

APPLICATION NOTE

Making sense of electrical signals

Devices that convert electrical power to mechanical power run the industrial world, including pumps, compressors, motors, conveyors, robots and more. Voltage signals that control these electro-mechanical devices are a critical but unseen force. So how do you capture and see that unseen force?

Oscilloscopes (or scopes) test and display voltage signals as waveforms, visual representations of the variation of voltage over time. The signals are plotted on a graph, which shows how the signal changes. The vertical (Y) axis represents the voltage measurement and the horizontal (X) axis represents time.

Most of today's oscilloscopes are digital, which enables more detailed accurate signal measurements and fast calculations, data storage capabilities and automated analysis. Handheld digital oscilloscopes such as the Fluke ScopeMeter® Test Tools offer several advantages over benchtop models: They are battery operated, use electrically isolated floating inputs and also offer the advantage of embedded features that make oscilloscope usage easier and more accessible to a variety of workers.

The newest generation of ScopeMeter® Portable Oscilloscopes are designed to be operated quickly and easily in the field and can even share readings in real time over a smartphone app in order to receive consultation from colleagues or other experts, or

to save data in the cloud for further analysis.

These designs also make safety-certified measurements possible in CAT III 1000 V and CAT IV 600 V environments—a critical need for safely troubleshooting electrical devices in high-energy applications.

Multimeter vs. oscilloscope

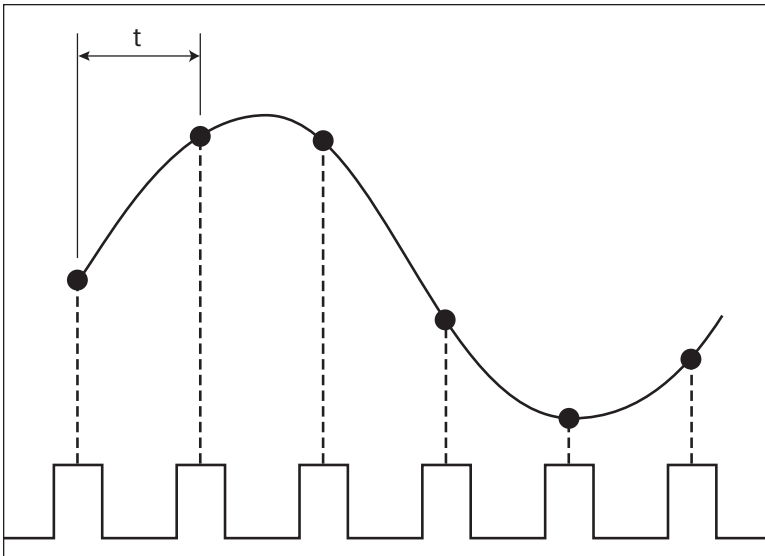
The difference between an oscilloscope and a DMM (Digital Multimeter) can be most simply stated as "pictures vs. numbers." A DMM is a tool for making precise measurements of discrete signals, enabling readings of up to eight digits of resolution for the voltage, current or frequency of a signal. On the other hand, it cannot depict waveforms visually to reveal signal strength, wave shape, or the instantaneous value of the signal. Nor is it equipped to reveal a transient or a harmonic signal that could compromise the operation of a system.

An oscilloscope adds a wealth of information to the numeric readings of a DMM. While displaying the numerical values of a wave instantaneously, it also



The graph on an oscilloscope can reveal important information:

- The voltage and current signals when operating as intended
- Signal anomalies
- Calculated frequency of an oscillating signal and any variations in frequency
- Whether signal includes noise and changes to the noise



Sampling and interpolation: sampling is depicted by the dots while interpolation is shown as the black line.

reveals the shape of the wave, including its amplitude (voltage) and frequency.

With such visual information, a transient signal that may pose a threat to a system can be displayed, measured and isolated.

Reach for an oscilloscope if you want to make both quantitative and qualitative measurements. Use a DMM to make high-precision checks of voltage, current, resistance and other electrical parameters.

ScopeMeter® Hand-Held Oscilloscope functions

Sampling

Sampling is the process of converting a portion of an input signal into a number of discrete electrical values for the purpose of storage, processing and display. The magnitude of each sampled point is equal to the amplitude of the input signal at the time the signal is sampled.

