EMC Pulse Measurements

and Custom Thresholding

LeCroy

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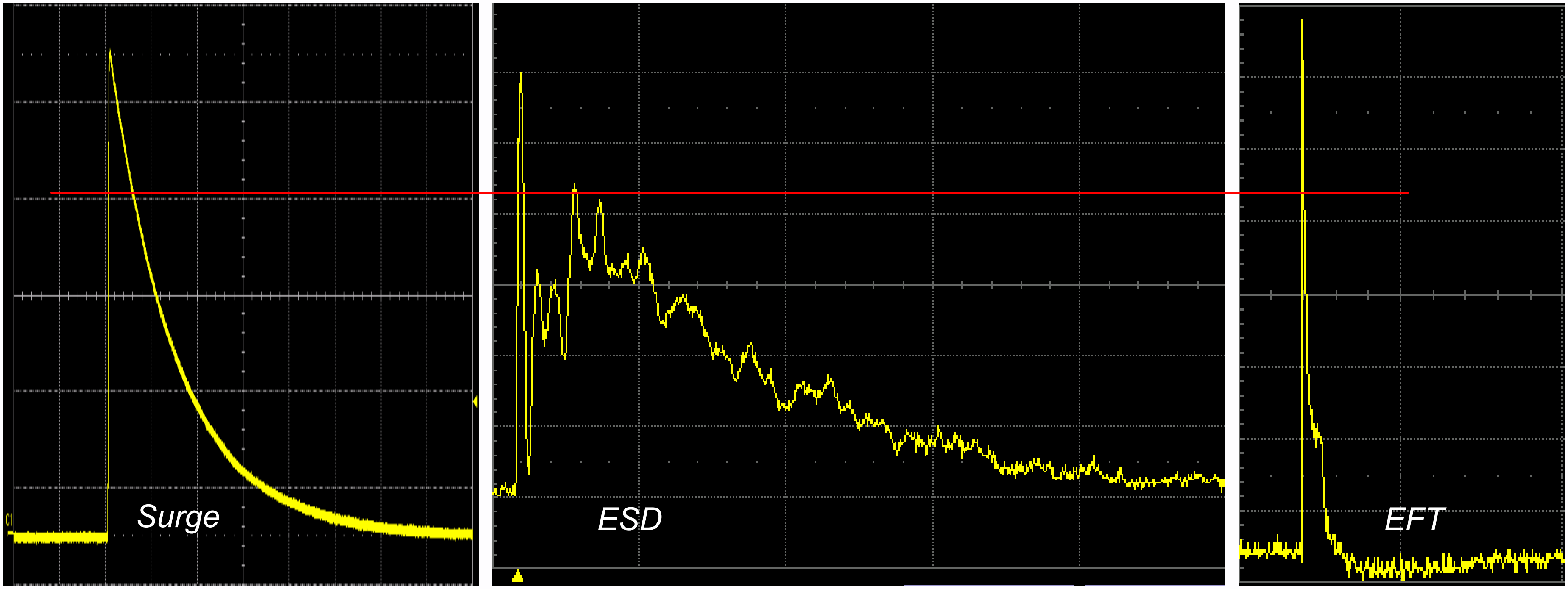


Contents

- EMC measurement requirements
- How thresholds affect pulse measurement definitions and why standard pulse parameters will not work for EMC pulses
- Measurement thresholds for ESD pulses
- Sequenced acquisition for EFT (Electrical Fast Transient) pulses
- Parameter limiters applied to filter EMC pulse statistics
- Custom measurements

EMC Measurement Requirements

4 Quadrants of EMC/ESD Testing

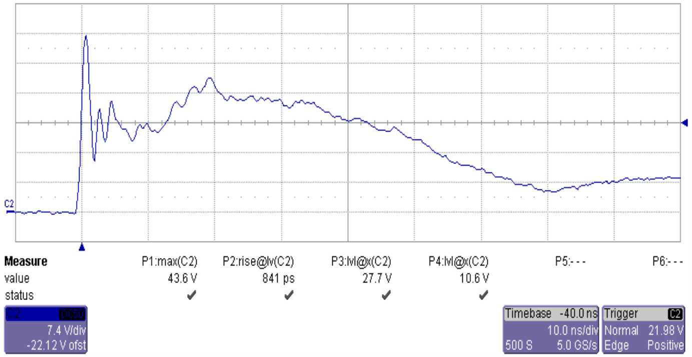
Radiated Emissions	Conducted Emissions
Will the EUT create emissions that interfere with the operation of other products?	How much noise voltage is injected back into the mains by the EUT?
Radiated Immunity	**Conducted Immunity**
Will the EUT be susceptible to emissions from other devices, either through the air or via cables?	Will the EUT be susceptible to transients generated by switching of capacitive or inductive components?

EUT = Equipment Under Test

- Oscilloscopes used for
  - Radiated Immunity
  - Conducted Immunity
- "Pulsed EMI tests:
  - ESD (Electrostatic Discharge)
  - EFT (Electrical Fast Transient)
  - Surge

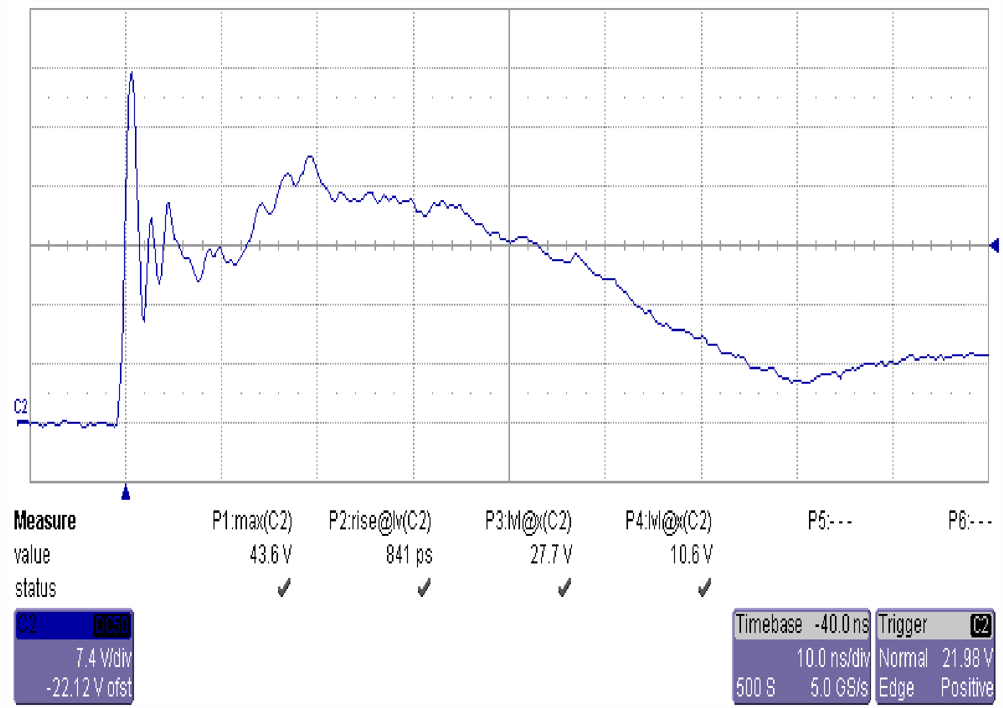
Test Requirements

- Generate a Burst, Surge, or ESD pulse (for example, with an ESD gun)
- Verify the pulse shape(s) from the generator with an oscilloscope before each test
  - Rise Time
  - Fall Time
  - Width
- Ensure that the DUT still operates correctly during test, for example:
  - Automotive engine control unit still transmits proper messages
  - Telecom board serial data messages are uncorrupted
  - Consumer electronics item still functions
- ESD Standards:
  - IEC 61000-4, EN 61000-4, ITU, UL, FCC, Telcordia, ANSI, Bellcore, Proprietary (Military, Automotive), etc.
  - The majority of Immunity Testing follows the IEC 61000 (CE Mark)



ESD Testing – Electrostatic Discharge
Measurement Steps

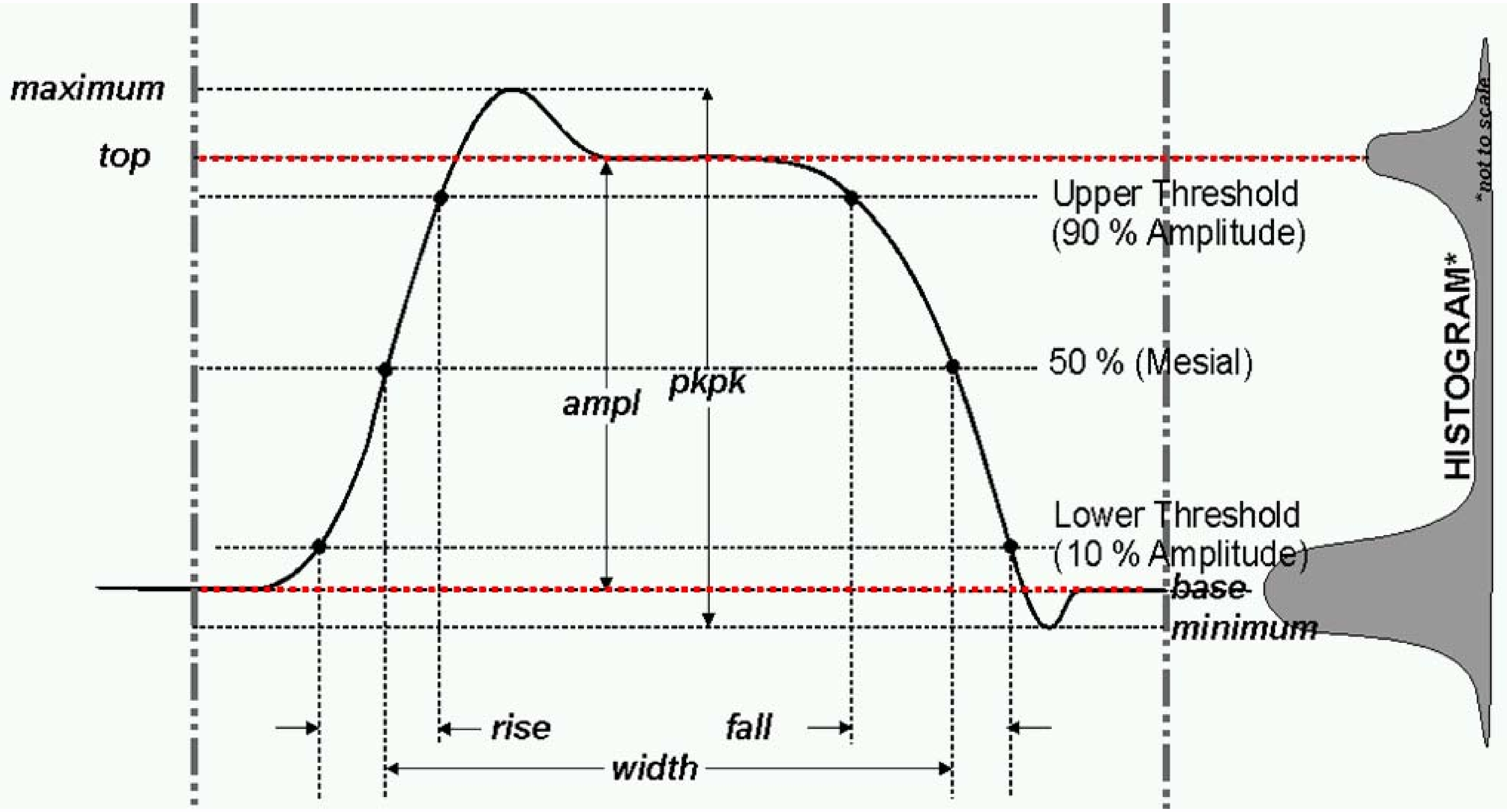
- Pulse Characteristics
  - T_{rise} = 0.7 to 1.0 ns
  - T_{fall} = 0.7 to 1.0 ns
- Measurement Needs
  - Capture a Single Pulse
  - Measure one pulse, verify rise time for positive pulses, verify fall time for negative pulses
  - 1 GHz, 2 GHz, or 3 GHz+ scope depending on standard specification



How is risetime defined on this ESD pulse? 10%-90% risetime is only meaningful if 0% and 100% levels exist and have been defined on the pulse.

Pulse Measurement Definitions

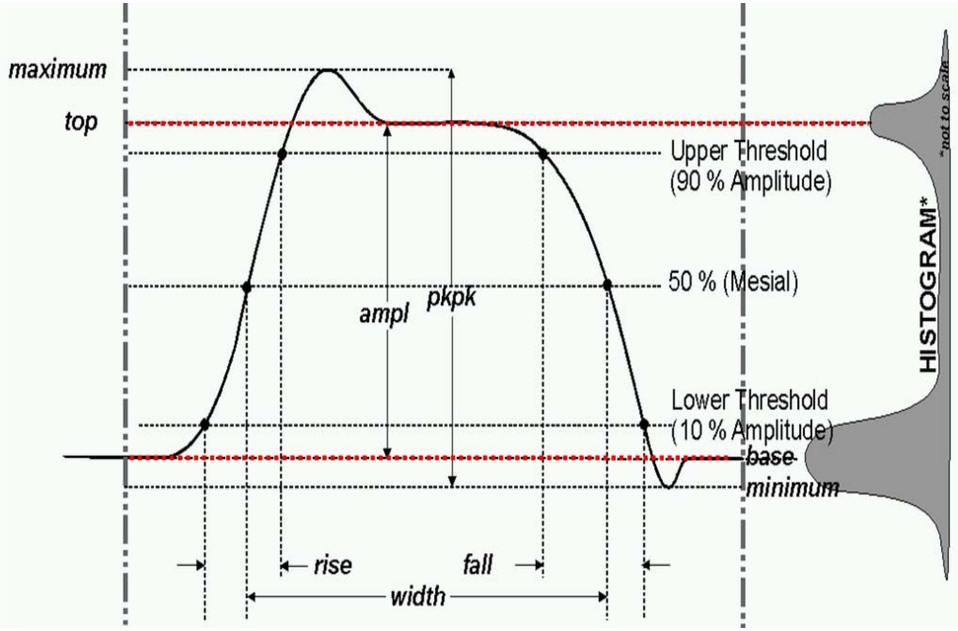
IEEE Standard Pulse Definitions
How Oscilloscopes Measure Pulse Parameters



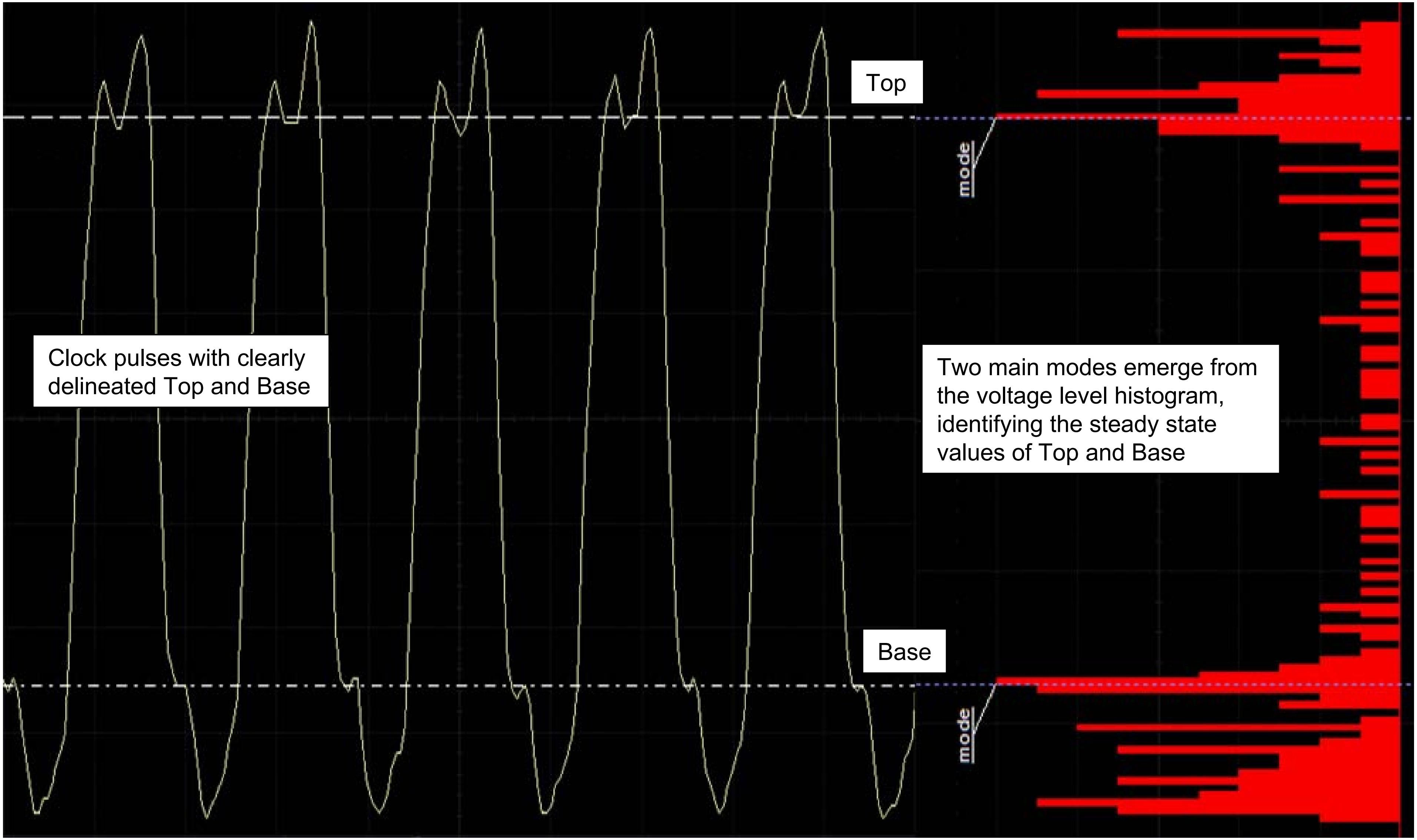
Oscilloscopes determine pulse parameters from Top and Base values

IEEE Pulse Definitions
How Pulse Measurements Are Determined

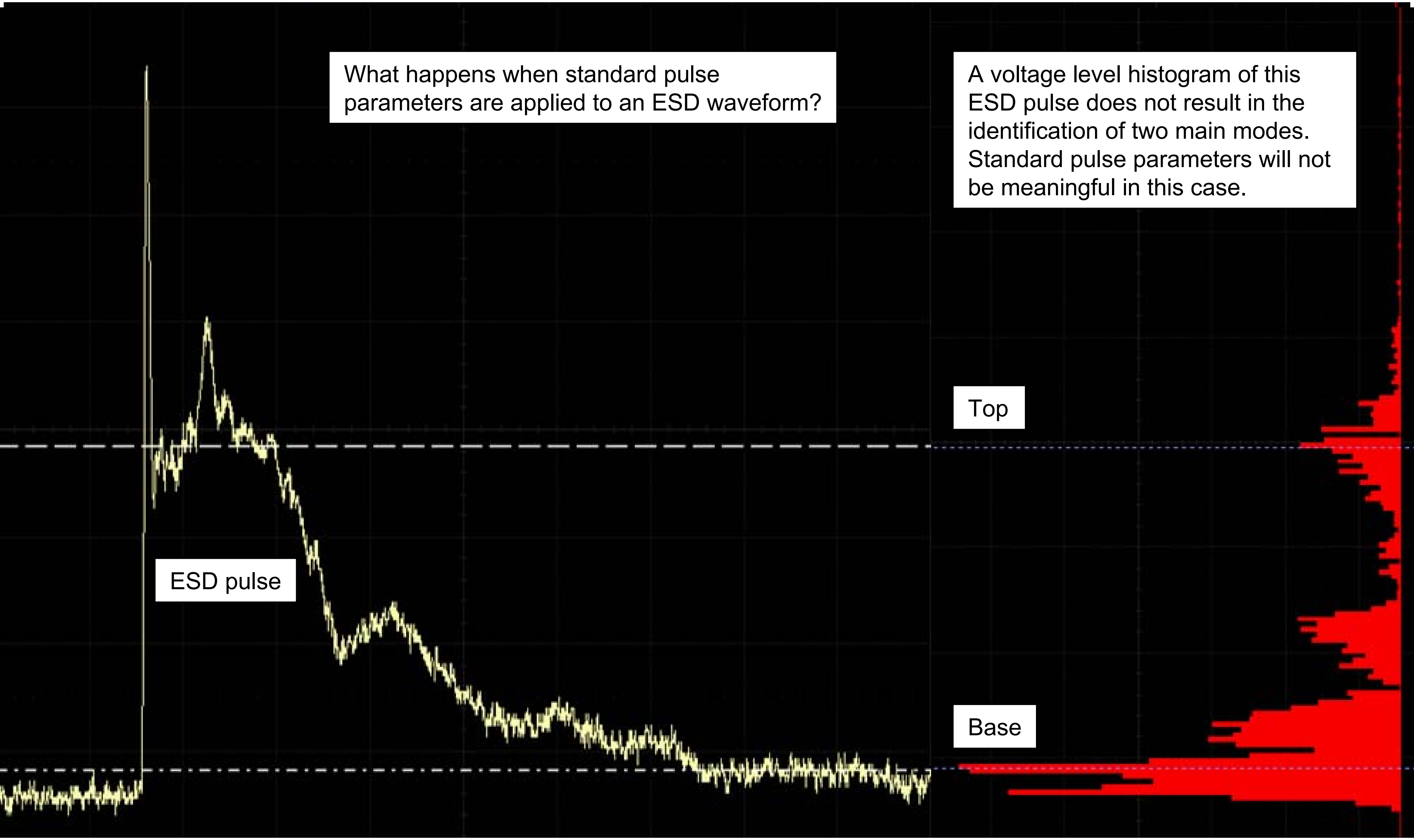
- Pulse measurement definitions are defined by the IEEE Std 181-2003 "IEEE standard on transitions, pulses, and related waveforms"
- Oscilloscopes conform to the IEEE pulse measurement definitions, and Top and Base are determined statistically based on the two modes of a voltage level histogram.
- Top and Base form the 100% and 0% reference levels which are used for measurements such as amplitude, risetime, falltime, period, frequency, width, duty cycle, overshoot, and virtually every timing measurement.
- Top and Base must first be calculated correctly in order for timing and amplitude measurements to produce the correct measurement result.



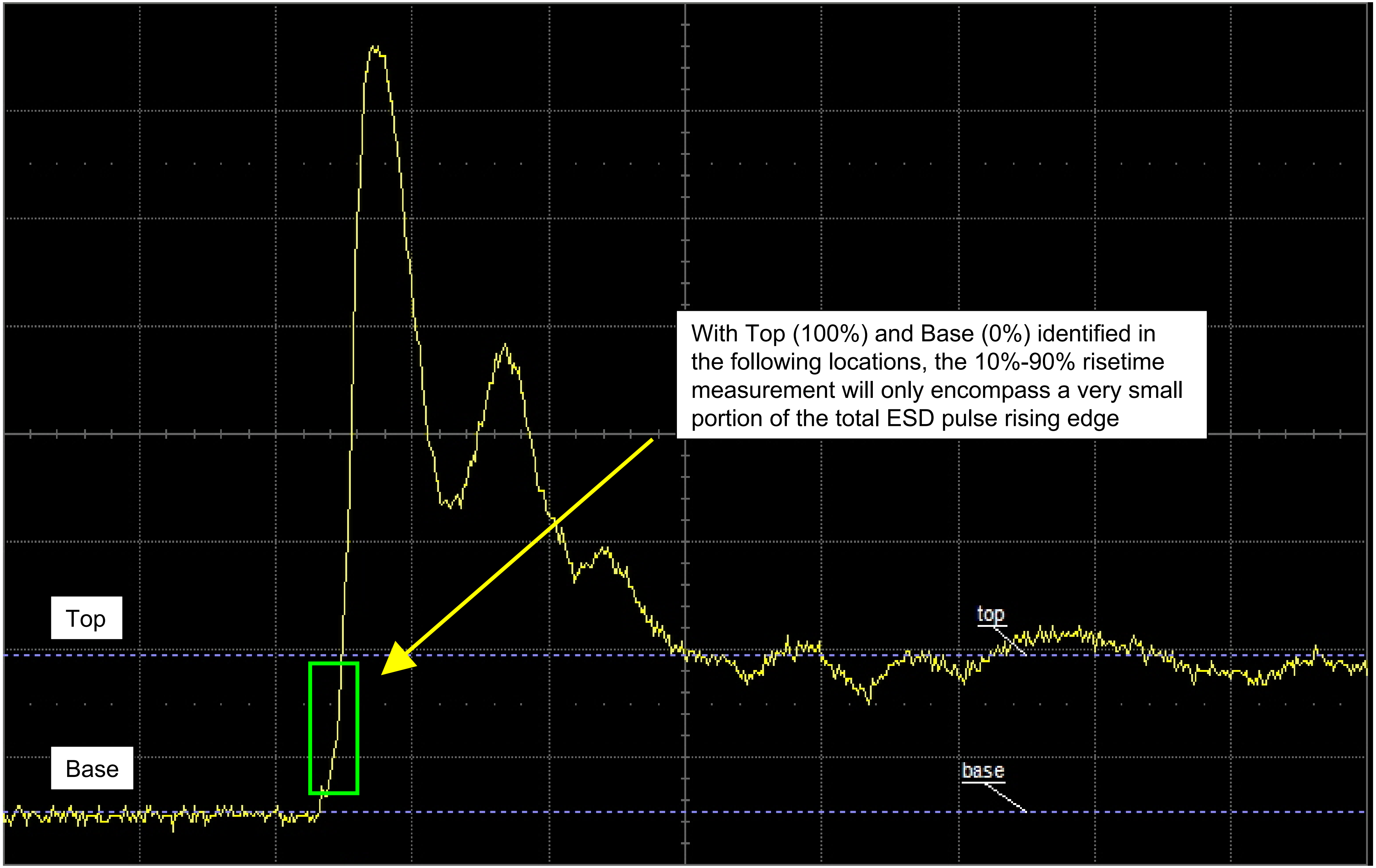
Clock Top and Base correctly determined from voltage histogram



ESD Top and Base are not meaningful for pulse measurements



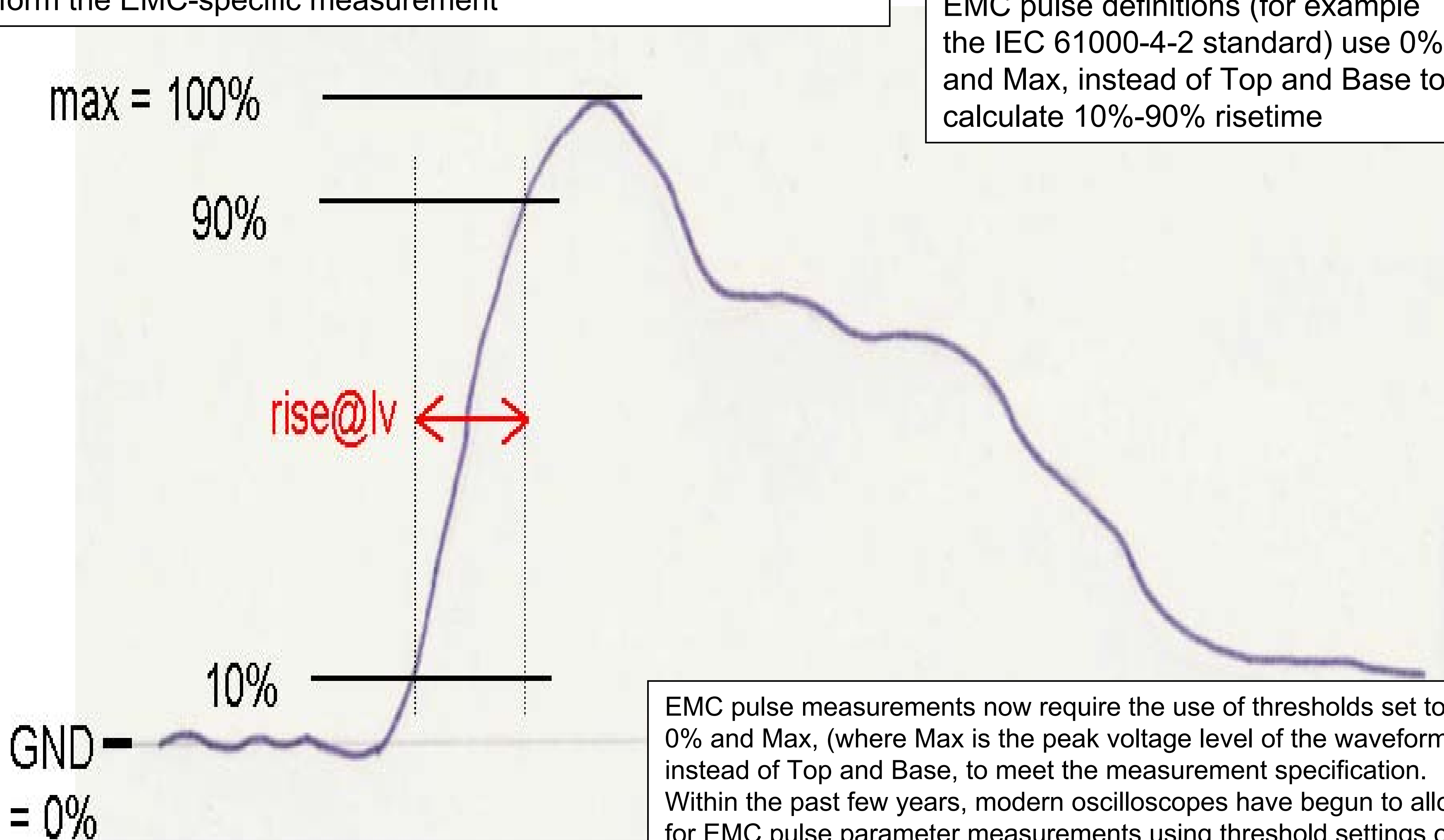
ESD Top and Base are not meaningful for pulse measurements



EMC Risetime Definitions use 0% and Max

An oscilloscope must use 0% and Max thresholds in order to perform the EMC-specific measurement

