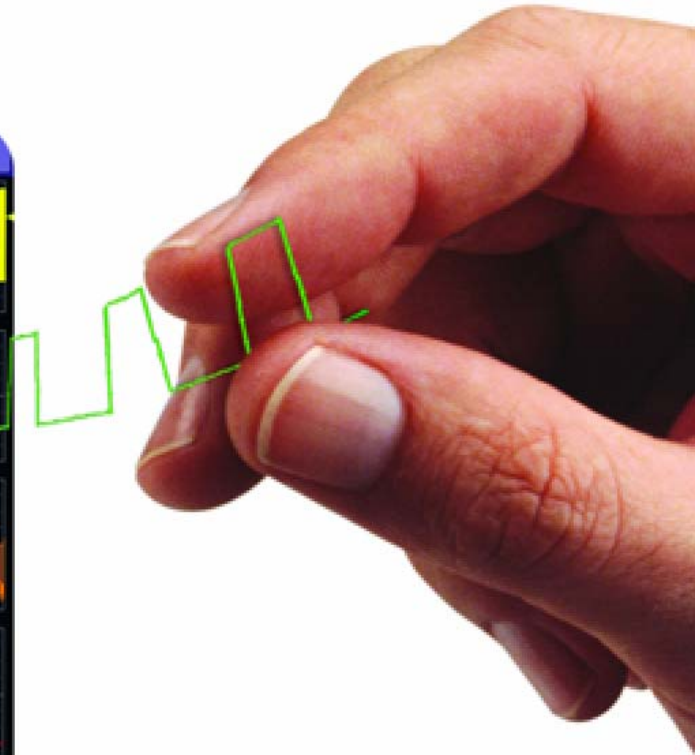
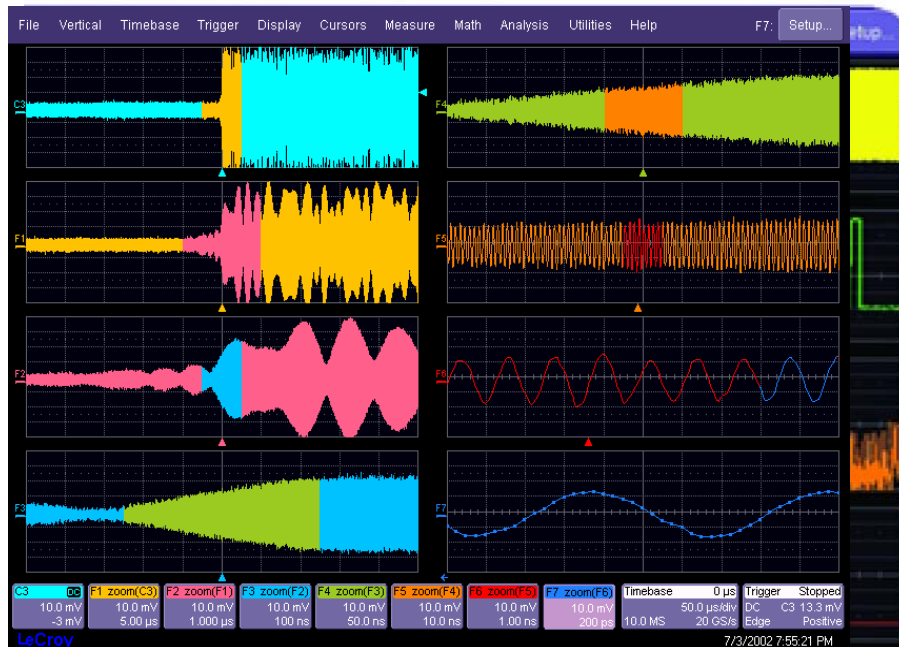
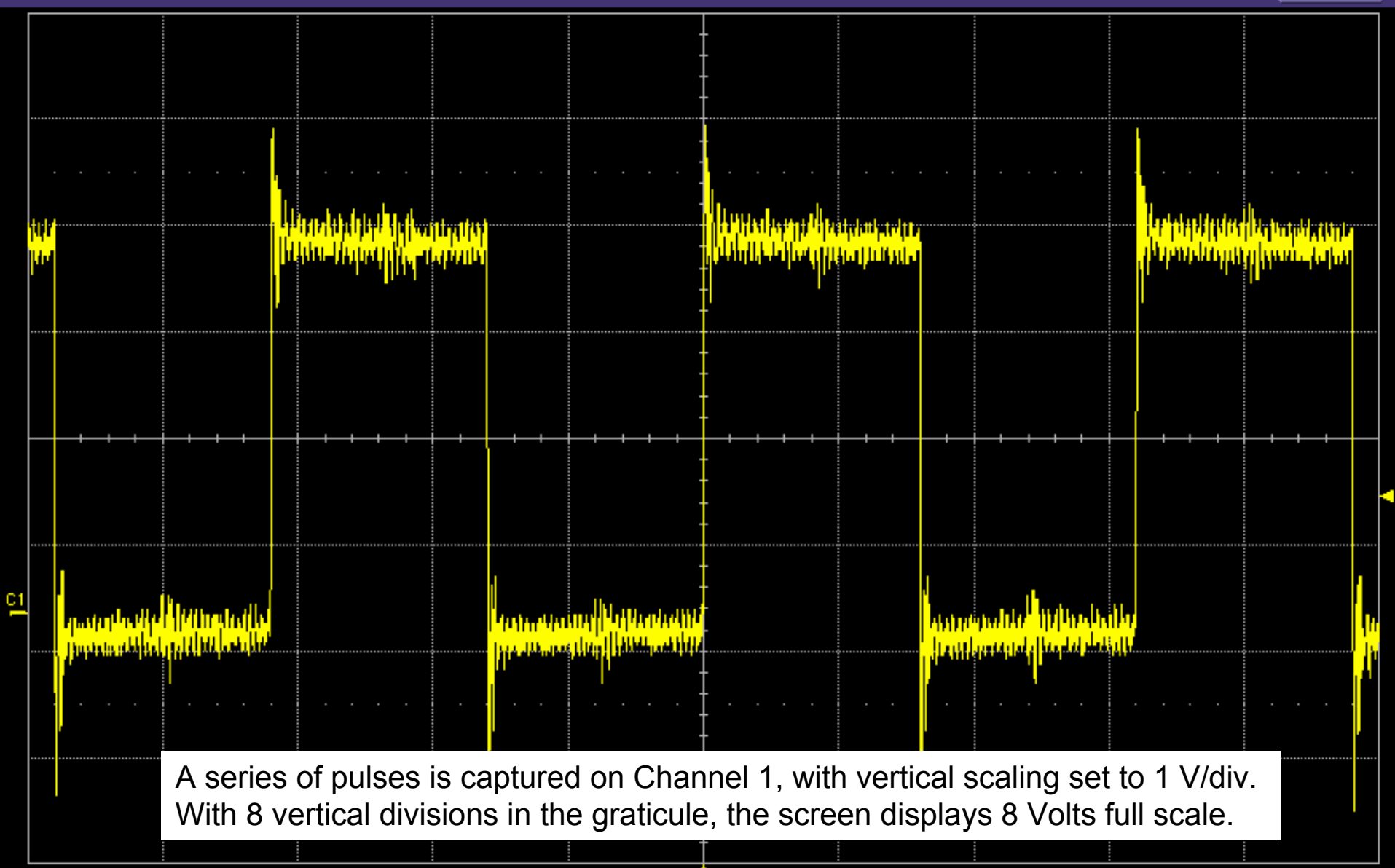


Dynamic Range and Multigrid Displays



Maximizing Signal Integrity Across Multiple Channels

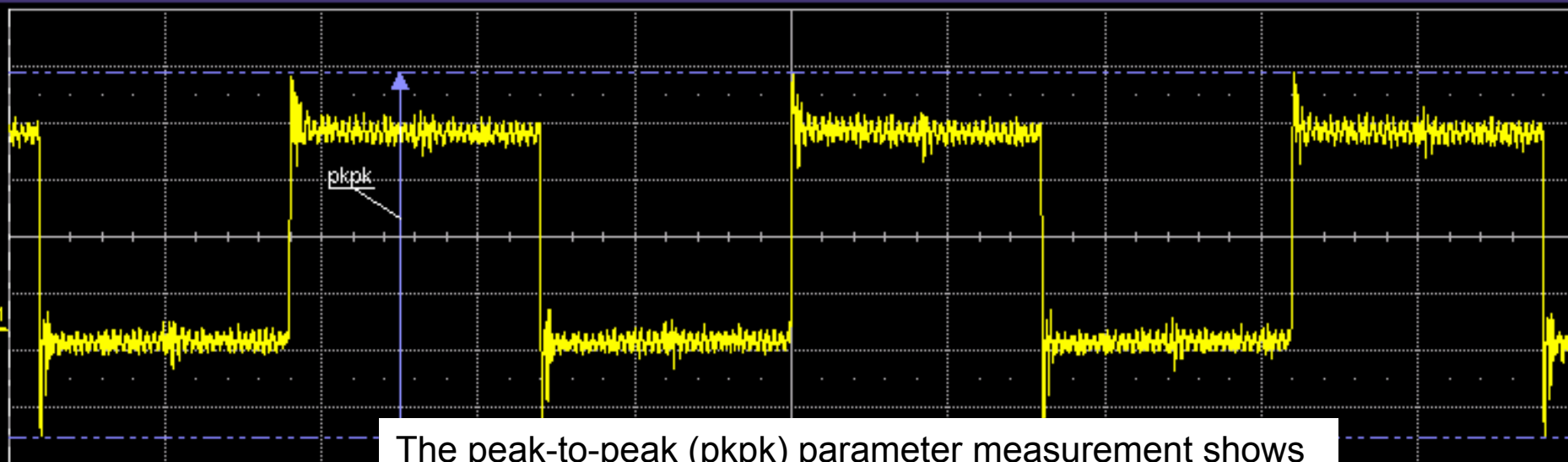
Vertical Scaling and Signal Integrity



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.

C1 DC1M
1.00 V/div
-1.650 V offset

Timebase	0 ns	Trigger	C1
	250 ns/div	Auto	1.10 V
12.5 kS	5.0 GS/s	Edge	Positive



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

F1:pkpk(C1)
6.41 V

✓

C1

1.00 V/div

-1.650 V offset

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

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

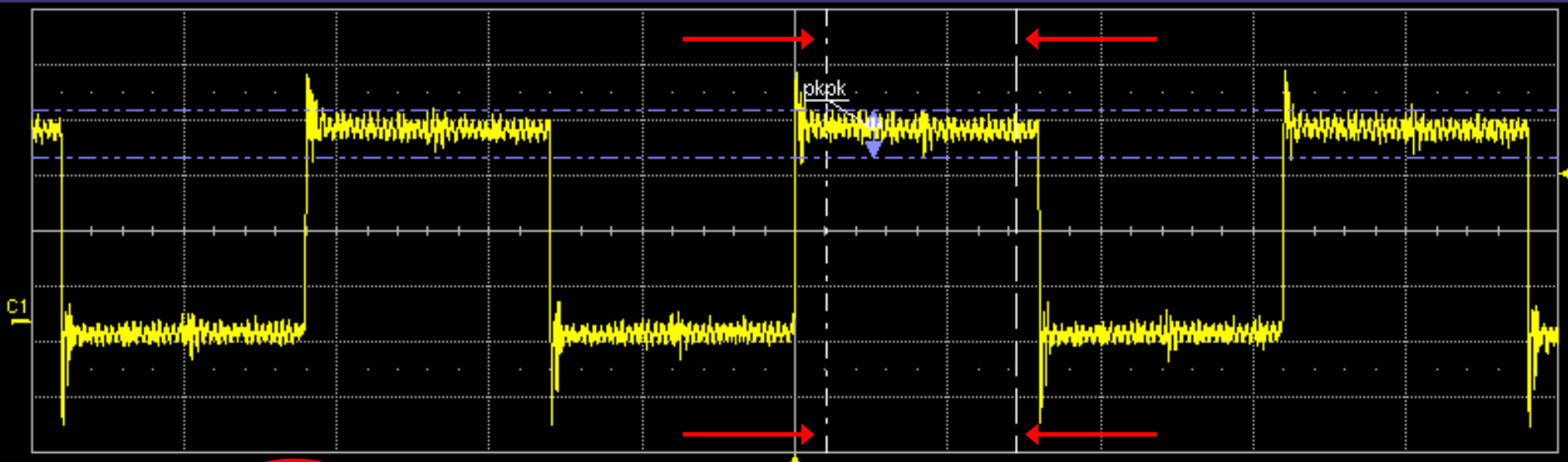
Help

Markers Always On

Detailed

Peak to Peak Gate Accept Close

Difference between maximum and minimum data values.



Measure
value
status

F1: pkpk(C1)
840 mV

C1 DC1M
1.00 V/div
-1.650 V ofst

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.

12.5 kS 5.0 GS/s

Trigger C1
Stop 2.64 V
Edge Positive

Peak to Peak Gate Accept Close

Measure P1 P2 P3 P4 P5 P6 P7 P8

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 Always On

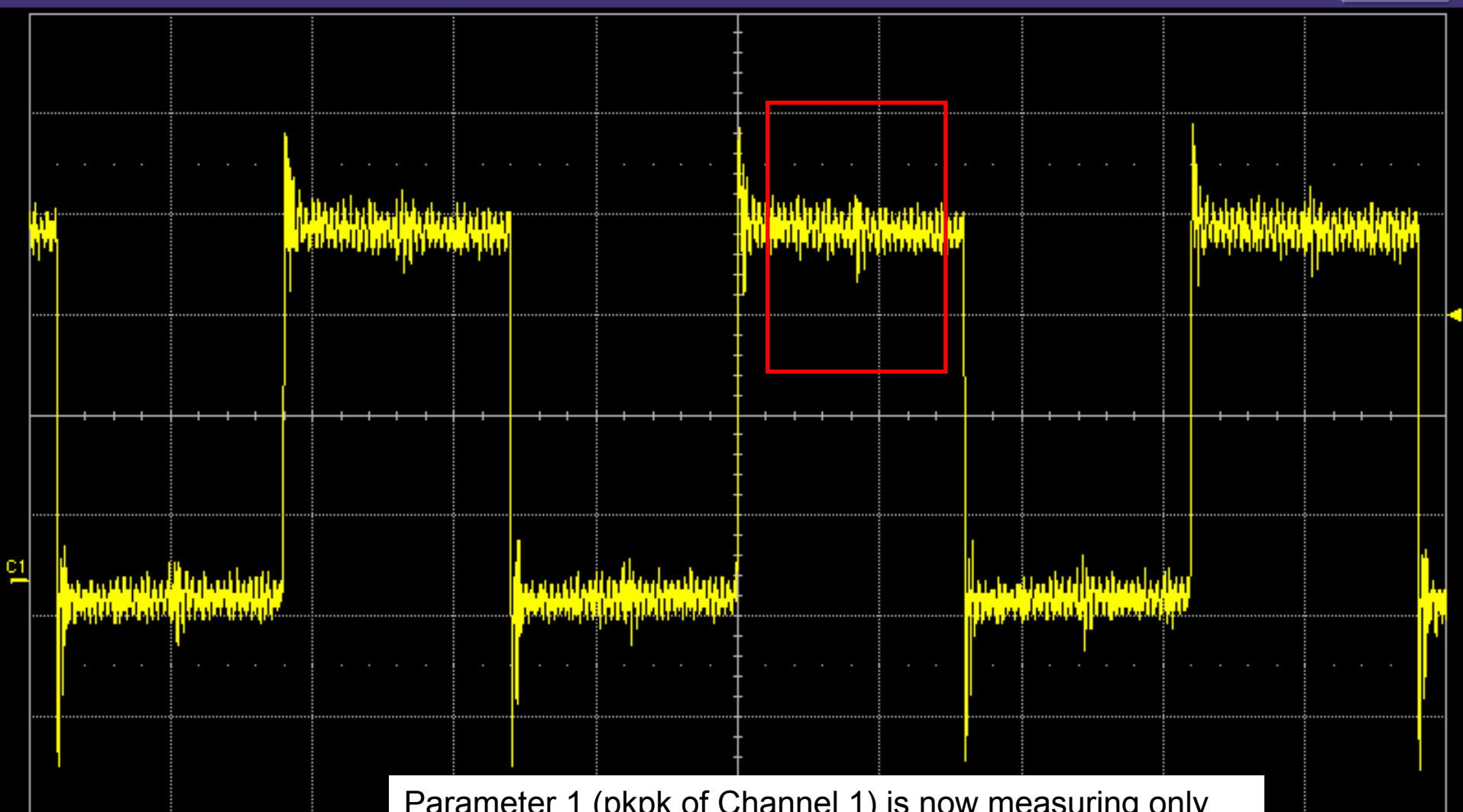
Detailed

Measure gate on Source(s)

