# Making Better Scope Measurements

## Oscilloscope Remains the Instrument of Choice for Time Domain Measurements

In part, this is due to their extreme flexibility in handling various signal types along with both analysis and measurement features. As scope performance and functionality have expanded, it may not always be clear how to determine the true instrument capabilities represented by the various manufacturers and setup selections available to the user. One example is just trying to understand the most common performance specification of scope bandwidth and how it is influenced by various acquisition modes like real-time and repetitive sampling, waveform interpolation and even the number of active channels.

When making measurements or looking for fine waveform details, the published specifications or scope features may make it unclear how to optimize the setup or even compare performance between various scope manufacturers. There can also be other factors like probing or signal conditioning, external signal interferences and even the scope itself.

In order to help you better understand how to optimize measurement results, this paper takes a more practical approach that focuses on the oscilloscope's:

- Vertical resolution
- Effects of noise
- Highlights techniques that can be easily applied

When making measurements, the best possible conditions are when the signals of interest meet the criteria of the scope's bandwidth, sampling rate and input dynamic range. For advanced signals like high speed serial data with embedded clock, jitter and timing measurements can no longer rely only on visual screen displays but require sophisticated DSP techniques and algorithms to provide accurate measurement results.

Similar to the challenges of high speed jitter and timing measurements are applications requiring the capture of very high amplitude signals along with very low amplitude details, and needing to view and measure both. Since this paper is focused on optimizing measurement results, it follows that the instrument needs very high dynamic range, high vertical resolution and the lowest possible signal-to-noise performance. Other factors that influence measurement results like probing, bandwidth and sampling rate will not be covered in detail as part of this paper.

In order to make this as practical as possible, all the measurements shown are based on single-shot acquisitions and are from an EL inverter operating in burst mode with a peak-to-peak signal of ≈660 volts.

Buried in the baseline of the signal is a very low voltage signal of less than a few volts. This signal is shown in Figure 1 but the low amplitude signal is masked in the baseline part of the signal (near red arrow).

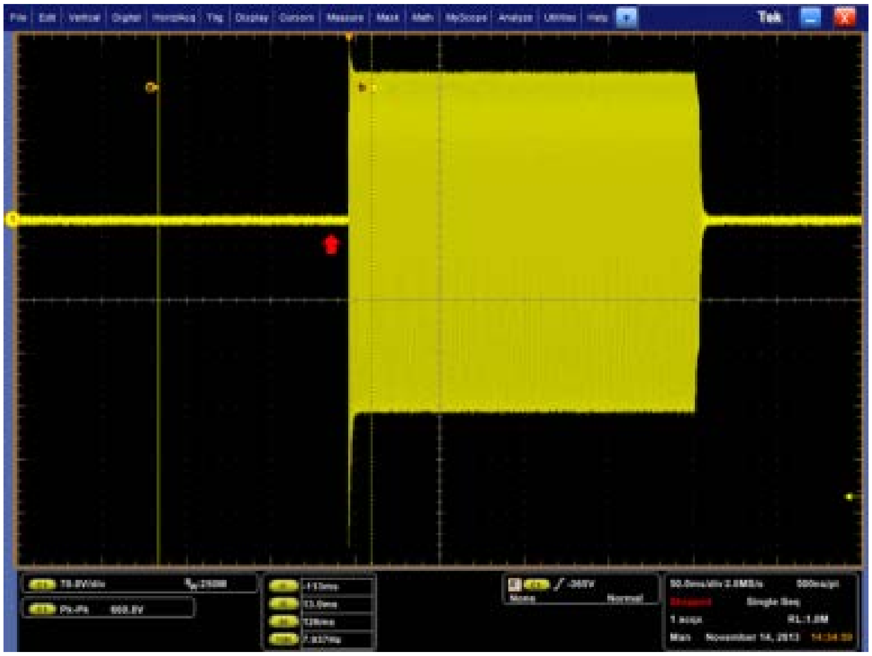

**Figure 1:** 660 Volts peak-to-peak signal.

## Overdrive Recovery

One approach to this measurement is to double probe the signal with channel one set to 70 V/div (full dynamic range) and channel four set to 1 V/div. As shown in Figure 2 the scope is able to capture the 660 V signal on channel 1 while also capturing the lower voltage signal on channel 2. In this example, the scope is operating in normal sample mode with 8 bits of vertical resolution. The zoomed display provides the visual details and the measurement system is showing a peak-to-peak value of 4.76 V with very little noise.

The advantage with this approach is the ability to increase the vertical sensitivity to see the desired details with very low noise while ensuring a higher quality measurement. The primary trade-off in this approach is the use of two scope channels, double probing and ensuring the scope has good overdrive recovery performance.

