Digital Multimeter Reference Guide

Courtesy of TRANSPORTATION LEARNING CENTER

Introduction and Purpose

This two-hour distance-based learning course on digital multi-meters (DMMs)was established by the Transportation Learning Center as part of its American Apprenticeship Initiative (AAI) grant. Its primary purpose is to provide bus maintenance apprenticeship programs a way to satisfy related technical instruction requirements. The course consists of using an existing web based course offered by Fluke, a manufacturer of DMMs, and a reference guide produced by the Center to help facilitate learning.

Reference Guide Outline

Learning Outcomes

By the end of this course, you will:

- Recognize the basic orientation and functions of a Fluke DMM
- Identify the symbols and functions around the DMM dial
- Recognize the functions of the DMM advanced measurement features
- Identify the ways to extend a DMM's capabilities
- Identify the selection of the appropriate DMM
- Recall the proper inspection and maintenance of a DMM

Accessing the Course

1. Using a computer, tablet or smartphone logon to an internet browser and go to the following link: https://www.fluke.com/en-us/learn/online-courses/digital-multimeter-basics-online-course

2. There will a "Learn" tab near the top of the screen in white text. Hover your mouse over this tab or click on it. If you are hovering, move the mouse to click on the "Online Course" item in the second column, second item down. If you click it, it will take you to a new screen, where you must scroll down until you see a block labeled "Online Courses".

3. On the new page, the "Digital Multimeter Basics" course will be the first box listed. Once you are loaded onto the next page, scroll down until you see a yellow "Register" box to sign up for the free course.

4. Once registered, you will be taken to the course homepage. Click on the blue "Go to Course" button to get started.

5. The course will present you with sectioned audio clips of the material, along with instructional videos to demonstrate the use of the multimeter. Under the screen that shows the material is a progress arrow that you will use to continue. There are six major sessions, each followed by a section quiz. Once you have completed all six sessions, there is one final exam comprised of all the quiz questions you have taken before.

Reference Guide
Glossary of Terms

Digital Multimeter (DMM):

An electronic testing device that is used to determine specific information about the current, resistance and voltage of electrical signals travelling through a line. A digital multimeter is differentiated from an analog multimeter by the display and accuracy of the device. Analog multimeters use a less-accurate needle and gauge to display results, whereas a digital multimeter converts the signals into a digital format that is shown on an LED display. A DMM is useful in resolving electrical problems in many types of equipment, ranging from residential, commercial, automobiles and to mobile electronics.

Accuracy:

The precision of the DMM's displayed measurements compared to the actual value of the signal being measured. This is expressed as a percentage of reading.

AC & DC Voltage/Current Measurements:

A DMM can measure the voltage of both alternating current (AC) and direct current (DC). Most generated electricity is AC, whereas most stored electricity is DC. However, electricity at certain voltages is both AC and DC.

Auto-ranging:

One useful function that is available, typically on higher-end digital multimeters is the auto-range capability. This capability enables the DMM to select the right range automatically. You only need to select DC / AC and Amps / Volts / Ohms, etc. and the meter will do the rest. This can be a very useful capability when undertaking a lot of measurements. When holding onto two probes, it can become awkward because at times it can be difficult to let one go to alter the range and then recontact probes to measuring points.

Autopolarity:

This function displays a negative reading with a minus sign that indicates you connected the leads in reverse. However, this will not cause damage to the meter.

Average-responding DMM:

A DMM that accurately measures voltage and current sinusoidal waveforms. However, it is incapable of measuring non-sinusoidal waveforms accurately.

Category Rating:

CAT ratings on a meter indicate the maximum voltage a meter can be used in a "geographic" area of the electrical system. IEC-1010-1 specifies categories of overvoltage based on the distance from the power source and the natural damping of transient energy that occurs in an electrical distribution system. Higher categories are closer to the power source and require more protection. Within each installation category there are voltage classifications. It is the combination of installation category and voltage classification which determines the maximum transient withstanding capabilities of the instrument. Categories are divided into four different groups:

CAT I: Electronic and other equipment after the main transformer.

CAT II: Anything connected to normal household outlets.