Default

Start 5.21 div

Stop 6.45 div

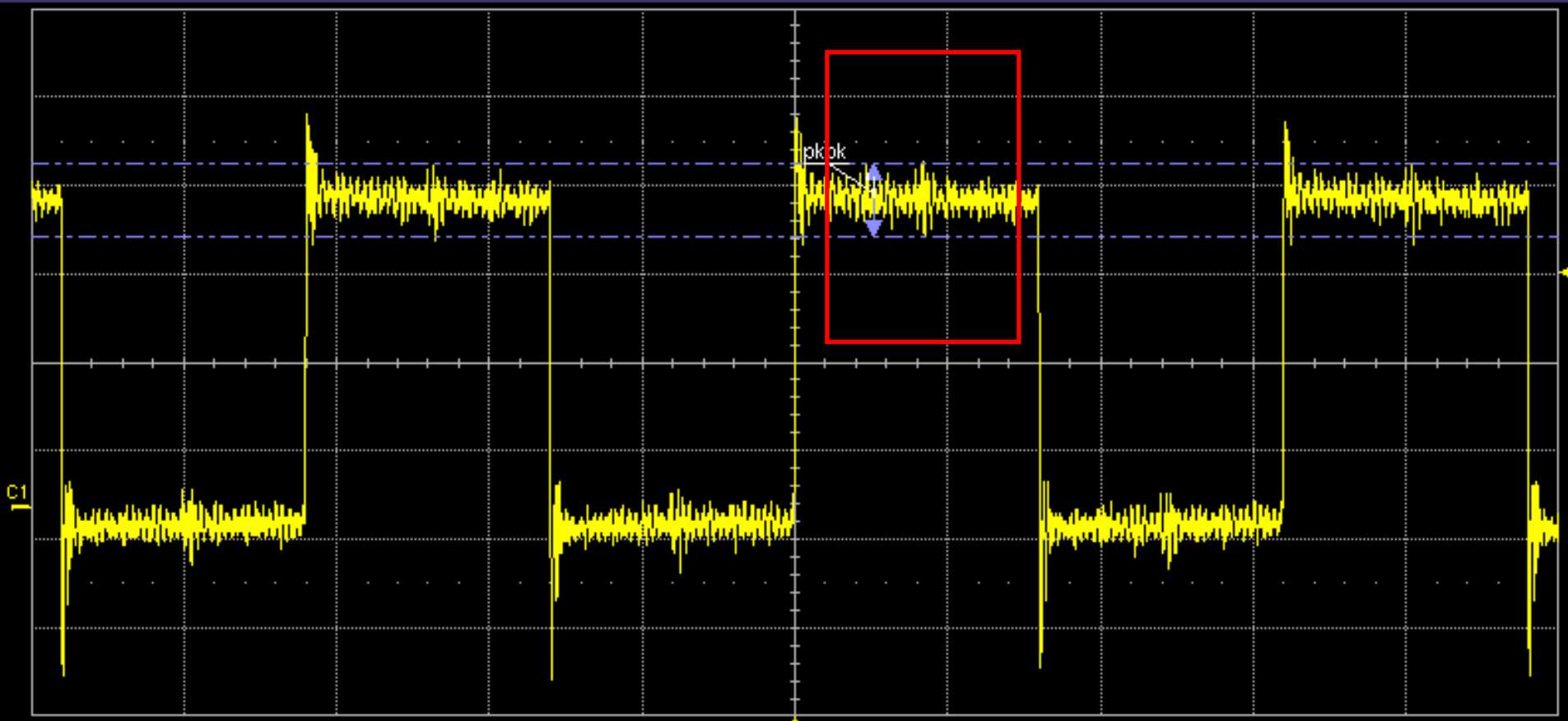


Parameter 1 (pkpk of Channel 1) is now measuring only the noise riding on the top of the pulse shown above.

Measure
value
status
F1:pkpk(C1)
840 mV

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

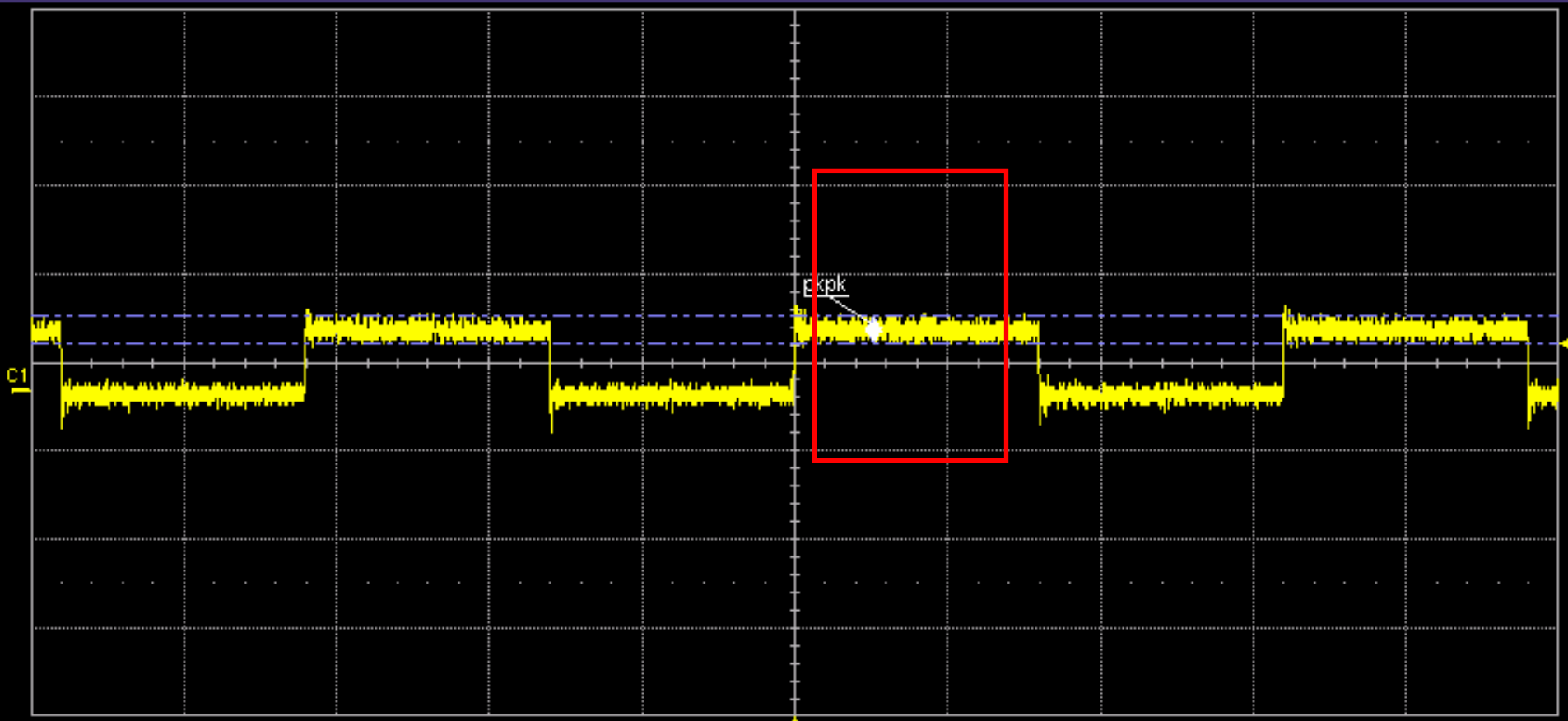


Measure	P1:pkpk(C1)	P2:---	P3:---	P4:---	P5:---	P6:---	P7:---	P8:---
value	840 mV							
mean	886.7 mV							
min	663 mV							
max	1.10 V							
sdev	60.6 mV							
num	1.000e+3							
status	✓							

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.

C1 **DC1M**
 1.00 V/div
 -1.650 V ofst

Timebase	0 ns	Trigger	C1
	250 ns/div	Stop	2.64 V
12.5 kS	5.0 GS/s	Edge	Positive



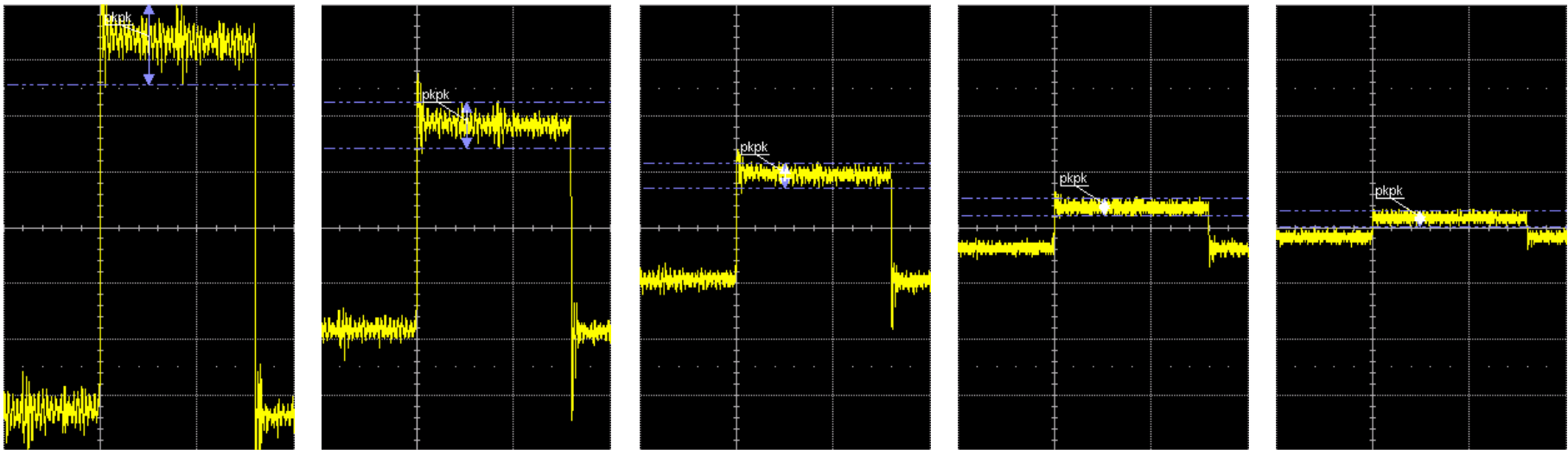
Measure	P1:pkpk(C1)	P2:---	P3:---	P4:---	P5:---	P6:---	P7:---	P8:---
value	1.5 V							
mean	1.783 V							
min	1.3 V							
max	2.4 V							
sdev	153 mV							
num	1.000e+3							
status	✓							

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

C1 DC1M
 5.00 V/div
 -1.60 V ofst

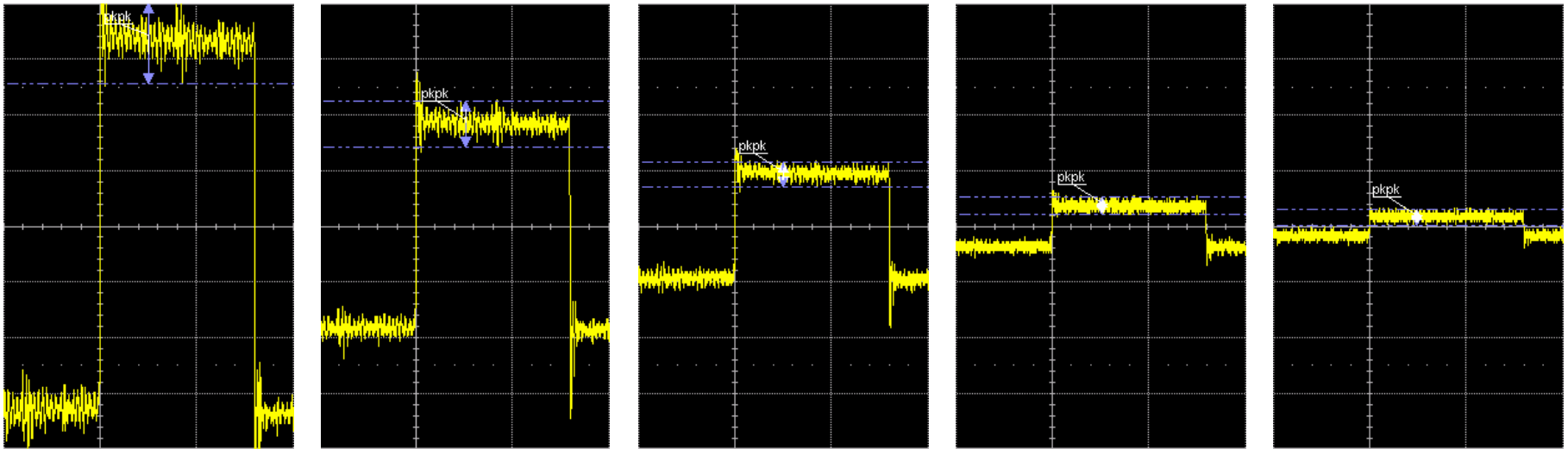
Timebase	0 ns	Trigger	C1
	250 ns/div	Stop	2.65 V
12.5 kS	5.0 GS/s	Edge	Positive

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.



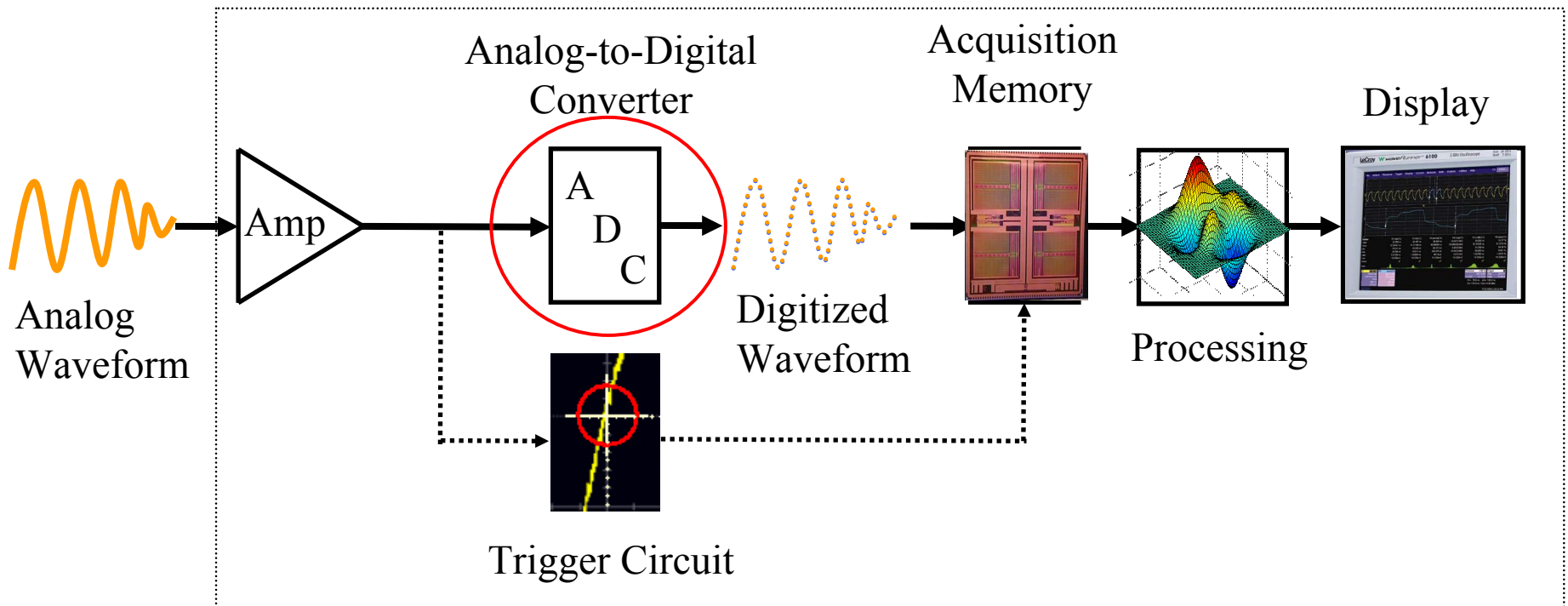
P1:pkpk(C1) 802 mV 821.7 mV 705 mV 948 mV 36.9 mV 1.000e+3 ✓ C1 DC1M 550 mV/div -1.640 V ofst	P1:pkpk(C1) 840 mV 886.7 mV 663 mV 1.10 V 60.6 mV 1.000e+3 ✓ C1 DC1M 1.00 V/div -1.650 V ofst	P1:pkpk(C1) 884 mV 1.022 V 796 mV 1.3 V 91 mV 1.000e+3 ✓ C1 DC1M 2.00 V/div -1.600 V ofst	P1:pkpk(C1) 1.5 V 1.783 V 1.3 V 2.4 V 153 mV 1.000e+3 ✓ C1 DC1M 5.00 V/div -1.60 V ofst	P1:pkpk(C1) 3.1 V 3.066 V 2.7 V 4.0 V 307 mV 1.000e+3 ✓ C1 DC1M 10.0 V/div -1.60 V ofst
--	--	--	--	--