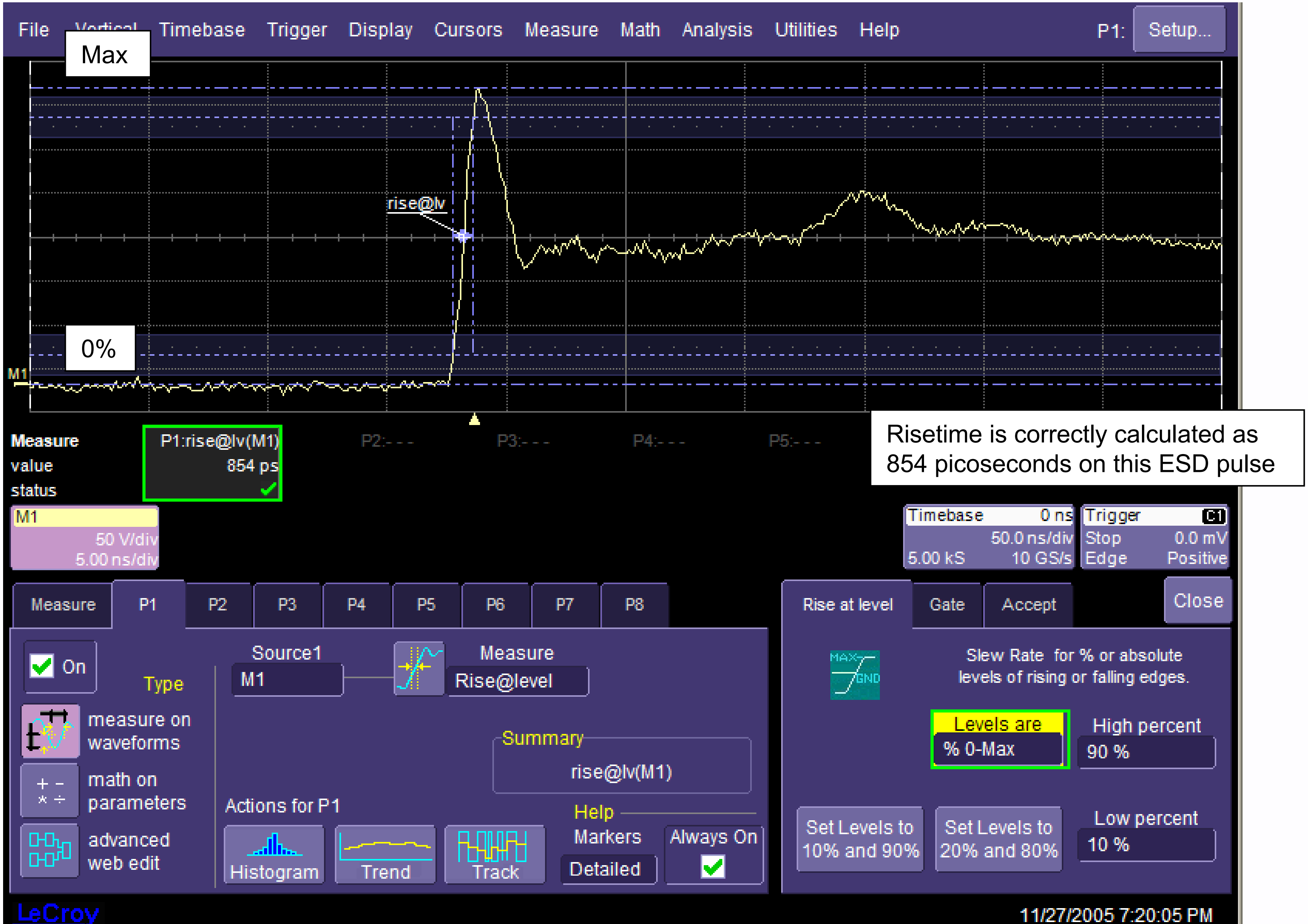
Differing from IEEE pulse definitions, EMC pulse definitions (for example the IEC 61000-4-2 standard) use 0% and Max, instead of Top and Base to calculate 10%-90% risetime



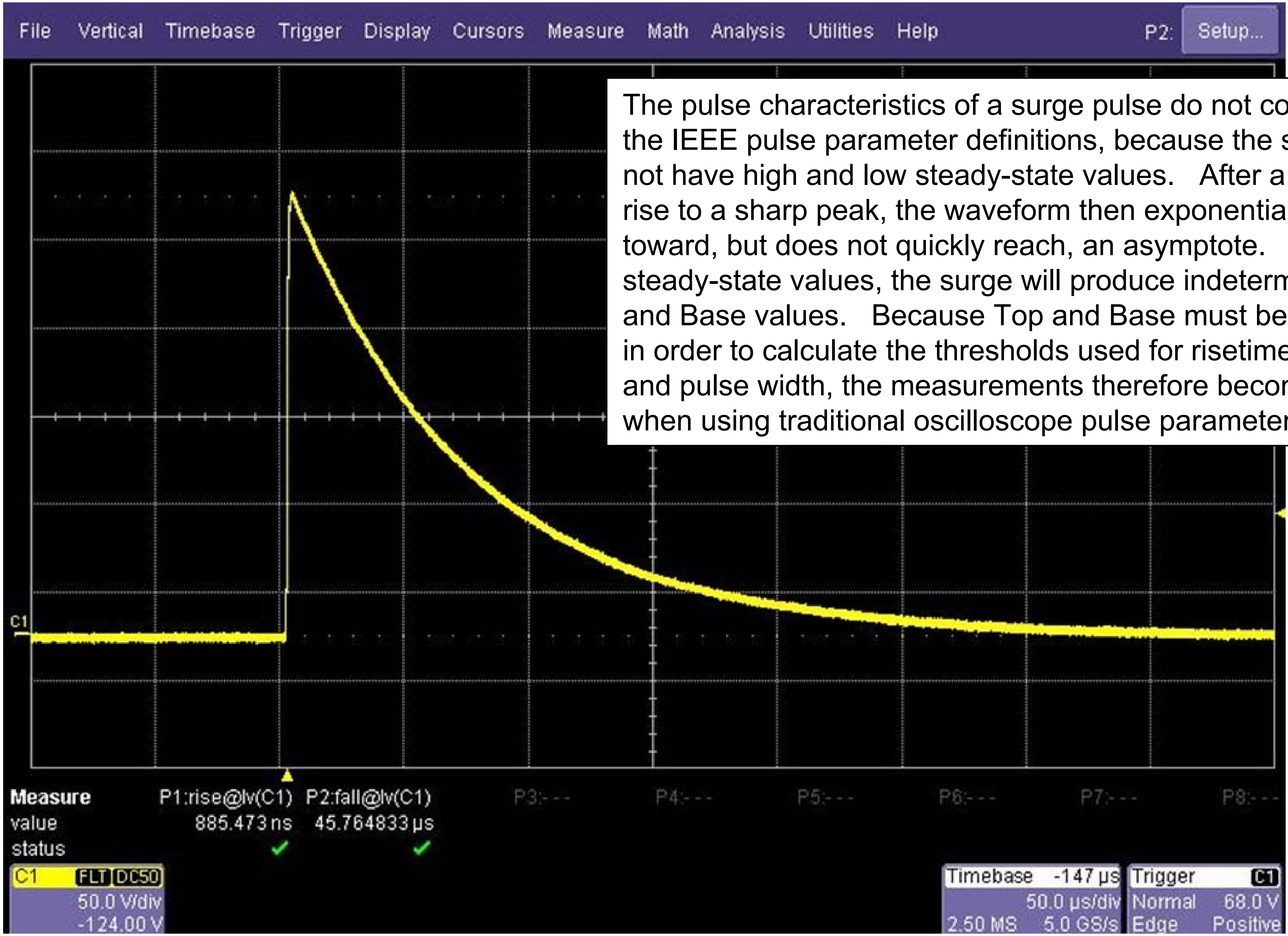
EMC pulse measurements now require the use of thresholds set to 0% and Max, (where Max is the peak voltage level of the waveform), instead of Top and Base, to meet the measurement specification. Within the past few years, modern oscilloscopes have begun to allow for EMC pulse parameter measurements using threshold settings of peak-to-peak, 0% to Max, and 0% to Min along with the standard absolute or percent levels.

Risetime calculated using standard IEEE pulse parameter definitions

Risetime calculated using EMC thresholds

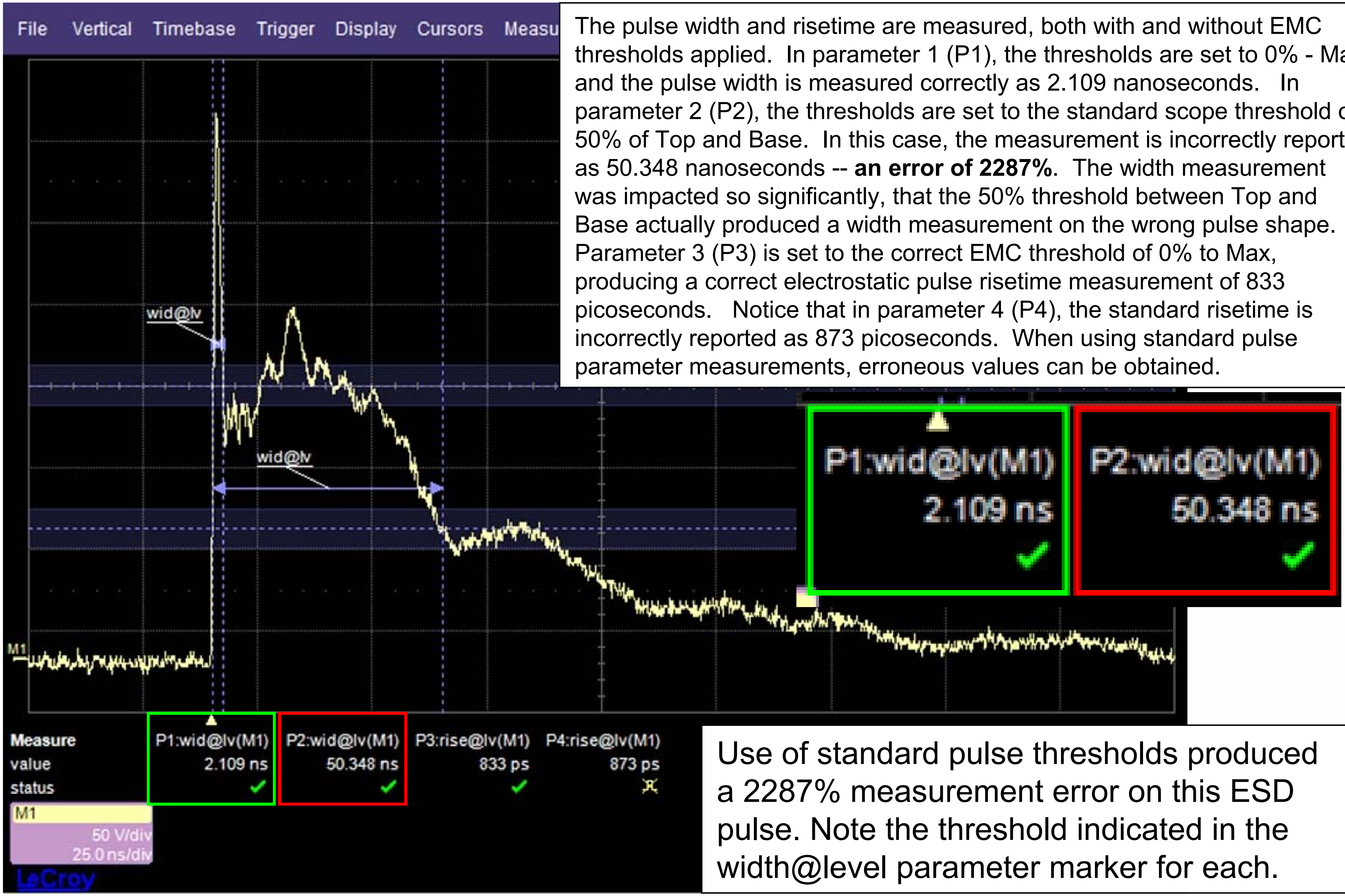


A Surge pulse does not have a clearly-defined Top and Base



The pulse characteristics of a surge pulse do not conform to the IEEE pulse parameter definitions, because the surge does not have high and low steady-state values. After a fast linear rise to a sharp peak, the waveform then exponentially decays toward, but does not quickly reach, an asymptote. With no steady-state values, the surge will produce indeterminate Top and Base values. Because Top and Base must be determined in order to calculate the thresholds used for risetime, falltime, and pulse width, the measurements therefore become invalid when using traditional oscilloscope pulse parameters.

Standard and EMC thresholds for ESD pulse width



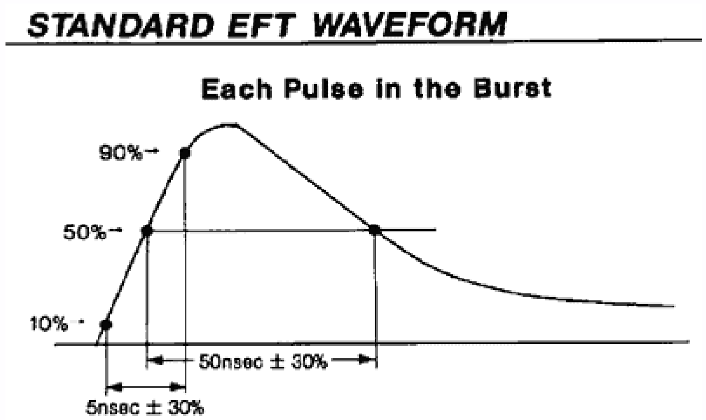
The pulse width and risetime are measured, both with and without EMC thresholds applied. In parameter 1 (P1), the thresholds are set to 0% - Max, and the pulse width is measured correctly as 2.109 nanoseconds. In parameter 2 (P2), the thresholds are set to the standard scope threshold of 50% of Top and Base. In this case, the measurement is incorrectly reported as 50.348 nanoseconds -- **an error of 2287%**. The width measurement was impacted so significantly, that the 50% threshold between Top and Base actually produced a width measurement on the wrong pulse shape. Parameter 3 (P3) is set to the correct EMC threshold of 0% to Max, producing a correct electrostatic pulse risetime measurement of 833 picoseconds. Notice that in parameter 4 (P4), the standard risetime is incorrectly reported as 873 picoseconds. When using standard pulse parameter measurements, erroneous values can be obtained.

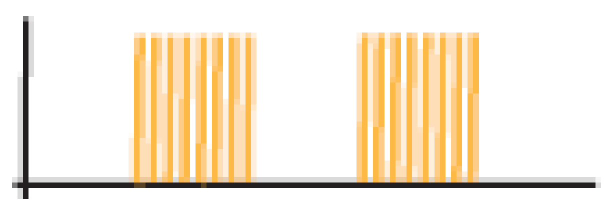
Use of standard pulse thresholds produced a 2287% measurement error on this ESD pulse. Note the threshold indicated in the width@level parameter marker for each.

EFT Testing – Electrical Fast Transient

Measurement Steps

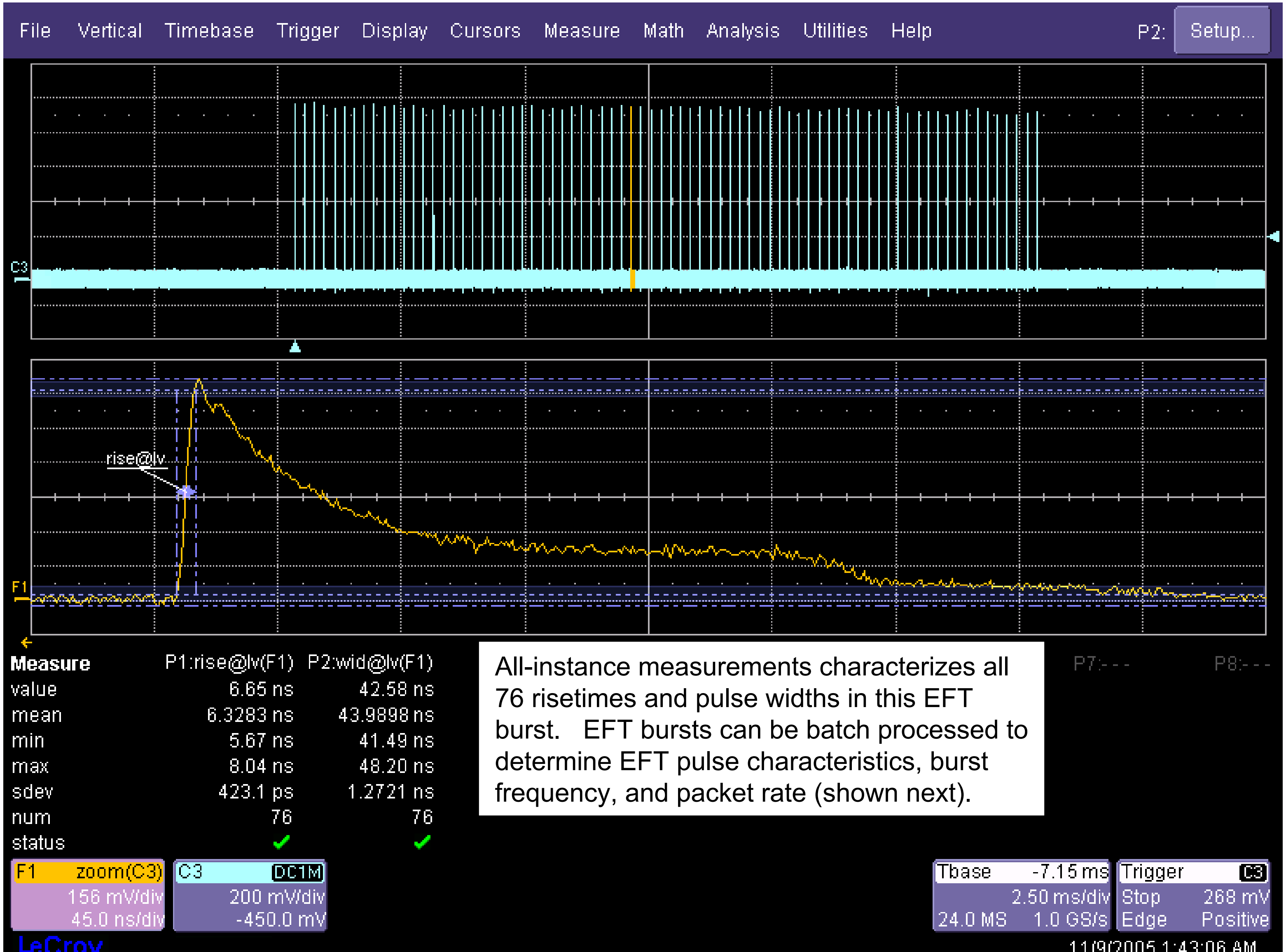
- Pulse Characteristics
  - T_{rise} = 5ns
  - T_{fall} = 50ns
  - Burst of many 5x50 pulses
- Measurement Needs
  - Capture 2ms of burst
  - Measure one pulse, verify shape (rise, fall, width)
  - Measure burst frequency (10-100 kHz)
  - Measure Capture time of burst packet (2ms)
  - Measure burst packet rate (300ms)





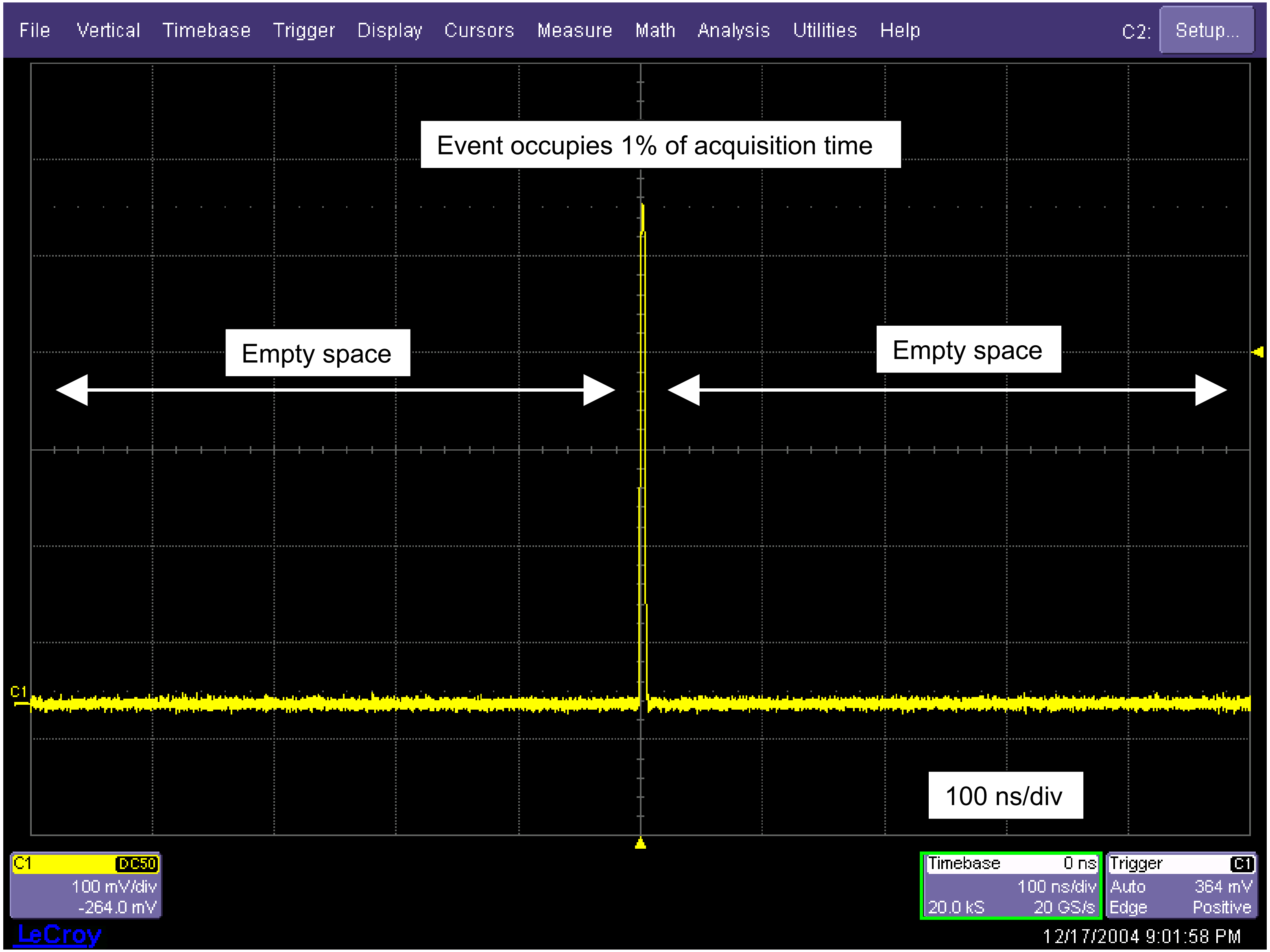
EFT Testing – Electrical Fast Transient

Measurement Statistics

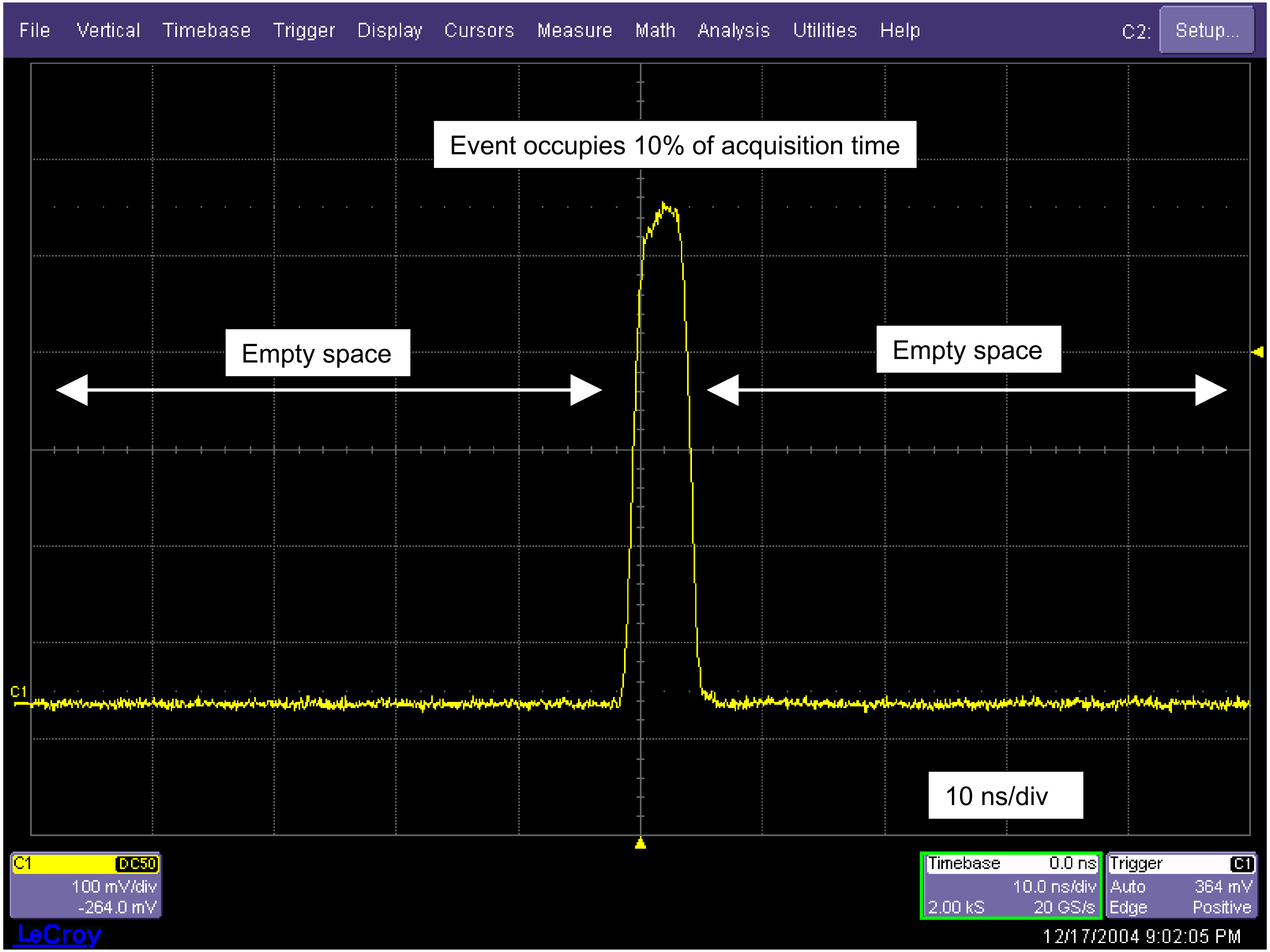


All-instance measurements characterizes all 76 risetimes and pulse widths in this EFT burst. EFT bursts can be batch processed to determine EFT pulse characteristics, burst frequency, and packet rate (shown next).

