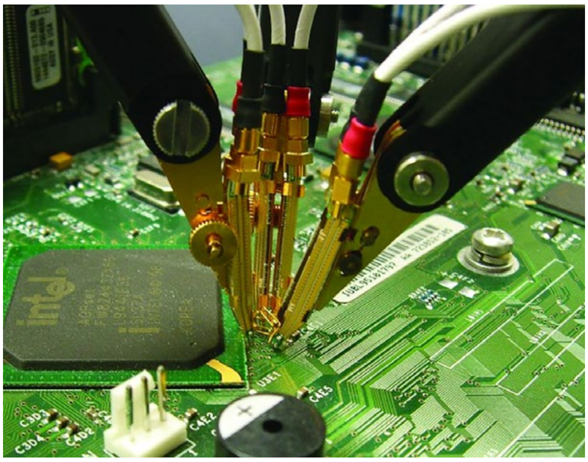
Maximising the performance and potential of your oscilloscope

By Cliff Ortmeyer

If there is one tool that is practically essential for electronic design, it is the oscilloscope. The oscilloscope makes it possible to look inside a circuit and see how it is really performing. If there are signal-integrity issues or glitches affecting the operation of the circuitry, they will most likely show up on the screen of an oscilloscope. But to ensure correct results, it is vital to ensure that the signal going into the probe is as high quality as possible. Distortions caused by poor choices over probe selection and attachment can easily mislead the engineer and you do not want to be debugging part of a design when the bug is actually an artefact of the probing rather than the design itself.



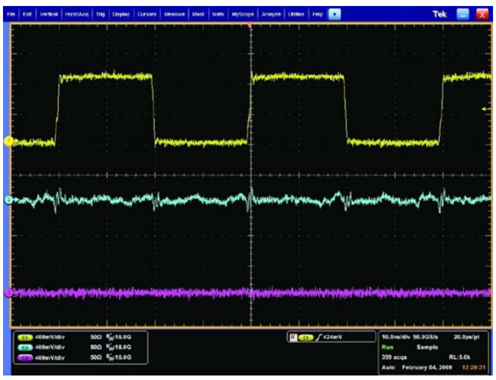
Like the instruments to which they are attached, probes are examples of precision engineering that ensure the signal you see on the screen is as accurate as possible. It is easy to think of probes measuring voltage on a signal line at a particular point and having no effect on the signal itself, however, probes become part of the circuit under test, and introduce resistive, capacitive and inductive loading that can affect circuit behaviour. With careful control, this impact can be minimised to ensure the signal is only subtly affected.

For the most accurate results, the goal is to select a probe with the most appropriate loading for the circuit-under-test to minimise unwanted interactions and enable you to access all of the power, features and capabilities of your oscilloscope.

Choosing the right probe: passive, active or logic?

An important starting point is the choice of appropriate probe type. Probes for high-performance oscilloscopes can be categorised as passive and active, with subdivisions into special-purpose probes for taking differential measurements, connecting to logic buses and high-power lines.

The passive probe is a good general-purpose option for measuring a variety of signal types and voltage levels. The passive probe, as its name suggests, has no active electronics and will impose some level of loading on the circuit under test, but, it is often the most affordable solution and the pairing of a passive voltage probe with a current probe will provide a good option for measuring power in many situations.



Oscilloscope screenshot.

Passive probes are typically associated with an attenuation factor, such as 10x or 100x.

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The 10x attenuation probe will impose less loading on the circuit under test compared to a 1x probe. As circuit loading becomes more of a challenge for instance as circuit frequency increases with higher-impedance signal sources, picking a probe with a higher attenuation factor can help maintaining measurement integrity. The drawback of using a higher attenuation ratio is that, although it reduces signal distortion, there will be reduction in the signal's amplitude at the oscilloscope. A 10x probe will reduce the input amplitude by a factor of 10.

Attenuation of 10x will make it difficult to look at signals of less than 10mV peak-to-peak. For many signals, however, the 10x attenuator probe is a good general-purpose probe and the 1x probe can be retained for measuring slower-changing signals with low amplitudes. Some probes have a convenient feature for switching between 1X and 10X attenuation at the probe tip and many oscilloscopes can automatically determine when a 1x or 10x probe is being used, but it is important to check that the instrument's input settings are matched to the probe and the volts/div display is accurate.

