



## *IDEAL Digital Multimeters An Introduction*

*The Basics of Digital Multimeters* is designed to give you a fundamental knowledge of Digital Multimeters (DMMs). It's an easy reference guide that shows you how to use IDEAL DMMs and how to select the right ones.

There are three things to remember about IDEAL DMMs. They're rugged, versatile and easy to use.

They're also easy to choose. IDEAL offers in-store merchandising, a toll free hot-line number, a technical support line and a comprehensive web site – all designed to better inform you about digital multimeters. Just a few of the ways we're committed to the DMM technician.

**Technical Support – Toll Free 877-201-9005**  
**[www.testersandmeters.com](http://www.testersandmeters.com)**

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# The Basics of Electricity



To better understand digital multimeters, it's helpful to become clear on the basics of electricity. After all, DMMs always measure some aspect of electricity.

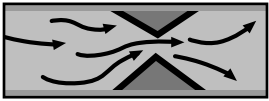
## Voltage, Current and Resistance

Electricity passing through a conductor is similar to water flowing through a pipe. Every pipe has a pump that creates a certain pressure, causing water to flow. In the case of electricity, that pump might be a generator, battery or some other power supply. The pressure created by that power supply is called voltage.



Current is the amount of electricity flowing through a conductor.

The amount of voltage determines how much electricity flows through the conductor. That flow is called current.



Resistance is anything that impedes the flow of current.

Anything restricting the flow of current is called resistance.

Voltage, current and resistance are the three most fundamental

components of electricity. Voltage is measured in volts, current in amps and resistance in ohms.

V = Volts (voltage)  
A = Amps (current)  
Ω = Ohms (resistance)

## Ohm's Law

Together, voltage, current and resistance comprise Ohm's Law. Ohm's Law is an important equation for electricians. By using a DMM, they can establish values for the three variables of Ohm's Law that help in diagnosing electrical problems.

Ohm's Law can be expressed in equation form in this way:

$$V = A \times \Omega$$

Voltage = Current x Resistance

Voltage determines the flow of current. The greater the voltage, the greater the current. Likewise, the greater the resistance the less current will flow, and the lower the resistance the more current will flow. These are the basics of Ohm's Law.

$$220V = 110A \times 2\Omega$$

One Example of Ohm's Law.

## Two Types of Electricity

Electricity comes in two types – Alternating Current (AC) and Direct Current (DC).

AC	~
DC	---

Alternating Current is the most common form of electricity, so named because it alternates, or reverses, its flow. AC is produced

by a generator and is used for many of the things in our everyday lives.

Direct Current flows in one direction only. Most commonly, DC power is the source of electricity found in batteries and used in portable equipment like cars, flashlights and cameras.

Electricians need to measure both AC and DC power. IDEAL DMMs measure both.

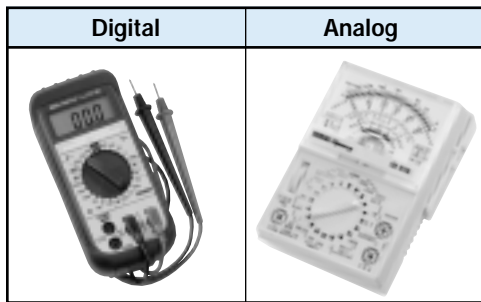
## Using a Digital Multimeter



At first glance, a digital multimeter looks complicated and intimidating. But once you understand the dial, display and port panel, you'll have a solid understanding of DMMs.

### The Display

Multimeters come in two types – digital and analog. Most electricians today use digital multimeters. DMMs feature a digital, or liquid crystal display (LCD). Measurement readings in exact numerical values are displayed in the LCD. The display also alerts you to any pertinent symbols and warnings.



Multimeters come in two types – digital LCD and analog meters, which use a needle to take a physical measurement.

### The Dial

#### Setting the Function

The dial of the DMM allows you to choose the function you're interested in measuring. Whether you intend to measure one of the three elements of Ohm's Law, or a more advanced function like frequency or capacitance, you must first set the dial to the appropriate function.

#### Setting the Range

The dial also plays another essential role in measuring electricity – that of determining the range of measurement. The range you select on the dial determines the placement of the decimal point as it appears on the LCD. In turn, the position of the decimal point determines how refined, or precise, your reading is. This is called resolution.

#### Understanding Resolution

To get a better understanding of resolution, let's take an example. You're going to test AC voltage, but what range do you set the dial to? The highest possible reading with the range set on 20V, for instance, is 19.99V. The highest reading with the range set on 200V is 199.9V. As you can see, in the transition from 20V to 200V, the decimal point has moved one place to the right, yielding a less refined resolution. So setting the dial to the lowest possible range yields the best resolution.

