# Laboratory Project 1a: Power-Indicator LED's

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***Abstract*-You will construct and test two LED power-indicator circuits for your breadboard in preparation for building the Electromyogram circuit in Lab 1b.**

## I. Preparation

For Lab 1a, which will last about one week, you will need the parts listed in Table I. You may purchase these parts from the stockroom next to the lab or purchase them elsewhere.

TABLE I
PARTS LIST

| Item | Qnty | Description |
|---|---|---|
| 1 | 1 | Breadboard |
| 2 | 1 | Breadboard Wire Kit |
| 3 | 2 | 1 kΩ Resistor |
| 4 | 2 | Red LED |
| 5 | 1 | Green LED |

## II. Learning Objectives

*1)* Understand and use Ohm's Law
*2)* Determine the voltage versus current characteristics of a Light Emitting Diode (LED)
*3)* Learn how to construct amplifiers to increase current drive

## III. Introduction

In Lab 1b you will build an electromyogram circuit to measure the tiny voltages produced by muscles. The gross muscle groups (e.g., biceps) in the human body are composed of a large number of parallel fiber bundles functionally arranged into individual motor units. When each motor unit is activated by nerve commands (action potentials) from the central nervous system, electrical impulses propagate down the length of the fibers that make up the unit. The electrical impulses can be picked up by electrodes and converted to voltages. A plot of the voltages from the muscles is called an *electromyogram*, or EMG ("myo" is a root meaning "muscle").

For the first part of Lab 1, which we call Lab 1a, your task is to build simple LED (Light Emitting Diode) circuits that indicate when power is on in your circuit. A red LED will light up when +9V is turned on, and a green LED will light up when –9V is turned on. These two voltages are needed for the pre-amps you will build this week. A power supply in the lab will produce the +9V and –9V power. The power supply is equivalent to two 9V batteries, such as those used in cameras. After constructing the LED circuits, you will make measurements to find current-versus-voltage characteristics of the LED's.

## IV. Construction of LED Power Indicators

### *A. LED Circuit Overview*

Fig. 3a shows how to put the components on a breadboard to build LED power indicators. The purpose of the LED power indicators is to show which power supplies for your circuit are turned on. Two nine-volt batteries, like the kind you can buy at a grocery store, will ultimately power the EMG circuit. One battery will supply positive nine volts, and the other battery will supply negative nine volts. You will build one LED power indicator for each battery. (Initially, to save batteries, you will use a laboratory power supply for the plus and minus nine volts.)

We are interested in the LED circuit both because it is helpful to know if power is on and because the LED has interesting current-versus-voltage behavior we can measure.

### *B. Breadboard*

All circuits for laboratory assignments will be built on a breadboard that you can purchase from the ECE Stockroom, or online from a company such as Jameco, or from a store such as Radio Shack. The breadboard is rectangular, is made of white plastic, and has small holes spaced 0.1" apart into which component leads may be inserted. Inside, the board has metal clips that hold components in place as well as connecting certain holes to other holes. The gray line segments between holes shown in Fig. 3a, below, indicate which holes are connected together. The idea is that that the breadboard helps us to wire up a circuit by simply plugging components into certain holes.

