HANDS-ON LAB INSTRUCTION SHEET – MODULE 2

VOLTAGE SOURCES, LEDS, DIODES & CHARACTERISTIC CURVES

NOTES:
1) To conserve the life of the Multimeter's 9 volt battery, be sure to turn the meter off if not in use for over 5 minutes.
Always double check that the multimeter is off when finishing your work, or leaving class.
2) ***All work is to be done individually***.
All results are to be written on these sheets AND on the Results Sheet(s) which should be submitted before you leave, finished or not, each class. Always keep these Instruction sheets on file for review. There are no "lab reports" in this course – only handed in results sheets.
3) ***If you did not finish Module 1, be sure to finish it NOW*** *before starting this Module or you will fall behind the rest of the class.* ***Labs need to be done in order.***

BILL OF MATERIALS

Radio Shack Electronic Learning Lab Console , AC Adapter (*9 volts at 150 mA*), Digital Multimeter, Wire Stripper, Miscellaneous Connecting leads and wires (Standard for all labs)
(1) Green LED
(1) 1N4007 Rectifier Diode
(1) 100Kohm, ½ Watt Resistor *with color code:* ***brown black yellow gold*** (*100KΩ at 5%*)
(1) 10Kohm, ½ Watt Resistor *with color code:* ***brown black orange gold*** (*10KΩ at 5%*)
(4) 1000 Ohm, ½ Watt Resistors *with color code:* ***brown black red gold*** (*1KΩ at 5%*)

USING THE DIGITAL MULTIMETER

Although your digital Multimeter has many functions – it can operate as an AC (alternating current) or DC (direct current) Voltmeter for measuring *voltages across a device*, a DC Ammeter for measuring *currents through a device*, as an Ohmmeter for measuring the resistance of a device (*with the power OFF!*), a diode and transistor hFE gain checking device – we will only use it for DC voltage, resistance, and diode testing in this course.
Connect the **red** test lead to **VΩmA** jack and the **black** lead to **COM** jack.

Multimeter DC Voltage Measurement

- Set the rotary switch at the desired position. If the voltage to be measured is not known, set the range switch at the highest range (Left **BLUE** Scale) position and then reduce it until a satisfactory resolution is obtained.
- **Connect the test leads *across the source or load being measured***.
- Read the voltage value and polarity on the LCD display.

Multimeter Resistance Measurement

Note: If the resistor being measured is connected to a circuit, ALWAYS turn off power and discharge all capacitors before applying measurements!
The polarity of **red** lead is positive "**+**" in this mode.
- Set the rotary switch at desired resistance range (Lower Left **GREEN** Scale) position.
- ***Connect the test leads across the resistance to be measured*** and read the LCD display.

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Multimeter Diode Testing

The polarity of **red** lead is positive "**+**" in this mode.
- Set the rotary switch to diode test (*Lower Right **BLACK** Scale, diode symbol*).
- Connect the **red** lead to the anode of the diode to be tested and the **black** lead to the cathode – *silver band side* – of the diode.
- The ***forward voltage drop*** of the diode will be displayed in **mV**. For a **good diode** this is **500-800** and when the connection is reversed, only the figure "**1**" should be displayed. **Bad diodes** will have the same values in both directions: if shorted: a very low voltage drop (001-010) or if open a 1 at left of scale.

1. VOLTAGE SOURCES

NOTE: Your AC Adapter is an *unregulated* power supply.
To get a constant output voltage a regulated supply can be used. Later this semester we will use a voltage regulator to get a nearly constant 5.0 volts for varying loads.
1.1) Plug your adapter into the Console and then into the AC power strip.
1.2) Set your Multimeter on the "20" volts DC scale (upper left BLUE scales) and connect the **red** lead to one of the top left five 'unregulated voltage' connections and the **black** lead to one of the 30 'ground' connections on the Console Breadboard.
1.3. Turn the Console Power Switch at the top left to the **ON** position.

The AC adapter is rated at 9 volts DC at 150 mA.

1.a) What is the *'unloaded'* unregulated source voltage, **V**? _____ **volts**

1.4) Without disconnecting your meter, connect the **10K ohm potentiometer** in parallel across the power supply with a **red** wire between **Spring #37** and one of the remaining unregulated voltage connections and a **black** wire between **Spring #39** and a ground connection as seen in Figure 1.

