Think SAFETY When Selecting a Handheld Multimeter

Application Note

Introduction

What do you do when you need to measure power from mains, or some other high voltage or high energy source? Should you just grab the nearest handheld multimeter available? Absolutely not!

The same goes for your helmet. All helmets attempt to protect the user's head, but the structure, design, and protective ability vary for different kinds of activities. A helmet designed for rock climbing needs to protect you against small rocks or falling objects. A bicycle helmet needs to protect you against blunt impact forces from the road or car hood.

Likewise, different handheld multimeters are designed with different levels of protection against common electrical hazards.

For your own safety and the safety of those near you, you must choose a handheld multimeter that is designed and tested to protect you against electrical hazards you might encounter.

Agilent Technologies

Electrical Hazards

Electricity is essential to modern life, both at home and on the job. Whether it is for an alarm clock or an oven, we all use electricity. Perhaps because it has become such a familiar part of our daily life, many of us do not give much thought to the hazards of electricity.

Engineers, electricians, electronic technicians, and power line workers are among those who may be exposed directly to electricity. They are at higher risk from electrical hazards.

Sales people and office workers, for example, use electrical equipment that has been designed to shield them from the hazards of electricity. They are at less risk from electrical hazards.

Because of this, the tools or equipment that you use must be designed with appropriate levels of protection to withstand the electrical hazards in your working environment.

Building Electrical Mains

Electricity is invisible. We cannot see it and are therefore unaware of its presence. Since you cannot see electric current, you might touch an energized conductor and receive an electric shock, which can be fatal. To stay safe, you need to consider three key characteristics when you are selecting a handheld multimeter to measure a circuit in a building.

The first key characteristic is the voltage rating of the circuit. You should know the maximum voltage at which the circuit is designed to work. There are many different mains voltage ratings for the operation of household and light commercial electrical appliances and lighting. All European and most South American, African, and Asian countries use supply that is within 10% of 230 V, whereas Japan, North America, and some parts of northern South America use voltages between 100 V and 127 V.

At minimum, you must choose a handheld multimeter rated to measure the voltage that is expected to be present on the circuit.

However, the circuit voltage rating alone does not tell the whole story. You must also take transient voltages into consideration when selecting a handheld multimeter for measurement. Occasionally, you might hear of an electrician who found himself to be the victim of a transient voltage spike that knocked him flat.

Where do these transient voltages come from?