### *C. LED Circuit Explanation*

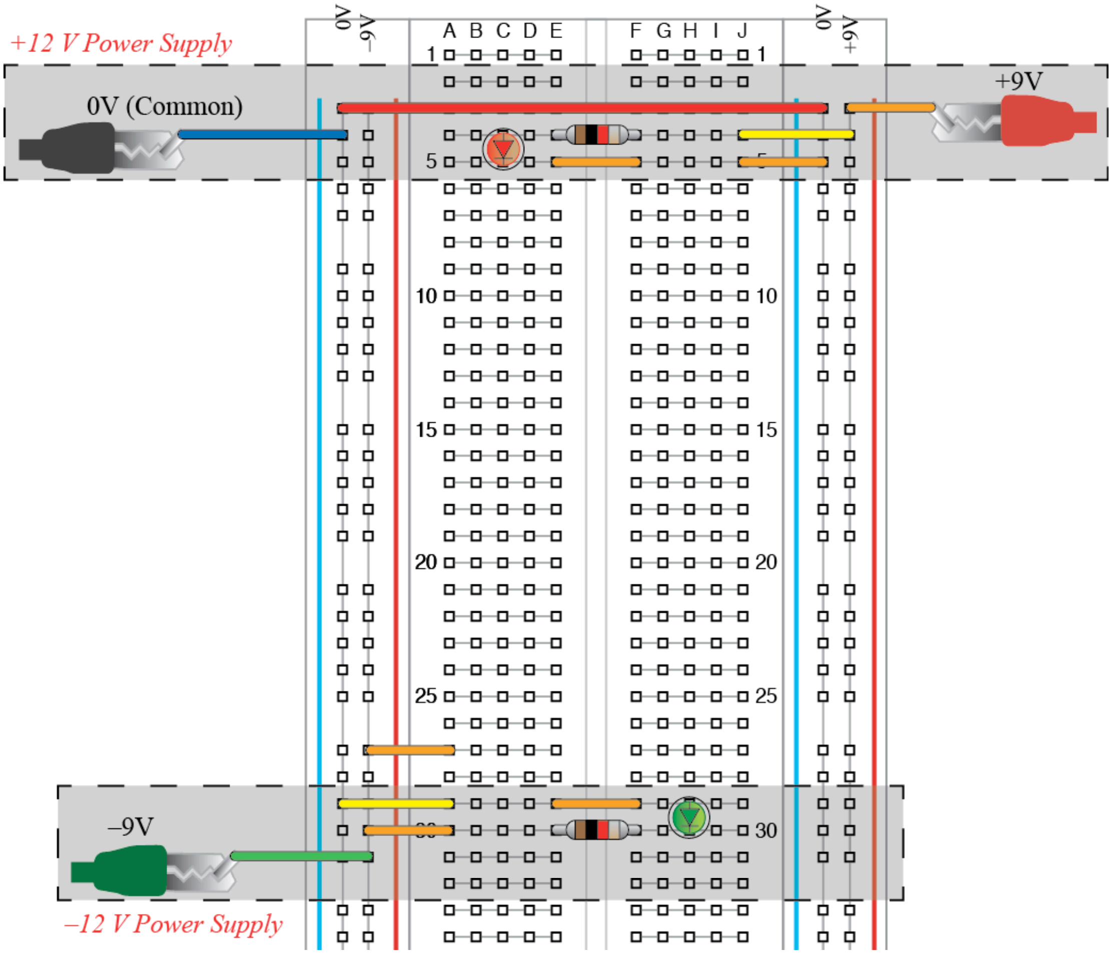
The red circle in Fig. 3b is a red LED, and the green circle in Fig. 3b is a green LED. Each LED lights up when current flows through it. The plus and minus nine volt supplies supply pressure to cause current to flow. When an LED is on, the voltage drop across it is about two volts, regardless of the current flow. Since this is less than the power supply voltage, a resistor (zig-zag line) is required to limit current flow. Otherwise, the LED will burn out. Since the voltage drop across the resistor is about seven volts, (9V – 2V = 7V), we may use Ohm's law, ($R = v/i$), to calculate the resistance value that will yield a desired current in the LED. Our circuit uses 1 kΩ resistors, which provides a current well below the 20 or 30 mA maximum rating for typical LED's.

1 kΩ resistor with brown, black, and red stripes. The wire colors indicate the lengths of wires using the same color code as resistors. Ignore the alligator clips initially; you will connect them after you build the circuit. Note that the breadboard has metal clips inside that connect certain holes to each other so that components inserted into those holes are automatically connected to one another. The gray line segments between holes in Fig. 3a show which holes are connected together. If you follow the wires, you can show that you obtain the schematic shown in Fig. 3b.

