FLUKE®

Clamp Meter ABCs

Application Note

What is a clamp meter and what can it do? What measurements can be made with a clamp meter? How do you get the most out of a clamp meter? Which clamp meter is best suited to the environment the meter will be used in? The answers to these questions can be found in this application note.

Choose a clamp meter rated to meet the electrical environment you'll be working in, as well as the resolution and accuracy of measurement you'll need for your testing.

With technological advances in electrical equipment and circuits come more challenges for electricians and technicians. These advances not only require more capability in today's test equipment, but more skills on the part of the people who use them. An electrician who has a good grounding in the fundamentals of test equipment use will be better prepared for today's testing and troubleshooting challenges. The clamp meter is a important and common tool found in the toolboxes of electricians and technicians alike.

A clamp meter is an electrical tester that combines a voltmeter with a clamp-type current meter. Like the multimeter, the clamp meter has passed through the analog period and into the digital world of today. Originally created primarily as a single-purpose test tool for electricians, today's models have incorporated more measurement functions, more accuracy, and in some instruments, some very special measurement features. Today's clamp meters have most of the basic functions of a digital multimeter (DMM), but with the added feature of a current transformer built into the product.

The transformer action

The ability of clamp meters to measure large ac currents is based on simple transformer action. When you clamp the instrument's jaws or flexible current probe around a conductor carrying ac current, that current is coupled through the jaws, similar to the iron core of a power transformer, and into a secondary winding that is connected across the shunt of the meter's input. A much smaller current is delivered to the meter's input due to the ratio of the number of secondary windings versus the number of primary windings wrapped around the core. Usually, the primary is represented by the one conductor around which the jaws or flexible current probe is clamped. If the secondary has 1000 windings, then the secondary current is 1/1000 the current flowing in the primary, or in this case the conductor being measured. Thus, 1 amp of current in the conductor being measured would produce 0.001 amps or 1 milliamp of current at the input of the meter. With this technique, much larger currents can be easily measured by increasing the number of turns in the secondary.

Clamp meters measure any combination of alternating and direct current. This includes static dc and charging dc as well as ac. Clamp meters measure dc current using Hall effect sensors. A Hall effect sensor, basically a kind of magnetometer, can sense the strength of an applied magnetic flux. Unlike a simple inductive sensor, the Hall effect sensor will work when the applied magnetic flux is static, not changing. It will work for alternating magnetic fields as well. A clamp meter contains a toroidal iron core that clamps together with a Hall effect chip in the gap between the two halves, so that the induced magnetic flux from the current-carrying wire is channeled through it.

Choosing your clamp meter

Buying a clamp meter not only requires looking at specifications, but also looking at features, functions, and the overall value represented by a meter's design and the care taken in its production.

Reliability, especially under tough conditions, is more important than ever. Fluke's design engineers make a point of building these test tools not only electrically, but also mechanically, robust. By the time Fluke clamp meters are ready to be tossed into toolcases, they've undergone a rigorous testing and evaluation program.

User safety should be a primary consideration in choosing a clamp meter—or any other piece of electrical test equipment. Fluke not only designs its clamp meters to the latest electrical standards, but each clamp meter is independently tested and then listed by certified testing labs such as CSA, TÜV, etc. Only with these certifications can you be assured an electrical tester meets these new safety standards.

Use a flexible current probe for situations like this, where large conductors make it difficult to use the clamp meter jaws.

Using a clamp meter in difficult situations

Electricians and technicians often need to use clamp meters in less-than-ideal situations. The newest clamp meters use the iFlex™ flexible current probe to enable measuring where it's difficult to access—for example, tight cabinets, bundled wires, or awkward conductors.

When it's necessary to measure remotely, a clamp meter with a detachable display (such as the Fluke 381) makes it possible to see the display at a location other than where the measurement is being taken. This means one person—not two—can take the measurement.

Resolution, digits and counts

Resolution refers to how fine a measurement a meter can make. By knowing the resolution of a meter, you can determine if it's possible to see a small change in the measured signal. For example, if the clamp meter has a resolution of 0.1 amp on a 600 amp range, it's possible to see a change of 0.1 amp while reading 100 amps.

