# HRO Flatness

*Of all the applications and measurements using an oscilloscope, flatness is one of the measurements that can be seen in parts of the power application where you are strictly looking at the transitions of a switching power device. Our 12-bit HRO flatness has the same or better flatness than our 8-bit scopes. All other specifications of the HRO are superior to 8-bit models.*

## 1 Purpose

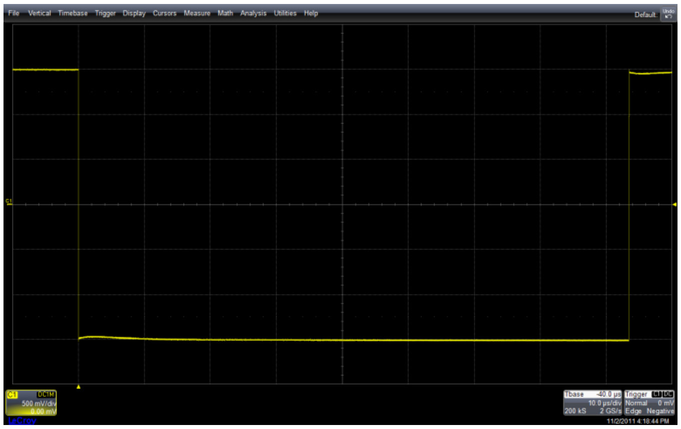
In this document, we will show you the 12-bit response from a fast edge and how it compares to 8-bit LeCroy scopes as well as competitive scopes. You will see that we meet and exceed our competitors in this area. We will look at short and long duration responses to a step edge.

This document will help to identify the flatness performance strengths and weakness, as well as how to properly position the HRO, or 8-bit oscilloscopes.

### 1.1 Setup

A typical measurement made from a customer looking at a signal with a fast rise or fall time. The application may require a measurement immediately following the fast edge, such as the settling time of an Op Amp or the saturation voltage of a MOSFET (turn-on characteristics).

For the test comparisons, we set the scope sensitivities so we were not overdriving the scopes. We are only focusing on flatness, not over-drive recovery.

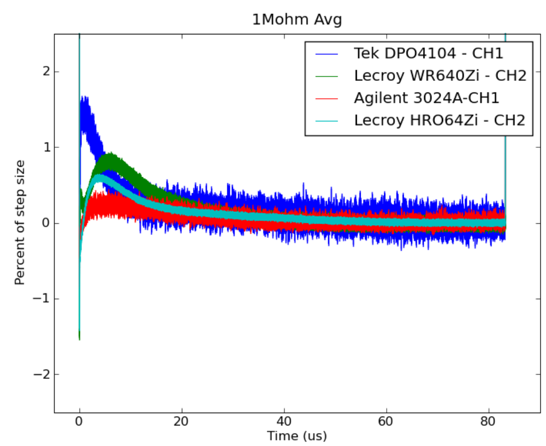
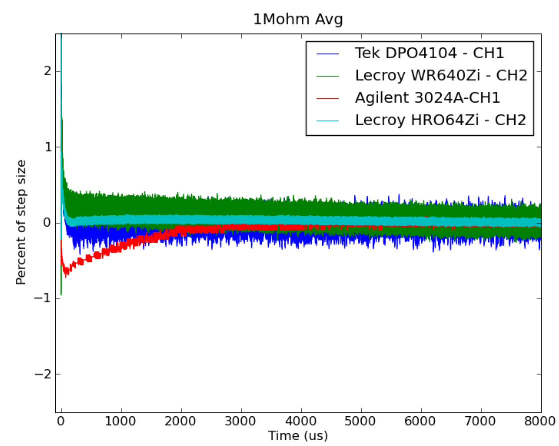
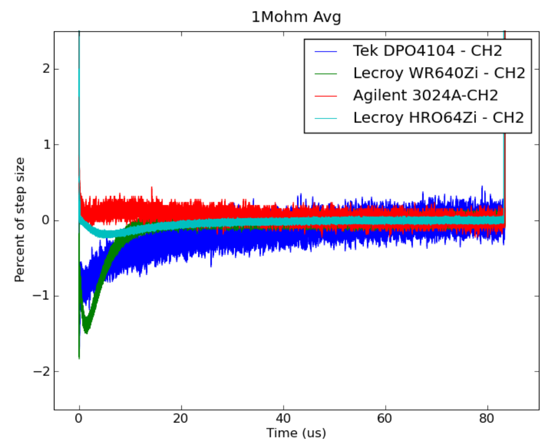
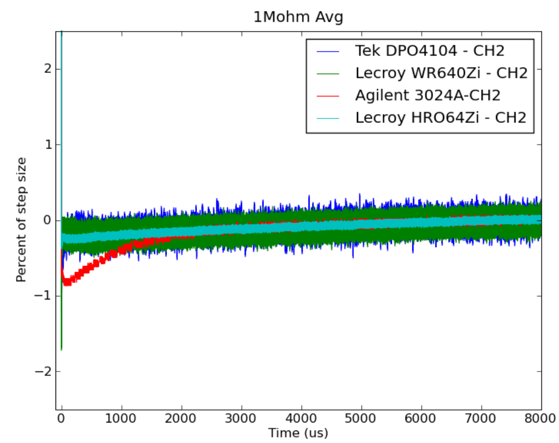



The *flatness* refers simply to how flat the region is following the falling edge. The ideal response is a perfectly symmetrical square wave with no settling time, overshoot, undershoot, and perfect linearity.

Because we have so much detail from the 12-bits 4096 quantization levels, all variances will be seen with 12-bits and hidden with 8-bit scopes.