1.b) What is the *'loaded'* unregulated source voltage, **V**?
_____ **volts**
Do NOT disconnect this circuit

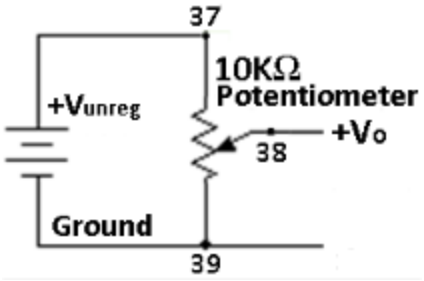

Figure 2.1. Variable Power Supply

2. CREATING A VARIABLE VOLTAGE SOURCE

The AC adapter has no controls to set its voltage. Its output voltage as seen above is controlled by the resistance of its load. The circuit of Figure 1 is often called a voltage divider since the voltage is divided across (in this simple case) two resistors or in the case of the potentiometer between **Spring #37 and #39** and **Spring #39 and #38**. If we connect between the **10K ohm potentiometer**'s variable wiper **Spring #38** and ground (**Spring #39**) by rotating the potentiometer's dial we can adjust the unloaded voltage $\mathbf{V_o}$ from zero to at least 10 volts.
2.1. Set the dial on the **10KΩ** potentiometer such that the DC Voltage between **Springs #38 and #39** is **5.0 (+/- 0.1) volts**. Turn **OFF** the power and without changing any wiring reset the Multimeter dial to read resistance on the **20K** scale (*lower left GREEN Scale*).

2.a) What is the *resistance of the potentiometer* for $\mathbf{V_o}$ **= 5.0 volts**? _____ **KΩ**
Return the Multimeter range dial to 20 volts DC before turning power back ON!

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THE LIGHT EMITTING DIODE
3. MEASURING THE VOLTAGES ACROSS LEDS

It is very common to use resistors in series with a device to reduce the overall voltage and current in a circuit. There are two **GREEN LED**s and one **RED LED** in your parts kit. We will insert these one at a time into our 3500 Ω resistor circuit and see what the voltage drop across an **LED** diode is in a working circuit. *This is NOT the same as a rectifier diode forward biased voltage drop as will become evident in the next section on Silicon Diodes*.

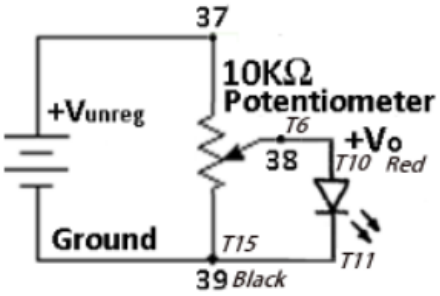

Figure 2.2. Variable Power Source and LED

3.1) With the **10KΩ** potentiometer still set such that the DC Voltage between **Springs #38 and #39** is **5.0 (+/- 0.1) volts**, connect a **black** wire from the ground or **Spring #39** to a convenient row of five connectors on the Breadboard (e.g., **T15**). Insert one of the **Green LEDs** into the Breadboard with the lead on its **FLAT** side in **T11** and the other lead in **T10**. Now take a **red** wire and connect it between **Spring #38** and connection **T6**. Turn **ON** the Power Switch and read the voltage **V_o** with an LED load.

3.a) What is the variable source voltage, **V_o** across the LED? _____ **volts**

3.b) Does the LED light up? _____ **Yes** _____ **No**

3.c) What is the lowest voltage, **V_o** across the LED for it to light up? _____ **volts**

This is instructor checkpoint 2A.

DIODES AND RECTIFIERS
4. THE FORWARD BIASED RECTIFIER DIODE

Turn OFF the Console and Multimeter. Remove the wires from Springs #37 and #38. Leave the **black ground** wire already connected to the **FLAT** side of the **Green LED** at **T11**. Wire the circuit of Figure 2.3 by removing the **red** power wire connected to **Spring #37** (at the potentiometer) and connecting it to a **red clip** lead. Connect a **1000 ohm** resistor between **T5** and **T9** as indicated. Put a **black** or **yellow** wire in **T3** and connect it to the black clip lead. Find the type **1N4007** silicon rectifier diode in the Pink Foam of your parts kit and connect it to the circuit using **red** and **black** colored clip leads as shown.