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

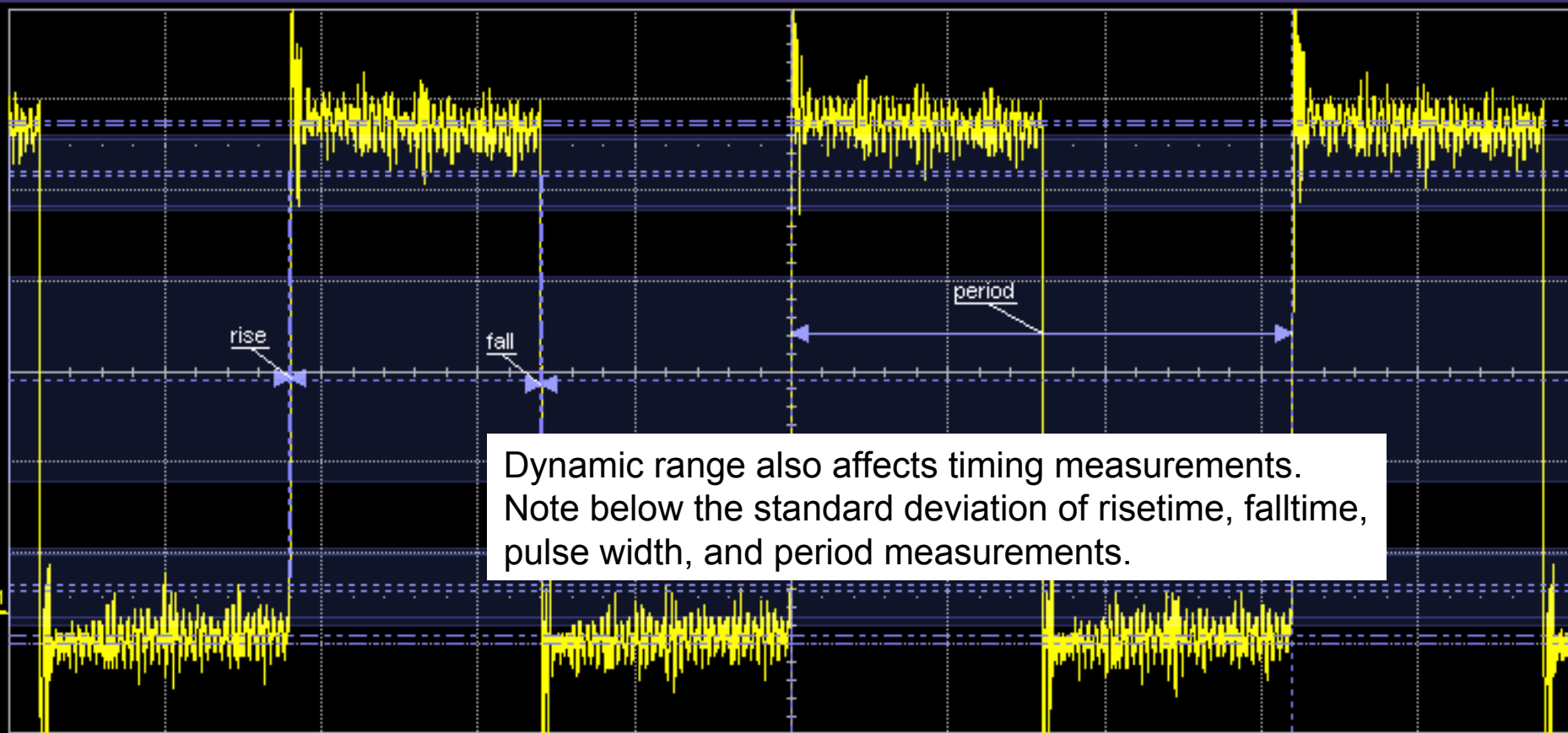


Dynamic Range

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

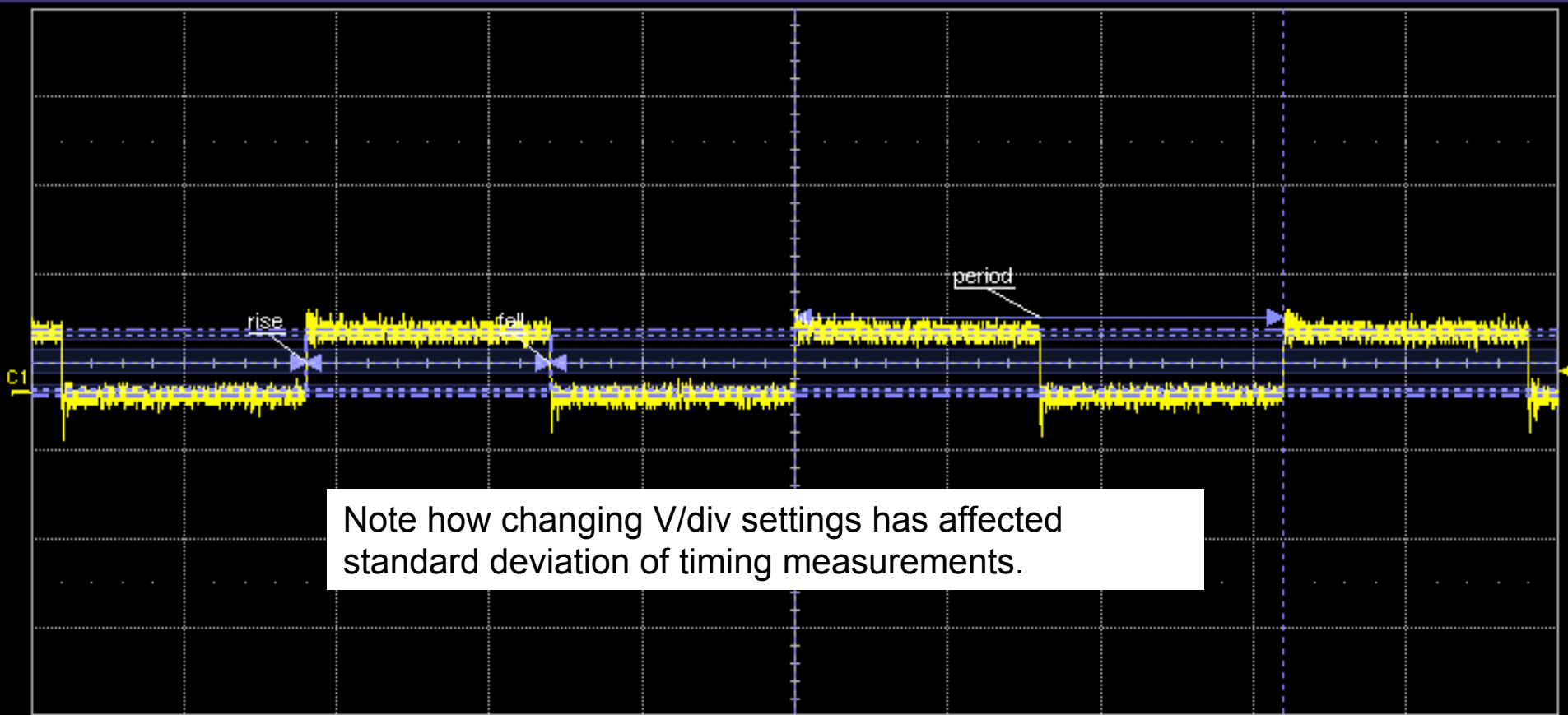


Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)	P5:---	P6:---	P7:---	P8:---
value	1.648 ns	1.335 ns	400.316 ns	800.007 ns				
mean	1.63438 ns	1.33528 ns	400.27507 ns	799.99620 ns				
min	1.515 ns	1.232 ns	400.211 ns	799.922 ns				
max	1.829 ns	1.432 ns	400.340 ns	800.055 ns				
sdev	41.08 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



Note how changing V/div settings has affected standard deviation of timing measurements.

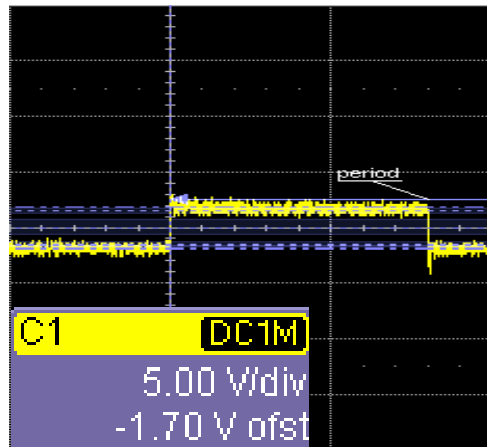
Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)	P5:---	P6:---	P7:---	P8:---
value	1.713 ns	1.496 ns	400.192 ns	800.121 ns				
mean	1.62728 ns	1.42165 ns	400.20818 ns	799.99405 ns				
min	978 ps	872 ps	399.781 ns	799.552 ns				
max	2.442 ns	2.181 ns	400.688 ns	800.417 ns				
sdev	214.79 ps	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

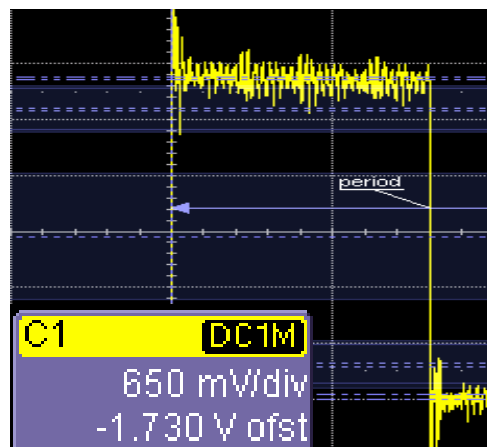
Timebase 0 ns
250 ns/div
12.5 kS 5.0 GS/s

Trigger C1
Stop 1.15 V
Edge Positive

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

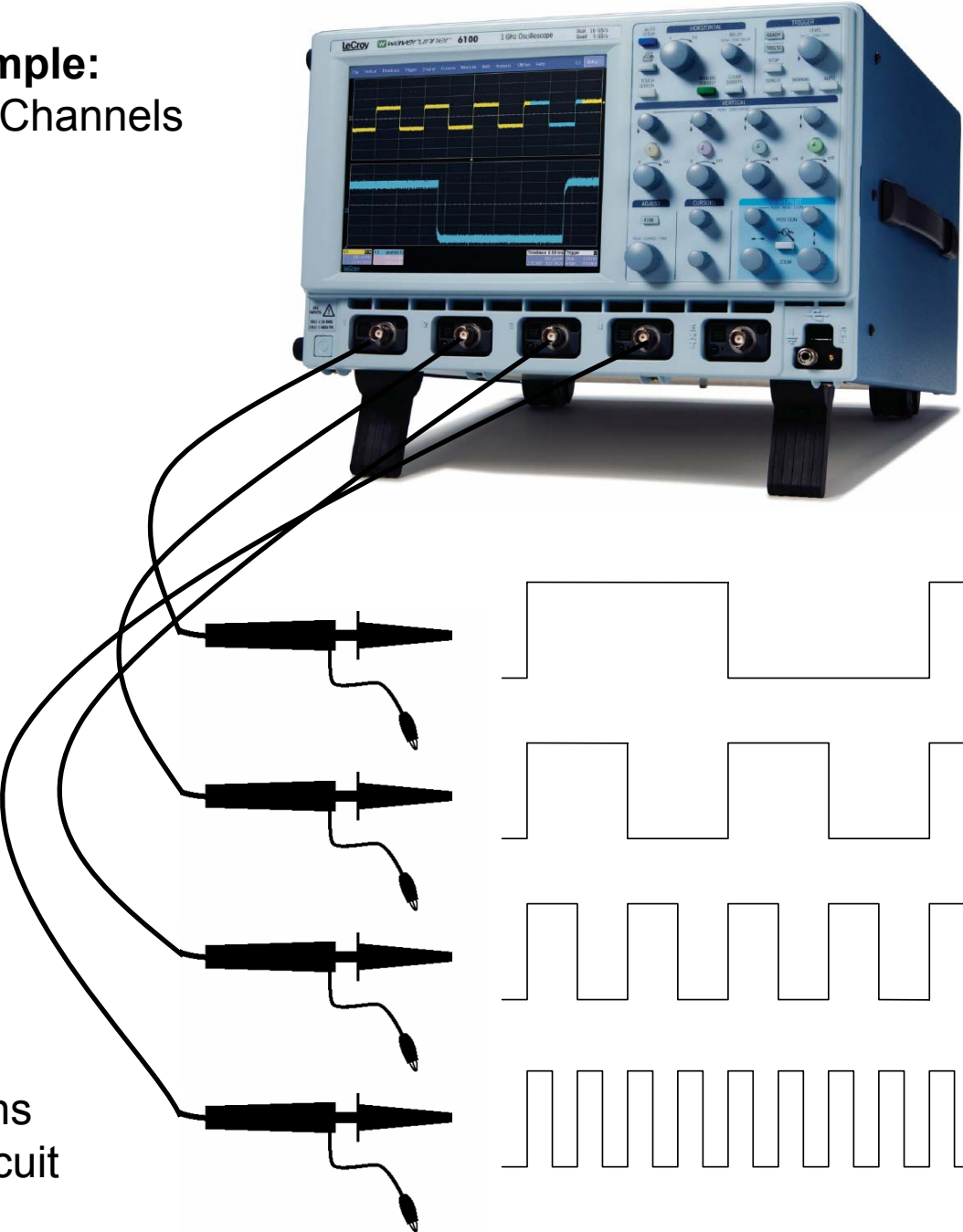


Measure	P1:rise(C1)	P2:fall(C1)	P3:width(C1)	P4:period(C1)
value	1.648 ns	1.335 ns	400.316 ns	800.007 ns
mean	1.63438 ns	1.33528 ns	400.27507 ns	799.99620 ns
min	1.515 ns	1.232 ns	400.211 ns	799.922 ns
max	1.829 ns	1.432 ns	400.340 ns	800.055 ns
sdev	41.08 ps	30.41 ps	21.45 ps	21.12 ps
num	1.000e+3	1.000e+3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

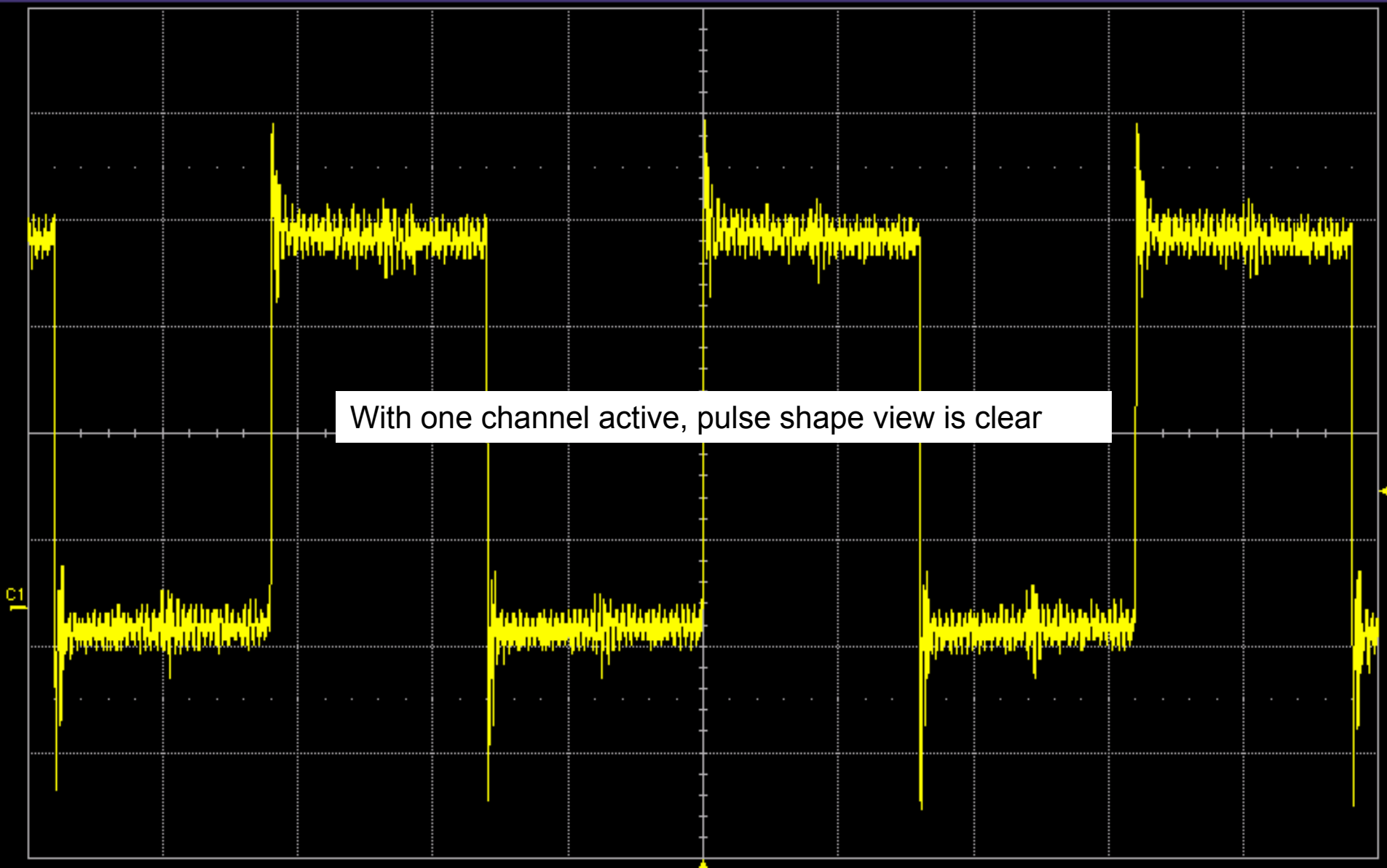
Practical Application:

