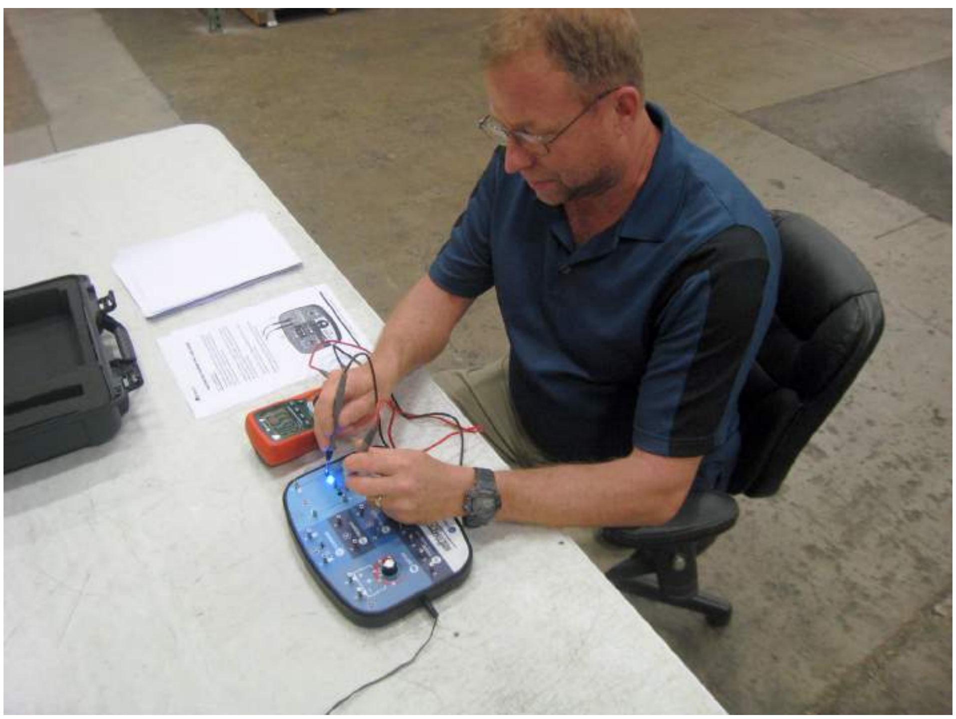
PURKEYS

A MISSION CRITICAL ELECTRONICS BRAND

# MTU

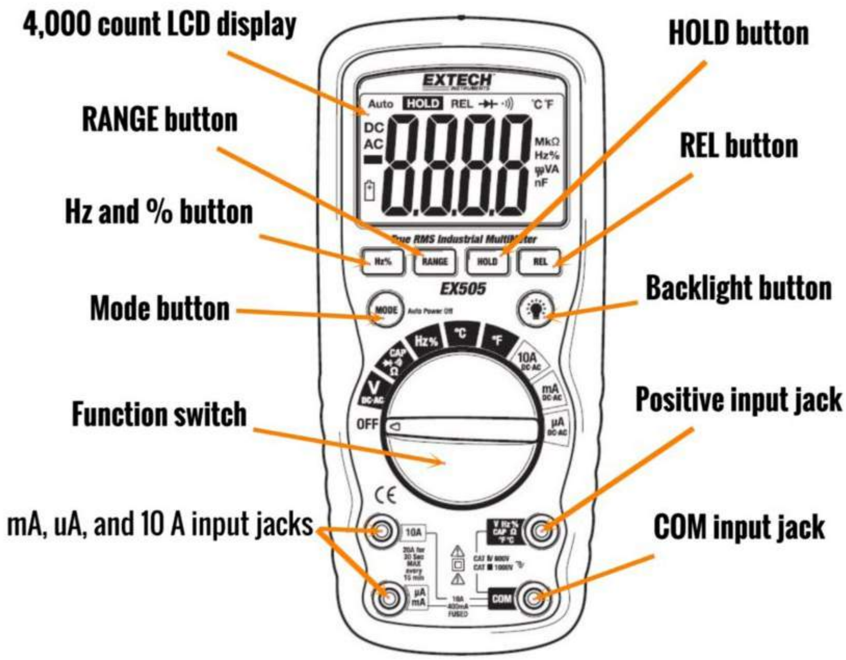
## WORKBOOK



# CONTENTS

PURKEYS

# MULTIMETER CALLOUTS





NOTE: The measurements given in this workbook are approximations and may vary slightly, depending on the multimeter and/or MTU.

# GLOSSARY

AC Voltage:

Alternating current (AC) changes direction periodically. The voltage in AC circuits also periodically reverses because the current changes direction.

AGM Battery:

AGM (absorbed glass mat) batteries are designed to wick the battery electrolyte between the battery plates. AGM batteries contain only enough liquid to keep the mat wet with the electrolyte. If the battery is broken, no free liquid is available to leak out.

Alternators:

Alternators produce DC power to charge the vehicle batteries and provide power to the electrical loads on the vehicle. They do this by converting AC current from the stator and converting it to DC current by way of the diodes in the rectifier bridge. The alternator also regulates the DC voltage. (For more details, see Section 3.)

Capacitance:

Capacitance is the ability of a device to store electrical charge. The unit of measurement of capacitance is a farad (F). (For more details, see Section 6.)

Current Measurement:

Current is the flow of electrons in an electrical circuit. To have current flow, there must be voltage to push the current and a complete circuit for current to flow through. The unit of measurement is an ampere. (For more details, see Section 8.)

Continuity Testing:

When testing continuity, you are connecting the circuit or device to the 9-volt battery in the multimeter via the red and black leads. If the circuit or device will allow this low current to flow from the red lead though the circuit or device back to the meter via the black lead, the meter will beep, indicating there is continuity. (For more details, see Section 9.)

DC Voltage:

Direct current (DC) is current flowing in one direction, with voltage with constant polarity. DC is the kind of electricity made by a battery (with definite positive and negative terminals).

Diodes:

A diode is a semi-conductor that works like an electrical one-way check valve; it only allows current to flow in one direction. (For more details, see Section 6.)

Duty Cycle:

Duty cycle is the ratio of time a load or circuit is on compared to the time the load or circuit is off.

Flooded Cell Battery:

Flooded batteries use positive and negative plates kept apart by separators. These plates are submerged completely in a solution of acid and water called electrolyte.

Frequency:

Frequency is the number of times a signal cycles from high to low each second and is measured in hertz (Hz). A period is the time required to produce one complete cycle of a waveform. There are various waveforms of electrical signals; the most common are sine waves and square waves. (For more details, see Section 4.)

Ground:

Ground is the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.

Hertz:

A unit of frequency equal to one cycle per second.

Load:

An electrical load is an electrical component or portion of a circuit that consumes electric power. This is opposed to a power source, such as a battery or generator, which produces power. In electric power circuits, examples of loads are appliances and lights.

Millivolt:

A millivolt is 1/1000 of a volt or 0.001 volts. Millivolts are displayed on the meter as mV. (For more details, see Section 5.)

OCV:

Open-circuit voltage (OCV) is the difference of electrical potential between two terminals of a device when disconnected from any circuit.

Open:

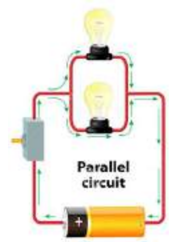
An electrical circuit that is not complete because the current path has been interrupted by either an opening in its pathway or by the intervention of a component.

Passive:

Passive components are components such as resistors, capacitors, and diodes. Passive components should be measured outside of a circuit, independently, so the reading isn't affected by the rest of the circuit. (For more details, see Section 6.)

Parallel:

Components connected in parallel are connected along multiple paths, so the same voltage is applied to each component.




Polarity:

Electrical polarity (positive and negative) is the term used to describe the direction of current flow in an electrical circuit. In a direct current (DC) circuit, one pole is always negative, the other pole is always positive, and the electrons flow in one direction only.

Pulse Width Modulation:

An electrical signal consisting of a square wave of fixed frequency. Because of the square wave patterns, the signal can be used to precisly power components. (For more details, see Section 6.)

Resistance:

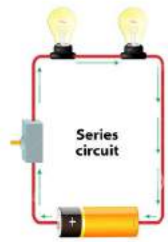
The resistance of an electrical conductor is a measurement of the difficulty to pass current through that conductor. The unit of measurement is an Ohm (Ω). (For more details, see Section 6.)

Ripple:

Ripple in electronics is the residual periodic variation of the DC voltage within a power supply which has been derived from an alternating current (AC) source. This ripple is due to incomplete suppression of the alternating waveform after rectification. (For more details, see Section 3.)

Series:

Components connected in series are connected along a single path, so the same current flows through all components.



Short:

A short circuit is an electrical circuit that allows a current to travel along an unintended path with no or a very low electrical impedance.

State of Charge:

If one thinks of a battery as a bucket of energy, then the state of charge is an indication of how full the the "bucket," or battery, is. When we say 20% state of charge, the battery is only 20% full. At 75% state of charge, the battery is 75% full. (For more details, see Section 1.)

Voltage Drop:

The difference in voltage between two points in a circuit with current flowing. (For more details, see Section 2.)

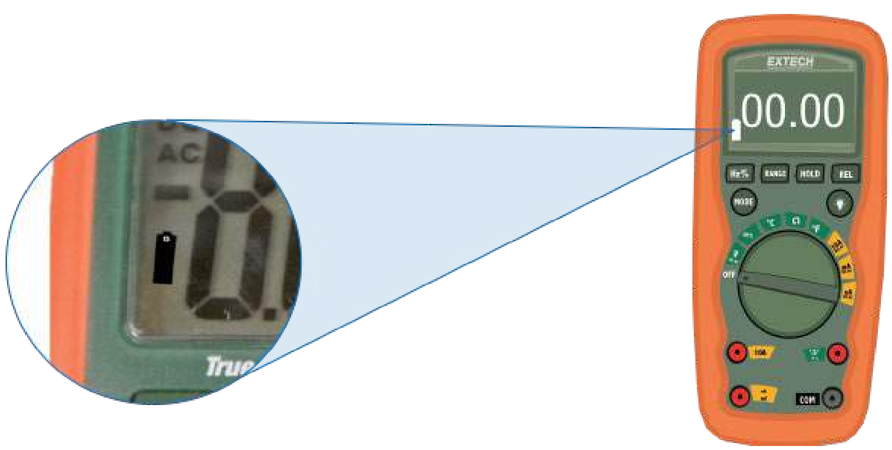
It is critically important that both positive and negative cables can carry the current load with minimal voltage loss. Typically, these cables have a resistance of 0.02 ohms or less. These low values are next to impossible to measure using a shop ohmmeter, as the values are too low to measure accurately. To measure these low values, we will use a digital voltmeter and ammeter to determine the voltage drop in a circuit at a specific amperage value. Then, using Ohm's law, we can calculate the resistance value—if we know two values in Ohm's law, the third can be mathematically determined.

## MULTIMETER PRE-CHECK

Before using a multimeter, it is a good idea to verify that the meter and leads are in good working condition. Follow this short procedure to verify that the battery, leads, and fuses are functioning properly.

### Check the battery status:

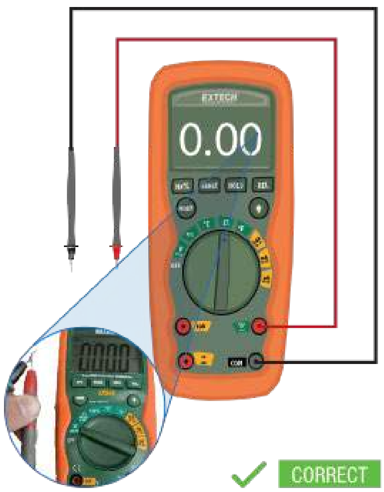
1. Check the battery status icon on the meter screen to ensure the battery is properly charged.

