



How to confirm what bandwidth of oscilloscope meets my request?

The bandwidth of a digital oscilloscope, often called analog bandwidth, refers to the bandwidth of the front-input amplifier of the oscilloscope and is equivalent to a low pass filter. Oscilloscope bandwidth is defined as the frequency at which the amplitude of the observed signal drops by -3dB (or drops to 70.7% of its actual value) as we increase the test signal's frequency as plotted on the amplitude-frequency characteristic curve (Figure 1).

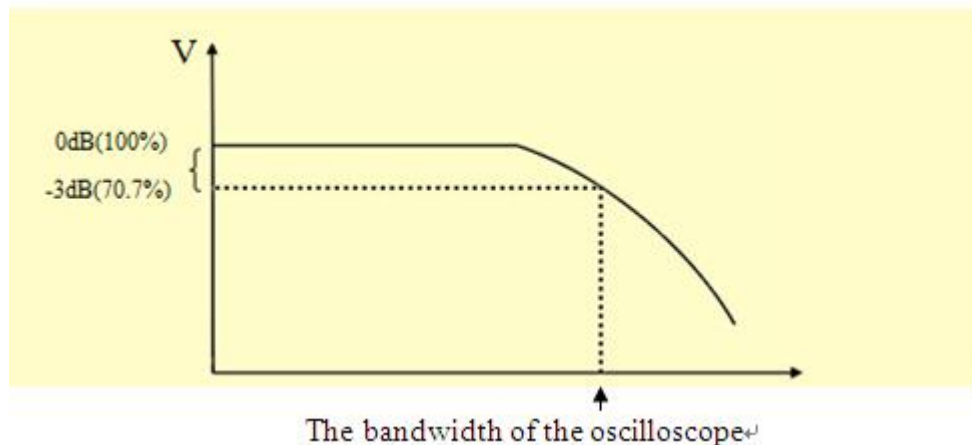


Figure 1 The amplitude-frequency characteristic curve

If we want to accurately measure the waveform, the bandwidth of the oscilloscope should be greater than the main harmonic of the waveform. So the bandwidth of the oscilloscope must be greater than the frequency of a sine wave. For a non-sinusoidal waveform we need a bandwidth out to 5 or more times the primary harmonic frequency, depending on the waveform and fidelity of the signal we are trying to observe.

The frequency content (or bandwidth) of the waveform affects our measurement in two ways:

1. The primary harmonic frequency disappears due to the low bandwidth, and the original waveform becomes an arc wave, which is similar to the sine wave.

2. The displayed and measured rise time will be distorted and incorrect while the amplitude will also be erroneous (too low).

Figure 2 is a 10 MHz square wave, which is displayed on a 200 MHz bandwidth and a 10 MHz bandwidth oscilloscope.

