

# How to Select a Handheld DMM That is RIGHT for You

## Introduction

Handheld digital multimeters (DMMs) are among the most widely used instruments for installation, test, and repair of electrical equipment. However, the variety of brands and DMM features can make it difficult to determine which handheld DMM is best suited to your application needs. Selecting a handheld with more capabilities than you need can mean spending more for equipment than necessary, while selecting a device under-equipped for the application can expose technicians to life-threatening electrical hazards.

To assist you in choosing a handheld DMM, this application note looks at some of the device's key attributes: handheld specifications, basic functionality, and features targeted for specific industrial applications. It also provides information on the design and features of Keysight Technologies handheld DMMs to guide you in your selection process.



## Things to Consider When Selecting a Multimeter

To choose the handheld DMM that is best suited to your requirements, first consider the following:

### Resolution, digit, and accuracy

Resolution is defined as the smallest change in an input signal that produces a change in the output signal. Resolution of a DMM is expressed in the number of digits the unit can display. For example, a 4½ DMM has four full digits that display values from 0 to 9, and the fractional digit, which is the most significant digit in the display. The fractional digit represents the highest level the most significant digit can display. In this example it is either a 0 or 1. Such a meter can also show positive or negative values from 0 to 19,999.

Sometimes resolution specified as the number of digits a DMM can display causes confusion, so manufacturers started specifying resolution in terms of “count”. The count of a DMM refers to how large a number it can display before it has to change measurement ranges, and how many digits it shows in total. This effects how precise a measurement the DMM can display. For example, a 4½ DMM can also be specified as a 19,999 display count or 20,000 display count multimeter.

Multimeter digit	Display range	Count
3½	± 1,999	2,000
4½	± 19,999	20,000
3¾	± 3,999	4,000

The accuracy of the DMM is different from the display resolution. The accuracy is the maximum allowable limit of error in the readings. All the DMM manufacturers express the accuracy specifications as  $\pm$  (% of reading + number of least significant digit (LSD)). The reading is the true value of the signal that the DMM measures. The LSD represents the error due to internal analog digital converter (ADC) tolerances, offset noise, and rounding errors that vary from function to function.

If a 4½-digit DMM with a DC voltage accuracy of  $\pm$  (1% + 2) is measuring a 10.5 VDC output, the meter is expected to display a reading of 10.5 V  $\pm$  1%, or 10.395 V to 10.605 V. When the LSD count is taken into consideration, the last digit on the display can vary by  $\pm$  2 counts. If the meter is set to the 20 V range, the two count will be 0.002 V. The total accuracy is  $\pm$  ((10.5  $\times$  (1/100)) + 0.002) =  $\pm$  0.107 V. The meter can display a value of 10.5  $\pm$  0.107 V, or a range of 10.393 V to 10.607 V.

## True RMS versus average- responding DMMs

Basically, there are two types of multimeters available: “average-responding” and “true RMS” (root mean square). True RMS is the measurement of AC voltage or current that reflects the amount of power dissipated by a resistive load driven by the equivalent DC value. This power is proportional to the square of the measured true RMS voltage, independent of wave shape. An average-responding AC multimeter is calibrated to read the same as a true RMS meter for sine wave inputs only. For other waveform shapes, an average-responding meter will exhibit substantial errors. Average-responding meters normally work well for linear loads measurement such as standard induction motors, resistance heating, and incandescent lights, but if non-linear loads such as electronic controls are present, errors occur that could make the reading be lower than expected. Always remember to consider what kind of applications you are measuring for before selecting a handheld DMM.

## Multimeter input impedance

The input impedance of the DMM is very high compared to the impedance of the circuit being measured. This design places very little load on the circuit under test to prevent effecting the circuit’s operation and causing the measured reading to be inaccurate. Typically handheld multimeters have input impedance that is greater than 1 M $\Omega$ , and the input impedance varies depending on the DMM’s design. It is especially important to select a DMM with high impedance for applications requiring the measurement of sensitive electronics or control circuits to ensure the accuracy of the reading.