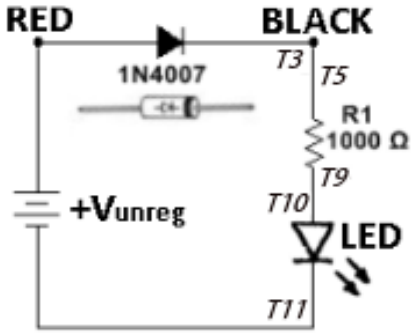

Figure 2.3. Forward Biased Diode

(*The diode is similar in size to your resistors, but it has a **BLACK body** on which there is a single **SILVER band** which indicates the diode's cathode.*) Make sure you connect the diode in the circuit with its **SILVER band** connected to the **black** clip lead.

4.a) Does the LED light? _____ **Yes** _____ **No**

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If the LED does NOT light, check your circuit for errors

4.2 Turn **ON** the Multimeter, use the **20** DC volts scale to make these measurements:

4.b) What is the voltage measured across the LED? _____ **volts**

4.c) What is the voltage measured across the diode? _____ **volts**

4.d) What is the voltage measured across the 1000 ohm resistor? _____ **volts**

4.e) What is the *'loaded'* unregulated source voltage, **V**? _____ **volts**

5. THE REVERSE BIASED DIODE

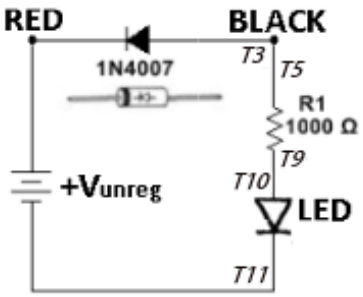

Fig 2.4 Reverse-Biased Diode

Turn OFF the Console and Multimeter.

5.1. Reverse the diode connections (*now the **silver** band should be connected to the **RED** wire*) creating the reverse-biased diode circuit of Figure 2.4

Turn ON the Console and Multimeter.

5.a) Does the LED light up? _____ **Yes** _____ **No**

5.b) Use your multimeter to measure the voltage across the reverse-biased diode: _____ **volts**

6. I-V CHARACTERISTIC CURVES

Diodes, LEDs and resistors have two connections and are called two-terminal devices. If we were to design circuits for their maximum efficiency we would do so using characteristic curves to match the device to the current (I) and voltage (V) available in a specific circuit. A circuit for measuring the current and voltage of a resistor, and its characteristic curve show the typical resistor to have a positive slope whose value is V/I – the device's resistance calculated according to Ohms Law!