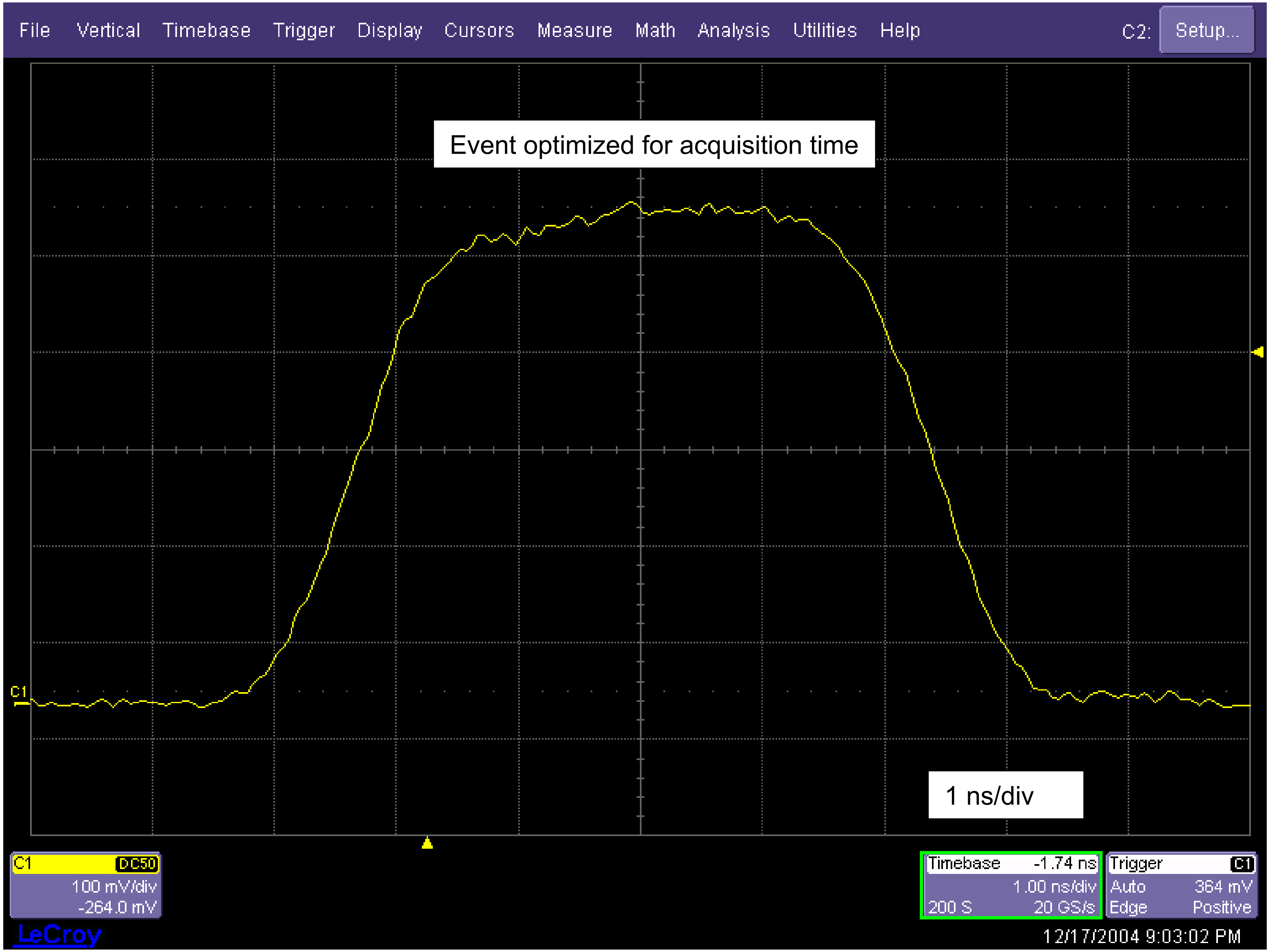
Maximizing Acquisition Memory for Events



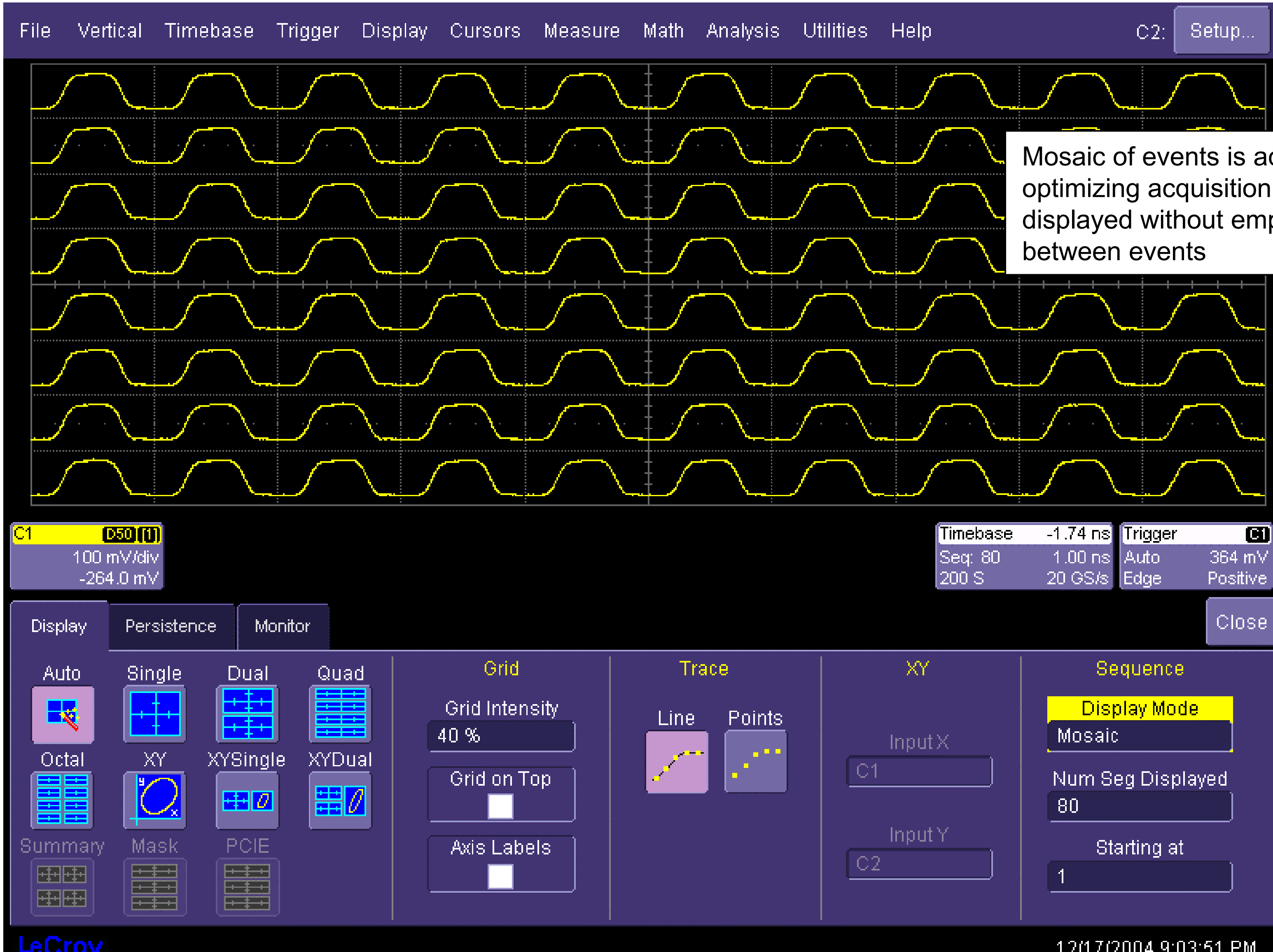
Maximizing Acquisition Memory for Events



Maximizing Acquisition Memory for Events

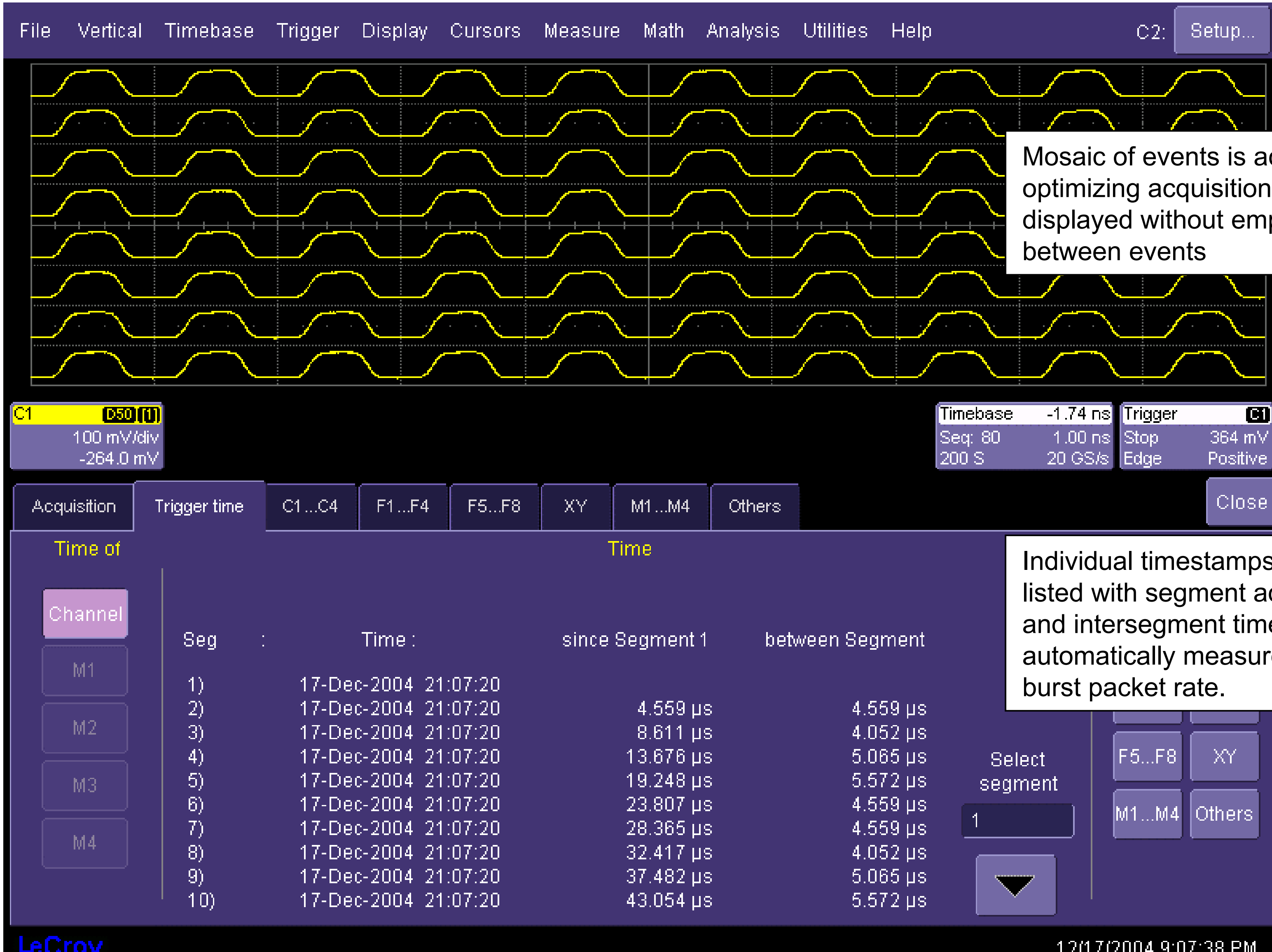


Maximizing Acquisition Memory for Events



Mosaic of events is acquired while optimizing acquisition memory, and displayed without empty spaces between events

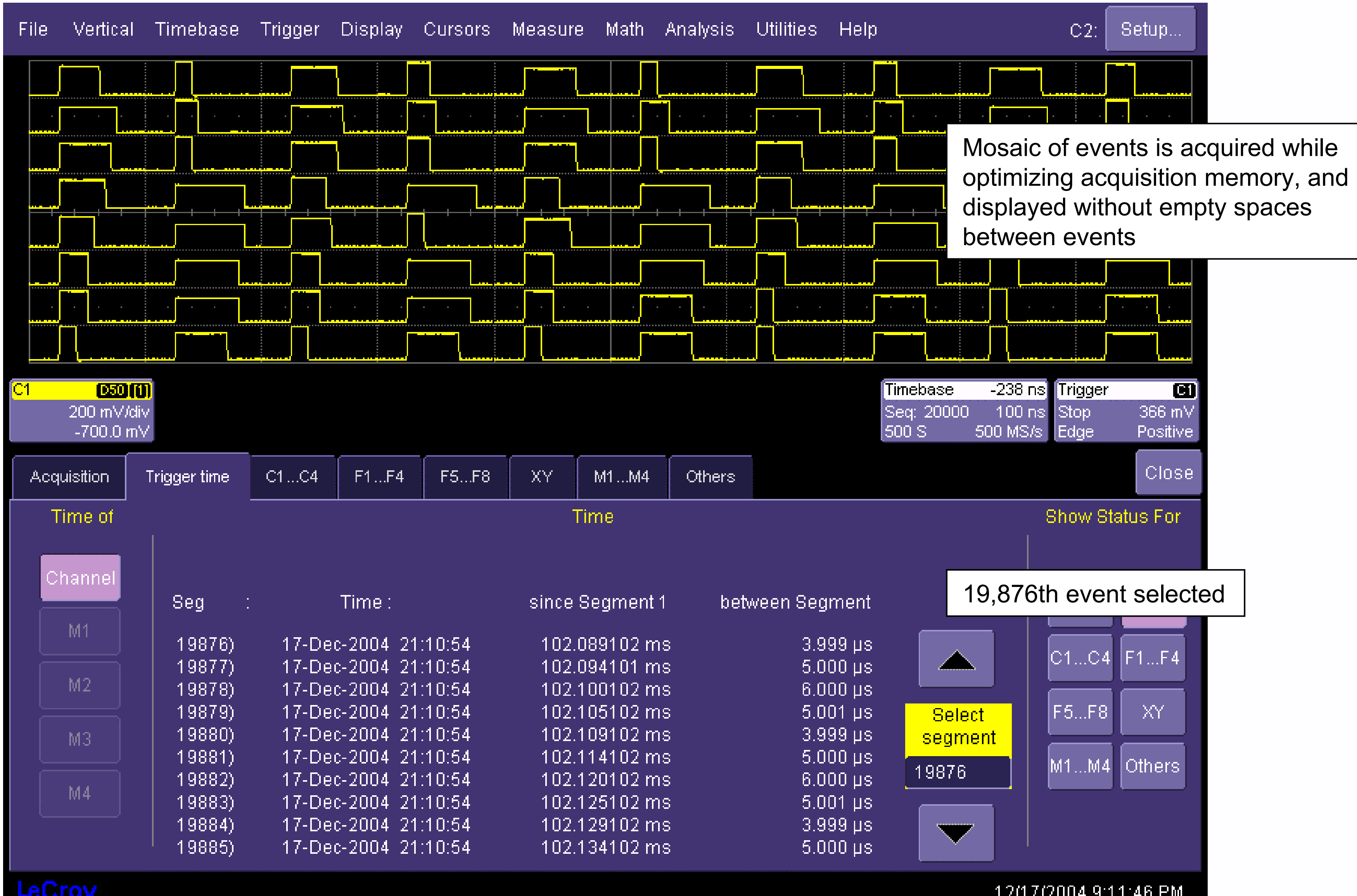
Maximizing Acquisition Memory for Events



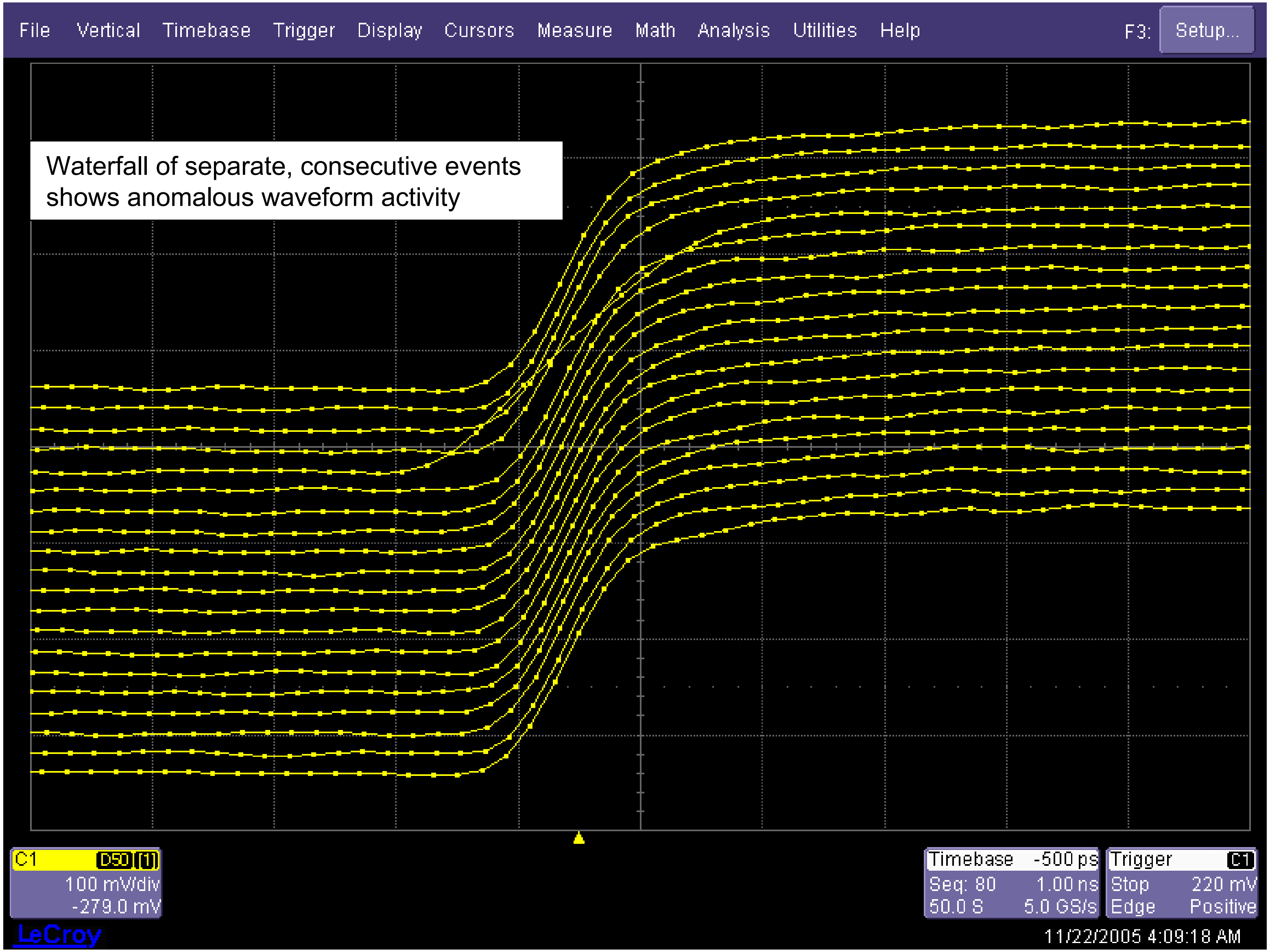
Mosaic of events is acquired while optimizing acquisition memory, and displayed without empty spaces between events

Individual timestamps for each event listed with segment acquisition time and intersegment time. This will automatically measure the EFT burst packet rate.

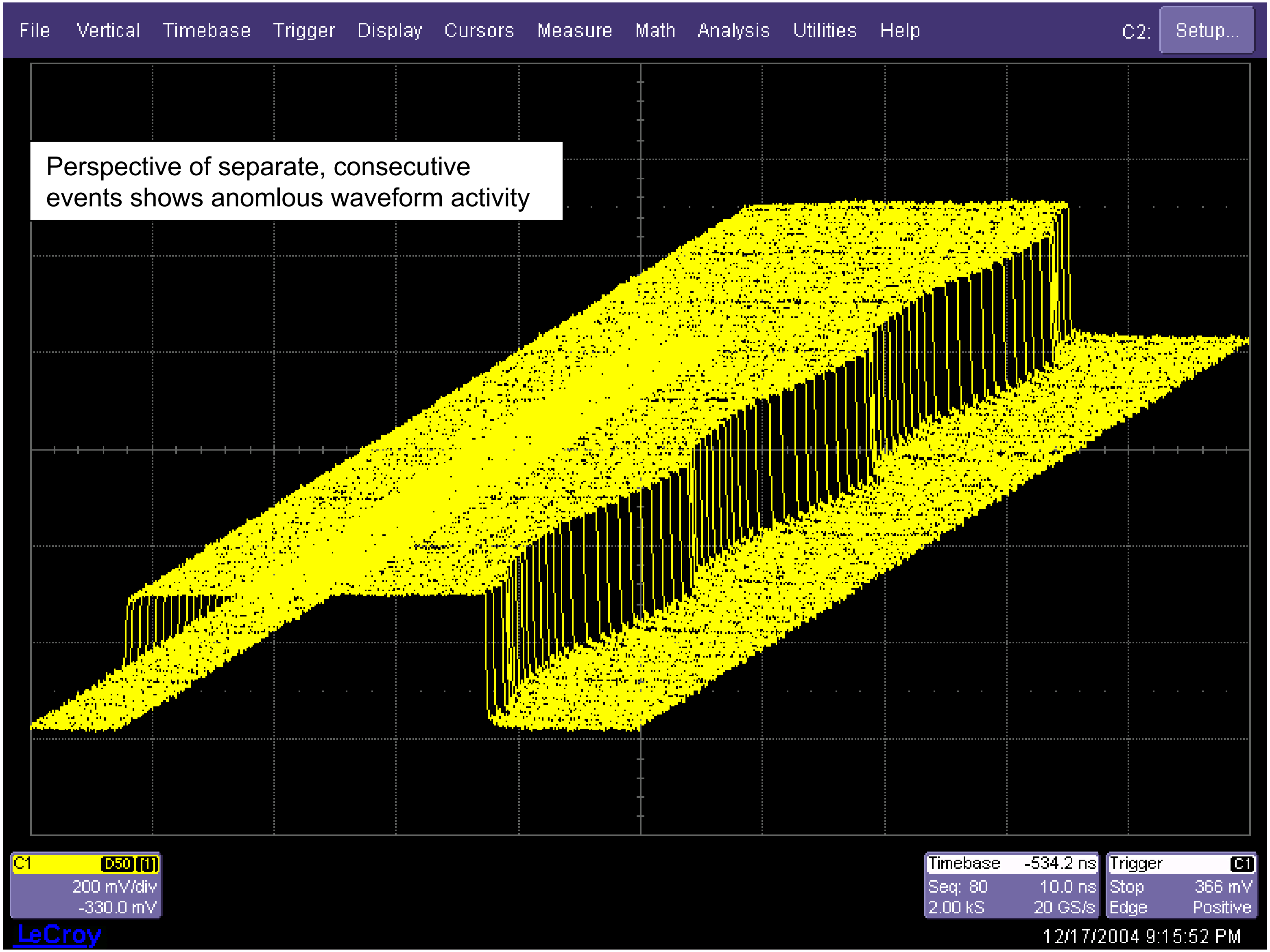
Maximizing Acquisition Memory for Events



Sequence Waterfall shows anomaly

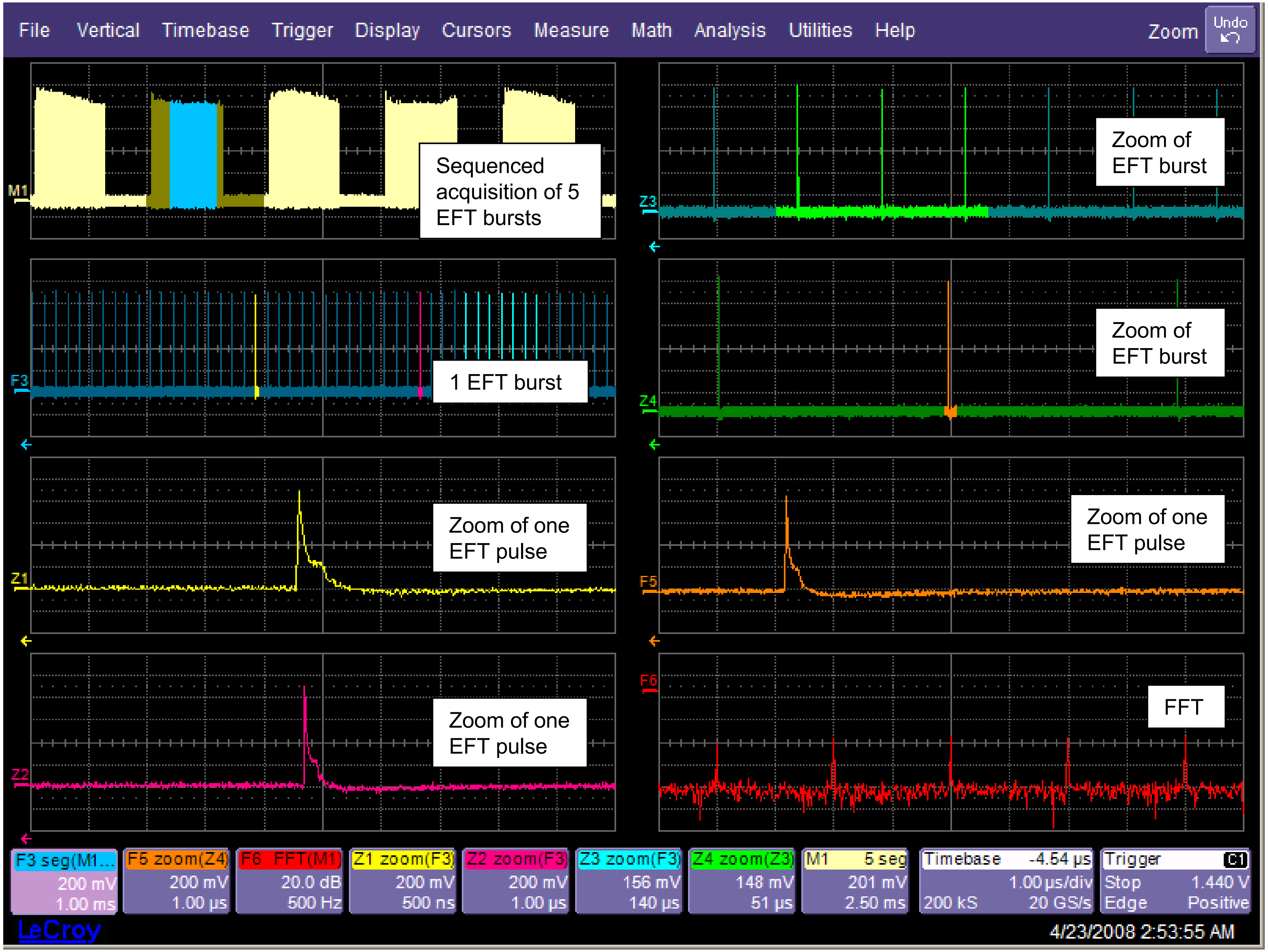


Sequence Perspective shows contour of acquired pulses

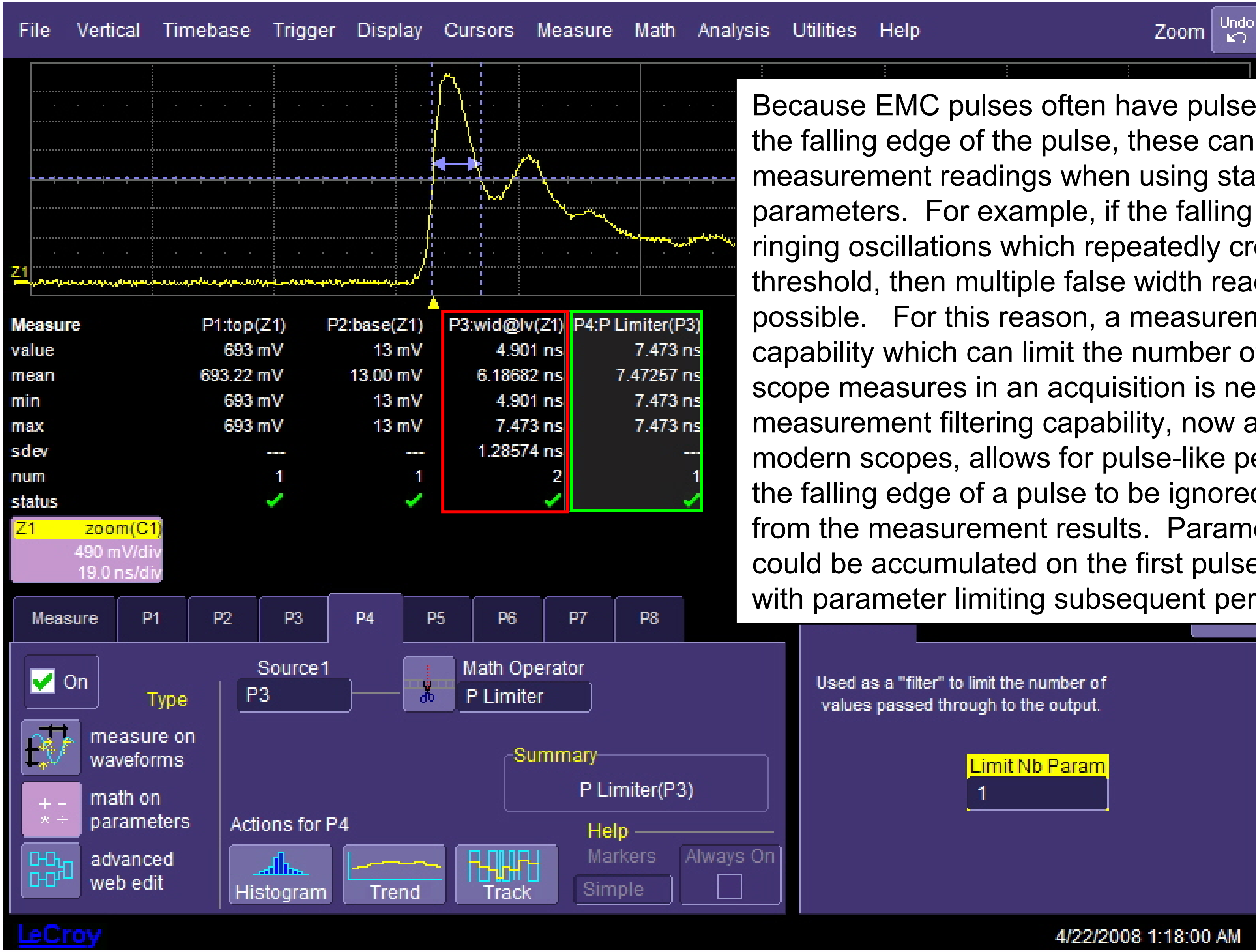


EFT Testing – Electrical Fast Transient

Sequence Mode and Octal Grid

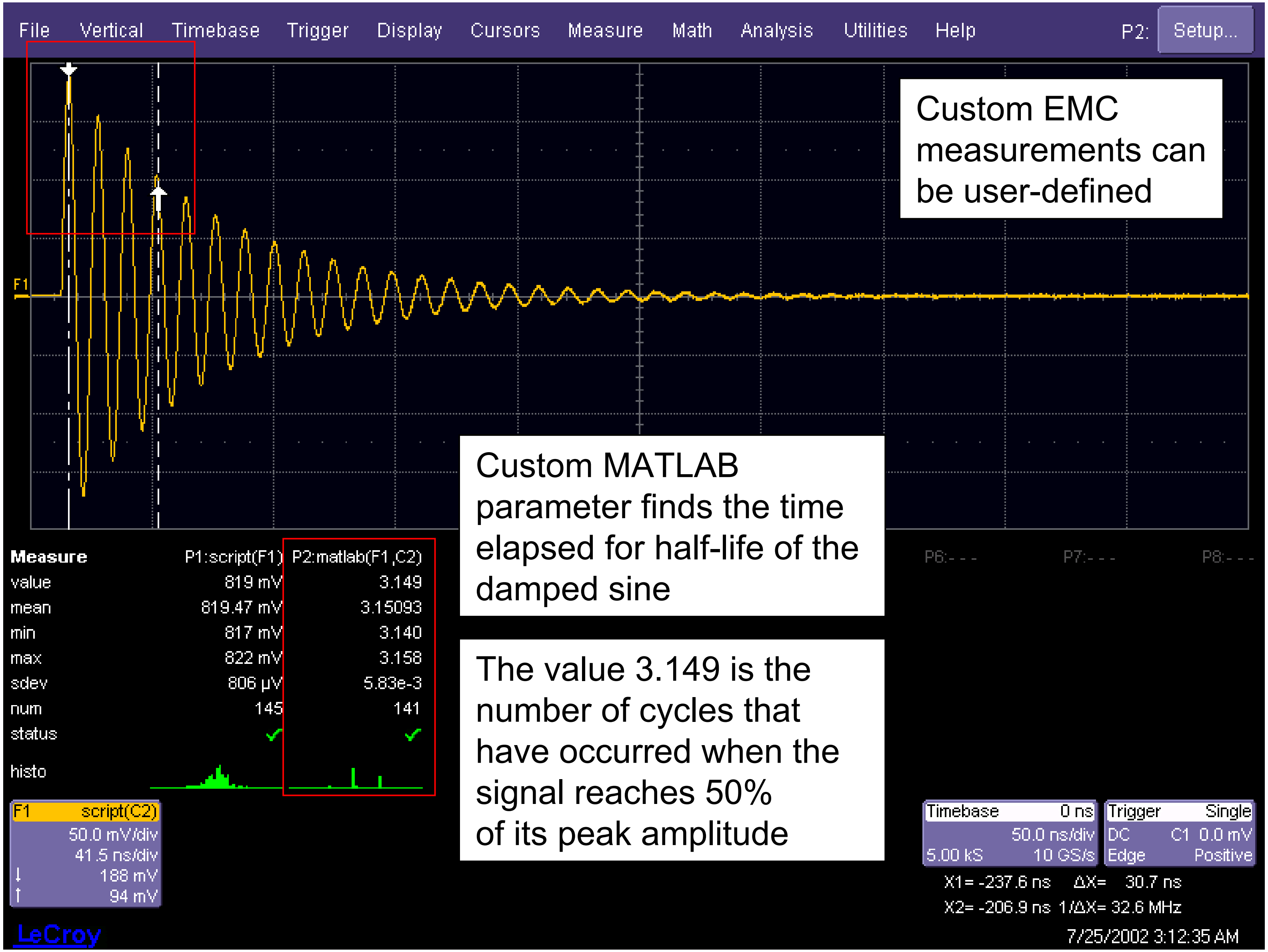


Parameter limiting technique for ESD width measurement



Because EMC pulses often have pulse perturbations on the falling edge of the pulse, these can result in false measurement readings when using standard parameters. For example, if the falling edge had ringing oscillations which repeatedly crossed the threshold, then multiple false width readings would be possible. For this reason, a measurement filtering capability which can limit the number of pulses the scope measures in an acquisition is needed. This measurement filtering capability, now available on modern scopes, allows for pulse-like perturbations on the falling edge of a pulse to be ignored and excluded from the measurement results. Parameter statistics could be accumulated on the first pulse in conjunction with parameter limiting subsequent perturbations.