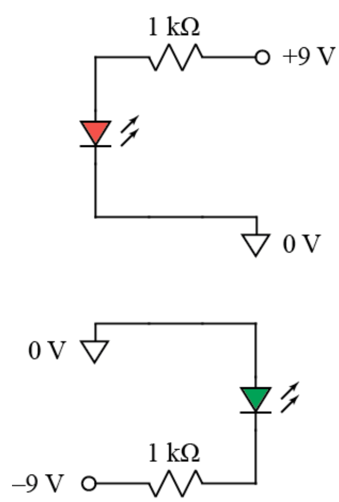
### *C. Procedure*

*1) Build the circuit shown in Fig. 3a.* (You will connect power later.) The red and green LED's are shown as circles. One side of the red LED goes in row 4, and the other side of the red LED goes in row 5. The LED allows current to flow in only one direction, so turn the LED around if it fails to light. (A backward LED will be unharmed but will fail to light.)

1 kΩ resistors are shown with brown, black, and red stripes. These stripes indicate the value of the resistor. Holding the resistor with the metallic colored stripe at the bottom and reading from the top, the first two colors indicate a two-digit number. (To find the color code online, type "resistor color code" into a search engine.) The third stripe indicates a power of 10 that multiplies the first two digits. Thus, brown = 1, black = 0, red = 2 gives $10 \times 10^2 = 1000$ Ohms.




(a)




(b)

Figure 3. LED power indicator circuit.: (a) Breadboard layout, (b) Schematic diagram.

Resistor leads should be cut to about 0.3" and bent perpendicular to the resistor so the resistor sits flat on the breadboard when inserted. Resistors standing above the breadboard on long leads are likely to short to other resistors. Likewise, wires from a wire kit are designed to sit flat on the breadboard when inserted. Note also that wire colors indicate the lengths of wires (using the same color code as resistors). Thus, a red wire has a length of two hole-separations, or 0.2".

Ignore the alligator clips initially; you will connect them after you build the circuit. Note that the breadboard has metal clips inside that connect certain holes to each other so that components inserted into those holes are automatically connected to one another. The gray line segments between holes in Fig. 3a show which holes are connected together. If you follow the wires, you can show that you obtain the schematic shown in Fig. 3b.

*2) Hook up leads to the power supply as shown in Fig. 4.* The power supply has so-called "banana plugs" to which cables with a banana plug at one end (and alligator clips at the other end) are connected. Whenever possible, we use certain cable colors to represent certain voltages. In the present case, we use red for +9V, black for 0V, and green for –9V. Unfortunately, the banana-plug cables in the lab are available only in red and black. Furthermore, the cables are in pairs connected with cable ties. The photo shows how one black cable lies unused on the left side, and a red cable is connected to a green alligator clip on the right side.

