The effects of analogue bandwidth on oscilloscope measurements

The effective bandwidth of a digital oscilloscope is dependent on its sample rate which also depends on memory length. This is discussed in a separate article. However, how much analogue bandwidth is required?

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Bandwidth

When selecting a digital or mixed signal oscilloscope, one of the first choices to make, along with the number of channels, is the analogue bandwidth. This determines the specific model in a series and hence has a direct influence on the price. The analogue bandwidth is defined as the frequency at which the amplitude measured by the oscilloscope has reduced by 3dB (-3dB point). This is approximately 70.9% of the actual signal amplitude (Figure 1). This means, for example, if a 200MHz pure sine wave with 10 Volts peak to peak is measured with an oscilloscope with a bandwidth of 200MHz, the amplitude of the displayed signal will be approximately 7 Volts peak to peak.

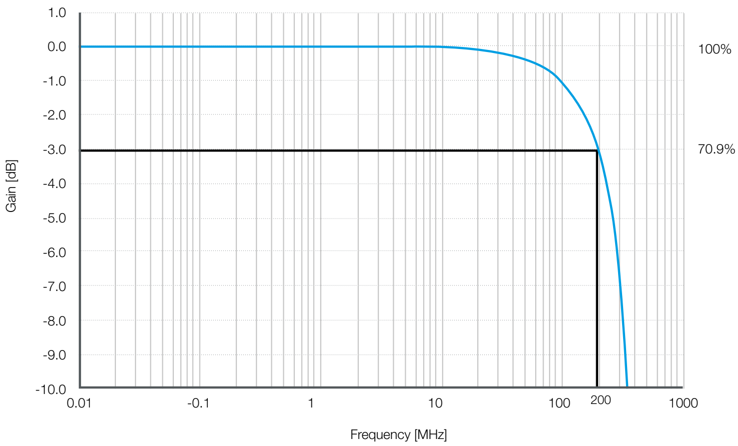

Figure 1: -3dB graph for an oscilloscope with 200MHz bandwidth

However measured signals are also typically not pure sine waves. A perfect square wave, for example, consists of the fundamental frequency plus an infinite number of odd harmonics where the 3rd harmonic has an amplitude 1/3 of the amplitude of the fundamental and the 5th order has an amplitude of 1/5 etc. If the 5th order also needs to be included in the measurement, the oscilloscope will need to have a bandwidth capable of measuring at least 5 times the frequency of the fundamental. In figure 2, the fundamental has a frequency of 40MHz therefore the relative amplitude of the 5th harmonic at 200MHz will be appear to be 1/7 of the fundamental (1/5 less 3dB).

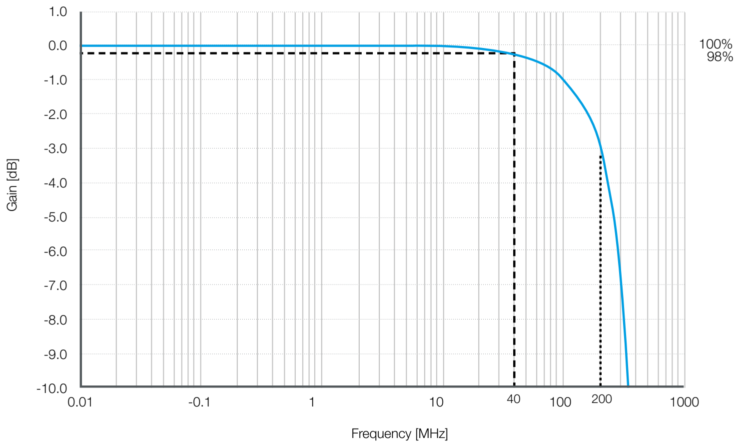

Figure 2: Graph showing a 40MHz fundamental and the position of the 5th harmonic.

Therefore in order to be able to measure the amplitude of a pure sine wave or a fundamental waveform with an error less than 2% (98% in figure 2), the rule-of-thumb is that the oscilloscope should have a bandwidth of at least 5 times the fundamental frequency, which also enables the 5th harmonic to be evaluated.

Rise time versus bandwidth

In practise, when examining digital signals, it is more useful to talk in terms of the 'rise time'. Rise time is typically defined as the time it takes for the signal voltage to go from10 % to 90% (Figure 3). Perfect square waves do not exist in digital electronics. All digital signals have a finite rise time and the rise time of the oscilloscope itself needs to be sufficient to be able to measure it with any form of accuracy. The rise time of the oscilloscope is related to its bandwidth and for scopes with bandwidths of less than 1GHz, which have Gaussian characteristics, the following rule-of-thumb formula is normally applicable.

Risetime = 0.35/bandwidth

Hence a 200 MHz oscilloscope has a rise time of 1.75 ns.

There is a formula for determining the measured rise time and which is dependent on the actual rise time of the signal and the rise time of the oscilloscope.

$$Tr_{measured} = \sqrt{(Tr_{signal})^2 + (Tr_{oscilloscope})^2}$$

If a signal has a rise time of 5.00 ns, the measured rise time using an oscilloscope with a bandwidth of 200 MHz is:

$$Tr_{measured} = \sqrt{(5.00\ ns)^2 + (1.75\ ns)^2} = 5.30\ ns$$

This is a difference or error of 5.7%

If a 350 MHz oscilloscope is used instead the result is:

$$Tr_{measured} = \sqrt{((5.00\ ns)^2 + (1.00\ ns)^2} = 5.10\ ns$$

The difference/error is thus reduced and becomes 2.0%

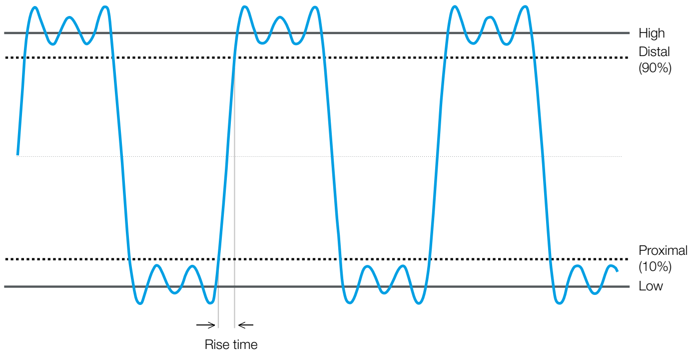

Figure 3:
Rise time measurement of a waveform containing 3rd and 5th order harmonics

Another rule-of-thumb is therefore that the oscilloscope should have a rise time which is at least 5 times faster than the rise time of the signal to limit the effect on the error of the rise time measurement to less than 2%, which is generally acceptable for oscilloscope measurements.

To read more about Yokogawa DLM2000 oscilloscopes, click here.
Or alternatively talk to one of our precision makers to find the best oscilloscope for your needs, contact us here.

(These error calculations do not include the measuring accuracy of the oscilloscope)
(The bandwidth and rise time of an oscilloscope measurement depends on the combination of the oscilloscope and any probe used. For Yokogawa DLM mixed signal oscilloscopes, the supplied passive probe is included in the specified bandwidth.)

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