Inline Custom Measurement

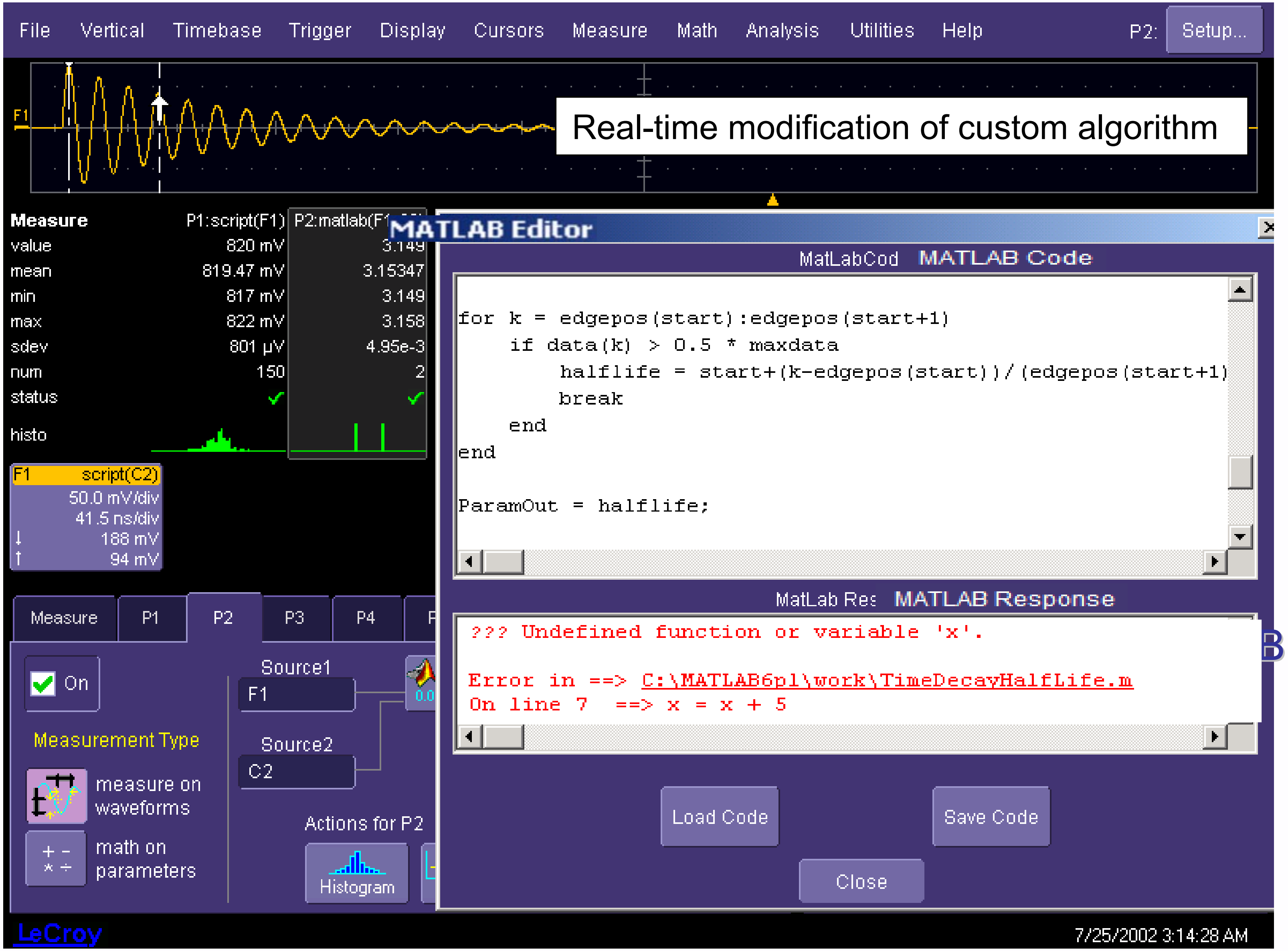


Custom EMC measurements can be user-defined

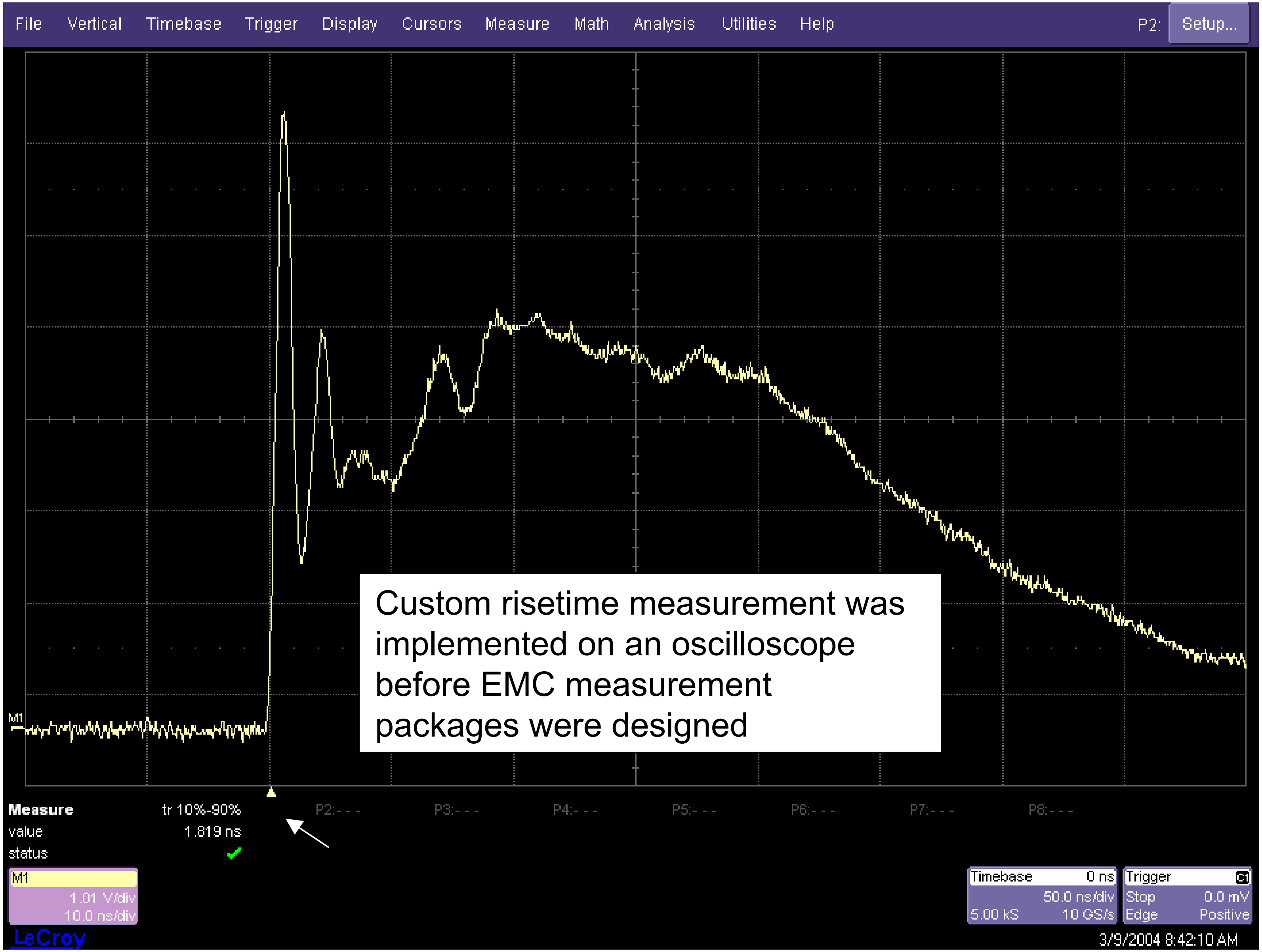
Custom MATLAB parameter finds the time elapsed for half-life of the damped sine

The value 3.149 is the number of cycles that have occurred when the signal reaches 50% of its peak amplitude

Real-Time Modification of Custom Measurement



EMC Risetime Custom Definition



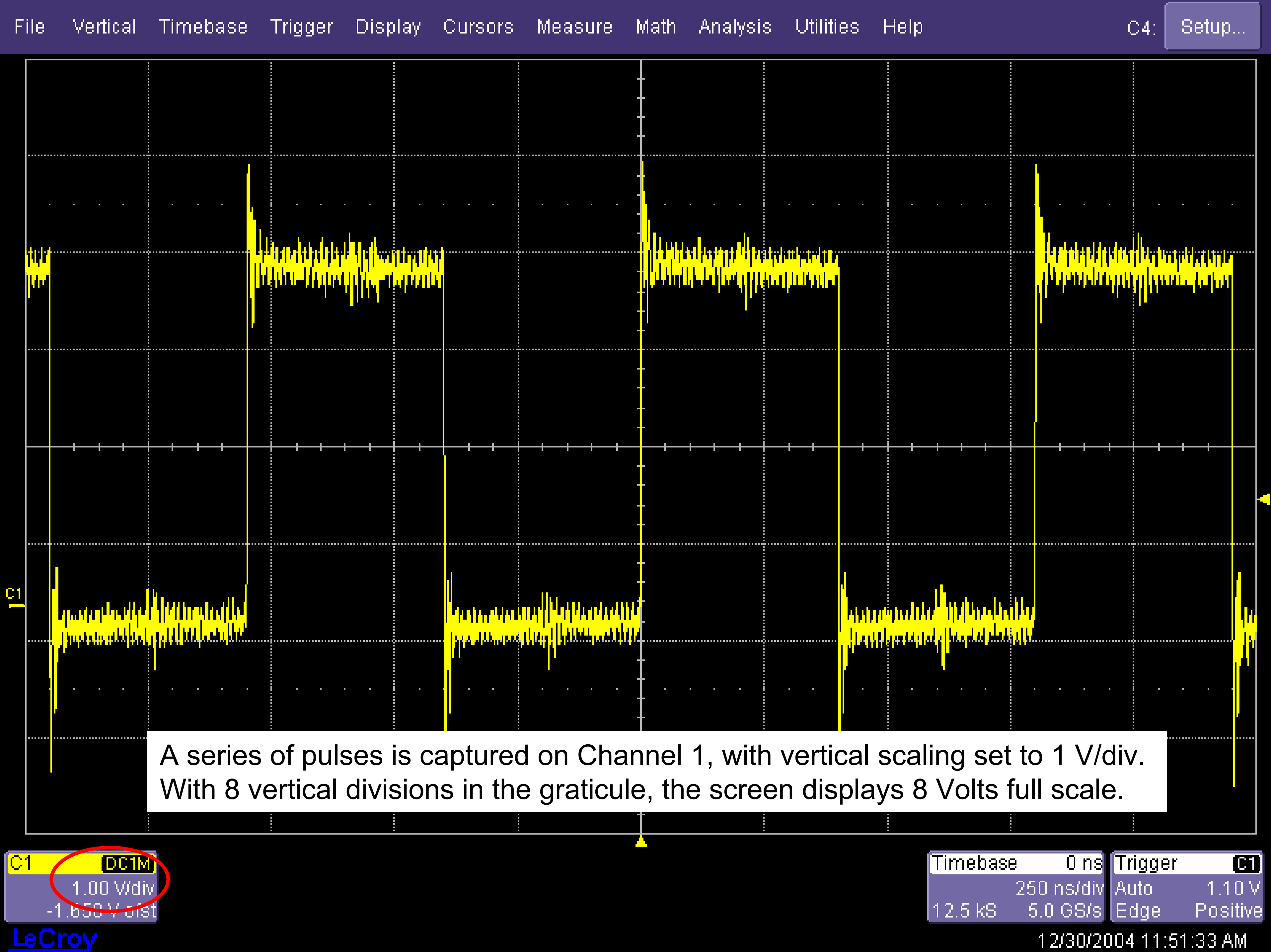
Custom risetime measurement was implemented on an oscilloscope before EMC measurement packages were designed

Summary

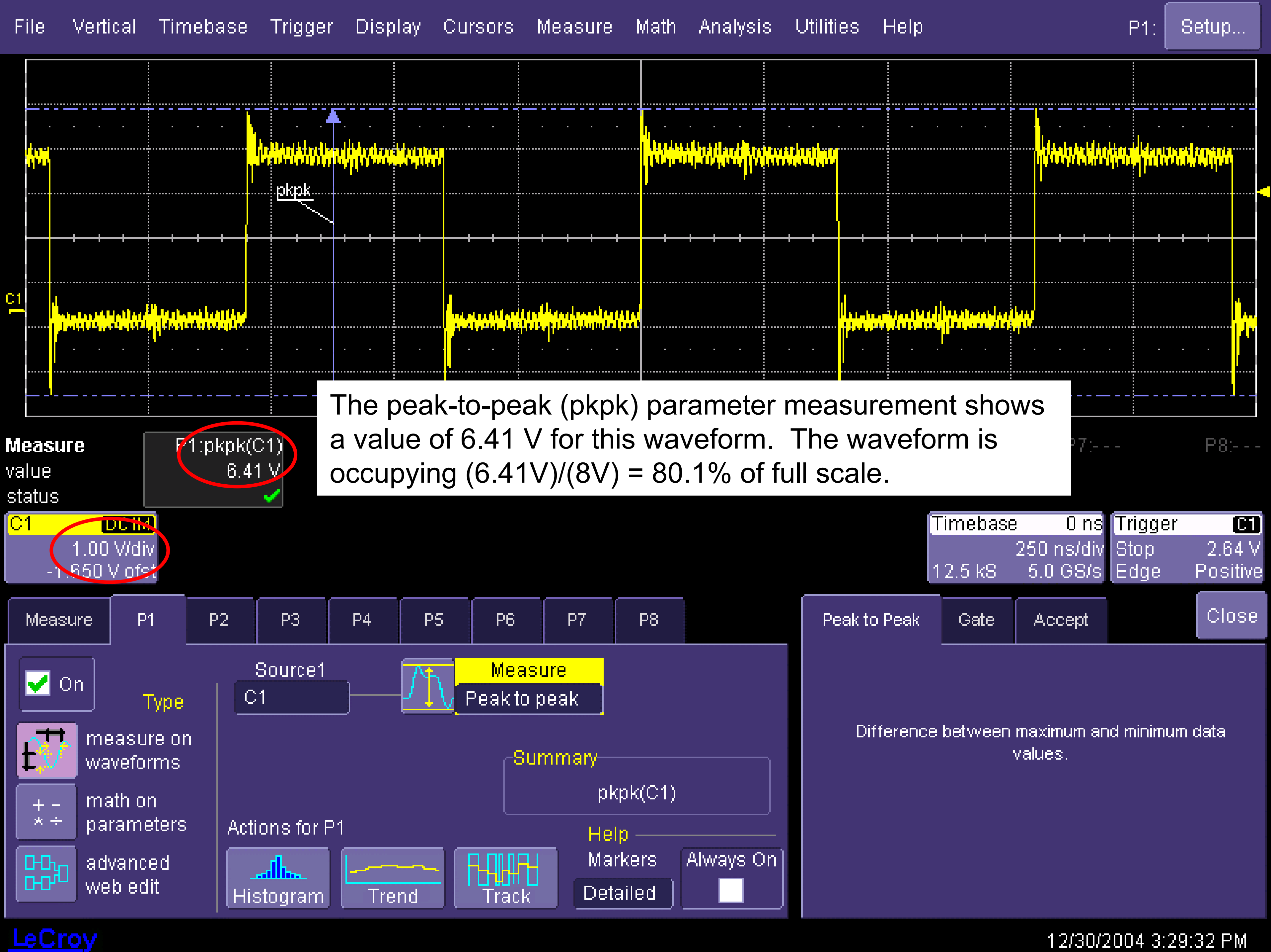
- EMC/ESD test specifications require verification of rise times, fall times, pulse widths and pulse shapes
- Standard oscilloscope pulse parameter measurements are based on IEEE pulse definitions
- EMC engineers use different pulse definitions which oscilloscopes are not designed to use
- Non-standard measurement setups are required to perform accurate pulse parameter measurements of electrostatic discharge, electrical fast transients, and surges.
- Selecting the correct measurement threshold can make a significant difference in the measurement accuracy of these signals.
- During acquisition of EMC pulses, vertical channel scaling affects signal integrity (shown next)

Vertical Scaling

of EMC pulses
affects Signal Integrity



A series of pulses is captured on Channel 1, with vertical scaling set to 1 V/div. With 8 vertical divisions in the graticule, the screen displays 8 Volts full scale.


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P1: Setup...
pkpk
C1
The peak-to-peak (pkpk) parameter measurement shows a value of 6.41 V for this waveform. The waveform is occupying (6.41V)/(8V) = 80.1% of full scale.
Measure
value
status
P1:pkpk(C1)
6.41 V
P7:- - -
P8:- - -
C1 DC1M
1.00 V/div
-1.650 V ofst
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s
Trigger C1
Stop 2.64 V
Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
Peak to Peak Gate Accept
Close
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
C1
Measure
Peak to peak
Summary
pkpk(C1)
Actions for P1
Histogram Trend Track
Help
Markers
Detailed
Always On
Difference between maximum and minimum data values.
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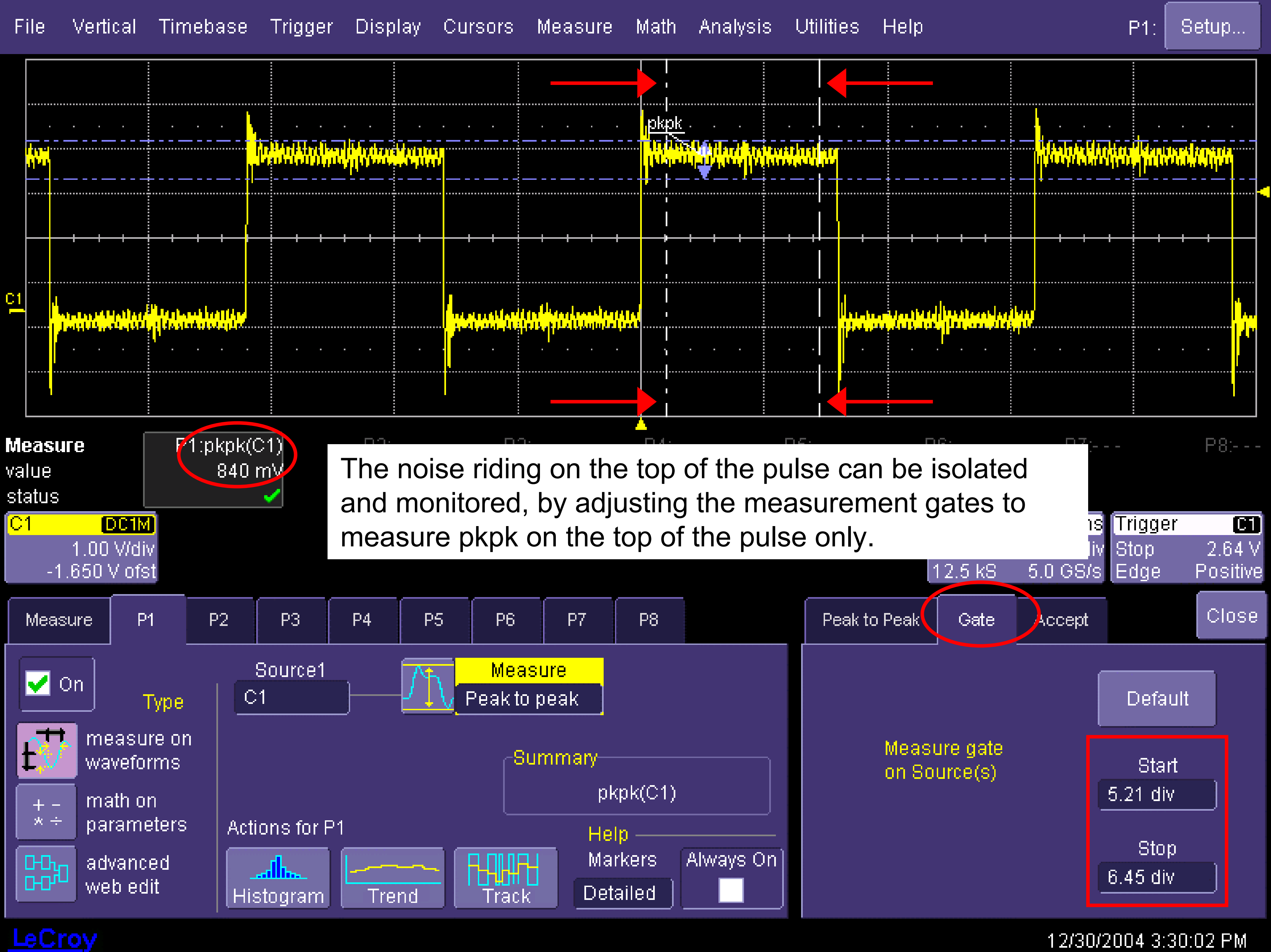
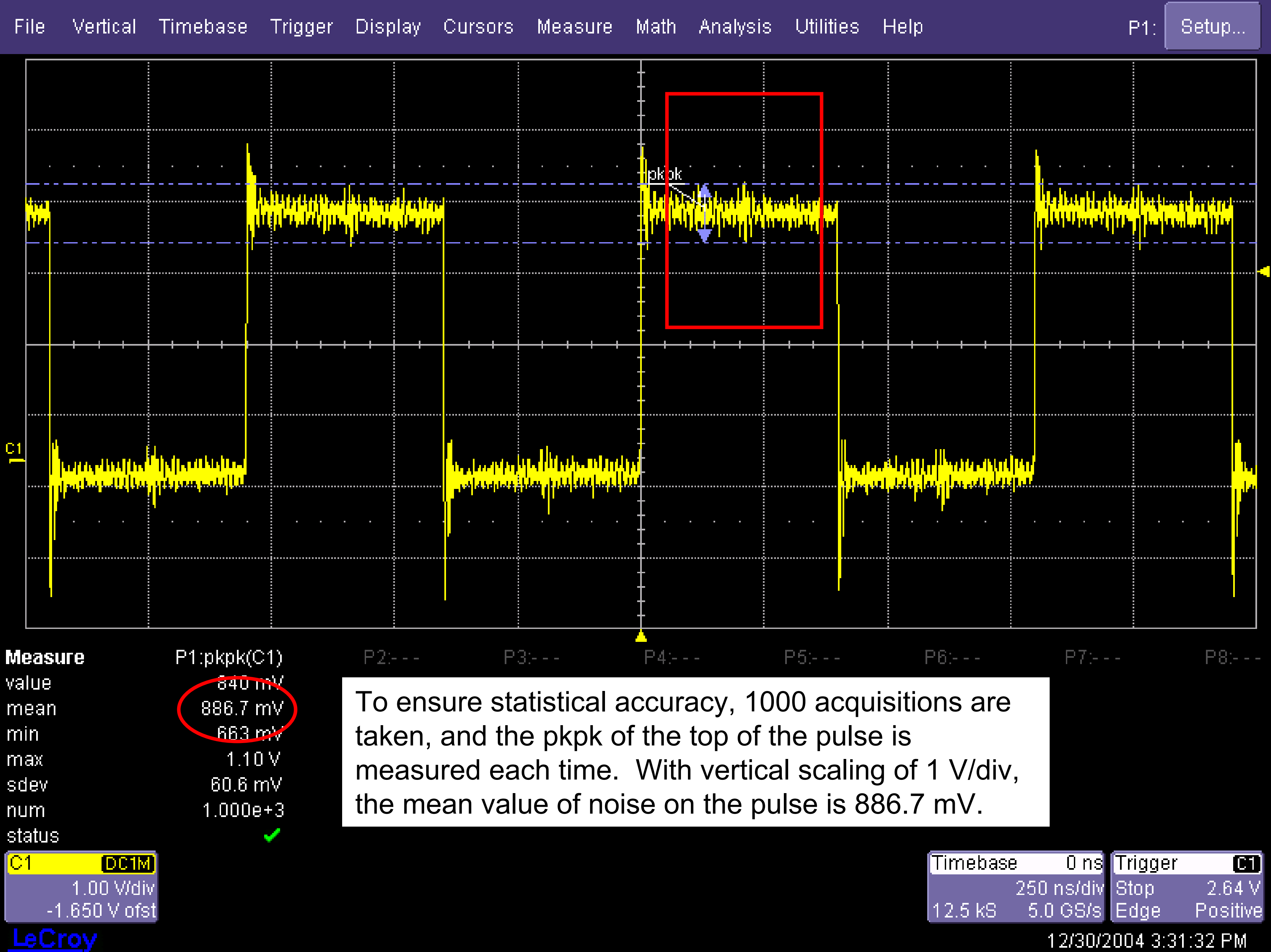
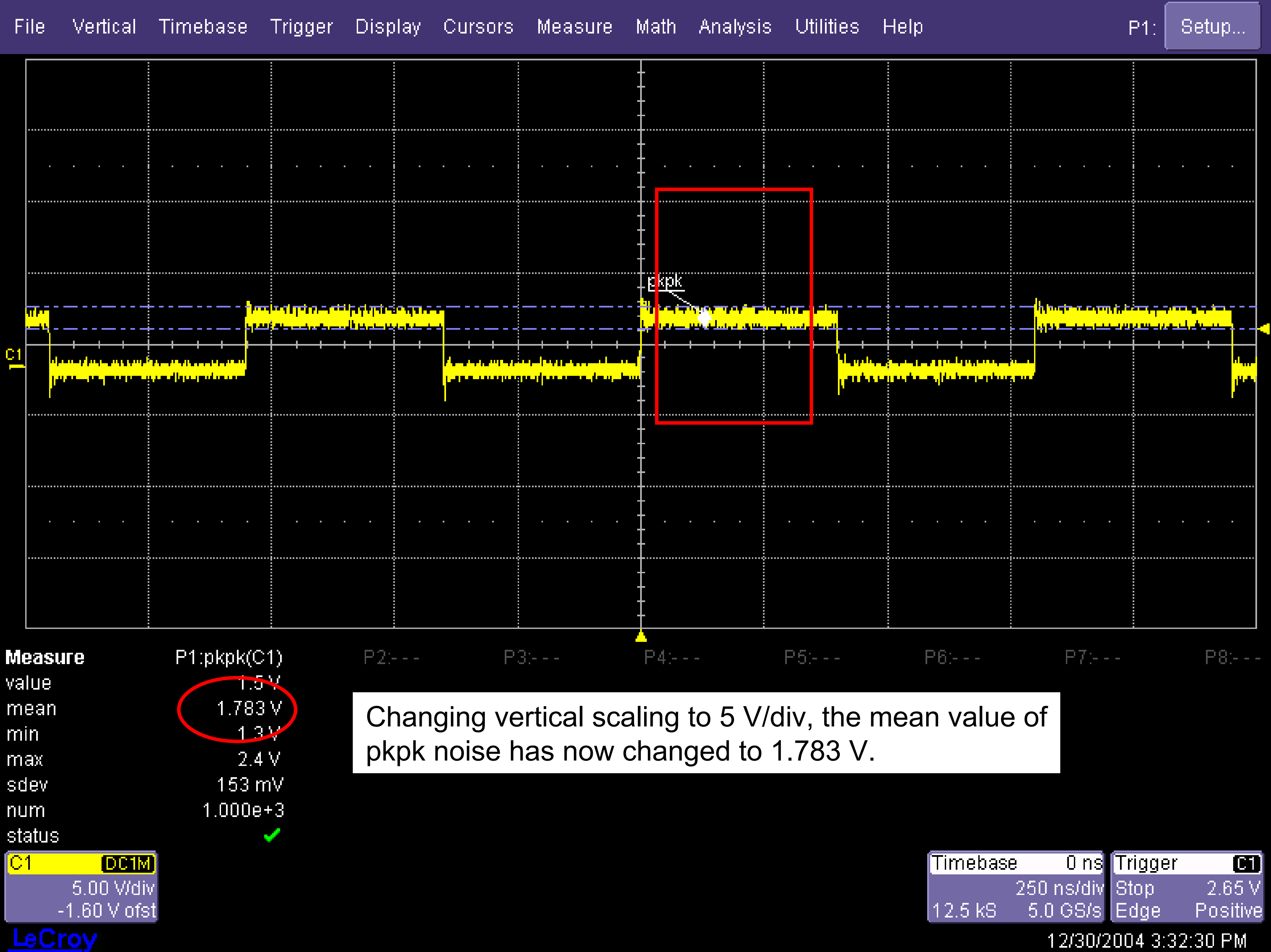


The noise riding on the top of the pulse can be isolated and monitored, by adjusting the measurement gates to measure pkpk on the top of the pulse only.