**Figure 2.** Dual channel capture with 8-bit resolution.

### HiRes Acquisition

Some oscilloscopes offer a specialized hardware acquisition mode called HiRes. This mode can be very effective by trading off over-sampling for additional vertical resolution to reveal more waveform details. Simply put, this acquisition mode increases vertical resolution by averaging adjacent samples that are normally discarded at slower time base settings.

In Figure 3, the scope is able to capture the entire signal while showing the low voltage signal details. When comparing results and signal details, the peak-to-peak measurement of 4.94 volts is similar to the signal captured with the scope set to 1 V/div (Figure 2).

**Figure 3.** HiRes capture with >13 bits at 2 MS/s.

### Noise

Measurement results can be dependent on multiple factors and setup conditions. One significant factor that can impact the measurement results is actual signal noise. This noise might come from external sources, probing or may even come from the scope itself. While techniques like differential probing or bandwidth filtering can reduce some of these effects, further enhancements can be achieved by applying DSP filtering.

Oscilloscopes that offer DSP filtering provide another option for improving the setup. In Figure 4, the oscilloscope captured the signal using HiRes acquisition running at 20 MS/s (10x faster than previous example). Since there appears to be more noise visible, the scope Math feature is used to apply a low-pass filter as shown in the red trace.

**Figure 4.** HiRes acquisition at 20 MS/s and low pass filtering.

Note that in this example the waveform again is similar to Figure 2 and Figure 3 but with the addition of more noise (yellow trace). While the additional noise has changed the peak-to-peak measurement results, the use of a low-pass filter improved both signal quality and measurement results.

## Higher Vertical Bits

Let's go back to the earlier assumption that more vertical bits and less noise should produce better results. The same signal was captured with a 12-bit instrument set to the same sampling rate of 2 MS/s and 1 M point record. In Figure 5, we compare the results from a 12-bit scope and an 8-bit scope using HiRes set to the same 100 V/div setting and an 8-bit acquisition (without HiRes) set to 1 V/div while overdriving the signal.

The signal that actually shows the least amount of noise and best overall signal detail is the signal captured with 8-bit sampling with a vertical input setting optimized (1 V/div) for the area of interest. The 12-bit instrument was able to capture the waveform details but exhibits more noise when compared to the other two techniques.

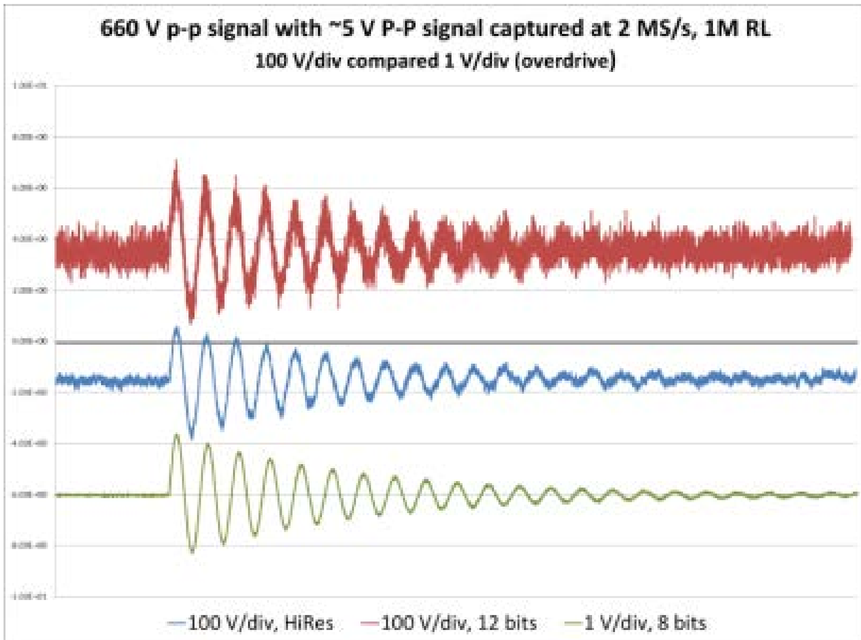


**Figure 5.** 100 V/div (12 bit and HiRes) and 1 V/div (8 bit).

## Conclusion

The tremendous flexibility of the modern oscilloscope to handle different signal types and measurement needs is a key reason why it remains the preferred instrument of choice. With this flexibility, the actual instrument capability is usually not a function of a single specification or feature. Rather than acquisition modes or vertical resolution, the number one factor to consider when setting the scope input is to ensure that dynamic range performance is optimized to capture the signal of interest with the least amount of noise.

While this paper used a known signal source to illustrate how to optimize measurement results utilizing different scope setups, it does not attempt to cover all possible scenarios and other setup factors that might influence your results. However, the features and setups shown can be applied to many applications to improve overall measurement results. For additional information, see the technical brief "Improving Vertical Resolution in Tektronix Digital Phosphor Oscilloscopes (# 48W-27802-1).


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