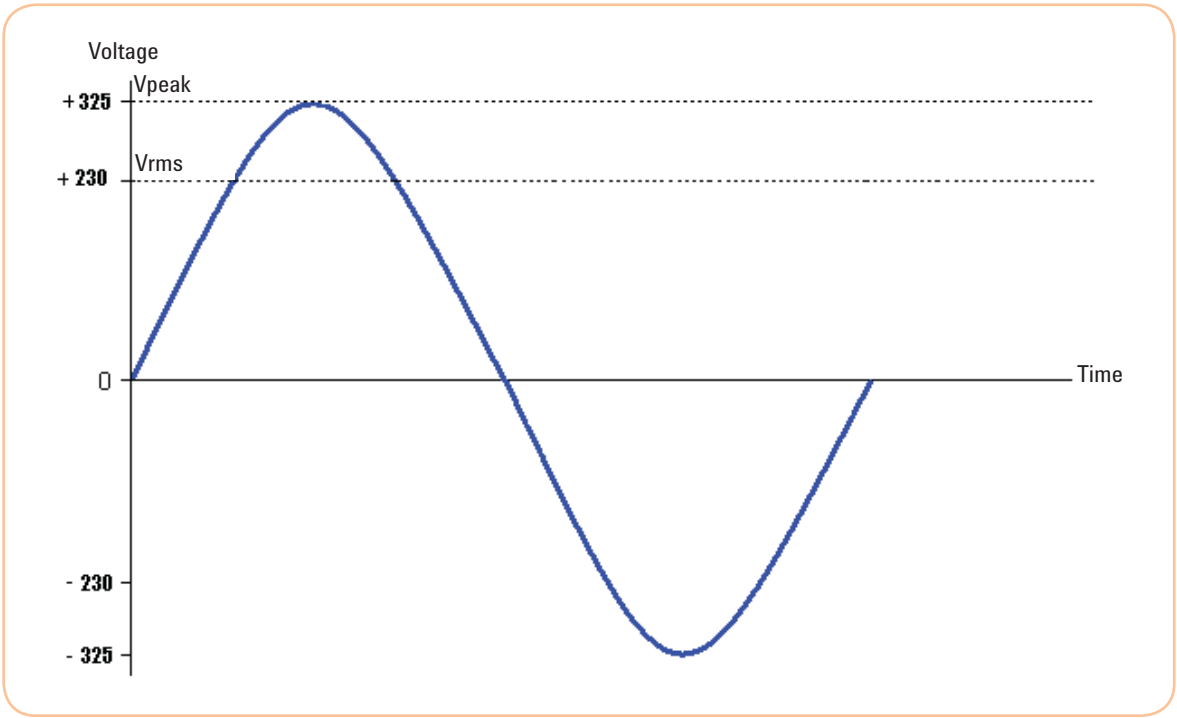

Figure 1. 230 V sinusoid waveform with the RMS voltage and peak voltage

Building Electrical Mains (continued)

Transient voltages come from two main sources: They can result from natural causes, such as lightning outside the building or they can be generated by switching operations on the power distribution system.

Switching events in power distribution include switching of transformer taps, motors, inductances, sudden variation of load, or disconnection of circuit breakers.

The amplitudes of these transient voltages vary from a few hundred volts peak to about 6000 V peak. These randomly occurring high voltage spikes tend to last from 50 to 200 microseconds. If a safety protection margin is not built into your meter to safely withstand such peak transients, they might trigger a sequence of events that could lead to serious injury or death.