Parameter 1 (pkpk of Channel 1) is now measuring only the noise riding on the top of the pulse shown above.

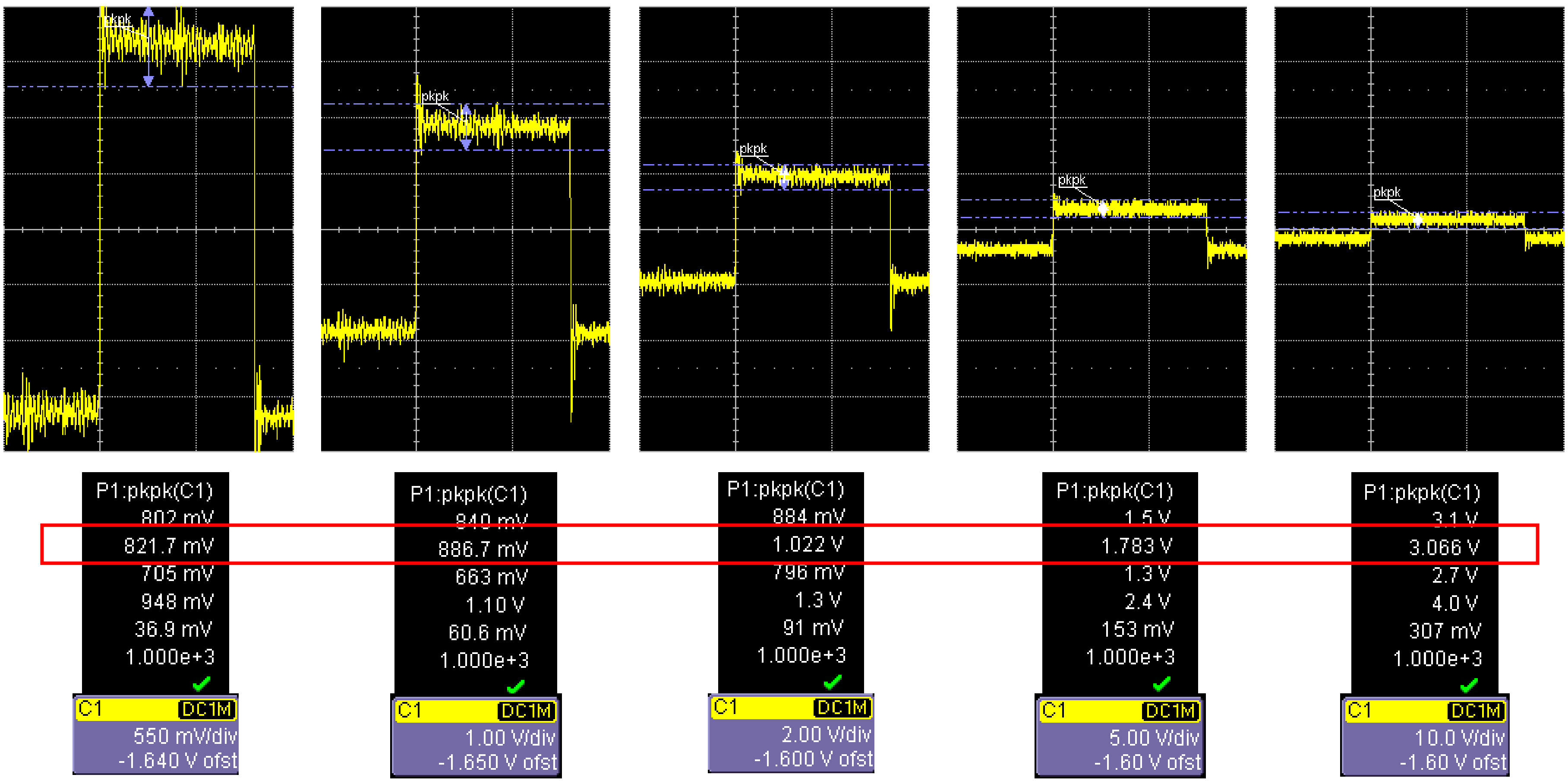


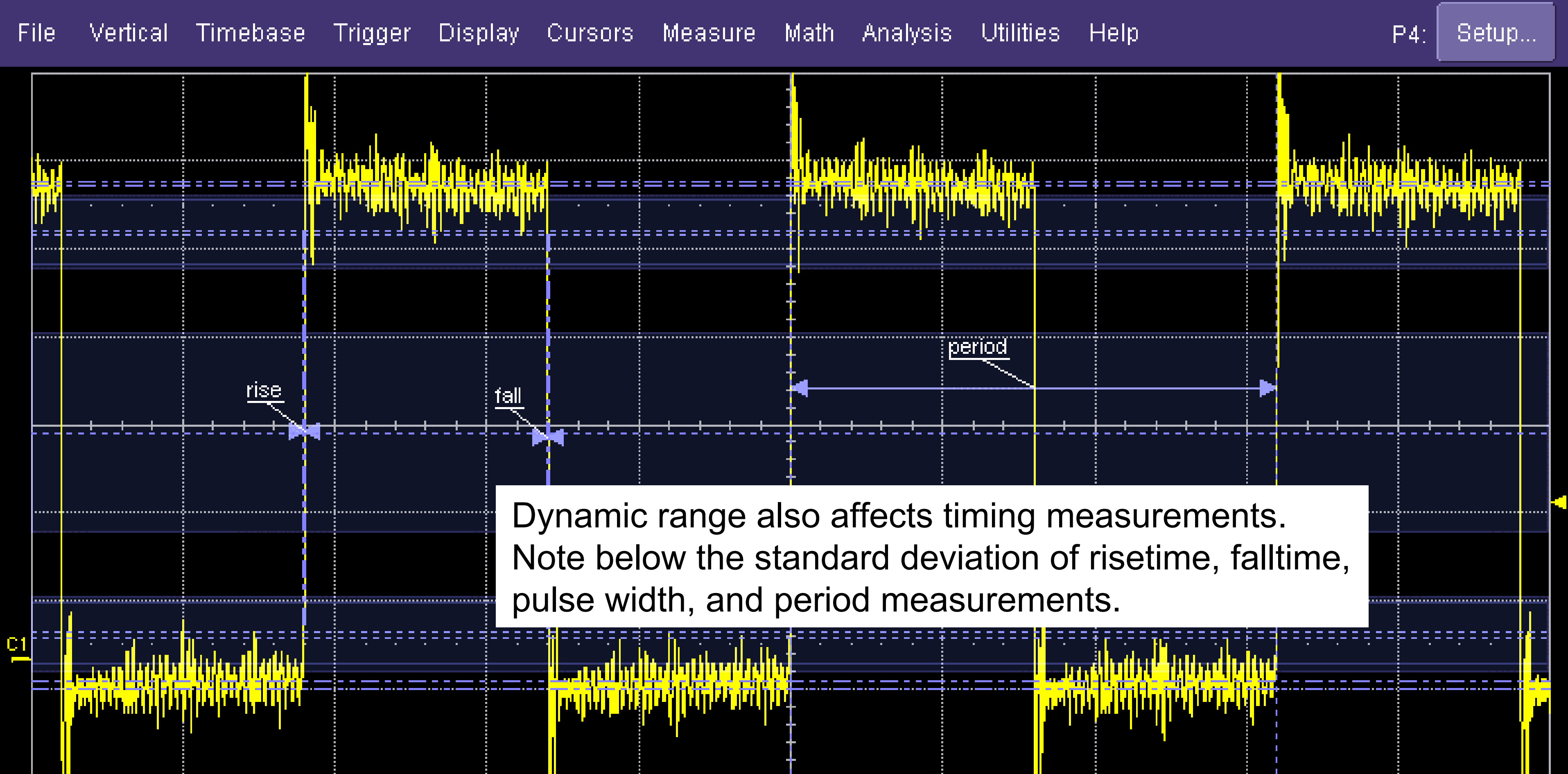
To ensure statistical accuracy, 1000 acquisitions are taken, and the pkpk of the top of the pulse is measured each time. With vertical scaling of 1 V/div, the mean value of noise on the pulse is 886.7 mV.



Changing vertical scaling to 5 V/div, the mean value of pkpk noise has now changed to 1.783 V.

Further adjusting vertical scaling shows that channel vertical scaling significantly affects the measured noise level. At 550 mV/div, the mean noise level is **821 mV**; at 2 V/div, the noise level is **1.02 V**, and at 10 V/div, the noise level is **3.06V**. Between 2 V/div and 10 V/div, the measured noise level tripled (factor of 3x) when changing the V/div by a factor of 5x.





Dynamic range also affects timing measurements. Note below the standard deviation of risetime, falltime, pulse width, and period measurements.

Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)	P5:- - -	P6:- - -	P7:- - -	P8:- - -
value	1.648 ns	1.335 ns	400.316 ns	800.007 ns				
mean	1.63438 ns	1.33528 ns	400.27507 ns	799.99620 ns				
min	1.515 ns	1.232 ns	400.211 ns	799.922 ns				
max	1.829 ns	1.432 ns	400.340 ns	800.055 ns				
sdev	41.08 ps	30.41 ps	21.45 ps	21.12 ps				
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3				
status	✓	✓	✓	✓				

C1 DC1M
650 mV/div
-1.730 V ofst

Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s

Trigger C1
Stop 1.157 V
Edge Positive

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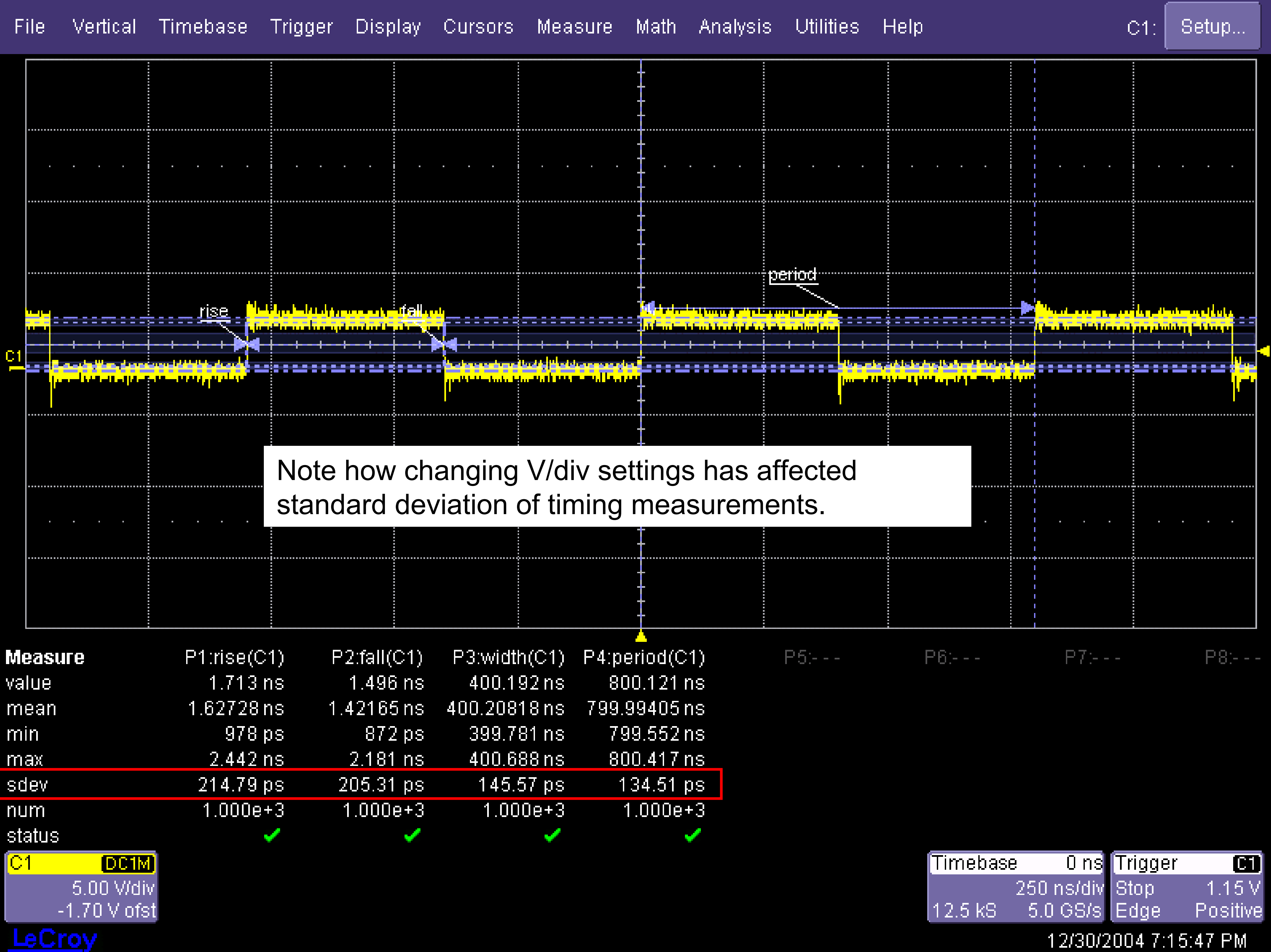
File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help C1: Setup...
rise
fall
period
C1
Note how changing V/div settings has affected standard deviation of timing measurements.
Measure P1:rise(C1) P2:fall(C1) P3:width(C1) P4:period(C1) P5:- - - P6:- - - P7:- - - P8:- - -
value 1.713 ns 1.496 ns 400.192 ns 800.121 ns
mean 1.62728 ns 1.42165 ns 400.20818 ns 799.99405 ns
min 978 ps 872 ps 399.781 ns 799.552 ns
max 2.442 ns 2.181 ns 400.688 ns 800.417 ns
sdev 214.79 ps 205.31 ps 145.57 ps 134.51 ps
num 1.000e+3 1.000e+3 1.000e+3 1.000e+3
status
C1 DC1M
5.00 V/div
-1.70 V ofst
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s
Trigger C1
Stop 1.15 V
Edge Positive
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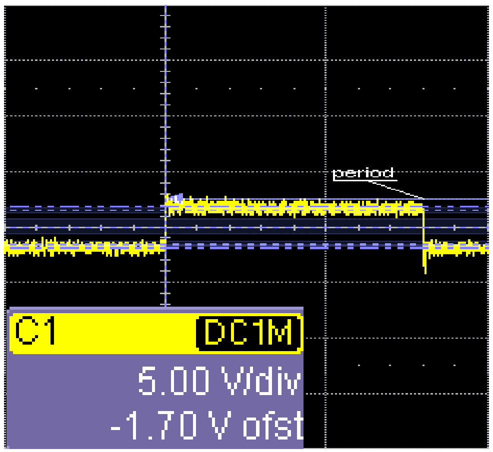
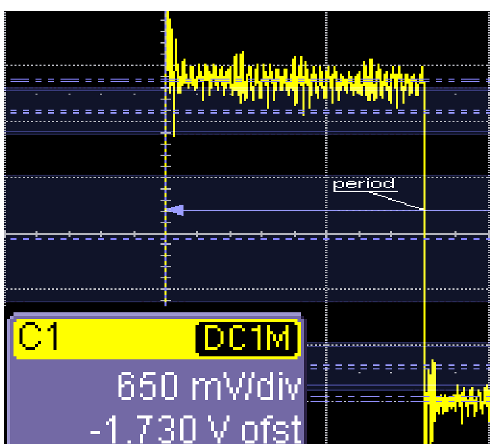
Summary: Adjusting the vertical scaling of waveforms also affects the accuracy of timing measurements.

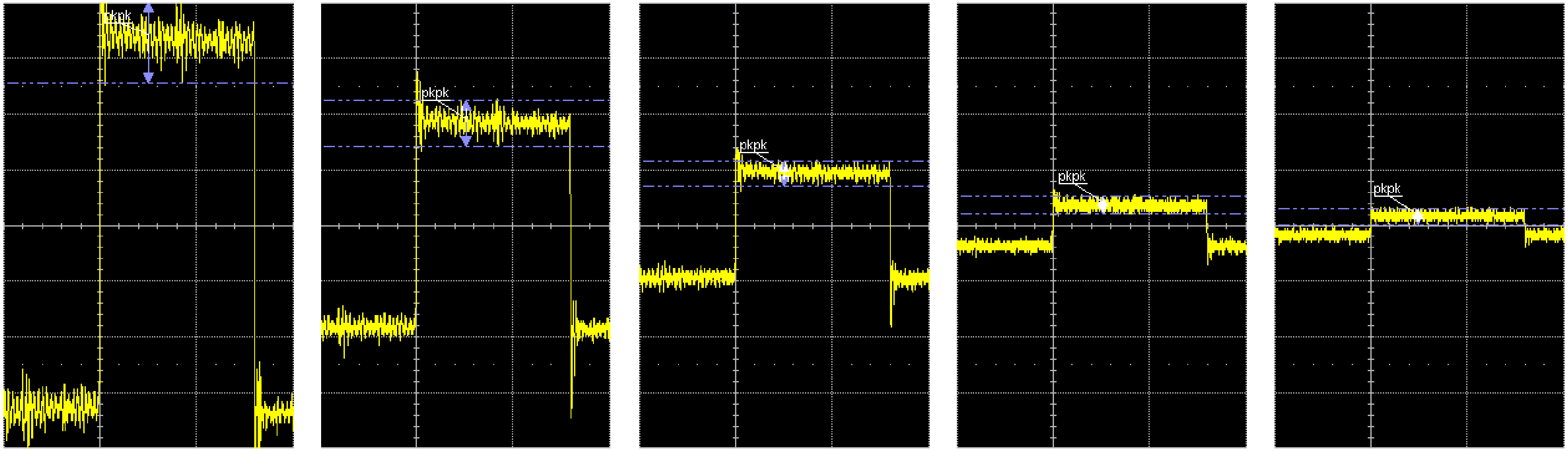


Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)
value	1.713 ns	1.496 ns	400.192 ns	800.121 ns
mean	1.62728 ns	1.42165 ns	400.20818 ns	799.99405 ns
min	978 ps	872 ps	399.781 ns	799.552 ns
max	2.442 ns	2.181 ns	400.688 ns	800.417 ns
sdev	214.79 ps	205.31 ps	145.57 ps	134.51 ps
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3



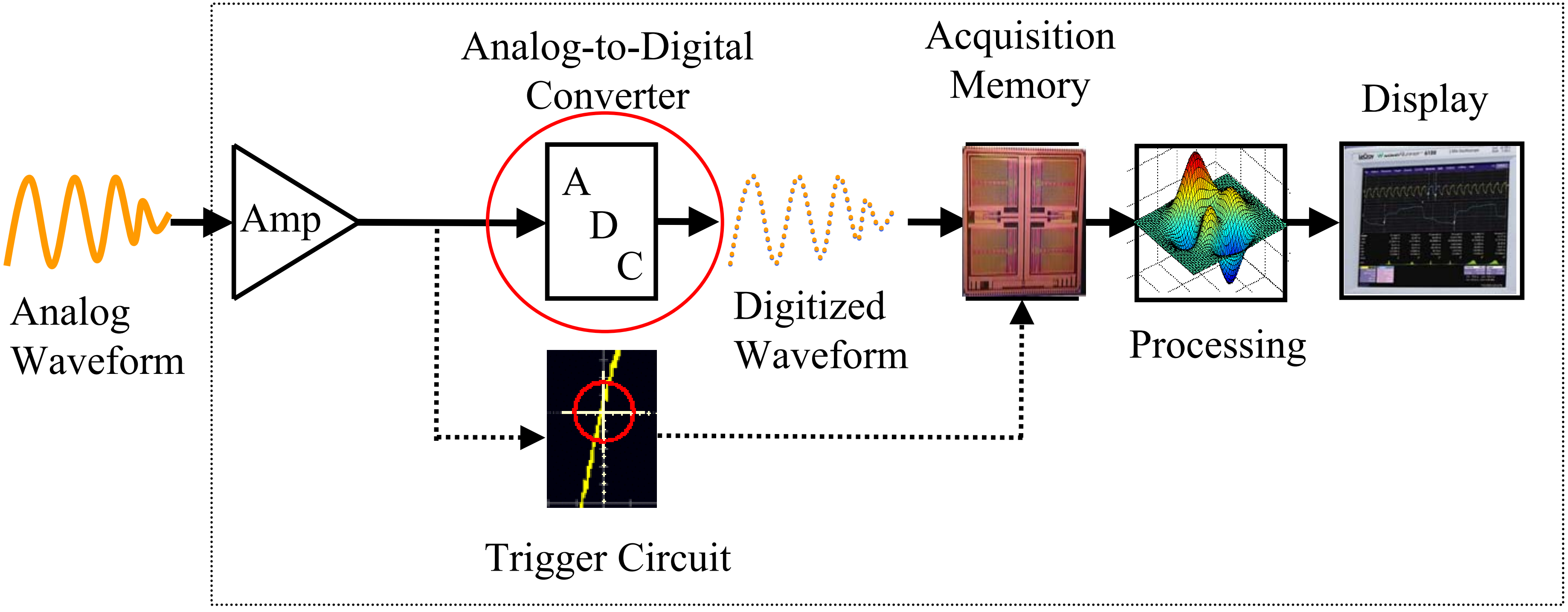
Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)
value	1.648 ns	1.335 ns	400.316 ns	800.007 ns
mean	1.63438 ns	1.33528 ns	400.27507 ns	799.99620 ns
min	1.515 ns	1.232 ns	400.211 ns	799.922 ns
max	1.829 ns	1.432 ns	400.340 ns	800.055 ns
sdev	41.08 ps	30.41 ps	21.45 ps	21.12 ps
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3

Why does measurement accuracy vary with changes in V/div setting?



Dynamic Range

When high-performance oscilloscopes acquire an input signal, the output of the amplifier is digitized by an **8-bit** analog-to-digital converter (ADC). The dynamic range of the oscilloscope is the range of signal amplitudes that the ADC can process effectively. The minimum of the range occurs where signal power equals noise power. The maximum of the range occurs at or near full scale where maximum counts of the ADC are used while digitizing the waveform, while distortion is minimized.

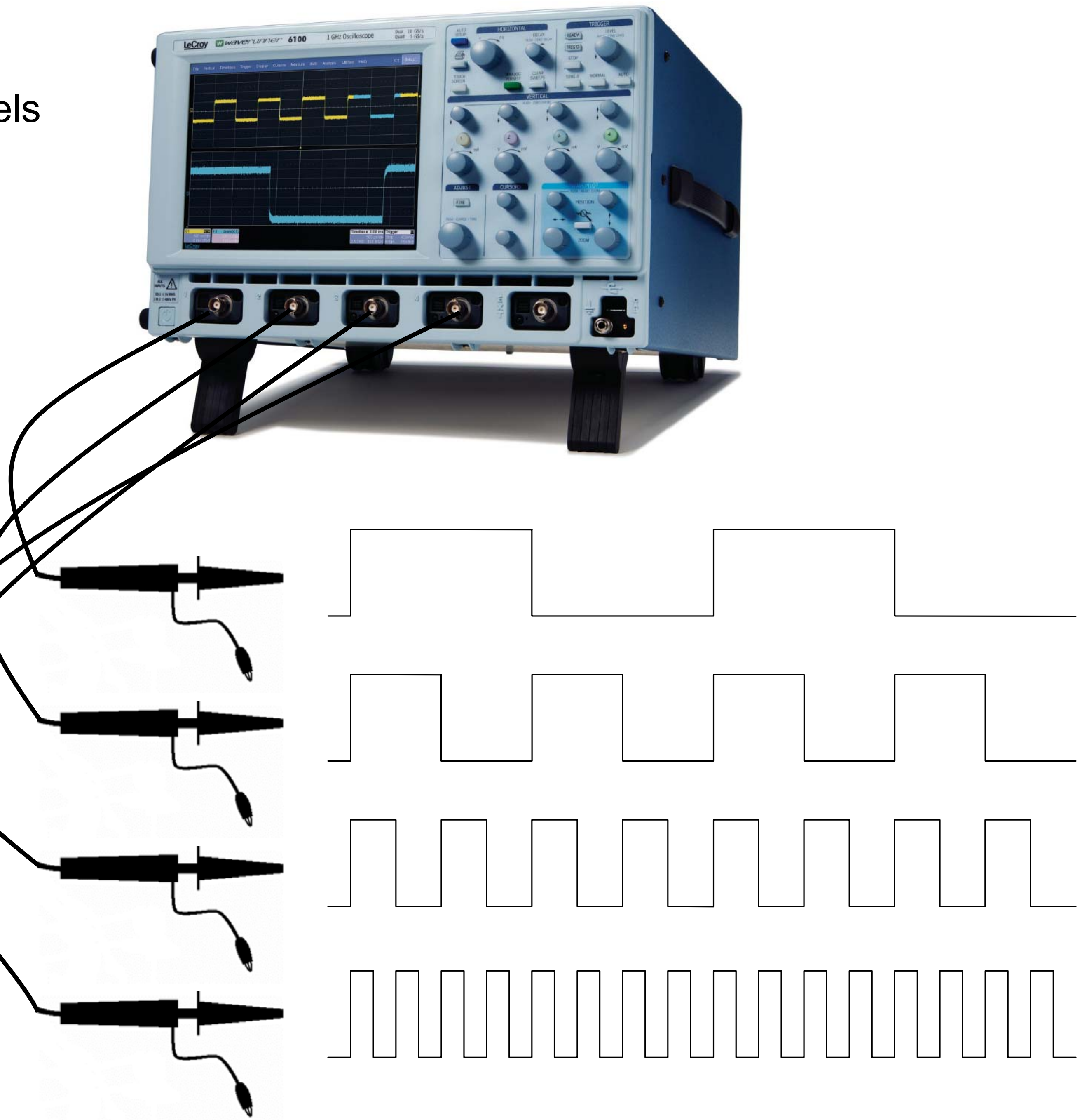


Oscilloscope Block Diagram

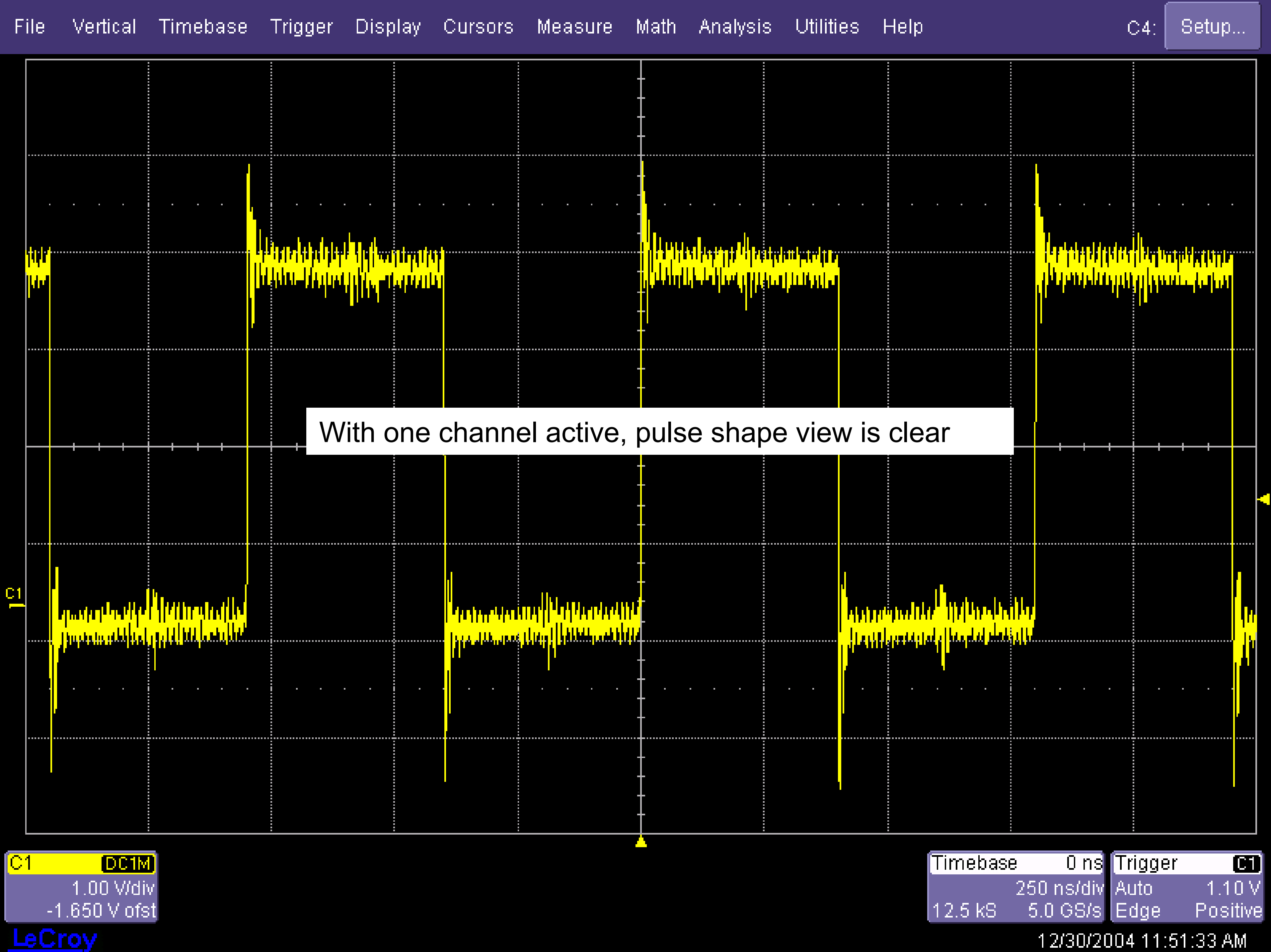
Practical Application:

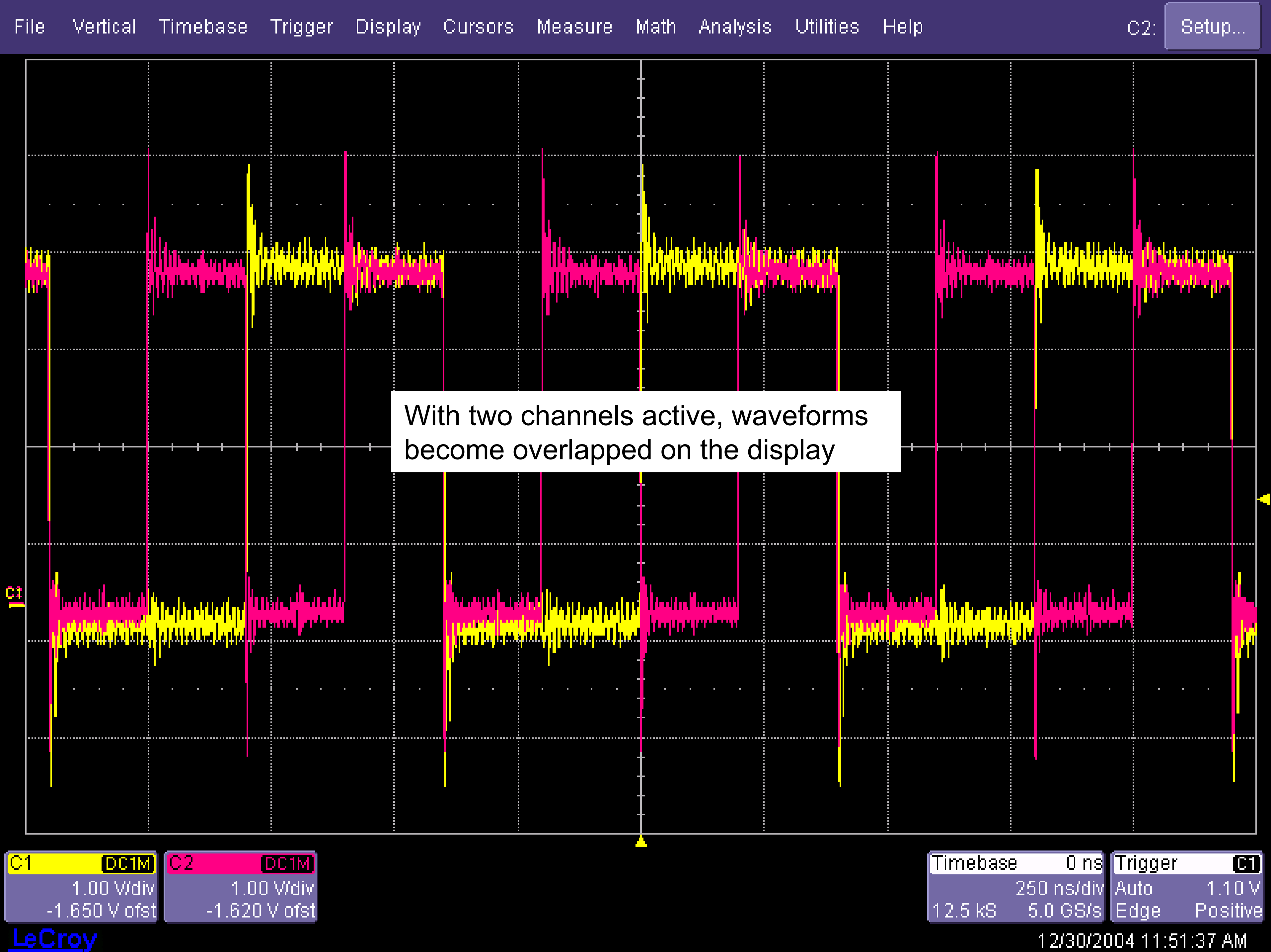
Using Multiple Channels
While Maximizing Dynamic Range

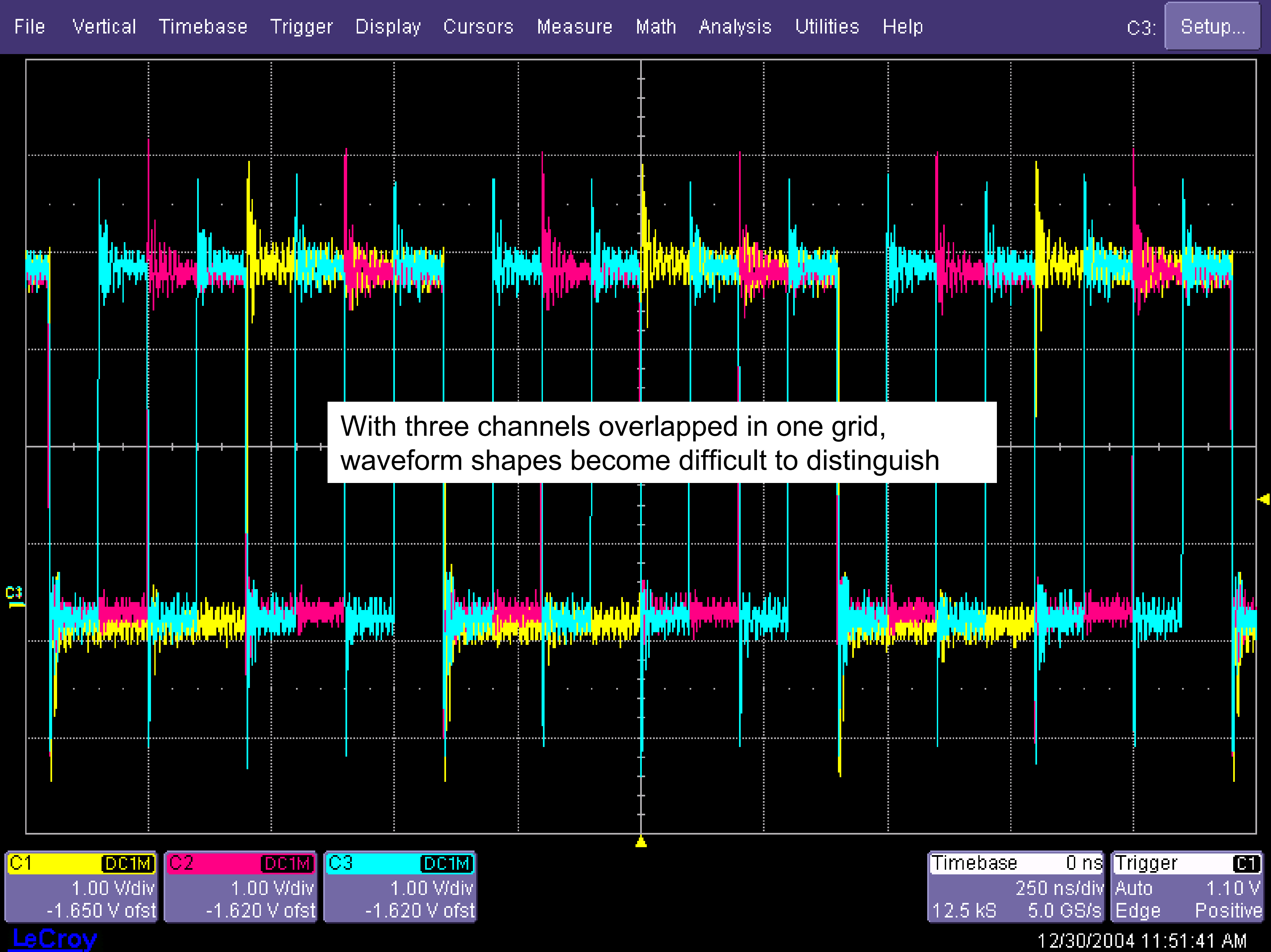
Practical Example:
Using Multiple Channels

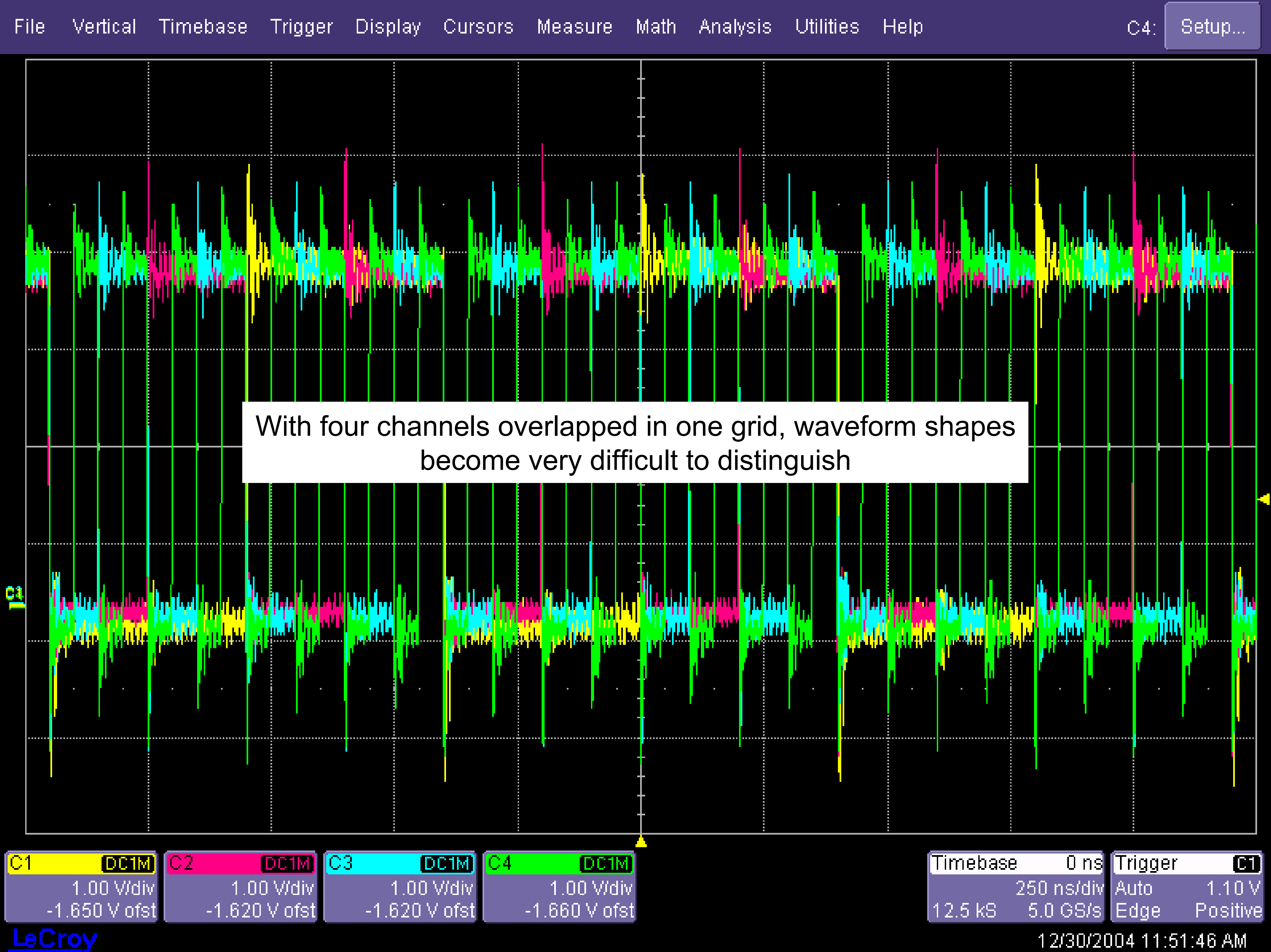


Probing four pins
of a counter circuit

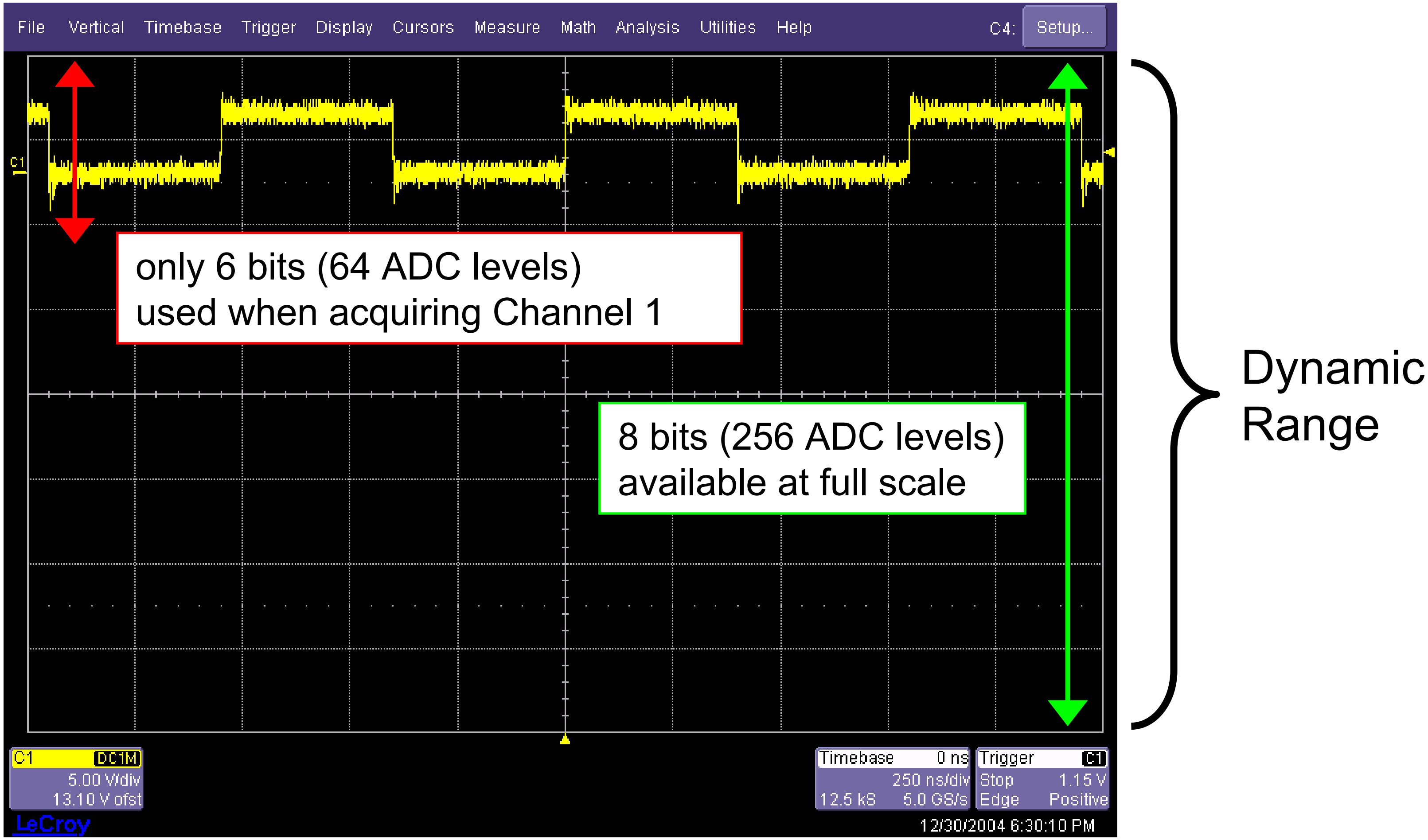

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C4: Setup...
With one channel active, pulse shape view is clear
C1
C1 DC1M
1.00 V/div
-1.650 V ofst
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s
Trigger C1
Auto 1.10 V
Edge Positive
LeCroy
12/30/2004 11:51:33 AM


File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
C2:
Setup...
With two channels active, waveforms become overlapped on the display
C1
C1 DC1M
1.00 V/div
-1.650 V ofst
C2 DC1M
1.00 V/div
-1.620 V ofst
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s
Trigger C1
Auto 1.10 V
Edge Positive
LeCroy
12/30/2004 11:51:37 AM


File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
C3:
Setup...
With three channels overlapped in one grid, waveform shapes become difficult to distinguish
C1
C1 DC1M
1.00 V/div
-1.650 V ofst
C2 DC1M
1.00 V/div
-1.620 V ofst
C3 DC1M
1.00 V/div
-1.620 V ofst
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s
Trigger C1
Auto 1.10 V
Edge Positive
LeCroy
12/30/2004 11:51:41 AM

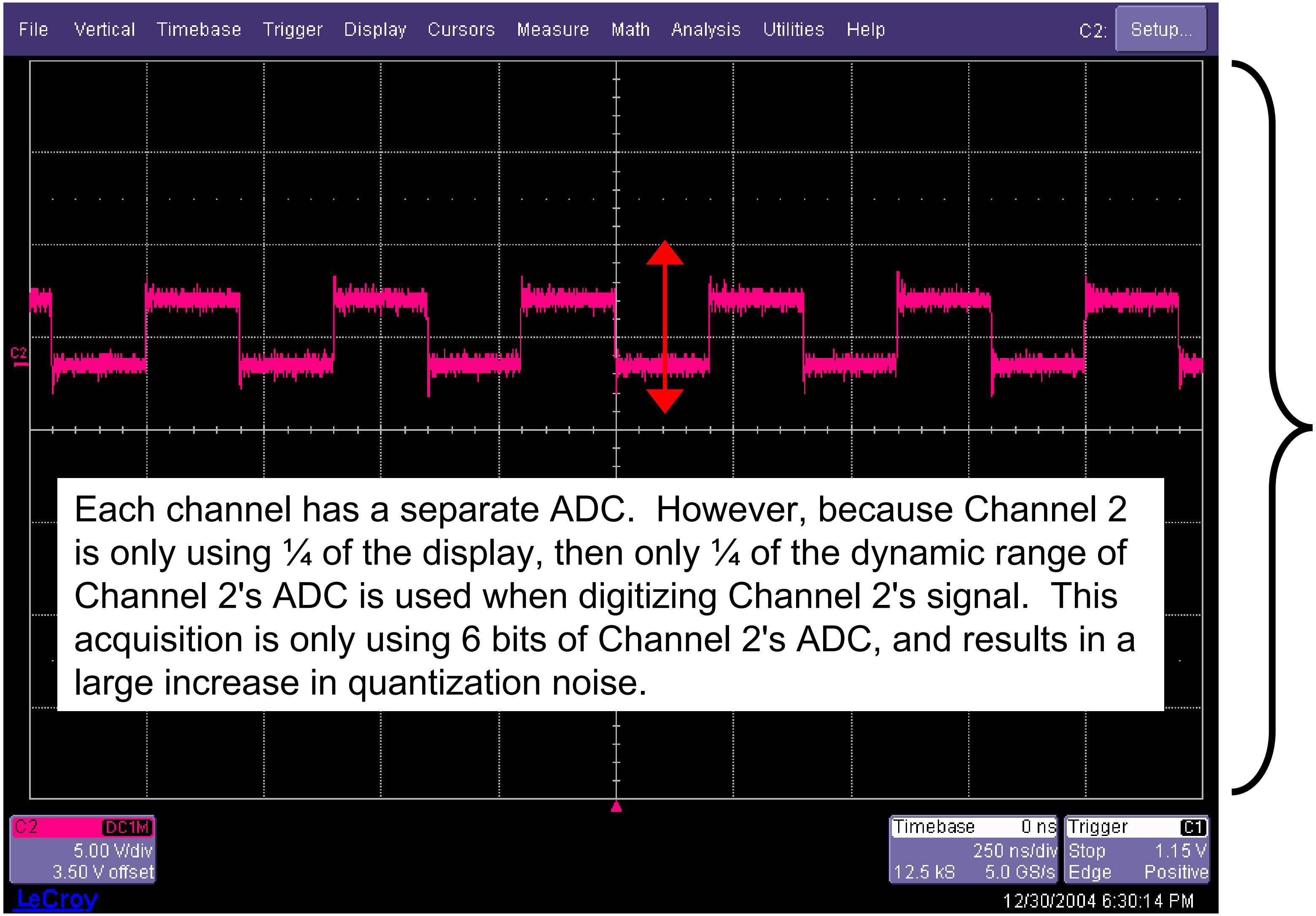

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C4: Setup...
With four channels overlapped in one grid, waveform shapes become very difficult to distinguish
C1 DC1M 1.00 V/div -1.650 V ofst
C2 DC1M 1.00 V/div -1.620 V ofst
C3 DC1M 1.00 V/div -1.620 V ofst
C4 DC1M 1.00 V/div -1.660 V ofst
Timebase 0 ns 250 ns/div 12.5 kS 5.0 GS/s
Trigger C1 Auto 1.10 V Edge Positive
LeCroy
12/30/2004 11:51:46 AM


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
C4: Setup...
C1
C2
C3
C4
What happens if vertical scaling is reduced, to fit all of the waveforms into a single grid?
C1 DC1M 5.00 V/div 13.900 V
C2 DC1M 5.00 V/div 3.300 V ofst
C3 DC1M 5.00 V/div -6.400 V ofst
C4 DC1M 5.00 V/div -15.700 V
Timebase 0 ns 250 ns/div 12.5 kS 5.0 GS/s
Trigger C1 Stop 2.70 V Edge Positive
LeCroy
12/30/2004 11:54:22 AM



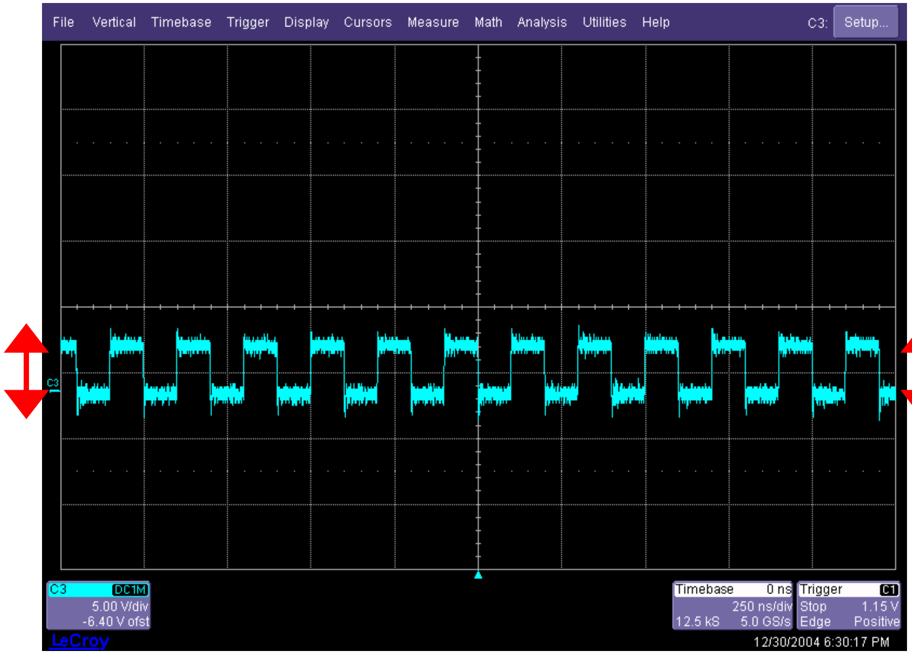
Because Channel 1 is only using ¼ of the display, only ¼ of the dynamic range of Channel 1's ADC is used when digitizing Channel 1's signal.

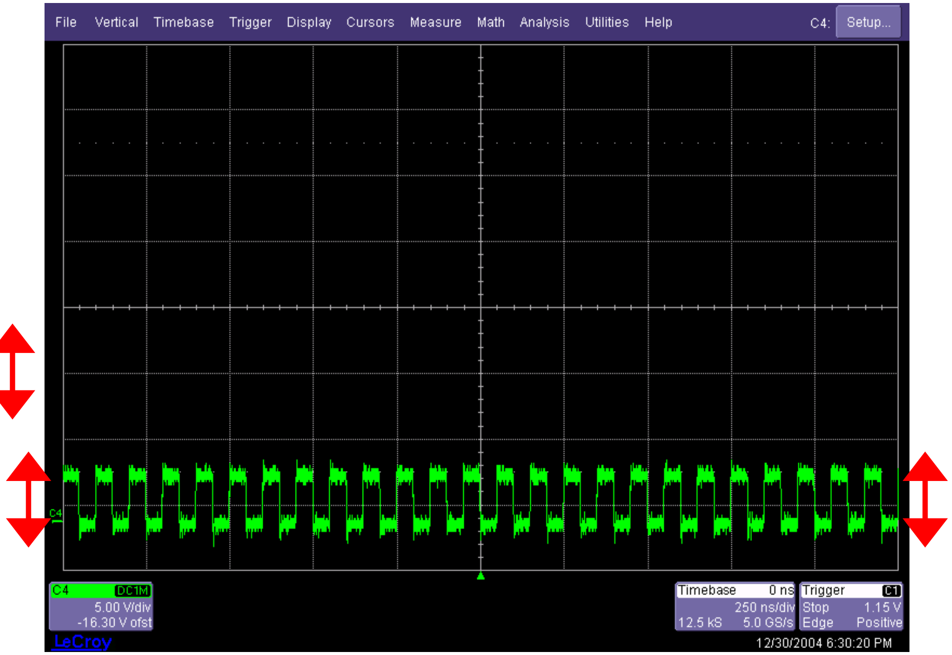
An 8-bit ADC has 2^8 = 256 quantization levels. When using ¼ of the dynamic range, only a maximum of 64 of the 256 quantization levels are used for acquiring Channel 1.
Using ¼ of quantization levels results in a maximum of 6-bit resolution on the acquired channel (2^6 = 64). This loss of resolution causes an increase in quantization noise.



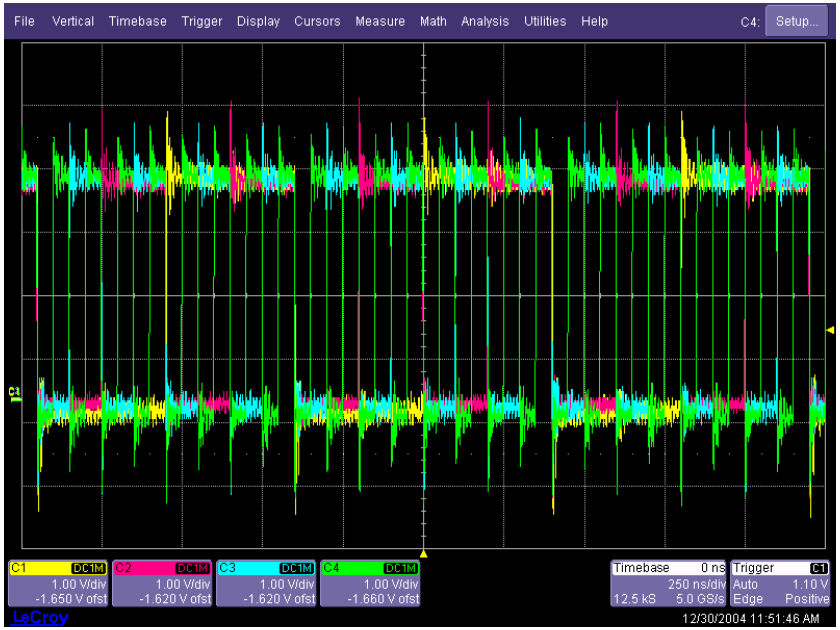
Each channel has a separate ADC. However, because Channel 2 is only using ¼ of the display, then only ¼ of the dynamic range of Channel 2's ADC is used when digitizing Channel 2's signal. This acquisition is only using 6 bits of Channel 2's ADC, and results in a large increase in quantization noise.

The same applies to Channels 3 and 4. When vertical scaling is reduced to fit four signals into the same grid, then each channel is only using ¼ of its dynamic range, which results in loss of vertical resolution and the addition of significant quantization noise.





How can the compromise between maximizing dynamic range, and clearly viewing multiple signals, be resolved?

