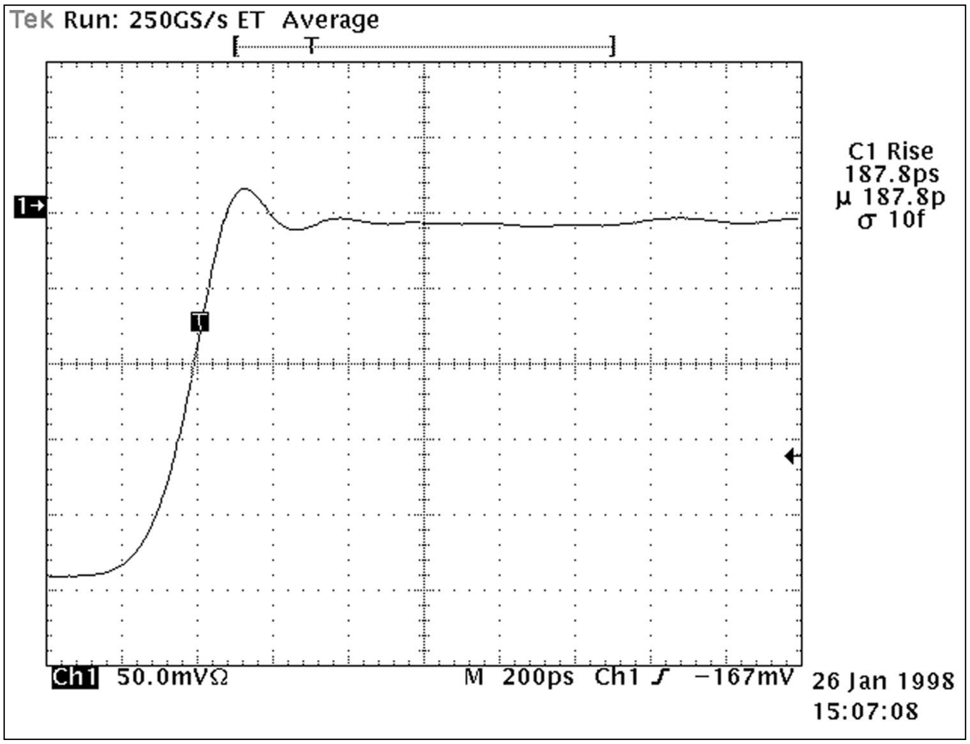
Tektronix

Application Note

Effects of Bandwidth on Transient Information



188 ps rise time measured on a 2 GHz TDS 794D DPO (Digital Phosphor Oscilloscope).

All digital systems are concerned with adequate timing margins. As clock speeds in communications and semiconductors continue to increase, timing margins get even narrower. As clock frequencies increase, a parameter that has even greater impact on measurement needs is edge speed. For example, the frequency of a 500 MHz clock can easily be measured with a 1 GHz oscilloscope. However, all that will be seen is the fundamental frequency; i.e., a 500 MHz sine wave. What's missing is the transient and edge information. It's not adequate to simply have bandwidth that will capture frequency information; it can be more important to view fast edges. For example, a 300 MHz clock can have 150 ps rise times and 400 ps set-up times. A 1 GHz scope can readily see the 200 MHz sinusoid but miss the necessary timing violation information.

This application note shows the results of measuring a 17.5 ps edge and a 500 MHz clock using oscilloscopes with different bandwidths.

Bandwidth Effects on A Fast Edge

The function generator used for the first set of measurements is a 20 GHz Tektronix SD-24 TDR/sampling head plugged into an 11801C. To maintain signal integrity, 50 Ω connectors are used.

Figure 1 shows the 17.5 ns edge viewed with a 700 MHz oscilloscope. The scope measures a mean rise time of 522 ps with a standard deviation of 600 femtoseconds. If a digital system has setup and hold times in the 400 ps ranges, the fast pulse has the edge speed needed for the design but the 700 MHz oscilloscope will not able to measure it.

