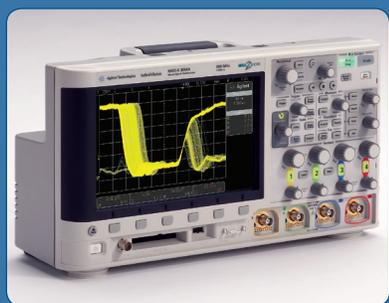# Oscilloscope Selection Tip 2:
Sample Rate

Part 2 of a 12-part series

Tip 2 *Select a scope that has a maximum specified sample rate fast enough to deliver the scope's specified real-time bandwidth.*

Agilent's 2000 and 3000 X-Series oscilloscopes provide the highest degree of over-sampling in their class of scopes, giving you more confidence in your measurements.

Closely related to a scope's real-time bandwidth is its maximum specified sample rate. "Real-time" simply means that the scope can capture and display signals commensurate with the scope's specified bandwidth in a single acquisition (not repetitive).

Most engineers are familiar with **Nyquist's Sampling Theorem**. The theorem states that for a limited bandwidth (band-limited) signal with maximum frequency f_{max}, the equally-spaced sampling frequency f_s must be greater than twice the maximum frequency f_{max}, i.e., $f_s > 2 \cdot f_{max}$, for the signal to be uniquely reconstructed without aliasing.

Dr. Harry Nyquist

Today f_{max} is commonly known as the Nyquist frequency (f_N). The mistake that some engineers make is that they sometimes assume that f_{max}, or f_N, is the same as f_{BW} (oscilloscope bandwidth). With this assumption, you might think that the minimum required sample rate for a scope of a particular specified bandwidth is just twice the scope's real-time bandwidth specification, as shown in Figure 1. But, f_{max} is NOT the same as f_{BW}, unless the scope had a brick wall filter response.

As you learned in "Tip 1" about scopes with bandwidth specifications of 1 GHz and below typically have a Gaussian frequency response. This means that although the scope attenuates the amplitude of signal frequencies above its -3 dB bandwidth frequency point, it does not entirely eliminate these higher frequency components. The aliased frequency components are shown by the red hashed area in Figure 1. Therefore f_{max} is always higher than f_{BW} for an oscilloscope.
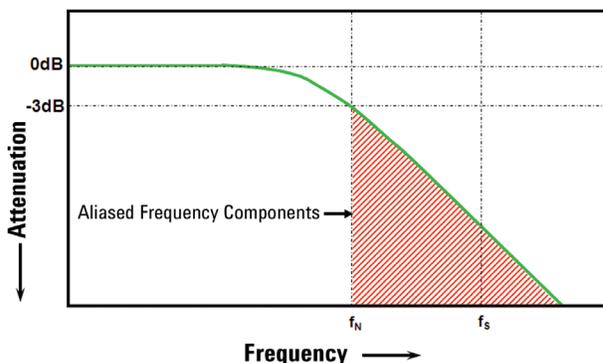

Figure 1. Aliased frequency components when the scope's bandwidth is specified at ½ the scope's sample rate.

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0dB

-3dB

Attenuation

Aliased Frequency Components

$f_s/4$ f_N f_s

Frequency

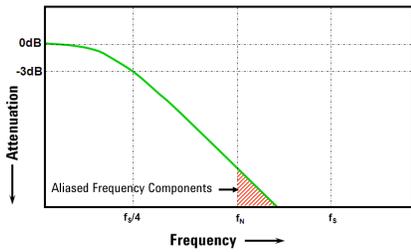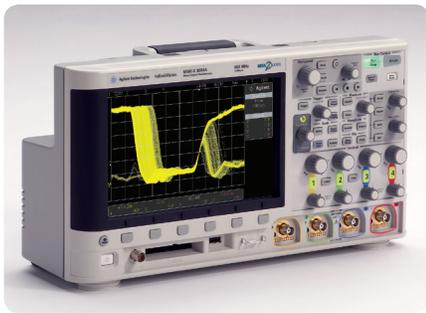*Figure 2. Aliased frequency components when the scope's bandwidth is specified at ¼ the scope's sample rate.*

Agilent recommends that a scope's maximum specified sample rate should be at least four to five times higher than the scope's specified real-time bandwidth, as shown in Figure 2. With this criterion, the scope's sin(x)/x waveform reconstruction filter can accurately reproduce the wave shape of higher speed signals with resolution in the tens of picoseconds range.

To learn more about oscilloscope real-time sampling, refer to Agilent's application note Evaluating Oscilloscope Sample Rates Versus Sampling Fidelity (Agilent publication 5989-5732EN).

Oversampling Provides Increased Measurement Confidence in Agilent's InfiniiVision 2000 and 3000 X-Series Oscilloscopes

If you are in the market today to purchase your next oscilloscope, Agilent Technologies' newest 2000 and 3000 X-Series oscilloscopes come in various bandwidth models ranging from 70 to 500 MHz. The entry-level InfiniiVision 2000 X-Series scopes provide maximum sample rates up to 2 GSa/s, which are the highest available sample rates for this class of oscilloscope.

The higher performance InfiniiVision 3000 X-Series scopes provide up to 4 GSa/s sample rates. Again, this is the highest sample rate available in this class of oscilloscope. With this degree of oversampling (a minimum of 8 times the scope's bandwidth), you can be confident that these scopes can capture your signals more accurately than other scopes in this class.

To learn more about Agilent's InfiniiVision 2000 and 3000 X-Series oscilloscope and mixed signal oscilloscopes, go to
www.agilent.com/find/2000X-Series or
www.agilent.com/find/3000X-Series.

Product specifications and descriptions in this document subject to change without notice.

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