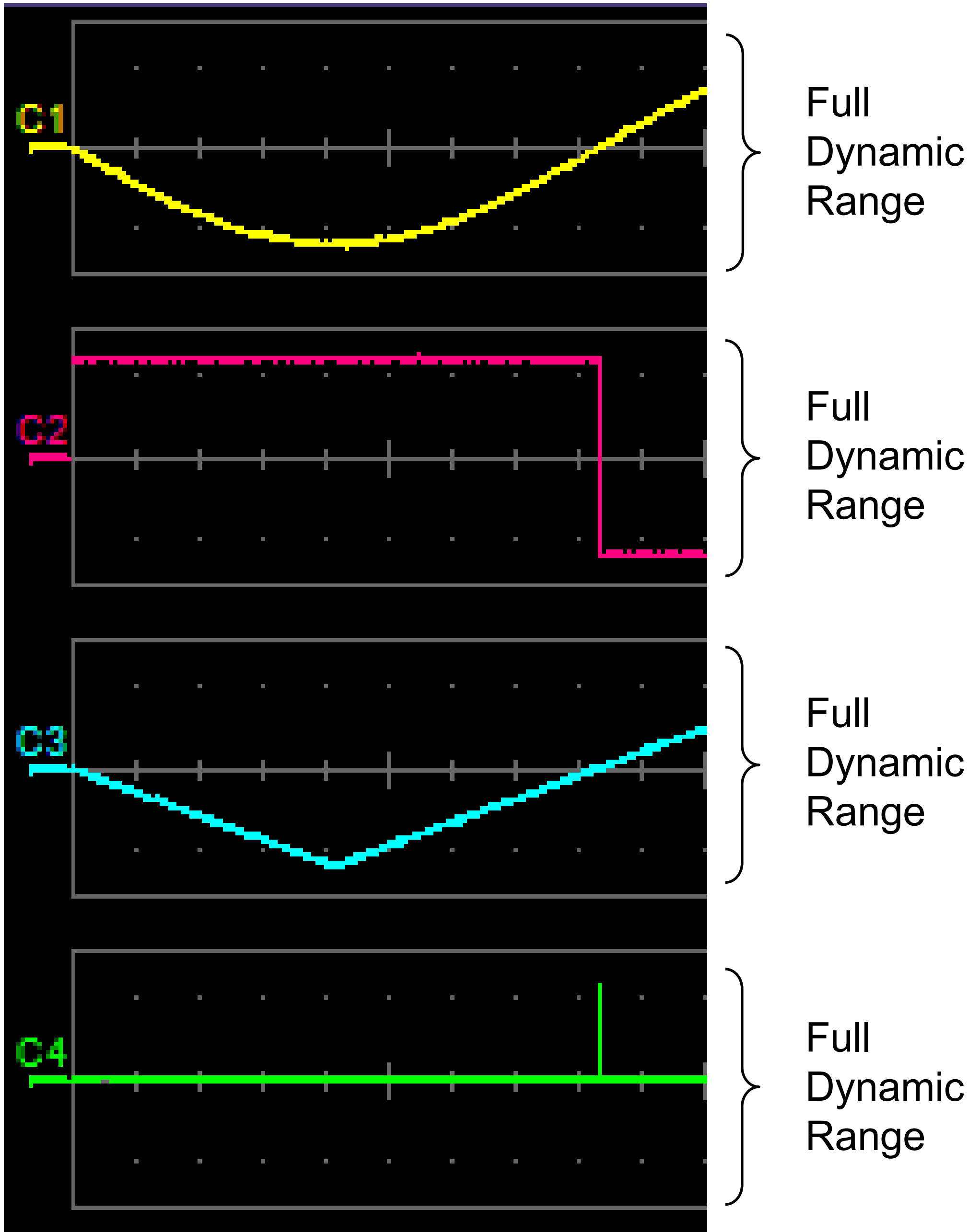


Maximize dynamic range

Clearly view all signals

Solution:

Multigrid Displays



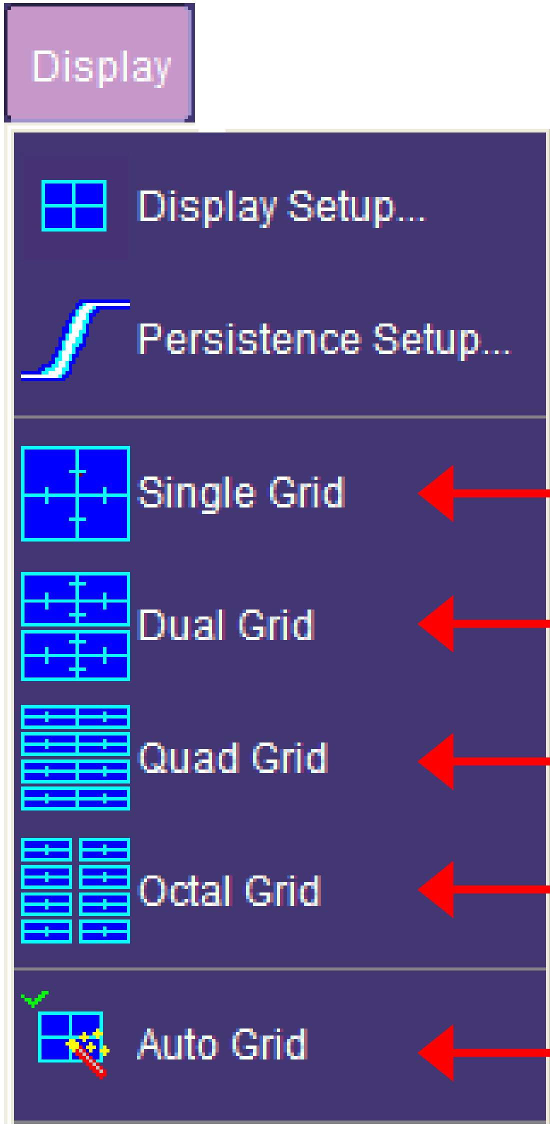
Multigrid Displays

Using Multigrid displays, each channel is contained within a separate grid.

Note that Channel 1 is fully contained within an independent grid that contains the full dynamic range of Channel 1's ADC.

The same is true for Channels 2, 3, and 4. Using Multigrid, dynamic range can be optimized while all signals are clearly viewed.

Selecting Multigrid Displays



Signals are displayed in a single grid

Signals are displayed in two grids, each with full dynamic range

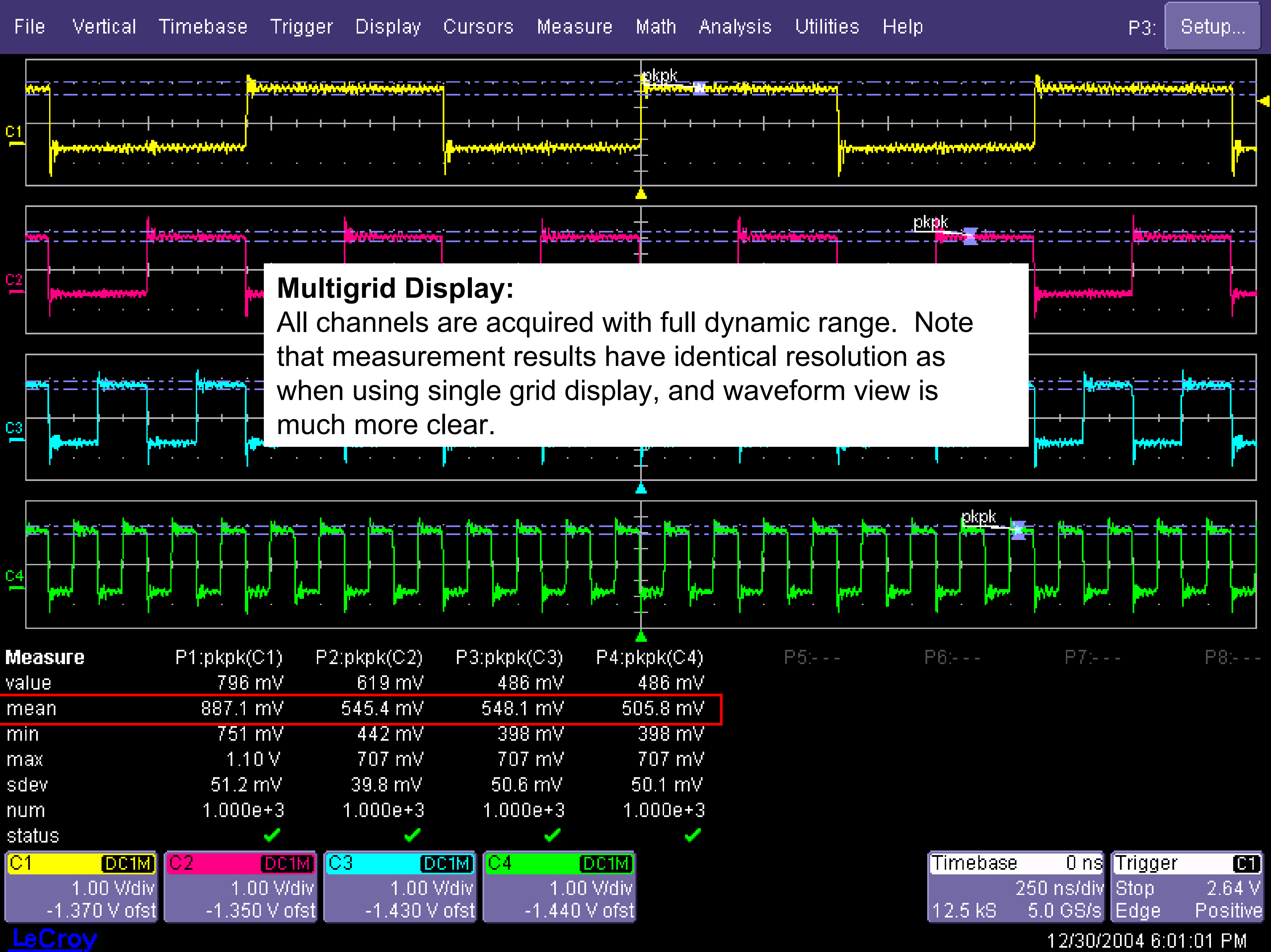
Signals are displayed in four grids, each with full dynamic range

Signals are displayed in eight grids, each with full dynamic range

Autogrid will select the optimal number of grids for the signals displayed

Multigrid displays eliminate the compromise between clearly viewing multiple channels and maximizing dynamic range.


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P3: Setup...
Single Grid Display:
When using the full dynamic range, measurements are more accurate, but waveform view is not clear
Measure P1:pkpk(C1) P2:pkpk(C2) P3:pkpk(C3) P4:pkpk(C4) P5:- - - P6:- - - P7:- - - P8:- - -
value 840 mV 663 mV 486 mV 575 mV
mean 857.2 mV 551.7 mV 540.3 mV 510.3 mV
min 751 mV 442 mV 398 mV 398 mV
max 1.06 V 663 mV 751 mV 751 mV
sdev 49.6 mV 41.8 mV 49.5 mV 50.2 mV
num 1.000e+3 1.000e+3 1.000e+3 1.000e+3
status
C1 DC1M 1.00 V/div -1.370 V ofst
C2 DC1M 1.00 V/div -1.350 V ofst
C3 DC1M 1.00 V/div -1.430 V ofst
C4 DC1M 1.00 V/div -1.440 V ofst
Timebase 0 ns 250 ns/div 12.5 kS 5.0 GS/s
Trigger C1 Stop 2.64 V Edge Positive
LeCroy
12/30/2004 6:05:08 PM

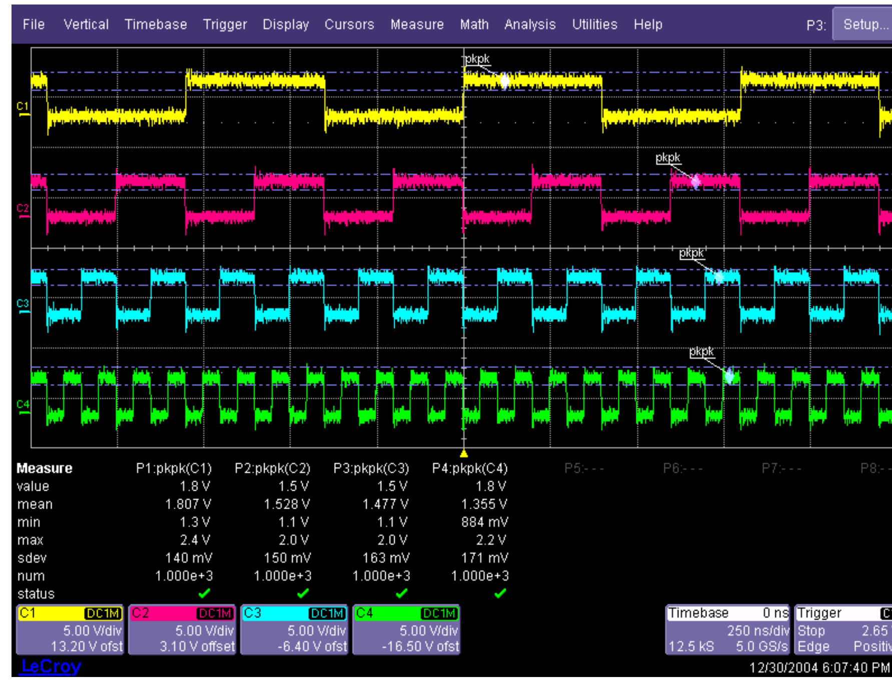


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P3: Setup...
C1
C2
C3
C4
pkpk
pkpk
pkpk
Multigrid Display:
All channels are acquired with full dynamic range. Note that measurement results have identical resolution as when using single grid display, and waveform view is much more clear.
Measure P1:pkpk(C1) P2:pkpk(C2) P3:pkpk(C3) P4:pkpk(C4) P5:- - - P6:- - - P7:- - - P8:- - -
value 796 mV 619 mV 486 mV 486 mV
mean 887.1 mV 545.4 mV 548.1 mV 505.8 mV
min 751 mV 442 mV 398 mV 398 mV
max 1.10 V 707 mV 707 mV 707 mV
sdev 51.2 mV 39.8 mV 50.6 mV 50.1 mV
num 1.000e+3 1.000e+3 1.000e+3 1.000e+3
status
C1 DC1M 1.00 V/div -1.370 V ofst
C2 DC1M 1.00 V/div -1.350 V ofst
C3 DC1M 1.00 V/div -1.430 V ofst
C4 DC1M 1.00 V/div -1.440 V ofst
Timebase 0 ns 250 ns/div 12.5 kS 5.0 GS/s
Trigger C1 Stop 2.64 V Edge Positive
LeCroy
12/30/2004 6:01:01 PM

Comparing Single Grid and Multigrid:

Shown below, the difference in noise level is apparent when acquiring the identical signal using Single Grid and Multigrid settings. The dynamic range improvement of Multigrid significantly reduces quantization noise.

Multigrid Display

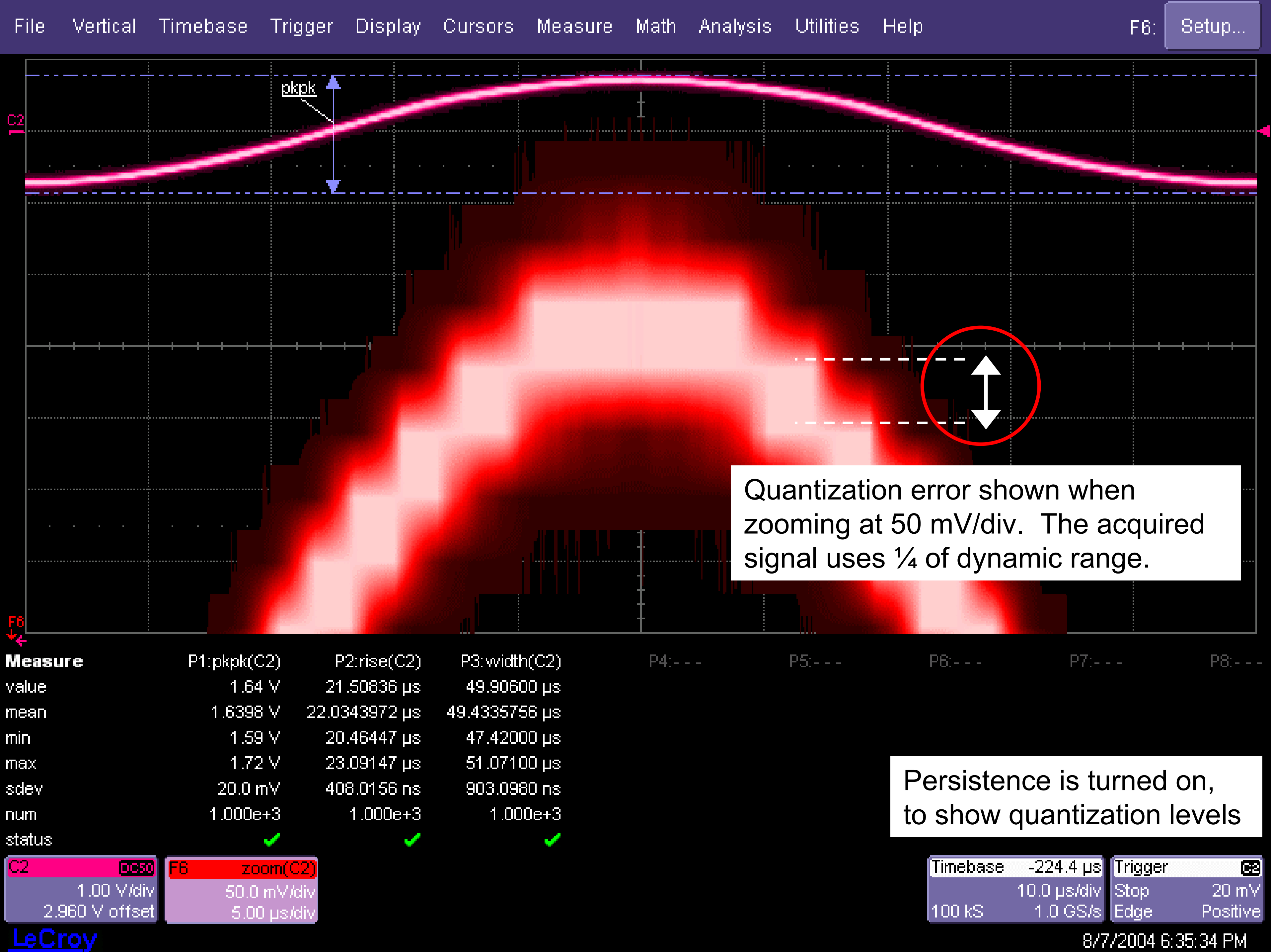


Single grid display

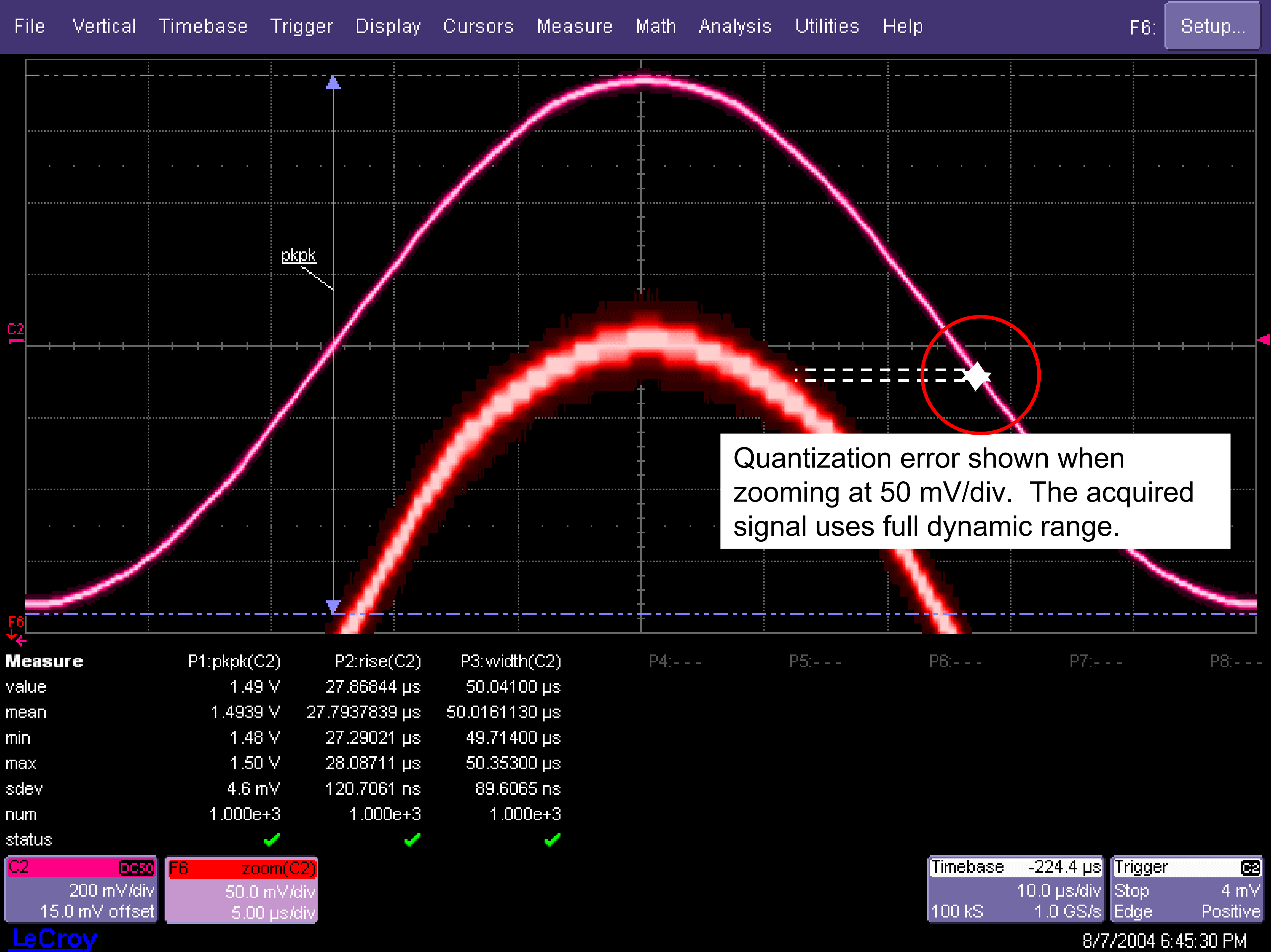
Measure	P1:pkpk(C1)	P2:pkpk(C2)	P3:pkpk(C3)	P4:pkpk(C4)
value	796 mV	619 mV	486 mV	486 mV
mean	887.1 mV	545.4 mV	548.1 mV	505.8 mV
min	751 mV	442 mV	398 mV	398 mV
max	1.10 V	707 mV	707 mV	707 mV
sdev	51.2 mV	39.8 mV	50.6 mV	50.1 mV
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3
status	✓	✓	✓	✓

Measure	P1:pkpk(C1)	P2:pkpk(C2)	P3:pkpk(C3)	P4:pkpk(C4)
value	1.8 V	1.5 V	1.5 V	1.8 V
mean	1.807 V	1.528 V	1.477 V	1.355 V
min	1.3 V	1.1 V	1.1 V	884 mV
max	2.4 V	2.0 V	2.0 V	2.2 V
sdev	140 mV	150 mV	163 mV	171 mV
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3
status	✓	✓	✓	✓

Viewing Quantization Noise

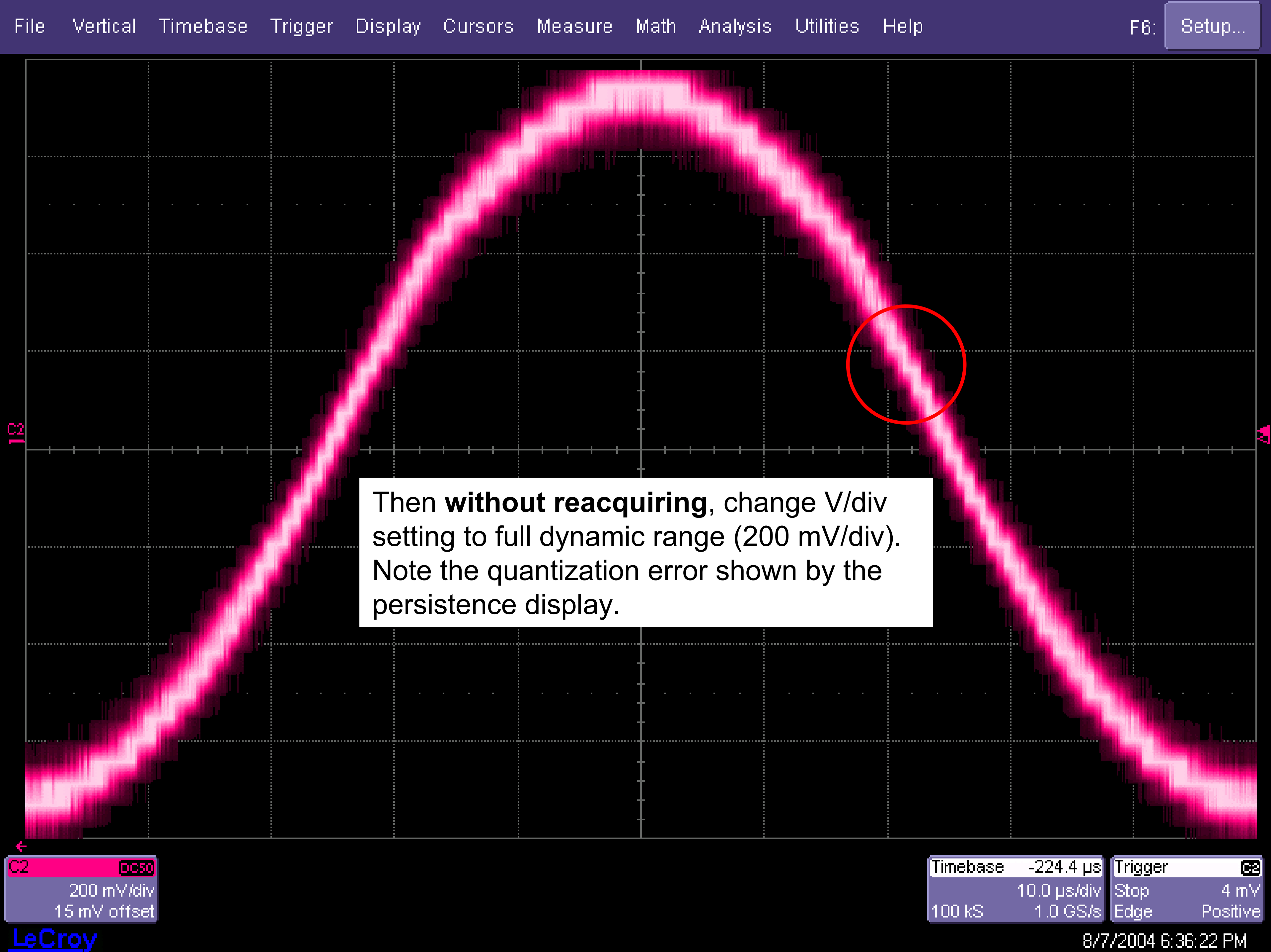


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
F6: Setup...
pkpk
C2
F6
Quantization error shown when zooming at 50 mV/div. The acquired signal uses ¼ of dynamic range.
Measure | P1:pkpk(C2) | P2:rise(C2) | P3:width(C2) | P4:- - - | P5:- - - | P6:- - - | P7:- - - | P8:- - -
value | 1.64 V | 21.50836 µs | 49.90600 µs
mean | 1.6398 V | 22.0343972 µs | 49.4335756 µs
min | 1.59 V | 20.46447 µs | 47.42000 µs
max | 1.72 V | 23.09147 µs | 51.07100 µs
sdev | 20.0 mV | 408.0156 ns | 903.0980 ns
num | 1.000e+3 | 1.000e+3 | 1.000e+3
status
Persistence is turned on, to show quantization levels
C2 DC50 1.00 V/div 2.960 V offset
F6 zoom(C2) 50.0 mV/div 5.00 µs/div
Timebase -224.4 µs 10.0 µs/div 100 kS 1.0 GS/s
Trigger C2 Stop 20 mV Edge Positive
LeCroy
8/7/2004 6:35:34 PM

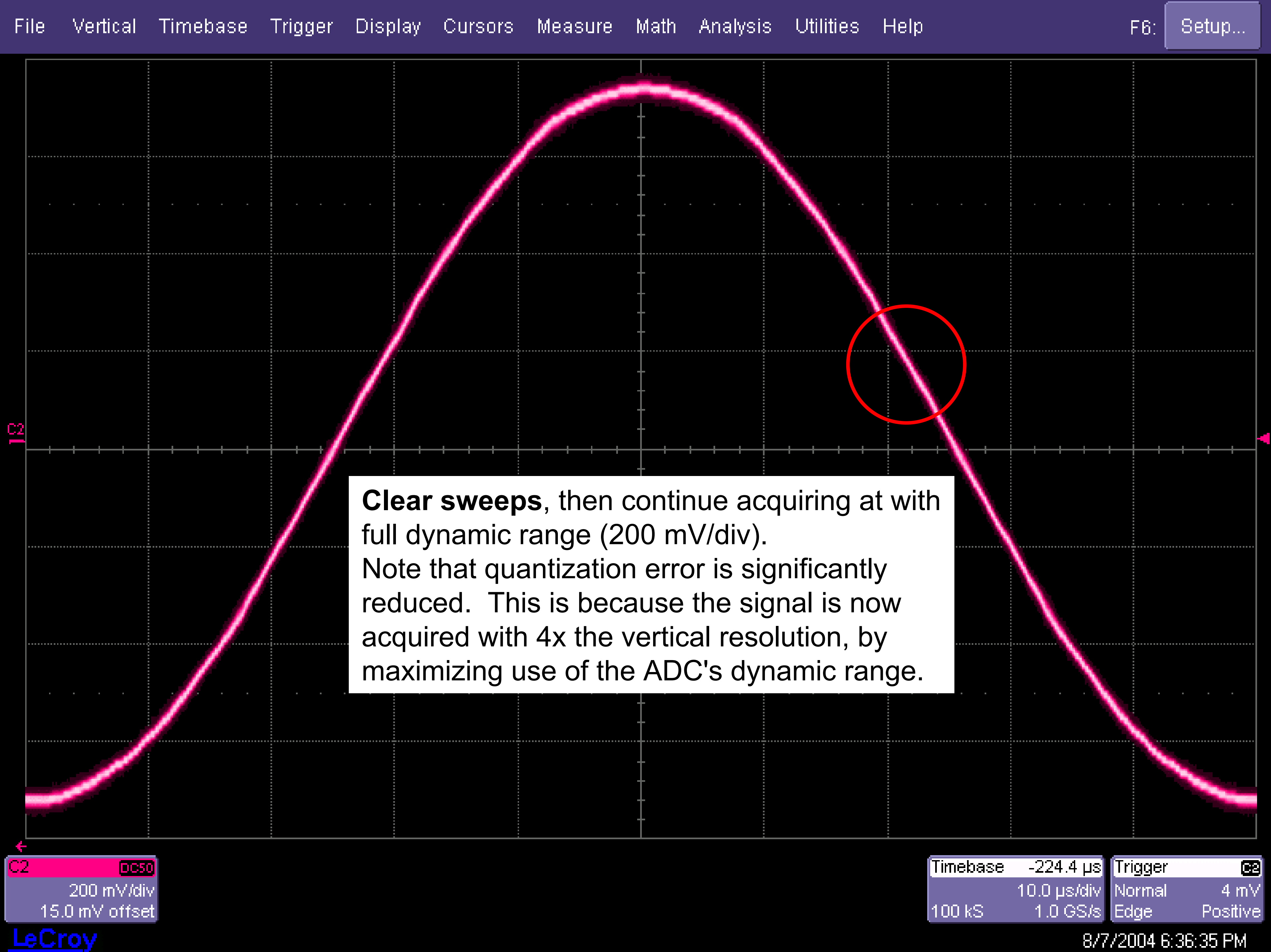


File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
F6:
Setup...
pkpk
C2
F6
Quantization error shown when zooming at 50 mV/div. The acquired signal uses full dynamic range.
Measure
P1:pkpk(C2)
P2:rise(C2)
P3:width(C2)
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
value 1.49 V 27.86844 µs 50.04100 µs
mean 1.4939 V 27.7937839 µs 50.0161130 µs
min 1.48 V 27.29021 µs 49.71400 µs
max 1.50 V 28.08711 µs 50.35300 µs
sdev 4.6 mV 120.7061 ns 89.6065 ns
num 1.000e+3 1.000e+3 1.000e+3
status
C2 DC50
200 mV/div
15.0 mV offset
F6 zoom(C2)
50.0 mV/div
5.00 µs/div
Timebase -224.4 µs
10.0 µs/div
100 kS 1.0 GS/s
Trigger C2
Stop 4 mV
Edge Positive
LeCroy
8/7/2004 6:45:30 PM