## 1.2 Test comparisons

Using the test methodology listed in the reference section, the four different scopes were measured with a short and long timebase and averaged. The results below show the four traces overlayed on top of each other, at both 50 mV/div and 500 mV/div. The 50 mV/div traces show the scope in a ÷1 attenuator path where the 500 mV/div path shows the response in a ÷10 path.

| ***1 MOhm – short duration (~80 µs)***<br>***500 mV/Div*** | ***1 MOhm – long duration (~8 ms)***<br>***500 mV/div*** |
|---|---|
|  |  |
| • ***Tektronix shows the worst settling***<br>• ***HRO and 8-bit are about the same***<br>• ***Agilent has the best flatness at this setting*** | • ***Tektronix has a slow ramp up***<br>• ***HRO is extremely flat***<br>• ***Agilent has the worst settling at longer time bases*** |
| ***1 MOhm – short duration (~80 µs)***<br>***50 mV/div*** | ***1 MOhm – long duration (~8 ms)***<br>***50 mV/div*** |
|  |  |
| • ***Tektronix and LeCroy 8-bit have poor settling***<br>• ***HRO and Agilent are both flat*** | • ***All scopes show a slight ramp***<br>• ***Agilent is the worst performer at this setting*** |

## 1.3 Flatness Defined

Flatness behavior is attributed to the flatness of the front end frequency response in the lower frequency region. To go even deeper to the root cause of this behavior relates to the dual path (50 Ω and 1 MΩ) nature of multi-purpose oscilloscopes. The 1 MΩ buffer creates the non ideal characteristics that are shown in the screen shots. To have a scope with better flatness would require removing the 1 MΩ path, which removes the flexibility of a general purpose oscilloscope.

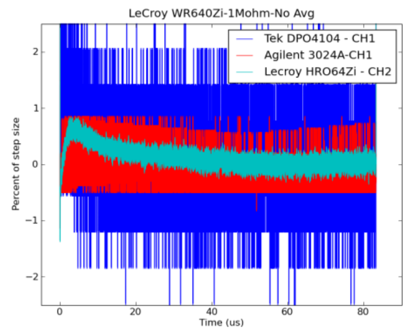
### 1.4 Conclusions

1. All oscilloscopes exhibit flatness error on the order of 0.5% to 1%.

2. Many setup settings can affect the performance of flatness. These include:
    a. Timebase setting
    b. Probes used
    c. Attenuation setting
    (Each oscilloscope clicks in an attenuator at different volt/div settings. That is why the above images are different between 50 mV and 500 mV)

    To properly assess if a certain oscilloscope can measure a particular % of flatness at a given timebase setting, there is no rule of thumb because of all the variables. It is best to involve your application engineer and measure the customers signal on an oscilloscope.

3. The HRO is a dominant test instrument for all applications. There are no areas where it is inferior and it can easily compete in all application areas. The HRO shows superior noise performance to see details that are otherwise hidden with competitive scopes. See figure showing the non-averaged waveforms from Tektronix and Agilent.




### 1.5 Reference

There are eight test cases presented:

1. 4 scopes in 50Ohm and 500 mV/div and looking over ~80us time window
2. 4 scopes in 1MOhm 500 mV/div and looking over ~80us time window
3. 4 scopes in 50Ohm 500 mV/div and looking over ~8ms time window
4. 4 scopes in 1MOhm 500 mV/div and looking over ~8ms time window
5. 4 scopes in 50Ohm and 50 mV/div and looking over ~80us time window
6. 4 scopes in 1MOhm 50 mV/div and looking over ~80us time window
7. 4 scopes in 50Ohm 50 mV/div and looking over ~8ms time window
8. 4 scopes in 1MOhm 50 mV/div and looking over ~8ms time window

### 1.6 Test Methodology

Agilent 33220A Arbitrary Waveform Generator

All oscilloscopes were tested with the same signal, for the same tests. Averages were set to 16.

The results Comparison50ohmAverages.png and Comparison1MohmAverages.png had an input of 6kHz square wave, 3Vpp.
The scopes were set to 10us/div horizontally and 500mV/div vertically.

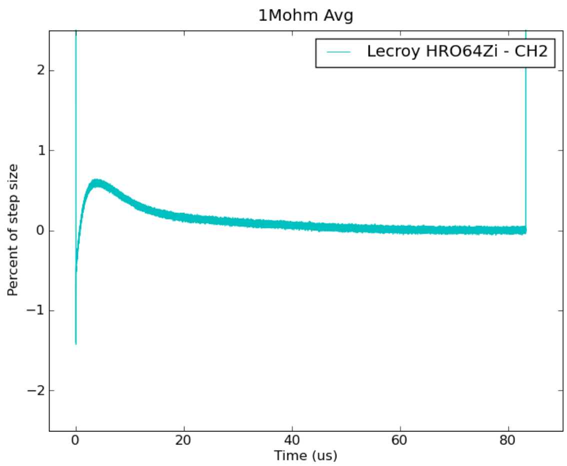
The results Comparison50ohmAveragesLong.png and Comparison1MohmAveragesLong.png had an input of 10Hz square wave, 3Vpp.
The scopes were set to 1ms/div horizontally and 500mV/div vertically.

In the 50ohm tests both the scopes and the Arb were put in 50ohm termination.
In the 1Mohm tests the Scopes were put in 1Mohm termination and the Arb was put in Hi-Z load.
The falling edge of the 50% duty cycle waveform was triggered on.