The input waveform appears as a series of dots on the display. If the dots are widely spaced and difficult to interpret as a waveform, they can

be connected using a process called interpolation, which connects the dots with lines, or vectors.

Triggering

Trigger controls allow you to stabilize and display a repetitive waveform.

Edge triggering is the most common form of triggering. In this mode, the trigger level and slope controls provide the basic trigger point definition. The slope control determines whether the trigger point is on the rising or the falling edge of a signal, and the level control determines where on the edge the trigger point occurs.

When working with complex signals like a series of pulses, pulse width triggering may be required. With this technique, both the trigger-level setting and the next falling edge of the signal must occur within a specified time span. Once these two conditions are met, the oscilloscope triggers.

Another technique is single-shot triggering, by which the oscilloscope will display a trace

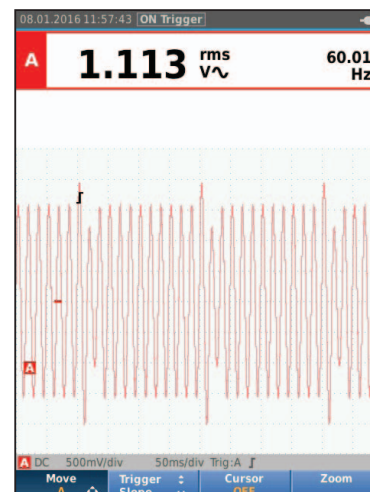
only when the input signal meets the set trigger conditions. Once the trigger conditions are met, the oscilloscope acquires and updates the display, and then freezes the display to hold the trace.

Getting a signal on the screen

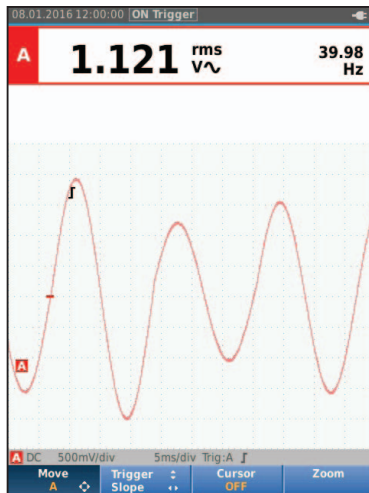
The task of capturing and analyzing an unknown waveform on an oscilloscope can be routine, or it can seem like taking a shot in the dark. In many cases, taking a methodical approach to setting up the oscilloscope will capture a stable waveform or help you determine how the scope controls need to be set so that you can capture the waveform.

The traditional method of getting a signal to show properly on an oscilloscope is to manually adjust three key parameters to try to achieve an optimum setpoint—often without knowing the correct variables:

- **Vertical sensitivity.** Adjusts the vertical sensitivity so that the vertical amplitude spans approximately three to six divisions.

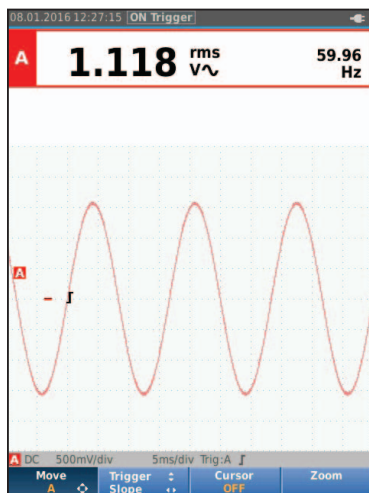


Unknown trace adjusted for 3–6 vertical divisions.



Unknown trace adjusted for 3-4 periods horizontally.

- **Horizontal timing.** Adjusts the horizontal time per division so that there are three to four periods of the waveform across the width of the display.
- **Trigger position.** Sets the trigger position to a point of the vertical amplitude. Depending on the signal characteristics, this action may or may not result in a stable display.



Trigger level adjusted to a unique repetitive position, outside the aberration on the second period.



Trigger point is set to a point but due to the aberration on the leading edge in the second period, an additional trigger results in an unstable display.

Those three parameters, when adjusted properly show you a symmetrical “trace,” the line that connects the samples of the signal to create the visual depiction of the waveform. Waveforms can vary indefinitely from the most common sine-wave that ideally mirrors between positive and negative on the zero axis point or a uni-directional square wave typical of electronic pulses, or even a shark tooth form.

