causing the scope to trigger on the mains drop which occur at the left of the lower trace.

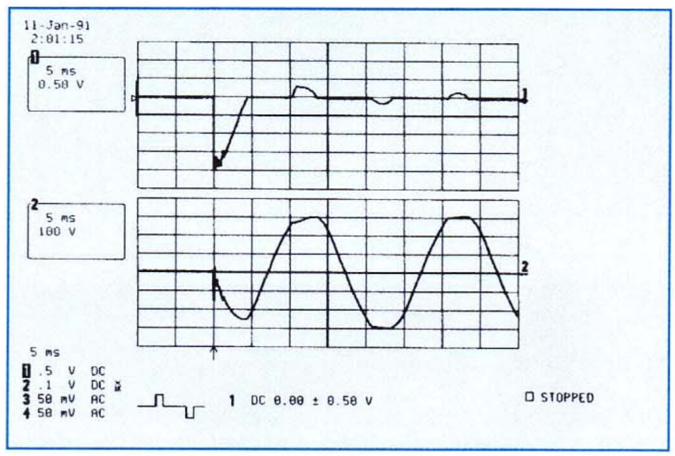


Figure 3: The in-rush current of a switching power supply (upper trace) is shown together with the input voltage. LeCroy's "Bi-slope" trigger is used to trigger on current transitions of any slope.

Alternatively it can compare the full current waveform with a reference mask (as required by the European Telecommunication Draft Standard pr ETS 300 132). If the test fails, that is, if the in-rush current exceeds the set limits, several actions can be taken.

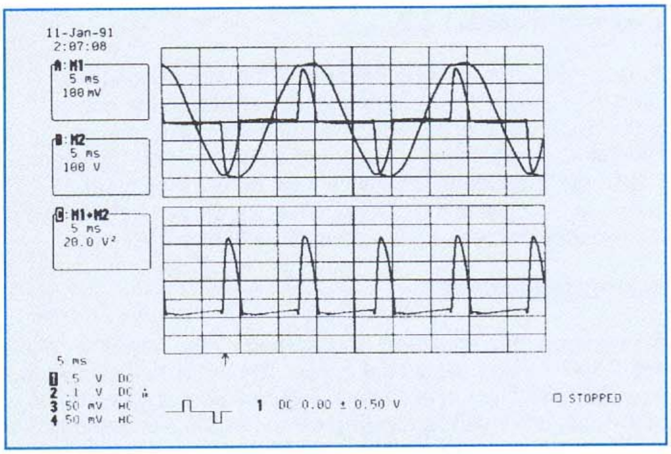


Figure 4: The power supply input voltage and input current (upper traces) are multiplied to provide the input power (lower trace).

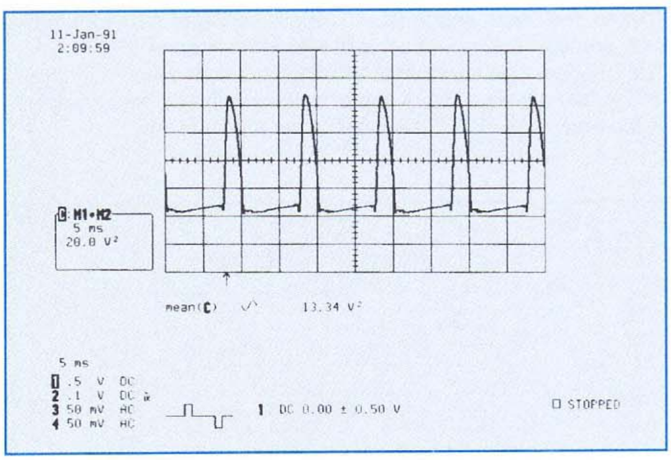


Figure 5: The same power waveform as in Figure 4, has been used to automatically calculate the mean value of the power.

POWER CALCULATION

The oscilloscope can be used to compute power. This is shown in Figure 4 where the two upper waveforms are respectively voltage and current at the input of a power supply. These two waveforms are multiplied point-by-point to provide the power waveform at the bottom.

Figure 5 shows again the same power waveform together with the mean value of the power automatically calculated below the grid. The ratio of the output power (a DC value) to the mean value of the input power, would provide the power supply efficiency.

RIPPLE AND NOISE

Figure 6 shows an example of ripple measurement, (i.e., a measurement of the remaining AC component on the output). The displayed trace is obtained using LINE trigger, and averaging the input waveform on Channel 1 a thousand times, to remove the asynchronous noise. The scope automatically calculates the peak-to-peak ripple value of 2.5 mV, which is displayed below the grid.

Figure 7 shows a single-shot measurement of the high frequency switching noise (upper trace). The bottom trace shows an optional feature which can be added to all LeCroy oscilloscopes, that is the possibility of calculating the Fourier Transform of the input waveform even though this was taken as a single shot. The frequency analysis of the output noise can give valuable information about the origin of the noise.

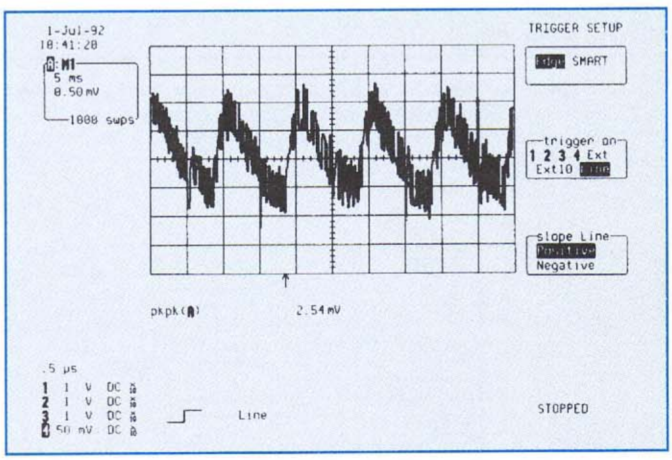


Figure 6: The output ripple is measured by averaging 1,000 acquisitions using "Line" trigger. A peak-to-peak voltage of 2.5 mV is automatically measured.

SAFE OPERATING AREA

In a switching power supply the switching transistor(s) is probably the most stressed component and it is often important to verify that its working points lie inside the Safe Operating Area. The upper trace in Figure 8 shows the collector-to-emitter voltage of a switching transistor, while the middle trace is the emitter current. The bottom trace is the product of the previous two traces and it shows therefore the power dissipated inside the transistor. The two horizontal cursor lines show the limits imposed by the Safe Operating Area.

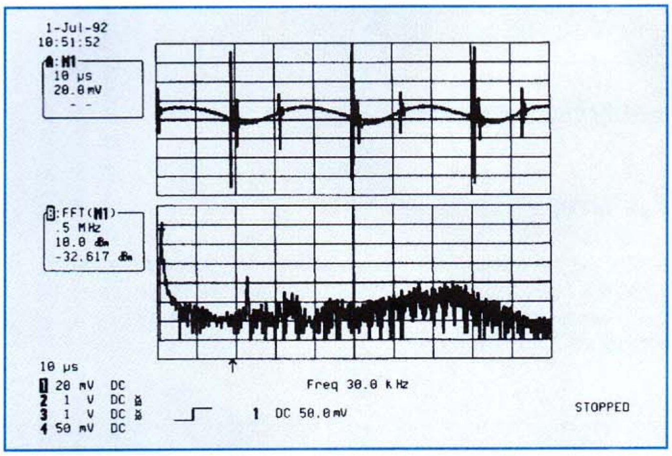


Figure 7: The high frequency noise induced by the power switching. The Fast Fourier Transform (lower trace) shows frequency components at much higher frequency than the switching frequency indicated by the cursor (30 kHz).

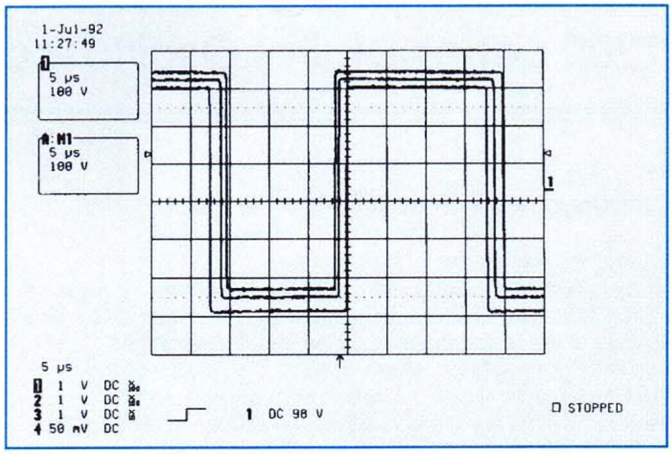


Figure 9: Automatic PASS/FAIL test on the PWM waveform. The scope automatically tests that any input signal (inner waveform) lies inside the two outer waveforms (reference mask). Actions can be taken in case of failure.

