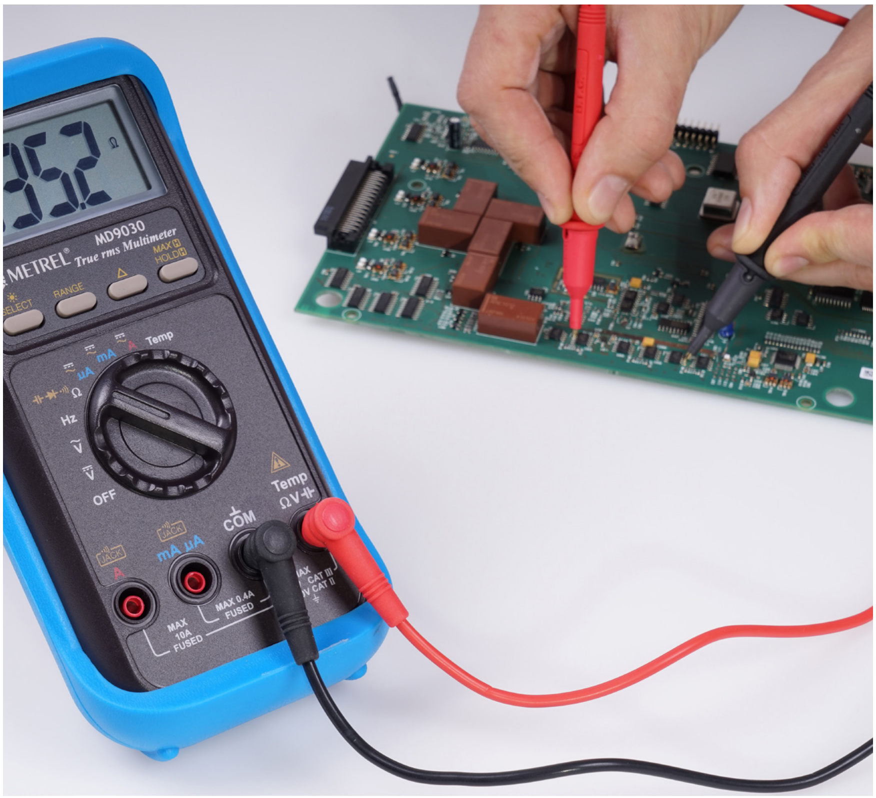
Application Note

Core handheld DMM functionality

Handheld digital mutimeter is the most basic and the most widely used electrical instrument. From field electrician to service worker to a kid with their first broken toy, everyone tests their setup with one of these. Let us review their characteristics.



One of the first actions an electrician or inspector should perform before doing any testing or measuring is visually checking the general state of facilities, with emphasis on electrical installations and systems and all metal or other conductors that could come into contact with individuals or animals. That usually includes machinery and appliance housings, pipes, valves, faucets, baths and similar objects. Besides looking for obvious signs of wear and tear and damage, especially that of electrical nature, attention should also be given to safe operation of connected electrical devices.

Performance characteristics

What makes the multimeter ‘better' than the rest? For lab work or any precision task, it might easily be its performance. For field work, it would be presence of the commonly used feature, but even then, one need to be aware of the instrument's limits.

Resolution, counts, digits

Being three ways to describe the same quality, these expressions only differ superficially. They all three mean the smallest change that the instrument can show. Resolution is usually given in units per range, e.g. 1 mV at 1V, which means that 1 mV is the smallest visible change when reading 1V value. Counts mean the largest number that can be displayed, which, combined with the chosen measuring range, means exactly the same as resolution. Digits are number of spaces for numbers on the screen. Most often it is decided that the first number or the most significant digit doesn't have a full 0-9 range, but a smaller one, like only 0-1. Typical notation for that is 3 ½ digits. It means that three digits are full-range and one can only show 0 or 1, giving the display 1999 counts. However, some manufacturers use the ½ fraction for any narrowed range, not only 0-1, so by knowing the number of digits, number of counts is not yet clear.

Accuracy

Accuracy is the biggest error the instrument by itself would make under certain controlled conditions, or a measure of how close the displayed value is to the actual. It does not take into account the impact (e.g. load) the instrument may make on the measured circuit. It is usually expressed as a percentage of the range and number of smallest digits. For example, if accuracy is ±1% at 100 V, it means that when the reading is 100 V, the actual value is between 99 V and 101 V. If the accuracy is ± (1% + 2d), the actual value is between 98.8 V and 101.2 V. Sometimes, the notation without the d is used, as in ± (1% + 2).

Effective or RMS value

RMS value is thermally equivalent DC value to AC (or different) signal. For periodic signals, it is calculated as square root of integral over one period length, of squared signal, divided by length of period. Modern multimeters usually give a reading by definition and can show true value regardless of waveform shape. Some cheaper variants, however, use rectifiers and calibration by fixed factor, and only give accurate reading for sine wave. The error can be given with crest factor – ratio between the largest and RMS values of the signal. For pure sine, it is 1.414. For some distorted signals, it may be even in multiple digits. For very high values, even TRMS meters might start giving bad readings. The range of crest factors with specified accuracy should be noted in the data sheet. Another part of TRMS measurement is considering the DC component. The multimeter might filter it out, only giving TRMS of the alternating part of the signal, or it might use it in measurement. On the other side of the spectrum, there are higher harmonic components. If left unfiltered (and many multimeters can 'see' them at least partially), they become a part of the TRMS calculation and make RMS value seem higher. Accuracy need a frequency specification as well.

General characteristics

They are what you see when taking the meter to your hand, and give a big impact on every use, but they are not measurement or performance-related.