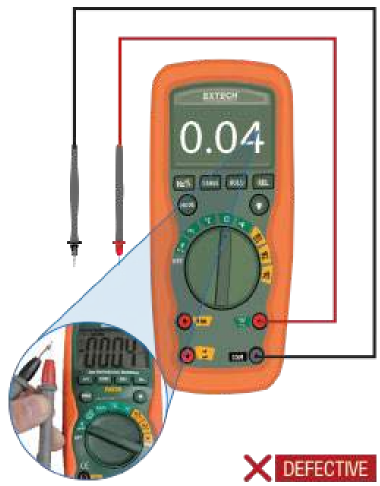


2. If the battery is not fully charged, replace the battery.

## Test the leads and meter:

1. Set the function switch to Ohms (Ω). Touch the leads together. If the meter reads less than 0.2, your multimeter pre-check is complete. If not, continue to step 2.

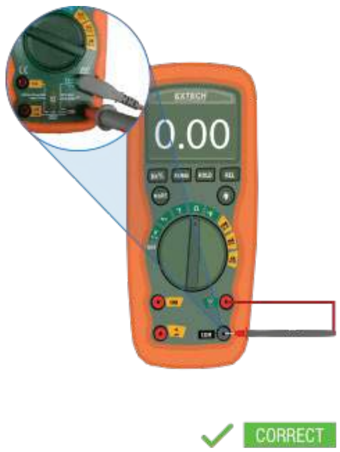



2. Check the meter by straightening a paper clip and inserting one end into the Positive Input Jack and the other end into the COM jack. (The examples below show two banana jacks with a fuse. These have no resistance also, but the paper clip works just as well.) The meter should read zero. If not, the meter needs to be calibrated.

3. Check the red lead by plugging it into the Positive Input Jack on the meter.


4. Place the tip of the red lead on the inside of the COM Input Jack on the meter.
5. If the meter reads less than 0.1, your red lead is working properly. If not, get a new red lead.
6. Check the black lead by plugging it into the COM Input Jack on the meter.





7. Place the tip of the black lead on the inside of the Positive Input Jack on the meter.
8. If the meter reads less than 0.1, your black lead is working properly. If not, get a new black lead.


## Test both fuses:

1. Test the 10 A fuse by setting the function switch to Ohms (Ω) and plugging the red lead into the Positive Input Jack on the meter.
2. Place the tip of the red lead into the 10 A Input Jack.
3. If the meter reads zero, your 10 A fuse is functioning properly. If the meter reads OL, your fuse is damaged and needs to be replaced (see step 7).


✓ CORRECT

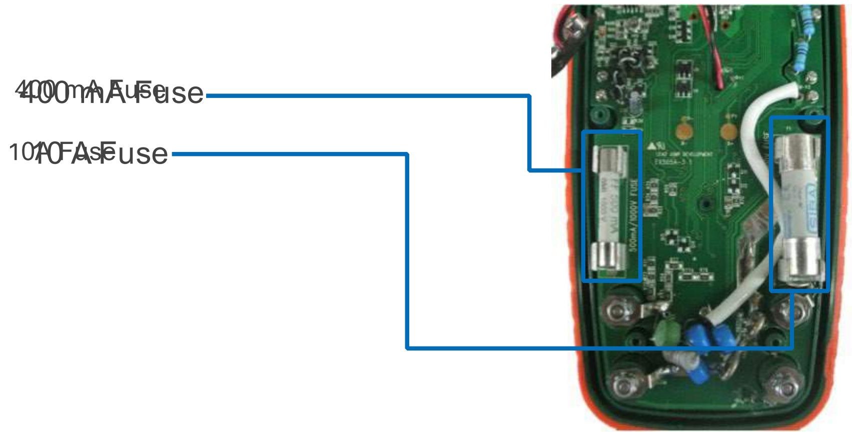

✗ BLOWN FUSE

4. Test the 400 mA fuse by setting the function switch to Ohms (Ω) and plugging the red lead into the Positive Input Jack on the meter.
5. Place the tip of the red lead into the 10 A Input Jack.
6. If the meter shows a reading, your 400 mA fuse is functioning properly. If the meter reads OL, your fuse is damaged and needs to be replaced (see step 7).
7. To replace the fuses, remove the back of the meter and change the appropriate fuse (this may vary for different meters, refer to your manual for specific instructions on changing fuses in your meter).


✓ CORRECT

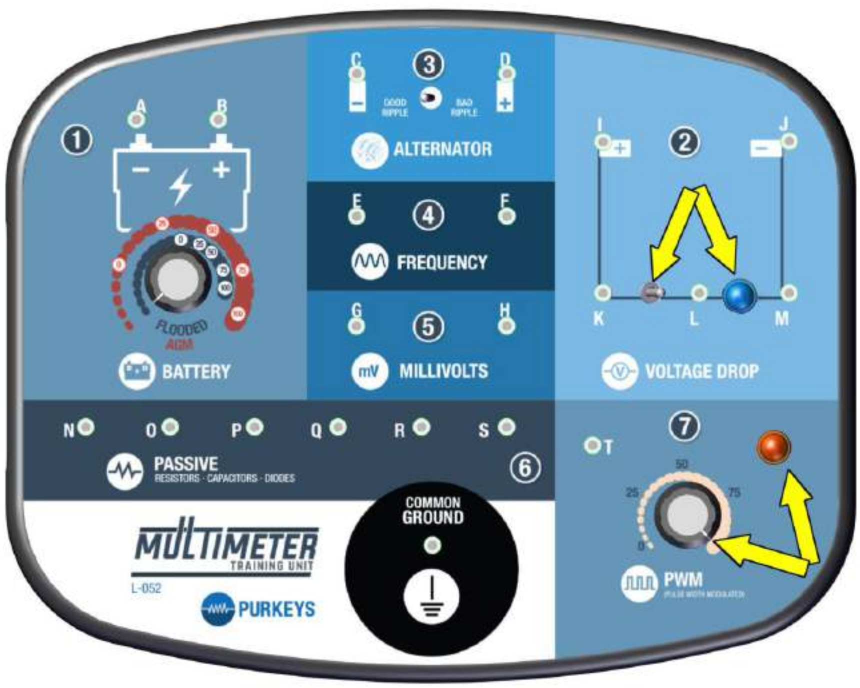

✗ BLOWN FUSE

*This was the reading for this particular meter; to see what the exact reading should be on your meter, refer to the product manual.




## MTU PRE-CHECK

1. Plug the MTU into 110 AC power (standard wall outlet).
2. Make sure the knob in section 7 is turned all the way to the right; the light should turn on (red).
3. Flip the switch in section 2 to the right; the light should turn on (blue).



# 1. BATTERY OPEN CIRCUIT VOLTAGE (OCV) MEASURMENT

Purpose:
This section will show you:

1. How a voltmeter can measure the OCV of the battery or battery pack.
2. How to approximate the battery or battery pack state of charge.

State of Charge:
If one thinks of a battery as a bucket of energy, then the state of charge is an indication of how full the the "bucket," or battery, is. When we say 20% state of charge, the battery is only 20% full. At 75% state of charge, the battery is 75% full.

How it works:
Section 1 of the MTU simulates a battery. It can represent either a flooded cell battery or an AGM battery. The knob can be set to a state of charge anywhere from 0 to 100, allowing you to measure the battery voltage at that state of charge.

Keep in mind that the MTU simulates the actual voltage readings that you would get on a real battery. Table 1 shows the OCV range associated with each state of charge.

Table 1

| Approximate % Charge | Approximate Open Circuit Voltage | |
|---|---|---|
| | FLOODED | AGM |
| 100 | 12.6 V or higher | 12.8 V or higher |
| 75 | 12.4 V | 12.6 V |
| 50 | 12.2 V | 12.2 V |
| 25 | 12.0 V | 11.8 V |
| 0 | 11.8 V | 11.4 V |

Example:

Place the knob at 100 on the AGM setting. Connect the leads from your multimeter to the simulated battery as shown by V1 in Figure 1 (remember to observe polarity).

Your multimeter should show a reading of approximately 12.86 volts, as shown in Figure 2.

This means that your AGM battery is at 100% state of charge at 12.96 volts.

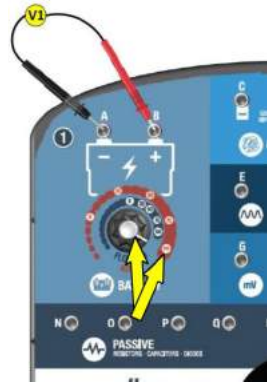



Figure 1


Figure 2

Let's try it!

Make sure the function switch on your multimeter is set to volts (see Figure 3), then use the MODE button to set the meter to DC voltage.

Adjust the knob to the following percentages and record the readings:


Figure 3

| | Flooded | AGM |
|---|---|---|
| 25% | ___________V | ___________V |
| 50% | ___________V | ___________V |
| 75% | ___________V | ___________V |
| 100% | ___________V | ___________V |

Key Take-Aways:

- At 12.00 volts, neither an AGM or flooded cell battery is at a high state of charge.
- The voltage spread from 25% state of charge to 100% state of charge is less than one volt.
- Reading the open circuit voltage is an easy way to determine a battery's state of charge.
- As flooded cell and AGM batteries approach 100% state of charge, the OCV will be different: 12.65 V vs. 12.86 V.
- Below about 12.2 volts, the battery should be charged before testing.
- High OCV does not mean the battery is good, only that is it at a good state of charge. To determine if good, it must be tested with a battery tester.

## 2. VOLTAGE DROP CIRCUIT MEASUREMENT

Purpose:
This section will show you how to perform a voltage drop test in a functioning circuit.

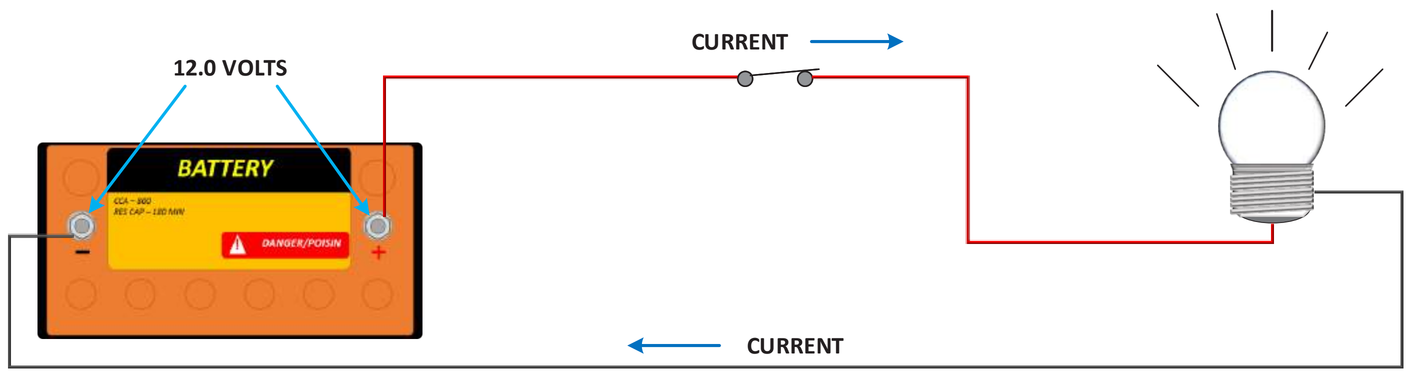
Voltage Drop:
The difference in voltage between two points in a circuit with current flowing.