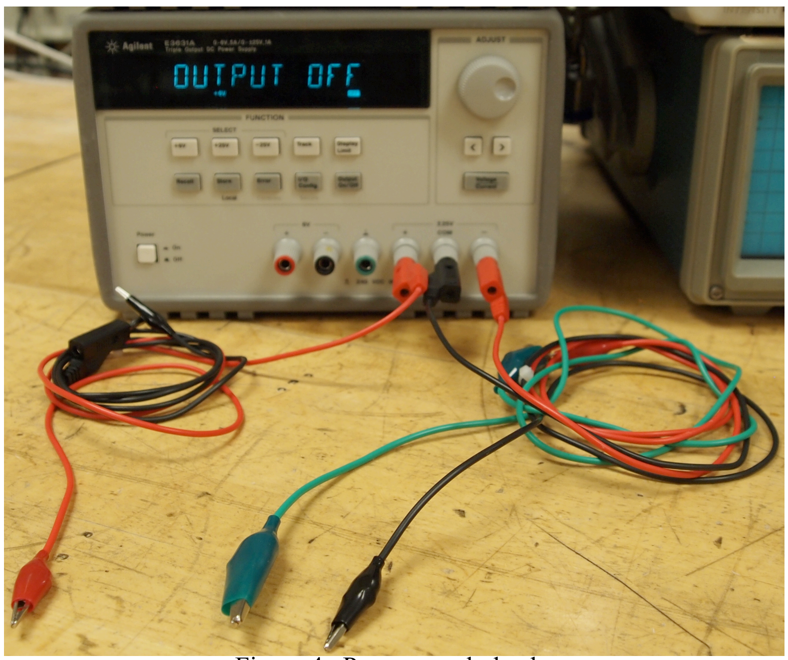



Figure 4. Power supply leads.

*3) Before connecting the alligator clips to the breadboard circuit, turn on the power supply and adjust the outputs of the +25 V and –25 V supplies to +9 V and –9V.* Note that the power supply is equivalent to three adjustable batteries. One "battery" is adjustable from 0V to 6V, a second battery is adjustable from 0V to +25V, and a third battery is adjustable from 0V to –25V. (A negative voltage is the same as using a battery backwards.) To adjust the three different batteries, you must turn on the power supply output (using a button on the front panel) and then tell the power supply which voltage you wish to adjust. Press the button on the front panel corresponding to the voltage you wish to change, and you will see that the display shows that voltage. The gray knob and the > and < buttons below it allow you to adjust the output voltages. Adjust the +25 V and –25 V supplies to +9 V and –9V and turn the output off again. (Be sure the alligator clips for the outputs do not touch one another. If they touch, no harm will probably be done, but the output voltage will drop to zero and you will be unable to adjust the voltage as desired.)

*4) Connect the three alligator clips from the power supply to the breadboard as indicated in Fig. 3a, and press the button on the power supply to turn on the +9V and –9V signals.* If either of your LEDs fail to light, try reversing the direction of the LED in the circuit. If the LEDs still fail to light, use a voltmeter on the DCV setting to measure the voltages across pairs of power supply leads. You should get ±9V or ±18V, depending on which pair of power supply leads you measure. If this also fails, try disconnecting the power leads from your circuit and measuring again. If the voltages are now present, you have probably made a wiring mistake that shorted out the power. If so, look at your circuit very carefully and verify that it matches Fig. 3a exactly.

If you are still having trouble, consult with your TA to get more trouble-shooting tips.

## V. Resistor and LED currents

### *A. Measurements of Voltages*

Using the Agilent multimeter, as shown in Fig. 5, you will make measurements of voltages across the resistor and LED in the +9V power indicator circuit you have built. To make a voltage measurement, turn on the multimeter and press the DC V button. You can then measure the voltage across any component by placing the red probe on one side of the component and the black probe on the other side of the component. (Holding both probes in place at the same time sometimes requires considerable dexterity.) Notice that in Fig. 5, even when the probes are disconnected, they register a nonzero voltage. The voltage reading is millivolts, however, meaning it is miniscule. This voltage reading is so small that it varies randomly. It is measuring tiny disturbances called noise that occur all the time. Because of noise, it is important to pay attention to how stable measurements are. If a digit in the reading is constantly changing, it is inaccurate, and the reading should be rounded off to fewer digits.