Using Multiple Channels
While Maximizing Dynamic Range

Practical Example: Using Multiple Channels



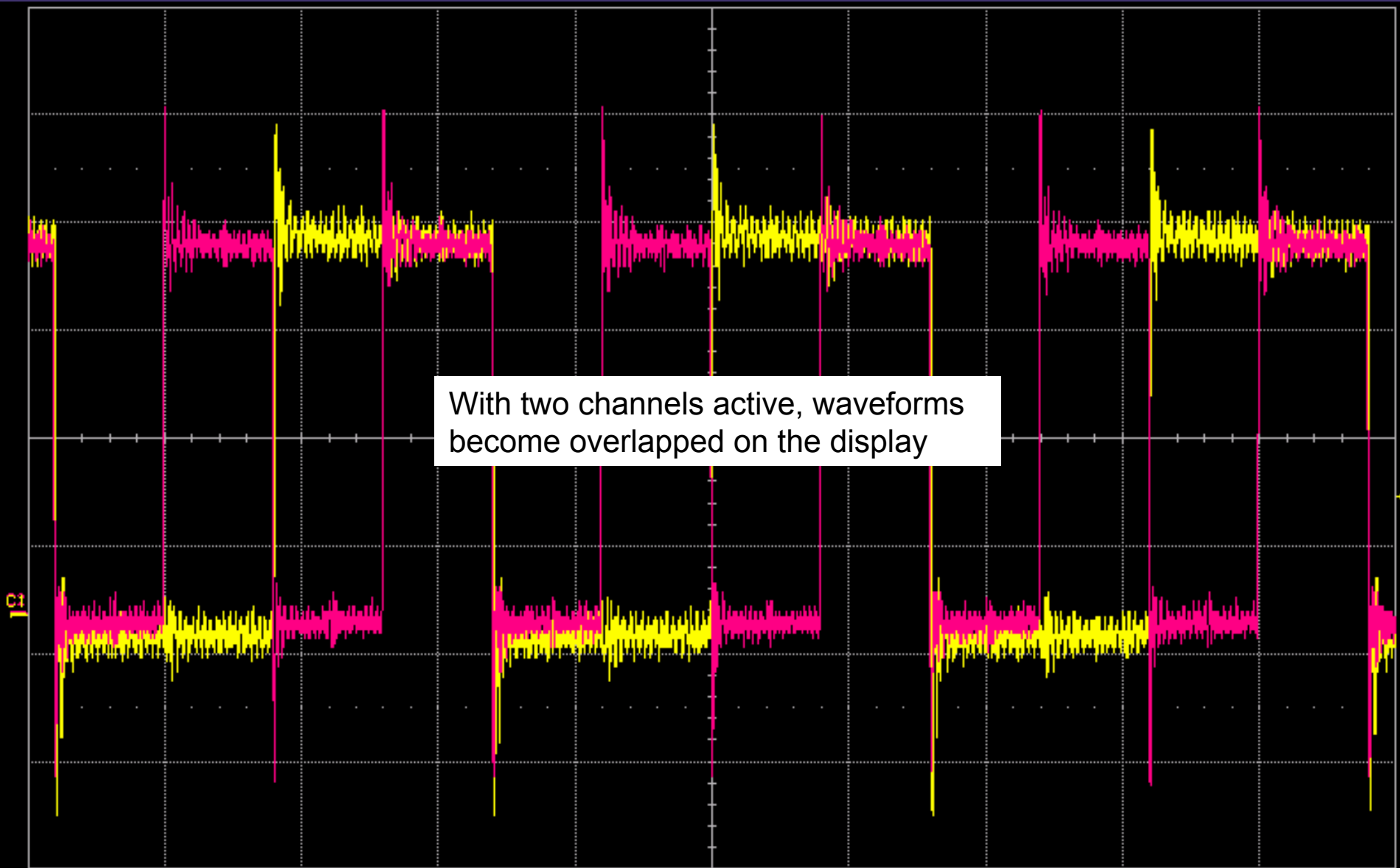
Probing four pins
of a counter circuit



With one channel active, pulse shape view is clear

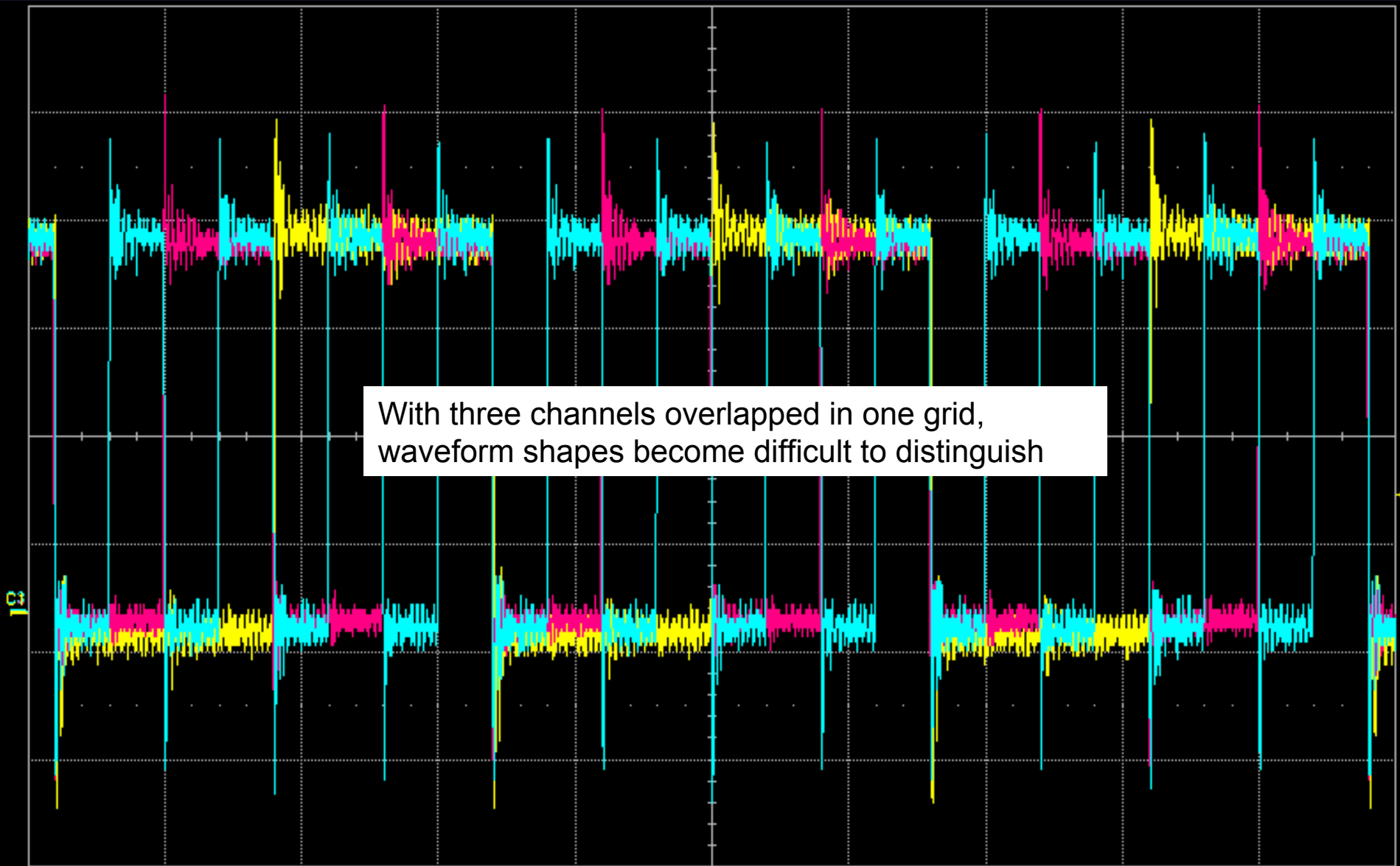
C1 DC1M
1.00 V/div
-1.650 V ofst

Timebase	0 ns	Trigger	C1
	250 ns/div	Auto	1.10 V
12.5 kS	5.0 GS/s	Edge	Positive



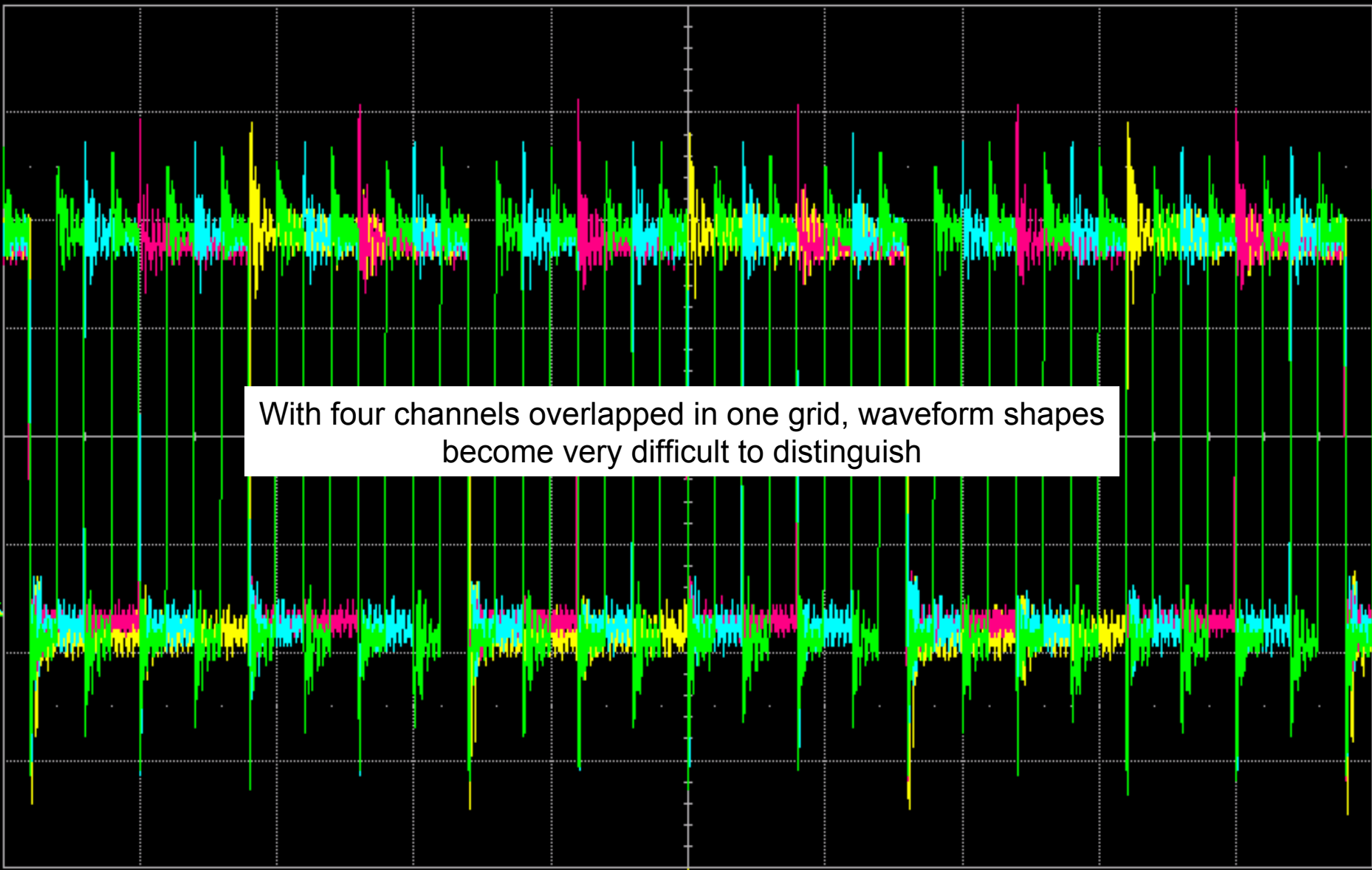
C1	DC1M	C2	DC1M
1.00 V/div		1.00 V/div	
-1.650 V ofst		-1.620 V ofst	

Timebase	0 ns	Trigger	C1
250 ns/div		Auto	1.10 V
12.5 kS	5.0 GS/s	Edge	Positive



C1	DC1M	C2	DC1M	C3	DC1M
1.00 Wdiv		1.00 Wdiv		1.00 Wdiv	
-1.650 V ofst		-1.620 V ofst		-1.620 V ofst	

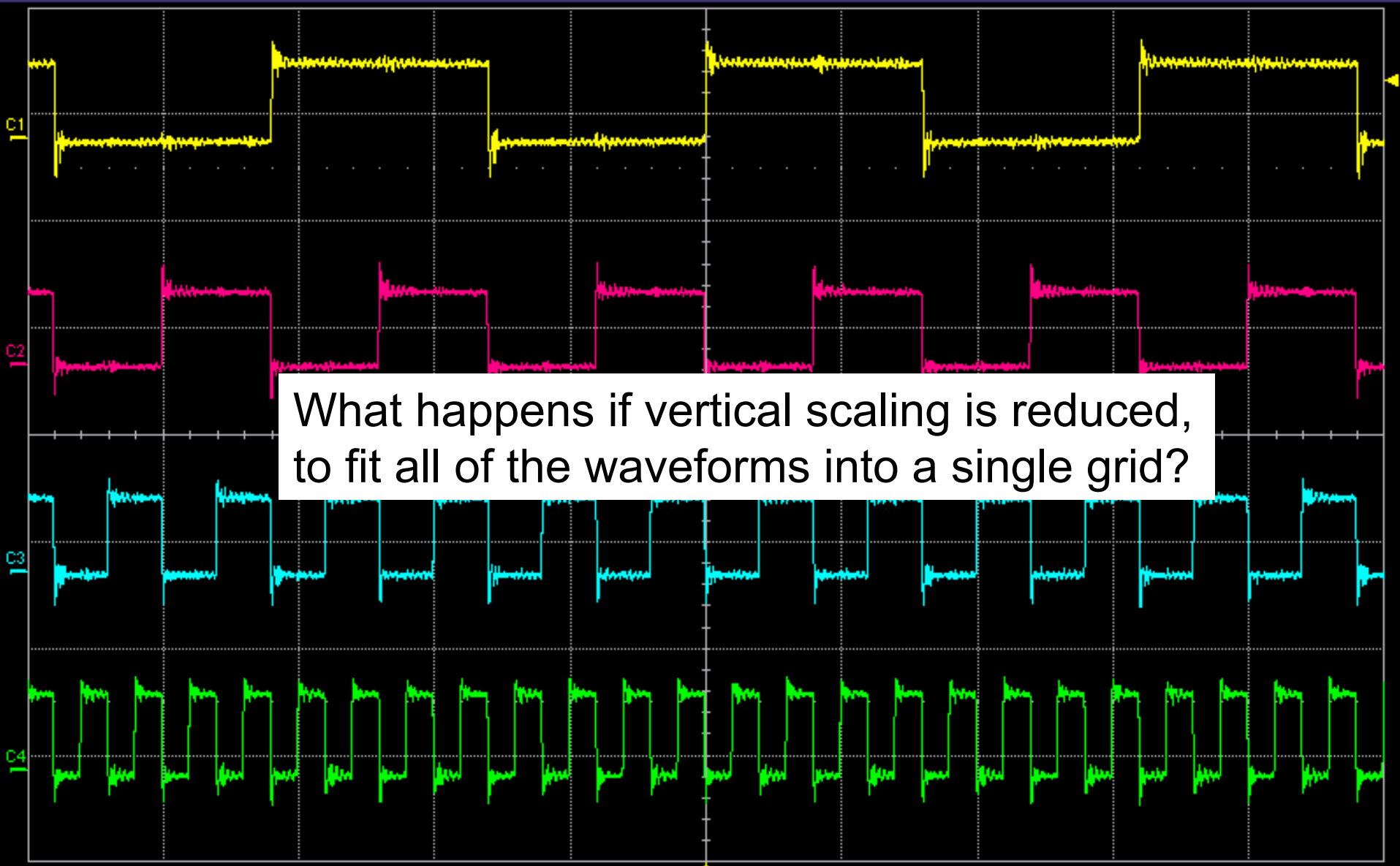
Timebase	0 ns	Trigger	C1
12.5 kS	250 ns/div	Auto	1.10 V
	5.0 GS/s	Edge	Positive



With four channels overlapped in one grid, waveform shapes become very difficult to distinguish

C1	DC1M	C2	DC1M	C3	DC1M	C4	DC1M
1.00 Wdiv		1.00 Wdiv		1.00 Wdiv		1.00 Wdiv	
-1.650 V ofst		-1.620 V ofst		-1.620 V ofst		-1.660 V ofst	

Timebase	0 ns	Trigger	C1
12.5 kS	250 ns/div	Auto	1.10 V
	5.0 GS/s	Edge	Positive



What happens if vertical scaling is reduced, to fit all of the waveforms into a single grid?

