Choosing the Right Handheld Oscilloscope

Application Note

From characterizing microelectronics to troubleshooting multi-industrial automation, process controls, facility maintenance, and automotive-service industries, handheld scopes can give you the performance of bench scopes in a rugged and mobile form factor. These handheld scopes integrate test tools designed for field use where conditions are rigorous, dangerous, and precarious. However, since all handheld scopes are not created equal it is advantageous to compare handheld scopes based on key specifications :

- Bandwidth
- Sample rate
- Memory depth

In addition, considering the following handheld attributes can also help you determine which handheld scope is right for your troubleshooting needs:

- Number of channels
- Channel isolation
- Safety ratings
- Other requirements to consider

How much bandwidth do I need?

A mistaken assumption is that bandwidth determines the highest frequency that you can capture. However, a scope's bandwidth is the frequency at which the input signal is attenuated by 3 dB, which translates into approximately –30% amplitude error. This means that you cannot accurately capture signals that have significant frequencies near the scope's bandwidth.

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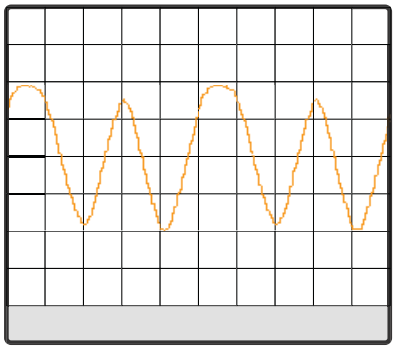
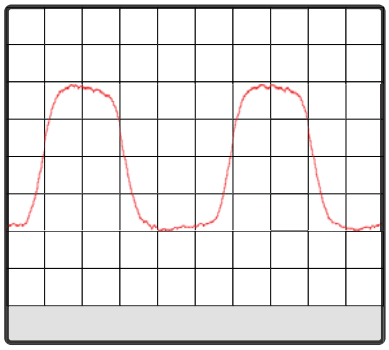
Table 1 compares two scopes: one with a bandwidth of 40 MHz and another with a bandwidth of 200 MHz. Looking at the 40 MHz clock signal on both scopes you can see that the scope with a 40 MHz bandwidth resolves the waveform poorly compared to the scope with a 200 MHz bandwidth.

Table 1: Waveform comparison of a 40 MHz scope and a 200 MHz scope



Scope with 40 MHz bandwidth



Scope with 200 MHz bandwidth

You should pick a scope that has a bandwidth that is five times higher than the highest frequency that you may need to capture. For example, if your design has a maximum clock rate of 40 MHz, then you should pick a scope with a bandwidth of 200 MHz.

Is a higher sample rate always better?

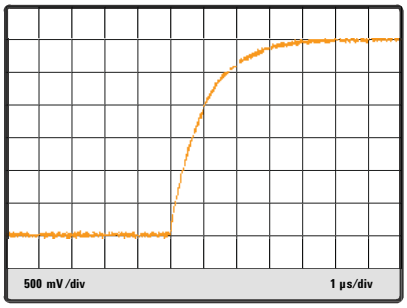
Most people have the impression that a scope with a higher sample rate is better than a scope with a lower sample rate. In reality, a scope with a higher sample rate does not necessarily provide any extra benefit when compared to a scope with a lower sample rate.

In order to faithfully reproduce a signal on a scope, Nyquist's sampling theorem states that the sample rate must be greater than twice the highest frequency in the signal. In theory, this means if you want to capture a 40 MHz signal, the sample rate should be at least 80 MSa/s. However, most scope manufacturers set the sample rate between four to five times the scope's bandwidth. For example, if the scope's bandwidth is 200 MHz, the sample rate should ideally be 1 GSa/s.

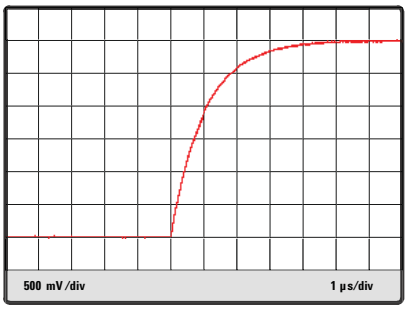
Table 2 compares a waveform captured using a scope with a 2 GSa/s sample rate with another scope with a 5 GSa/s sample rate. This comparison shows that there is no noticeable difference when viewed at the same timebase setting.

Therefore, bandwidth being equal, is a scope with 5 GSa/s sample rate better than another with 2 GSa/s sample rate? Not necessarily because another scope component comes into the equation: memory depth.

Table 2: Waveform comparison of a 2 GSa/s scope and a 5 GSa/s scope



Scope with 2 GSa/s sample rate



Scope with 5 GSa/s sample rate

Why is memory depth important?

