HANDS-ON LAB INSTRUCTION SHEET – Learning Kit 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.
2) ***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 MUST be done in order.***

BILL OF MATERIALS

AC Adapter (*9 volts at 1A*), Solderless Breadboard, Power Module, Digital Multimeter, miscellaneous colored leads (*standard for all labs*) and also From the ELEGOO Kit (EL-KIT-004):
(1) **Green** LED
(5) **1000 Ohm**, 1% Resistors *with 5-band color code:* ***brown black black brown brown***
(1) **10Kohm**, 1% Resistor *with 5-band color code:* ***brown black black red brown***
(1) **100Kohm**, 1% Resistor *with 5-band color code:* ***brown black black orange brown***

USING THE DIGITAL MULTIMETER

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 h_{FE} gain checking device. We will only use it for DC voltage, resistance, and diode testing in this course. Always 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 range**. If the voltage to be measured is not known, set the meter to the highest range (upper Left scale) and then, after connecting the leads across the component, turn ON the meter and reduce the range until a satisfactory measurement is obtained.
- **Connect the test leads *across the source or load being measured***.
- Read the voltage value and polarity on the LCD display. (*Negative voltages indicate that the **RED** and **BLACK** leads are probably reversed*.)

Multimeter Resistance Measurement

Note: Whenever the resistance of a resistor is being measured in a circuit, ALWAYS turn off power and discharge any capacitors before applying meter leads! Our resistors have no polarity and there should not be a negative sign on the display.
- Set the rotary switch at desired resistance range (Lower Left scale).
- ***Connect the test leads across the resistance to be measured*** and read the LCD display. If a "**1**" is shown on the display it indicates '*over-range*' – decrease the range.

Multimeter Diode Testing *(This is NOT useful for LEDs)*

The polarity of **red** lead is positive "**+**" in this mode.
- Set the rotary switch to diode test (*Lower Right **s**cale, diode symbol*).

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- 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** (typically 650) and when the connection is reversed, 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** circuited a "**1**" at left of scale. (*If you try using this to test an LED, when the long lead is RED and the short lead BLACK the LED will turn on and the meter will read "1" if the leads are reversed the LED will be OFF but the meter will still display "1" – NOTE the meter provides about 3 volts at up to 1 mA to power the diode*).

1. VOLTAGE SOURCES

NOTE: Your AC Adapter is an *unregulated* power supply.

To get a constant regulated output supply voltage, we can either use a voltage regulator circuit (with a LM7805 IC) or, we use the Power Module to provide a constant 5.0 volts for varying loads. Since the AC adapter provides up to 1 ampere of current and the Power Module can provide up to 750 mA, we saw NO CHANGE in the output voltage from the Power Module with even a 1K Ohm load in Hand-on Module #01, section 1h4.

1.1) Plug your adapter into the Power Module on the breadboard and then into the AC power strip.

1.2) Set your Multimeter on the "20" volts DC scale (upper left scales) and connect the **red** lead to one RED voltage 'bus' connections on the breadboard and the **black** lead to one of the BLUE voltage 'bus' connections on the breadboard.

1.3. Turn the Power Module switch to the **ON** position.

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

2. CREATING A VARIABLE VOLTAGE SOURCE

The Power Module has no controls to set its voltage. Its output voltage is either a regulated 3.3 volts or 5.0 volts.

2.1) Although some Arduino Starter Kits include a **10K ohm potentiometer** the Elegoo one DOES NOT. If you have a potentiometer, wire it in parallel across the power supply with a **red** wire from one of the RED 'busses' and a **black** wire from one of the BLUE (ground) bus connection (see Figure 2.1). This circuit will permit you to turn the potentiometer and generate V_0voltages from 0 to 5 volts.

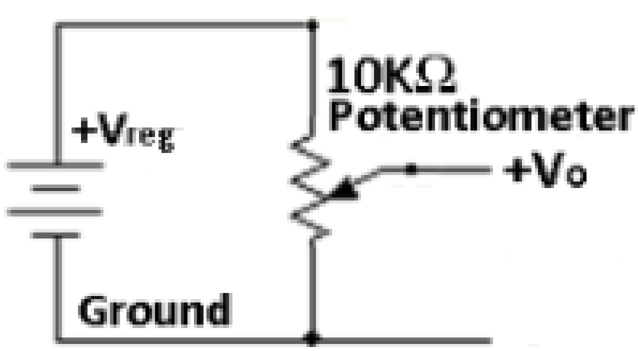

Figure 2.1. Potentiometer Variable Power Supply

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If your Arduino Kit does NOT have a potentiometer, we can simulate a 'discrete value' potentiometer with a series resistor voltage divider circuit. We already have a four-resistor circuit from Lab Module #01(Figure 1.6). We can do this by adding a fifth, 1K Ohm, resistor (5-band color code: brown black black brown brown) between J21 and J26 and connecting a **red** wire from one of the RED 'busses' and a **black** wire from one of the BLUE (ground) bus connection (see Figure 2.2). This circuit will permit you to create individual voltages (0, 1,2, 3, 4, and 5 volts) using the voltage divider concept.