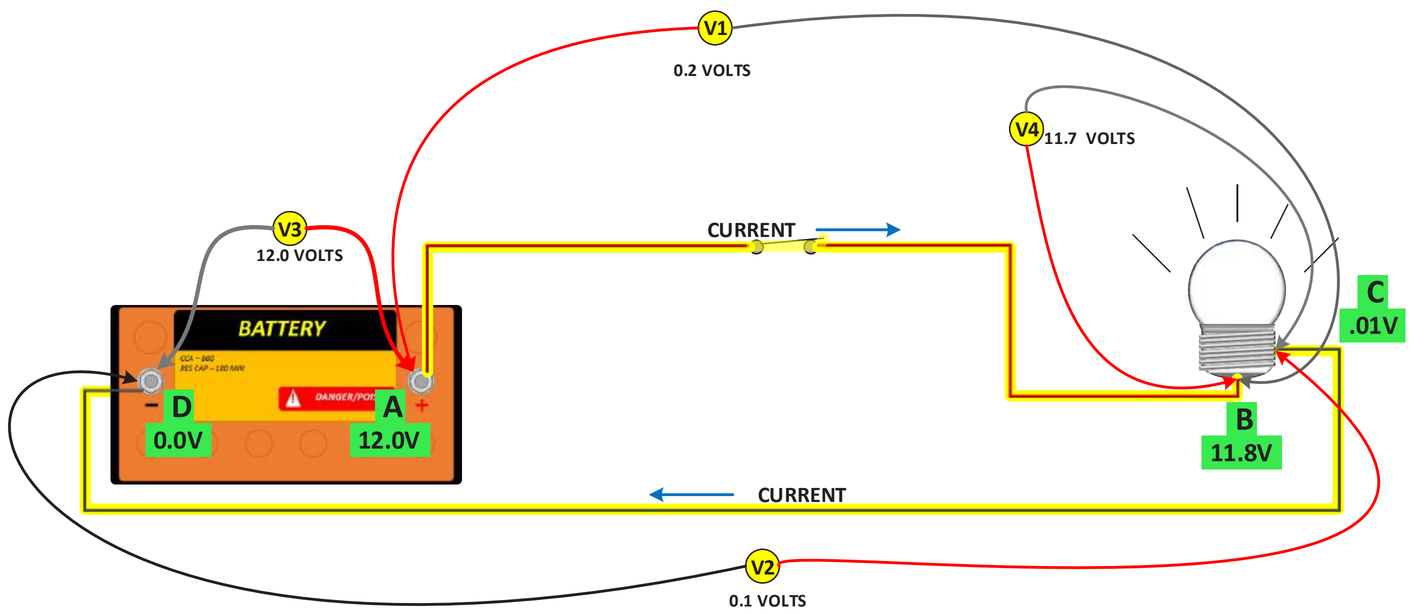
How it works:
Once a circuit is completed and current is flowing, there will be voltage drops across each of the circuit components. These voltage drops always add up to the voltage of the source. The voltage drops in the wires supplying power to the load reduce the voltage that gets to the load.

It is critically important that both positive and negative wires can carry the current load with minimal voltage loss.

Let's show an example using this basic circuit:

In this case, we have a 12.0 volt power source with the positive terminal connected to a wire that goes to an on/off switch, then continues on to the load (light bulb). The negative terminal of the power source connects to a wire that connects to the load. When the on/off switch is turned on, current flows and the light turns on.




In the picture above:

- A is positive terminal of source
- D is negative terminal of source
- B is positive terminal of load
- C is negative terminal of load

The measurements on the figure above are made with a multimeter in the voltmeter setting. Notice the voltage drop on the positive side of the circuit (A) is 0.2 volts between A and B. The voltage drop on the negative side (D) is 0.1 volts between C and D.

If you add the positive and negative voltage drop, it will equal 0.3 volts. If you measure the voltage at the battery (V3) during this test, the voltage will read 12.0 volts.

If you measure across the bulb during load (V4), it will measure 11.7 volts. So, if you add the bulb voltage of 11.7 volts to the wiring volts (11.7 plus 0.30) it will equal the 12.0 volt source voltage.

Section 2 of the MTU simulates a complete circuit connected to a battery. Think of (I) as the positive post of a battery and (J) as the negative post of the battery.

When the switch between (K) and (L) is to the right, and the light is blue, the circuit is complete and current is flowing. When the switch is to the left, it means there is a break in the circuit and no current is flowing.

## Let's try it!

Turn the meter function switch to volts (V), then use the MODE button to select DC (see Figure 4).

Figure 4

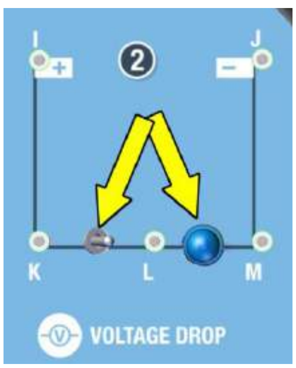



Figure 5

Flip the switch in section 2 of the MTU to the right; the blue light should illuminate (see Figure 5), indicating that current is flowing within the circuit from point (I) to point (J).

Following the lead placement configurations in Figure 6, measure the voltage of the following and record the readings:

V2 (I to J) __________V

V3 (I to K) __________V

V4 (K to L) __________V

V5 (L to M) __________V

V6 (M to J) __________V

Remember that the voltmeter measures the difference in voltage between the two leads.

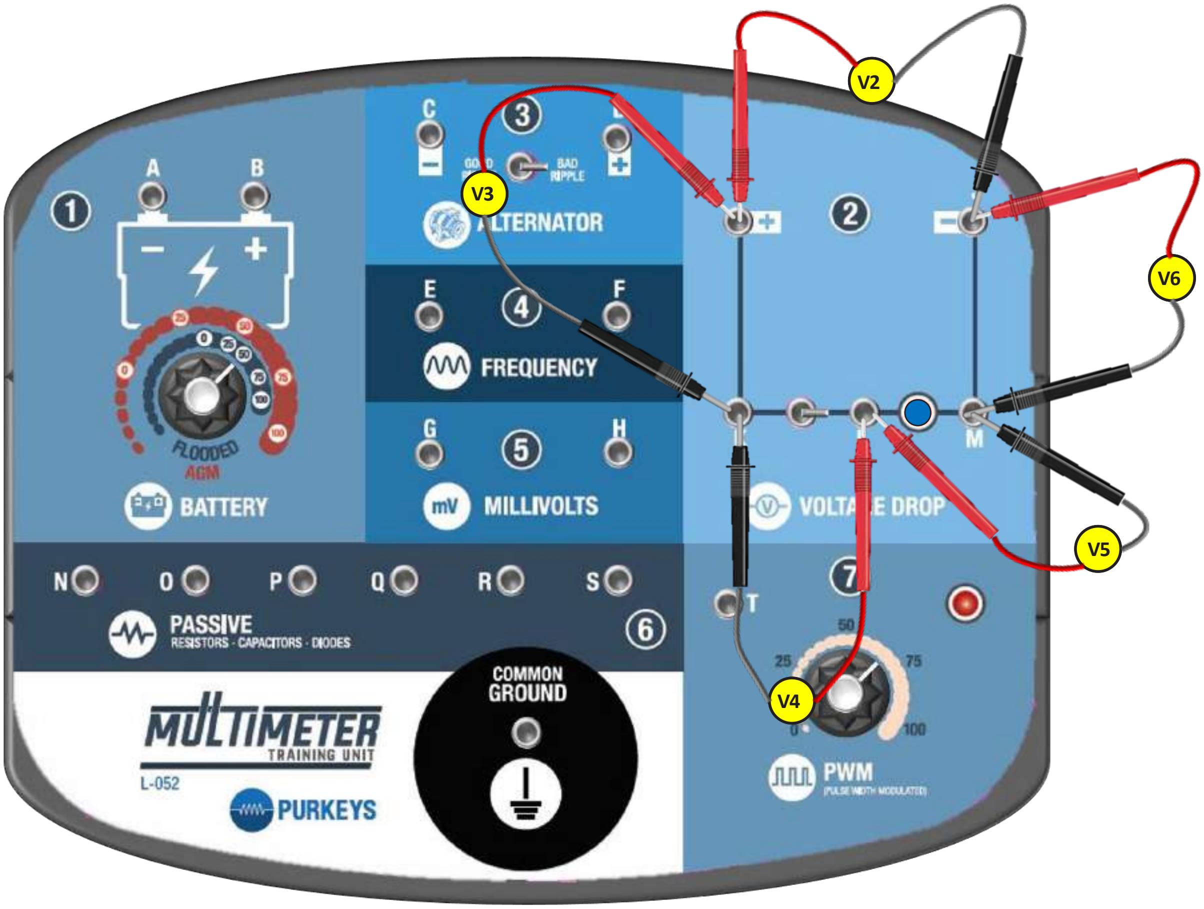

V2
V3
V4
V5
V6
A
B
C
D
E
F
G
H
M
T
N
O
P
Q
R
S
ALTERNATOR
FREQUENCY
MILLIVOLTS
BATTERY
VOLTAGE DROP
PASSIVE
RESISTORS - CAPACITORS - DIODES
COMMON GROUND
MULTIMETER
TRAINING UNIT
L-052
PURKEYS
PWM

Figure 6

Based on the results from your measurements in Figure 6, carefully look at Figure 7. Notice that ground and post (J) are exactly the same voltage; 0. Now, based on the measurements conducted in Figure 6, what will the values be of each post when the other end of the voltmeter is connected to ground as shown in Figure 7? Write down your projected values.

When you are done with your projections, use your voltmeter to measure the voltages and write them down.

| | Projected | Measurements |
|---|---|---|
| V7 | __________V | __________V |
| V8 | __________V | __________V |
| V9 | __________V | __________V |
| V10 | __________V | __________V |
| V11 | __________V | __________V |

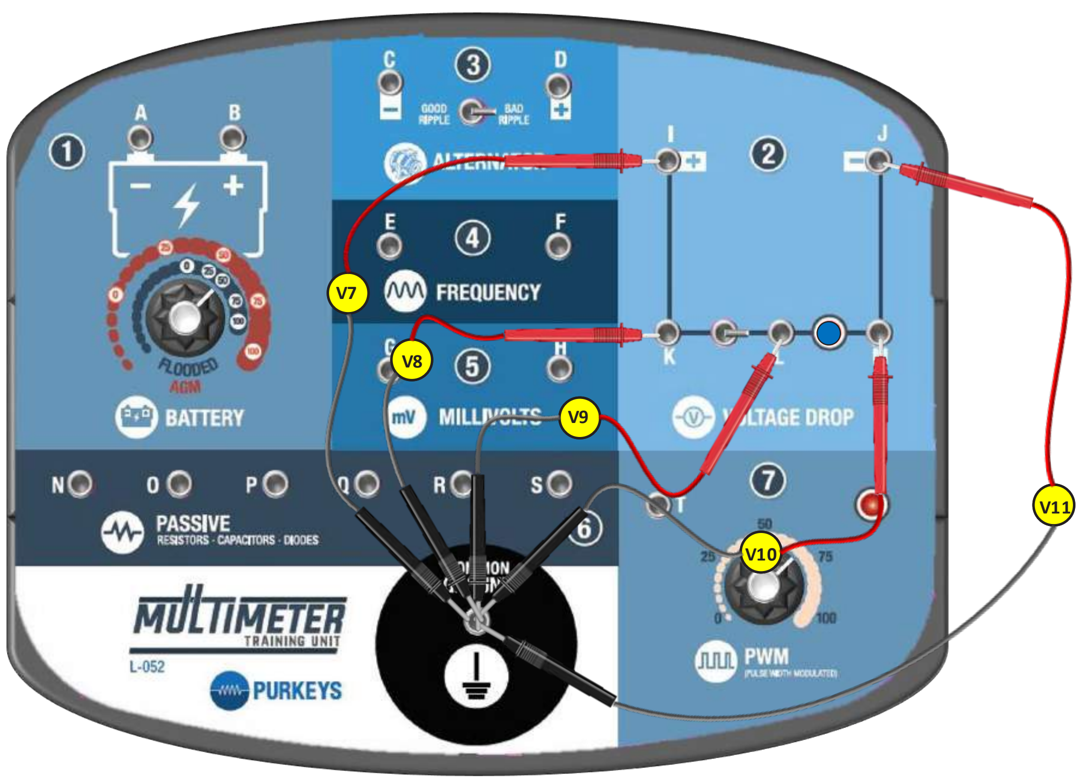



Figure 7

Here is what the voltage will be at each post.