AUTOMATIC PASS/FAIL TESTING

The Safe Operating Area test just described can also be done completely automatically. The user selects the "Peak-to-Peak" parameter and applies it to the third (dissipated power) trace of Figure 8. He can then specify that this pk-pk power must be, for instance, smaller than 400 V^2. If the test fails, the scope can stop the acquisition, store the failing waveform on paper or on the memory card, "beep" and/or send an interrupt to the computer.

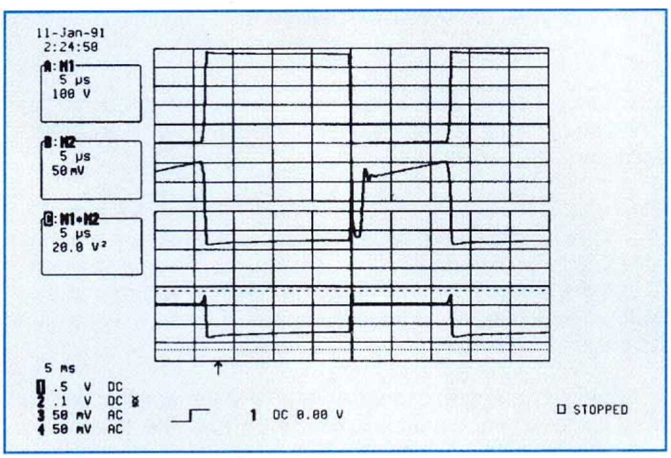


Figure 8: Voltage and current across the switching element. The product of the two gives the power waveform at the bottom. The oscilloscope can perform a PASS/FAIL test on the peak power, alerting the operator when violations of the Safe Operating Area are found.

Another approach to the automatic test is shown in Figure 9. The two outer traces shown constitute a Test Mask for the Pulse Width Modulated waveform on the collector of the switching transistor. They represent the maximum excursions that the upper trace in Figure 8 is allowed to have. (This mask may be generated automatically inside the scope. The user simply takes an acquired waveform and then specifies the desired tolerances.) When the test is activated, the scope will verify that all input waveforms fall inside the mask. In case of failure, the same actions mentioned previously can be taken.

Disk Drive Testing with LeCroy 7200 Series Digital Oscilloscopes

INTRODUCTION

During the design and manufacture of a disk there are certain measurements that are generic to the industry. These tests are used to characterize the uniformity of the recording media and look for variations in the height the head is flying above the surface of the media. Additional tests are performed to characterize and look for anomalies in the read/write electronics. The LeCroy 7200 Series Modular Oscilloscope System is ideally suited to make many of these measurements in a very cost effective way.

THE 7200 SERIES REPLACES FOUR INSTRUMENTS

Disk test stands currently use four instruments which the 7200 Series can replace:

- A conventional oscilloscope
- A spectrum analyzer
- A time interval analyzer
- A network analyzer

This application note examines the various classes of tests and describes the role that the LeCroy 7200 Series plays in performing these tests in a new and unique way.

TWO CLASSES, FOUR TYPES OF TESTS

There are four types of tests that are performed on disks. These are (1) amplitude measurements in the time domain, (2) amplitude measurements in the frequency domain, (3) time jitter measurements, and (4) pulse width measurements. There are two different classes of disk tests. One class uses a test called "window margin", "phase margin", or "bit shift" in order to determine disk drive performance. These three names all refer to the same test and are equivalent to the time jitter tests that are described later in the text concerning Figure 6. The other class of tests uses amplitude variation and pulse width variation to determine performance. These two classes of tests, (bit shift vs amplitude and pulse width variation) are complementary and each can be used to characterize disk performance. The 7200 Series performs every one of these tests with equal ease.

AMPLITUDE TESTS

Because the magnetic media is driven hard into saturation, the data read from the disk has significant harmonic content and has a shape similar to Lorentzian. Figure 1 shows a waveform that is the result of reading data from a disk.

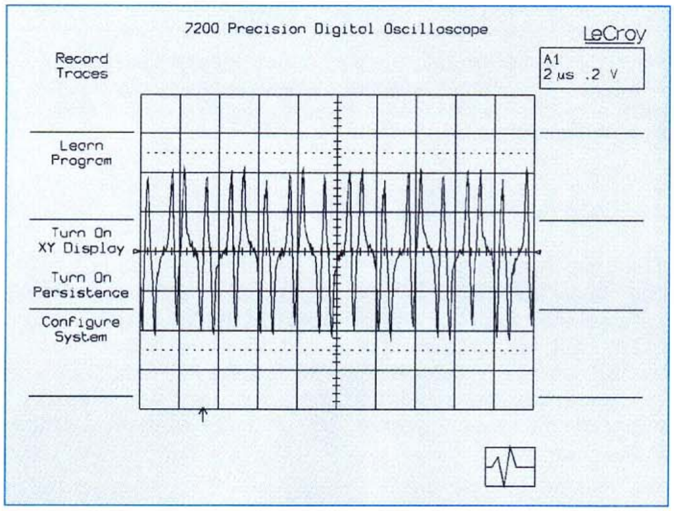


Figure 1: Typical waveform from reading a disk.

In order to test the disk, a square wave is used to record data. The frequency is as high as possible and the resulting "read" waveform is as shown in Figure 2.

The head that reads the disk is actually flying above the disk surface. If the read/write electronics are perfect, the magnetic media is uniform and the head flies a constant distance above the surface, then all the pulse heights read from the disk will be the same. Variations in any of these will cause amplitude fluctuations in the read signal.

In order to characterize these fluctuations the amplitude of the read signal is histogrammed. Figure 3 shows the setup menu in the LeCroy 7200 Series that is used to histogram the value of the peak-to-peak voltages of the waveform of Figure 2 and also shows a typical histogram. The parameter that is histogrammed is each of the individual peak-to-peak values contained in the waveform. This local peak-to-peak is called "LPP" in the 7200 Series.

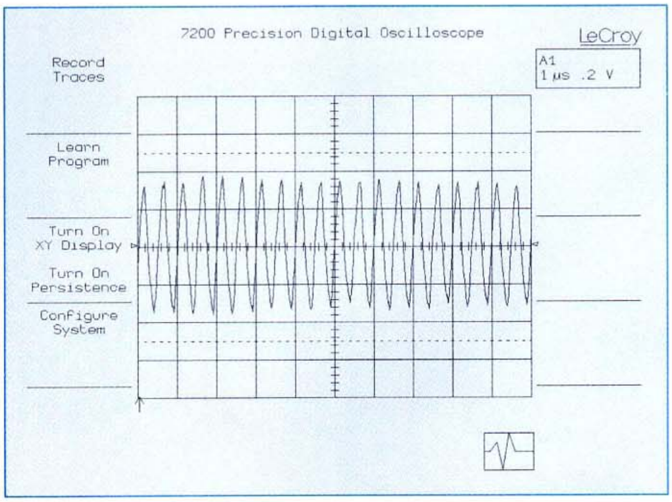


Figure 2: "Constant" amplitude waveform read back during disk test.

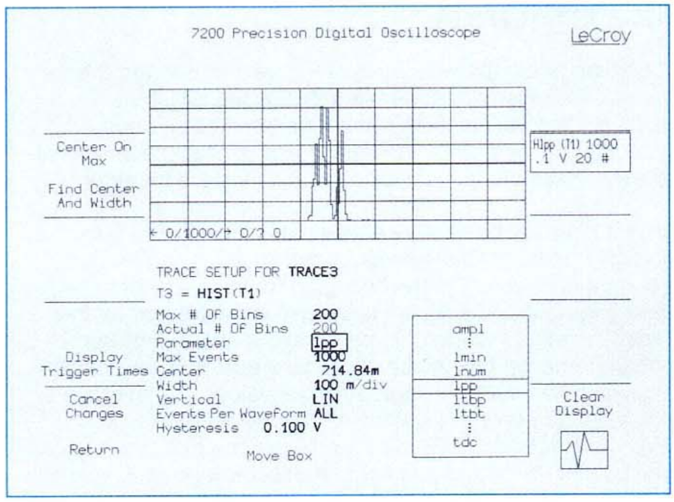


Figure 3: Setup menu for histogramming the peak-to-peak values of the constant amplitude test waveform shown in Figure 2.

In the setup menu for the histogram there is a field called "events per waveform". In Figure 3 this field is shown with the choice "all". This is because every value of the parameter LPP has been included in the statistics. Other choices are "first" or "average" in which case only the first value or the average of all the values of the parameter LPP are included in the statistics. Of equal interest might be the values of the local maxima (LMAX) or the values of the local minima (LMIN). LMAX and LMIN are additional pulse parameters that can be histogrammed.