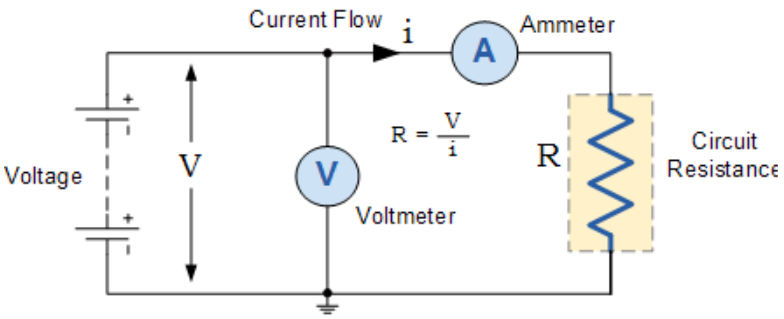

Fig 2.5 Characteristic Curve Measuring Circuit

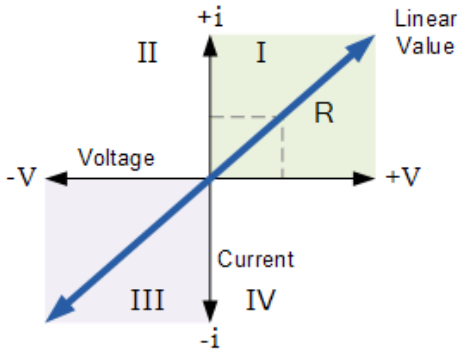

Fig 2.6 I-V Curve for a Resistor

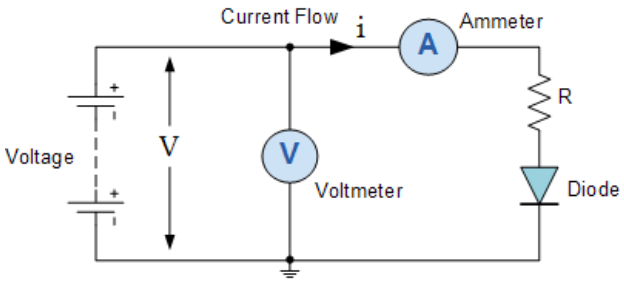

Fig 2.7 Diode Characteristic Curve Circuit

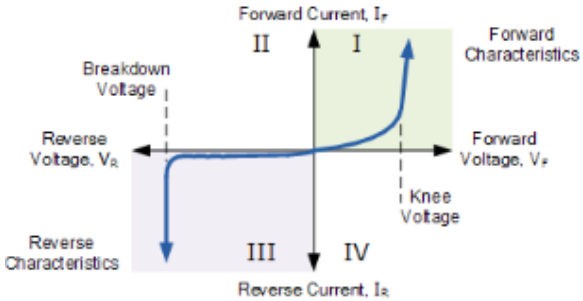

Fig 2.8 I-V Curve for a Diode

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Although the resistor's IV curve in Figure 2.6 is linear, Figure 2.8 shows that the curve for the diode is NOT linear. In fact the reverse-biased current is typically in microamperes until breakdown. Zener diodes are specifically designed diodes whose breakdown voltages are precise and usable in voltage regulators. Forward-biased silicon diodes have a knee in the range of 0.5-0.8 volts which must be accounted for in circuit calculations… We will use the value 0.6 volts for all silicon PN junctions.

6.1) Referring to Figure 2.9 we will measure the *voltage across* a type **1N4007** rectifier diode as a function of current. The "9 volt" AC adapter supply voltage when loaded yields about 13-16 volts. We will measure the diode voltage $\mathbf{V_d}$ directly across the diode and the resistor voltage directly across a known $\mathbf{R_1}$. KCL tells us that the diode current $\mathbf{I_d}$ is the same as the resistor current $\mathbf{I_R}$. Fill in the data for Table 2.1 (below) showing on each line the values for the resistance $\mathbf{R_1}$, and the measured voltages across the resistor and diode. Then calculate the current $\mathbf{I_R = I_d}$ in mA. The schematic symbol at the bottom of diode $\mathbf{D_1}$ in Figure 2.9 is called the "ground" or sometimes the "common ground" (*in this case it is the* ***BLACK LEAD*** *from the negative side of the power source connector*).

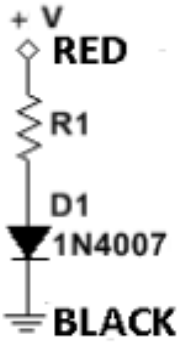


Fig 2.9. Diode Test Circuit

Use the following ½ watt resistors from the Pratt kit to create as the $\mathbf{R_1}$ in Figure 2.9: **100K Ω [brown black yellow gold]**; **10K Ω [brown black orange gold]**; (four each) **1K Ω [brown black red gold]**.
Use two (2) 1K resistors in parallel to create a ***500 Ω*** *resistance, use three (3) 1K resistors in parallel to create* ***333 Ω*** *and four (4) 1K resistors in parallel for* ***250 Ω.***

Enter your results, both measured and calculated, here on the Instruction Sheet for future reference, and on the Results page (which you hand in when completed.)

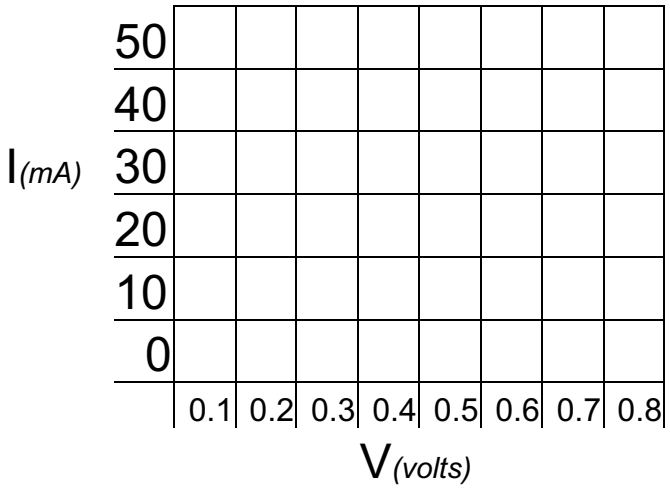
R_1	V_d diode voltage (measured)*	V_{R1} resistor voltage (measured)	$I_R = I_d$ current - mA (calculated)
100KΩ			
10KΩ			
1KΩ			
500 Ω *(2@1K)*			
333 Ω *(3@1K)*			
250 Ω *(4@1K)*			

NOTE: Whenever applying the equation **I = V/R** or
V = IR or **R = V/I** remember that
$\mathbf{V_R}$ is the ***voltage measured across*** resistor **R**
$\mathbf{I_d = I_R}$ is the ***current calculated through*** resistor **R**
When Resistance is in KΩ and Voltage is in volts, Current is in mA.