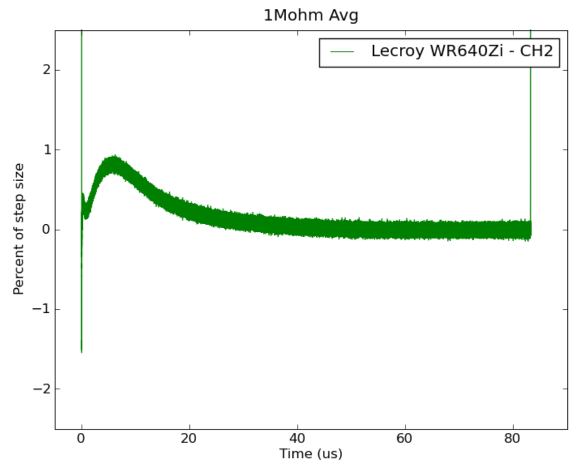
# 2 Appendix

## 2.1 1 MOhm – 80 µs (500 mV)

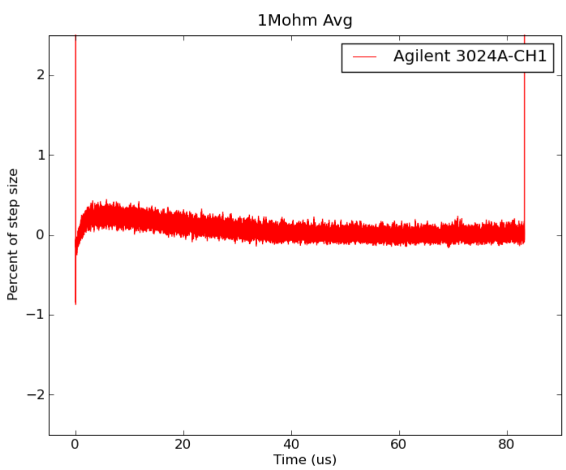
***LeCroy HRO***



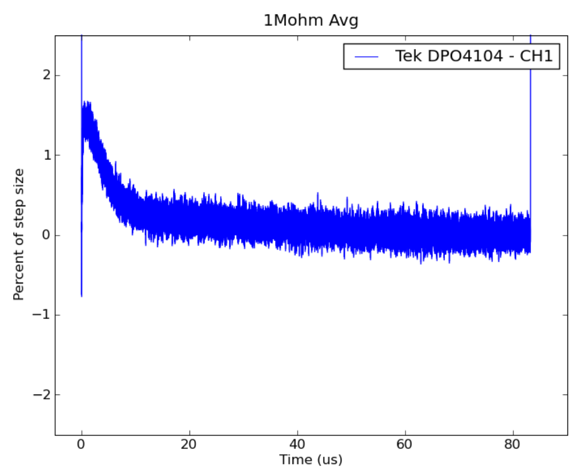

***LeCroy 8-bit***



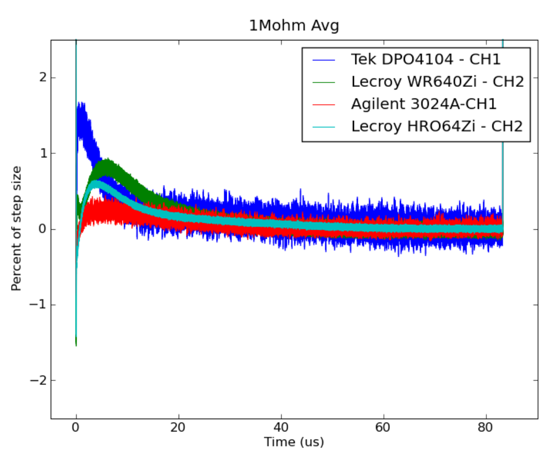

***Agilent X3024***



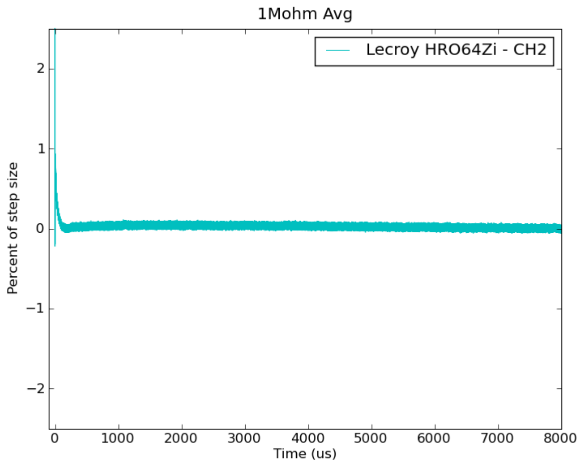
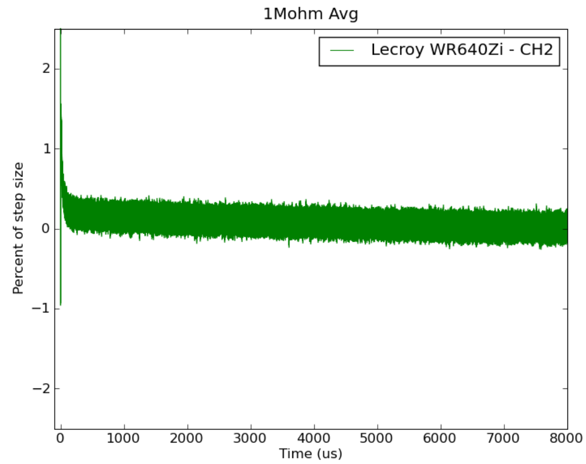
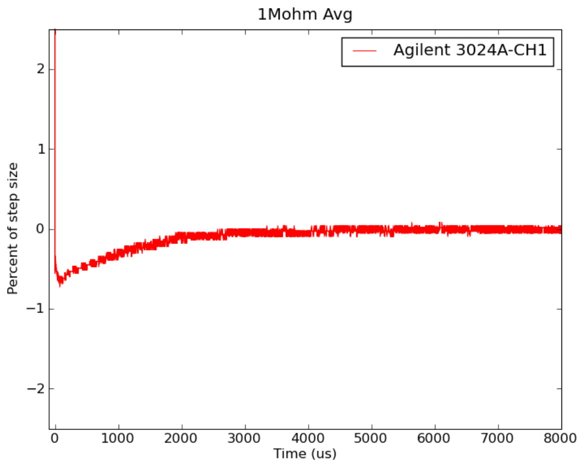
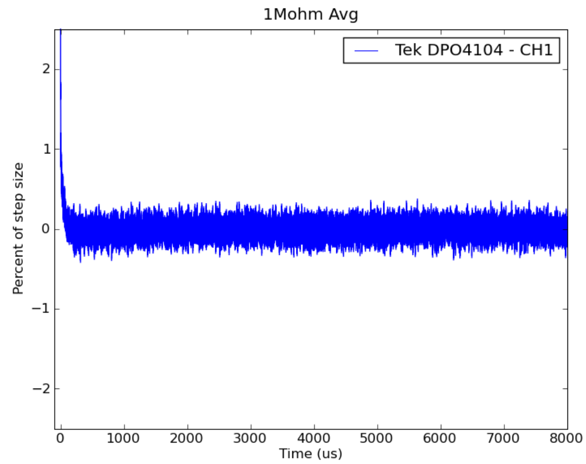