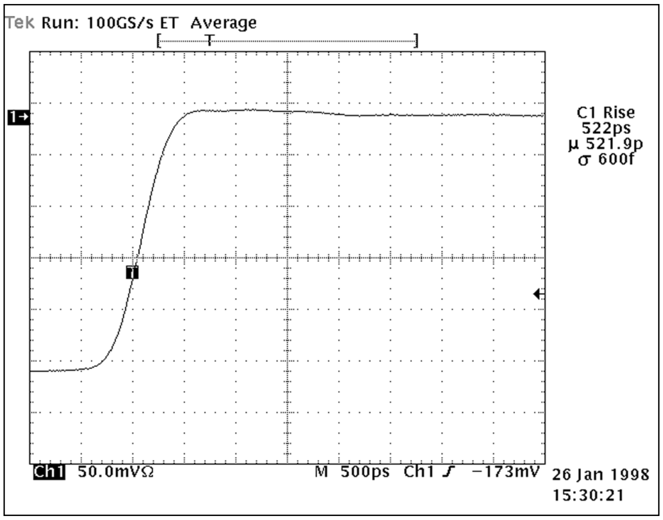


Figure 1. 17.5 ps edge with 700 MHz scope.

Figure 2 shows the same edge viewed with a 1 GHz instrument. You can now see a small ringing in the waveform. The 1 GHz instrument measures a rise time of 388 ps for the 17.5 ps rise time signal. Trying to resolve a 400 ps setup time with this oscilloscope would be marginal.

Figure 3 shows the same edge now viewed with a 2 GHz bandwidth oscilloscope. You can now see that the waveform has 10% overshoot with a 188 ps rise time. With sufficient bandwidth, you can now resolve 400 ps timing margins.

Rise Time Calculation

A useful equation relating to rise time measurements is:

$$RT_{measured} = \sqrt{RT_{scope}^2 + RT_{probe}^2 + RT_{signal}^2}$$

To illustrate this example, let's assume that we have a 200 ps rise time oscilloscope, a 100 ps rise time probe, and we're measuring a signal that has a rise time of 200 ps. From the equation above, the rise time measured by the scope is:

$$RT_{measured} = 300 \text{ ps}$$

Another way to look at this; if you measure a 300 ps rise time with this equipment, the real rise time of your edge is less than or equal to 200 ps.

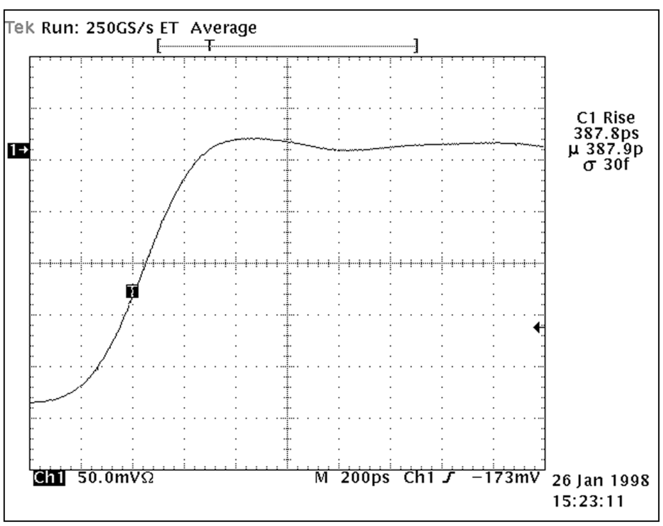


Figure 2. 17.5 ps edge with 1 GHz scope.

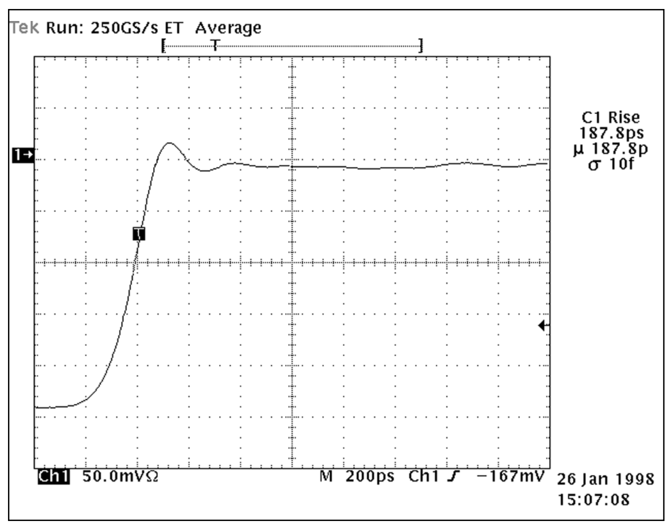


Figure 3. 17.5 ps edge with 2 GHz scope.