Although general-purpose passive probes are often effective, they are less suitable for accurately measuring signals with fast rise times or circuits that are susceptible to loading. The steady increase in signal clock rates and edge speeds demands higher speed probes with less loading effects. High-speed active and differential probes provide ideal solutions when measuring high-speed and/or differential signals.

Active and differential probes incorporate integrated circuits (ICs) designed specifically to link the circuit under test to the probe cable and retain maximum signal integrity. The latest generations of active probes can take a variety of measurements – differential, single-ended and common-mode – without adjusting the probe-tip connections.

Logic probes provide a convenient method for probing digital buses as they provide signal probes as well as a way of attaching ground connections in a compact fashion. Measuring a signal requires two connections: one for the probe tip itself and the other for a ground connection and this adds to the amount of space required on the PCB being tested to make a good connection. Dedicated logic probes reduce the space required by using specialised connectors: each channel ends with a probe tip featuring a recessed ground that simplifies connection to the circuit-under-test.

With an array of signal connections in a logic probe, it is therefore possible to reduce total space required through the use of a common ground connection. One type of design employs an automotive-style connector which eases the creation of custom grounds. For example, when connecting to square pins, an adapter that attaches to the probe head makes it possible to connect to a header. These probes offer good electrical characteristics with minimal capacitive loading.

Other forms of probe include current, high-voltage and optical probes that are used for more specialised measurements, such as high-voltage AC or DC power rails. The probe interfaces of more advanced digital oscilloscopes will recognise the type of probe automatically and configure the instrument appropriately, including supplying power. Active probes have their own amplifier and buffer circuitry that requires DC power.


Oscilloscope probes.

Ground lead and probe tip accessories are also available to improve signal integrity when measuring high-speed signals. For example, ground lead adapters provide flexibility for the spacing between probe tip and ground lead connections to the circuit under test and maintain very short lead lengths from probe tip to the circuit under test to avoid compromising measurement integrity.

Understanding the tools inside an oscilloscope

Once the probes are connected, the next step is to use the tools inside the oscilloscope to measure the parameters in which you are interested. Most digital oscilloscopes include automated measurement tools that simplify and accelerate common analysis tasks, however, there are important principles behind these techniques and knowing how to make those measurements manually helps ensure you have the right setup.


Various probe accessories.

The oscilloscope is primarily a voltage-measuring device, but voltage measurements also provide the ability to calculate the values of other parameters, such as current and power through Ohm's law and the power law. Though these calculations can be performed by hand, many of today's instruments allow these properties to be derived automatically. Analysis of the shape of the signal can also provide important clues as to the behaviour of the circuit under test. For example, in digital circuits, pulses can become distorted and cause a digital circuit to malfunction: a key reason for keeping distortion from probing to a minimum.

Another useful mode is XY. This mode on an oscilloscope provides a useful way of analysing phase shift between two otherwise identical periodic signals. To perform this measurement, one signal is fed as standard to the vertical system whilst other is directed to the horizontal system that would normally be used for the time base. The waveform that results from this arrangement is called a Lissajous pattern and different characteristic shapes will show up as visually distinct patterns. Traditionally, digital storage oscilloscopes (DSOs) can have difficulty displaying real-time XY displays and some instruments create an XY image by accumulating triggered data points over time and then creating the Lissajous pattern but digital phosphor oscilloscopes (DPOs) will acquire and display real-time XY-mode images.

Using high-speed internal processors, digital oscilloscopes offer many advanced math operations that are useful in interpreting measurements and reducing the impact of distortion. For example, the insertion of a digital filter block can be used de-embed the characteristics of the fixture on the circuit under test. In many cases, the processing block will be flexible enough to act as an arbitrary filter and it can be used, for example, to simulate the pre-emphasis and de-emphasis schemes used in high-speed serial protocols.

With bandwidths that now reach into the tens of gigahertz and increasingly sophisticated software that can automatically de-embed signals, digital oscilloscopes make it possible to debug a wide range of circuit problems quickly but careful attention to probing and measurement techniques ensure the engineer is not misled by unwanted distortions.