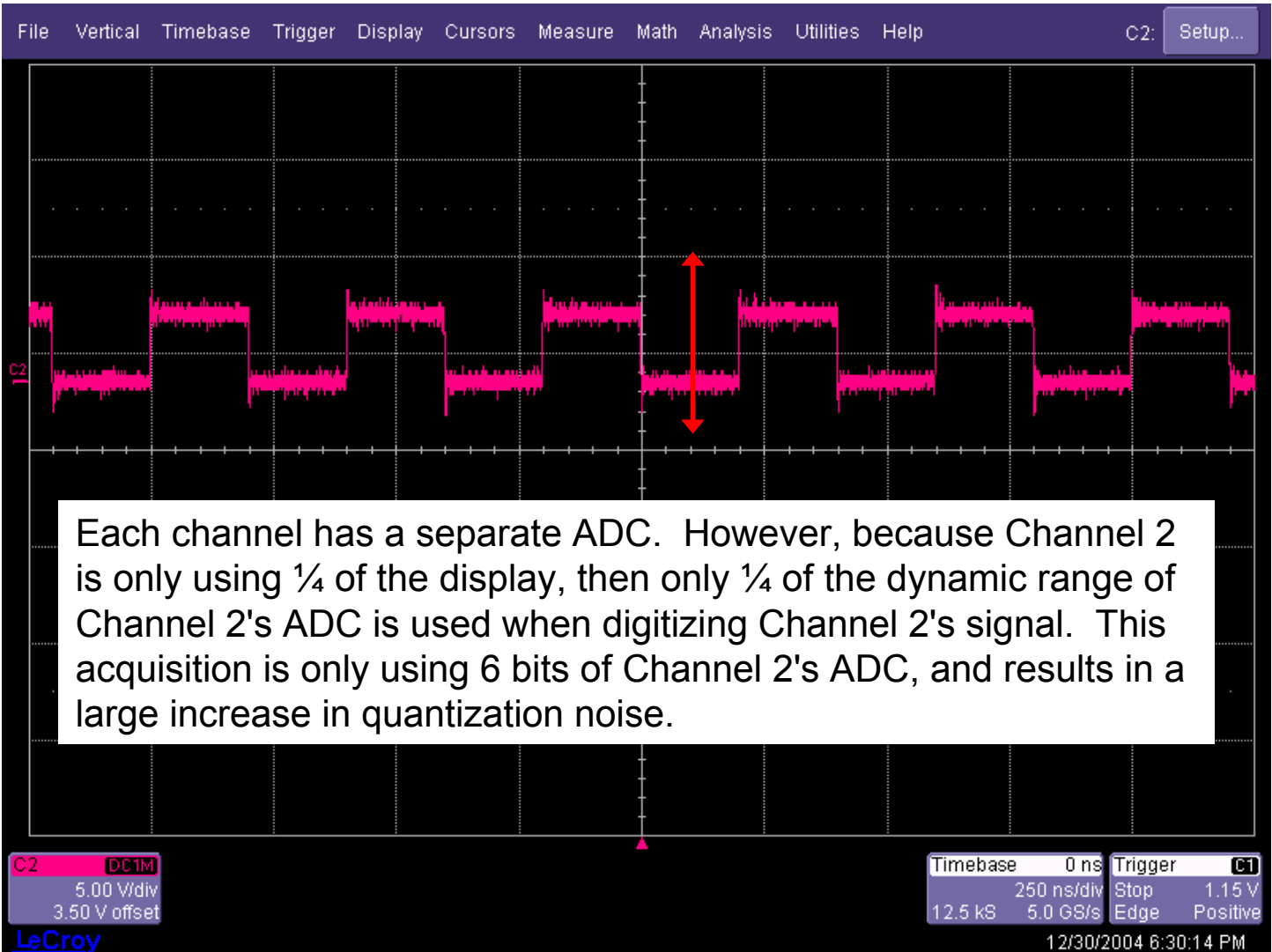
Channel	Scale
C1	5.00 V/div 13.900 V
C2	5.00 V/div 3.300 V ofst
C3	5.00 V/div -6.400 V ofst
C4	5.00 V/div -15.700 V

Timebase	0 ns	Trigger	C1
	250 ns/div	Stop	2.70 V
12.5 kS	5.0 GS/s	Edge	Positive



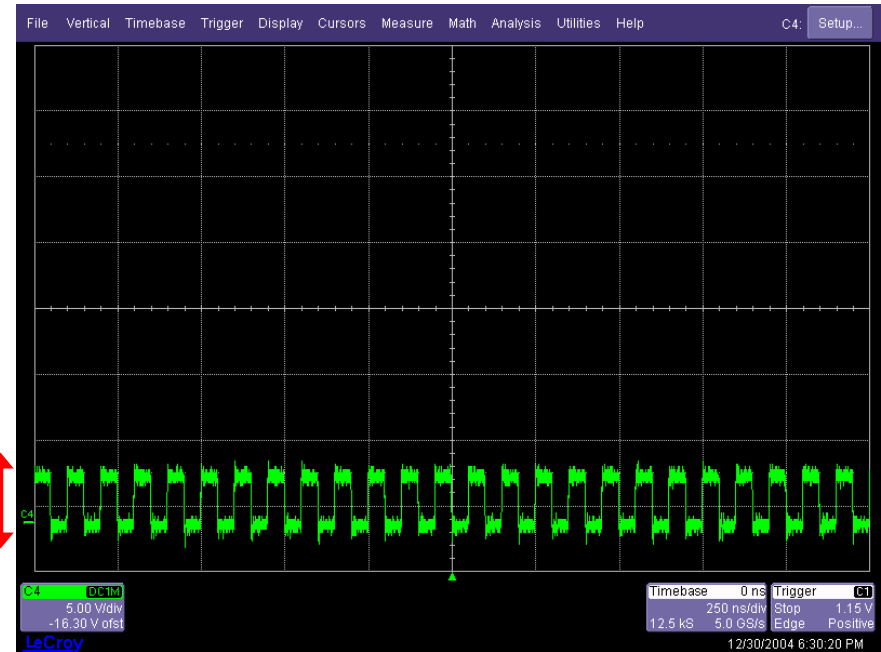
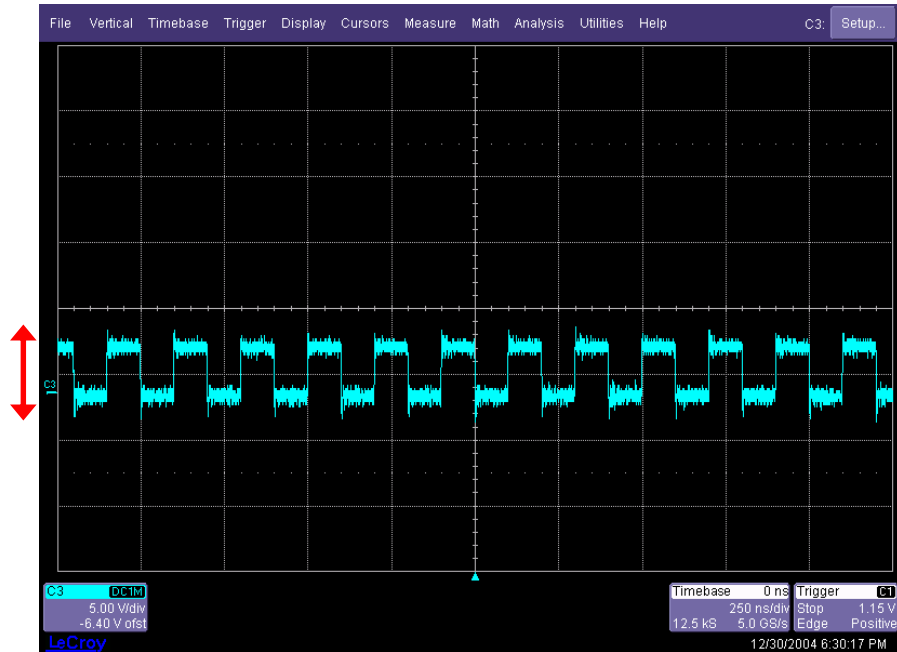
Because Channel 1 is only using $\frac{1}{4}$ of the display, only $\frac{1}{4}$ of the dynamic range of Channel 1's ADC is used when digitizing Channel 1's signal.

An 8-bit ADC has $2^8 = 256$ quantization levels. When using $\frac{1}{4}$ of the dynamic range, only a maximum of 64 of the 256 quantization levels are used for acquiring Channel 1. Using $\frac{1}{4}$ 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.



Dynamic Range

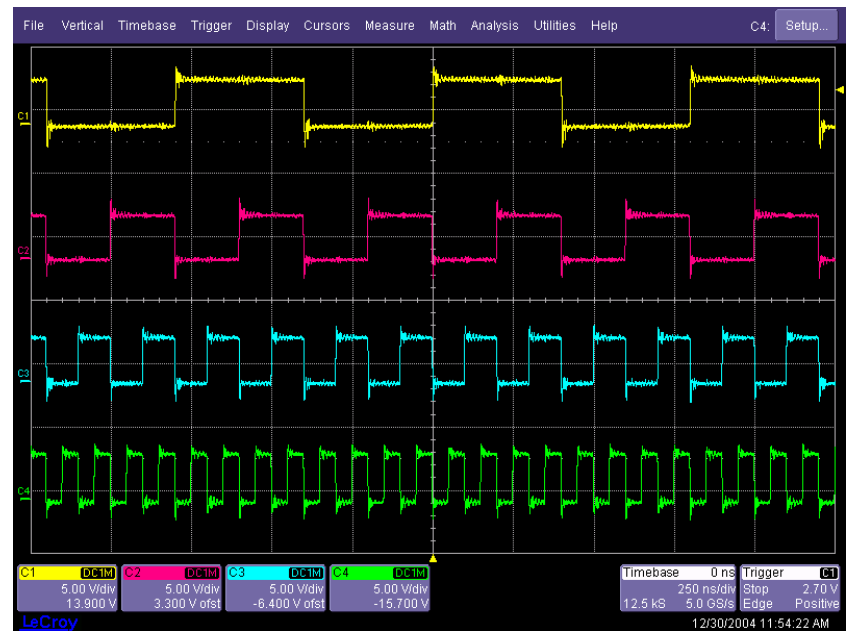
The same applies to Channels 3 and 4. When vertical scaling is reduced to fit four signals into the same grid, then each channel is only using $\frac{1}{4}$ of its dynamic range, which results in loss of vertical resolution and the addition of significant quantization noise.



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

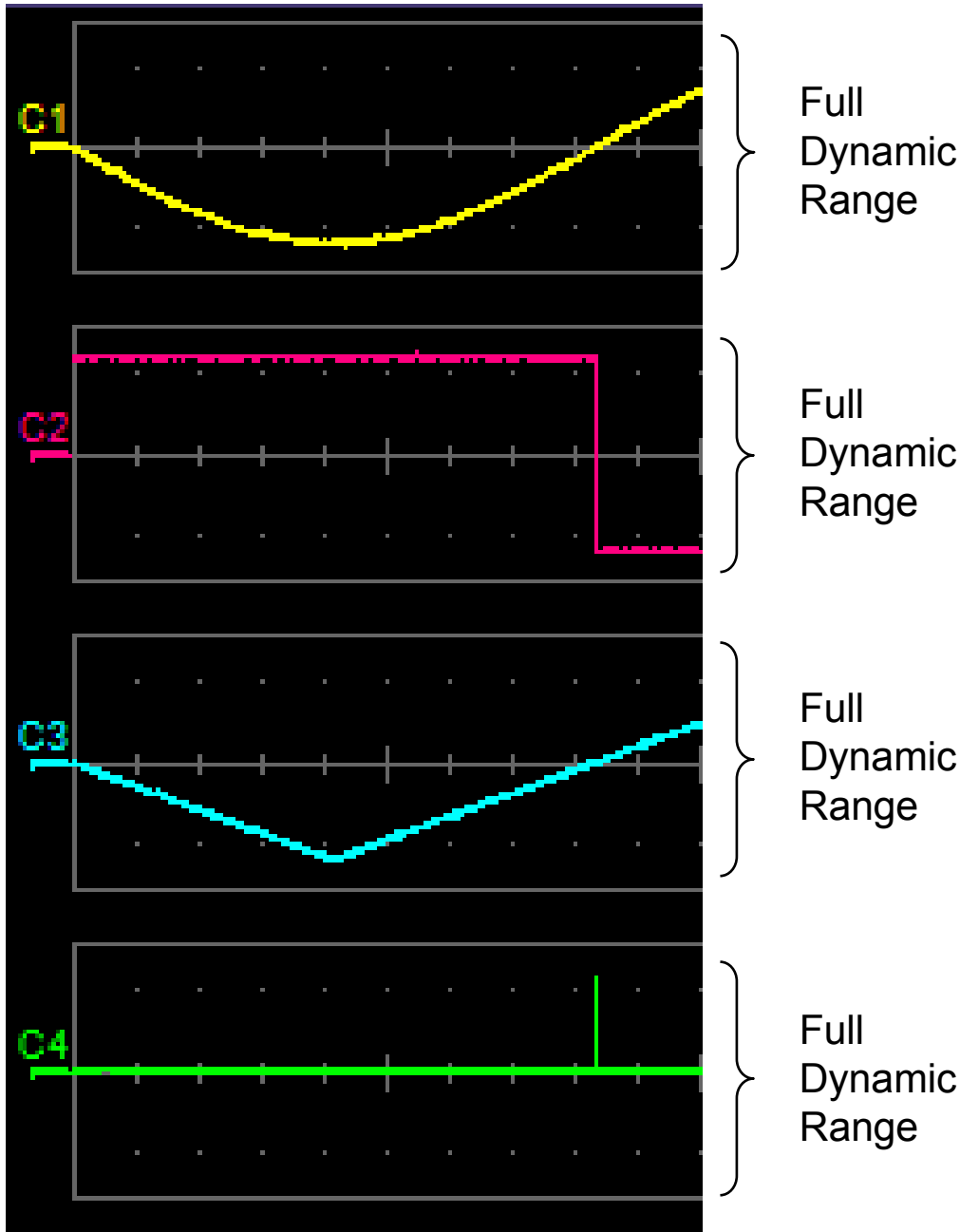


Maximize dynamic range



Clearly view all signals

Solution:
Multigrid Displays



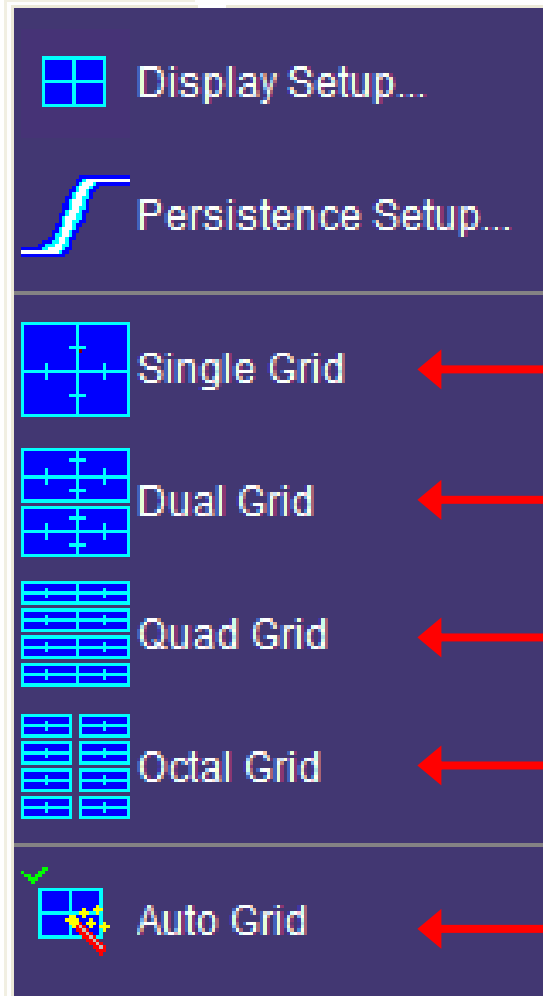
Multigrid Displays

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.

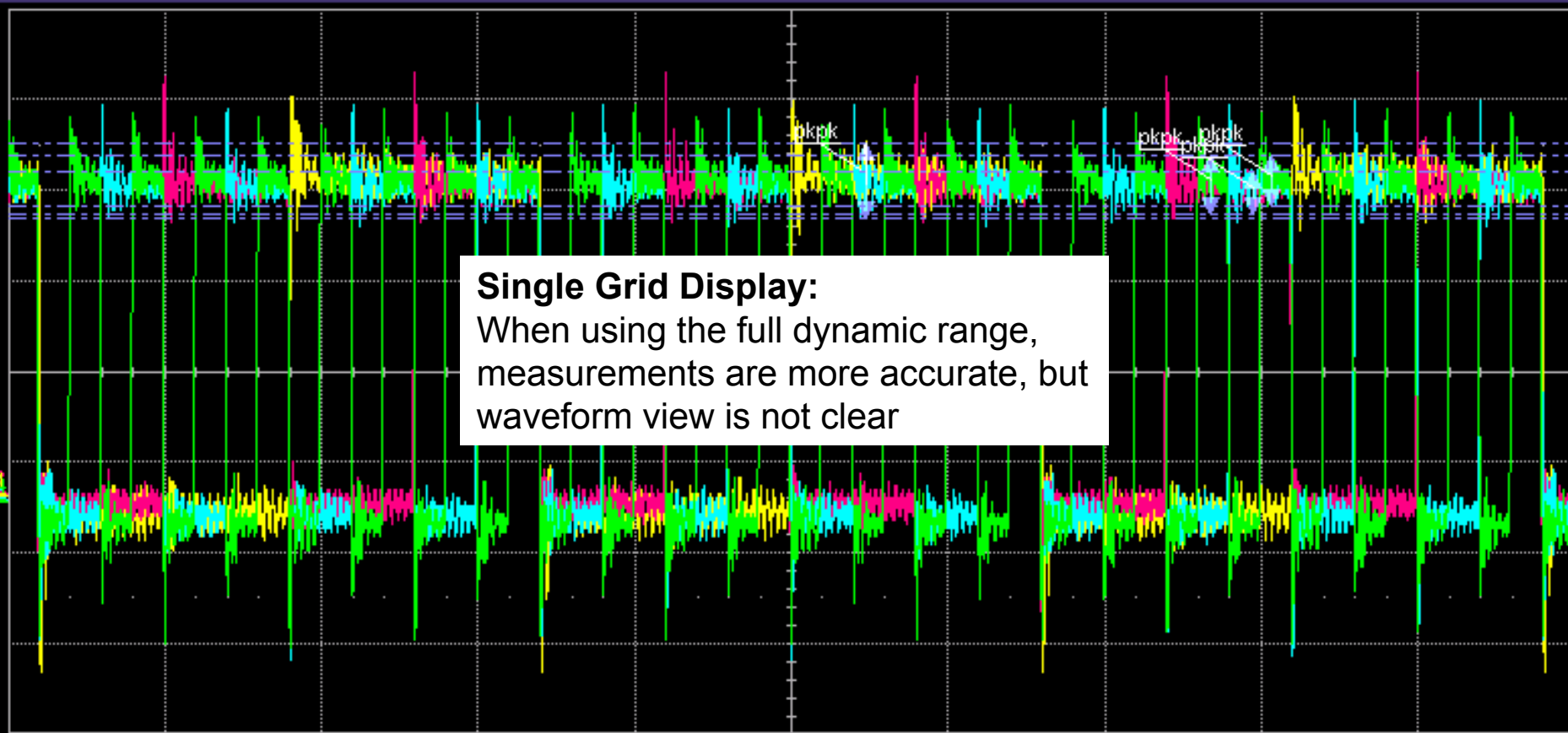
Display



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.