CAT III: Industrial and other high current installations. Electric battery bus systems *may* fall under this category.

CAT IV: Distribution and outdoor conductors.

Clamp Meter:

Clamp Meter allows users to simply clamp around wire, cables, and other conductors at any point in the electric system and measure its current, without disconnecting it. There are two types:

- A transformer–type clamp meter that scales down the clamp being measured. The DMM displays 1mk for every amp being measured.
- A Hall Effect clamp meter that measures AC or DC high current by scaling down the current and converting this reduced current to a voltage. The DMM displays 1mV for every amp.

Conductance:

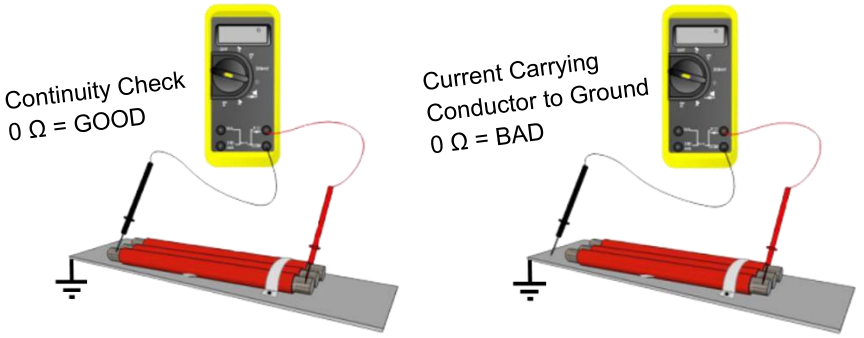
Conductance is a measurement of how easily an electrical signal can be transmitted through a specific medium. Conductance is measured by the standard unit known as siemens, which is the equivalent of 1 ampere per volt.

Diode Check:

Diodes are connected to an electrical circuit to ensure that electricity flows in only one direction through the circuit. A diode check can reveal if a diode is malfunctioning by conducting electricity in the opposite direction. It can also discover the voltage loss experienced by electricity as it passes through the diode.

Continuity Check:

A continuity check is one of the basic tests that can be performed with a DMM. Continuity determines whether an electrical circuit is open or closed. A closed circuit is one in which an electrical signal may be transmitted, whereas an open circuit is one that is broken or blocked, impeding the signal. A circuit that does not check out as having continuity may often be fixed by replacing a broken or disconnected wire.



Don't confuse a good continuity reading with an undesirable short to ground reading.

Display Count:

The display count of a DMM refers to how large or how accurate a measurement can be taken and shown on the LED display. Display count is stated in terms of x00. The x is a whole number that represents the maximum top digit before a unit of precision is lost. For instance, a 2000 display count has four total digits that will measure voltage up to 1999. At 20 volts, the precision drops, so the display would read 020.0. See Tutorial 2 under the DMM Resources and Tutorials section.

Display Digits:

Display digits are the number of digits the display of a DMM will show. Half digits mean only a 1 or 0 will be displayed as the final digit.

Hold Function:

The hold function stops the DMM from making a new reading while freezing the currently displayed value.

Min/Max Function:

The min/max function of a DMM records the lowest and highest readings taken since the function was started.

Frequency, Period, Duty Cycle Measurements

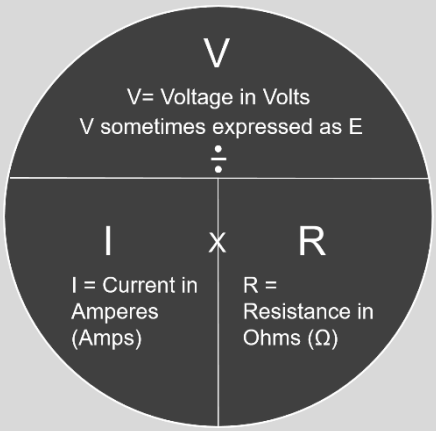
Many DMMs can measure more than current, resistance and voltage. Frequency is a measurement of the number of cycles of the electrical signal, expressed in hertz. Period refers to the time it takes for the signal to complete one cycle. Duty cycle is the ratio of electrical pulses to the duration of the pulses, which is equivalent to the ratio of average power to peak power.