However, if the range is set on 20V and you're measuring an application that puts out more than 20V, the display will read OL, or overload. You must reset the dial to a higher range and take a new reading. The most refined reading, therefore, uses the range that provides the best resolution without overloading. Select the range just higher than the expected reading.

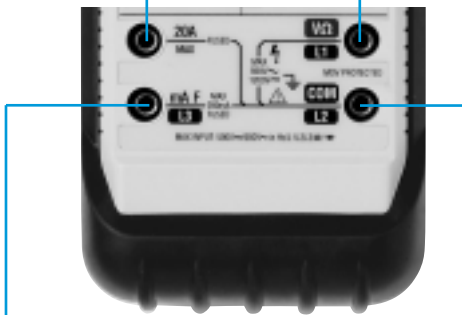
Range Setting	Maximum Reading and Resolution
2V	1.999V
20V	19.99V
200V	199.9V
1000V	1000V

## Port Panel

The port panel is where you plug in your test leads. The diagram below explains where the test leads go for specific tests.

Insert RED lead here to test:  
 • Current (AC and DC)  
 • Capacitance

Insert RED lead here to test:  
 • Voltage (AC or DC)  
 • Resistance  
 • Continuity  
 • Frequency  
 • Diode



Insert RED lead here to test:  
 • mA Current  
 (AC and DC)

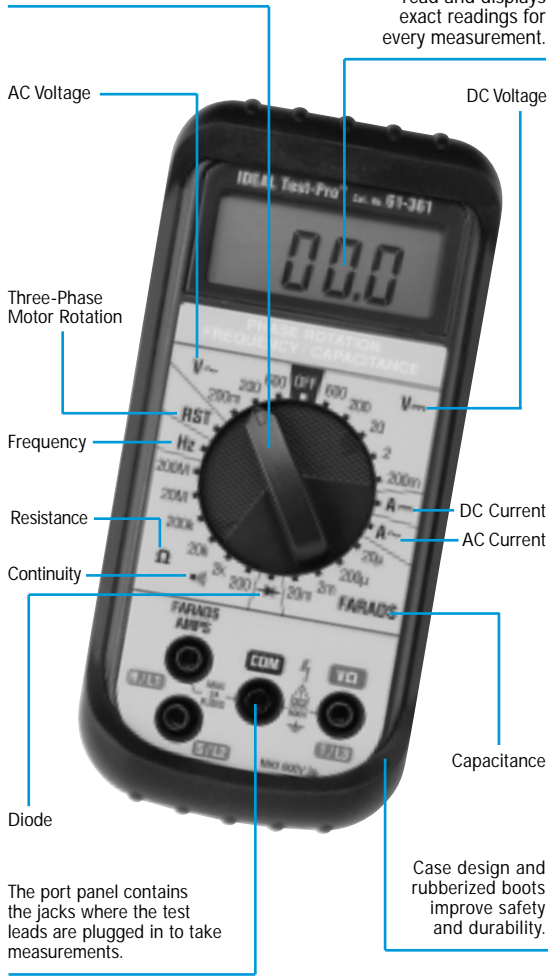
Insert BLACK (common) lead here for every test.

Common DMM Symbols & Abbreviations		
	AC	Hz Hertz
	DC	⊖(⊕) Capacitor
	AC or DC	MFD MicroFarads
	Positive	μ Micro
	Negative	m Milli
	Ground	M Mega
	Diode	K Kilo
	Audible Continuity	OL Overload

## DMMs at a Glance

The dial determines the function under measurement, as well as the measurement range.

The digital display, or LCD, is easy to read and displays exact readings for every measurement.



The port panel contains the jacks where the test leads are plugged in to take measurements.

Case design and rubberized boots improve safety and durability.

## Testing Voltage



Voltage is the pressure in a circuit. AC voltage is supplied by AC generators, while DC voltage is produced by chemical (batteries) or electromagnetic sources (DC generators).

To test for voltage, first determine whether the application you're testing uses AC or DC voltage. Then set the dial to the appropriate function – V~ for AC voltage or V= for DC voltage.



*Measuring the voltage of a standard residential outlet is one example of testing AC voltage.*

Like all test procedures, when testing voltage set the range to the number just higher than the expected reading. If you don't know the expected reading, set the range to the highest number.

Plug your test leads into the port panel as described on page six. For AC voltage, take the leads and apply them to the circuit, being sure that no part of your body contacts any part of the live circuit. The position of the test leads may need to be adjusted until a reliable measurement appears on the LCD. Then read the voltage measurement displayed.