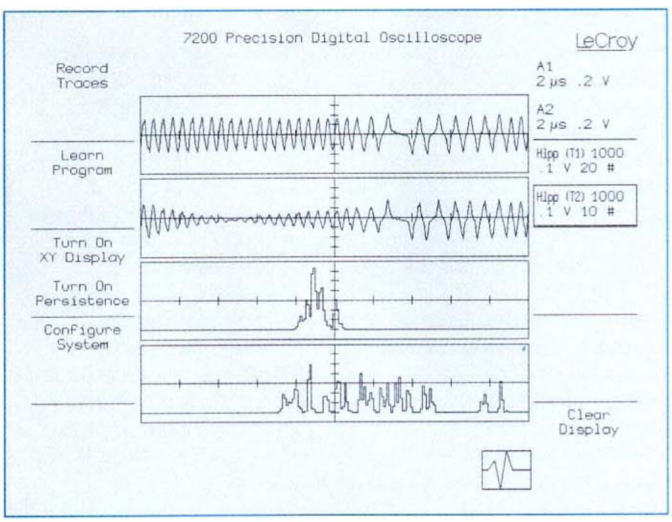


Figure 4: Examples of "good" and "bad" waveforms (top traces) and the histograms of their peak-to-peak values (LPP).

The histograms of the local peak-to-peak values of both waveforms are also shown. The "good" histogram is above the "bad" histogram. Note the very broad spread in the bottom histogram indicating a very wide spread in the values of LPP.

Sometimes it is interesting to characterize an entire track of a disk. Imagine a disk spinning at 3600 RPM. This corresponds to 60 Hz and therefore it takes 16 milliseconds to make a complete revolution. This is beyond the recording time of the 7200 Series at full resolution of .5 nsec/point. In order to fully characterize a complete track or one complete revolution of the disk the sequence mode of the 7200 Series is used. Each segment in the sequence will contain data that is characteristic of each sector of the disk.

Imagine for example that each track of the disk is composed of 70 sectors. The head read electronics is used to generate a trigger that is related to each sector and 70 segments of data are collected. Because of the limited record length (500 points per segment for a 70 segment sequence at 50 nsec/div) each segment contains just a little bit of data from each sector. It is not possible to capture all the data from each sector in a single record. The sequence record is sufficient, however, to identify trends such as fluctuations that are characteristic of mechanical wobble. Any anomaly showing up in the histogram of all the data can then be investigated by looking at the individual sector data.

TIME JITTER TESTS

Consider again the waveform of Figure 1 and 2. What happens if the pulse are non-uniformly spaced i.e., there is bit shifting taking place? The data from a disk drive is decoded by measuring the time of arrival of these individual pulses; therefore, fluctuations in the timing are important.

In order to fully characterize these statistical fluctuations in time, the local time between peaks (LTBP) is histogrammed. Figure 5 is the histogram of the LTBP obtained from Figure 2 and Figure 6 is the similar histogram for the "real" signal of Figure 1. Note, as in the above amplitude measurements, the choice of "all, average, first" is available allowing the user to histogram all the values, the average of the values or only the first value of LTBP in each record. What is displayed in Figure 5 and 6 are the histograms of all the values. As in the amplitude measurements, it is possible to characterize a disk track by histogramming the LTBP data obtained in segment mode where the data in each segment corresponds to a specific sector of a track on the disk. This test is one of the functions normally performed by a Time Interval Analyzer (TIA) and is characteristic of the ease in which the 7200 Series can replace other instruments.

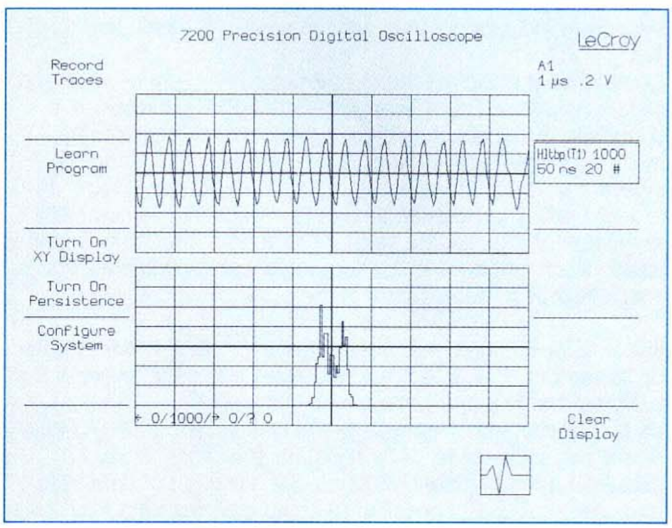


Figure 5: Local time between peaks (LTBP) for a relatively uniform signal.

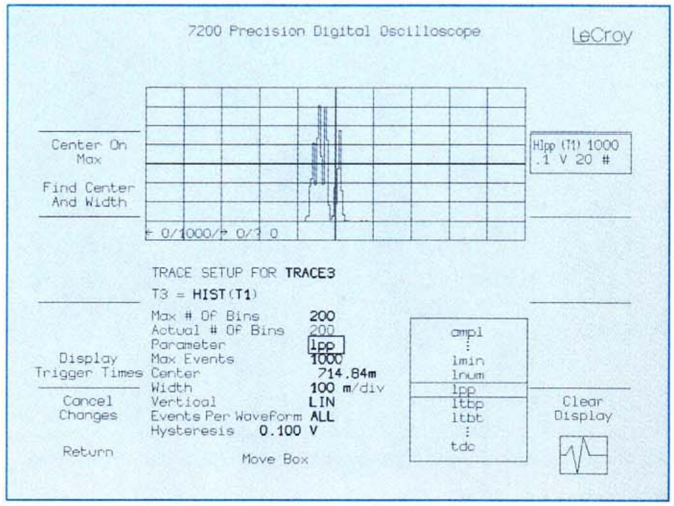


Figure 6: Local time between peaks for an actual disk data signal.

PULSE WIDTH JITTER

When the magnetic media is driven into saturation, the read signal has the characteristic shape called Lorentzian. Variations in the width of these pulses give information about the frequency response of the head and read electronics. For example, pulses that are too narrow indicate poor low frequency response. Conversely, pulses that are too wide indicate poor high frequency response. Information from the pulse widths can therefore be used to guide in equalization of the disk electronics.

In order to obtain information about these pulse width variations, a parameter called local time over threshold (LTOT) is used. This parameter permits the user to set a threshold. It then calculates the amount of time the pulse has a value in excess of the pre-selected threshold. The threshold is selected as a percentage of peak value and the default is 50 percent. All of the comments previously made about segmenting the memory to look at pulse widths that are characteristic of each sector are applicable here as well.

Figure 7 is a composite of all the above measurements showing the enormous power of the 7200 Series to do all these things in concert. The top trace of Figure 7 is the time domain signal of Figure 2 and the other three traces are, in descending order; 1) the histogram of the local time between peaks, 2) the histogram of the local peak-to-peak amplitudes, and 3) the histogram of the local time over threshold.

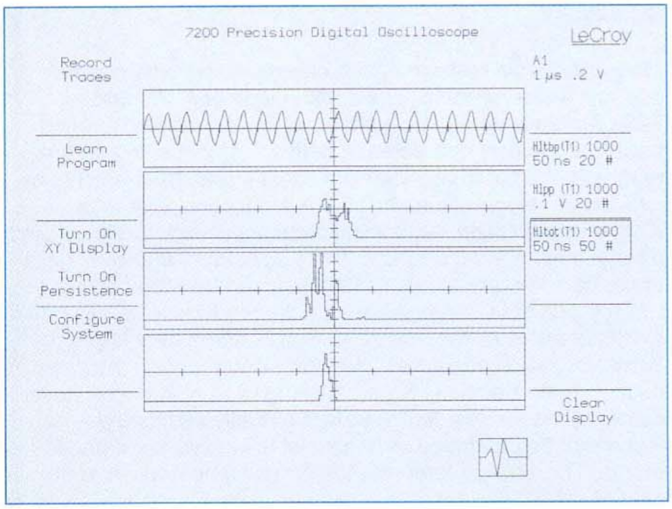


Figure 7. The constant amplitude test signal of Figure 2 and its time between peaks, peak-to-peak amplitude and time over threshold, all histogrammed simultaneously.

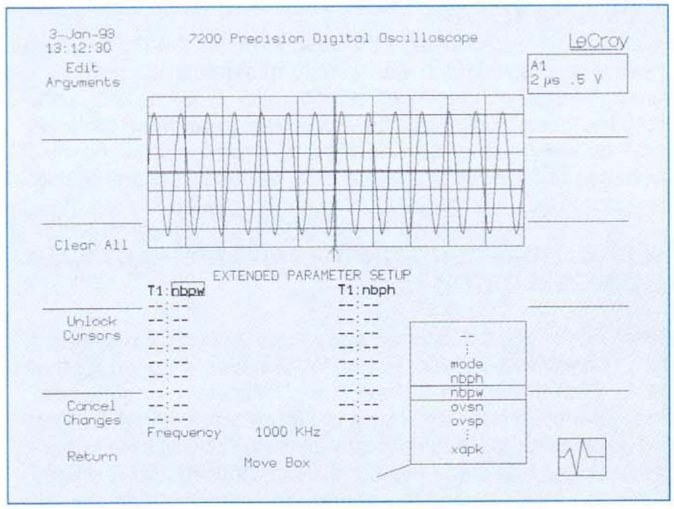


Figure 8. Setting up to calculate narrow band power (NBPW) and narrow band phase (NBPH) for Trace 1 in an overwrite test.