The manual setup method often requires tediously adjusting the settings to make the waveform readable in order to analyze it.

Automating setup

In contrast, Fluke ScopeMeter® Hand-held Oscilloscopes include a technology called Connect-and-View™ that automates the process of digitizing the analog waveform to see a clear picture of the signal. Connect-and-View adjusts the vertical and horizontal timing and the trigger position for you, enabling hands-off operation to display complex unknown signals. This function optimizes and stabilizes the display on nearly all waveforms. If the signal changes, the setup will track these changes.

By pressing the AUTO button you enable Connect-and-View. At this point you should see a trace that 1) lies within the vertical range of the display, 2) shows at least three periods of a waveform, and 3) is stable enough to allow you to recognize the overall characteristics of the waveform. Next, you can start fine-tuning the settings.

Understanding and reading waveforms

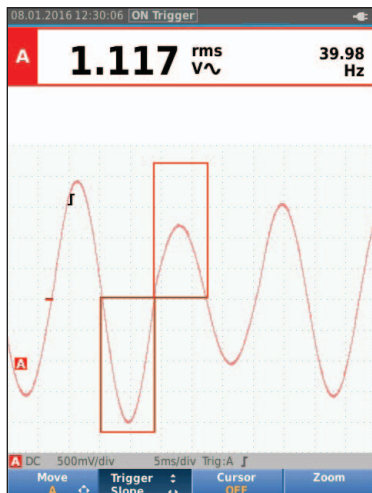
The majority of electronic waveforms encountered are periodic and repetitive, and they conform to a known shape. However, there are several wave characteristics to consider in order to train your eye to look at the various dimensions.

Some Fluke ScopeMeter® Test Tools offer a proprietary onboard algorithm called IntellaSet™ to assist waveform analysis. Once the waveform is displayed on screen, if initiated, the new IntellaSet™ technology evaluates the signal and associated waveform by comparing it against a database of known waveforms. The ScopeMeter® Test Tool then intelligently suggests critical measurements to characterize the unknown signal so potential areas of concern can be identified. As an example, when the measured waveform is a line voltage signal, the V ac + dc and Hz readings are automatically displayed.

While intelligent programs help minimize the time it takes to scrutinize waveforms, it’s important to know what to look for when using an oscilloscope.

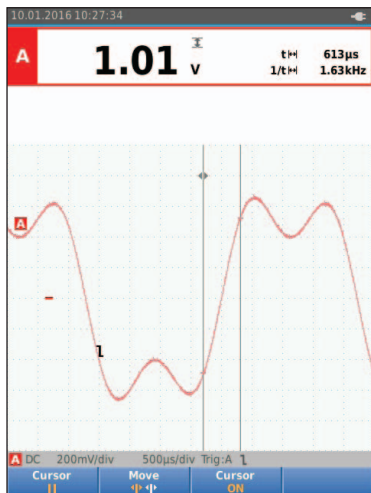
Here are the factors to consider in analyzing waveforms:

Shape. Repetitive waveforms should be symmetrical. That is, if you were to print the traces and cut them in two like-sized pieces, the two sides should be identical. A point of difference could indicate a problem.



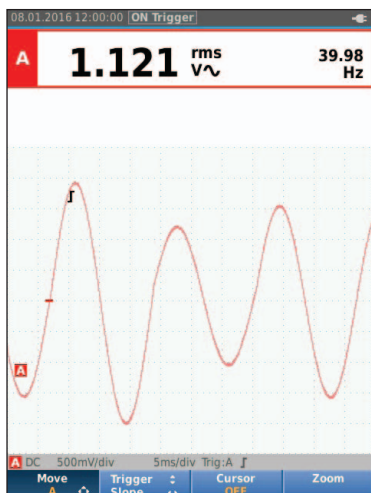
If the two components of the waveform are not symmetrical, there may be a problem with the signal.

Rising and falling edges. Particularly with square waves and pulses, the rising or falling edges of the waveform can greatly affect the timing in digital circuits. It may be necessary to decrease the time per division to see the edge with greater resolution.