This is Instructor check point 2B.

6.2) *Plot the I-V Characteristic Curve for the* ***1N4007*** *diode.*

* *If the voltage measured across the* ***1N4007*** *diode is less than* ***0.45*** *volts or greater than* ***0.8*** *volts consult your instructor.* ***BEFORE you break the circuit apart, please have your instructor review your setup for the last data set of measurements - in case repeat measurements are needed.***



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RESISTOR NOTES AND COLOR CODE CHART

COMMONLY USED 5% CARBON FILM RESISTORS

1.0	2.4	5.6	13	33	75	180	430	1K	2.4K	5.1K	12K	30K	68K	160K	390K	910K	2.2M	5.1M
1.1	2.7	6.2	15	36	82	200	470	1.1K	2.7K	5.6K	13K	33K	75K	180K	430K	1M	2.4M	5.6M
1.2	3.0	6.8	16	39	91	220	510	1.2K	3K	6.2K	15K	36K	82K	200K	470K	1.1M	2.7M	6.2M
1.3	3.3	7.5	18	43	100	240	560	1.3K	3.2K	6.6K	16K	39K	91K	220K	510K	1.2M	3M	6.8M
1.5	3.6	8.2	20	47	110	270	620	1.5K	3.3K	7.5K	18K	43K	100K	240K	560K	1.3M	3.3M	7.5M
1.6	3.9	9.1	22	51	120	300	680	1.6K	3.6K	8.2K	20K	47K	110K	270K	620K	1.5M	3.6M	8.2M
1.8	4.3	10	24	56	130	330	750	1.8K	3.9K	9.1K	22K	51K	120K	300K	680K	1.6M	3.9M	9.1M
2.0	4.7	11	27	62	150	360	820	2K	4.3K	10K	24K	56K	130K	330K	750K	1.8M	4.3M	10M
2.2	5.1	12	30	68	160	390	910	2.2K	4.7K	11K	27K	62K	150K	360K	820K	2M	4.7M	

OHM'S LAW FORMULAS FOR D-C CIRCUITS

$$I = \frac{E}{R} = \sqrt{\frac{P}{R}} = \frac{P}{E} \; ; \; R = \frac{E}{I} = \frac{P}{I^2} = \frac{E^2}{P}$$

$$E = IR = \frac{P}{I} = \sqrt{PR} \; ; \; P = I^2R = EI = \frac{E^2}{R}$$

RESISTORS IN SERIES

$$R_{total} = R_1 + R_2 + R_3 \cdots$$

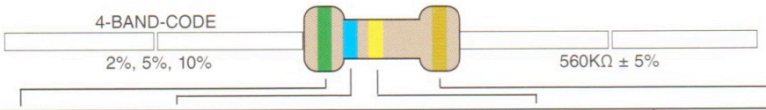
RESISTORS IN PARALLEL, GENERAL FORMULA

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots}$$

CONVERSION FACTORS

1 meter = 39.37 inches = 3.28 feet
1 kilometer = 0.621 mi. (app. 3/5 mi.)
1 inch = 2.54 centimeters
1 kilogram = 2.2 pounds
1 liter = 1.06 quarts
1 ounce = 28.35 grams
1 horsepower = 746 watts
1 horsepower = 42.4 BTU min
1 radian = 57.3°

Electronix Express / RSR **REFERENCE GUIDE** **1-800-972-2225**



COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE	
BLACK	0	0	0	1Ω		
BROWN	1	1	1	10Ω	± 1%	(F)
RED	2	2	2	100Ω	±2%	(G)
ORANGE	3	3	3	1KΩ		
YELLOW	4	4	4	10KΩ		
GREEN	5	5	5	100KΩ	±0.5%	(D)
BLUE	6	6	6	1MΩ	±0.25%	(C)
VIOLET	7	7	7	10MΩ	±0.10%	(B)
GREY	8	8	8		±0.05%	
WHITE	9	9	9			
GOLD				0.1	± 5%	(J)
SILVER				0.01	± 10%	(K)

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