OVERWRITE TESTS

In an audio tape deck, an erase head precedes the write head so that when new data is placed on the tape the old data is first erased. Not so with the disk industry; the new data is written right on top of the old data. This leads one to ask "what is the signal-to-noise ratio", or "how effective is this process of writing over the old data". Typically, in order to characterize this performance, a signal at some frequency, f, is recorded on the disk. Then a different but harmonically related signal, say 2f, overwrites it.

Traditionally, a spectrum analyzer is used to look at the frequency content of the read signal to see how much residual power there is at frequency f when 2f is read. The residual power should be down by about 25 to 30 dB.

The 7200 Series can do this measurement by using its Fast Fourier Transform capability. In order to speed up the process, however, two parameters are provided. These are narrow band power (NBPW) and narrow band phase (NBPH). These two parameters, NBPW and NBPH, are the result of calculating the Discrete Fourier Transform (DFT) over a narrow band of frequencies centered on a frequency that is selected by the user. The center frequency is selectable from 1 HZ to 1 GHz. NBPW and NBPH are selected from the list of extended pulse parameters just like any other pulse parameter (see Figure 8). The input waveform is in the time domain and the center frequency for the calculation is selected by pressing "edit arguments" in the setup menu for extended parameters.

ADDITIONAL TESTS

1. Servo System Characterization

There are several other tests that the 7200A can perform. The servo system that positions the head electronics is a very complex closed loop feedback control system. In order to fully characterize this system and ensure there are no unwanted resonances, it is desirable to stimulate the system at various frequencies and measure the response. Once again, narrow band power and phase are in the picture. For example, the servo system can be stimulated with a sine wave at 100 Hz and the response measured.

The DFT of the response is just the narrow band power and phase centered at 100 Hz. This measurement is repeated at many different frequencies and the servo system can therefore be fully characterized. Afterwards, a plot of amplitude vs frequency is generated. This is called a "Bode" plot and is the result one would have obtained from a network analyzer. Thus the 7200 Series has replaced the network analyzer normally used for this measurement.

2. Drop-In Tests

Another test performed on disk media is called a drop-in test. This test is used to locate holes in the magnetic material. The disk or media is DC erased then it is read. If there is a hole in the material it will show up as a pulse or perhaps as two pulses; one at each end of the hole. A histogram of almost any of the local (amplitude related) pulse parameters (such as LMAX) will show such a phenomena clearly.

3. Drop-Out Tests

A closely related cousin to the drop-in test is the drop-out test. Here a disk is recorded with a uniform signal and then it is read. An area of missing magnetic material will be characterized by "missing bits" or drop-outs. Histogramming the local time between peaks will show this phenomena very clearly because at the spot where the drop-out occurs there will be an anomalously large time between the peaks.

SELF-CALIBRATION WITH THE 9109 ARBITRARY WAVEFORM GENERATOR

Many of the tests described above use a waveform synthesizer. The LW400 or 9100 series AWG is ideally suited for this task. First the Arbitrary Waveform Generator can generate the Lorentzian such as shown in Figure 1 and can therefore be used as an input to calibrate all the electronics and characterize the test stand without the magnetic media in place. Also, the AWG is used to generate the stimulus sine waves for the overwrite tests as well as the servo characterization tests. This combination of AWG and 7200 Series is clearly very powerful.

SUMMARY

Magnetic media test are based on amplitude, time and frequency measurements. The combination of AWG and 7200 Series is able to perform all of the test and calibration necessary to fully characterize both the electronics and the magnetic media. Every disk drive test stand, be it in an engineering development lab or on the production floor, has a signal synthesizer, an oscilloscope, a network analyzer, and often a time interval analyzer and a spectrum analyzer. This entire complement of instrumentation can be replaced with LeCroy products and provide a packaged functional solution to media testing. Also, the 7200 Series offers very high performance which translates into high throughput on the production floor. Because the processing is all built in, the development time for new test stands is virtually eliminated. The test methods described here are not exclusive to magnetic media. The LeCroy total solution can also be applied to the field of optical disk testing.

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Service & Warranty information

ON SITE SERVICE

Most LeCroy service is performed at regional service offices. However, some customers have special requirements for on site service. This can be arranged either through an advance contract for Supplemental Support or through on-call service. A Supplemental Support arrangement covers 32 hours of on-site time by a LeCroy technician for repairs, upgrades, calibration, installation, training or any other service desired by the customer. It also covers travel time and travel costs. LeCroy on-call service bills the customer for the expenses involved with each individual service trip.

WARRANTY

LeCroy warrants its digital oscilloscopes to operate within specifications under normal use and service for a period of two years from the date of shipment. 9200 series pulse generators are warranted for five years and all other instruments for one year. Component products, replacement parts, and repairs are warranted for 90 days. This warranty extends only to the original purchaser. Software is thoroughly tested, but is supplied "as is" with no warranty of any kind covering detailed performance. Accessory products not manufactured by LeCroy are covered by the original equipment manufacturer's warranty only.

In exercising this warranty, LeCroy will repair or, at its option, replace any product returned to the factory or an authorized service facility within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and has not been caused by misuse, neglect, accident or abnormal conditions or operations.

The purchaser is responsible for the transportation and insurance charges arising from the return of products to the servicing facility. LeCroy will return all in-warranty products with transportation prepaid.

This warranty is in lieu of all other warranties, express or implied, including but not limited to any implied warranty of merchantability, fitness, or adequacy for any particular purpose or use. LeCroy will not be liable for any special, incidental, or consequential damages, whether in contract, or otherwise.

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Products requiring maintenance should be returned to the factory or authorized service facility. If under warranty, LeCroy will repair or replace the product at no charge. The purchaser is only responsible for the transportation charges arising from return of the goods to the service facility.

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All products returned for repair should be identified by the model and serial numbers and include a description of the defect or failure, name and phone number of the user. In the case of products returned, a Return Authorization Number is required and may be obtained by contacting the Service Office in your area. Any returned goods should be shipped in the original packaging material. Returned goods that have not been packed in the original packing material and have been damaged in shipping will not be repaired under warranty. Any goods returned for credit are subject to a 20% restocking charge.

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FREE PRODUCT ASSISTANCE

Answers to questions concerning installation, calibration, and use of LeCroy equipment are available from your local field office (see pages PAGE# and PAGE# for the office nearest you) or from our Customer Care Center, 700 Chestnut Ridge Road, Chestnut Ridge, New York 10977-6499. Calling 800-553-2769 (in the USA) will vector you to the correct party.

In the USA

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LeCroy sales engineers are experts in the field of measurement. Many of them have a BSEE, Masters degree or doctorate in addition to several years experience in solving measurement problems. Customers find that the advice of a LeCroy sales engineer allows them to find the instrument most ideally suited to their application. The result is better quality work, shorter time to market for new designs, higher manufacturing throughput and lower costs for equipment. While other companies are changing to distribution outlets that give a lower level of customer support, LeCroy is expanding its sales service to customers.

TEST DRIVES

Some instrument users prefer to "test drive" a product prior to purchase. A few days using the instrument at their own bench with typical signals gives the customer excellent insight into whether the product is right for them. This can be especially true for people who are converting from older style analog scopes to digital oscilloscopes or for those who want to compare a more powerful scope with an older digital scope to see if they can do their job better. LeCroy can often arrange for a "test drive" by having a salesperson drop off the instrument and give a brief tutorial on its use. You can arrange a test drive in the USA by calling 1-800-5-LeCroy (1-800-553-2769).

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LeCroy's electronic bulletin board allows customers to download utility programs, send their programs to LeCroy, send samples of interesting data or receive customized programs from the factory. Popular programs include interface routines for GPIB and RS-232, basic graphing to draw the data on PCs and other utilities. Customers should call the LeCroy Customer Care Center (1-800-5-LeCroy) if they want to send data or programs to the factory for analysis. The phone number for the bulletin board is 914-578-6090.

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SERVICE IN THE USA

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A substantial benefit of owning LeCroy equipment is the availability of free upgrades to the operating system during the warranty period. If LeCroy improves the performance of a product those improvements can often be passed on to previous customers by installing new software or firmware in their units. In some cases, features such as floppy disk drives, built-in printers, spectrum analysis software or other new features can be added at a reasonable cost. LeCroy always endeavors to make new features retrofitable into previous designs. This protects your investment against obsolescence. LeCroy even offers the capability to upgrade the acquisition memory in most oscilloscopes. This very important upgrade path is not available from other companies.