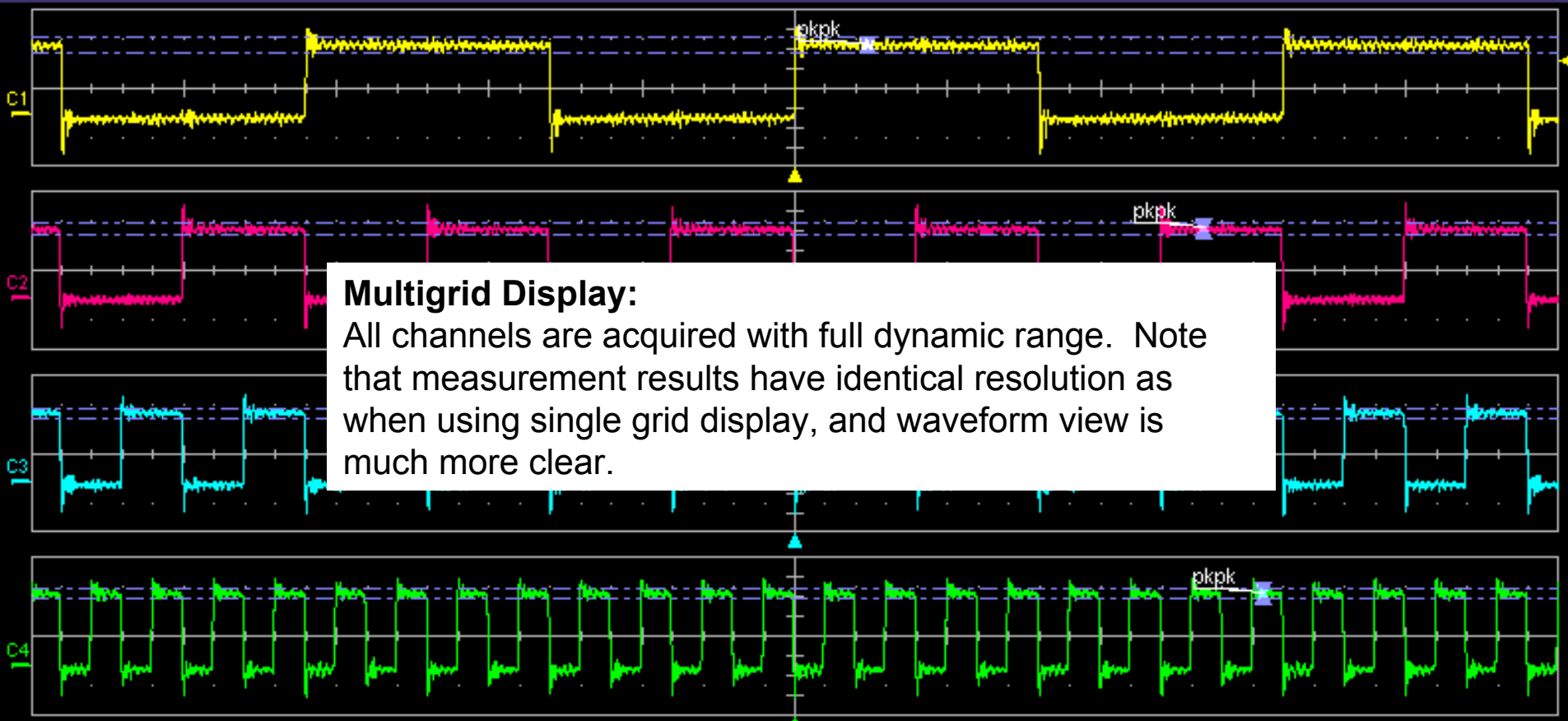


Single Grid Display:
 When using the full dynamic range,
 measurements are more accurate, but
 waveform view is not clear

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	C2 DC1M	C3 DC1M	C4 DC1M
1.00 W/div	1.00 W/div	1.00 W/div	1.00 W/div
-1.370 V ofst	-1.350 V ofst	-1.430 V ofst	-1.440 V ofst

Timebase	0 ns	Trigger	C1
	250 ns/div	Stop	2.64 V
12.5 kS	5.0 GS/s	Edge	Positive



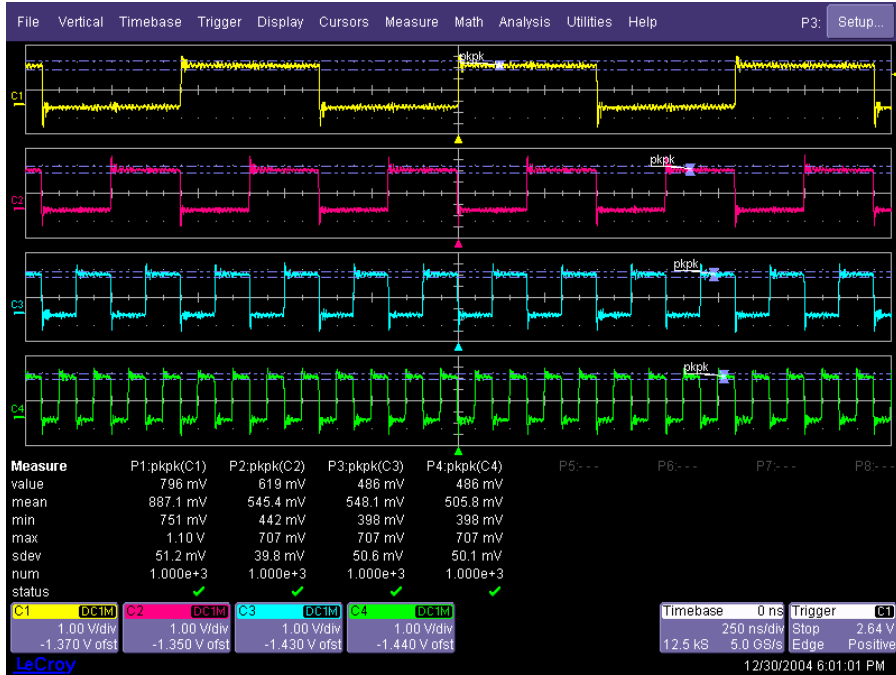
Measure	P1:pkpk(C1)	P2:pkpk(C2)	P3:pkpk(C3)	P4:pkpk(C4)	P5:---	P6:---	P7:---	P8:---
value	796 mV	619 mV	486 mV	486 mV				
mean	887.1 mV	545.4 mV	548.1 mV	505.8 mV				
min	751 mV	442 mV	398 mV	398 mV				
max	1.10 V	707 mV	707 mV	707 mV				
sdev	51.2 mV	39.8 mV	50.6 mV	50.1 mV				
num	1.000e+3	1.000e+3	1.000e+3	1.000e+3				
status	✓	✓	✓	✓				

C1 DC1M 1.00 W/div -1.370 V ofst	C2 DC1M 1.00 W/div -1.350 V ofst	C3 DC1M 1.00 W/div -1.430 V ofst	C4 DC1M 1.00 W/div -1.440 V ofst
---	---	---	---

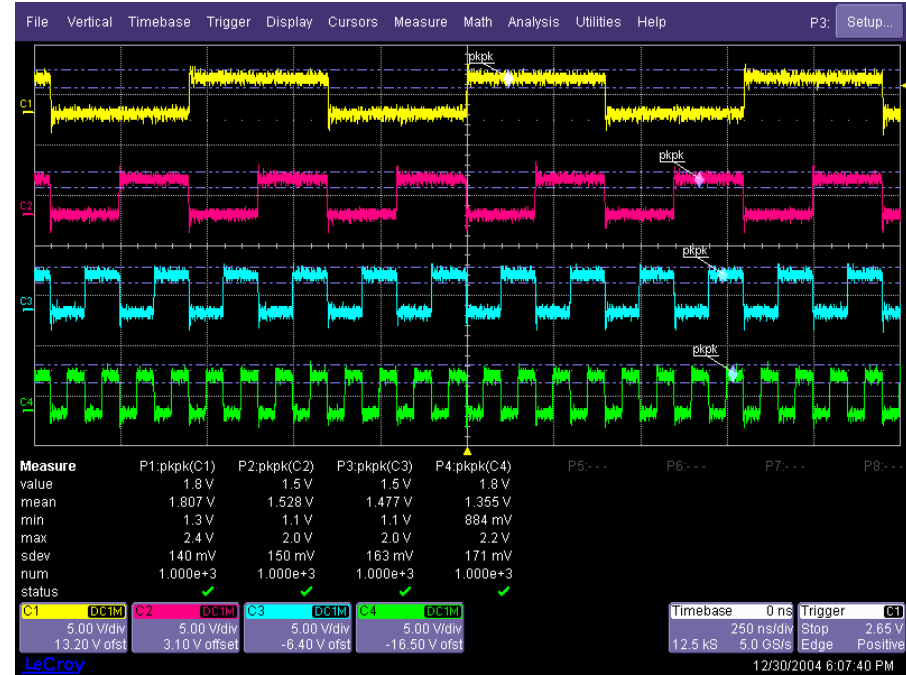
Timebase 0 ns	Trigger C1
250 ns/div	Stop 2.64 V
12.5 kS	Edge Positive
5.0 GS/s	

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

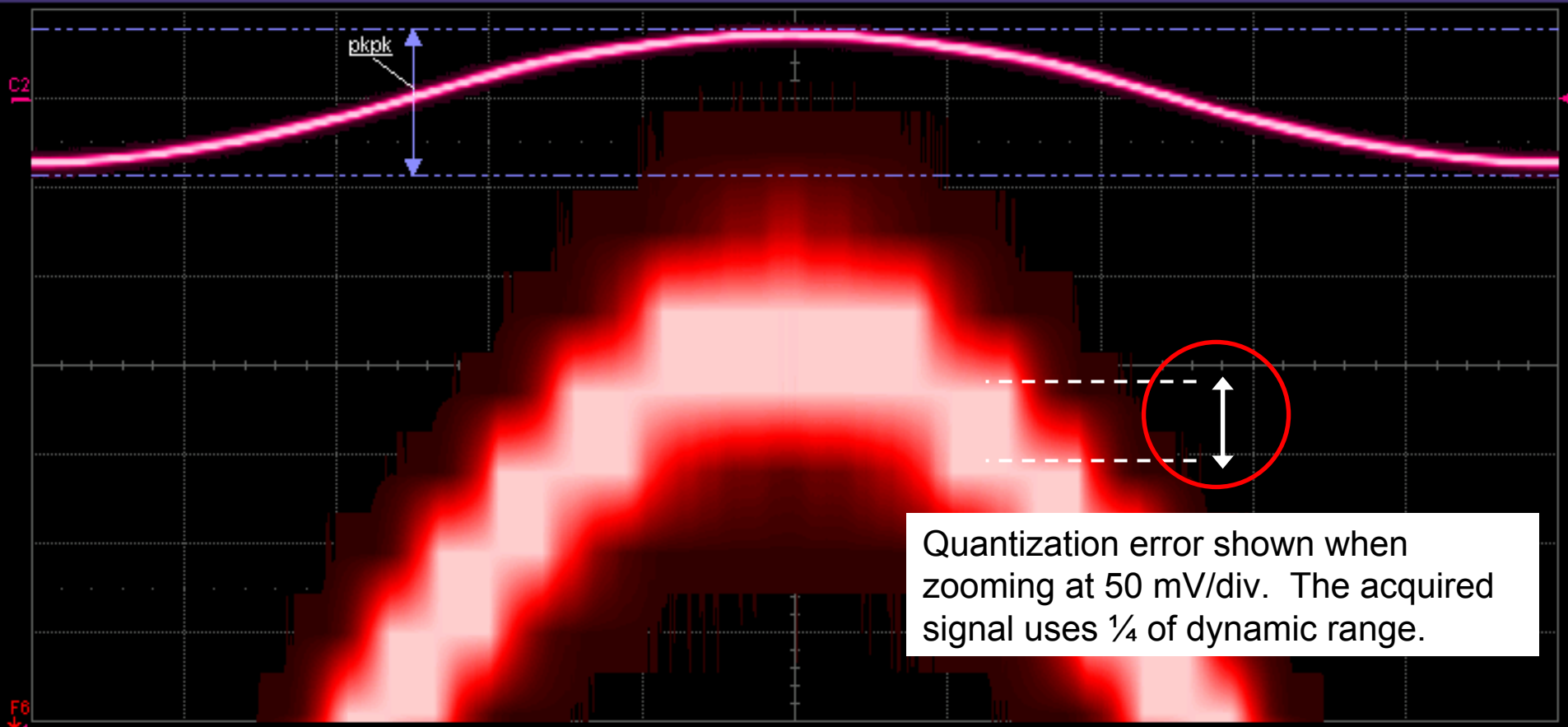


Single grid display

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



Quantization error shown when zooming at 50 mV/div. The acquired signal uses 1/4 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								

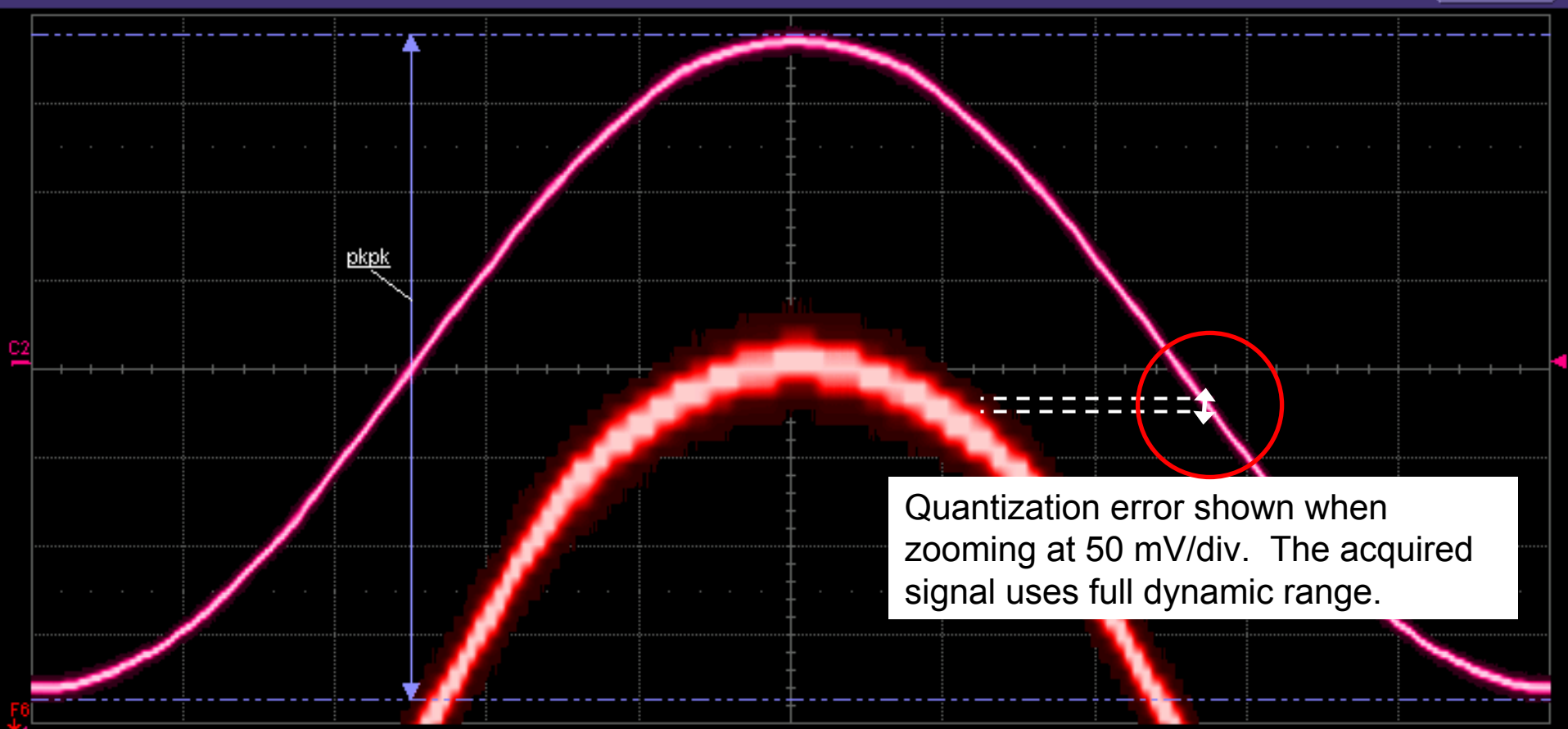
Persistence is turned on, to show quantization levels