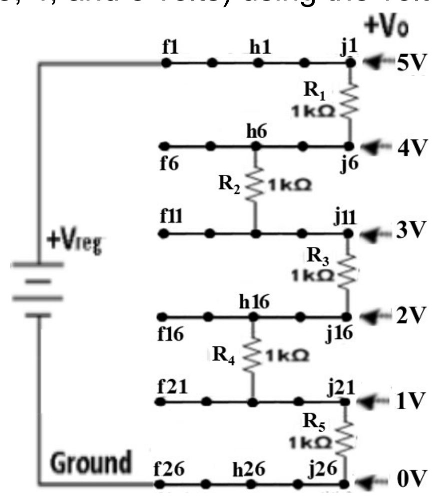

Figure 2.2. Resistors in Series Variable Power Supply

2.a) What is the *'loaded'* regulated source voltage, **+V_{reg}**? ________ **volts**

The circuit of Figure 2.1 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, resistance between **+5 volts** and the wiper arm connection and the resistance between that connection and **ground**. If we connect the Multimeter between the **10K ohm potentiometer**'s variable wiper and ground we can adjust the output voltage **V_o** from zero to 5 volts nearly continuously by rotating the potentiometer's dial.

2.1. Set the dial on the **10KΩ** potentiometer such that the output voltage **V_o** is **2.5 (+/- 0.1) volts**. Turn **OFF** the power. Without changing any wiring reset the Multimeter dial to read resistance on the **20K** scale (*lower left scale*).

2.b) What is the *resistance of the potentiometer* for **V_o** = **2.5 volts**? ______ **KΩ**

Return the Multimeter range dial to 20 volts DC before turning power back ON!

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 five each **RED, GREEN, YELLOW, BLUE** and **WHITE LED**s in your Arduino kit. We will use the GREEN LED in our Voltage Divider circuit and see what the voltage drop across a GREEN **LED** diode is in a working circuit. *NOTE: An LED forward voltage drop is greater than 1.5 volts. A standard forward biased PN junction diode's voltage drop is approximately 0.6 volts.*

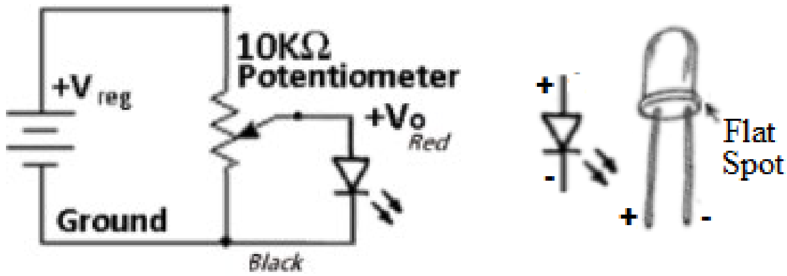

Figure 2.3. Variable Potentiometer Power Source and LED

IF YOU HAVE A Potentiometer (Figure 2.3)

3.1) With the **10KΩ** potentiometer still set such that the voltage **V_o** is **2.5 (+/- 0.1) volts**, connect a **black** wire from the ground to a convenient row of tie-points on the breadboard (e.g., **a15**). Insert one of the **Green LEDs** into the breadboard with the short lead (LED's **FLAT** side) in **c15** and the other 'longer' lead in **c16**. Now take a **red** wire and connect it from the +5 bus/top of potentiometer to tie-point **e15**.

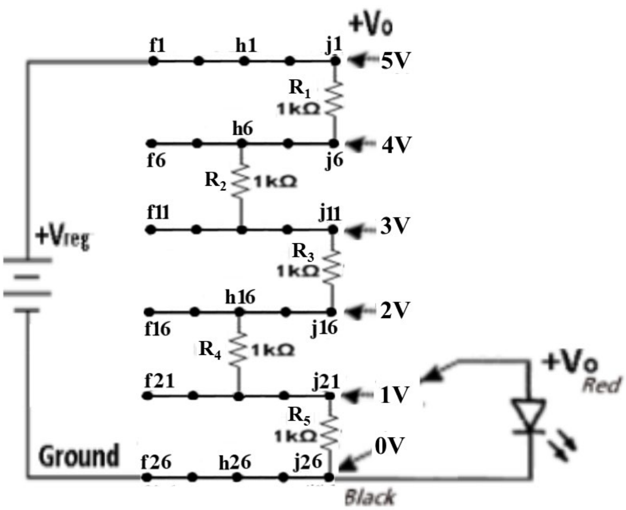

Figure 2.4. Resistive Voltage Divider Power Source and LED

IF YOU DON'T HAVE A Potentiometer - Voltage Divider Circuit (Figure 2.4)

3.2) Using the circuit of Figure 2.4, connect a **black** wire from the ground to a convenient row of tie-points on the breadboard (e.g., **a15**). Insert one of the **Green LEDs** into the breadboard with the short lead (LED's **FLAT** side) in **c15** and the other 'longer' lead in **c16**. Now take a **red** wire and connect it the 3 volt **V_o** tie-point (e.g., **f11**) and the LED tie-point at **e15**.