You wouldn't buy a ruler marked in one-inch segments if you had to measure down to one-quarter inch. Similarly, you must choose a meter that can display the resolution you need to see in your measurements.

Accuracy

Accuracy is the largest allowable error that will occur under specific operating conditions. In other words, it is an indication of how close the meter's displayed measurement is to the actual value of the signal being measured.

Accuracy for a clamp meter is usually expressed as a percent of reading. An accuracy of 3 % of reading means that for a displayed reading of 100 amps, the actual value of the current could be anywhere between 97.0 and 103.0 amps.

Specifications may also include a range of digits added to the basic accuracy specification. This indicates how many counts the digit to the extreme right of the display might vary. So the preceding accuracy example might be stated as ± (2 % + 2). Therefore, for a displayed reading of 100.0 amps, the actual current could then be estimated to be between 97.8 and 102.2 amps.

Crest factor

With the growth of electronic power supplies, the current drawn from today's electrical distribution system are no longer pure 60 or 50 cycle sine waves. These currents have become fairly distorted, due to the harmonic content these power supplies generate.

However, electrical power system components such as fuses, bus bars, conductors, and thermal elements of circuit breakers are rated in rms current because their main limitation has to do with heat dissipation. If we want to check an electrical circuit for overloading, we need to measure the rms current and compare the measured value to the rated value for the component in question. Therefore, today's test equipment must be able to accurately measure the true-rms value of a signal regardless of how distorted the signal might be.

Crest factor is a simple ratio of a signal's peak value to its rms value. For a pure ac sine wave, the crest factor would be 1.414. However, a signal that has a very sharp pulse would cause the ratio, or crest factor, to be high. Depending on the width of the pulse and its frequency, you can see crest factors of 10:1 or higher. In real power distribution systems, crest factors of greater than 3:1 are rarely seen. So as you can see, crest factor is an indication of a signal's distortion.

A crest factor specification will be found only in specifications for meters that can make true-rms measurements. It indicates how much distortion a signal can have and still be measured within the meter's accuracy specification. Most true-rms reading clamp meters have crest factor specifications of 2:1 or 3:1. That rating will handle most electrical applications.

Measuring current

One of the most basic measurements of a clamp meter is current. Today's clamp meters are capable of measuring both ac and dc current. Typical current measurements are taken on various branch circuits of an electrical distribution system. Determining how much current is flowing in various branch circuits is a fairly common task for the electrician.

How to make current measurements

1. Select Amps ac $\tilde{A}$ or Amps dc $\overline{A}$.
2. Open the jaws of the clamp meter and close the jaws around a single conductor. (If you are measuring ac current, you can switch to the iFlex setting and use a flexible current probe.)
3. View the reading in the display.

By taking current measurements along the run of a branch circuit, you can easily tell how much each load along the branch circuit is drawing from the distribution system.When a circuit breaker or transformer appears to be overheating, it's best to take a current measurement on the branch circuit to determine the load current. However, make sure you are using a true-rms responding meter so you can get an accurate measurement of the signal heating up these components. The average responding meter will not give a true reading if the current and voltage are non-sinusoidal due to non-linear loads.

Measuring voltage

Another common function for a clamp meter is measuring voltage. Today's clamp meters are capable of measuring both ac and dc voltage. AC voltage is usually created by a generator and then distributed through an electrical distribution system. An electrician's job is to be able to take measurements throughout the system to isolate and fix electrical problems. Another common voltage measurement would be testing battery voltage. In this case, you would be measuring direct current or dc voltage.

Testing for proper supply voltage is usually the first thing measured when troubleshooting a circuit. If there is no voltage present, or if it is too high or too low, the voltage problem should be corrected before investigating further.

A clamp meter's ability to measure ac voltage can be affected by the frequency of the signal. Most clamp meters can accurately measure ac voltages with frequencies from 50 Hz to 500 Hz, but a digital multimeter's ac measurement bandwidth might be 100 kHz or higher. This is why the reading of the same voltage by a clamp meter and digital multimeter can have very different results. The digital multimeter allows more of the high frequency voltage through to the measurement circuitry, while the clamp meter filters out some of the voltage contained in the signal above the bandwidth of the meter.