I = 13.01 V

K = 9.77 V

L = 9.77 V

M = 3.23 V

J = 0.0 V

If your projected voltages are correct, congratulations! If they are different, let's figure out why. Remember that the voltmeter measures and displays the voltage difference between the red and black leads.

Remember, the voltmeter only reads the difference in voltage and displays that number. So…

When the leads are connected as follows:

| | | | |
|---|---|---|---|
| I to J | = | 13.01 minus 0 | = 13.01 volts |
| I to K | = | 13.01 minus 9.77 | = 3.24 V |
| K to L | = | 9.77 minus 9.77 | = 0.0 V |
| L to M | = | 9.77 minus 3.23 | = 6.54 V |
| M to J | = | 3.23 minus 0 | = 3.23 V |

When the leads are connected as follows:

| | | | |
|---|---|---|---|
| I to ground | = | 13.01 minus 0.0 | = 13.01 V |
| K to ground | = | 9.77 minus 0.0 | = 9.77 Volts |
| L to ground | = | 9.77 minus 0.0 | = 9.77 volts |
| M to ground | = | 3.23 minus 0.0 | = 3.23 Volts |
| J to ground | = | 0.0 minus 0.0 | = 0.0 Volts |

While the value of the various points never changed in voltage, what you compared to did change. Thus, the values appeared to be different.

Now, flip the switch to the left, and the blue light should turn off. This indicates that current is NOT flowing within the circuit from point I to point J.

Following the lead placement configurations in Figure 8, measure the voltage and record the readings:

V2 (I to J) __________V

V3 (I to K) __________V

V4 (K to L) __________V

V5 (L to M) __________V

V6 (M to J) __________V

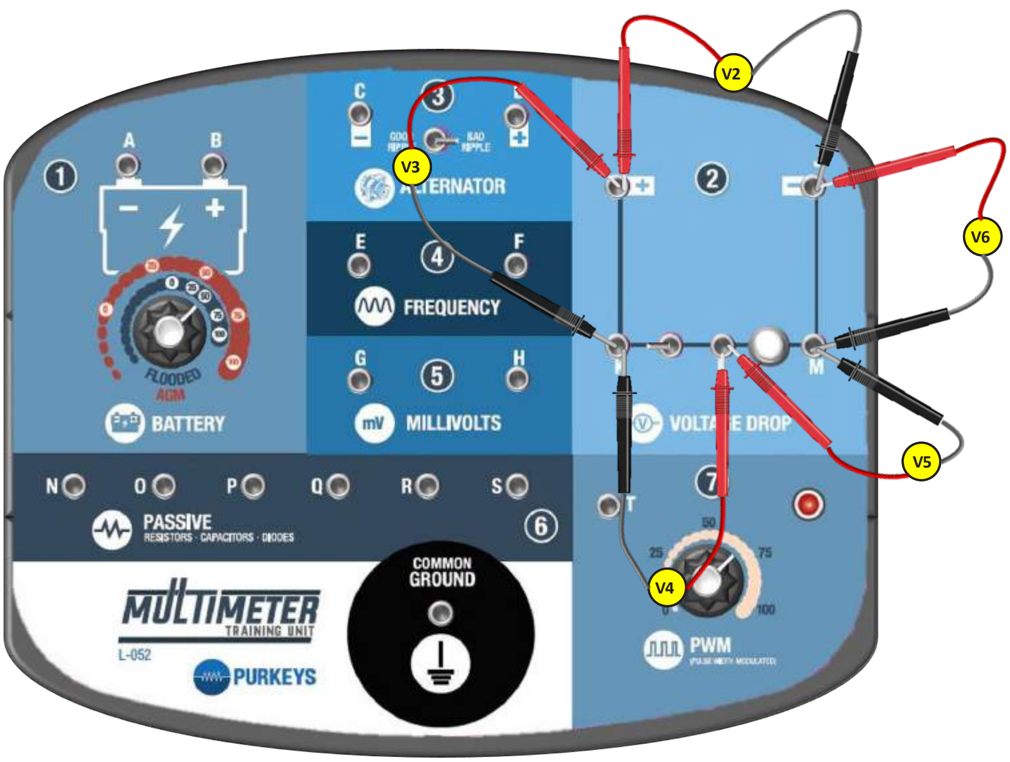



Figure 8

Based on your readings from Figure 8, what do you think the voltage will be for the following measurements in Figure 9? Write down your projected voltages.

When you are done with your projections, use your voltmeter to measure the voltages and write them down.

| | Projected | Measurements |
|---|---|---|
| V7 | ___________V | ___________V |
| V8 | ___________V | ___________V |
| V9 | ___________V | ___________V |
| V10 | ___________V | ___________V |
| V11 | ___________V | ___________V |

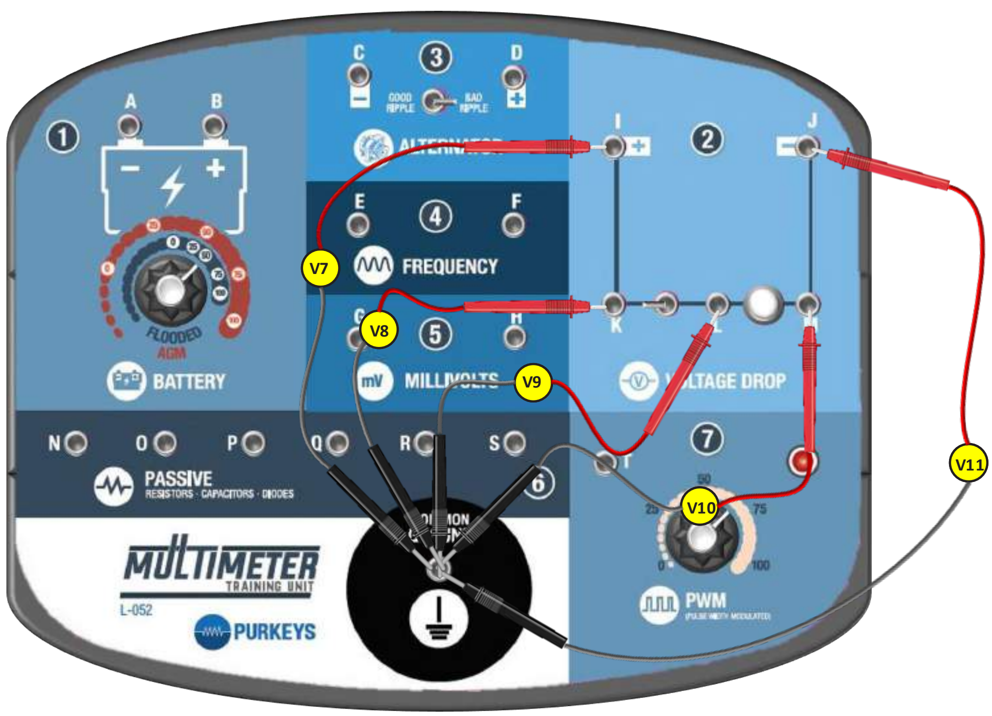



Figure 9

Here is what the voltage would be at each post.

I = 13.01 V

K = 13.01 V

L = 0.00 V

M = 0.00 V

J = 0.00 V

If your projected voltages are correct, congratulations! If not, let's review the voltages at each point, following the path the current takes as it flows through the circuit, and determine what the meter will read.

When you opened the switch (flipped it to the left), the circuit opened, so no current can flow. With no current following, you cannot have any voltage drop. Even though there is no voltage drop, there can still be voltage at the point of the break (open) in the circuit. See Figure 10. There are 13.01 volts at both I and K while all the point to the right of the switch would have zero volts.

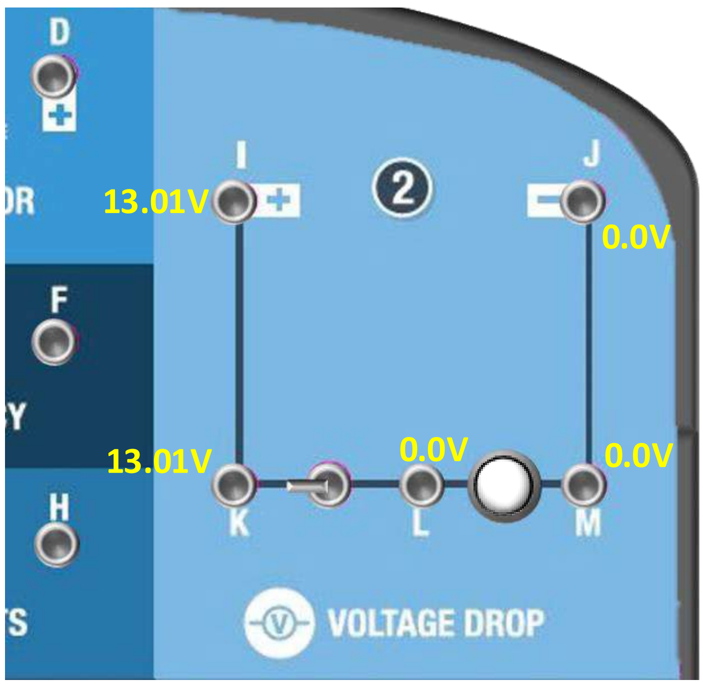



Figure 10

Key Take-Aways:

- Voltage drop only occurs when there is a complete circuit and current is flowing. No current flow, no voltage drop.
- Connecting the voltmeter in parallel shows the voltage drop in that leg of the circuit.
- Connecting the voltmeter from a positive point to ground will tell you the voltage at that point in relationship to ground.
- When connected in parallel, no current is flowing, and both points are at the same potential, the meter will read zero.

# 3. ALTERNATOR TEST

Purpose:
This section will explain how an alternator produces DC current and a small amount of AC ripple voltage, as well as show you how to measure the DC voltage and the AC ripple voltage of the alternator. This is a very good method to determine if an alternator is good or defective.

Alternators:
Alternators produce DC power to charge the vehicle batteries and provide power to the electrical loads on the vehicle. They do this by converting AC current from the stator and converting it to DC current by way of the diodes in the rectifier bridge. The alternator also regulates the DC voltage.

How it works:
A good alternator will produce a DC voltage of approximately 14.2 volts and an AC ripple voltage below 0.5 volts.

A faulty alternator will:

- produce a high DC voltage (over approx. 14.5 volts), or
- produce a low DC voltage (under approx. 13.9 volts), and/or
- produce a high AC ripple (over approx. 0.5 volts AC).