## Multimeter Basic Features

A basic DMM measures AC voltage, DC voltage, AC current, DC current, resistance, continuity, and diodes. More expensive DMMs also measure capacitance, frequency, temperature, and pressure. Before purchasing a handheld DMM, you should first identify the type of testing you will need to perform, establish which features are important, and determine the anticipated tolerance range for those tests.



### AC/DC voltage measurement

There are many main voltage ratings for the operation of household and industrial electrical appliances. It is important to know the voltage range that is going to be present on the circuit you are going to measure, and choose a DMM with a voltage rating that is higher than that range. All European and most South American, African, and Asian countries use a supply that is within 10% of 230 V, whereas Japan, North America, and some parts of northern South America use voltages between 100 and 127 V.

## AC/DC current measurement

The same applies for measuring current with a DMM. Users have to know the maximum current of the circuit that will be measured. For example, using a 100 ampere-rated DMM to measure a 1,000 ampere circuit leaves technicians exposed to a high risk of electrical hazards.

## Resistance measurement/continuity check

Another important DMM feature is the ability to measure resistance. To measure resistance, the component must be removed from the circuit altogether. Resistance measurement works by passing a current through the component being tested. Resistance measurement is also commonly used to test for continuity. An open circuit will have infinite resistance. A closed circuit will have a small resistance measurement. Most of the DMMs currently on the market are designed with a continuity beeper to indicate continuity, rather than relying on the resistance display. Some DMMs come with both an audible and visual alert for continuity, which can be beneficial in noisy environments where the audible alert may be difficult to hear.

## Diode check

Today's DMMs are equipped with a diode check function that displays the actual forward voltage drop of the diode. The meters inject a small current through the diode and measure the voltage dropped between the two test leads. The forward bias voltage reading of a silicon type diode will be about 0.7 volts and 0.3 volts for Germanium-type diodes.

## Temperature measurement

The maximum temperature range measurement capability of a DMM is limited by the type of thermocouples that can be used with the unit. Check which types of thermocouples are supported by the DMM to ensure compatibility with your application needs. For example, for maintenance of an air conditioner's compressor, it is sometimes necessary to obtain the temperature difference at the inlet and the outlet of the compressor. With a dual and differential temperature function, the two temperature measurements can be made simultaneously, the differential temperature computed automatically, and the results displayed on the DMM screen.

## Capacitance measurement

DMMs also provide the ability to measure capacitance. Before purchasing a DMM, make sure that it covers the anticipated capacitance range. Most DMMs can measure from a few picofarads to at least 1 microfarad. It should be noted that a capacitor measurement obtained with a handheld DMM can be substantially different from the same capacitor measurement result obtained using an LCR meter. This is because the LCR meter is testing the capacitor with an AC signal that has a known frequency. This measurement technique provides highly accurate readings, as well as additional data such as dissipation factor, magnitude, and phase. The handheld multimeter uses a precise current source to charge through the capacitor which is characterized by the equation  $I = C \, dV/dt$ . By observing the rate of change on the voltage across the capacitor, the capacitance can be computed. However, undesirable capacitor traits such as dielectric absorption, leakage, dissipation factor, and equivalent series resistance (ESR) can cause substantial error when using this type of measurement technique. If you require precise capacitance measurements, an LCR meter should be used rather than a handheld multimeter.

## Frequency measurement

Maintaining the right frequency is crucial for electrical devices that rely on a steady AC voltage and current. The frequency measurement function is ideal for simultaneous monitoring of real-time voltage or current with frequency, duty cycle, or pulse width. However, it's important to realize that not all DMMs support frequency measurement.

## Advanced DMM Features

Besides the basic multimeter measurement functions such as AC voltage, DC voltage, AC current, DC current, resistance, continuity, and diodes check; consider looking for a DMM that offers advanced capabilities to suit your application needs. These advanced DMM functions save you time when performing troubleshooting tasks. Here are some of the advanced capabilities designed to ease the job of engineers and technicians.