CALIBRATION

LeCroy recommends annual verification of the calibration for all its instruments. You can arrange for calibration from local LeCroy field service offices anywhere in the world, from our factory headquarters in NY or from our European headquarters in Switzerland. LeCroy will check the calibration of any instrument under warranty once per year at no charge. Customers who require copies of test data and traceable certificates for NIST, ISO 9000 or MIL-STD 45662A quality standards may obtain those documents for a reasonable service fee. Calibrations performed according to LeCroy standards are substantially more rigorous than those performed by the test systems of other vendors or by "calibration houses". For example, few users of oscilloscopes use them to measure DC voltages but most oscilloscope calibration systems only verify DC accuracy. LeCroy's calibration checks the accuracy of the scope using sine waves of various frequencies and amplitudes. LeCroy tests include trigger modes, probe calibrator accuracy, ground line accuracy, pulse response, GPIB data transmission and a variety of other tests in addition to the usual bandwidth, DC accuracy and timebase verification.

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LeCroy makes it easy for customers to provide for future service of their instruments by offering optional five year repair warranty, five year calibration contracts or five year total coverage which includes repair and calibration. These services make future support of the instrument easy. No P.O. is needed for future repair or calibration, the customer doesn't have to worry about budgeting money for maintenance and the lifetime cost of the instrument (which is often depreciated over five years) can be set in one lump sum.

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Terms & Conditions

REQUESTS FOR QUOTATIONS AND TECHNICAL INFORMATION

LeCroy's worldwide network of offices and technical sales engineers will assist you in specifying, ordering, installing and operating LeCroy equipment. Please refer to the Sales and Service Office listing on Page 133 for the one nearest you.

PRICING

Export prices are available from our worldwide sales offices. Prices in the U.S.A. can be obtained by calling 1-800-5-LeCroy.

HOW TO ORDER

When placing an order, please specify the model number as well as the name of the instrument. Many model numbers include letter designations such as the 9450AWP01 or the DP9001. Some models are offered with several options designated by a slash followed by a number such as P9010/2. Special care should be taken to include these alphanumeric designations on your order.

MINIMUM ORDER

All purchase orders are subject to a $100 minimum value for U.S.A. products and SFR 200 - for Swiss products.

U.S. Government Sales: Most products listed in this catalog are on G.S.A. Federal Supply Schedule Contract. Prices are available upon request.

WHERE TO ORDER AND CURRENCY

Purchase orders may be forwarded to your local sales office or directly to the manufacturing facility producing the product you desire. Your local currency may be used for orders placed with direct LeCroy subsidiaries or sales representatives. A list of all the sales offices and representatives is given starting on Page 138.

Rental company orders within the U.S.A. should be called in directly to Corporate Headquarters in New York at (914) 578-6020.

ACKNOWLEDGMENT

When a purchase order is accepted by LeCroy Corporation, an acknowledgment is issued immediately confirming the equipment type, quantity and price, and indicating an estimated delivery date. Please read this acknowledgment carefully. Any unacceptable discrepancy between the purchase order and the acknowledgment should be reported immediately to the local sales office.

SHIPPING

The standard FOB point for all orders placed in the United States is Chestnut Ridge, New York except for GSA orders, where FOB is destination. The standard shipping method for most products is via two-day parcel service. Some products require either air freight or motor freight.

Special shipping instructions should be arranged prior to placing a purchase order so that any additional shipping charges are properly taken into account.

TERMS

Domestic Orders: Payment terms are "Net 30-Days, acceptance period included" for all orders originating within the United States. The 30-day period begins on the actual shipping date. Any exception to these payment terms should be requested before placing a purchase order. Credit references will be required for new customer accounts. *GSA Prompt Payment Terms* - 1% - 10 days. Net 30 days.

Export Orders: For orders placed directly with LeCroy's main location in Chestnut Ridge, New York in U.S. dollars, payment terms for orders less than $5,000 are via 30-day date draft, acceptance period included. > $5,000 - Irrevocable Letter of Credit drawn on The Bank of New York, 48 Wall Street, New York, N.Y., 10015, USA. For the account name of LeCroy Corporation at The Bank of New York in Spring Valley, N.Y., Acct. #254-00-8881, Routing Code: 50-244/219.

For orders placed in Swiss Francs directly with LeCroy's European Headquarters in Geneva, Switzerland, for digital oscilloscope products, payment terms for less than SFR 10,000 are 30-day date draft, acceptance period included. > SFR 10,000 - Irrevocable Letter of Credit drawn on Credit Suisse, Charmilles - Balexert, Geneva, Switzerland.

Terms for orders placed with LeCroy export sales subsidiaries are Net 30-days, unless other special arrangements have been made in advance.

Glossary of Technical Terms

Acquisition Time: In a sample-and-hold or track-and-hold circuit, the time required after the sample or track command for the output to slew through a full scale voltage change and settle to its final value to within a specified error band.

ADC: Analog-to-digital converter.

Aliasing: Whenever a dynamic signal is synchronously sampled, a possibility of misunderstanding its frequency content exists. This difficulty is termed “aliasing”, and occurs whenever the sampling rate is less than twice the highest frequency component in the signal being measured.

AND: Logical designation or circuit function meaning that all inputs must be in the TRUE state for a TRUE output.

Aperture Jitter: In a sample-hold or ADC, the jitter between the time of the sample (or convert) command pulse and the time the input signal is actually sampled. This jitter is usually due to thermal noise. It leads to an uncertainty in the sampled amplitude equal to $\Delta t \times dV/dt$ where Δt is the aperture jitter, and dV/dt is the rate of change of the input voltage at the time of sampling. The terms aperture jitter and aperture uncertainty are often used interchangeably.

Aperture Uncertainty: In a sample-hold or ADC, the total uncertainty in the time of the sample (or convert) command pulse and the time the input signal is actually sampled, due to all causes including noise, signal amplitude dependent delay variation (as in a flash ADC), temperature, etc. Often used interchangeably with aperture jitter, but aperture uncertainty is the more inclusive term.

Area: In a time domain DSO waveform measurement, area is the sum of the sampled values between the cursors times the duration of a sample.

Artifact Rejection: Used in summation averaging to exclude waveforms which have exceeded the dynamic range of recording system.

Automatic Setup: In an oscilloscope, automatic scaling of the time base, trigger, and sensitivity settings. Provides a stable display of repetitive input signals.

Average: See Mean Value, Summation Averaging and Continuous Averaging.

Bandwidth: In normal use, the frequency range over which the gain of an amplifier or other circuit does not vary by more than 3 dB.

BER: See BIT ERROR RATE.

Binning: A technique for combining points in a histogram to be compatible with the resolution of the display device.

Bit: An abbreviation of “binary digit”, one of the two numbers, 0 and 1, used to encode data. A bit is often expressed by a high or low electrical voltage.

Bit Error Rate: Ratio of the number of bits of a message incorrectly received to the total number received.

Blanking: Setting an output signal to its quiescent level for the duration of the blanking input signal. (Not the same as RESET).

Bridged Outputs: Parallel output connections which are internally tied common from one signal source.

Byte: A group of eight bits used to encode a single letter, number or symbol.

Cascade Display: An oscilloscope display of a series of measured traces extending vertically with the first at the top to the last on the bottom. LeCroy's ScopeStation can display up to 24 traces in its Cascade display mode.

Cascading: Using units in series to augment a desired characteristic (e.g., amplification, number of inputs, etc.).

CCD: Charge Coupled Device. An integrated circuit which allows the transfer of a variable amount of charge through a series of cells; an analog shift register.

Channel: 1. A path through an arrangement of components (modules and electrical and/or optical cabling) along which signals can be sent (e.g., a data channel, voice channel,etc.).
2. A path through a single module often containing many iden-

tical parallel paths (e.g., "12-channel amplifier" usually implies a module with 12 identical amplifiers).

3. A band of amplitudes, frequencies, or time domains, as when a general region of interest is divided into many small slices (also called bins). (For example, a multichannel analyzer is an instrument that accepts a train of signals and sorts them into their appropriate bins or channels.)

NOTE: in referring to ADCs, there is often confusion whether definition 2 or 3 applies. A 256 channel ADC may mean 256 independent ADCs in one module or may mean a single ADC with 256 (2^8) amplitude bins or channels (usually referred to as an 8-bit ADC).

Channel Paralleling: Analogous to paralleling outputs. Two or more channels give exactly the same output as a function of all the inputs to the given channels.

Channel Profile: A measure of intrinsic ADC or TDC noise, normally expressed as the nominal width at a defined height of the probability vs. input distribution of the channel.