Section 3 of the MTU simulates an alternator. (C) represents a connection to the negative side of the battery and (D) represents a connection to the positive side of the battery. The MTU produces a signal that simulates the DC voltage and AC ripple voltage of an alternator.

The switch changes the signal to simulate an alternator with good diodes (good ripple) or an alternator with a faulty diode (bad ripple).

## Let's try it!

Make sure your meter is ready to use (see Figure 11):

- Red lead in the top right jack
- Black lead in the bottom jack (COM)
- Selection knob to volts
- You will be using both the DC and AC settings on your multimeter. Use the MODE button to switch between DC and AC voltages. When you set the meter to AC, press the RANGE button to read two decimal places on volts, so the meter can stabilize.

Figure 11

Connect to the MTU by placing the red lead on the (D) post and the black lead to the (C) post (see Figure 12).

Flip the switch in section 3 of the MTU to the left. This will give a ripple value for a good alternator.

Flip the switch in section 3 of the MTU to the left. This will give a ripple value for a good alternator.

Record the DC reading: __________V

Record the AC reading: __________V

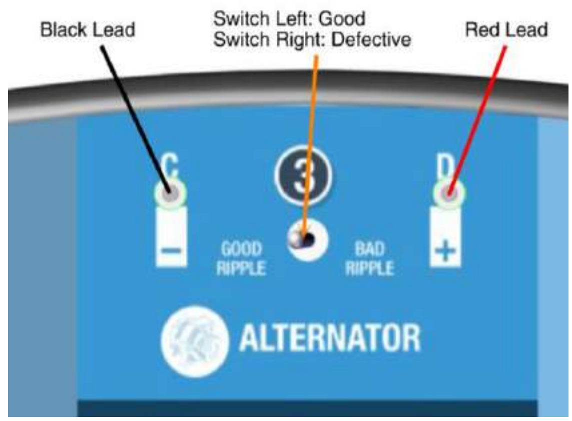



Figure 12

Flip the switch in section 3 of the MTU to the right. This will give a ripple value for a defective alternator.

Record the DC reading: __________V

Record the AC reading: __________V

Notice that when the switch is to the left, the DC reading is approx. 14.2 volts, which indicates good regulation and the AC reading is about .2 volts, which indicates good diodes.

When the switch is to the right, the DC reading is approx. 13.7 volts, which indicated low regulation, and the AC reading is about 0.7 volts, which indicates a bad diode.

Remember: When conducting this test on a vehicle, make sure the alternator is loaded and producing at least ½ of its output in amps. This can be accomplished by turning on some of the electrical loads, such as head lights, blower, etc. Alternators that are producing little or no output may show an artificially low ripple.

## Key Take-Aways:

- Alternators produce DC power
- A good alternator outputs approx. 14.2 volts
- Alternator ripple voltage is measured in AC volts
- Alternator ripple voltage must be measured while the alternator is under load
- A high AC ripple (over 0.5 volts AC) indicates an alternator that is faulty and will not be capable of producing full output

## 4. FREQUENCY

Purpose:
This section will explain electrical frequency and show how to measure it.

Frequency:
Frequency is the number of times a signal cycles from high to low each second and is measured in hertz (Hz). A period is the time required to produce one complete cycle of a waveform. There are various waveforms of electrical signals; the most common are sine waves and square waves.

At its most basic, frequency is how often something repeats. In the case of electrical signals, frequency is the number of times a waveform repeats.

Here are some common frequency ranges:

Power line frequency in the U.S.: 60 Hz.

Audio frequency: 15 Hz to 20 kHz (the range of human hearing).

Radio frequency: 20 kHz to 300 GHz.

Example: If an alternating current is said to have a frequency of 3 Hz (see Figure 13), that indicates its waveform repeats 3 times in 1 second.

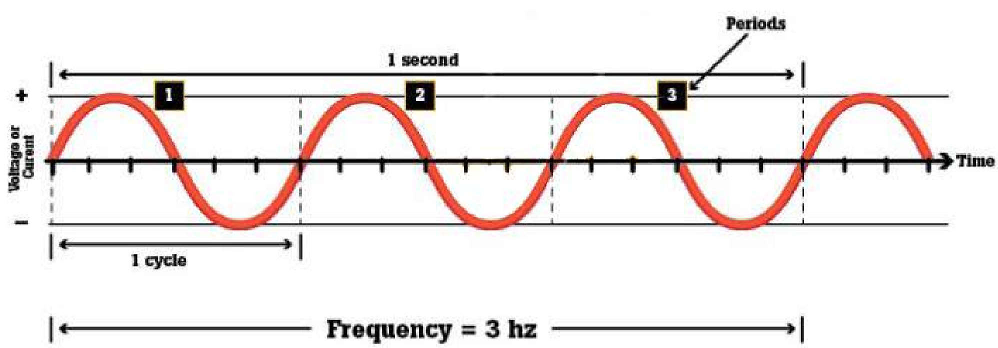



Figure 13

## How it works:

To measure frequency on the MTU, adjust the multimeter to the frequency (Hz) setting by (see Figure 14):

- Setting the meter selection knob to HZ%
- Use the MODE button to set Hz on the display

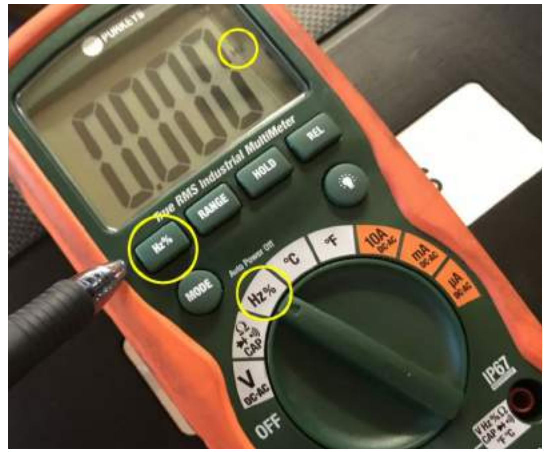



Figure 14

The Hz button on the multimeter also has a % setting. When on this setting, the reading shows the duty cycle of the signal. See section 7 for more information about duty cycle.

Some sensors on commercial vehicles produce waveforms. For example, the speed sensor may produce a signal that increases in frequency as the speed of the vehicle increases.

Section 4 of the MTU has two different frequencies that can be measured. To do this, touch the black lead to contact point COMMON GROUND and the red lead to point (E) (see Figure 15). Move the red lead to contact point (F) to measure the other signal.

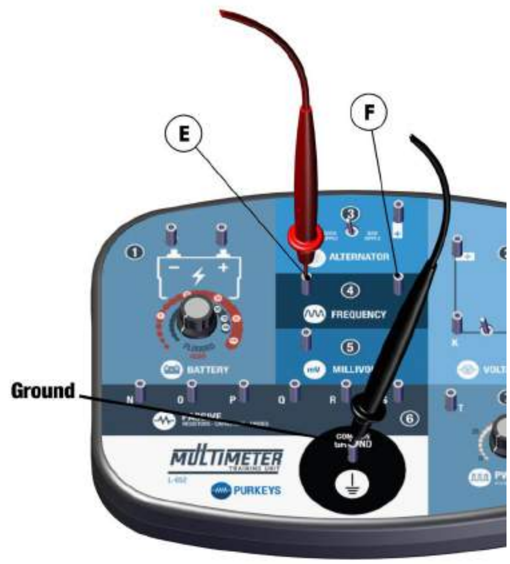



Figure 15

## Let's try it!

Place the black lead on the COMMON GROUND point. Place the red lead on point (E) and record the readings (see H1 on Figure 16):

________________Hz

Place the black lead on the COMMON GROUND point. Place the red lead on point (F) and record the readings (see H2 on Figure 16):

________________Hz

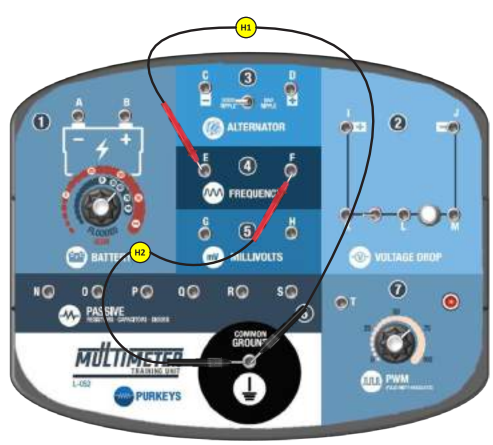



Figure 16

Notice that the frequency at point (F) is about two times the frequency of point (E). Also, note that if there is a K on the display, the reading is multiplied by 1,000.

Key Take-Aways:

- Frequency is the number of cycles per second
- To measure frequency, the mode must be in Hz on the display
- AC powerline frequency in the U.S. is 60 Hz
- Some sensors on commercial vehicles produce signals at various frequencies and duty cycles

## 5. MILLIVOLT MEASUREMENT

Purpose:
This section will explain millivolt measurements. On a commercial vehicle, being able to measure millivolts is sometimes useful when measuring small signals from sensors.

Millivolt:
A millivolt is 1/1000 of a volt, or 0.001 volts. Millivolts are displayed on the meter as mV.

Understanding millivolt or voltage readings can sometimes be confusing, especially with an auto-ranging function on the multimeter that automatically changes the scale from volts to millivolts. Whenever measuring voltage, pay close attention to whether the meter displays mV or V on the right side of the display. Millivolts can be measured on both AC and DC voltages.

The reason you would use the millivolt scale on a vehicle is to get better resolution of very small voltage readings. If the reading on the meter is not stable, or the decimal place keeps moving, you can use the RANGE button to fix the range. For small voltages, the meter will automatically adjust the range to measure the small signals.

If you exceed the range the meter is set to, the meter will display OL for Over Limit. This will not damage the meter, just remember that OL means you are measuring a voltage that exceeds the range of your meter. If this happens, simply press the RANGE button to adjust the range, or turn the meter selection knob to OFF, then back to voltage. The meter is now on auto-ranging and will measure the voltage in the correct range.

How it works:
To measure millivolts, set up your multimeter:

- Red lead in the top right jack
- Black lead in the bottom jack (COM)
- Turn selection knob to V
- Press MODE button to select DC
- Use range to move to mV scale


Figure 17

Section 5 of the MTU has two different millivolt signals that can be measured. To do this, touch the black lead to contact point COMMON GROUND and the red lead to point G (see Figure 18). Move the red lead to contact point H to measure the other signal.

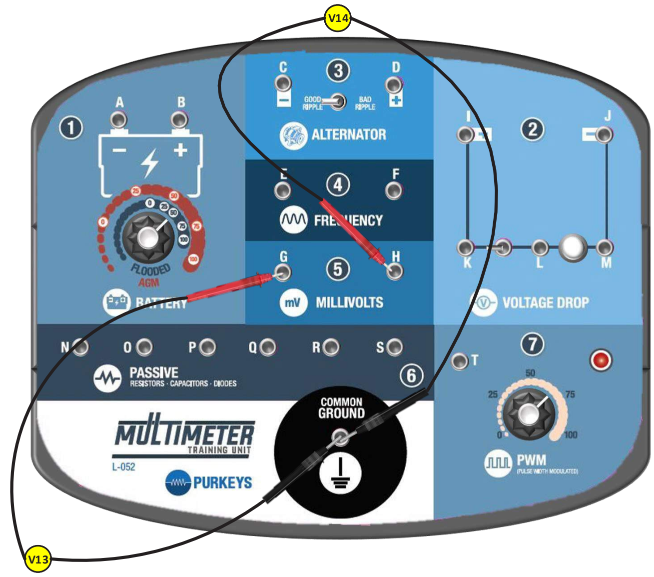



Figure 18

## Let's try it!

Place the black lead on the COMMON GROUND point. Place the red lead on point G (see V13 on Figure 18).