***Tektronix DPO4104***




**Summary**



## 2.2 1 MOhm – 8 ms (500 mV)

| ***LeCroy HRO*** | ***LeCroy 8-bit*** |
|---|---|
|  |  |
| ***Agilent X3024*** | ***Tektronix DPO4104*** |
|  |  |

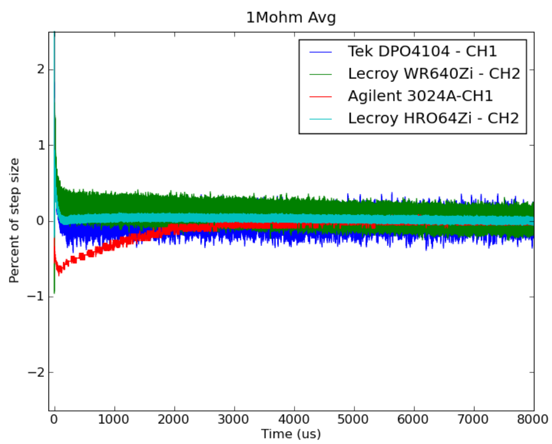






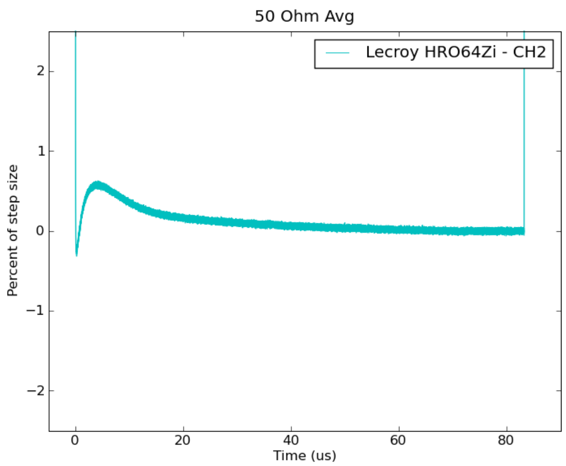


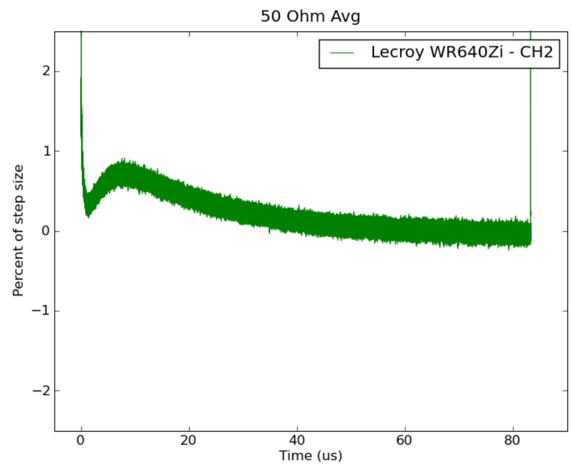
**Summary**



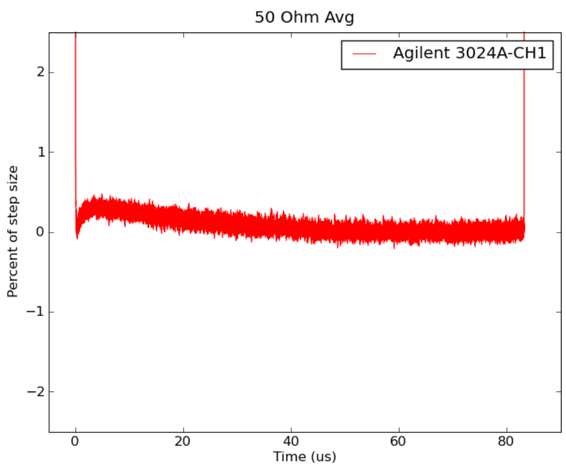
## 2.3 50 Ohm - 80 µs (500 mV)

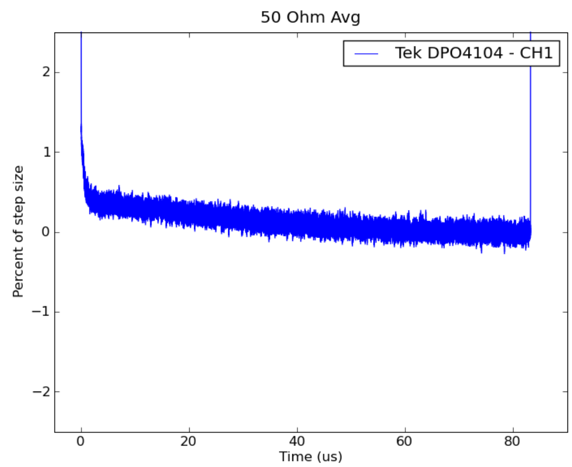
| ***LeCroy HRO*** | ***LeCroy 8-bit*** |
|---|---|