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

Trigger C2
Stop 20 mV
Edge Positive
1.0 GS/s



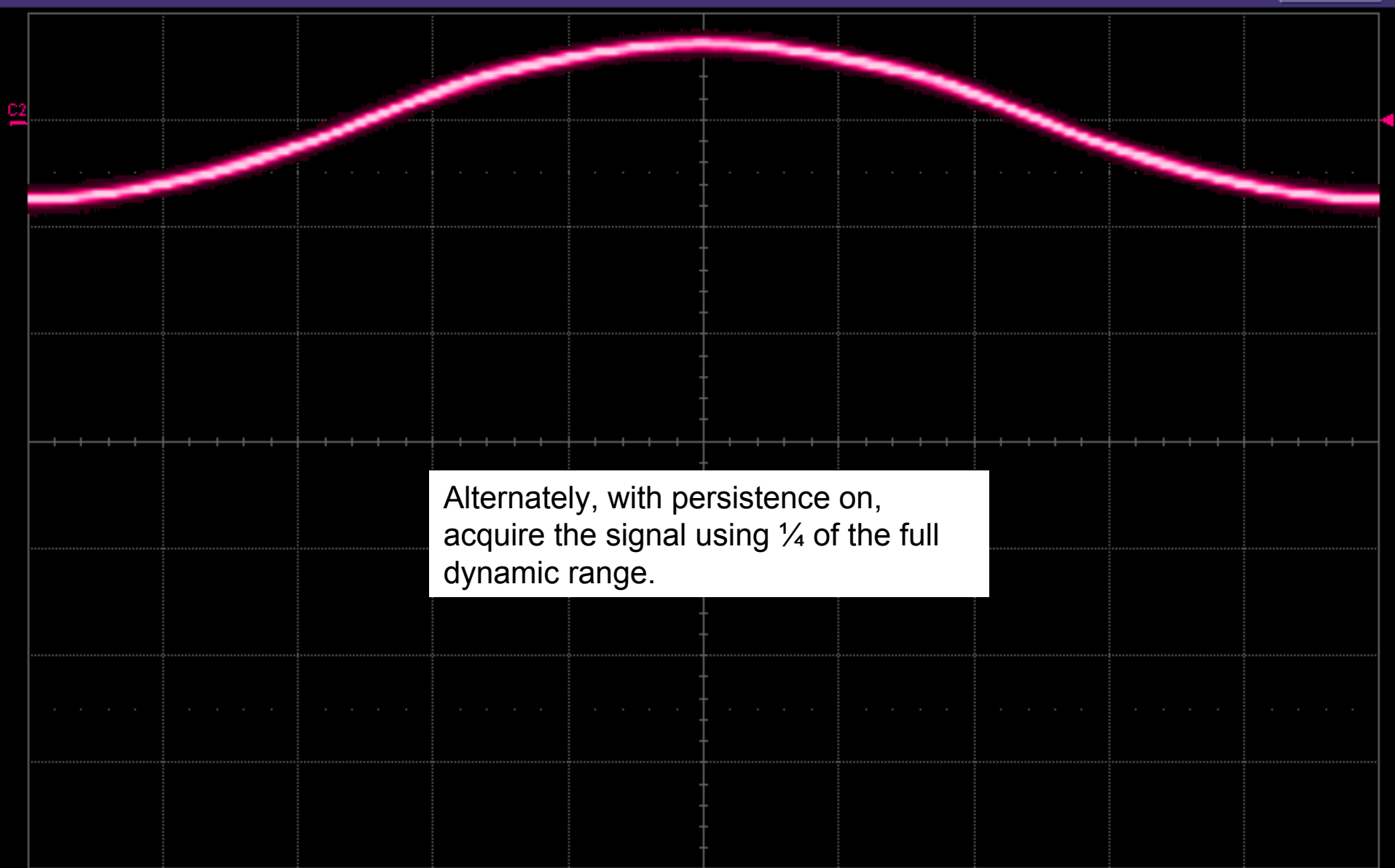
Measure	P1:pkpk(C2)	P2:rise(C2)	P3:width(C2)	P4:---	P5:---	P6:---	P7:---	P8:---
value	1.49 V	27.86844 μ s	50.04100 μ s					
mean	1.4939 V	27.7937839 μ s	50.0161130 μ s					
min	1.48 V	27.29021 μ s	49.71400 μ s					
max	1.50 V	28.08711 μ s	50.35300 μ s					
sdev	4.6 mV	120.7061 ns	89.6065 ns					
num	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 μ s/div

Timebase -224.4 μ s
10.0 μ s/div
100 kS 1.0 GS/s

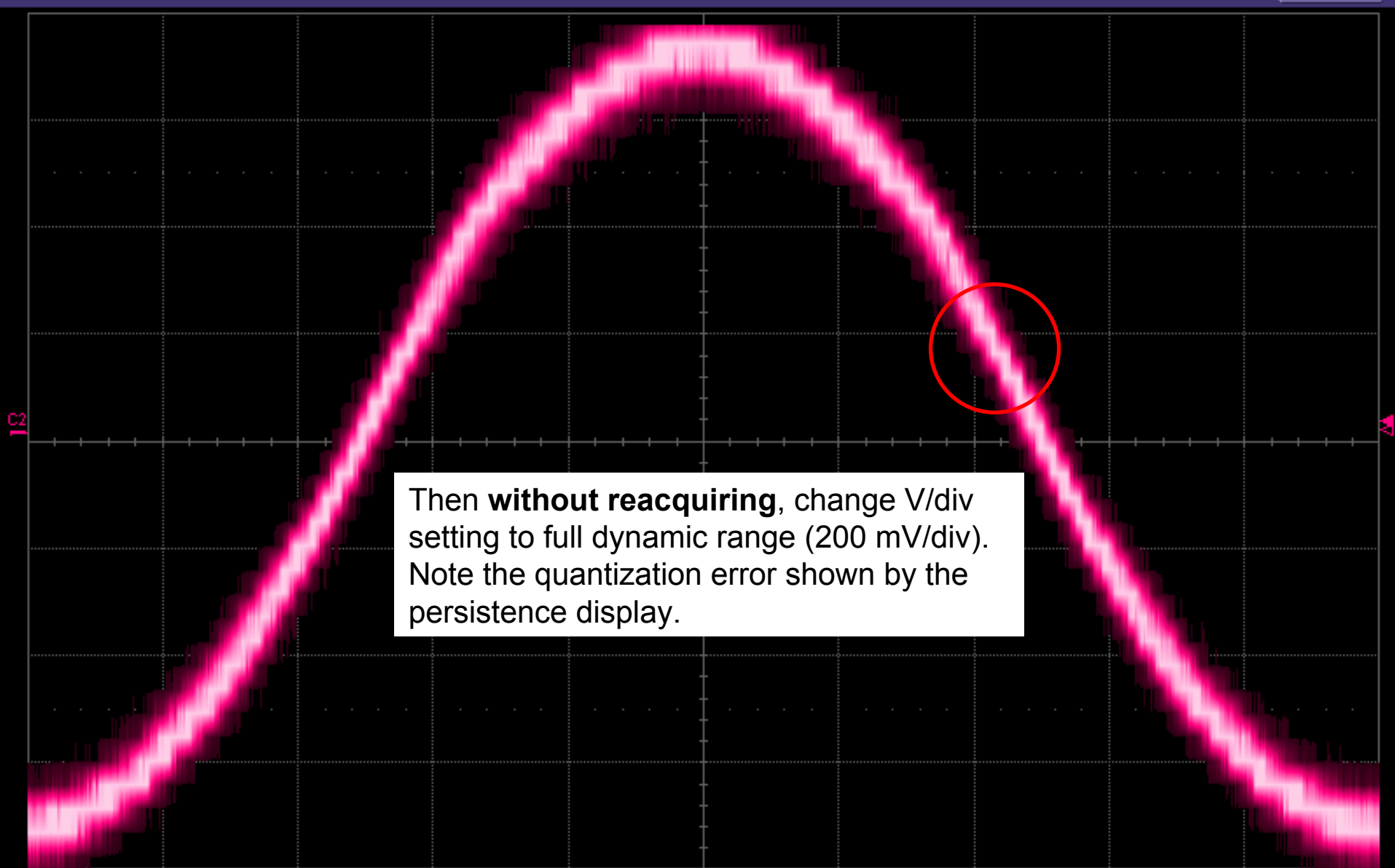
Trigger C2
Stop 4 mV
Edge Positive



Alternately, with persistence on, acquire the signal using $\frac{1}{4}$ of the full dynamic range.

C2 DC50
990 mV/div
2.940 V offset

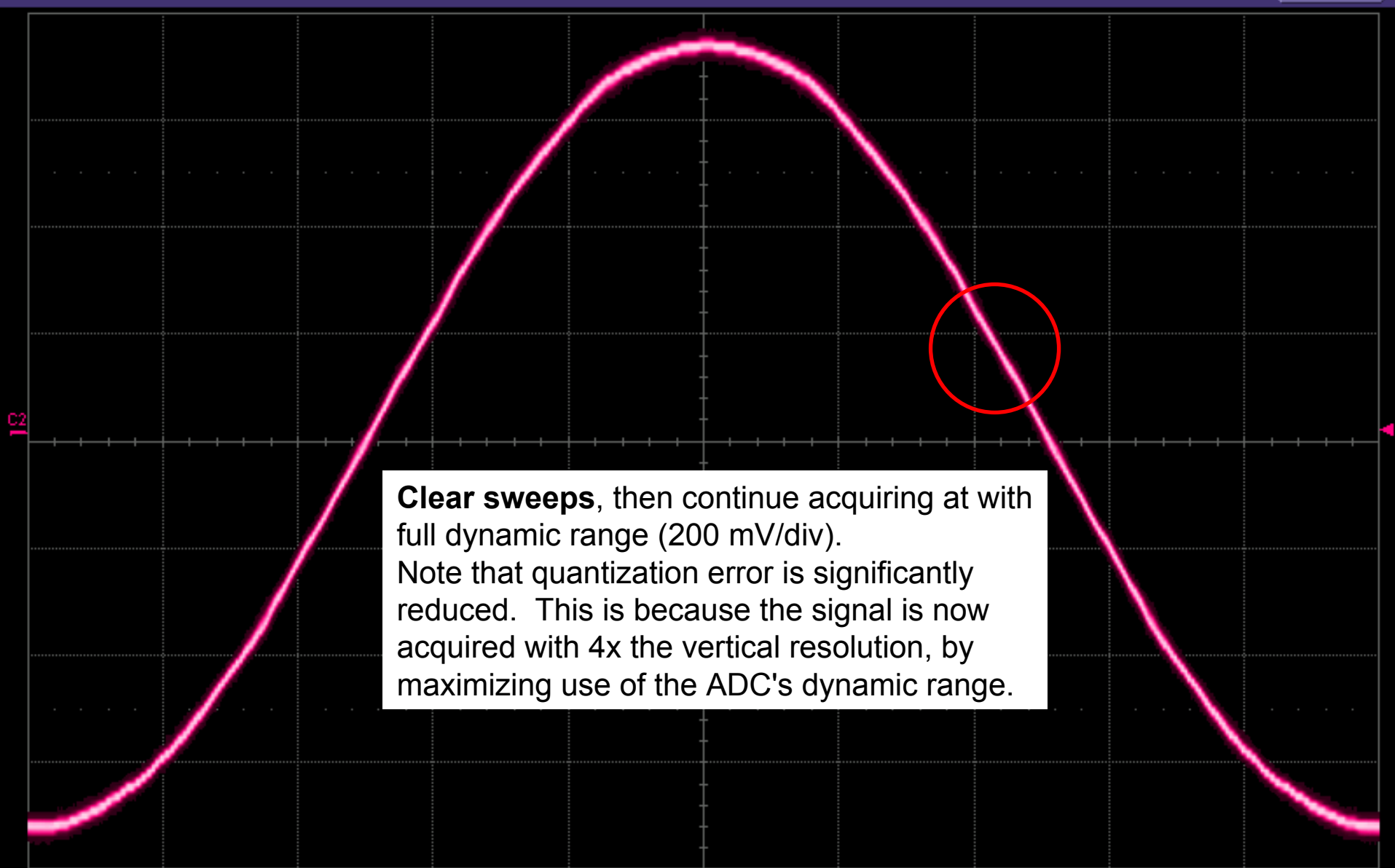
Timebase	-224.4 μ s	Trigger	C2
	10.0 μ s/div	Stop	20 mV
100 kS	1.0 GS/s	Edge	Positive



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

C2 DC50
200 mV/div
15 mV offset

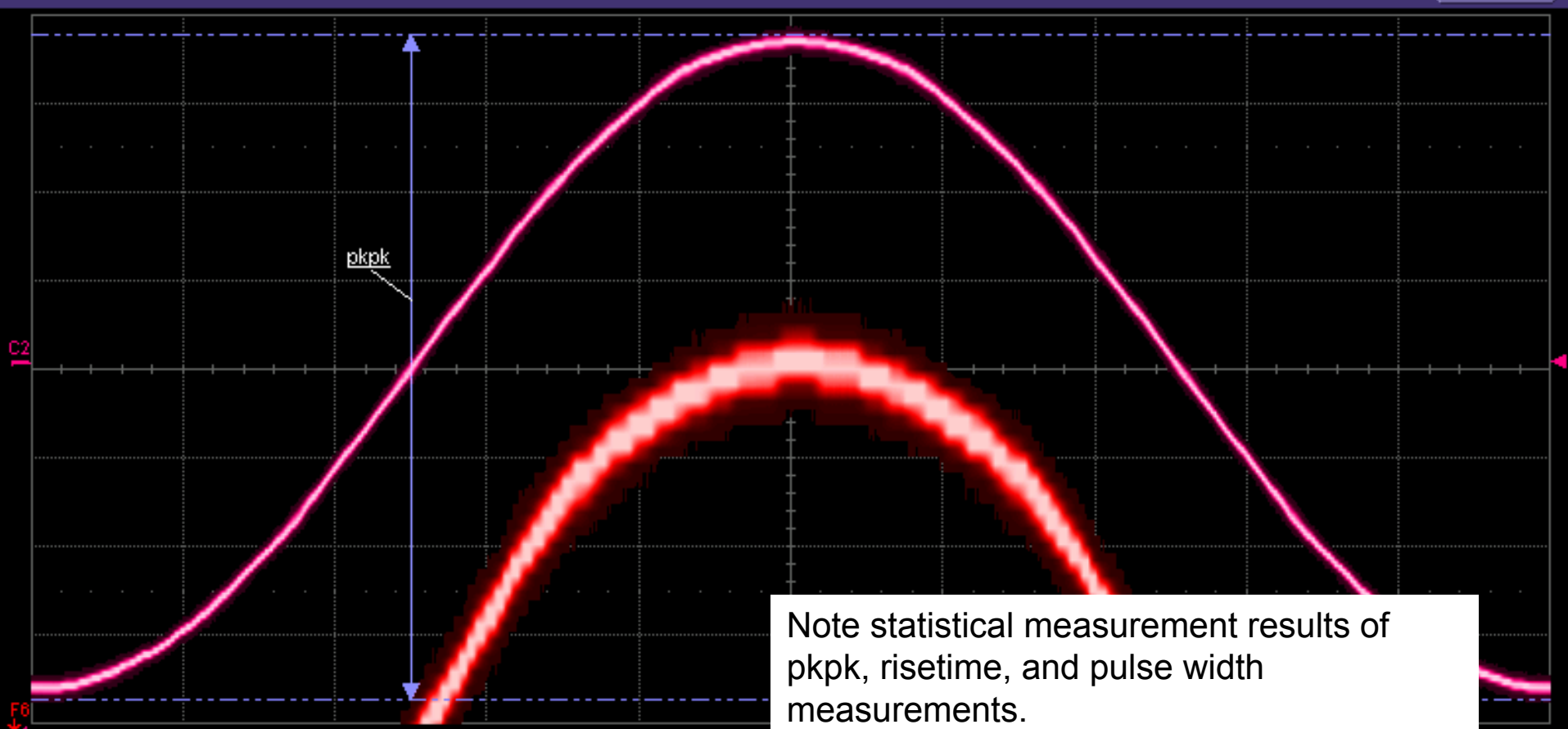
Timebase	-224.4 μ s	Trigger	C2
	10.0 μ s/div	Stop	4 mV
100 kS	1.0 GS/s	Edge	Positive



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 μ s	Trigger	C2
	10.0 μ s/div	Normal	4 mV
100 kS	1.0 GS/s	Edge	Positive



Note statistical measurement results of pkpk, risetime, and pulse width measurements.

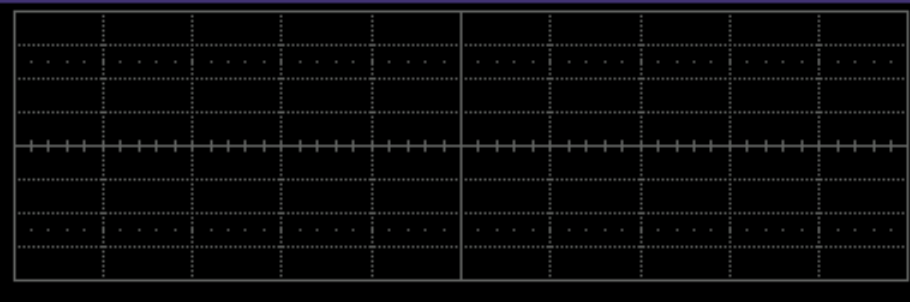
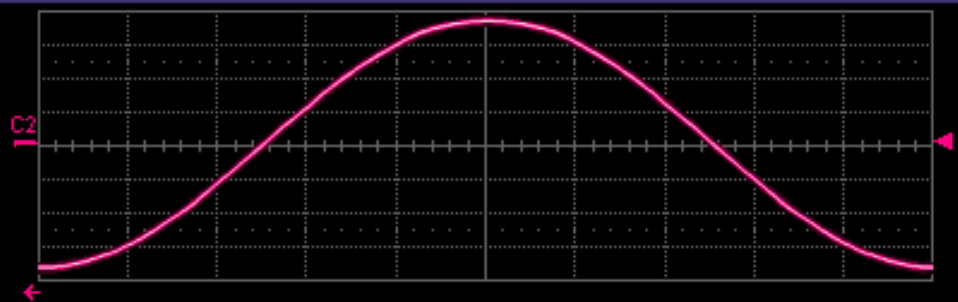
Measure	P1:pkpk(C2)	P2:rise(C2)	P3:width(C2)	P4:---	P5:---	P6:---	P7:---	P8:---
value	1.49 V	27.86844 μ s	50.04100 μ s					
mean	1.4939 V	27.7937839 μ s	50.0161130 μ s					
min	1.48 V	27.29021 μ s	49.71400 μ s					
max	1.50 V	28.08711 μ s	50.35300 μ s					
sdev	4.6 mV	120.7061 ns	89.6065 ns					
num	1.000e+3	1.000e+3	1.000e+3					
status	✓	✓	✓					