### Data logging

The data logging feature makes it easy for factory maintenance personnel to generate a range of troubleshooting, monitoring, and process documentation. For example, the GUI data logger software can collect information on general trends and develop an environmental profile of a factory. The data logger can also collect data over an extended duration to support the installation or repair of factory systems such as heating, ventilation, and air-conditioning (HVAC). The GUI data logger provides a simple way of tabulating and plotting acquired data for further data analysis.

*(Note: Not all the handheld DMMs on the market are designed with data logging capability. For those DMMs that do support data logging, the data logging software may not be free.)*

### $Z_{\text{LOW}}$ (low impedance mode)

The  $Z_{\text{LOW}}$  (low input impedance) function is designed to remove ghost or induced voltages from measurements. This function works by presenting low impedance across the leads to obtain a more accurate measurement.  $Z_{\text{LOW}}$  reduces the possibility of false readings in areas where the presence of ghost voltages are suspected. These stray voltages are normally caused by capacitive coupling between energized wiring and adjacent unused wiring.

### Smart $\Omega$ (smart ohm)

Smart ohm (offset compensation) is another feature designed to remove unexpected DC voltages within the instrument at the input, or at the circuit being measured; where resistance measurement errors are introduced. Using offset compensation, the DMM takes the difference between two resistance measurements when two different test currents are applied and uses that data to determine if there are any offset voltages in the input circuitry. The resultant displayed measurement corrects this offset, giving a more accurate resistance measurement. The bias voltage or leakage current is shown on the secondary display.

## LPF (low pass filter)

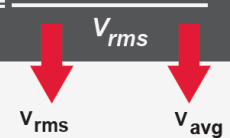
While the trend to replace mechanical systems with electronic systems is growing, troubleshooting motor drives can be difficult. This is especially true when taking voltage, frequency, and current measurements on the output side of the motor drive. A regular true RMS multimeter cannot measure the output from a motor drive because the variable frequency drive (VFD) applies pulse width modulated, non-sinusoidal voltage to the motor terminals. Many true RMS meters display readings 20 to 30% higher than the drive's controller display as most of true RMS digital multimeters have wide bandwidth. These multimeters are measuring the carrier frequency/switching frequency generated by VFDs. The low pass filter (LPF) is designed to help block unwanted voltages above 1 kHz when measuring AC voltage or AC frequency. The LPF can improve measurement performance on composite sine waves that are typically generated by inverters and variable frequency motor drives.

## $V_{\text{sense}}$ (voltage sense detector)

The voltage sense ( $V_{\text{sense}}$ ), or the non-contact voltage detector, is an important feature for personal safety.  $V_{\text{sense}}$  offers significant protection for any person that will potentially come in contact with energized electrical components. For example,  $V_{\text{sense}}$  determines the presence of AC voltage in insulated wires, wall receptacles, fuses, junction boxes, switches, and other voltage-carrying electrical systems without breaking into power lines.

## Harmonic ratio

Harmonic distortion has become increasingly prevalent in today's world due to the expanded use of equipment and machinery. The harmonic ratio feature can help technicians quickly check for the presence of harmonics in the electrical power system. This harmonic ratio function calculates a value from 0 to 100% to indicate the deviation of non-sinusoidal and sinusoidal waveform. This value indicates the presence of harmonics. A pure sinusoidal waveform without harmonics has a harmonic ratio of 0%. Measurements with a higher harmonic ratio show that more harmonics are present in the signal. The figure below illustrates how the harmonic ratio is derived.

$$\text{Harmonic ratio (\%)} = \frac{V_{\text{rms}}}{V_{\text{rms}}} \frac{V_{\text{avg}}}{V_{\text{rms}}} \times 100\%$$




## Think Safety When Selecting a Handheld DMM

Safety is frequently not given much consideration when selecting a multimeter. However, different handheld DMMs are designed with different levels of protection against common electrical hazards. For that reason, one of the most important considerations in selecting a handheld DMM centers on thoroughly understanding the test environment and test requirements. Using this knowledge you can choose the appropriate device.