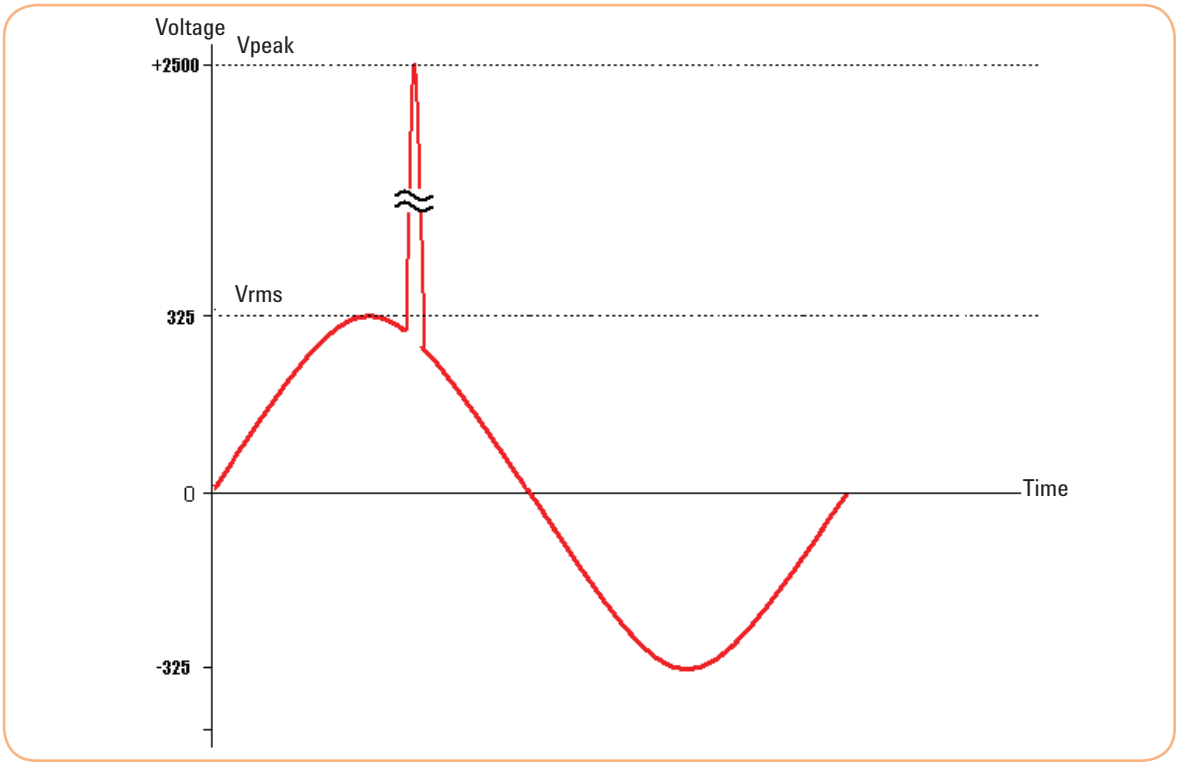

Figure 2. *230 V sinusoid waveform with a 2500 V peak transient*

In addition to the transient voltage ratings of circuits, you should consider circuits' energy capacity. To protect yourself, you should know your circuits' energy capacity before you start taking measurement.

Circuits with higher energy capacity can deliver more current and energy into faults than can low energy circuits. Therefore, measurements performed on higher energy circuits are much more hazardous than measurements performed on lower energy circuits.

The energy capacity of the circuit is defined by three characteristics: the operating voltage, the circuit impedance, and the characteristics of the circuit fuse or circuit breaker. The closer your circuit is to the mains source, the lower the circuit impedance. In other words, the fault current is higher and extra precautions are needed.

Measurement Category

The International Electrotechnical Commission (IEC) has defined three "measurement categories" for mains circuits. The higher the category number, the greater the danger posed by transient voltages on the mains circuit.

The three measurement categories are Category II, Category III, and Category IV.

Table 1. IEC definitions of its measurement categories

Category	Description
Measurement Category II	This category is applied to all equipment connected from the wall socket up to the equipment's first level of power conversion. Measurements at the wall socket itself might not be limited to CAT II levels. Handheld multimeters should always be capable of CAT III measurements.
Measurement Category III	This category is applied to building circuit installations that are completely within the building, including parts of the service panel and the branch circuits. It also applies to much of the buildings' fixed equipment which is connected directly to the building mains instead of being connected through a cord and plug.
Measurement Category IV	This category is applied to the source of the building electrical installation: the entrance service panel, the primary mains meter, or perhaps the secondary side of the building distribution transformer, if the transformer is located within the building.

The current family of test and measurement equipment product safety standards also defines "Measurement Category I", but this category does not apply to mains circuits; it is everything *except* mains circuits. In future versions of IEC 61010 standards, this equipment will be considered to be "uncategorized" rather than being "Measurement Category I".