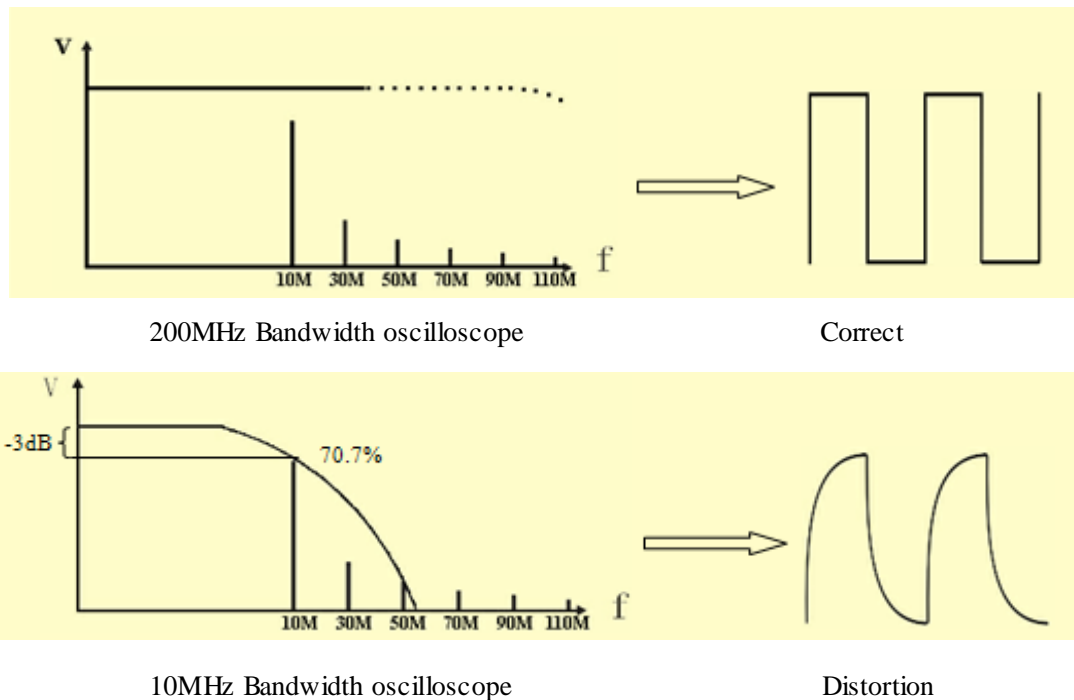


Figure 2 A 10MHz square wave displayed on different oscilloscopes

Rise time is typically defined as the length of time it takes for the signal to go from 10% to 90% of its maximum value.

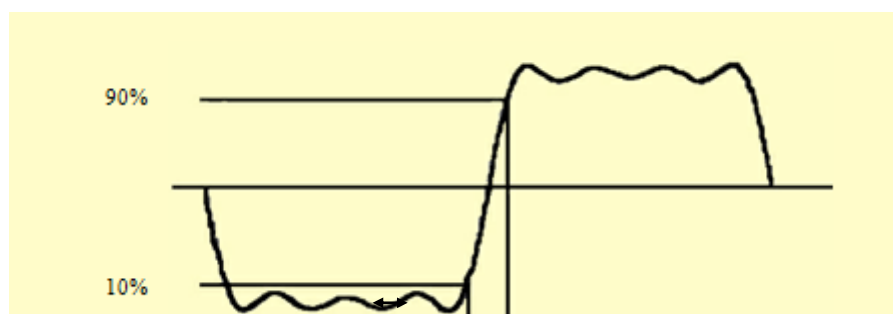


Figure 3 Rise Time

The rise time of an oscilloscope is directly related to its bandwidth, and their

relationship is as follows:

$$T(\text{rising}) = 0.35 / \text{oscilloscope bandwidth (below 1 GHz)}.$$

A 100MHZ bandwidth, 3.5 ns rise time square wave, measured by a 100 MHZ bandwidth oscilloscope, according to the above theory, the measuring error of the displaying signal and the original signal is:

$$\text{The rise time of the 100 MHZ oscilloscope} = 0.35/100\text{MHz} = 3.5 \text{ ns}$$

$$\text{The rise time of displaying signal} = \sqrt{(3.5\text{nS})^2 + (3.5\text{nS})^2} = 4.95\text{nS}$$

$$\text{Measuring error} = (4.95 \text{ ns} - 3.5 \text{ ns}) / 3.5 \text{ ns} = 0.414 = 41\%$$

To improve the accuracy of measurement we can only improve the bandwidth of oscilloscope, such as selecting an oscilloscope with a bandwidth that is 5 times higher when compared to the bandwidth associated with the rise time of the signal we are trying to measure. Now we can see that the Measurement Error is:

$$\text{The rise time of 500 MHZ oscilloscope} = 0.35/500\text{MHz} = 0.7 \text{ ns}$$

$$\text{The displayed signal rise time} = \sqrt{(3.5\text{nS})^2 + (0.7\text{nS})^2} = 3.569\text{nS}$$

$$\text{Measuring error} = (3.569 \text{ ns} - 3.5 \text{ ns}) / 3.5 \text{ ns} = 0.0198 = 2\%$$

This is sometimes referred to as the five times rule of the oscilloscope bandwidth selection:

The required bandwidth of a oscilloscope = the highest frequency component of the measured signal x 5

The measuring error of an oscilloscope followed five times rules will be less than $\pm 2\%$, which is enough for most measurements.