When testing AC voltage, fluctuations will occur in the reading. As the test continues, the reading will stabilize to yield a reliable measurement.

For DC voltage, connect the black test lead to the negative polarity test point (ground) and the red test lead to the positive polarity test point. Then take a reading.

<i>Common Voltage Measurements</i>	
AC	DC
Security System 24V	Fire Alarm 9V
Household 120V	Car Battery 12V
Heating Element 480V	Railway System 600V

*Caution:*

Before undertaking any electrical test, always refer to the owner's manual for proper operating procedures, safety precautions and instrument limitations.



## Testing Current



Current is the electron flow that causes electrical equipment to operate. When the equipment is turned on, it is considered a “load” on the circuit. A load is any electrical component, such as a lamp, stereo, motor or heating element, that draws current. Current is measured in amperes, or amps.

Each load has a rated current limit that should not be exceeded. If a load pulls too much current, excessive heat is produced that may cause insulation damage, component failure and possible fire hazards. If the load is under its rated current limit, it may perform poorly.

Testing current may be done in several ways, but the most common method, and the most simple, is with a clamp meter.



Using a clamp meter to test common loads, such as this heating unit, helps to ensure proper load capacity.

The advantage of testing current with a clamp meter – or with a standard DMM with a clamp head accessory – is that readings can be taken without opening the circuit.

To test for current, first determine if you’re testing AC or DC current. Then set the dial to the appropriate function –  $A\sim$  for AC current or  $A-$  for DC current. Next, set the appropriate range on the dial as described on page five.



### Testing with a Clamp Meter

If using a clamp meter, simply open the clamp head by pressing the lever.

Enclose the clamp head around a single conductor and release the lever, being sure the clamp head has completely enclosed the conductor. Take a measurement.

### Testing with a Standard DMM

#### With Current Clamp Adapter

The clamp adapter will convert the current measurement into voltage. Therefore, set the dial to the AC voltage function and select the millivolt range. Plug in the leads as described on page six. Open the

clamp adapter and enclose it around a single wire. Then take a reading.



#### With Test Leads

To measure current on an open line using test leads, plug in the leads as described on page six. Set the dial to AC or DC current depending on what you’re testing. Apply your leads to the open circuit and take a reading.

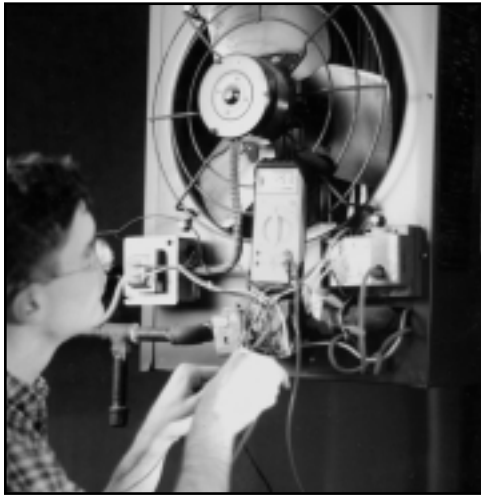


For current measurements above one amp, it’s most common to use a clamp meter. For measurements less than one amp, it’s preferable to use a standard DMM.

## Testing Resistance

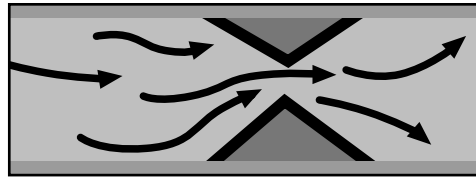


Resistance opposes the flow of current. The higher the resistance, the lower the current flow. Insulation used for cables has a very high resistance, impeding current flow. Conversely, the cable's copper conductor has low resistance, facilitating current flow.



*Resistance must be low to avoid safety and performance problems.*

Proper resistance is critical. Too much resistance in electric wires and connections can result in overheating and possible fire hazards, while too little resistance may result in a short or performance problems. Components called resistors help maintain proper resistance in equipment.



*Resistance opposes the flow of current. Too much or too little may lead to performance and/or safety problems.*

To test for resistance, first turn the power off in the circuit or component you're testing. Otherwise, you may not get the most accurate reading and may damage the DMM.



*The most common residential test for resistance is performed on a standard outlet where ground resistance should be 1 ohm or less.*

After ensuring that all power is off, set the dial to the resistance mode. Select the appropriate range on the dial as described on page five. Plug in your test leads as described on page six. Then connect the test leads to the component under test, and take a reading.