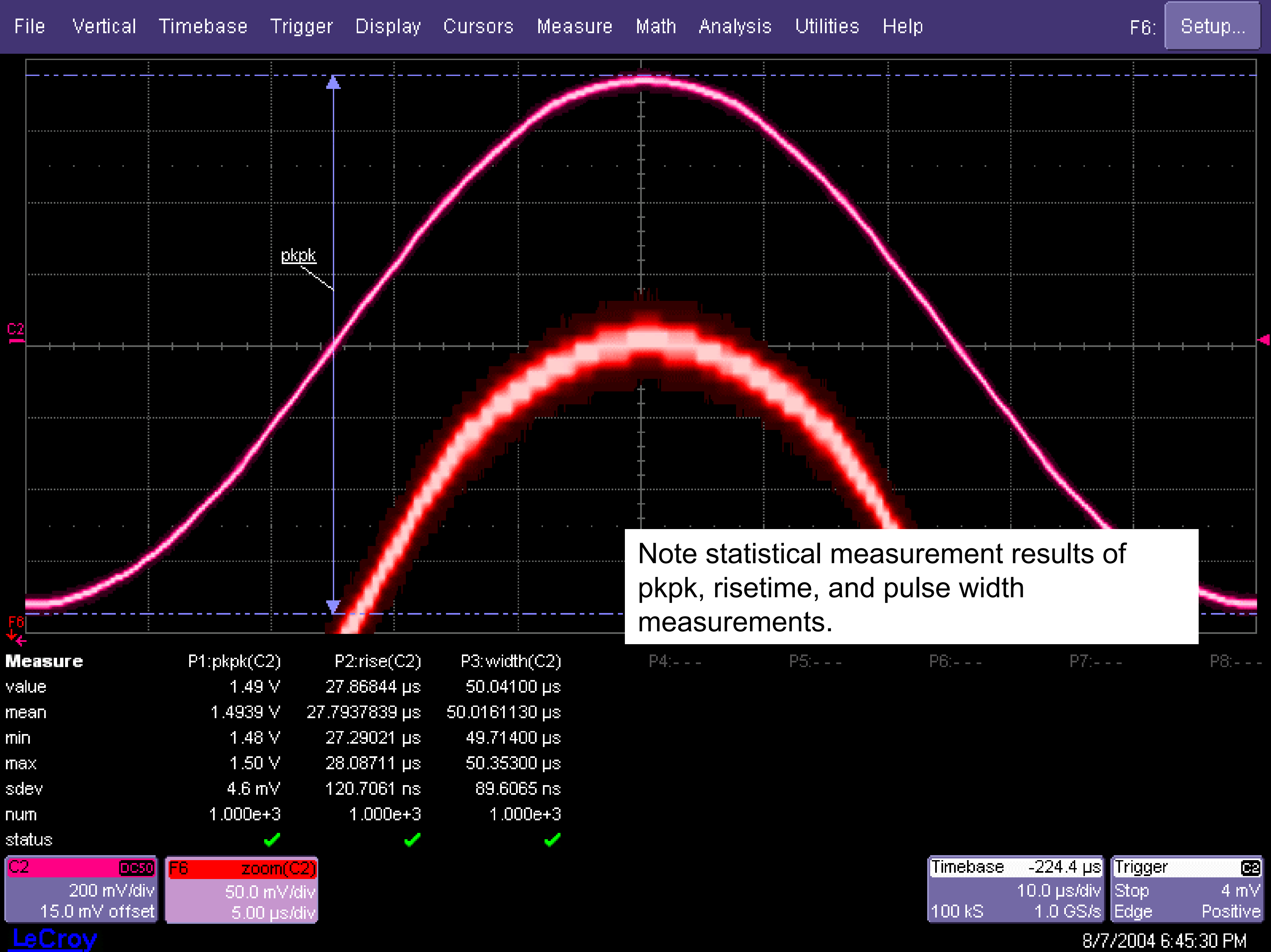

File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
F6:
Setup...
C2
Alternately, with persistence on, acquire the signal using ¼ of the full dynamic range.
C2 DC50
990 mV/div
2.940 V offset
LeCroy
Timebase -224.4 µs
10.0 µs/div
100 kS 1.0 GS/s
Trigger C2
Stop 20 mV
Edge Positive
8/7/2004 6:31:44 PM

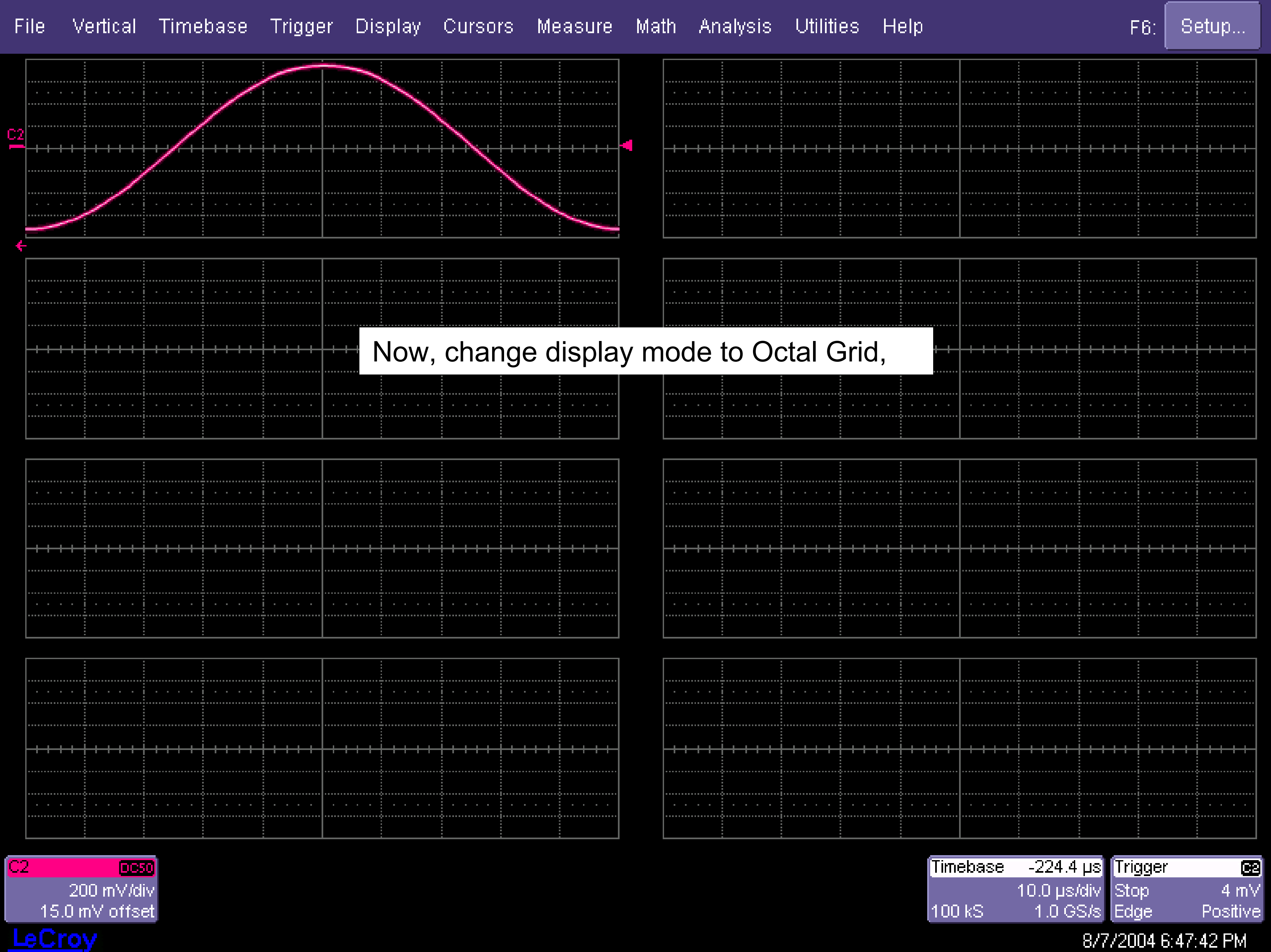


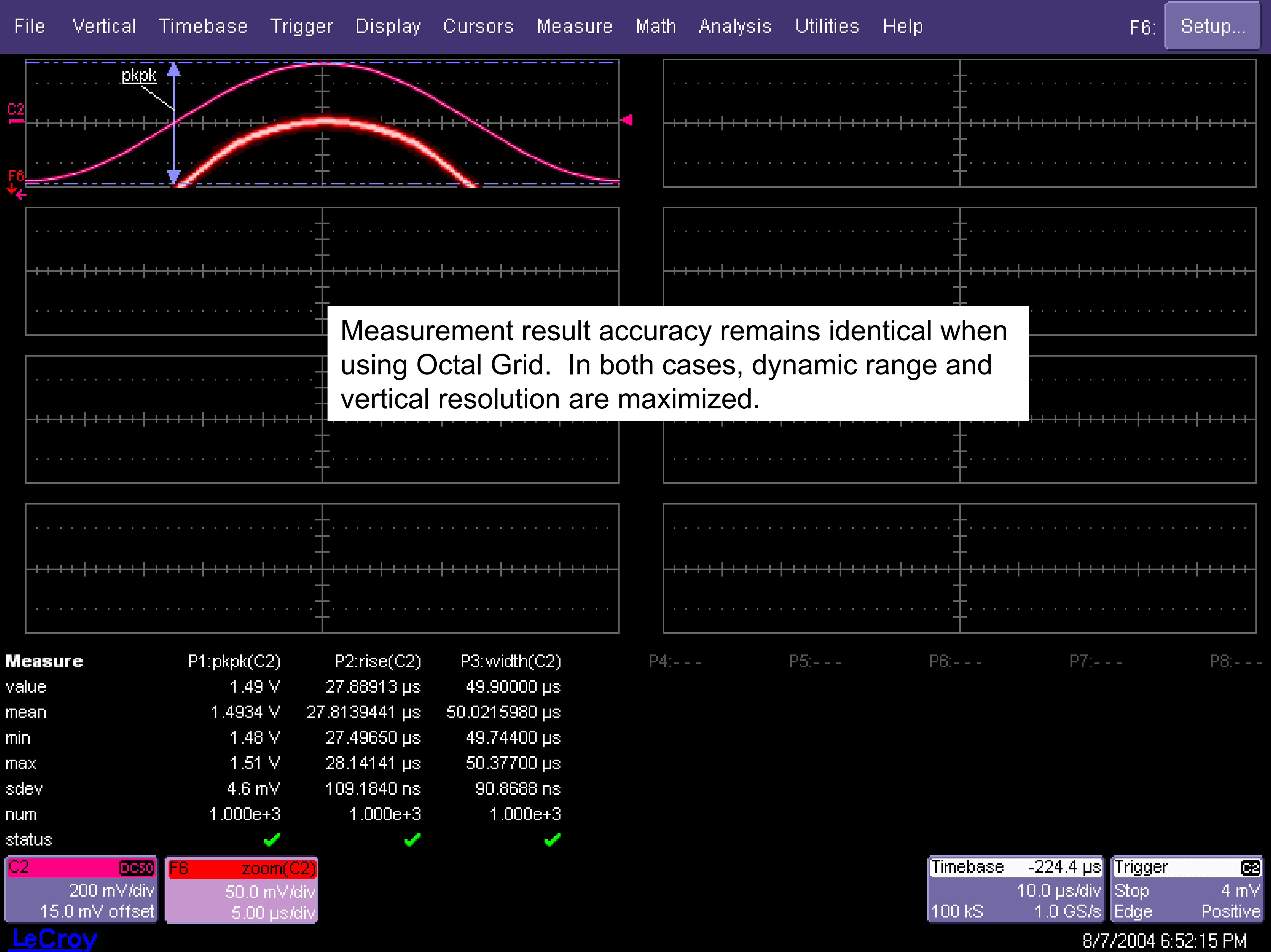
Then **without reacquiring**, change V/div setting to full dynamic range (200 mV/div). Note the quantization error shown by the persistence display.



File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
F6: Setup...
C2
Clear sweeps, then continue acquiring at with full dynamic range (200 mV/div).
Note that quantization error is significantly reduced. This is because the signal is now acquired with 4x the vertical resolution, by maximizing use of the ADC's dynamic range.
C2 DC50
200 mV/div
15.0 mV offset
Timebase -224.4 µs
10.0 µs/div
100 kS 1.0 GS/s
Trigger C2
Normal 4 mV
Edge Positive
LeCroy
8/7/2004 6:36:35 PM

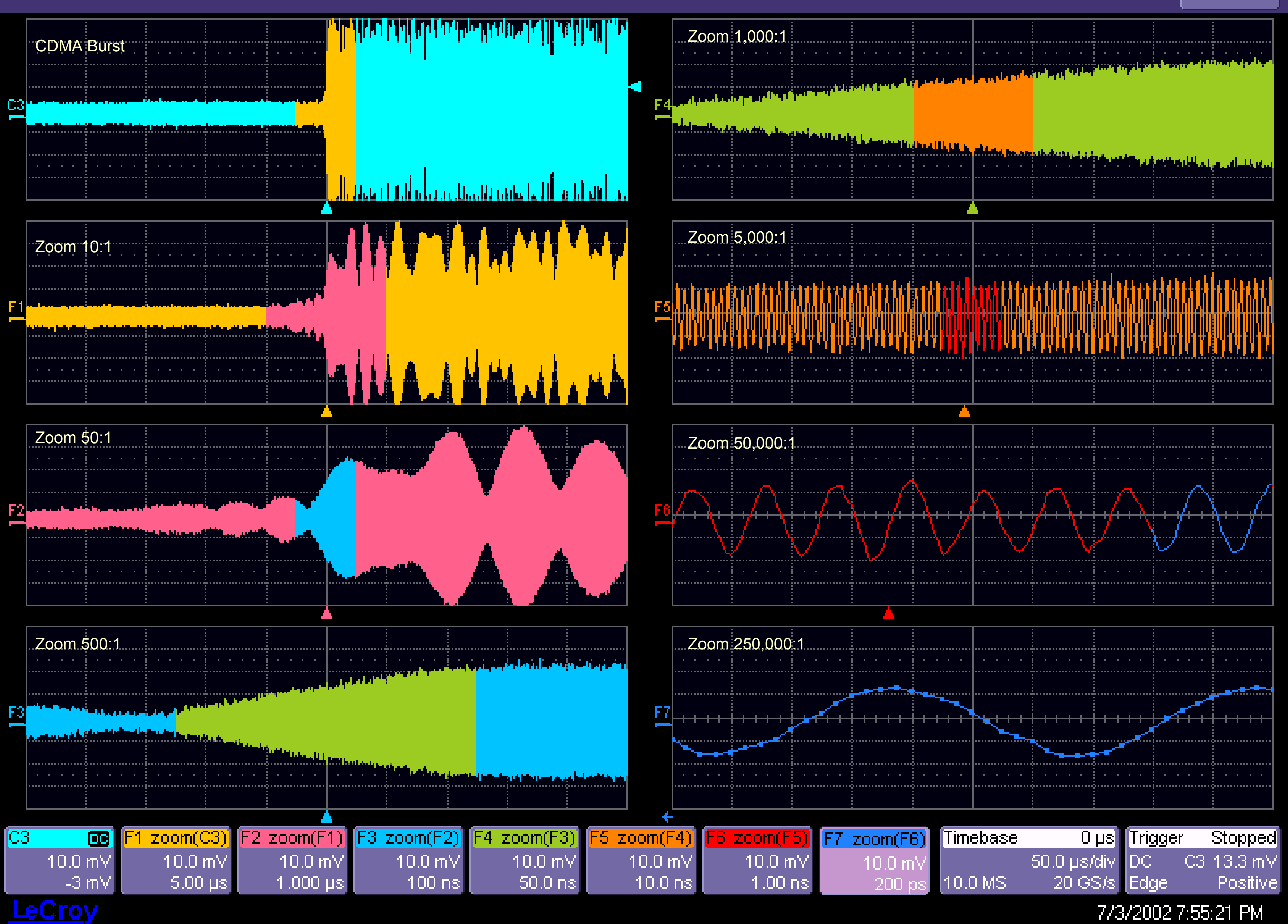

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
F6: Setup...
pkpk
C2
F6
Note statistical measurement results of pkpk, risetime, and pulse width measurements.
Measure P1:pkpk(C2) P2:rise(C2) P3:width(C2) P4:- - - P5:- - - P6:- - - P7:- - - P8:- - -
value 1.49 V 27.86844 µs 50.04100 µs
mean 1.4939 V 27.7937839 µs 50.0161130 µs
min 1.48 V 27.29021 µs 49.71400 µs
max 1.50 V 28.08711 µs 50.35300 µs
sdev 4.6 mV 120.7061 ns 89.6065 ns
num 1.000e+3 1.000e+3 1.000e+3
status
C2 DC50
200 mV/div
15.0 mV offset
F6 zoom(C2)
50.0 mV/div
5.00 µs/div
Timebase -224.4 µs
10.0 µs/div
100 kS 1.0 GS/s
Trigger C2
Stop 4 mV
Edge Positive
LeCroy
8/7/2004 6:45:30 PM


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
F6: Setup...
C2
Now, change display mode to Octal Grid,
C2 DC50
200 mV/div
15.0 mV offset
Timebase -224.4 µs
10.0 µs/div
100 kS 1.0 GS/s
Trigger C2
Stop 4 mV
Edge Positive
LeCroy
8/7/2004 6:47:42 PM



Measurement result accuracy remains identical when using Octal Grid. In both cases, dynamic range and vertical resolution are maximized.

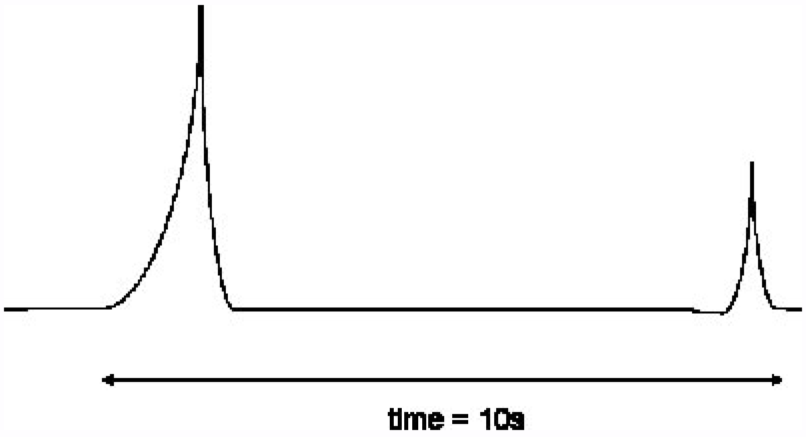
Real Application: Using Octal Grid to View Multizoomed Data Burst at a 250,000:1 ratio



Reference Slides

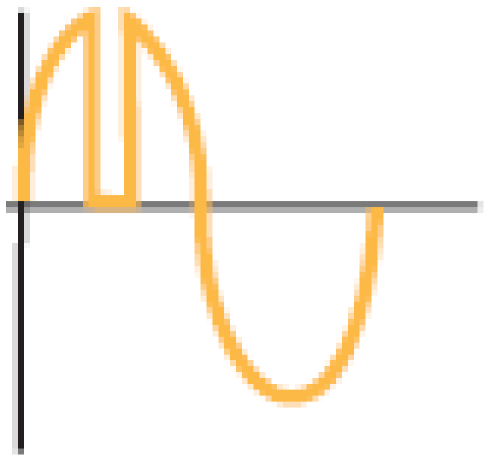
Transient Testing (Automotive)

- Pulse Characteristics
  - Capacitive load dump
  - Inductive kickback/spike (back EMF from motor turn off)
- Measurement Needs
  - Capture Time – longer the better:
    - Relay bounce (μs to ms)
    - Transient time
      - μs (motor)
      - ns (FET switch)
    - Measure 50-100 MHz transient
    - 10s capture = 2Mpts at 100 MHz Sample Rate



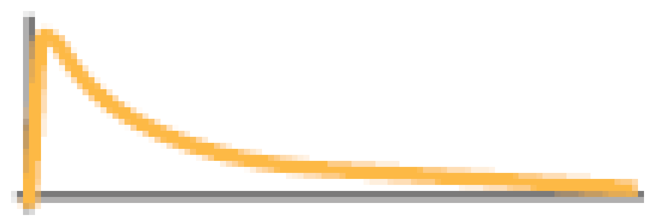
Dropout and Interrupt Testing

- Monitor AC or DC voltage line with oscilloscope during EMC testing
- Verify that dropout or interrupt occurred, and that device under test was unaffected



Surge Testing

- Pulse Characteristics
  - T_{rise} = typically 1.2 to 10 μs
  - T_{fall} = typically 20 to 10,000μs
- Measurement Needs
  - Capture a Single Pulse
  - Measure one pulse, verify rise and fall time




File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P1: Setup...
Standard scope measurements revert to peak-to-peak if Top and Base are not found. (Compare risetime value below to risetime value in next slide.)
rise@lv
M1
Measure
value
status
P1:rise@lv(M1)
896 ps
P2:- - -
P3:- - -
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1
50 V/div
25.0 ns/div
Timebase 0 ns
50.0 ns/div
5.00 kS 10 GS/s
Trigger C1
Stop 0.0 mV
Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
Rise at level Gate Accept
Close
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
M1
Measure
Rise@level
Summary
rise@lv(M1)
Actions for P1
Histogram
Trend
Track
Help
Markers
Detailed
Always On
Slew Rate for % or absolute levels of rising or falling edges.
TOP
BASE
Levels are
Percent
High percent
90 %
Low percent
10 %
Set Levels to 10% and 90%
Set Levels to 20% and 80%
LeCroy
11/27/2005 7:21:37 PM


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P1: Setup...
Standard scope measurements revert to peak-to-peak if Top and Base are not found. (Compare risetime value below to risetime value in previous slide.)
rise@lv
M1
Measure
value
status
P1:rise@lv(M1)
854 ps
P2:- - -
P3:- - -
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1
50 V/div
25.0 ns/div
Timebase 0 ns
50.0 ns/div
5.00 kS 10 GS/s
Trigger C1
Stop 0.0 mV
Edge Positive
Measure
P1
P2
P3
P4
P5
P6
P7
P8
Rise at level
Gate
Accept
Close
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
M1
Measure
Rise@level
Summary
rise@lv(M1)
Actions for P1
Histogram
Trend
Track
Help
Markers
Detailed
Always On
Slew Rate for % or absolute levels of rising or falling edges.
Levels are
% 0-Max
High percent
90 %
Low percent
10 %
Set Levels to 10% and 90%
Set Levels to 20% and 80%
LeCroy
11/27/2005 7:22:12 PM

File
Vertical
Timebase
Trigger
Display
Cursors
Measure
Math
Analysis
Utilities
Help
P1:
Setup...
Effect of thresholds on the Width measurement of this ESD pulse
wid@lv
M1
Measure
value
status
P1:wid@lv(M1)
13.246 ns
P2:- - -
P3:- - -
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1
50 V/div
25.0 ns/div
Timebase 0 ns
50.0 ns/div
5.00 kS 10 GS/s
Trigger C1
Stop 0.0 mV
Edge Positive
Measure
P1
P2
P3
P4
P5
P6
P7
P8
Width at Level
Gate
Accept
Close
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
M1
Measure
Width@level
Summary
wid@lv(M1)
Actions for P1
Histogram
Trend
Track
Help
Markers
Detailed
Always On
Time between two transitions of opposite slope at a specified level. (Slope specified for 1st transition)
Level is
% 0-Max
Percent level
50 %
Find level
Slope
Pos
Hyst. Type
Divisions
Hysteresis
500 mdiv
LeCroy
11/27/2005 7:24:06 PM


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P1: Setup...
Effect of thresholds on the Width measurement of this ESD pulse
wid@lv
M1
Measure
value
status
P1:wid@lv(M1)
23.084 ns
P2:- - -
P3:- - -
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1
50 V/div
25.0 ns/div
Timebase 0 ns
50.0 ns/div
5.00 kS 10 GS/s
Trigger C1
Stop 0.0 mV
Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
M1
Measure
Width@level
Summary
wid@lv(M1)
Actions for P1
Histogram
Trend
Track
Help
Markers
Detailed
Always On
Width at Level
Gate
Accept
Close
Time between two transitions of opposite slope at a specified level. (Slope specified for 1st transition)
Level is
Percent
Percent level
50 %
Find level
Slope
Pos
Hyst. Type
Divisions
Hysteresis
500 mdiv
LeCroy
11/27/2005 7:23:41 PM

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
P1: Setup...
Effect of thresholds on the Width measurement of this ESD pulse
wid@lv
M1
Measure
value
status
P1:wid@lv(M1)
83.106 ns
P2:- - -
P3:- - -
P4:- - -
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1
50 V/div
25.0 ns/div
Timebase 0 ns
50.0 ns/div
5.00 kS 10 GS/s
Trigger C1
Stop 0.0 mV
Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1
M1
Measure
Width@level
Summary
wid@lv(M1)
Actions for P1
Histogram
Trend
Track
Help
Markers
Detailed
Always On
Width at Level
Gate
Accept
Close
Time between two transitions of opposite slope at a specified level. (Slope specified for 1st transition)
Level is
Absolute
Absolute level
52.2 V
Find level
Slope
Pos
Hyst. Type
Divisions
Hysteresis
500 mdiv
LeCroy
11/27/2005 7:25:19 PM


File Vertical Timebase Trigger Display Cursors Measure
The pulse width and risetime are measured, both with and without EMC thresholds applied. In parameter 1 (P1), the thresholds are set to 0% - Max, and the pulse width is measured correctly as 2.109 nanoseconds. In parameter 2 (P2), the thresholds are set to the standard scope threshold of 50% of Top and Base. In this case, the measurement is incorrectly reported as 50.348 nanoseconds -- an error of 2287%. The width measurement was impacted so significantly, that the 50% threshold between Top and Base actually produced a width measurement on the wrong pulse shape. Parameter 3 (P3) is set to the correct EMC threshold of 0% to Max, producing a correct electrostatic pulse risetime measurement of 833 picoseconds. Notice that in parameter 4 (P4), the standard risetime is incorrectly reported as 873 picoseconds. When using standard pulse parameter measurements, erroneous values can be obtained.
wid@lv
wid@lv
M1
Measure
value
status
P1:wid@lv(M1) 2.109 ns
P2:wid@lv(M1) 50.348 ns
P3:rise@lv(M1) 833 ps
P4:rise@lv(M1) 873 ps
P5:- - -
P6:- - -
P7:- - -
P8:- - -
M1 50 V/div 25.0 ns/div
Timebase -4.54 µs 1.00 µs/div 200 kS 20 GS/s
Trigger C1 Stop 1.440 V Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1 M1
Measure Width@level
Summary wid@lv(M1)
Actions for P1
Histogram Trend Track
Help Markers Detailed
Always On
Width at Level Gate Accept Close
Time between two transitions of opposite slope at a specified level. (Slope specified for 1st transition)
Level is % 0-Max
Percent level 50 %
Find level
Slope Pos
Hyst. Type Divisions
Hysteresis 500 mdiv
LeCroy
9/7/2007 12:01:38 AM

The pulse width and risetime are measured, both with and without EMC thresholds applied. In parameter 1 (P1), the thresholds are set to 0% - Max, and the pulse width is measured correctly as 2.109 nanoseconds. In parameter 2 (P2), the thresholds are set to the standard scope threshold of 50% of Top and Base. In this case, the measurement is incorrectly reported as 50.348 nanoseconds -- an error of 2287%. The width measurement was impacted so significantly, that the 50% threshold between Top and Base actually produced a width measurement on the wrong pulse shape. Parameter 3 (P3) is set to the correct EMC threshold of 0% to Max, producing a correct electrostatic pulse risetime measurement of 833 picoseconds. Notice that in parameter 4 (P4), the standard risetime is incorrectly reported as 873 picoseconds. When using standard pulse parameter measurements, erroneous values can be obtained.

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File Vertical Timebase Trigger Display Cursors Measure
rise@lv
M1
Measure P1:wid@lv(M1) P2:wid@lv(M1) P3:rise@lv(M1) P4:rise@lv(M1) P5:- - - P6:- - - P7:- - - P8:- - -
value 2.109 ns 50.348 ns 833 ps 873 ps
status
M1 50 V/div 25.0 ns/div
Timebase -4.54 µs 1.00 µs/div 200 kS 20 GS/s
Trigger C1 Stop 1.440 V Edge Positive
Measure P1 P2 P3 P4 P5 P6 P7 P8
On
Type
measure on waveforms
math on parameters
advanced web edit
Source1 M1
Measure Rise@level
Summary rise@lv(M1)
Actions for P3
Histogram Trend Track
Help Markers Detailed
Always On
Rise at level Gate Accept Close
Transition time for % or absolute levels of all rising edges
Levels are % 0-Max
High percent 90 %
Low percent 10 %
Set Levels to 10% and 90%
Set Levels to 20% and 80%
LeCroy
9/7/2007 12:02:27 AM

The pulse width and risetime are measured, both with and without EMC thresholds applied. In parameter 1 (P1), the thresholds are set to 0% - Max, and the pulse width is measured correctly as 2.109 nanoseconds. In parameter 2 (P2), the thresholds are set to the standard scope threshold of 50% of Top and Base. In this case, the measurement is incorrectly reported as 50.348 nanoseconds -- an error of 2287%. The width measurement was impacted so significantly, that the 50% threshold between Top and Base actually produced a width measurement on the wrong pulse shape. Parameter 3 (P3) is set to the correct EMC threshold of 0% to Max, producing a correct electrostatic pulse risetime measurement of 833 picoseconds. Notice that in parameter 4 (P4), the standard risetime is incorrectly reported as 873 picoseconds. When using standard pulse parameter measurements, erroneous values can be obtained.

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