BW Effects on a Clock

To further understand the effects of bandwidth on measurements, let's view a 500 MHz square wave clock. From Fourier analysis, the frequency components of a square wave can be broken into a fundamental sine wave component and multiple odd harmonic components. As the edge of the square wave gets progressively faster, there are more components to these harmonics.

The function generator used for the next set of measurements is a Tektronix HFS 9003. To maintain signal integrity, 50 Ω connectors are used.

Figure 4 shows the 500 MHz clock viewed with a 500 MHz oscilloscope. You can clearly see that the clock is present and it even has the right frequency. However, the clock appears sinusoidal. The bandwidth of the scope acts as a harmonic limiter to the higher frequency components. The fundamental frequency is present with higher frequency components greatly attenuated.

Figure 5 shows the same 500 MHz clock viewed with a 2 GHz bandwidth scope. There's considerably more edge information and the clock's timing parameters can now be measured more accurately.

Conclusion

As clock speeds rapidly increase, scopes require greater and greater bandwidths to capture the signal. However, timing margins are even more critical as bandwidth increases. Sufficient scope bandwidth to resolve timing information should not be overlooked when making edge measurements.

For today's high speed digital systems, the bandwidth of the oscilloscope is critical to ensuring the proper measurement of transient parameters.

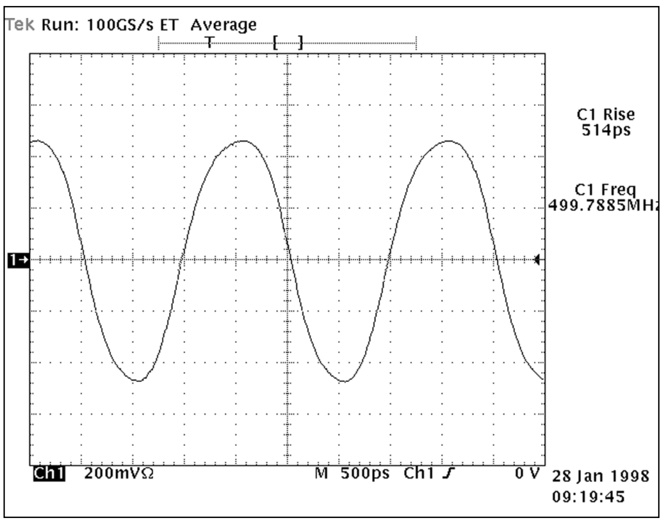


Figure 4. 500 MHz clock with 500 MHz Scope.

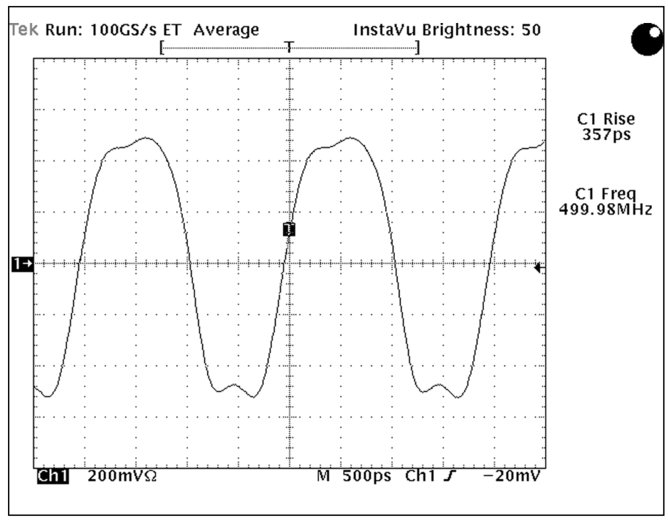


Figure 5. 500 MHz clock with 2 GHz scope.

For further information, contact Tektronix:

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