| ***Agilent X3024*** | ***Tektronix DPO4104*** |
|---|---|

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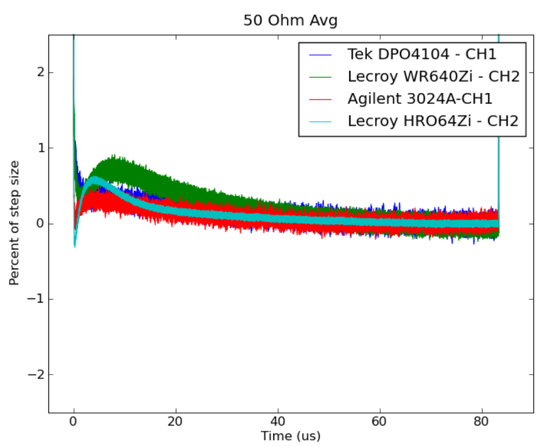
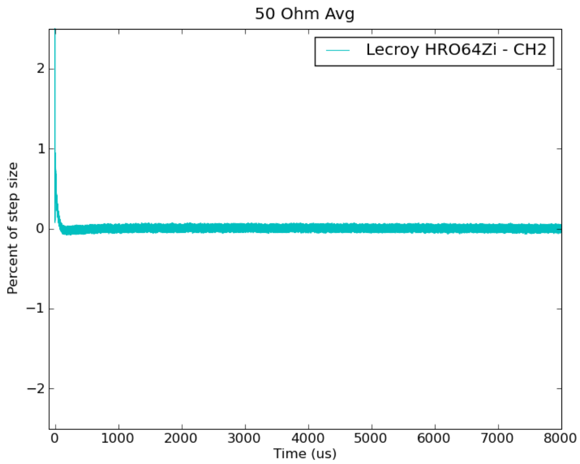
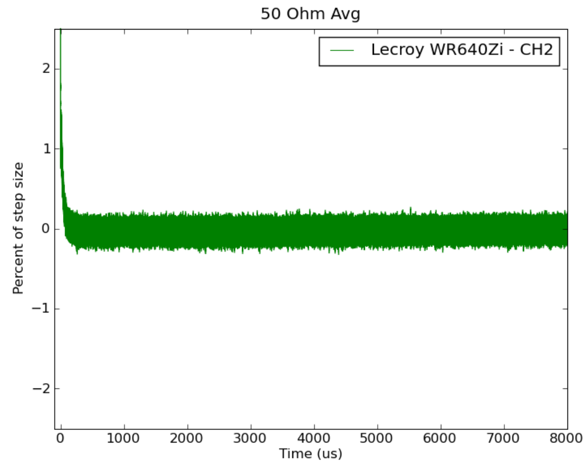


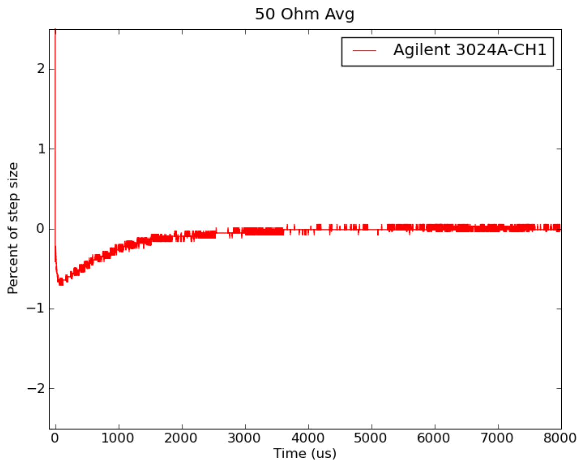
## 2.4 50 Ohm – 8 ms (500 mV)

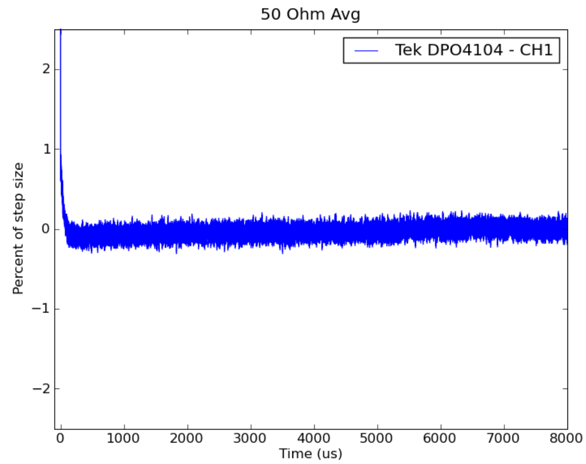
| ***LeCroy HRO*** | ***LeCroy 8-bit*** |
|---|---|