When troubleshooting a variable frequency drive (VFD), the input bandwidth of a meter can become very important in getting a meaningful reading. Due to the high harmonic content in the signal coming out of a VFD to the motor, a DMM would measure most of the voltage content (depending on its input bandwidth). Measuring the voltage output of a VFD is now a common measurement. A motor connected to a VFD only responds to the average value of the signal, and to measure that power the input bandwidth of the clamp meter must be narrower than its DMM counterpart. The Fluke 375, 376, and 381 clamp meters have been specifically designed for testing and troubleshooting VFDs.

How to make voltage measurements

1. Select Volts AC (V~) or Volts DC (V⎓), as desired.
2. Plug the black test probe into the COM input jack. Plug the red test probe into the V input jack.
3. Touch the probe tips to the circuit across a load or power source (in parallel to the circuit).
4. View the reading, being sure to note the unit of measurement.
5. (Optional) Press the HOLD button to freeze the reading in the display. Now you can remove the meter from the live circuit and then read the display when you are safely clear of the electrical hazard.

By taking a voltage measurement at the circuit breaker and then at the input of the load on that breaker, you can determine the voltage drop that occurs across the wires connecting them. A significant drop in voltage at the load might affect how well the load functions.

Measuring resistance

Resistance is measured in ohms (Ω). Resistance values can vary greatly, from a few milliohms (mΩ) for contact resistance to billions of ohms for insulators. Most clamp meters measure down to 0.1 Ω. When the measured resistance is higher than the upper limit of the meter, or the circuit is open, "OL" appears in the meter's display.

Resistance measurements must be made with the circuit power off—otherwise, the meter or circuit could be damaged. Some clamp meters provide protection in the ohms mode in case of accidental contact with voltages. The level of protection may vary greatly among different clamp meter models.

How to make resistance measurements

1. ⚠ Turn off power to the circuit.
2. Select resistance (Ω).
3. Plug the black test probe into the COM input jack. Plug the red test probe into the VΩ input jack.
4. Connect the probe tips across the component or portion of the circuit for which you want to determine resistance.
5. View the reading in the meter's display

⚠ Make sure the power is off before making resistance measurements.

Continuity

Continuity is a quick go/no-go resistance test that distinguishes between an open and a closed circuit.

A clamp meter with a continuity beeper allows you to complete many continuity tests easily and quickly. The meter beeps when it detects a closed circuit, so you don't have to look at the meter as you test. The level of resistance required to trigger the beeper varies from meter to meter. The typical resistance setting to turn on the beeper is a reading less than between 20 ohms and 40 ohms.

Special functions

A fairly common measurement function is reading the frequency of an ac current waveform. With the clamp meter's jaws (or a flexible current probe) wrapped around a conductor carrying ac current, switch on the Frequency function and the meter's display will indicate the frequency of the signal flowing in the conductor. This is a very helpful measurement when tracking down harmonic problems in an electrical distribution system.

Another feature that can be found in some clamp meter models is min, max, and average storage. When this feature is activated, each reading the clamp meter takes is compared against any previously stored readings. If the new reading is higher than the reading in the high reading memory, it replaces that reading as the highest reading. The same comparison is made against the low reading memory, and the new reading, if lower, replaces the stored reading. The average reading is updated accordingly. As long as the min, max, and average feature is active, all readings are processed in this way. Thus, after a period of time, you can call up each of these memory values to the display and determine the highest, lowest, and average reading over a specific period of time.

In the past, not all clamp meters could measure capacitance. The

Measuring current with a clamp meter.

capacitance measurement function is now being incorporated into the feature set of many new clamp meters. This function is useful for checking motor start capacitors or measuring values of electrolytic capacitors contained in controllers, power supplies or motor drives.For electricians who deal with motors in their work, the ability to capture the amount of current drawn by a motor during its start up can tell a lot about a motor's condition and loading. The Fluke 374, 375, 376, and 381 clamp meters incorporate inrush current measurement as part of their feature sets. After clamping the jaws (or the flexible current probe) around one of the motor's input leads, activate the inrush mode. Next, turn on the motor. The clamp meter's display will indicate the maximum current drawn by the motor over the first 100 milliseconds of its start cycle. This proprietary inrush measurement technology filters out noise and captures motor starting current exactly as the circuit protection sees it.