Measure the voltage __________________mV

Place the black lead on the COMMON GROUND point. Place the red lead on point H (see V14 on Figure 18).

Measure the voltage __________________mV

Remember: When mV shows on the right side of the display, the value displayed is millivolts. To convert that to volts, divide by 1,000. For example, if the meter reads 192.5 mVolts, this is equivalent to 0.1925 volts.

## Key Take-Aways:

- 1 mV is 0.001 volts
- 59 mV would be 0.059 volts
- If mV range is exceeded while on the manual mV range, the meter will display OL for Over Limit
- If the multimeter is on auto-range and the measurement exceedes the mV range, it will automatically move to a higher voltage range
- Use mV to measure very small voltages

# 6. PASSIVE: RESISTANCE, CAPACITANCE, DIODES

Purpose:
This section will explain how to use a multimeter to measure passive components. Each component will be explained separately.

Passive:
Passive components are components such as resistors, capacitors, and diodes. Passive components should be measured outside of a circuit, independently, so the reading isn't affected by the rest of the circuit. In these tests, the multimeter provides the power (from the internal 9-volt battery) for testing.

Sections on resistance, capacitance, and diode testing are included on the following pages.

## Resistance

Purpose:
Explain what resistance is and how to measure it.

Resistance:
The resistance of an electrical conductor is a measurement of the difficulty to pass current through that conductor. The unit of measurement is an Ohm (Ω).

The Ohmmeter in most multimeters will measure resistance from about 0.1 to 40,000,000 Ω. Since the meter cannot show all the zeros, it uses symbols to indicate the resistance measured in Ohms. M Ω means the value displayed must be multiplied by 1,000,000. Another way to explain is that if the meter reads 5.86 MΩ, this means the decimal point needs to be moved six places to the right. The reading represents 5,860,000 Ω. If the meter reads 5.367 kΩ, this means the value should be multiplied by 1,000. Again, another way to explain is that 5.367 k Ω is 5,376 Ω. If the meter reads 35.8 Ω and has no "M" or "k" before the Ω symbol, the meter is displaying the Ohms, 35.8 Ω.

When measuring resistance, the circuit should not be powered at all. The meter's battery provides the power for testing. Do NOT TEST in a "LIVE" circuit powered by a battery in the system. Also, polarity does not matter (it doesn't matter which side of the resistor the black and red leads are touching, as long as they are on opposite sides—it doesn't work if they are next to each other).

NOTE: A typical multimeter cannot be used to measure resistance below 0.1 Ω. The resistance from the battery to the starter is typically less than .0005 Ω. To measure very low resistance, different equipment must be used. For example, a carbon pile could be used to draw 500 amps from the battery to the starter post, then the voltage across the positive cable could be measured. The resistance would be equal to the voltage drop divided by the current.

PURKEYS

## How it works:

To measure resistance, set up your multimeter (see Figure 19):

- Red lead in the top right volt plug
- Black lead in the bottom plug (COM)
- Selection knob to Ω

Figure 19

On Section 6 of the MTU, there are three resistors. One is located between (N) and COMMON GROUND, the second is between (O) and COMMON GROUND, and the third is between (P) and COMMON GROUND.

## Let's try it!

Remember, when measuring resistance, the circuit should not be powered.

Place the black lead on the COMMON GROUND point. Place the red lead on point (N) (see R1 on Figure 20).

Record the value shown on the meter display: __________

How many Ohms does this number represent: __________

Place the black lead on the COMMON GROUND point. Place the red lead on point (O) (see R2 on Figure 20).

Record the value shown on the meter display: __________

How many Ohms does this number represent: __________

Place the black lead on the COMMON GROUND point. Place the red lead on point (P) (see R3 on Figure 20).

Record the value shown on the meter display: __________

How many Ohms does this number represent: __________

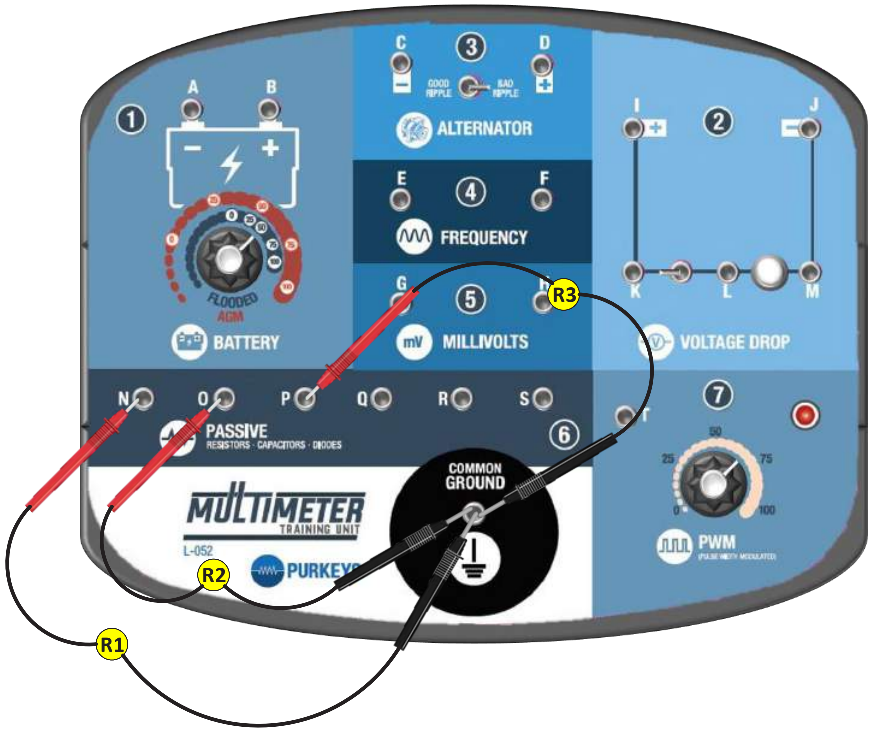



Figure 20

Key Take-Aways:

- Do not attempt to measure resistance in a live circuit
- Resistance values can be measured from about 1 to 40 M Ω
- M Ω means 10 to the 6th power or 1,000,000
- k Ω means 10 to the 3rd power or 1,000
- Multimeters cannot be used to measure very low resistance, such as the resistance of sections of wire or cable

NOTE: See our Meter Reference Sheet in the Appendix for more details.

## Capacitance

Purpose:
Explain what capacitance is and how to measure it.

Capacitance:
Capacitance is the ability of a device to store electrical charge. Capacitors are used on almost all printed circuit boards. The unit of measurement of capacitance is a farad (F). Farads are typically measured in the following:

- Millifarad is 10 to the minus 3rd power (mF) 0.001
- Microfarad is 10 to the minus 6th power (uF) 0.000001
- NanoFarad is 10 to the minus 9th power (nF) 0.000,000,001

Most capacitors are small and are measured in uF and nF.

## How it works:

To measure capacitance, set up your multimeter (see Figure 21):

- Red lead in the top right volt plug
- Black lead in the bottom plug (COM)
- Selection knob to CAP
- Use mode button to display nF


Figure 21

On Section 6 of the MTU, there are two capacitors. One is located between (R) and common ground, and the second is between (S) and common ground.

## Let's try it!

NOTE: While making these measurements, you will want to give your multimeter a little time to stabilize.

Place the black lead on the COMMON GROUND point. Place the red lead on point (R) (see C1 on Figure 22).

Measure and record the reading: _______________

Place the black lead on the COMMON GROUND point. Place the red lead on point (S) (see C2 on Figure 22).

Measure and record the reading: _______________

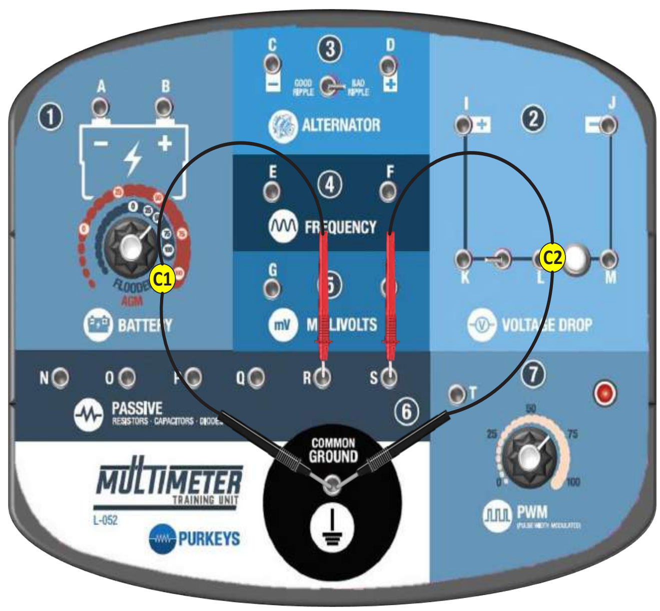



Figure 22

## Key Take-Aways:

- On vehicles, capacitors are rarely seen except on printed circuit boards

## Testing Diodes

Purpose:
Explain what a diode is and how to determine whether it is good or bad.

Diodes:
A diode is a semi-conductor that works like an electrical one-way check valve; it only allows current to flow in one direction.

A multimeter with a diode setting can determine the condition of a diode:

- A good diode will only let current flow in one direction.
- A shorted diode will allow current to flow in both directions.
- An open diode will not allow current to flow in either direction.

When using the diode setting, you are measuring the voltage drop across the diode.

For a typical, good diode, the meter will read between 0.3 to 0.7 volts across the diode when the red lead is placed on the anode (+) and the black lead is placed on the cathode (-) (see Figure 23). The multimeter will read OL if the leads are reversed.

For a shorted diode, the meter will read a value near 0.0 volts in both directions.

For an open diode, the meter will read OL in both directions.

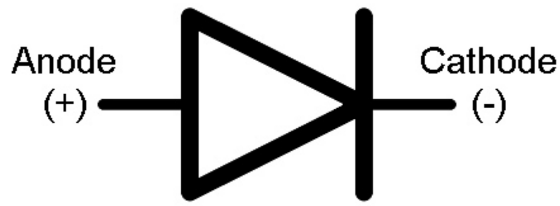


Figure 23

How it works:
To test diodes, set up your multimeter (see Figure 24):

- Red lead in the top right volt plug
- Black lead in the bottom plug (COM)
- Selection knob to Ω
- Use MODE button until the diode symbol displays on the screen

Figure 24

On Section 6 of the MTU, there is one diode. It is located between (Q) and common ground.

## Let's try it!

Place the black lead on the COMMON GROUND point. Place the red lead on point (Q) (see D1 on Figure 25).

What does the screen display?: _________

Place the red lead on the COMMON GROUND point. Place the black lead on point (Q) (see D2 on Figure 25).

What does the screen display?: _________

Based on your testing, which way would current flow?

(Q) to COMMON GROUND or COMMON GROUND to (Q)? _________________

Which terminal of the diode is connected to (Q)?