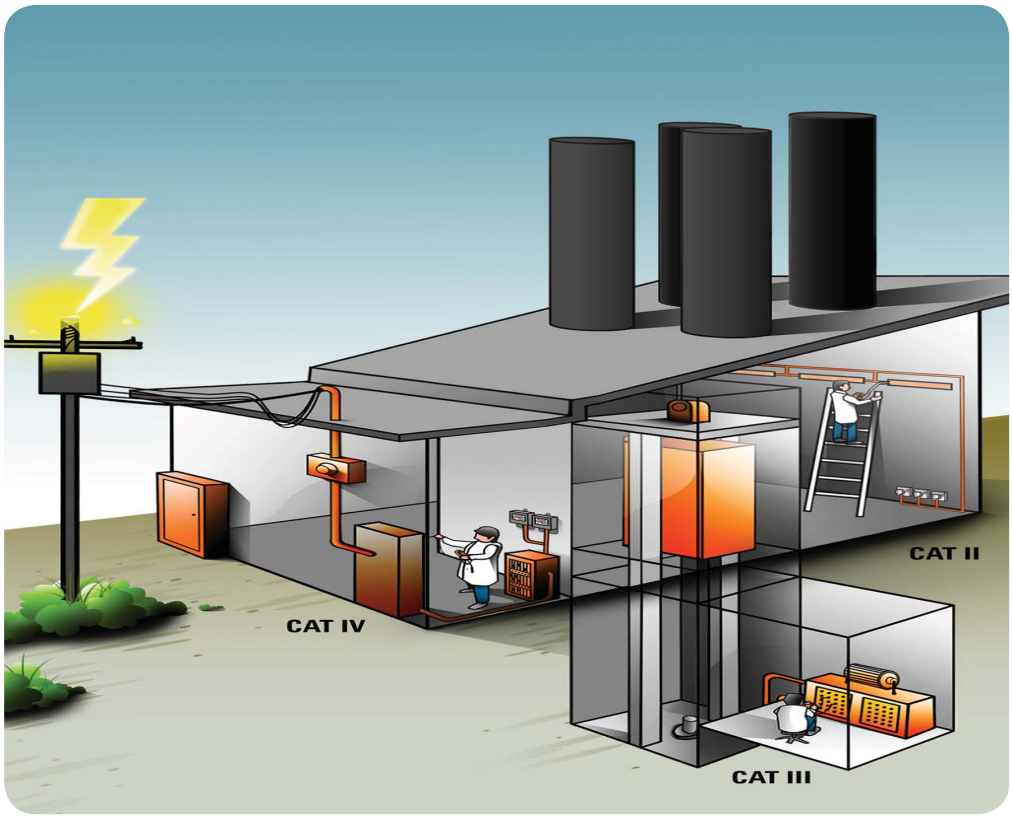

Figure 3. *Illustration of measurement categories*

Measurement Categories - What They Really Mean to You?

In the current IEC 61010 standards, measurement categories define the maximum amplitude of transient voltages that might be present on the mains voltage. These transient voltages are defined as shown in Table 2.

Table 2. Amplitude of transient voltages in different measurement categories

Mains Voltage Rating (to Earth) V_{rms}	Measurement Category II V_{Peak}	Measurement Category III V_{Peak}	Measurement Category IV V_{Peak}
100	800	1,500	2,500
150	1,500	2,500	4,000
300	2,500	4,000	6,000
600	4,000	6,000	8,000
1,000	6,000	8,000	12,000

All manufacturers of handheld multimeters are required to mark their products with the rated measurement category (CAT II, CAT III, or CAT IV). This marking is a convenient way for users to identify the maximum transient voltage that the meter can safely withstand. Most handheld multimeters display this rating near the handheld multimeter voltage/current input terminals.

Some manufacturers (including Agilent) mark two different measurement categories. As you can see from the above table, CAT III for 1000 V mains has the same transient-withstanding capability as CAT IV for 600 V mains. Therefore, it is common practice to mark a handheld multimeter with the combination rating like this on the multimeter:

The transient-withstanding voltage capability alone is not quite enough information. This is only one of the characteristics that you must consider before you select a handheld multimeter. In this case, the definitions of the measurement categories are changing.

In the next versions of the product safety standards, all handheld multimeters must safely withstand certain levels of energy surges in addition to the transient voltages. These requirements have not yet been introduced in the current IEC 61010 standard, but some manufacturers, including Agilent, are already designing handheld multimeters that will meet these new requirements.

Arc Flash

CAUTION

Arc Flash is the result of a very common mistake when using a handheld multimeter.

An assistance and you are performing a series of measurements on a building installation at an electrical service panel. You have just finished measuring a small current draw for some ancillary piece of equipment, and you want to measure the circuit voltage so you can calculate power consumption. Your assistant is holding the meter, and switches it from the current function to the voltage function, but forgets to switch the test leads from the current terminal to the voltage terminal.

When you touch the test leads to the voltage busses, this causes a direct short across the source voltage through a low-value resistor inside the handheld multimeter. A very high current will flow through the test leads and the meter. If you are working in an area with very low circuit impedance, this fault current can be thousands of amperes, or even tens of thousands of amperes.

The test leads and the meter circuitry are not designed to handle such a high current. The test lead or the meter will cause an open circuit. When this happens, an arc will form across the open part of the circuit.

If it is not immediately controlled, the arc will cause the air in the vicinity to become superheated and convert into a plasma (which is conductive) and allow even more current to flow through the air. This is called arc flash. In extreme cases, it releases the same amount of energy as a few sticks of dynamite. An arc-flash victim may suffer fatal burn injuries from the fierce heat. Could this happen? Absolutely!