A scope stores the captured data in a waveform buffer and the size of the waveform buffer is referred to as memory depth. A scope with deep memory lets you maintain a higher sample rate for a longer duration.

The duration that a scope acquires a signal is given by Equation 1.

$$\textit{Acquisition time} = \frac{\textit{Memory depth}}{\textit{Sample rate}}$$

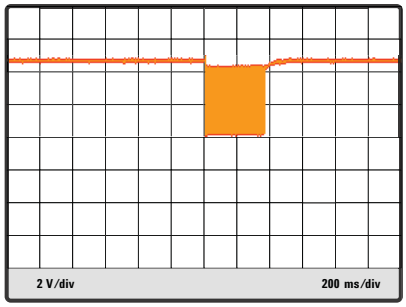
Equation 1

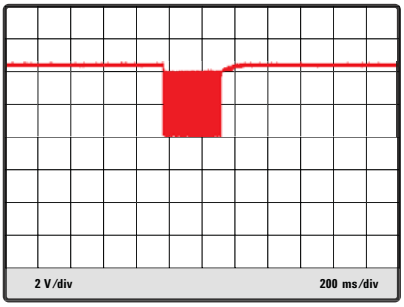
Earlier, you observed that a scope with 5 GSa/s sample rate may not necessarily be better than a scope with 2 GSa/s sample rate. Based on Equation 1, memory depth plays an important role in ensuring that a scope can sustain a higher sample rate for a longer duration.

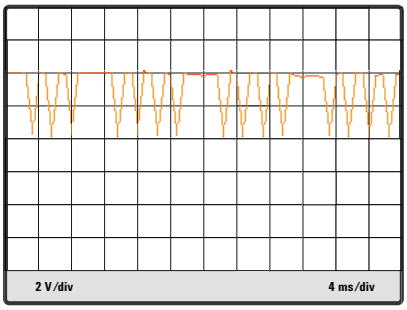
As an example, compare a waveform captured using two scopes with the same maximum sample rate of 2 GSa/s, but one with a memory depth of 10 k points and another with 2 M points.

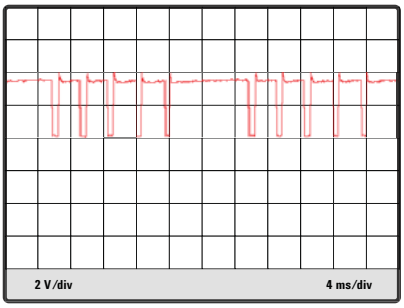
At high sample rates, the memory buffer is quickly filled; therefore, the only way a scope with a maximum sample rate of 2 GSa/s and less memory depth can continue collecting data is to reduce its sample rate. When this happens, the scope cannot capture the waveform accurately because the sample points are too far apart. However, a scope with deeper memory can sustain its maximum sample rate and therefore capture the waveform more accurately. This is apparent when the view of the signal is enlarged, as shown in the bottom row of Table 3.

Table 3: Waveform comparison of two scopes with the same maximum sample rate of 2 GSa/s but with different memory depths









Scope with 10 k points of memory

Scope with 2 M points of memory

Do I need two or four channels?

Each channel in a scope lets you measure and record one signal at a time. Scopes come in two- and four-channel varieties. How do you decide how many channels you need? Basically, you need to determine how many signals you want to display on the scope.

Scopes with four independently isolated channels are used when you want to see three or more signals simultaneously. An example of this situation is when troubleshooting three-phase applications such as variable-frequency motor drives, high-power inverters, and industrial motors. However, these scopes are usually more expensive and are typically used in rare instances; most of the time you only need two channels.

Why is channel isolation so important?

When working with high voltages and currents, engineers often need to make "floating" measurements where neither point of the measurement is at ground potential. Picking a two-channel handheld scope in which the inputs are independently isolated—unlike conventional scopes with inputs connected to common ground—lets you connect the handheld scope to a wide range of different voltage reference level signals and measure with complete accuracy and safety.