Charge Sensitive: A device in which the output is directly proportional to the total integrated charge contained in the input pulse. A nominal integrating time must be specified.

Clamping: Holding a circuit point to some reference level (frequently ground) by means of a low-impedance element such as a saturated transistor, FET, forward-biased diode, relay, etc.

Coherent Gain: The normalized coherent gain of a filter corresponding to each window function is 1.0 (0 dB) for the Rectangular window and less than 1.0 for other windows. It defines the loss of signal energy due to the multiplication by the window function.

Common Mode Range: The maximum range (usually voltage) within which differential inputs can operate without a loss of accuracy.

Common Mode Rejection Ratio: The ratio of the common-mode input voltage to the output voltage expressed in dB. The extent to which a differential amplifier does not provide an output voltage when the same signal is applied to the both inputs.

Common Mode Signal (Noise): The signal (usually noise) which appears equally, and in phase on each of the differential signal conductors to ground. See DIFFERENTIAL INPUT

Continuous Averaging: Sometimes called exponential averaging the technique consists of the repeated addition, with unequal weight, of successive source waveforms. Each new waveform is added to the accumulated average according to the formula:

S(i,new) = N/(N+1) x [S(i,old) + 1/(N+1) x [W(i)]

where

i	index over all data points of the waveforms
W(i)	newly acquired waveform
S(i,old)	old accumulated average
S(i,new)	new accumulated average
N	Weighting factor (1,3,7...)

Control and Status Register (CSR): A register used to control the operation of a device and/or record the status of an operation.

Conversion Cycle: Entire sequence involved in changing data from one form to another, e.g. digitizing an analog quantity, changing binary data to BCD, etc.

Conversion Time: The amount of time taken to measure an analog phenomenon (e.g., a time duration, peak waveform voltage, quantity of charge within a pulse, etc.) and have its digital representation ready for readout.

Crosstalk: Unwanted coupling of a signal from one channel to another.

Cursor: A visible marker that identifies a horizontal and/or vertical position on an oscilloscope display. LeCroy DSO's offer "waveform riding" cursors which conveniently give both the horizontal and vertical values without selecting one or the other.

DAC: Digital-to-analog converter.

Data Logger: An instrument which accepts input signals (usually slow analog), digitizes them, and stores the results in memory for later readout. The digital equivalent of a strip-chart recorder.

DC: Direct current. Normally means a voltage or current which remains constant.

DC Level Shift: A change in the nominal DC voltage level present in a circuit.

DC Offset: See DC LEVEL SHIFT. This term may imply that the shift is intentional, for example, adjustable by a control knob.

DC Overload: An overload signal of long duration compared to the normal input pulse width or duty ratio of a circuit.

Dead Time: In a digital oscilloscope, the dead time is the time from the end of one acquisition of data to the start of the next acquisition.

Decimation: The process of reconstructing a source waveform with a reduced number of data points by using only every Nth data point, where N is an integer.

Differential Input: A circuit with two inputs that is sensitive to the algebraic difference between the two.

Differential Linearity: A term often inappropriately used to mean differential non-linearity.

Differential Non-Linearity: 1. The percentage departure from the average of the slope of the plot of output versus input from the slope of a reference line.

2. The percentage of variation in ADCs or TDCs from the mean of the analog (or time) width of any single digital step. Usually measured by driving the input with a large number of random amplitude pulses and then measuring the relative number of events in each digital bin.

Differential Output: A circuit with two outputs supplying one normal and one complementary level of output signal.

Differential Pulses: Two opposite polarity pulses coincident in time.

Dithering: Typically used when averaging signals (which have low noise content) to improve vertical resolution and decrease the effects of an ADCs non-linearities. The technique applies different offsets to each incoming waveform to ensure the signal is not always digitized by the same portion of the ADC. The offsets must be subtracted from the recorded signals before being included in the summed average.

Digital Filtering: The manipulation of digital data to enhance desirable and remove undesirable aspects of the data.

Double-Pulse Resolution: The minimum input pair spacing at which a comparator responds properly to the second of a pair of pulses.

DPR: See DOUBLE-PULSE RESOLUTION.

Dropout Trigger: A trigger that occurs if the input signal drops out for a time period longer than a preset amount (between 25 nsec to 20 sec on some LeCroy DSOs).
Very useful for triggering on microprocessor crashes, network hangups, bus contention problems or other phenomena where a signal stops occurring.

Duty Cycle: A computed value in digital scopes, representing the average duration above midpoint value as a percentage of the period for time domain waveforms.

Dynamic Range: The ratio of the largest to smallest signal which can be accurately processed by a module.

Dynamic RAM (DRAM): A random access memory in which the internal memory must be refreshed periodically.

ECL: Emitter-coupled logic, an unsaturated logic performed by emitter-coupled transistors. Normally, ECL LOGICAL 1 = -1.6 V and LOGICAL 0 = -0.8 V.

EMI: Electromagnetic interference caused by current or voltage induced into a signal conductor by an electromagnetic field in the conductor's environment.

ENBW (Equivalent Noise Bandwidth): For a filter associated with each frequency bin, ENBW is the bandwidth of an equivalent rectangular filter (having the same gain at the center frequency) which would collect the same power from a white noise signal.

Enhanced Resolution (ERES): A facility in LeCroy DSOs to increase the amplitude resolution of single shot waveform measurements. This technique, which applies digital filtering to achieve resolution enhancement at a reduced bandwidth, is optimum when the sampling rate of the instrument exceeds that required for the input signal bandwidth. For repetitive signals, either ERES or Signal Averaging, or both, can be used to achieve higher resolution with substantially smaller loss of bandwidth than for single shot signals.

Envelope: The maximum, minimum, or maximum and minimum values of a sequence of measured waveforms. In LeCroy DSOs, the number is programmable from 1 to 10^6.

EPROM: Erasable programmable read-only memory. An integrated circuit memory array that is made with a pattern of either all logical zeros or ones and has a pattern written into it by the user with a special hardware program.

Equivalent Time Sampling (EQT): Equivalent Time Sampling (EQT or sometimes ETS) is a means of exploiting the aliasing phenomenon to increase the usable bandwidth of a digitizer by making it appear to sample more rapidly than its maximum single shot sample rate. Works only with stable, repetitive signals.

Extrema: The computation of a waveform envelope, by repeated comparison of successive waveforms, of all maximum points (roof) and all minimum points (floor). Whenever a given data point of the new waveform exceeds the corresponding maximum value in the roof record, it is used to replace the previous value. Whenever a given data point of the new waveform is smaller than the corresponding floor value, it is used to replace the previous value.

Fall Time: Unless otherwise defined, the time required for a pulse to go from 90% to 10% of full amplitude. Can also refer generally to the trailing edge of a pulse.

Fan-in: The mixing of more than one input to obtain one of the following outputs: 1. Linear — a circuit which linearly adds the amplitudes of more than one input signal and creates an output signal equal to the algebraic sum of the inputs; or 2. Logic — a circuit with more than one input which gives a logic output signal whenever a logical signal appears in any input (equivalent to a logical OR function.)

Fan-Out: The reproduction of an input signal at more than one output.

Fast Fourier Transform (FFT): In signal processing applications, a Fast Fourier Transform is a mathematical algorithm which takes a discrete source waveform, defined over N points, and computes N complex Fourier coefficients, which are interpreted as harmonic components of the input signal. For a "real" source waveform (imaginary part equals 0), there are N/2 independent harmonic components.

Feedthrough: Unwanted signal which passes a closed gate, or disabled input.

FFT: See Fast Fourier Transform.

FFT Frequency Bins: A Fast Fourier Transform (FFT) corresponds to analyzing the input signal with a bank of N/2 filters, all having the same shape and width, and centered at N/2 discrete frequencies. Each filter collects the signal energy that falls into the immediate neighborhood of its center frequency, and thus it can be said that there are N/2 "frequency bins". The distance, in Hz between the center frequencies of two neighboring bins is always: $\Delta f = 1/T$, where T is the duration of the time-domain records in seconds. The nominal width of bin is equal to Δf.

FFT Frequency Range: The range of frequencies computed and displayed in a FFT is 0 Hz to the Nyquist frequency.

FFT Frequency Resolution: In a narrow sense, the frequency resolution is equal to the bin width, Δf. That is, if the input signal changes its frequency by Δf, the corresponding spectrum peak will be displaced by Δf. For smaller changes of frequency, only the shape of the peak will change.

However, the effective frequency resolution (i.e., the ability to resolve two signals whose frequencies are almost the same) is further limited by the use of window functions. The ENBW value of all windows other than the rectangular is greater than Δf, i.e. greater than the bin width.

FFT Number of Points: FFT is computed over the number of points (Transform Size) whose upper bound is the source number of points. FFT generates spectra having N/2 output points.

FFT Total Power: Area under the power density spectrum in frequency domain measurements.