C2 DC50
200 mV/div
15.0 mV offset

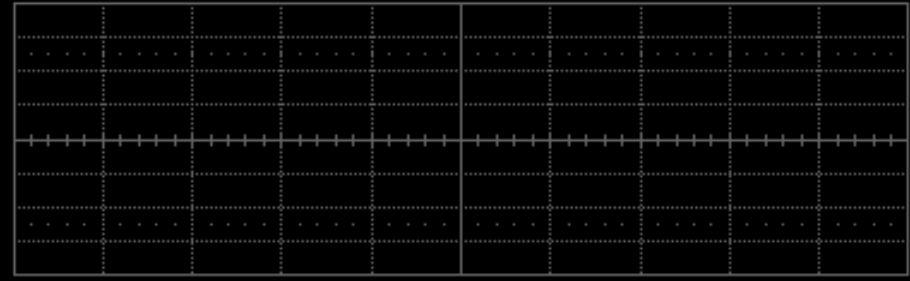
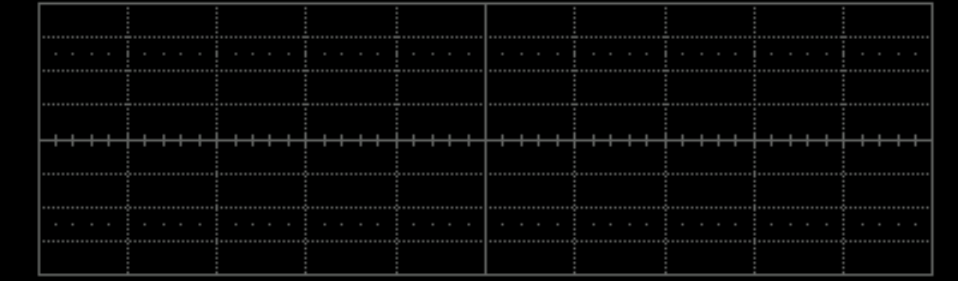
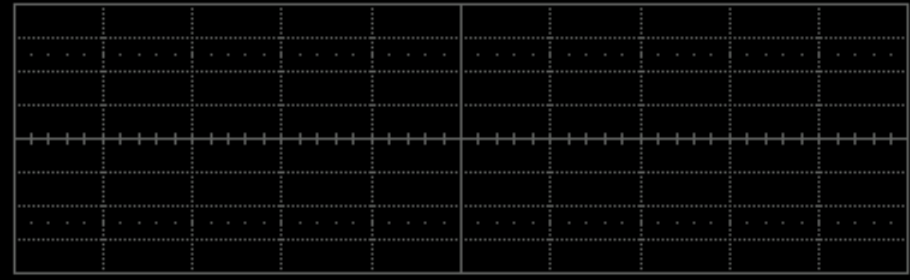
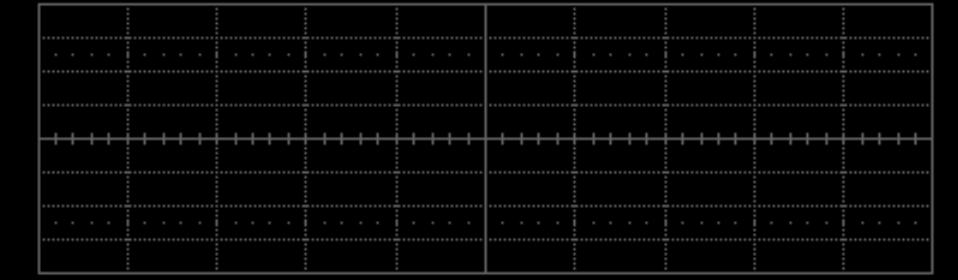
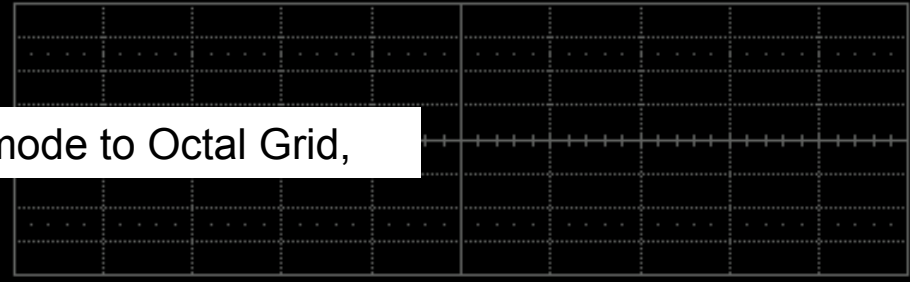
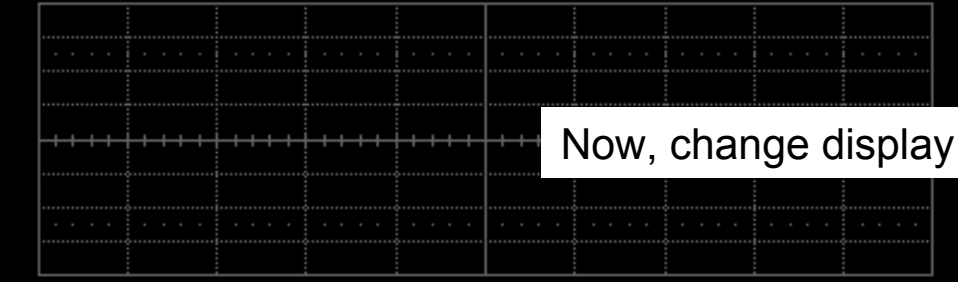
F6 zoom(C2)
50.0 mV/div
5.00 μ s/div

Timebase -224.4 μ s
100 kS 10.0 μ s/div
1.0 GS/s

Trigger C2
Stop 4 mV
Edge Positive

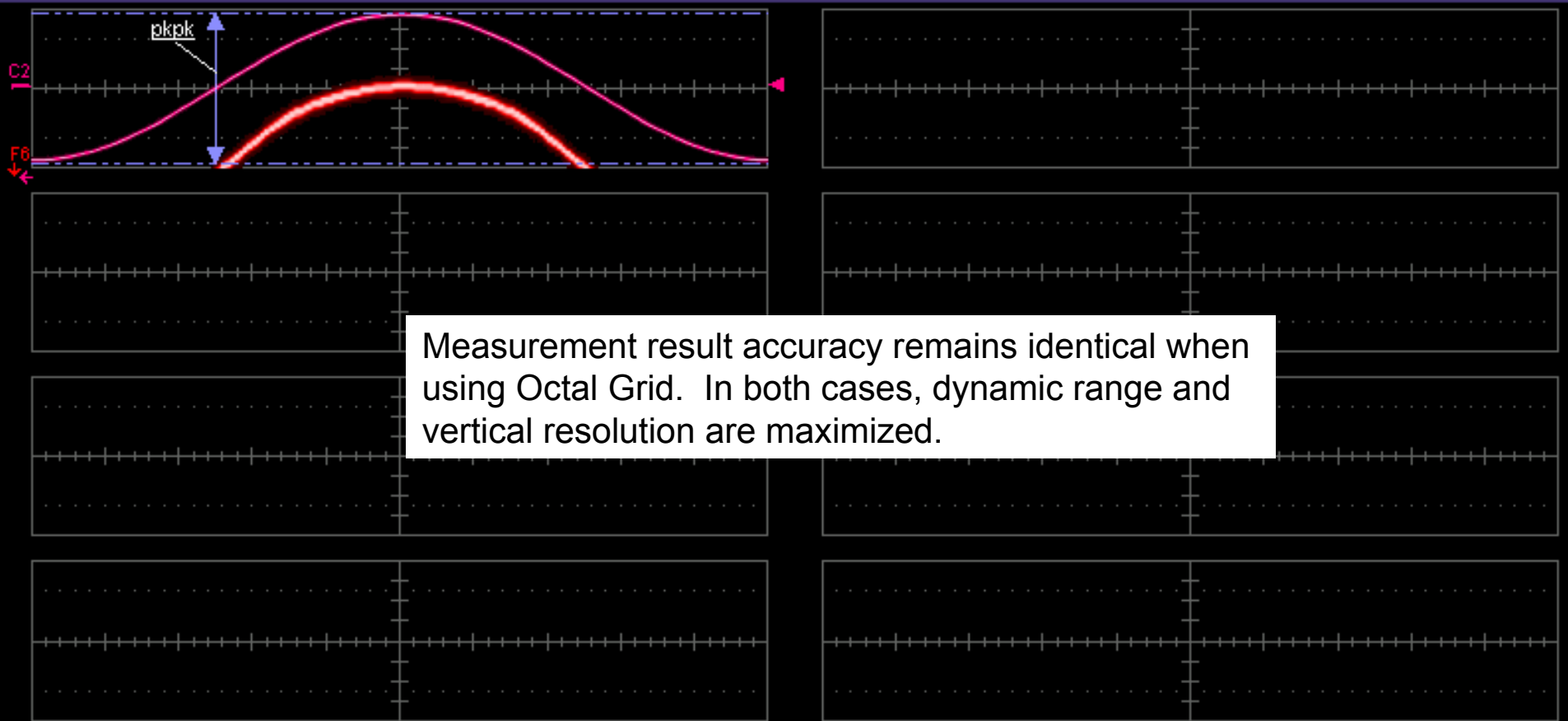


Now, change display mode to Octal Grid,



C2 DC50
200 mV/div
15.0 mV offset

Timebase	-224.4 μ s	Trigger	C2
	10.0 μ s/div	Stop	4 mV
100 kS	1.0 GS/s	Edge	Positive

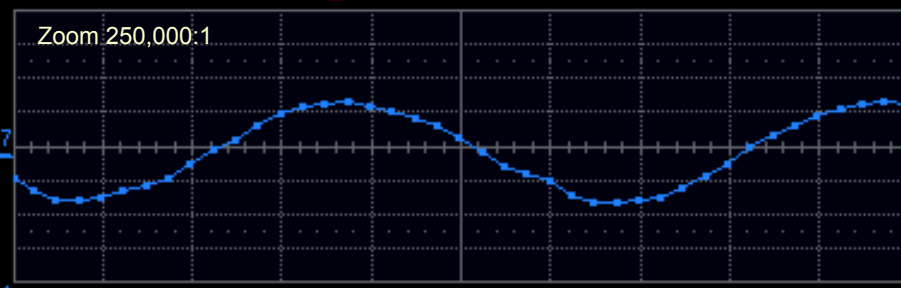
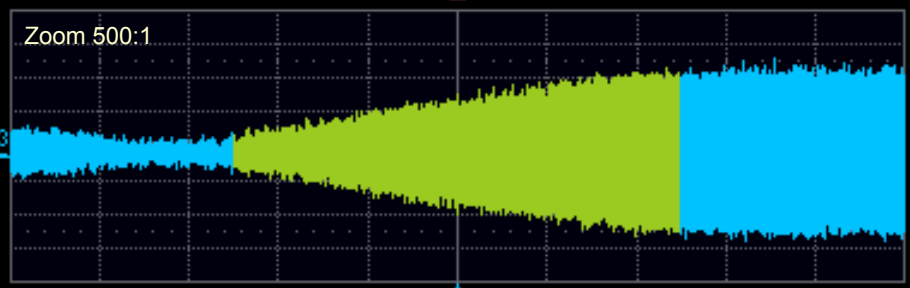
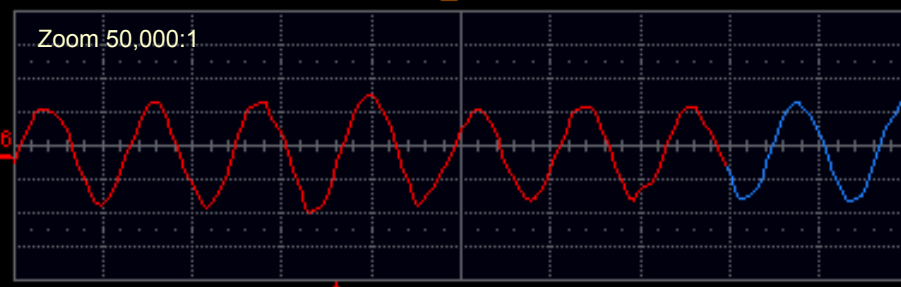
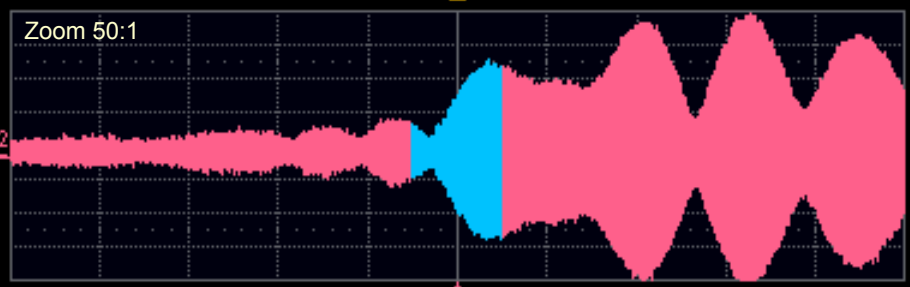
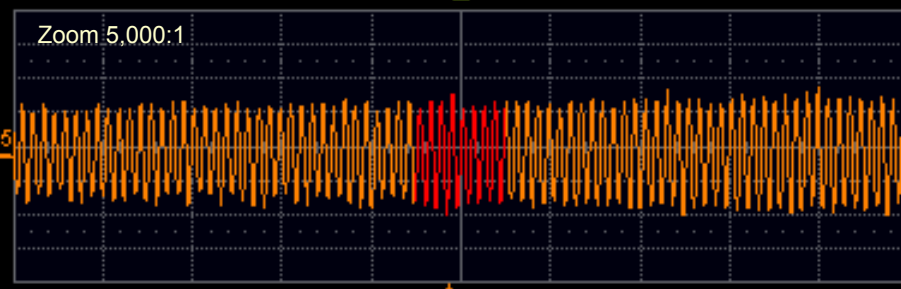
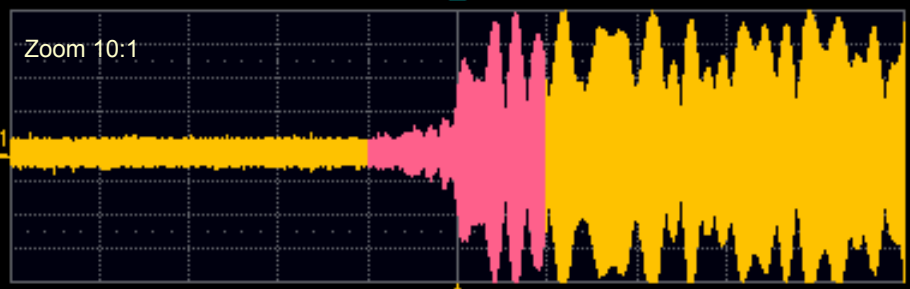
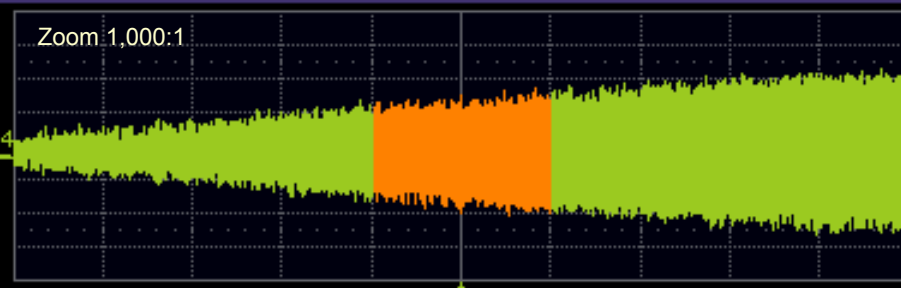
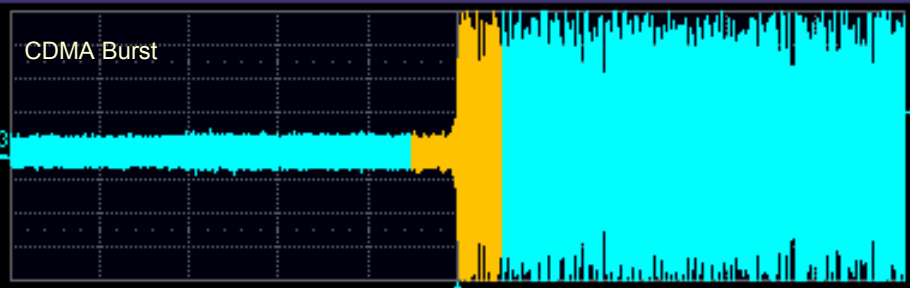


Measurement result accuracy remains identical when using Octal Grid. In both cases, dynamic range and vertical resolution are maximized.

Measure	P1:pkpk(C2)	P2:rise(C2)	P3:width(C2)	P4:---	P5:---	P6:---	P7:---	P8:---
value	1.49 V	27.88913 μ s	49.90000 μ s					
mean	1.4934 V	27.8139441 μ s	50.0215980 μ s					
min	1.48 V	27.49650 μ s	49.74400 μ s					
max	1.51 V	28.14141 μ s	50.37700 μ s					
sdev	4.6 mV	109.1840 ns	90.8688 ns					
num	1.000e+3	1.000e+3	1.000e+3					
status	✓	✓	✓					

C2	DC50	F6	zoom(C2)
200 mV/div	15.0 mV offset	50.0 mV/div	5.00 μ s/div

Timebase	-224.4 μs	Trigger	C2
100 kS	1.0 GS/s	Stop	4 mV
		Edge	Positive



C3	F1 zoom(C3)	F2 zoom(F1)	F3 zoom(F2)	F4 zoom(F3)	F5 zoom(F4)	F6 zoom(F5)	F7 zoom(F6)	Timebase	0 μ s	Trigger	Stopped
10.0 mV	10.0 mV	10.0 mV	10.0 mV	10.0 mV	10.0 mV	10.0 mV	10.0 mV	50.0 μ s/div	DC	C3	13.3 mV
-3 mV	5.00 μ s	1.000 μ s	100 ns	50.0 ns	10.0 ns	1.00 ns	200 ps	10.0 MS	20 GS/s	Edge	Positive