There are three key DMM characteristics to consider:

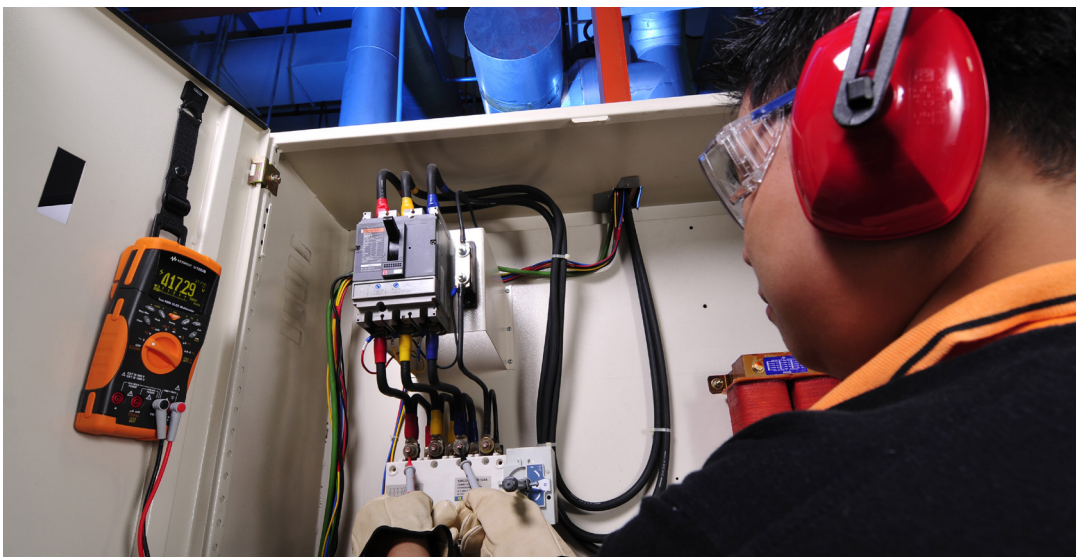
1. Voltage rating of the circuit
2. Transient voltage rating of the circuit
3. Energy capacity

### Voltage rating of the circuit

There are many different mains voltage ratings for the operation of household and light commercial electrical appliances and lighting. It is important to identify the maximum voltage at which the circuit is designed to work and, at minimum, choose a handheld DMM rated to measure the voltage that is expected to be present on the circuit.

### Transient voltage rating of the circuit

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  $6,000 V_{\text{peak}}$ . These randomly occurring high voltage spikes tend to last from 50 to 200 microseconds.



## Energy capacity

In addition to the transient voltage ratings of circuits, you need to consider the energy capacity of the circuit. To protect yourself, you should know the energy capacity of the circuit before you start taking measurements. Circuits with higher energy capacity can deliver more current and energy into faults than 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 generally defined by three characteristics: the operating voltage, the circuit impedance, and the characteristics of the circuit fuse or circuit breaker.

The International Electrotechnical Commission (IEC) has defined three “Measurement Categories” for mains circuits (Table 1) the higher the category number, the greater the danger posed by transient voltages on the mains circuit. All manufacturers of handheld DMMs 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 DMMs display this rating near the handheld DMM’s voltage/current input terminals.

Table 1. IEC measurement categories defined by IEC

Category	Description
CAT 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 DMM should always be capable of CAT III measurements.
CAT 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 many of the building’s fixed equipment, which is connected directly to the building mains instead of being connected through cords and plugs.
CAT IV	This category is applied to the source of the building’s 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.

## Safety indicators

Safety certification is important. Responsible manufacturers of handheld DMMs, like Keysight, obtain safety certifications from third-party independent testing agencies such as the Canadian Standard Association (CSA), which evaluate products or systems for compliance with specific requirements.

