Fully Automated True Bandwidth Testing of High Performance Oscilloscopes

FLUKE ®

Calibration

Application Note

Modern high performance oscilloscopes are pushing bandwidths ever higher, and these instruments are not just confined to highly specialized applications—scopes with bandwidths of several GHz are becoming increasingly commonplace. Traditional methods for bandwidth testing are complex and can easily introduce errors, particularly if bandwidth is calculated from a risetime measurement. This application note discusses how and why to make true bandwidth tests using levelled sinewaves and explores the use of fast edges to test pulse response, illustrating how using the 9500 dedicated oscilloscope calibrator simplifies the measurement.

What is bandwidth?

Bandwidth, in relation to oscilloscopes, is often used as a generic performance differentiator much like the resolution of a DMM—is it a 5.5 digit DMM or a 4.5 digit DMM, is it a 400 MHz scope or a 1 GHz scope?

The bandwidth referred to is that of the vertical channels and carries the usual definition of the frequency at which the response falls by 3 dB from its low frequency value, or to 70.7 % in voltage amplitude terms.

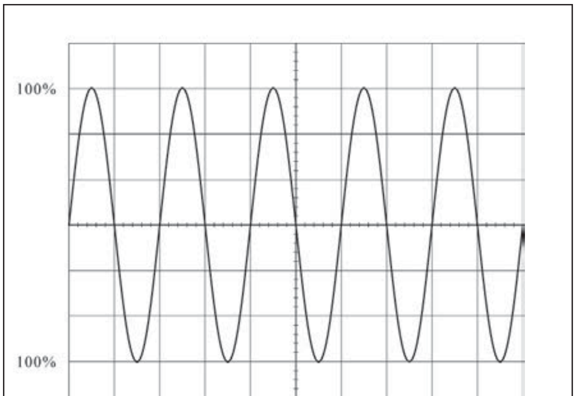
This “figure of merit” should not be confused with the equivalent maximum sampling rate of a digital storage or sampling oscilloscope.

How do we measure bandwidth?

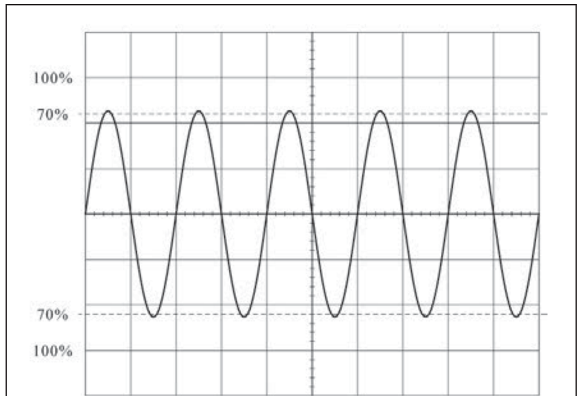
The most obvious approach is to use a sinewave signal and determine the frequency at which the displayed signal amplitude diminishes by 3 dB (70.7 %), relative to a low frequency reference (usually 50 kHz or in the region of 1 MHz for some higher bandwidth scopes). In the past, the lack of dedicated oscilloscope calibration sources led to the use of levelled signal generators, and power meters, requiring the user to consider the effects of generator accuracy, mismatch and harmonic content when determining a peak to peak value from a calibrated RF power output. Additional complexities arise from the shape of the frequency response, its’ impact on roll-off at the 3 dB point, and accuracy of determining the bandwidth which are beyond the scope of this document. Furthermore, it was often difficult to obtain signals to the required frequency and accuracy for the higher bandwidth scopes, leading to the practice of calculating bandwidth from a risetime test.

What is wrong with calculating bandwidth from a risetime test?

There is a relationship which relates bandwidth to risetime (tr). Calculating an equivalent bandwidth from a measured risetime is known as imputing. The bandwidth (BW) can be imputed



Setting the Amplitude at the Reference Frequency



Measuring the Amplitude at the 3dB Point Frequency (calculated) from BW (MHz) = 350 / tr (ns), which is only valid if the scope's response follows that of a theoretical Gaussian filter. But most scopes do not follow a Gaussian response, errors can be introduced in the imputed bandwidth, and a simple risetime test will not provide information on the shape of the scope's frequency response. In the absence of a suitable sinewave source, this method has been popular as an alternative, and is still used for the very high bandwidth scopes, in the region of 20 GHz.

It is necessary to know the actual risetime (transition time) of the calibration signal (trcal) to calculate the risetime of the UUT (truut) from the displayed risetime trdisp2 = trcal2 + truut2.

Using a sinewave for bandwidth testing will enable the entire frequency response to be examined, looking for dips and peaks in the frequency response, which cannot be determined from risetime testing alone.

What should fast edges be used to test?