Figure 4. *Illustration of possible arc flash*

High Energy Fuse

The measurement hazards in measurement Category III and measurement Category IV locations are significant enough that many authorities require protective clothing (fire-resistant vests, insulated gloves, face shields, insulated hand tools) when working in those areas.

Agilent recommends that you check with your local electrical safety authority for such recommendations.

The manufacturers of high-quality handheld multimeters address this phenomenon by including a special high-energy fuse in the meter. This fuse is designed to control and extinguish the arc flash within the fuse before it spreads outside the meter.

Not just any fuse will do.

Many meters are equipped with small glass fuses that will not always control arc flash, and in some cases may explode themselves. Some meters do not even have any fuses on the current input circuit, which makes their reaction to this type of event unpredictable.

Today's product safety standards do not require a high energy fuse, but injury data indicates that these fuses should be used in handheld multimeters. For your protection, you should insist on selecting handheld multimeters with this type of fuse on the current input circuits.

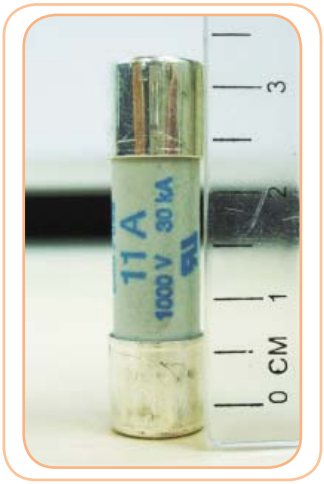

Figure 5. *Fuse used in Agilent Handheld Multimeters*

Table 3. Characteristics of fuses

Characteristics	Description
Voltage Rating	1,000 Vdc or 750 Vac rms
Operating Current	Typically 11 A, but may vary depending on the design
Operating Time	Very fast acting
Breaking Capacity	Typically 10,000 A or more

Certification

Safety certification is important. Most products carry safety certification markings to signify that the products comply with the relevant standards and have been tested by a third-party agency.

Responsible manufacturers of handheld multimeters like Agilent obtain safety certifications from third-party independent testing agencies such as the Canadian Standard Association (CSA). However, these certification bodies do not "approve" products. Rather, they evaluate products or systems for compliance to specific requirements.

Before you buy a new handheld multimeter, remember to check for the symbol of a recognized testing organization. Those symbols can only be used if the product successfully completed testing to the agency's standard, which is based on national/international standards. Normally, you can find this distinctive marking at the back of the meter.

Similarly, the multimeter probes should also be marked with a logo of a third-party safety agency.

German Association for Electrical, Electronic & Information Technologies (VDE)

Canadian Safety Association (CSA)

ETL SEMKO (ETL)

Technical Inspection Association (TüV)

What About the CE Mark?

The "CE" marking is an abbreviation for European Conformity (from the French phrase "Conformité Européene"). The CE marking is neither a mark of origin nor a quality mark.

This marking symbolizes conformity of the product to all of the applicable EU safety, health, and environmental requirements. It is a mandatory conformity mark on all products marketed in the European Union.

Manufacturers are permitted to self-certify. They must meet the standards, issue their own Declaration of Conformity, and mark the product "CE." Therefore the CE marking is not a guarantee of independent testing.

In the Declaration of Conformity, the manufacturer lists the standards that the manufacturer used when evaluating the meter. At a minimum, the manufacturer should list EN 61010-1:2001 for product safety in the Declaration of Conformity.

For safety purposes, you should not accept a handheld multimeter that has only a CE mark unless you know the manufacturer to be trustworthy and you have reviewed the Declaration of Conformity of the manufacturer.

CONCLUSION

When you are measuring mains power or other high voltages, safety is of great concern. No one should compromise personal safety for any reason. To be safe, you should choose a multimeter with a voltage rating higher than the circuit you are measuring. Also, choose a CAT III multimeter for mains measurements and a CAT IV multimeter for measurements close to the mains source. For protection against arc flash, be sure you select a handheld multimeter designed with a high-energy fuse on the current input circuit.

Remember to check that the multimeters and probes that you are going to use are marked with third-party safety agency logos such as CSA, ETL, TÜV, or VDE. Do not overlook the safety of the probes! With safety in mind, you will be assured that the high voltage goes into your measurement instrument instead of you!

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