Before you purchase a new handheld DMM, 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)



## Keysight Solutions

Keysight offers many DMMs with different combinations of features to enable you to make fast, safe, and accurate measurements at an affordable price. Each delivers superior performance and provides a wealth of functionality while maintaining portability, ruggedness, and safety compliance. All handhelds come in vivid orange cases to provide greater visibility, and all Keysight handheld products highlight investment protection through feature sets that go beyond those of typical handhelds. Below is the highlight of some of the capabilities of Keysight's handheld DMM models. For complete details refer to the Keysight Handheld Tools brochure (literature number 5989-7340EN).

### U1230 Series

At the lower end of Keysight's offering is the U1230 Series. It offers all the basic handheld DMM features, plus low impedance mode ( $Z_{LOW}$ ), and non-contact voltage sensing ( $V_{sense}$ ) capability. You can toggle the high and low sensitivity to increase or reduce the sensor and trigger threshold when trying to find a live wire in a group of wiring. The U1230 Series is rated at CAT III 600 and has an operating range of  $-10$  to  $+55$  °C. In case a test lead is mistakenly plugged into current terminal when performing voltage measurement, this series also comes with a flashing backlight alert with audible continuity indication, which is useful for dark and noisy environments.



## U1240 Series

The U1240 Series is a 4-digit DMM with 10,000 counts dual display. The 10,000 count resolution allows better viewing of measurements down to the smallest reading. This series comes with true RMS capability and 0.09% DC voltage accuracy. The handhelds are also designed with an adjustable backlighting function (with two intensity levels) that allows you to complete your jobs even in subdued lighting conditions and at the same time prolonging the battery life. The U1240 Series offers features like harmonic ratio, switch counter, and dual differential temperature measurement. Comprehensive temperature measurements can be done easily with dual and differential temperature capabilities. The switch counter allows the detection of intermittent failure in switches or relays. The harmonic ratio function helps determine the presence of harmonics in AC signals.



## U1250 Series

The U1250 Series is a 4½-digit DMM with a high-resolution display of 50,000 counts. The U1250 Series lets you achieve greater confidence in your measurements with accurate true RMS AC measurements and a low DC voltage rate up to 0.025%. Keysight U1251A/B and U1252A/B handheld DMMs expand your capabilities beyond typical DMM measurements to include data logging. The U1252A/B starts with the same foundation as the U1251A/B and adds a 20-MHz frequency counter and programmable square-wave generator, so you can conveniently perform more tests with one tool.

Offering the same functionality as the U1252A/B, the U1253A/B is the world's first organic light emitting diode (OLED) handheld DMM. It is designed with high a contrast ratio of 2000:1 and a wide viewing angle of 160°. You can toggle the large numerical display to dual-display mode, with both displays at 50,000-count high resolution. As a result, you get crystal-clear viewings outdoors and indoors—even in dark, off-angle situations.



## U1270 Series

The U1270 Series is a 4½-digit DMM with 30,000 counts resolution. This series comes with flashing backlight alert with audible continuity indicator, and dust and water resistance. This series is designed for maximum efficiency and productivity in industrial settings. The U1270 Series offers convenient functions such as  $Z_{LOW}$  to eliminate stray voltages, Smart  $\Omega$  to minimize false readings due to leakage current, and Qik-V to determine the existence of AC and/or DC voltages. When it comes to VFD troubleshooting, the U1270 Series has LPF to handle the job with ease. The U1270 Series is IP 54-certified to protect against water, dust, and damage. The loud beeper and backlight alert function, which flashes the backlight to indicate continuity, facilitates continuity detection in noisy and dark environments.