| ***Agilent X3024*** | ***Tektronix DPO4104*** |
|---|---|

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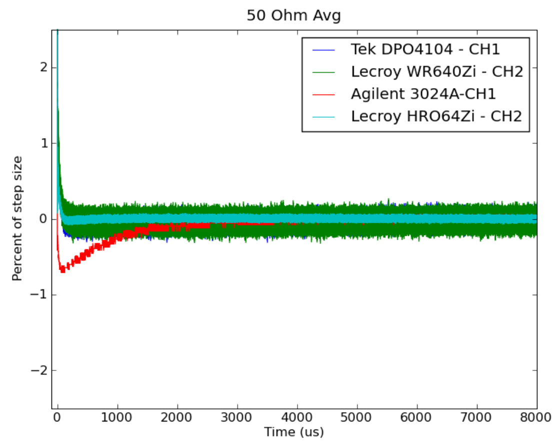
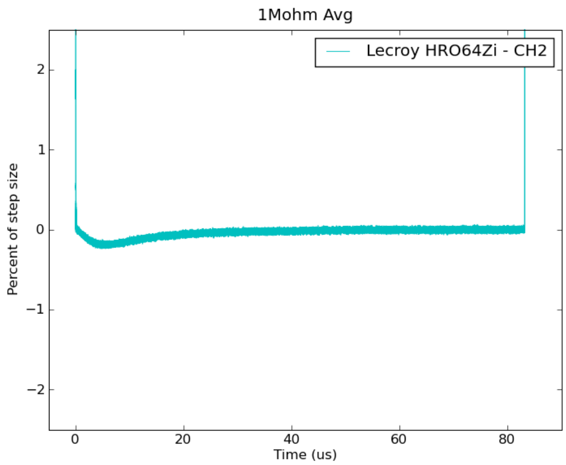
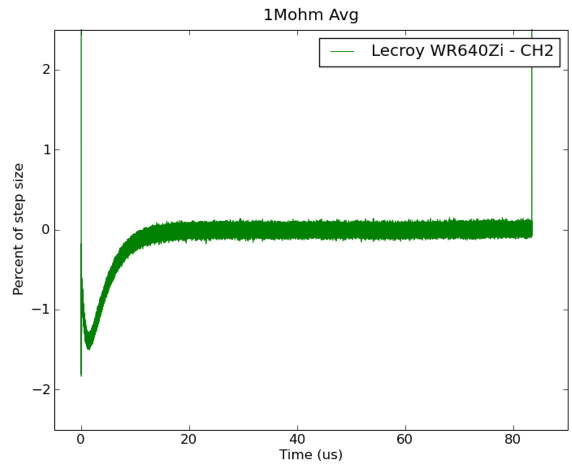


## 2.5 1 MOhm – 80 µs (50 mV)

***LeCroy HRO***




***LeCroy 8-bit***

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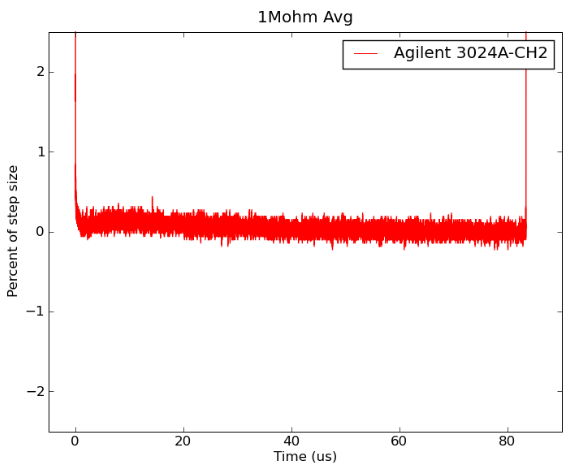
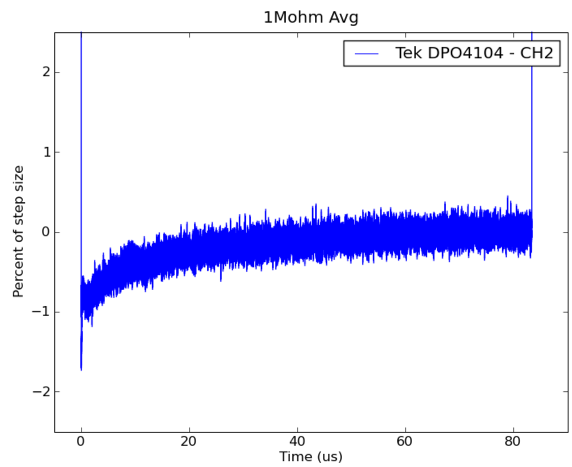



***Tektronix DPO4104***

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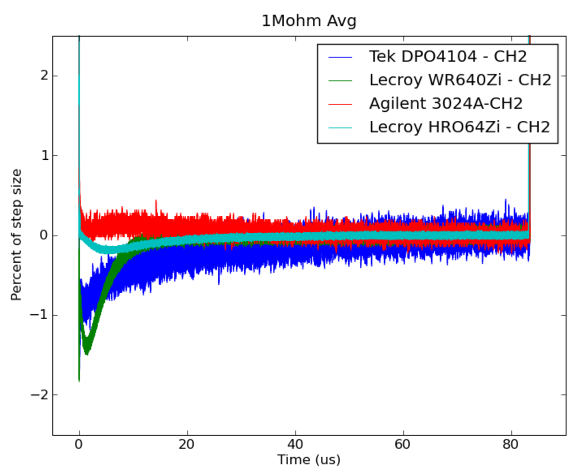
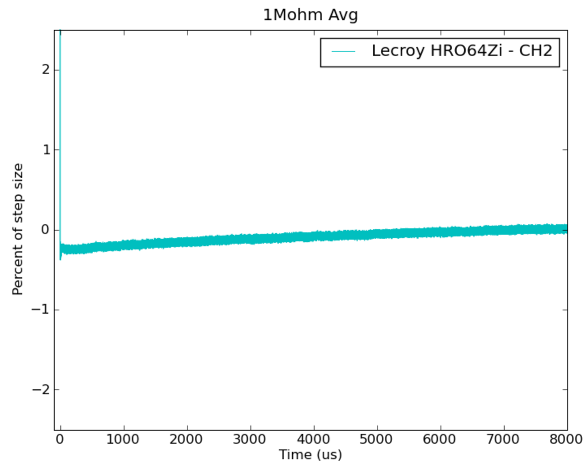
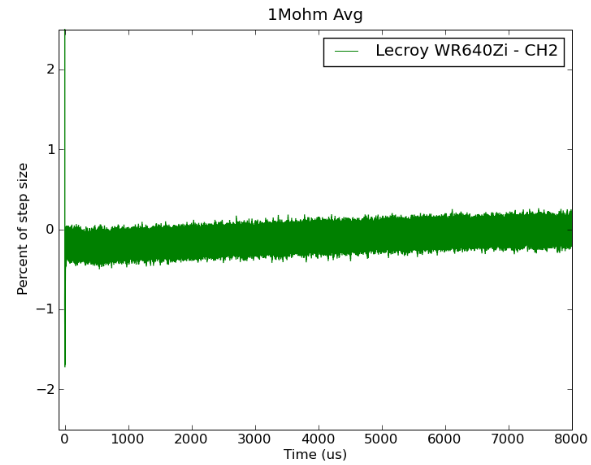