Anode or Cathode? _________________

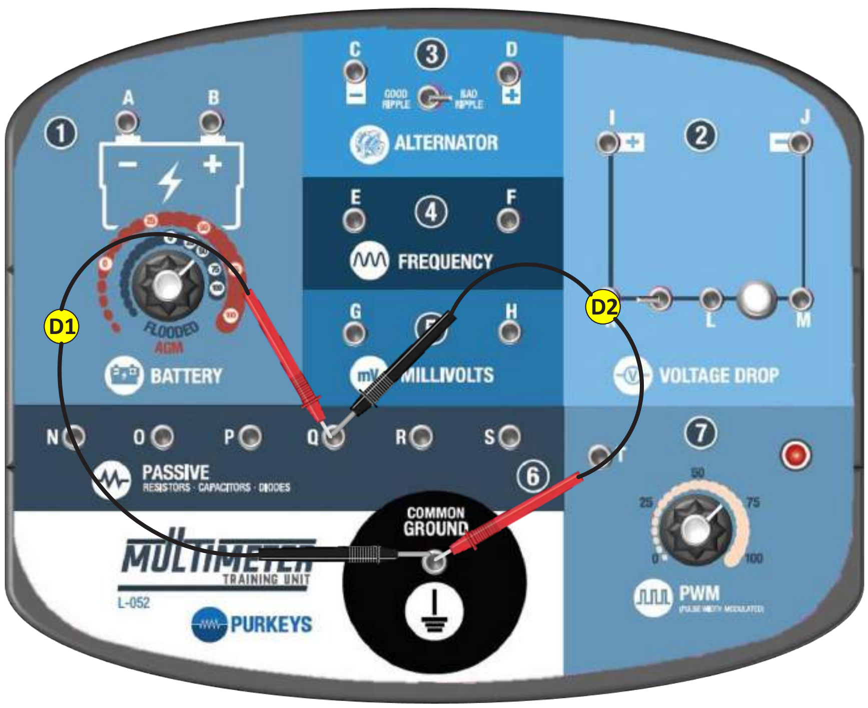



Figure 25

## Key Take-Aways:

- Diodes are like one-way electrical valves
- Diodes must be tested in both directions
- You must have the diode symbol showing on the multimeter display before testing diodes
- An OL reading both ways means the diode is open
- A zero reading both ways indicates a shorted diode

# 7. PULSE WIDTH MODULATED SIGNAL

Purpose:
To explain what a pulse width modulated signal looks like, and show how to measure the signal.

Pulse Width Modulation:
Pulse width modulated (PWM) signals are being used more and more on vehicles to control electrical components such as lights and electric motors. PWM is an electrical signal consisting of a square wave of fixed frequency. Because of the square wave patterns, the signal can be used to precisly power components. The percentage of on time is called the duty cycle (see Figure 26).

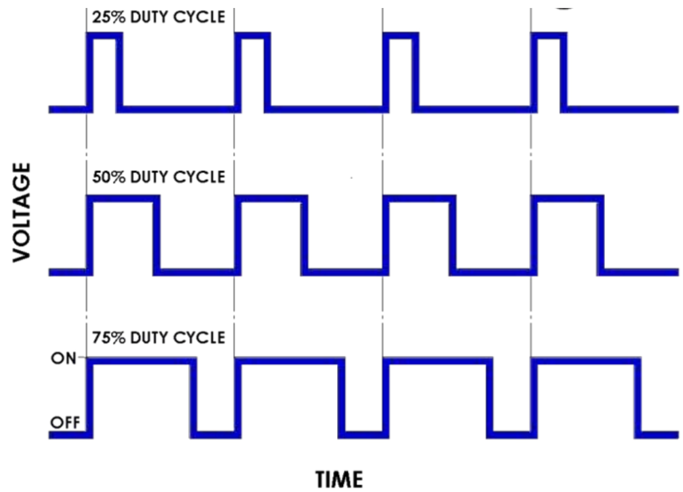



Figure 26

How it works:
To measure the duty cycle of a PWM signal, set up your multimeter (see Figure 27):

- Red lead in the top right volt plug
- Black lead in the bottom plug (COM)
- Selection knob to Hz%
- Push Hz% button until % is displayed

To measure the frequency of a signal, change your multimeter by pressing the Hz% button until Hz is displayed.

Figure 27

Section 7 of the MTU has a PWM signal (point (T)), an adjustable knob to change the duty cycle of the PWM signal, and a light.

The signal can be adjusted between 0% and 100%. As the % increases, the red light gets brighter, indicating that more power is going to the light.

## Let's try it!

- Place the black lead on the COMMON GROUND point.
- Place the red lead on point (T) (see P1 on Figure 28).
- Adjust the knob to change the duty cycle of the signal

With the knob to the far left (0) and the light very dim or off, measure and record the value: ______________

Turn the knob to the right (25), record the value: ___________

Turn the knob to the right (50), record the value: ___________

Turn the knob to the right (75), record the value: ___________

Now turn the knob all the way to the right (100) and record the value: _________________

Notice how the light gets brighter as the knob is turned to the right, or as the duty cycle increases.

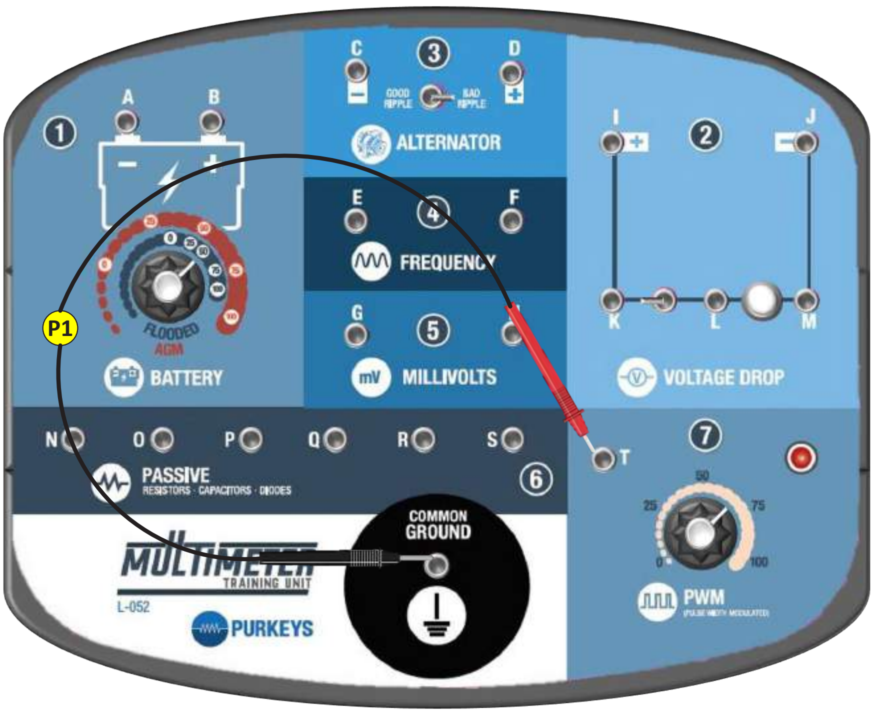



Figure 28

## Key Take-Aways:

- PWM is an electrical signal consisting of a square wave of fixed frequency
- The percentage of on-time is called the duty cycle
- A PWM signal can precisely control a signal
- A PWM signal is a square wave with a varying duty cycle
- Duty cycle (% of time on) can be measured with a multimeter

# 8. DC CURRENT MEASUREMENT

## Purpose:

The measurement of current is very important when working on electrical systems. This section will explain what current is and how to use the in-line ammeter in the multimeter.

## Current Measurement:

Current is the flow of electrons in an electrical circuit. To have current flow, there must be voltage to push the current and a complete circuit for current to flow through. Remember that whatever current leaves the battery(s) must come back to the battery(s). The unit of measurement is an ampere.

An ammeter is used to measure current. In this section, we will show how to use the in-line ammeter. Normally, in-line ammeters have two settings: a 10 amp and a 400 mAmp setting. Before testing the circuit for current flow, you must insure that the fuses in your meter are functioning (see page 7).

## How it works:

To measure the current in the 10A scale, set up your multimeter (see Figure 29):

- Red lead in the top left jack
- Black lead in the bottom right jack (COM)
- Selection knob to 10 A
- Push MODE button until DC is displayed

Figure 29

The current is measured by using Section 2 of the MTU. Flip the switch to the left, and the LED light will go out (see Figure 30).

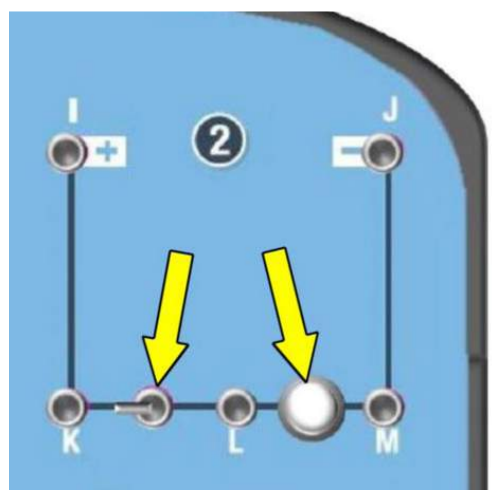



Figure 30

Now, if you place the red lead on post (K), and the black lead on post (L), the blue light should illuminate (see Figure 31). This is because there is now a current path around the switch. The in-line ammeter provides the path for the current to flow around the switch.

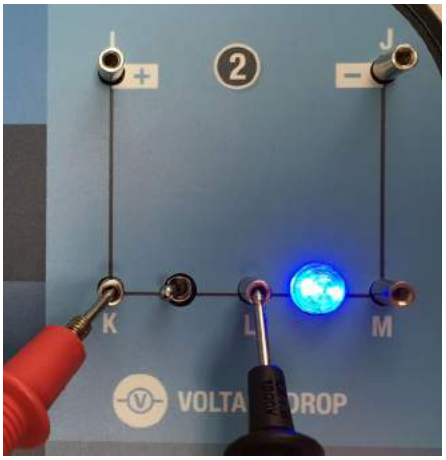



Figure 31

## Let's try it!

Place the red lead on post (K) and the black lead on post (L). Since the light is on, you can see that current is flowing.

Record the reading on the multimeter: ___________________

Because this amp value is very low, you can get much better resolution on the lower scale. The lower scale on this multimeter is 400 mAmps. 400 mAmps is 0.400 amps. Let's see what happens when we change the multimeter settings:

To measure the current in the mA scale, set up your multimeter (see Figure 32):

- Red lead in the bottom left jack
- Black lead in the bottom right jack (COM)
- Selection knob to mA
- Push MODE button until DC is displayed

Figure 32

## Let's try it!

Once again, place the red lead on post (K) and the black lead on post (L). The blue light should illuminate, so you know current is flowing.

Record the reading on the multimeter: ___________________

How many amps does the reading on the display represent? ___________________

Key Take-Aways:

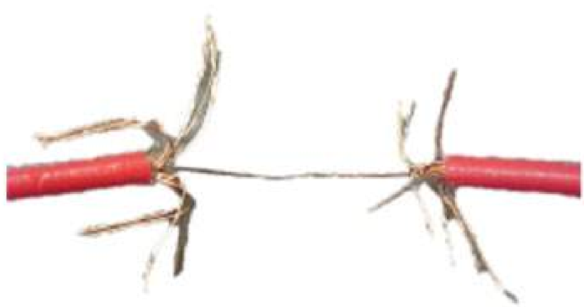
- Current flow is measured in amps
- mAmp is 0.001 of one amp
- You must have complete circuit to measure current
- You must have voltage in order for current to flow
- In-line meters are limited to the current rating on the meter
- Excessive current will cause the fuse to blow
- An in-line ammeter must be placed in series with the circuit being measured

## 9. CONTINUITY TESTING

Purpose:
To show what continuity test does and highlight some of the weaknesses of this test.

Continuity Testing:
When testing continuity, you are connecting the circuit or device to the 9-volt battery in the multimeter via the red and black leads. If the circuit or device will allow this low current to flow from the red lead though the circuit or device back to the meter via the black lead, the meter will beep, indicating there is continuity.