3.3) 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**

3.4a) Using the potentiometer, turn the knob to **lower** the **V_o**.

3.4b) Using the resistive voltage divider, connect to tie-point **f16**, the **2 volt V_o**.

DO NOT RAISE THE VALUE OF **V_o** *AS THAT MIGHT BURN OUT YOUR LED.*

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

Do NOT disconnect this circuit - This is instructor checkpoint 2A.

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4. 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!

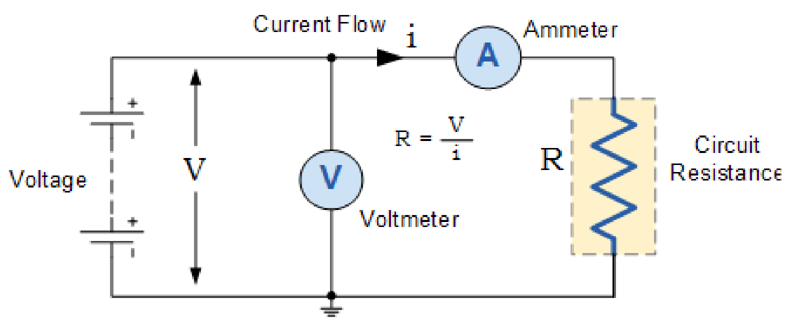

Fig 2.5 Characteristic Curve Measuring Circuit

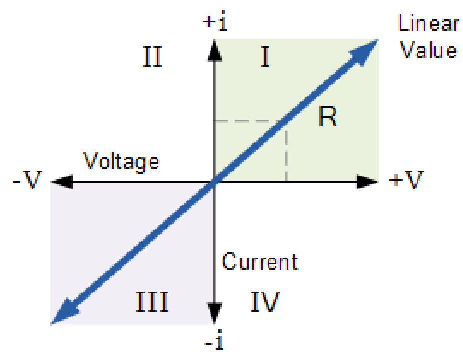

Fig 2.6 I-V Curve for a Resistor

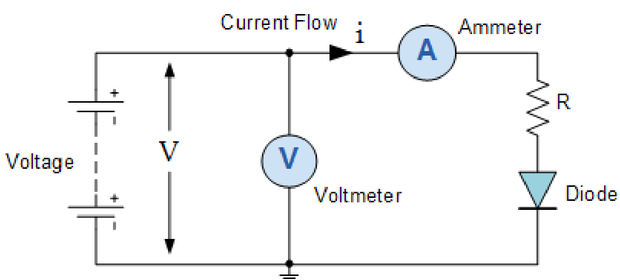

Fig 2.7 Diode Characteristic Curve Circuit

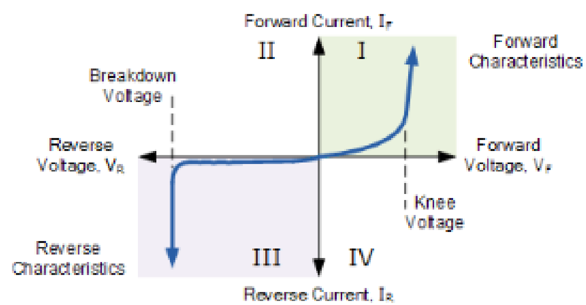

Fig 2.8 I-V Curve for a Diode

Although the **resistor**'s **IV** curve in Figure 2.6 is linear, Figure 2.8 shows that the **IV** curve for a **diode** is *NOT* linear. In fact, the reverse-biased *current* is typically measured in microamperes until breakdown of the device occurs (breakdown = destruction here). 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*. We can also find the forward biased LED I-V characteristic curve

5. LIGHT-EMITTING DIODE I-V CHARACTERISTIC CURVES

5.1) Referring to Figure 2.9 we will the LED forward voltage drop **V_D** directly across the **GREEN** LED and the voltage drop directly across a known series, current-limiting resistor **R_1**. KCL tells us that the diode current **I_D** will be the same as the resistor current **I_R**. To create the various resistance values for **R_1** shown in Table 2.1, we use resistors from your Arduino kit:

4 @ **1K Ω [brown black black brown brown]** *; **1 @ 10K Ω [brown black black red brown]** and **1 @ 100K Ω [brown black black orange brown].**

(To create resistances lower than 1KΩ we use two (2) 1K resistors in parallel to create a **500 Ω** resistance, we use three (3) 1K resistors in parallel to create **333 Ω** and we use four (4) 1K resistors in parallel for **250 Ω.**)*

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5.2) The schematic symbol in Figure 2.9 at the bottom of diode **D1** is called the "ground" or sometimes the "common ground" (we *use **BLACK** wires to connect to ground*). We are using LEDs and thus the shorter lead, or the lead on the flat side of the LED are connected to ground and the longer lead connected to +V. The same circuit could be used for silicon rectifier diodes, resistors, etc.