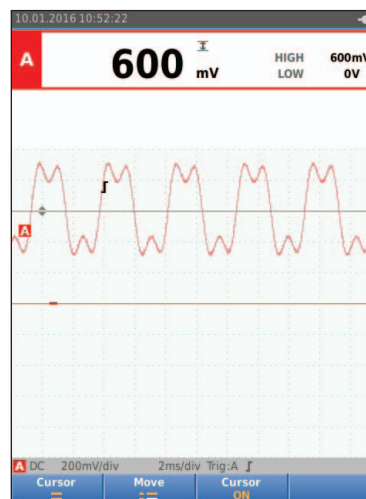
Use cursors and the gridlines to evaluate the rise and fall times of the leading and trailing edges of a waveform.

Amplitude. Verify that the level is within the operating specifications of the circuit. Also check for consistency, from one period to the next. Monitor the waveform for an extended period of time, watching for any changes in amplitude.



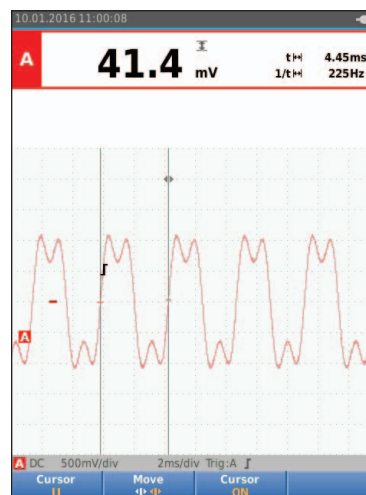
Use horizontal cursors to identify amplitude fluctuations.

Amplitude offsets. DC-couple the input and determine where the ground reference marker is. Evaluate any dc offset and observe if this offset remains stable or fluctuates.



Evaluate waveform dc offsets.

Periodic wave shape. Oscillators and other circuits will produce waveforms with constant repeating periods. Evaluate each period in time using cursors to spot inconsistencies.

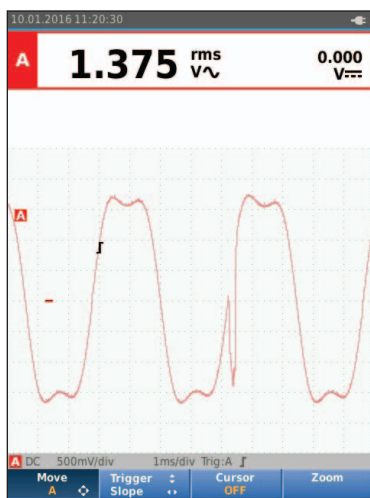


Evaluate period-to-period time changes.

Waveform anomalies

Here are typical anomalies that may appear on a waveform, along with the typical sources of such anomalies.

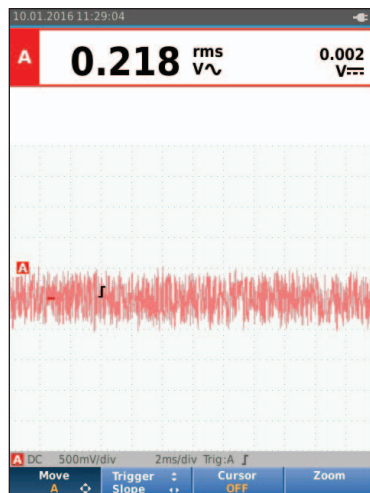
Transients or glitches. When waveforms are derived from active devices such as transistors or switches, transients or other anomalies can result from timing errors, propagation delays, bad contacts or other phenomena.



A transient is occurring on the rising edge of a pulse.

Noise. Noise can be caused by faulty power supply circuits, circuit overdrive, crosstalk, or interference from adjacent cables.

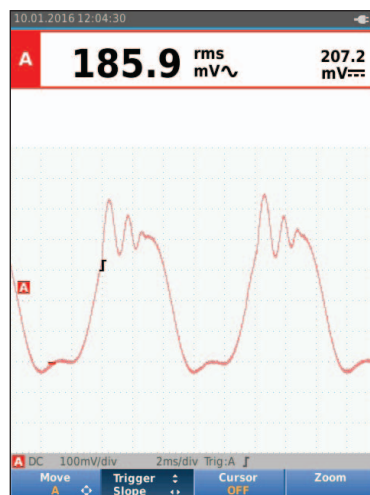
Or, noise can be induced externally from sources such as dc-dc converters, lighting systems and high-energy electrical circuits.



A ground reference-point measurement showing induced random noise.