FIFO: First-in, first-out shift registers (sometimes called first-in, first-out memory).

Filter: An electronic circuit or digital data manipulation routine that either enhances desirable or removes undesirable aspects of an analog waveform or its digital representation. Filters are used to block specific frequency components from passing through a circuit, to linearize otherwise identical components (such as CCDs) used in a common circuit, or to perform waveform integration, differentiation, or smoothing, just to name a few types.

Flash ADC: A very fast analog-to-digital converter in which the analog signal simultaneously is compared to $2^n - 1$ different reference voltages, where n is the ADC resolution. Also called a parallel converter. A very fast analog-to-digital converter usually consisting of a large set of fast comparators and associated logic.

Floor: The record of points which make the bottom (or minimum) of an envelope created from a succession of waveforms.

FWHM: Full-Width Half Maximum. The width of a pulse or waveform at 50% amplitude used to measure the duration of a signal.

Gate: 1. A circuit element used to provide a logical function (e.g., AND, OR); 2. An input control signal or pulse enabling the passage of other signals.

Glitch: A spike or short-time duration structural aberration on an otherwise smoother waveform that is normally characterized by more gradual amplitude changes. In digital electronics, where the circuit under test uses an internal clock, a glitch may be considered to be any pulse narrower than the clock width.

Glitch Trigger: A trigger on pulse widths smaller than a given value.

Ground Loop: A long ground connection along which voltage drops occur due either to heavy circuit current or external pick-up, with the result that circuit elements referred to different points along it operate at different effective ground references.

Hardwire Option: An option available by soldering an appropriate connecting wire into the circuit.

HF Sync: Reduces the trigger rate by including a frequency divider in the trigger path, enabling the input trigger rate to exceed the maximum for repetitive signals.

Histogram: A graphical representation of data such that the data is divided into intervals or bins. The intervals or bins are then plotted on a graph where the height is proportional to the number of data points contained in each interval or bin.

Hold-off by Events: Selects a minimum number of events between triggers. An event is generated when the trigger source meets its trigger conditions. A trigger is generated when the trigger condition is met after the selected number of events from the last trigger. The hold-off by events is initialized and started on each trigger.

Hold-off by Time: Selects a minimum time between triggers. A trigger is generated when the trigger condition is met after the selected delay from the last trigger. The timing for the delay is initialized and started on each trigger.

HPGL: Hewlett-Packard Graphics Language Format, Hewlett-Packard Company, San Diego, CA.

Hybrid Circuit: A small, self-contained high-density circuit element usually consisting of screened or deposited conductors, insulating areas, resistors, etc., with welded or bonded combinations of discrete circuit elements and integrated circuit chips.

IC: Integrated Circuit. A self-contained multiple element circuit such as a monolithic or hybrid.

ICL: LeCroy's Internal Command Language developed to customize and/or automate operation of the 7200 Series DSOs.

Importance Sampling: Increasing the sample rate during certain periods of recording to obtain denser sampling information. (A technique often used with transient recorders to optimize use of memory areas).

Integral Linearity: A term often used inappropriately to mean integral non-linearity.

Integral Non-Linearity: Deviation of ADC response from an appropriate straight line fit. The specification is sometimes defined as maximum deviation expressed as a fraction of full scale. More recent ADCs have a specification expressed as a percent of reading plus a constant.

Interchannel Dead Time: The time required to switch from one circuit path to another.

Interleaved Clocking: Supplying clock pulses of equal frequency but different identical circuits or instruments in order to increase the system sample rate. For example, use of two transient recorders with inputs in parallel but complementary clocks to allow operation at twice the maximum rate of a single unit.

Interval Trigger: Selects an interval between two edges of the same slope. The trigger can be generated on the second edge if it occurs *within* the selected interval or *after* the selected interval. The timing for the interval is initialized and restarted whenever the selected edge occurs.

Isolation Amplifier: A circuit which accepts single-ended signals, yet its isolated ground return offers common mode rejection properties similar to a fully differential input. In general, the common mode rejection is effective only for low frequencies.

Jitter: Short-term fluctuations in the output of a circuit or instrument which are independent of the input.

Leakage: When observing the Power Spectrum of a sine wave having an integral number of periods in the time window using the Rectangular Window, leakage is the broadening of the base of the peak spectral component that accurately represents the source waveform's amplitude.

Learn Mode: The ability of a software program or instrument to interpret and store a sequence of key presses and/or knob changes in a format it will recognize and properly execute when later called upon.

LED: Light Emitting Diode.

Limiter: A circuit element which limits the amplitude of an input (used for input protection, pulse standardizing, etc.).

Logical 1: A signal level indicating the TRUE state; corresponds to the unit being set (i.e. if interrogated, the answer is yes).

Logical 0: A signal level indicating the FALSE state; corresponds to the unit NOT being set (i.e. if interrogated, the answer is no).

Long-Term Stability: Refers to stability over a long time, such as several days or months.

MCA: Multichannel Analyzer (e.g., pulse height analyzer).

Mean Value: Average or DC level of all data points selected in a waveform. i.e.,

$$\frac{1}{N}\sum_{i=1}^{N} V_i$$

Median Value: The data value of a waveform above and below which there are an equal number of data points.

Mode Value: The most frequently occurring data value of a waveform.

Monolithic IC: An integrated circuit whose elements (transistors, diodes, resistors, small capacitors, etc.) are formed in situ upon or within a semiconductor substrate.

Monotonic: A function with a derivative that does not change sign.

Multiplexer: A device used to selectively switch a number of signal paths to one input or output.

NAND: An AND circuit, except with a complementary (negative true) output.

Negation: The process of transposing all negative values into positives and all positive values into negatives.

Noise Equivalent Power: NEP (W); the rms value of optical power which is required to produce unity rms signal-to-noise ratio.

NOR: An OR circuit, except with a complementary (negative true) output.

Nyquist Frequency: The Nyquist frequency (f/2) is the maximum frequency that can be accurately measured by a digitizer sampling at a rate of (f). In other terms, a digitizer sampling at a rate of (f) cannot measure an input signal with bandwidth components exceeding f/2 without experiencing "aliasing" inaccuracies.

Offset: The amount by which an analog or digital output or input baseline is shifted with respect to a specific reference value (usually zero).

OR: A logic circuit having the property that if at least one input is true, the output is true.

Overshoot, Negative: A time domain parameter in waveform measurements, equal to the base value of a waveform minus the minimum sample value, expressed as a percentage of the amplitude.

Overshoot, Positive: A time domain parameter in waveform measurements, equal to the maximum sample value minus the top value, expressed as a percentage of the amplitude. The top value is the most probable state determined from a statistical distribution of data point values in the waveform.

Parallel Converter: A technique for analog-to-digital conversion in which the analog signal is simultaneously compared to $2^n - 1$ different reference voltages, where n is the ADC resolution.

Pass/Fail Testing: Post-acquisition testing of a waveform against a reference mask or of waveform parameters against reference values.

Pattern Trigger: The pattern trigger logically combines the states of the trigger inputs. The combination, called a pattern, is defined as the logical AND of the trigger states. A trigger state is either high or low; high when a trigger source is greater than the trigger level and low if it is less that the trigger level. For example, the pattern can be defined as present when the trigger state for channel 1 is high, 2 is low, and EXT is high. If any are not met, the pattern state is considered absent.

Pattern Width: Selects a pattern width, either maximum or minimum. If the width is less than the selected width, the trigger is generated when the pattern ends. If the width is greater than the selected width, the trigger is generated when the pattern ends. The timing for the pattern width is initialized and restarted at the beginning of the pattern.

PCMCIA: Personal Computer Memory Card Industry Association standard for PC memory cards. Also known as JEIDA in Japan.

PCX: The PC Paintbrush Format for graphic images, ZSoft Corporation, Marietta, GA.

Peak Spectral Amplitude: Amplitude of the largest frequency component in a waveform in frequency domain analysis.

Peak Sensing ADC: An analog-to-digital converter which measures only peaks of waveforms occurring within the measurement period.

Period: A full period is the time measured between the first and third 50% crossing points (mesial points) of a cyclic waveform.

Persistence: An display operating mode of a DSO where a user-determined number of measured traces remain on the display without being erased and overwritten.

PHA: Pulse Height Analyzer. A device that gives a measure of the amplitude of a signal applied to its input.

Picket Fence Effect: If a sine wave has a whole number of periods in the time domain record, the Power Spectrum obtained with the Rectangular window will have a sharp peak, corresponding exactly to the frequency and amplitude of the sine wave. If it does not, the spectrum obtained will be lower and broader. The highest point in the power spectrum can be 3.92 dB lower (1.57 times) when the source frequency is halfway between two discrete bin frequencies. This variation of the spectrum magnitude is called the Picket Fence Effect (the loss is called the Scallop Loss). All window functions compensate this loss to some extent, but the best compensation is obtained with the Flat Top window.