## Other features

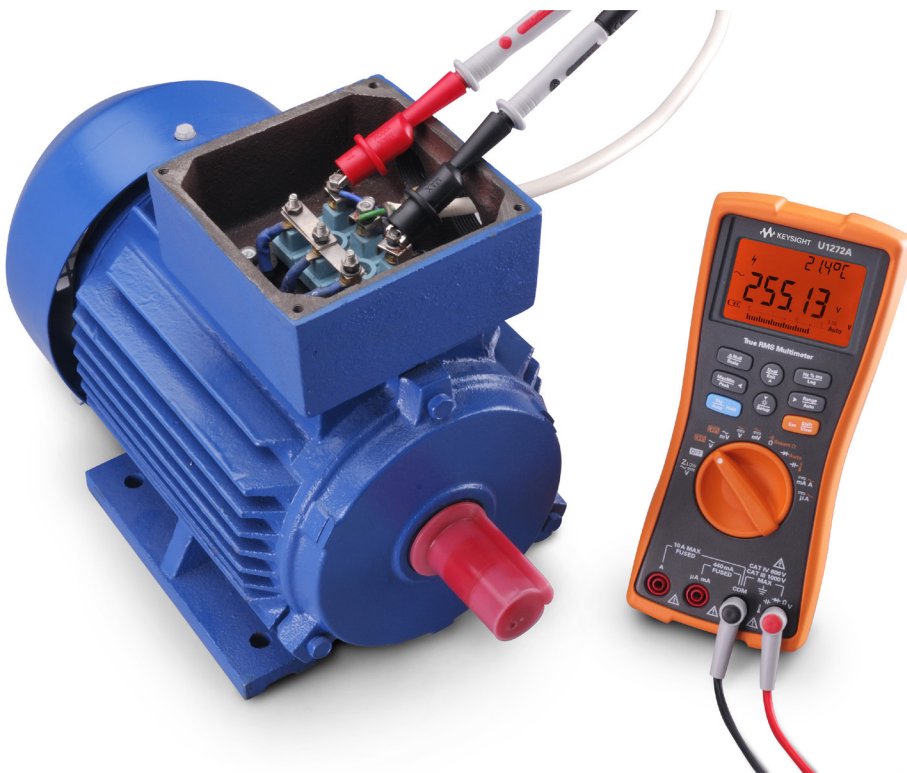
Keysight also provides various types of standard test lead kits and accessories for high current and temperature measurement. IR-to-USB cables make it easy to connect the DMM to a PC. Every unit is shipped with test probes using 4-mm tips, a length that reduces the likelihood of high-energy sparking, especially in CAT IV environments.

Keysight U1240, U1250, U1230, and U1270 Series use 30-kA fuses to provide greater protection from high-voltage transients. Most comparable DMMs use 10-kA fuses. During qualification of the 30-kA fuse, all models pass HIPOT testing at 2,000 VAC and 2,000 VDC between the microamp, milliamp, and ampere terminals, and common ground.

The U1240, U1250, and U1270 Series DMMs are housed in robust over-mold enclosures, rated at CAT III 1000 V and CAT IV 600 V, and suited for use over a  $-20$  to  $+55$  °C temperature range. The U1230 is rated at CAT III 600 V and suited for use over a  $-10$  to  $+55$  °C temperature range.

## Conclusion

Choosing a proper handheld product for electrical service, repair, and installation needs has become more complex. In addition to the product's electrical specifications and features, the product safety features and safety specifications should be important purchasing considerations when you deal with main power or high-voltage measurements. Keysight's handheld DMMs are designed with many features and capabilities and perform with high accuracy in application and test environments, while meeting the latest and most demanding safety standards.





## Related Keysight Literature

Publication title	Publication number
Keysight U1241B and U1242B Handheld Digital Multimeter, User's and Service Guide	U1241-90063
Keysight U1251B and U1252B Handheld Digital Multimeter, User's and Service Guide	U1251-90036
Keysight U1253B True RMS OLED Multimeter, User's and Service Guide	U1253-90035
Keysight U1231A, U1232A and U1233A Handheld Digital Multimeter, User's and Service Guide	U1231-90026
Keysight U1271A and U1272A Handheld Digital Multimeter, User's and Service Guide	U1271-90010
Think SAFETY When Selecting a Handheld Multimeter, Application Note	5990-4578EN

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