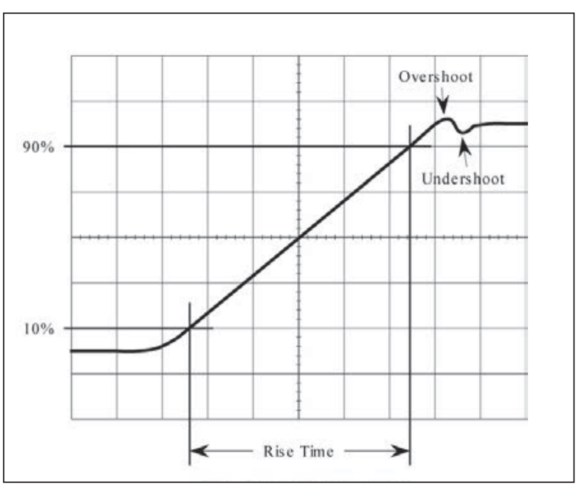
A high integrity fast edge is used to test the pulse response of the oscilloscope, measuring the vertical channel risetime and looking for any aberrations (undershoot and overshoot) on the displayed edge.

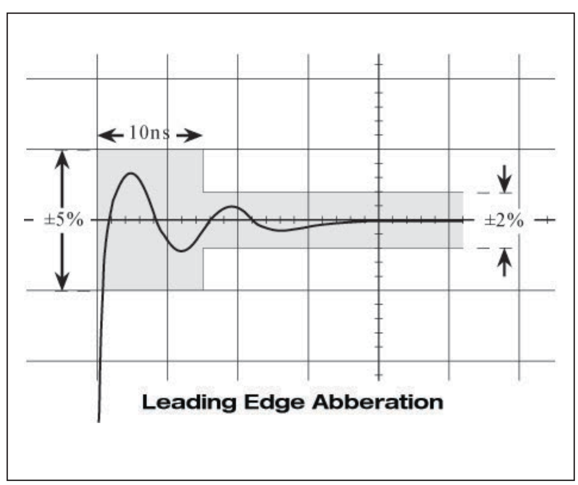
It should be remembered that the observed risetime depends on the speed of the edge used for testing, and the actual risetime of the edge used should be known and corrected for, otherwise there can be a significant error in the measurement. If the applied edge speed is faster than 20% of the scope risetime, less than 2 % error is introduced in the displayed risetime, which is generally considered acceptable.

Using the 9500 Oscilloscope Calibrator

The Fluke Calibration 9500 Oscilloscope Calibrator is available with a number of maximum levelled sinewave output frequency options from 400 MHz to 3.2 GHz, calibrated directly in terms of peak to peak voltage. When fitted with the 3.2 GHz option and using a 9530 Active Head, the Fluke Calibration 9500 can supply accurately levelled sinewaves up to 3.2 GHz, enabling true bandwidth testing of scopes up to 3.2 GHz. These high bandwidth scopes will have a dedicated 50Ω input and the 9500 should be configured for the 50Ω setting. If multiple 9530 heads are available, the testing can be fully automated with no user intervention to swap channels or change terminators. The 150 ps fast edges available from the 9530 Active Head enables accurate risetime and pulse response testing. The 9500 displays the actual calibrated risetime of the output, allowing the true scope risetime to be calculated from the observed risetime. (The calibrator risetime is also available via GPIB allowing for full automation.) For scopes of bandwidth less than around 450 MHz (corresponding to a risetime of greater than 750 ps), it is generally not necessary to consider the calibrator's risetime when using the 150 ps edge output from a 9530 Active Head.

If you have one of the lower frequency option 9500s and a 9530 Active Head, you could use the 150 ps fast edge to impute the equivalent bandwidth of a scope from a risetime test, bearing in mind the limitations discussed above. Remember to consider the calibrated risetime of the 9500 edge output when making the calculation, by first determining the scope risetime from the displayed risetime and 9500 edge risetime,





and then calculate the equivalent bandwidth from the actual scope risetime. Established practice considers this approach viable up to bandwidths where the scope risetime and edge risetime are similar in magnitude, corresponding to 2.5 GHz for a 150 ps edge. So even if your 9500 does not have the 3.2 GHz option but you have a 9530 Active Head, this method can be used to test scope bandwidths up to 2.5 GHz.

Using other pulse calibration sources

Alternative instruments may use accessories such as Tunnel Diode Pulsers (TDPs) to provide faster risetime signals, and users are often unaware of the pitfalls of these devices. There are additional support costs to ensure their traceability and provide regular recalibration, their output voltage range is limited, they cannot be fully automated, and there are additional uncertainties to be considered. Unlike the 9500, which displays the calibrated risetime of its output, TDP devices simply state a maximum risetime specification, which prevents an accurate value for the scope risetime being determined from the observed risetime and the actual TDP signal risetime. Consequently, there is a large uncertainty in the imputed bandwidth measurement, which is not present when using the 9500.

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