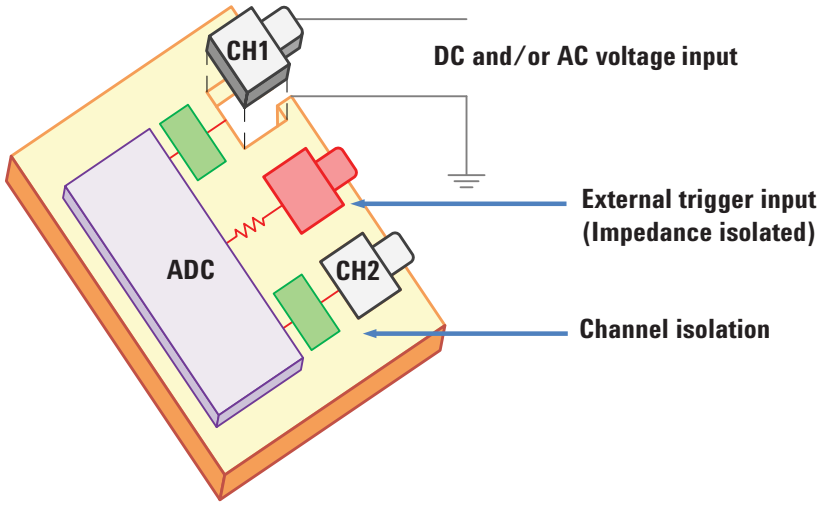


Figure 1: Channel isolation

A handheld scope with isolated channels reduces the risk of accidental short circuits and supports a wide range of applications, from microelectronics to heavy-duty, high-voltage electrical machinery.

In addition to providing electrical protection, using a handheld scope with channel-to-channel isolation gives you improved measurement accuracy by minimizing signal-degrading lead inductance and capacitance (parasitic effects) that can hamper measurement quality in conventional scopes with a common ground.

Should I be concerned about the safety ratings of a scope?

Taking on challenges of testing industrial equipment and power conversion systems, you need a handheld scope that's safety-rated for measurements in CAT III environments. If you find yourself making measurements on distribution boards, three-phase motors, variable-speed drives, building installations, or equipment for industrial use, then you're working in CAT III environments.

Table 4: Safety categories

Safety category	Environment
CAT I	Measurements on circuits not directly connected to mains
CAT II	Measurements on circuits directly connected to the low-voltage installation
CAT III	Measurements on equipment in a building installation
CAT IV	Measurements at the source of the low-voltage installation

In CAT III environments, you should also consider the maximum voltage that you can probe between two channels. When working on circuits such as three-phase main buses and feeder lines; motor control centers (MCCs); and distribution panels, you are exposed to voltages that range from 480 to 600 V. For these environments, a handheld scope not only has to give you an accurate measurement, it also has to provide you with adequate safety.

A measurement system is only as strong as its weakest link, and the weakest link is often not the scope but the test leads and probes. Besides looking for the safety category and voltage you need in a handheld scope, you should also make sure proper safety-rated test leads and probes are included.

An integrated troubleshooting tool

An integrated troubleshooting tool includes a scope, multimeter, and data logger. A built-in multimeter lets you easily switch from waveform analysis to precise multimeter measurements, while a data logger functions like a long-term monitoring feature.

Possibly the most difficult and frustrating to trace and solve, intermittent electrical faults are an engineer's worst nightmare, particularly in today's complex systems. Conventional troubleshooting requires you to spend hours monitoring the equipment until the elusive electrical fault appears. Fortunately the situation can be made easier using a handheld scope with a long-term monitoring feature. Just leave the handheld scope connected to the equipment for as long as you like, and afterwards analyze the captured events by reviewing the captured events on the scope, exporting the results to a PC, or printing a hardcopy.

A functional display

In industrial applications, you may not have the luxury of a proper work area when hunting for signal abnormalities. In addition to choosing a handheld scope that captures signals accurately and completely, you also need a scope that displays the signal clearly and quickly.

Unlike bench scopes, a functional display is another consideration when choosing a handheld scope. The display on a handheld scope should be readable in various lighting conditions, have wide viewing angles, and have a generous viewing area.

With a high-resolution display, a handheld scope can display more relevant information to help in your troubleshooting tasks. For example, when you zoom into a particular area of a waveform, the ability to also view the overall waveform is a useful feature.

Rugged mobility

Safety and accuracy are both important attributes when deciding on a handheld scope. However, you'll also need a handheld scope you can confidently rely on to continue working during critical events and be able to capture and record those critical events. Therefore, look for a handheld scope that offers a long battery life and delivers protection against dust, humidity, and shock.

A handheld scope meant for use in the field should let you swap batteries to extend usage, provide a battery access cover, and include a desktop charger. Also, you should be able to confidently carry the handheld scope securely while you work, so a hand strap or neck strap is useful while you're away from your desk, and a tilt-stand is useful for positioning the handheld scope when you're back on your work bench. While placed on your work bench, a way to secure the handheld scope against theft, such as a Kensington lock, is an added convenience.

Conclusion and Recommendation

A properly designed handheld scope combines the bandwidth, sample rate, and memory depth specifications into a cohesive troubleshooting tool, so you can capture a more accurate waveform representation of a signal across a larger number of timebase settings. A clear and useable display lets you quickly view the measurements, while a long-term monitoring feature leaves the recording task to the scope. You also need a handheld scope that protects you from high voltage and current, and is able to function in harsh environments.

The Agilent U1610/20A handheld scope is designed for engineers that insist on accuracy, reliability, and safety when making measurements in demanding environments. For more details, visit our Web site at: www.agilent.com/find/U1600

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