Loading Effect:

Meters used to measure voltage or current have an internal resistance. Since the meter must be connected to the circuit to make a measurement, the circuit can be affected by the resistance of the meter. In most cases, the internal resistance of a voltmeter (≥ 10MΩ) and a current meter (≈ 0Ω) is insignificant.

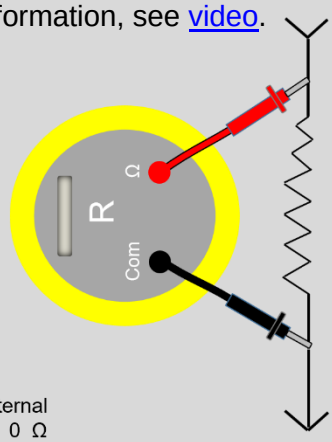
Ohm's Law:

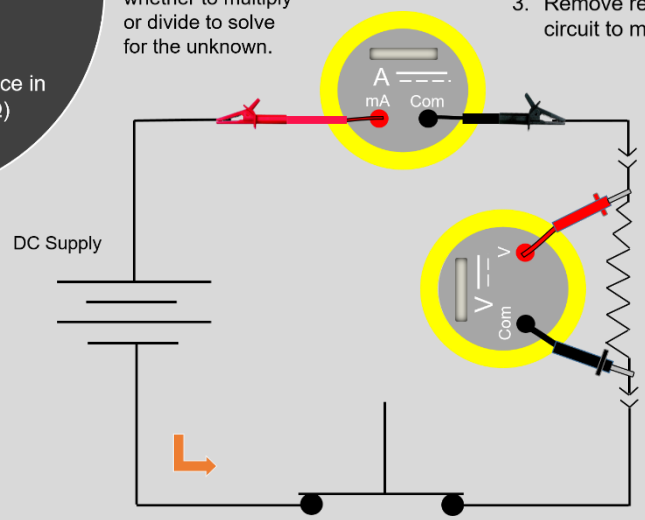
An equation that explains the relationship between voltage, current and resistance. DMM measurements can illustrate the relationship between voltage, current and resistance. For more information, see video.



Place your finger over the unknown value to determine whether to multiply or divide to solve for the unknown.

To measure resistance:
1. Open switch
2. Measure voltage across resistor [verify power has been removed]
3. Remove resistor from circuit to measure value





Ampmeter Internal Resistance ≈ 0 Ω

Voltmeter Internal Resistance ≈ 10 Ω

Solve for Unknown:

DMM Readings		
mA	Volts	KΩ
3.2	12	?
6.81	?	2.2
?	36	5

Prefix [Symbol	Number
Mega- [M]	1,000,000
Kilo- [k]	1,000
Unit	1
Milli- [m]	0.001
Micro- [µ]	0.000 001

Figure 1

Overload Protection:

Overload protection prevents damage to the meter and the circuit while protecting the user.

Relative Mode (REL):

Stores existing reading (a delta) and resets display to zero. Sets a relative reference point to measure against the next reading.

Resolution:

Resolution is the level of detail that is quantifiable on a DMM. The higher the number of DMM display digits, the higher the resolution of the DMM. By safely selecting the lowest range, before it over-ranges, this will display the most accurate reading. [See Figure 2 or Tutorial 2]

Temperature Measurements, J-Type/K-Type:

Temperature can be measured by some DMMs through the use of a thermocouple. J-type thermocouples measure lower temperatures than do K-type thermocouples. J-type thermo-couples only measure temperatures up to 600° C, while K-type thermocouples measure temperatures up to 1,273° C.

Figure 2

TRMS Responding DMM:

TRMS stands for **true root mean squared**. TRMS multimeters apply a compensating factor that accounts for distortion in order to achieve a more accurate reading.

Voltage/Current Measurement Accuracy:

The voltage and current measurements taken by a DMM are not always totally accurate. The potential for variation is given in the specific device's accuracy rating, which is usually around 0.5 percent.