It is imperative that contact between the test leads and the circuit you're testing is good. Dirt, oil, bodily contact and poor test lead connections can significantly increase resistance readings.

## Testing Continuity



Why test for continuity? Because it is essential that circuits are continuous or complete, allowing current to flow. Switches, fuses, conductors and wire connectors demand good continuity. Good fuses and closed switches have good continuity. Blown fuses and open switches have no continuity. A common continuity test is verifying that the test leads are good before using the DMM.

The continuity test on a DMM is simple. Set the dial to the continuity function. Plug in your leads as described on page six. Ensuring that the power is off, make contact with the component under test using the leads. If there is good continuity, or a good path that allows current to flow, the DMM will beep. If there is no continuity, the DMM will not beep.

## Testing Capacitance



Capacitors are small, battery-like devices that store electrical energy. They are designed to start motors and other components with an initial energy boost. Capacitance, measured in microFarads ( $\mu\text{F}$  or MFD), is the ability of a capacitor to hold this electrical charge.



Poorly functioning motors may just be the result of a bad capacitor.

To test capacitance, set the dial on the DMM to the capacitance function. Plug in your leads as described on page six. Ensuring that the capacitor has been discharged, connect the test leads to the capacitor terminals. Take a reading. If the measurement is similar to the rating listed on the capacitor, the capacitor is good. A significant variation from the rating indicates the capacitor should be replaced.

### Caution:

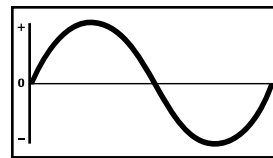
Before testing capacitance, be sure to turn all power off and to discharge the capacitor.



## Testing Frequency



Some IDEAL DMMs measure frequency, which is measured in Hertz (Hz) – the number of times per second a wave form repeats. These DMMs include a Hz setting on the dial.



The typical frequency supplied by utility companies is 60Hz.

Maintaining the right frequency is crucial for devices that rely on AC voltage and current. Otherwise, poor performance and possible damage may result.

To test frequency, set the function switch to Hz. Plug in your test leads as described on page six and connect them to the circuit. Read the frequency measurement, then compare the measurement with the frequency listed for the component under test.

## Advanced Features



IDEAL DMMs come in a variety of models that together measure all the functions an electrician needs to effectively troubleshoot any electrical problem. Some IDEAL DMMs also come with additional features that make measuring easier and more accurate.

## True RMS



When taking AC measurements in commercial and industrial environments, you need a DMM with the True RMS feature. DMMs take AC measurements using either an averaging method or a True RMS method. Average responding DMMs take an AC measurement, multiply it by 1.11, then display it in the LCD. This method is accurate when a pure sine wave exists such as in residential environments. But, in commercial and industrial environments, electronic lighting ballasts, variable speed motor drives, computers and other electronic equipment cause harmonics that distort the sine wave. In these cases, a DMM needs True RMS, which measures the wave form using a Root Mean Square (RMS) calculation to provide an accurate reading.

## Data Hold and Max Hold



### Data Hold

When taking a measurement using a DMM, an electrician sometimes needs to capture and retain the reading as it appears on the display. If you're taking a measurement in a dimly lit or tight area, the Data Hold button retains the measurement on the LCD until it can be easily read. The Data Hold captures the reading simply by pushing the button.

### Max Hold

It may also be important for an electrician to capture the highest reading of any given measurement. This can be achieved by pushing the Max Hold button. If the reading falls to a lower value, the Max Hold button ensures the highest value remains on the screen. The Max Hold button is especially helpful in capturing the in-rush current flow when equipment is first turned on.

## Auto Ranging and Manual Ranging



IDEAL offers two different types of digital multimeters – auto ranging DMMs and manual ranging DMMs.



### Auto Ranging DMMs

An auto ranging DMM does not require you to set the range on the dial. Simply select the function you're measuring and the auto ranging DMM automatically establishes the range that yields the best resolution.

### Manual Ranging DMMs

A manual ranging digital multimeter requires you to set the range yourself. If you know the range of the application you're testing, set the range on the dial that yields the best resolution. If you don't know the range, simply select the highest range possible. If the reading is less refined than what you desire, you may be able to lower the range for better resolution.



## Three-Phase Rotation Tester



IDEAL offers a number of specialty test instruments designed to perform functions that the expert electrician may need to execute.



*The Three-Phase Rotation Tester ensures properly wired motors, eliminating possible damage.*

The IDEAL Three-Phase Rotation Tester ensures that motors are properly connected to the three phases. Incorrect connections result in motors spinning in the wrong direction, which may cause motor damage or improper operation.