## 2.6 1 MOhm – 8 ms (50 mV)

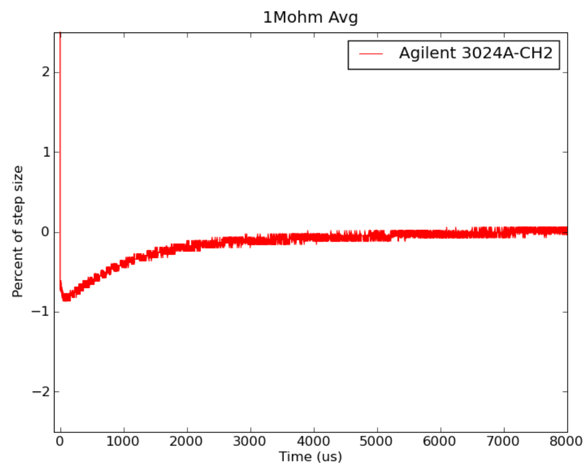
***LeCroy HRO***



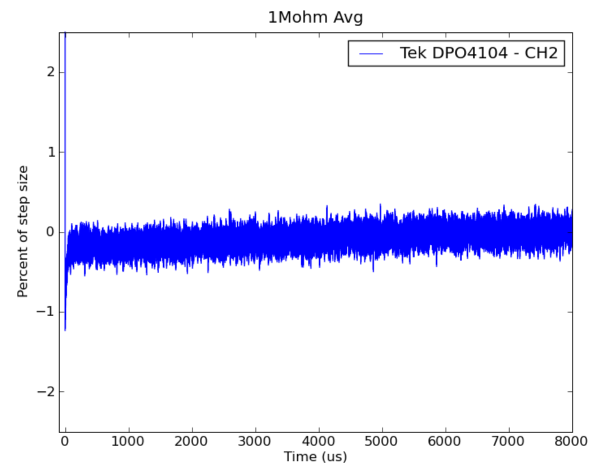

***LeCroy 8-bit***




***Agilent X3024***




***Tektronix DPO4104***

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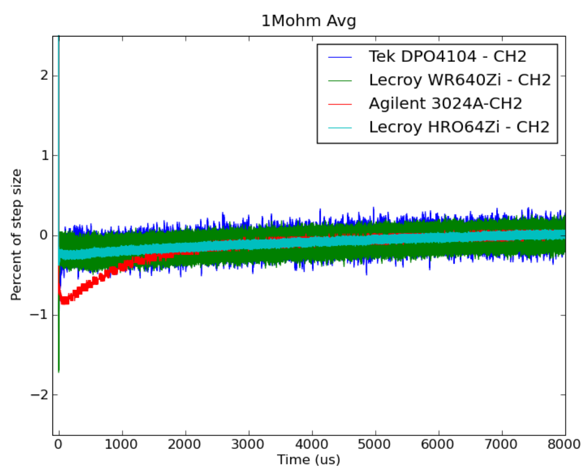

## 2.7 50 Ohm - 80 µs (50 mV)

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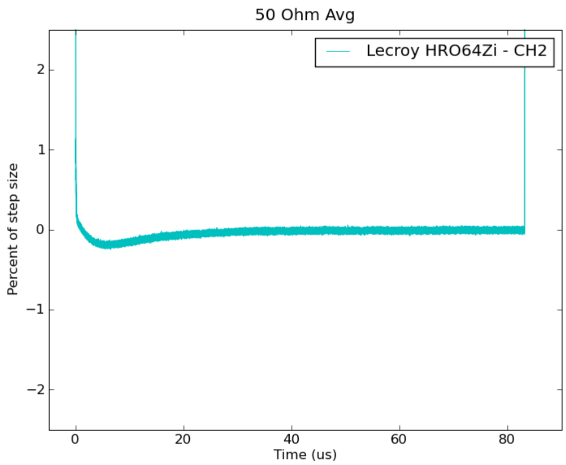
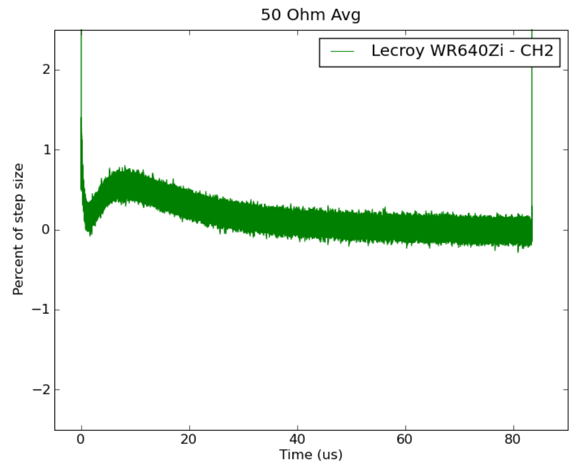
|---|---|
|  |  |