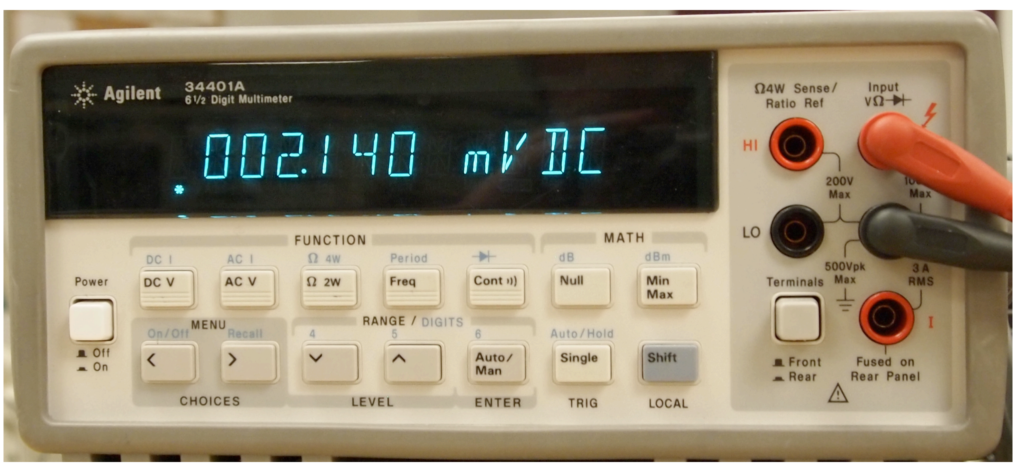



Figure 5. Agilent Multimeter

### *B. Procedure*

*1) Using the buttons and knob on the power supply, change the +9V supply to at least five different values distributed (roughly uniformly) between 0 V and +9 V and measure the voltage across both the 1 kΩ resistor and LED in the +9V power indicator circuit.* (If your readings give negative values, reverse the probes.) Make a copy of Table II, below, in your notebook and enter the values you measure. (Use the power supply display for the power supply voltage reading.)

TABLE II

+12V POWER INDICATOR CIRCUIT VOLTAGES

| Power Supply Voltage (V) | Resistor Voltage (V) | LED Voltage (V) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

By Kirchhoff's current law, the current that flows through the resistor must also flow through the LED. Thus, the LED current equals the resistor current. By Ohm's law, the current in the resistor is a function of voltage, as in (1):

$$i = \frac{v}{R} \tag{1}$$

The LED does *not* obey Ohm's law, as you will now show.

*2) Use the Agilent multimeter to measure your 1 kΩ resistor.* Use the button labeled Ω on the multimeter and place the probes across the resistor *after you have taken the 1 kΩ resistor out of the circuit.* (If you leave the resistor in the circuit, it is connected to other devices through which current could flow, which could affect the measurement.) Note the value of the resistor in your notebook and replace it in the circuit.

*3) Using your values from Table II and (1), compute the current in the LED for each of the power supply voltages in Table II. Fill out Table III with these current values and copy the other columns from Table II.* Note that, to make your calculations, you need the value of the 1 kΩ resistor, *R*.

Then complete Table III. Remember to use engineering units for your calculations and values.

TABLE III

LED CURRENT AND VOLTAGE

| Power Supply Voltage (V) | LED Voltage (V) | LED Current (A) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

*4. Plot by hand the values of LED current (y values) versus LED voltage (x values).* Use graph paper in your notebook or draw a square grid in your notebook for the plot. Choose an appropriate scale for *x* and *y* and label the horizontal axis with both a description (such as "LED voltage") and units in parentheses (such as "(V)"). Draw circles around the data points as you plot them and, when you are done, connect the data points with line segments and add a title to your plot.

Note that the plot you have made is nonlinear. The LED current versus voltage is described by an exponential equation. In practice, we approximate the behavior of the LED by assuming its voltage is constant, regardless of how much current is flowing through it. Your plot will show that this is not quite true, although it is usually accurate enough for designing an LED circuit.

## VI. Notebook and Report

Turn in a copy of your laboratory notebook pages and a separate formal report. Refer to the grading information on the course website for the section numbering to use while writing the formal report. Use the IEEE format for typesetting. Information about the IEEE format, including a template file, is available on the course website. Additional information about writing the report and keeping a notebook is listed in the *Course Procedure* on the course website. Note that Matlab® plots, if there are any, must appear both in the laboratory notebook *and* the formal report.