To test for proper motor rotation, plug the three color-coded leads of the tester to each of the three phases. Turn the power on. The disk on the Three-Phase Rotation Tester should be spinning in the same direction as the rotation of the motor as described in the owner's manual. If the rotation desired is in the opposite direction, the tester is improperly connected to the three phases. Switch any two leads, and the rotation will reverse to the proper direction. Mark the three phases, then hook up your equipment.

### *Note:*

The IDEAL 61-361 indicates three-phase rotation up to 480V. Voltage in excess of 480V requires the IDEAL Three-Phase Rotation Tester (61-520).

## Insulation Tester



Maintaining the integrity of insulation in motors, cables and other devices is critical for a number of reasons. Insulation keeps current flowing safely through the copper conductor. Bad or damaged insulation allows electricity to "leak out" much like water leaks out of a broken pipe. This could cause shorts, performance problems or safety complications.



*The Insulation Tester pressurizes electric wire to indicate whether or not insulation is good.*

To test for proper insulation, IDEAL offers the Insulation Tester. By pressurizing the electric wire under test with a surge of voltage, the Insulation Tester indicates whether or not the insulation is good. A rough rule of thumb for good insulation is 1 megohm of resistance per 1000 volts of rating.

## Glossary

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**A, ampere or amp** – The basic unit of electric current.

**AC, alternating current** – An electric signal in which the current and voltage vary in a repeating pattern over time; the most common type of voltage.

**analog meter** – A mechanical measuring device using a needle moving across a graduated scale or dial.

**auto ranging** – A DMM that automatically selects the range with the best resolution and accuracy in response to the application.

**calibration** – Zeroing of an instrument to a known standard.

**capacitance** – Ability of a component to hold an electrical charge, usually stated in microfarads.

**capacitor** – Electronic component which stores energy and then discharges it; blocks DC and allows AC to pass through.

**clamp-on** – DMM with jaws that allow it to fit around a conductor to measure AC or DC current without breaking the circuit.

**contact** – A connection between two conductors that allows a flow of current.

**continuity** – The continuous path for current flow in a closed circuit.

**current** – The flow of an electrical charge through a conductor; measured in amperes or amps.

**DC, direct current** – an indirectional, steady voltage; typically produced through electromagnetism, chemicals (batteries), light, heat or pressure.

**data hold** – Feature of DMM that allows continued display of last reading taken after probes have been removed.

**diode** – Electronic device in circuits that allows current to flow easily in only one direction and blocks flow in the opposite direction.

**DMM, digital multimeter** – An instrument that uses an LCD typically capable of measuring voltage, current and resistance.

**F, farad** – The basic unit of capacitance.

**frequency** – The number of cycles per second that a wave form repeats; measured in hertz. (Line voltage in U.S. is 60 Hz.)

**ground** – A large conducting body (earth) used as a common return for current in a circuit.

**H, hertz** – One cycle per second; the unit of frequency.

**harmonics** – A signal with a frequency which is a multiple of the fundamental frequency (60Hz); may damage or degrade the performance of electrical devices.

**harmonic distortion** – Diminishes power quality; caused by non-linear loads such as variable speed motor drives, electronic lighting ballasts and computers.

**impedance** – Total opposition to current flow; includes resistance, capacitance and reactance.

**load** – Any device which consumes power in a circuit.

**manual ranging** – DMM that requires the user to manually select the range using the meter's dial.

**min/max** – Feature that allows a meter to capture and store the highest and lowest readings during a specific measurement.

**ohm** – The basic unit of resistance, specified as equal to that of a conductor in which one amp of current is produced by one volt of potential across its terminals.

**OL, overload** – Signal amplitudes or frequencies above the specified limits of the instrument; typically displayed as "OL" on the display of a DMM.

**peak hold** – Feature of DMM that allows retention of highest reading in a series of measurements.

**polarity** – The positive or negative direction of DC voltage or current.

**resolution** – Increments in value that can be displayed by a DMM; the greater the resolution the more precise the readout.

**resistance** – Opposition to current; measured in ohms.

**sleep mode** – Automatically shuts down unit not in use to preserve battery life.

**short** – Any connection that has relatively low resistance or any resistance between two points below a preselected threshold.

**true RMS meter** – DMM that has the True RMS feature, allowing for accurate measurement of AC voltage in environments with harmonics (see harmonics).

**V, volt** – The unit of electrical pressure; one volt is the potential difference needed to cause one amp of current to pass through one amp of resistance.