Power Spectrum: The Power Spectrum (V^2) is the square of the Magnitude spectrum. The Power Spectrum is displayed on the dBm scale, with 0 dBm corresponding to $V_{ref}^2 = (0.316\ V_{peak})^2$, where V_{ref} is the peak value of the sinusoidal voltage which is equivalent to 1 mW into 50 Ω.

Power Density Spectrum: The Power Density Spectrum (V^2/Hz) is the Power Spectrum divided by the equivalent noise bandwidth of the filter, in Hz. The Power Density spectrum is displayed on the dBm scale, with 0 dBm corresponding to (V_{ref}^2/Hz).

Pretrigger Sampling: A design concept used in transient recording in which a predetermined number of samples taken before a stop trigger are preserved.

Pulse Width: Determines the duration between the Pulse Start (mesial point, i.e. the 50% magnitude transition point, on the leading edge) and the Pulse Stop (mesial point on the trailing edge) of a pulse waveform.

Pulse Start: The 50% magnitude transition point (mesial point) on the leading edge of a pulse waveform.

Pulse Stop: The 50% magnitude transition point (mesial point) on the trailing edge of a pulse waveform.

Pulse Trigger: Selects a pulse width, either maximum or minimum. The trigger is generated on the selected edge when the pulse width is either greater than or less than the selected width. The timing for the width is initialized and restarted on the edge opposite to the edge selected.

Quasi-Differential: An input which accepts single-ended signals, yet its isolated ground return offers common mode rejection properties similar to a fully differential input. In general, the common mode rejection is effective only for low frequencies.

RAM: A memory in which each data address can either be written into or read from at any time.

Random Interleaved Sampling (RIS): Random Interleaved Sampling is one method of Equivalent Time Sampling. Acting upon stable, repetitive signals, it represents the process of storing different full sampling sweeps in a DSO or digitizer system, where each sweep is slightly offset from the other to achieve a higher effective sampling rate than the single shot rate. A major advantage of RIS over other EQT (ETS) techniques is "pretrigger viewing."

Real Time: A process that occurs without having to pause for internal conversions and references. Real time processes usually have little or no intrinsic dead time and are able to proceed at a rate which permits almost simultaneous transitions from inputs to outputs.

Reciprocal: The division of unity by the data value being processed.

Reflection Coefficient: The amount of signal amplitude that is reflected from an input, expressed as a percentage of the original input signal.

Resolution: The minimum measurable increment, such as one bit level of an ADC.

Reverse Termination: An output so constructed that pulses reflected back from the rest of the system meet a matching impedance and are absorbed.

RF: Radio Frequency. Normally in the megahertz range.

RFI: Radio Frequency Interference. A special case of EMI wherein the field causing the induced signal falls into the radio portion of the electromagnetic spectrum.

Rise Time: Unless otherwise defined, the time required for a pulse to go from 10% to 90% of full amplitude. Can also refer generally to the leading edge of a pulse.

RMS (Root Mean Square): Is derived from the square root of the average of the squares of the magnitudes, for all the data as described above.

$$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(V_i)^2}$$

For time domain waveforms, the square root of the sum of squares divided by the number of points for the part of the measured waveform between the cursors. For histogram waveforms, the square root of sum of squares divided by number of values computed on the distribution.

ROM: Read only memory is any type of memory which cannot be readily rewritten. The information is stored on a permanent basis and used repeatedly. Usually randomly accessible.

Roof: The record of points which make the top (or maximum) of an envelope created from a succession of waveforms.

Sample and Hold: A circuit that on command stores on a capacitor the instantaneous amplitude of an input signal.

Sampling Frequency: The clock rate at which samples are taken during the process of digitizing an analog signal in a DSO or digitizer.

SCA: Single channel analyzer. A circuit which responds only to input signals falling between an upper and lower amplitude level.

Scallop Loss: Loss associated with the picket fence effect.

Sensitivity: 1. The minimum signal input capable of causing an output signal with the desired characteristics.

2. The ratio of the magnitude of the instrument response to the input magnitude (e.g., a voltage ADC has a sensitivity that is usually measured in counts/mV). Often, sensitivity is referred to the input and is therefore stated as the inverse.

Shot Noise: Noise caused by current fluctuations, due to the discrete nature of charge carriers and random emission of charged particles from an emitter. Many refer to shot noise loosely, when speaking of the mean square shot noise current (amps) rather than a noise power (watts).

Smart Trigger: The Smart Trigger allows setting additional qualifications before a trigger is generated. These qualifications can be used to capture rare phenomena such as glitches or spikes, specific logic states or missing bits. One qualification can include, for example, generating a trigger only on a pulse wider or narrower than specified.

Smoothing, N-Point The process of evening out the display of a waveform by displaying a moving average of "N" adjacent data points added to each other.

SNR: Signal-to-noise ratio is the ratio of the magnitude of the signal to that of the noise.

Square: The process of multiplying a value by itself.

Stage Delay: The time delay in circuit between input and output, usually measured between the front edges (half maximum) of the respective signals.

Standard Deviation: Is the standard deviation of the measured points from the mean. It is calculated from the following formula:

$$\frac{1}{N-1}\sum_{i=1}^{N}(V_i - \text{mean})^2$$

Standard Trigger: Standard Trigger causes a trigger to occur whenever the selected trigger source meets its trigger conditions. The trigger condition is defined by the trigger level. coupling, high frequency sync, and slope.

State Qualified: State qualified triggering generates a trigger when the trigger source meets its trigger conditions during the selected pattern. A pattern is defined as a logical AND combination of trigger states. A trigger state is either high or low; high when a trigger source is greater than the trigger level and low if it is less than the trigger level.

Stop Trigger: A pulse which is used to stop a transient recording or similar sequence.

Strobe: A digital signal used to read or write data or initiate a conversion cycle at a controlled time.

Summation Averaging: The repeated addition, with equal weight, of successive waveforms divided by the total number of waveforms acquired.

TDC: Time-to-digital converter.

Terminate: Normally, to provide a matching impedance at the end of coaxial cable to prevent reflections.

Test Template: A general form of waveshape limit test, which defines an arbitrary limit (or non-uniform tolerance) on each measured point in a waveform.

Threshold: The voltage or current level at which a circuit will respond to a signal at its input. Also referred to as trigger level.

TIFF: Tagged Image File Format. Industry standard for bit-mapped graphic files.

Time Between Patterns: Selects a delay, either maximum or minimum, between exiting one pattern and entering the next. The trigger is generated on entering the second pattern either within the selected time or after the selected minimum time.

Timeout: A Timeout occurs when a protective timer completes its assigned time without the expected event occurring. Timeouts prevent the system from waiting indefinitely in case of error or failure.

Time Qualified: Time qualified triggering generates a trigger when the trigger source meets its trigger condition after entering or exiting the pattern. The trigger can occur even if the pattern disappears before the trigger meets its trigger conditions. See "Pattern Trigger."

Tolerance Mask: A form of waveshape limit test which defines a maximum deviation equal to a uniform tolerance on each measured point in a waveform.

Track and Hold: A circuit that precedes an analog-to-digital converter which has the ability on command to store instantaneous values of a rapidly varying analog signal. Allows the ADC to accurately digitize within tighter time domains.

Transient Recorder: See Waveform Digitizer.

TTL: Transistor-transistor logic. Signal levels defined as follows: LOGICAL 0 = 0 to 0.8 V and LOGICAL 1 = 2.0 to 5.0 V.

Trend: Plot of a parameter value or other characteristic of a measurement over a period of time. Such a function is routinely performed in LeCroy Series 7200 DSOs, where statistics and parameters can be applied to the trend itself.

Twisted Pair: Cable composed of two isolated wires twisted together. It features high noise immunity because the same amount of noise is induced on both wires. It is suitable for differential pulse pair transmission.

Waterfall Display: Another name for "cascade display." (In LeCroy DSOs, an oscilloscope display of a series of measured traces extending vertically with the first at the top to the last on the bottom. LeCroy's ScopeStation can display up to 24 traces in its cascade display mode.)

Waveform Digitizer: An instrument which samples an input waveform at specified intervals, digitizes the analog values at the sampled points and stores the results in a digital memory.

Window Functions: Used to modify the spectrum of a truncated waveform prior to Fourier analysis. Alternately, window functions determine the selectivity (filter shape) in a Fourier transform spectrum analyzer. In LeCroy scopes, all window functions belong to the sum of cosines family with 1 to 3 non-zero cosine terms ($W = \sum a_m \cos(2\pi k/N)$, where N is the # of points in the decimated source waveform, and k is the time index).

X-Y Display: A plot of one trace against another trace. This technique is normally used to compare the amplitude information of two waveforms. It can reveal phase and frequency information through the analysis of patterns called Lissajous figures.

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