5.3) Fill in the data for Table 2.1 (below) showing on each line the values for the resistance R_1, and the measured voltages across the resistor and GREEN LED. Then using Ohm's Law ***($I = V_{R1}/R_1$)*** calculate the current flowing in the circuit: $I_R = I_D$ in milliamperes (mA).

NOTE: Whenever applying the equation **I = V/R** or **V = IR** or **R = V/I** remember that V_R is the voltage ***measured*** across resistor **R** and that $I_D = I_R$ is the current ***calculated*** flowing through resistor **R**

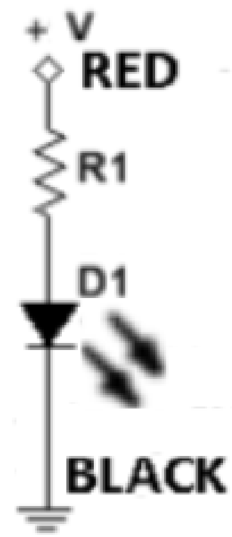


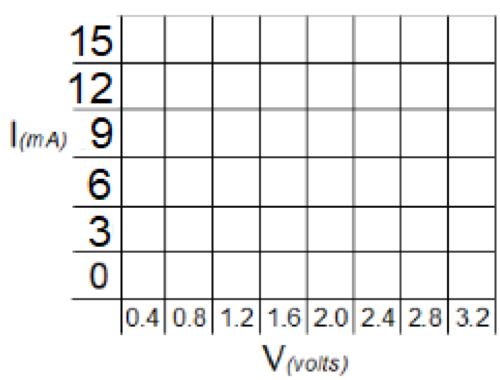
Fig 2.9 Circuit for Measuring an LED I-V Curve

When Resistance is in KΩ and Voltage is in volts, Current is always in mA.

*As noted above, the 100K, 10K and 1K resistors from your Arduino Kit are single components. To create resistances lower than 1KΩ we use two (2) 1K resistors in parallel to create a **500 Ω** resistance, we use three (3) 1K resistors in parallel to create **333 Ω** and we use four (4) 1K resistors in parallel for **250 Ω.** (Some Arduino kits do have 330 Ω and 220 Ω resistors – but we already have the 1K resistors from the initial module on the breadboard – so we will use 1KΩ resistors in parallel.*

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

Table 2.1 Calculations for creating an LED I-V Curve



Graph 2.1 LED I-V Characteristic Curve

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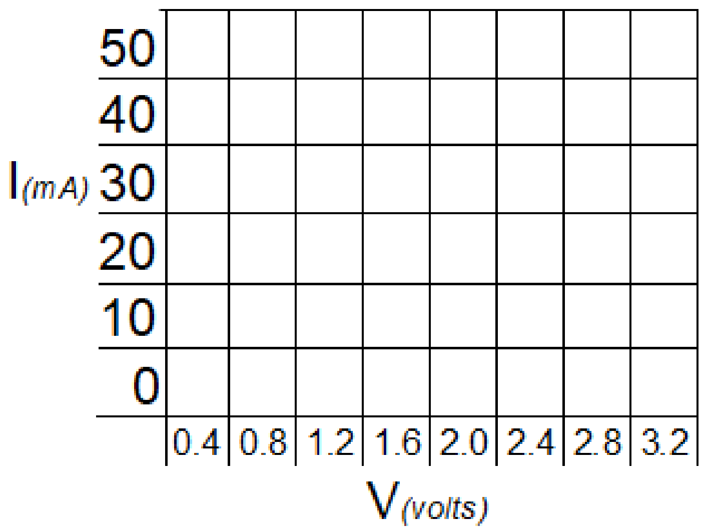
R_1	V_D diode voltage (*measured*) *	V_{R1} resistor voltage (*measured*)	$I = V_{R1} / R_1$ current - mA (*calculated*)
100KΩ			
10KΩ			
1KΩ			
500 Ω (*2@1K*)			
333 Ω (*3@1K*)			
250 Ω (*4@1K*)			

Table 2.2 Calculations for creating a Silicon Diode I-V Curve



Graph 2.2 Silicon Diode I-V Characteristic Curve