Safety Precautions

When measuring voltages, particularly on electrical installations it is necessary to ensure that the digital multimeter has an adequate safety rating. IEC 1010 categorizes meters according to their safety ratings. These ratings not only take into account the working voltage, but also the source impedance and the resilience to peak transients that often occur on the lines. These specifications and certifications are normally only available for the top DMMs. Companies who produce DMMs to these specifications need to have them tested and this costs time and money. The low end DMMs for occasional use are imports and neither the manufacturers nor importers are generally set up to gain these certifications, and also it would not be financially viable for them. It is necessary to ensure that any meter being used for these applications is suitably rated. This may result in needing to buy a more expensive meter. [See Table 1].

CAT RATINGS:

Category	Voltage	Transient Voltage	Impedance (Ohms)
CAT 1	150	800	30
CAT 1	300	1500	30
CAT 1	600	2500	30
CAT 1	1000	4000	30

Category	Voltage	Transient Voltage	Impedance (Ohms)
CAT III	150	2500	2
CAT III	300	4000	2
CAT III	600	6000	2
*CAT III	1000	8000	2

*Recommended for BEBs and/or Hybrid buses

Category	Voltage	Transient Voltage	Impedance (Ohms)
CAT II	150	1500	12
CAT II	300	2500	12
CAT II	600	4000	12
CAT II	1000	6000	12

Category	Voltage	Transient Voltage	Impedance (Ohms)
CAT IV	150	4000	2
CAT IV	300	6000	2
CAT IV	600	8000	2
CAT IV	1000	12000	2

Table 1

User Errors:

- Wrong settings (i.e., ohms scale selected when testing voltage)
- Wrong value of DMM replacement fuse installed
- Wrong “CAT” area application
- Wrong probe socket used (i.e., amps instead of volts)
- Wrong use of the product, such as switching settings under power
- Wrong voltage applied, exceeding limits of meter
- Adding to the user error problem is wear, tear and contamination within the meter that creates internal component failures or compromises the components’ dielectric properties. Still other causes concluded that because of complicated markings on the meter, many users have no idea what a “CAT” rating is, let alone the fact that using a CAT II meter in a CAT III area can lead to their catastrophic failure.

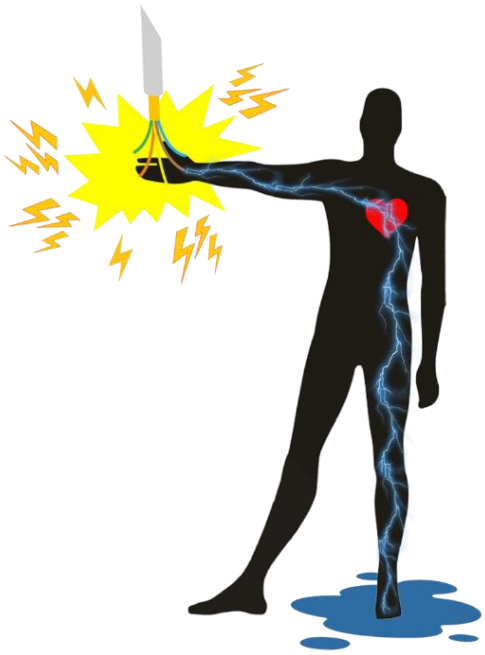
DMM Safety Tips:

- **Never** apply power to the circuit when measuring resistance with a DMM
- **Do not** use your test leads if the protective insulation on the leads or probes is cracked or worn.
- Make sure leads and probes match the DMM Category Rating
- Inspect your DMM before usage. **Do not** assume the multimeter is in a good working condition. Verify that it functions properly by measuring a known voltage source before you work on a high-energy live circuit.
- Make sure that the DMM is switched to AC before making AC measurements.
- In case you want to verify the presence of dangerous voltage in a circuit with a digital multimeter, it is crucial to verify both AC and DC voltages, including capacitor voltages.
- Set the ideal current range before measuring higher current or else it will blow the digital multimeter fuse.
- When measuring the resistance of a component, disconnect it from the circuit completely to avoid erroneous readings.