| ***Agilent X3024*** | ***Tektronix DPO4104*** |
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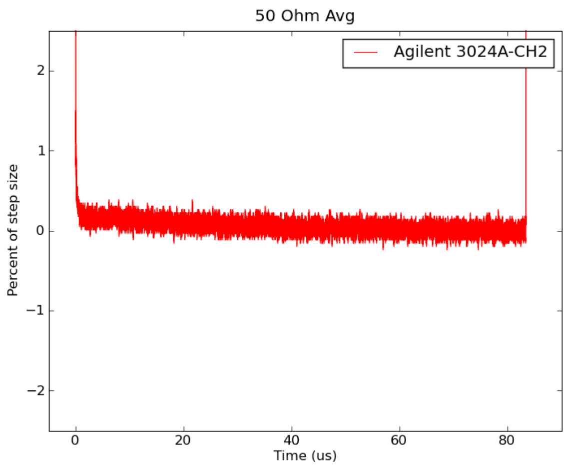
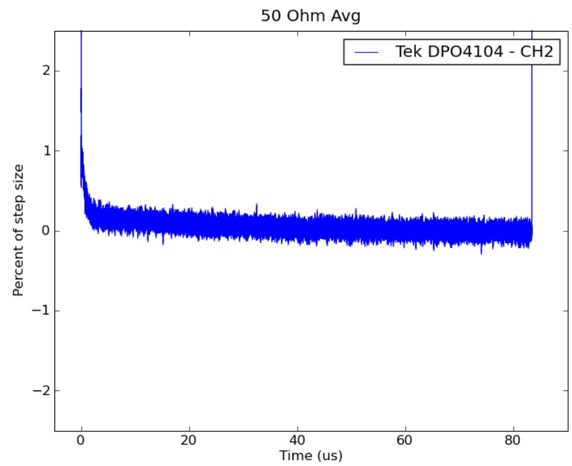
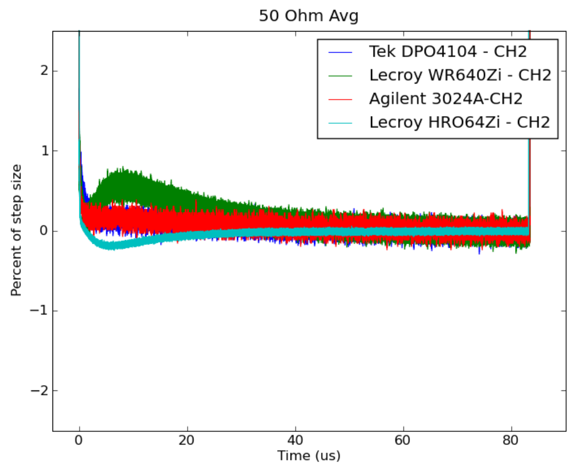
|  |  |

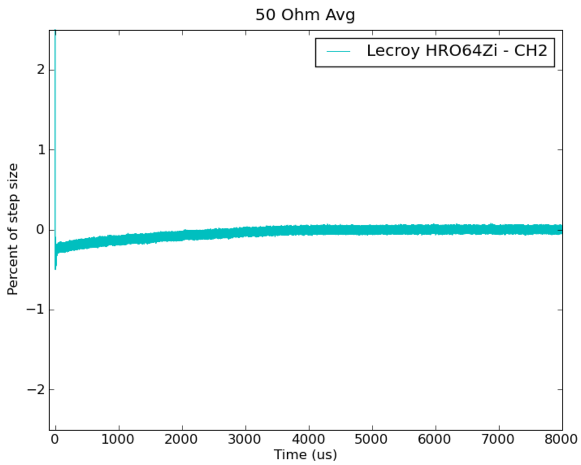
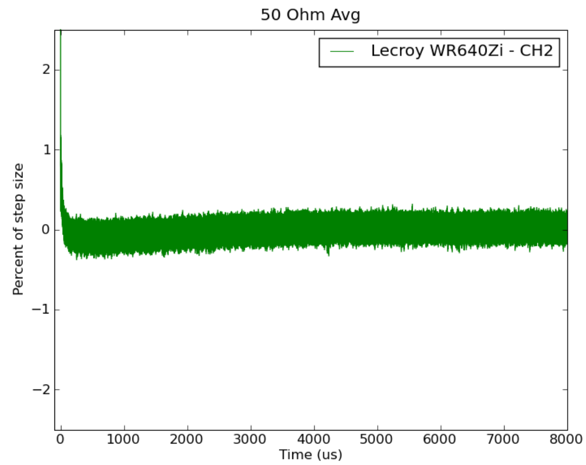




### Summary

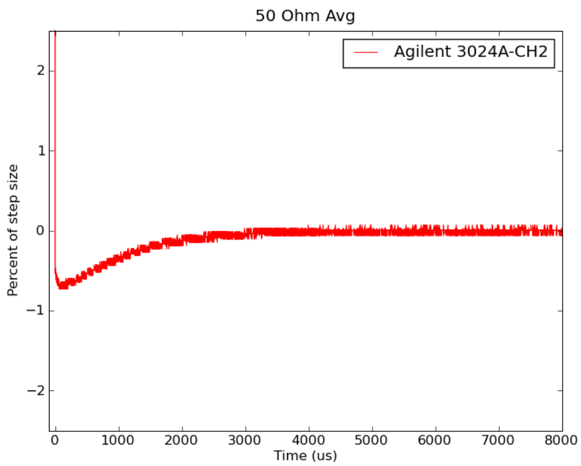
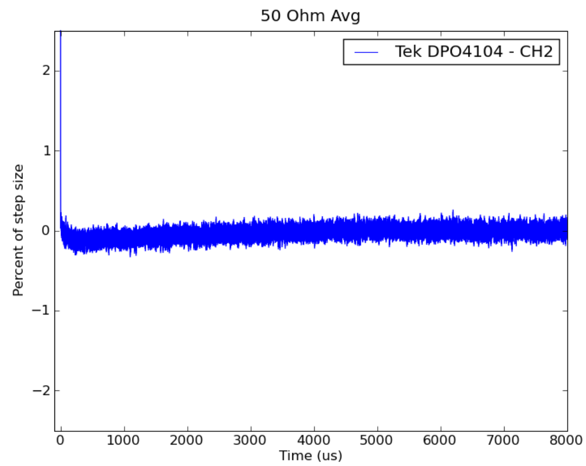


## 2.8 50 Ohm – 8 ms (50 mV) notdone

| *LeCroy HRO* | *LeCroy 8-bit* |
|---|---|
|  |  |





| *Agilent X3024* | *Tektronix DPO4104* |
|---|---|
|  |  |





**Summary**