Clamp meter safety

Making measurements safely starts with choosing the proper meter for the environment in which the meter will be used. Once the proper meter has been chosen, you should use it by following good measurement procedures.

The International Electrotechnical Commission established new safety standards for working on electrical systems. Make sure you are using a meter that meets the IEC category and voltage rating approved for the environment where the measurement is to be made. For instance, if a voltage measurement needs to be made in an electrical panel with 480V, then a meter rated Category III—600 V or higher should be used. This means the input circuitry of the meter has been designed to withstand voltage transients commonly found in this environment without harming the user.[1] Choosing a meter with this rating, which also has a CSA or TÜV certification, means the meter not only has been designed to IEC standards, but has been independently tested and meets those standards. (See independent testing sidebar).

Many new clamp meters now carry a Cat IV safety rating, which means they can be used in outdoor or underground settings where lightning strikes or transients can occur more frequently and at higher levels.

Safety checklist

- ✓ Use a meter that meets accepted safety standards for the environment in which it will be used.
- ✓ Inspect test leads or flexible current probe for physical damage before making a measurement.
- ✓ Use the meter to check continuity of the test leads or flexible current probe.
- ✓ Use only test leads that have shrouded connectors and finger guards.
- ✓ Use only meters with recessed input jacks.
- ✓ Be sure the meter is in good operating order.
- ✓ Always disconnect the "hot" (red) test lead first.
- ✓ Don't work alone.
- ✓ Use a meter that has overload protection on the ohms function.

[1]See the *ABCs of Multimeter Safety* (literature code 1263690) to learn more about IEC-1010 and how it applies to multimeter use.

Special features

The following special features and functions may make it easier to use your clamp meter.

- Annunciators (display icons) show at a glance what is being measured (volts, ohms, etc.)
- Data Hold allows you to freeze the reading in the display.
- One-switch operation makes it easy to select measurement functions.
- Overload protection prevents damage to both the meter and the circuit, and protects the user.
- Autoranging automatically selects proper measurement range. Manual ranging lets you lock into a specific range for repetitive measurements.
- Low battery indicator warns you when the battery needs changing.
- Display with backlight, easy-to-read characters, and wide viewing angle makes readings easier to see in all sorts of conditions. The backlight display automatically sets the correct measurement range so you do not need to change the switch positions while taking a measurement.
- Integrated low pass filter and state of the art signal processing allows for use in noisy electrical environments while providing stable readings.

Glossary

Accuracy. How close the displayed measurement is to the actual value of the signal being measured. Expressed as a percentage of reading or a as a percentage of full scale.

Analog Meter. An instrument that uses a needle movement to display the value of a measured signal. The user judges the reading based in the position of the needle on a scale.

Annuciator. A symbol or icon that identifies a selected range or a function

Average Responding Meter. A meter that accurately measures sinusoidal waveforms, while measuring non-sinusoidal waveforms with less accuracy.

Non-Sinudoidal Waveform. A distorted waveform such as a pulse train, square waves, triangular waves, sawtooth waves and spikes.

Resolution. The degree to which small changes in a measurement can be displayed.

RMS. The equivalent dc value of an ac waveform.

Sinusoidal Waveform. A pure sine wave without distortion.

True-rms Meter. A meter that can accurately measure both sinusoidal and non-sinusoidal waveforms.

Independent testing is the key to safety compliance

How can you tell if you're getting a genuine CAT III or CAT II meter? Unfortunately it's not always that easy. It is possible for a manufacturer to self-certify its meters as CAT II or CAT III *without any independent verification*. Beware of wording such as "Designed to meet specification..." Designer's plans are never a substitute for an actual independent test. The IEC (International Electrotechnical Commission) develops and proposes standards, but it is not responsible for *enforcing* the standards.

Look for the symbol and listing number of an independent testing lab such as UL, CSA, TÜV or other recognized approval agency. That symbol can only be used if the product successfully completed testing to the agency's standard, which is based on national/international standards. UL 3111, for example, is based on IEC 1010-1 2nd Edition. In an imperfect world, that is the closest you can come to ensuring that the multimeter you choose was actually *tested* for safety.

Meter ratings and capabilities vary by manufacturer. Before working with a new meter, be sure to familiarize yourself with all operating and safety procedures for that meter contained in the users manual.

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