Avoiding Electric Shock:

Electric shock occurs when an individual's body becomes part of an electrical circuit. One should always assume that all the component of an electrical circuit is energized. To avoid electric shock, follow the tips below:

- You should constantly be aware of the positioning of your body when you are moving about in electrical environments and while working on energize equipment.
- You should perform energize electrical work following the quote, "One Hand Rule." This requires the individual to place one hand in a pocket to prevent contact with grounded work surfaces while performing energize electrical work. This will prevent electrical current from flowing through the heart.
- Use your personal protective equipment. Wear your insulated gloves, and headwear, and use the insulated rubber mats when working near or on electrical circuits that are 50V or greater. Use specified test probes whereas the exposed metal tips match the energy potential of a given measurement.
- Review equipment manuals and drawings to note safety cautions and warnings. Caution and Warning Notices indicates a potentially hazardous condition. Caution Notice indicate, if not avoided it can lead to minor or moderate injury. Warning Notice indicate, if not avoided it can lead to death or major injury. [See Table 2]



Effects of Electrical Current on the Human Body

Current (mA)	Effects on the Body
1 or less	No sensation; probably not noticed
1 – 3	Mild sensation not painful
3 – 10	Painful shock
10 – 30	Muscular control could be lost or muscle clamping
30 – 75	Respiratory paralysis
75 mA – 4 A	Ventricular Fibrillation
Over 4 A	Tissue begins to burn. Heart muscles clamp and heart stops beating.

Table 2

- When working near or on energized or exposed circuit, do not work alone.
- Avoid operating the meter in damp or humid environments.
- Watch for the audio or visual warnings in your multimeter display unit.
- Know the CAT rating of your DMM.

Understanding the Dangers:

The severity of an electric shock depends on:

- How long the body is exposed to the flow of current
- The amount and type of current flowing through the body
- The area of the body exposed to the energy and the path through which the current flows
- The condition of the exposed body to the current i.e. skin resistance and moisture, body size, and health-condition/age of the body.

Transient overvoltage (power surge):

Transient overvoltage is a fast-rising, erratic, spike in energy that can reach up to thousands of volts in duration of milliseconds. Lightning strikes, switching operation of inductive loads, air conditioning units, motors, and unfiltered electrical equipment give rise to these spikes. Transient overvoltage is an unexpected danger of testing electrical equipment.

*Arc blasts, arc flashes:

These are the current discharge across an air gap. They are caused by:

a) accidental contact between conductors or

b) excess voltage ionizing the air between the conductors.

*__Note__: Arc blast or flash can occur in an electrical system when a power line transient happens as a multimeter is used to record the voltage. CAT-rated multimeters are made to reduce, lower or forestall the occurrence of this situation within the meter.

Online DMM Resources and Tutorials

Use the following resources to boost your skills:

Websites

- Sources: Used-Line Glossary ; Medium
- Visit "Fluke" (Fluke has specific online training courses: Fluke Online Training)
- Visit "All About Circuits" (many videos to watch: Video Tutorials or Basic Concepts)

Tutorials

1. Electrical Measurement Safety by Fluke (24.59 minutes) Electrical Measurement Safety by Fluke
2. Multimeter Counts and Digits - What do they mean? (6.53 minutes) Multimeter Counts and Digits - What do they mean?
3. View How to use a Digital Multimeter for Beginners – How to Measure Voltage, Resistance, Continuity and Amps (8.07 minutes) How to use a Digital Multimeter for Beginners
4. How to Use a MULTIMETER – Beginner's Guide (Measuring volts, resistance, continuity & amps) (9:29) How to Use a MULTIMETER -- Beginner's Guide
5. View How to Use a Multimeter (10.33 minutes) How to Use a Multimeter
6. View Checking for Open Circuitry using an Ohmmeter/Voltmeter (1.52/2.37 minutes)* Checking for Open Circuitry using an Ohmmeter/Voltmeter

***Instructions for Tutorial 6**: After going to the link, click on the Resources Tab. Scroll over it and there will be a dropdown menu with the option of "Video Tutorials" at the bottom. Click on it and it will take you to the video tutorials.