If checking a wire, the beeping does not indicate the wire is good and can handle the load it needs to handle. The beep is simply saying that at least one strand is still intact.



Testing for continuity does give you an indication of the wires ability to carry current. An example of a good use for a continuity test is when you have a circuit that blows a fuse as soon as you turn it on. On the wire diagram, the positive wire goes directly to the device from the fuse. This positive wire should not be connected to ground. When you touch the wire with the red lead and then touch the black wire to ground, and the meter beeps, this means the positive wire is ground somewhere between the fuse and the device the positive lead is connected to. If the meter does not beep, it is not grounded.

## How it works:

To test continuity, set up your multimeter (see Figure 33):

- Red lead in the top, right jack
- Black lead in the bottom right jack (COM)
- Selection knob to Ω
- Push MODE button until the sound symbol is displayed
- Touch the leads together; the meter should beep

Figure 33

If you place the black lead on the COMMON GROUND post and touch the other posts on the MTU with the red lead, you will notice that only some of them cause the meter to beep. Those that beep have continuity with the common ground.

## Let's try it!

Place the black lead on the COMMON GROUND post and touch the other posts on the MTU, one at a time, with the red lead (see Figure 34).

List the posts that beep: ______________________________


Figure 34

Key Take-Aways:
- Continuity testing only shows the circuit is complete
- Continuity testing does not mean the circuit is good
- Beep sound means the circuit is complete
- Continuity testing should not be used in a live circuit

# APPENDIX

## Using HOLD Button

If you have a reading on the display that you need to use as a reference, you can press HOLD and the display will freeze the reading on the display. Once you are done refering to that reading, press the HOLD button again, and it will unfreeze.

## Using REL Button

The relative measurement (REL) feature lets you make measurements relative to a stored zero reference value. A reference voltage or current can be stored and measurements can be made in comparison to that value. The displayed value is the difference between the reference value and the measured value.

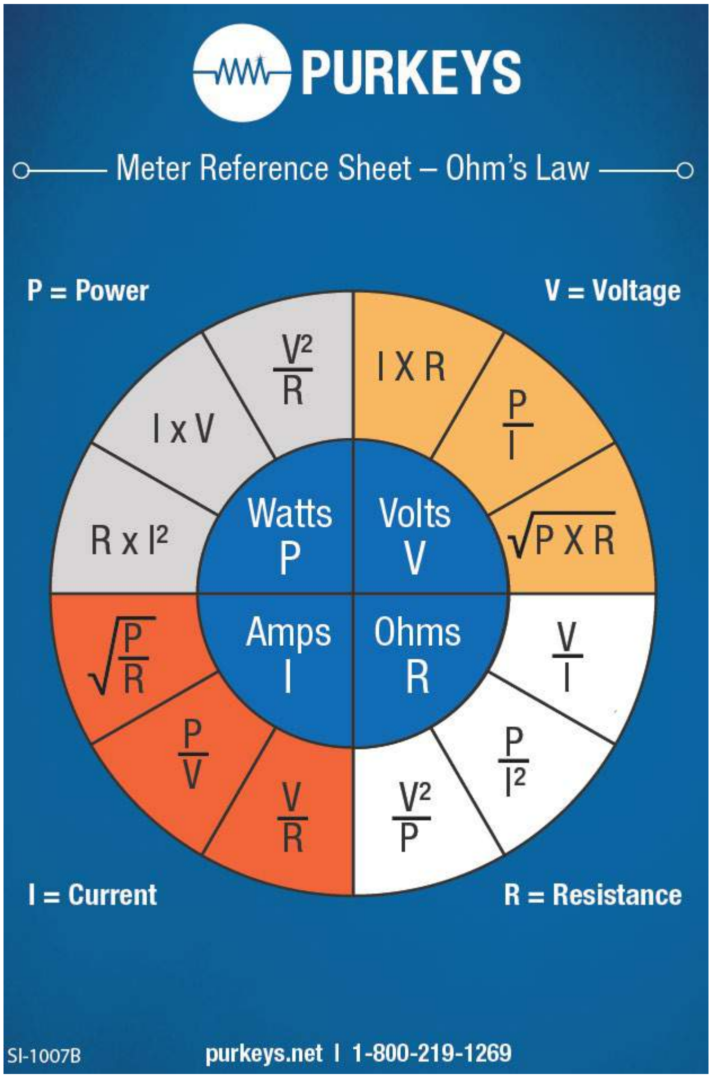
- Take a measurement as described in the other sections of this workbook.
- Push the REL button to store (zero) the reading on the display and the REL indicator will appear on the display.
- The display will now indicate the difference between the stored value and the measured value.
- Push the REL button to exit the relative mode.

NOTE: the relative function does not operate in the Frequency function.

## Temperature

Purkeys Electrical Tool Kit includes a temperature probe that can be used with your multimeter to measure temperature.

## Meter Reference Sheet




PURKEYS

Meter Reference Sheet

| | |
|---|---|
| $X > 10$ | Value of x is greater than 10 |
| $X < 10$ | Value of x is less than 10 |
| $X \geq 10$ | Value of x is equal to or greater than 10 |
| $X \leq 10$ | Value of x is equal to or less than 10 |

**Voltage Drop Calculations**

m = Thousandth Part ..... $10^{-3}$ (.000)

**Voltage and Amperage Calculations**

k = Thousand Fold ..... $10^3$ (1,000)

M = Million Fold ..... $10^6$ (1,000,000)

**Examples**

| | | | | | | |
|---|---|---|---|---|---|---|
| 3.15 MΩ | = | 3.15 Ω | x | $10^6$ | = | 3,150,000 Ω |
| 0.85 MΩ | = | 0.85 Ω | x | $10^6$ | = | 850,000 Ω |
| 21.02 MΩ | = | 21.02 Ω | x | $10^6$ | = | 21,020,000 Ω |
| 26.32 kΩ | = | 26.32 Ω | x | $10^3$ | = | 26,320 Ω |
| 2.156 kΩ | = | 2.156 Ω | x | $10^3$ | = | 2,156 Ω |
| 0.952 kΩ | = | 0.952 Ω | x | $10^3$ | = | 952 Ω |
| 3.4 Ω | = | 3.4 Ω | x | 1 | = | 3.4 Ω |
| 28.6 Ω | = | 28.6 Ω | x | 1 | = | 28.6 Ω |

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## Answer Key

NOTE: The MTU can be configured with different values. Answers included in this section are for default settings. Answers may vary slightly, due to differences in the multimeter or MTU.

Page 17:

| | Flooded | AGM |
|---|---|---|
| 25% | 12.09 V | 11.80 V |
| 50% | 12.27 V | 12.16 V |
| 75% | 12.51 V | 12.55 V |
| 100% | 12.69 V | 12.86 |

Page 21:

V2 (I to J) ____12.96___V

V3 (I to K) ____3.23____V

V4 (K to L) ____0______V

V5 (L to M)____6.51____V

V6 (M to J) ____3.217___V

Page 22:

| | Projected | Measurements |
|---|---|---|
| V7 | __________V | ____13.01___V |
| V8 | __________V | ____9.77____V |
| V9 | __________V | ____9.77____V |
| V10 | __________V | ____3.23____V |
| V11 | __________V | ____0.0_____V |

Page 25:

V2 (I to J) ____13.01___V

V3 (I to K) ____13.01___V

V4 (K to L) ____0.00____V

V5 (L to M)____0.00____V

V6 (M to J) ____0.00____V

Page 26:

| | Projected | Measurements |
|---|---|---|
| V7 | __________V | ____13.01___V |
| V8 | __________V | ____13.01___V |
| V9 | __________V | ____0.00____V |
| V10 | __________V | ____0.00____V |
| V11 | __________V | ____0.00____V |

Page 31:

Value for a good alternator.

Record the DC reading: ____14.20_V

Record the AC reading: ____0.2___V

Value for a defective alternator.

Record the DC reading: ___13.7___V

Record the AC reading: ___0.9____V

Page 35:

H1:

______1.191______Hz

H2:

______2.382______Hz

Page 39:

V13:

Measure the voltage ____32.3_______mV

V14:

Measure the voltage ____202.7______mV

Page 42:

R1:

Record the value shown on the meter display: __1.985___

How many Ohms does this number represent: _1985000_

R2:

Record the value shown on the meter display: __1.983__

How many Ohms does this number represent: __1983___

R3:

Record the value shown on the meter display: __20.1__

How many Ohms does this number represent: __20.1___

Page 45:

C1:

Measure and record the reading: ____2.900_______

C2:

Measure and record the reading: ____0.900_______

Page 48:

D1:

What does the screen display?: __OL______

D2:

What does the screen display?: ___0.536_

(Q) to GROUND or GROUND to (Q)? _GROUND to Q__

Anode or Cathode? _____Cathode____

Page 52:

Turn the knob to the right (25), record the value: __1.5______

Turn the knob to the right (50), record the value: __25_______

Turn the knob to the right (75), record the value: __50_______

Now turn the knob all the way to the right (100) and record the value: ______99.9________

Page 55:

Record the reading on the multimeter: ____0.069_________

Page 56:

Record the reading on the multimeter: ____65.85_________

How many amps does the reading on the display represent? ________0.066_______

Page 58:

List the posts that beep: _____A, C, J_____________

PURKEYS

# NOTES

# LIMITED COMMERCIAL WARRANTY POLICY

MCE Purkeys FE, LLC (hereafter "Purkeys"), warrants each product to be free of defects in material or workmanship under normal use and service. This warranty is for the benefit of Original Equipment Manufacturers, Dealers, Warehouse Distributors, Fleets, or other End Users (hereafter "Customers") and covers products manufactured by Purkeys and sold new to Customers either directly by Purkeys or by its authorized dealers, distributors, or agents. The length of the Warranty Period is 36 months.

The warranty period commences on the in-service or install date and is not transferable. Failure to provide the in-service or install date on the warranty claim form will cause the warranty period to begin on the date the part was manufactured, or date of sale recorded on the original sales invoice, whichever is earlier.

A completed warranty claim form should accompany all parts submitted to Purkeys for consideration for repair or replacement under warranty. The submitted claim form should contain all of the information required. Lack of a properly or fully completed claim form will result in delay or denial of warranty claim. Claims must be submitted no later than 30 days after part is removed.

This warranty does not apply if, in sole judgement of Purkeys, the product has been damaged or subjected to accident, faulty repair, improper adjustment, improper installation or wiring, neglect, misuse, or alteration or if the product failure is caused by defects in peripheral vehicle components or components attached to the Product or failure of a part not manufactured by Purkeys.

This warranty shall not apply if any Purkeys product is used for a purpose for which it is not designed or is in any way altered without the specific prior written consent of Purkeys. ANY product alleged by a Customer to be defective must be inspected by Purkeys as a part of the warranty claims process in order to confirm that the part has failed as a result of a defect in material or workmanship.

Transportation for products and parts submitted to Purkeys for warranty consideration must be prepaid by Customer. Repaired or replaced products and or components will be returned to Customer pre-paid by Customer or "freight collect" to the address provided by Customer in the warranty claim form. No charge will be made for labor or material in effecting such repairs.

The Warranty provided by Purkeys hereunder is specifically limited to repair or replacement of the Product as Purkeys deems most appropriate in its sole discretion. Purkeys neither assumes nor authorizes any other person to assume on its behalf any other warranty or liabilities in connection with Purkeys products. The Warranty does not apply to fuses or other "consumable" or maintenance items which are or may be a part of any Purkeys product.

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