Ringing. Ringing can be seen mostly in digital circuits and in radar and pulse-width-modulation applications. Ringing shows up at the transition from a rising or falling edge to a flat dc level.

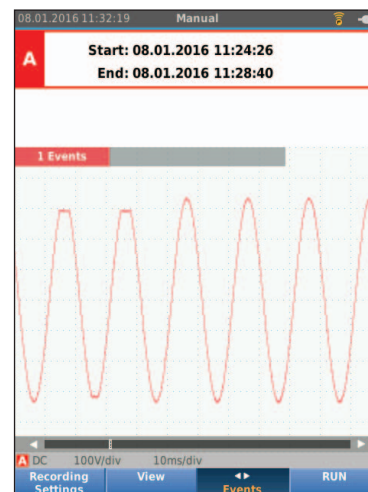
Check for excessive ringing, adjusting the time base to give a clear depiction of the transitioning wave or pulse.



Excessive ringing occurring on the top of the square wave.

Momentary fluctuation

Momentary changes in the measured signal generally result from an external influence such as a sag or surge in the main voltage, activation of a high-power device that is connected to the same electrical circuit, or a loose connection. Use the ScopeRecord function and Event Capture mode of the ScopeMeter Test Tool to monitor the signal over long periods of time to detect the elusive momentary events.



A momentary change of approximately 1.5 cycles in the amplitude of the sinewave.

Diagnosing problems and troubleshooting

Although successful troubleshooting is both an art and a science, adopting a troubleshooting methodology and relying on the functionality of an advanced ScopeMeter® Hand-held Oscilloscope can greatly simplify the process.

Good troubleshooting practices will save time and frustration. The time-tested approach known as KGU, Known Good Unit comparison, accomplishes both goals. KGU builds on a simple principle: an electronic system that is working properly exhibits predictable waveforms at critical nodes within its circuitry, and these waveforms can be captured and stored.

This reference library can be stored on the ScopeMeter Test Tool as a resource or transmitted via the Fluke Connect® app to a smartphone and to the cloud. It can also be printed out to serve as a hard-copy reference document. If the system or an identical system later exhibits a fault or failure, waveforms can be captured from the faulty system—called the Device Under Test (DUT)—and compared with their counterparts in the KGU. Consequently, the DUT can either be repaired or replaced.

To build a reference library, start by identifying appropriate test points, or nodes, on the DUT.

Now, run the KGU through its paces, capturing the waveform from each node. Annotate each waveform as required.

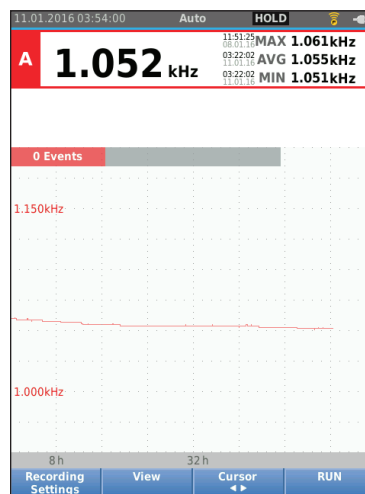
Get into the habit of always documenting key waveforms and measurements. Having a reference to compare to will prove invaluable during future troubleshooting.

When troubleshooting, it's important to inspect waveforms for fast-moving transients or glitches, even if a spot check of the waveform reveals no anomalies.

These events can be difficult to spot, but the high sampling rate of today's ScopeMeter Test Tools, together with effective triggering, make it possible. In addition, the recording capabilities of the latest ScopeMeter Test Tools can trend critical test point electrical signals over time, identifying changes or random events that occur outside of user defined thresholds and cause system shutdowns or resets.

Drift. Drift—or minor changes in a signal's voltage over time—can be tedious to diagnose. Often the change is so slow that it is difficult to detect. Temperature changes and aging can affect passive electronic components such as resistors, capacitors and crystal oscillators. One problematic fault to diagnose is drift in a reference dc voltage supply or oscillator circuit. Often the only solution is to monitor the measured value (V dc, Hz, etc.) over an extended time.

CAUTION: For the correct and safe use of electrical test tools it is essential that operators follow safety procedures as outlined by their company and local safety agencies.



Performing a frequency measurement on a crystal oscillator that has been trend-plotted over an extended period (days or even weeks) can highlight the effect of drift caused by temperature changes and aging.

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