Batteries

Most handheld multimeters are battery powered. It makes them easy to carry and use wherever one goes, but it also makes them prone to failing at the worst possible times. Expected battery life is given as hours of 'common' use, which may or may not be described. It is often only useful for comparison of different models by the same manufacturer. Meters with additional energy-hungry features, like insulation testing, will usually specify number of test possible with single charge. Instrument can be made to use rechargeable batteries and have an integrated charger, an external charger, or use single-use batteries only. Battery-low warning should be clear and easily readable.

Safety

Above specified maximum measurement range or in case of improper use, both the instrument and the user may be in danger from electrical phenomena. Safety features include many ideas, from proper insulating materials for the housing and shape of the terminals to exchangeable fuses. The most common hazard to the instrument is setting the multimeter to current or resistance measurement and applying leads to low-impedance voltage source. For safety towards user, instruments are most commonly specified by standard IS61010-1 categories. They include expected working environment (defined by expected amount of energy present) and the voltage transients that the circuit must be able to sustain. Multimeters are most often specified as CAT III 1000 V and CAT IV 600 V, meaning:

- **CAT III 1000 V:** working voltage 1000 V in building installations, meaning work on distribution boards, circuit-breakers, wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and equipment for industrial. It can withstand a surge of 8 kV at 2 Ω source impedance or 4 kA.
- **CAT IV 600 V:** working voltage 600 V at source of low-level instalations, like primary overcurrent protection devices and ripple control units. The specified surge protection is the same, 8 kV at 2 Ω source. Some multimeters are specified to CAT IV 1000 V, which can withstand a surge of 12 kV at 2 Ω source or 6 kA.

Conectivity

While not first property one considers when choosing a handheld instrument, option to connect it to the computer can be life-saving. Main functionality extension is logging data directly to PC's hard drive. If the instrument has internal drive, the data can also be moved for further processing.

Handheld multimeters are usually rather protected from elements than have unprotected ports. If anything, there is an IR interface available, and a special accessory to connect instrument to USB port is generally needed as well as software.

Other considerations

The multimeter should be light, comfortable in hand, possibly controllable with a single hand while the other is holding the leads. Screen can be one- or two-line, showing one or multiple results at once. They should be immediately recognizable to avoid confusion. A flashlight for the measured area and backlight on the screen can come in handy in darker environments. The housing should be sturdy enough to survive a fall from hand, a touch of water and any amount of dust. Most manufacturers opt at least for protection level IP40.

Functions

The first multimeters could measure only voltage, current and resistance, barely justifying their name. Today, the general-purpose instruments do at least 6 measurements.

Voltage

AC and DC voltages are the very core measurements anyone expects of a multimeter. Presence of voltage on power supply is also the very first test when troubleshooting a device. DC voltages are normally found on batteries or battery-powered devices and in devices with rectifiers in the supply line. AC voltage is present on mains and anything powered directly from them. Other shapes can appear unpredictably, either on a special device or as result of distortion. Again, one needs to consider whether the value shown is true RMS or not.

Current

To measure current, the meter needs to be put in series with the element of interest. This may not be possible, as it normally requires taking the circuit apart and including the instrument in it. Special leads are available to avoid this, e.g. current clamps, that measure current through induction or Hall effect. To measure current, the leads are set into different terminals than for voltage measurement and have to be exchanged again before measuring voltage again – or damage to instrument can occur as voltage is applied over (very) low shunt on current input. Normally, there is a fuse in place.

Resistance, continuity and diode measurement

Resistance is the most basic material electric property. It ranges from a few milliohms of contact resistance to hundreds of gigaohms of insulation resistance. It is measured by introducing a voltage through lead tips and measuring the current between them. Therefore, the unit under test must be off and isolated from power, or damage may occur. For low resistance measurements, the resistance of test leads is an important source of error and should be subtracted.

Continuity is a check of connection between two points in the circuit. It is different from resistance in intent – one is not looking for exact resistance value, only that it is low enough. Most multimeters will give a beep when that happens, so that not even a look to the screen is needed. Diode test measures voltage drop over a silicone junction. It should read less than 0.7 V for forward direction and open circuit for reverse. If the instrument uses voltage lower than 0.6 V to measure resistance, it can be used to test resistors that would be normally isolated by silicone elements.

Frequency

Multimeters can usually give the frequency of a base component in the signal. However, certain signals can give them trouble with high harmonic content or unusual shape. The best known is output from variable frequency drives for electric motors, a pulse-width modulated signal. Motors only respond to the base component. Multimeters that don't take high harmonic content and noise into account will show a much higher value than motor's internal indicator. Filters need to be applied to the signal before the reading can become meaningful. On the other edge of the spectrum one can find multimeters with bandwidth up to 100 kHz.

Capacitance

Capacitance is another common troubleshooting measurement. Capacitors can fall out of tolerance without looking bad on the outside and sometimes, there is no other option but to check them one by one. It is however a slow and energy-hungry going only using the test leads, and most multimeters cannot successfully measure values higher than some milifarads, while being accurate only much lower.

Temperature

Special probes are needed, most commonly thermocouple. The probes give out a voltage in proportion to the measured temperature. The accuracy is quite poor (usually worse than ±1oC), but a wide range of temperatures can be measured.

Other measurements

Multimeters with additional special features are increasingly common. Some can help with installation testing, checking earth insulation and connectivity. Others can measure power or power quality factors (THD, load balance) and even log measured values for a time. Non-touch voltage sense can help find wires in the walls. Ideas and options are only limited by our imagination.

METREL D.D.
Measuring and Regulation Equipment Manufacturer
Ljubljanska 77, SI-1354 Horjul, Slovenia
T +386 (0)1 75 58 200, F +386 (0)1 75 49 226
metrel@metrel.si, www.metrel.si

METREL®