

EK 307 Lab: Light-Emitting Diodes

- **Laboratory Goal:** To explore the characteristics of the light emitting diode.
- **Learning Objectives:** Voltage, current, power, and instrumentation.
- **Suggested Tools:** Voltage sources, LEDs, multimeter, breadboard.

Pre-lab assignment and questions (These should answered in your notebook):

- 1) Download this datasheet for a typical red LED:
<http://media.digikey.com/pdf/Data%20Sheets/Lite-On%20PDFs/LTL-10223W.pdf>
If the link doesn't work use your favorite search engine to search for the manufacture's part number: Lite-On Inc. part number LTL-10223W. Using the datasheet find the absolute maximum power dissipation and the typical forward voltage.
- 2) Based on your experience in lab 0, which instrument is better (more precise and accurate) for measuring current? The power supply or the multimeter? Don't remember which is better? Find the specifications for both instruments on the Internet. The multimeter is an Agilent, Keysight, or HP model 34401. The power supply is an Agilent, keysight, or HP model 3631A (the name changed but the instrument is the same).
- 3) If you connect a 32 Ohm 1/2 Watt resistor across the terminals of a DC power supply, what is the maximum voltage you can apply to the resistor without exceeding the power limit (1/2 Watt)?

In-lab Assignment (Complete Level 1 and additionally level 2 if you choose to):

LEVEL 1: Construct a simple LED circuit, test the power rating of LEDs

- a) Select a red LED from your electronics kit. Obtain a 220 Ω and a 1k Ω resistor from the component bins. Using the +25V supply (set to 5 volts) as the power source, connect the LED, 220 Ω resistor (R1), and power supply using your breadboard and wires so that it produces visible light. **Figure 1** is a schematic of the circuit. The datasheet you downloaded has instructions on the polarity and pin labels of the LED.
- b) Measure the voltage across the LED using the voltmeter. Measure the current through the LED using the ammeter. Calculate the power dissipation of the LED. Measure the voltage across the resistor and compute the amount of power it is dissipating. Record the values in your lab notebook. A convenient way to record the values is to annotate the drawing of the schematic. Yes, you should draw the schematic in your notebook. Before proceeding to part c you can turn off the output of the power supply without turning off the instrument using the "Output on/off" button. Disabling the output with this button will make it safe to manipulate the circuit.

$$P = VI \quad (\text{Power} = \text{voltage across} \times \text{current through})$$

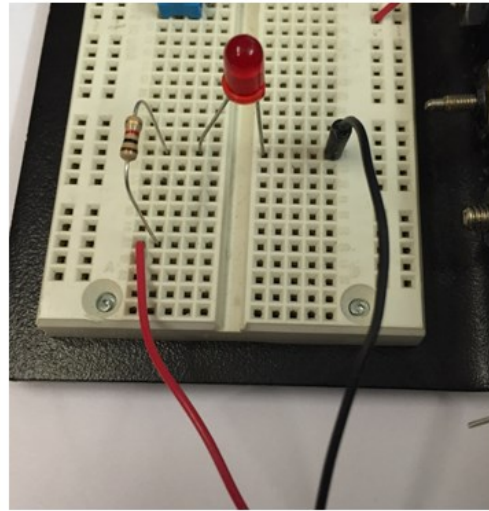
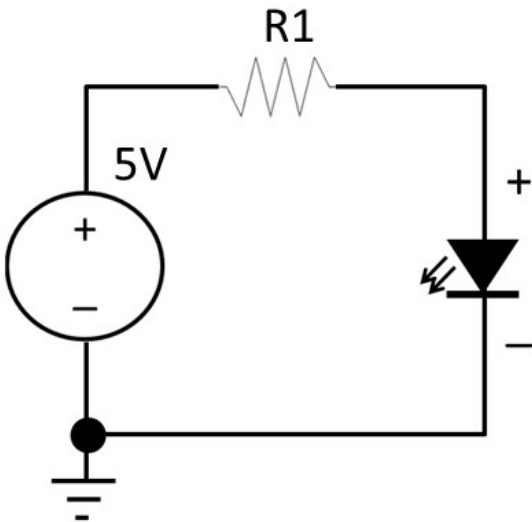


Figure 1: Basic LED circuit and breadboard realization of the circuit. Note the power supply is not shown.

- c) Next switch out the 220Ω resistor (R1) for the $1k\Omega$ resistor. Now enable the power supply by turning on the output and re measure the parameters in part b. Is there a difference in the LED light intensity?
- d) Determine the maximum current and power that an LED can sustain before it burns out: To do this part of the lab, remove the resistor from your circuit and replace it with the ammeter as shown in **figure 2**. Now we will collect current and voltage data to make a graph of current vs. voltage (I-V curve). The burn out of the LED can usually be measured by looking at the I-V curve and observing when the slope (dI/dV) starts to decrease. The LED may still be lit but it is damaged once the power is exceeded. Recall you found the burnout power in the datasheet.

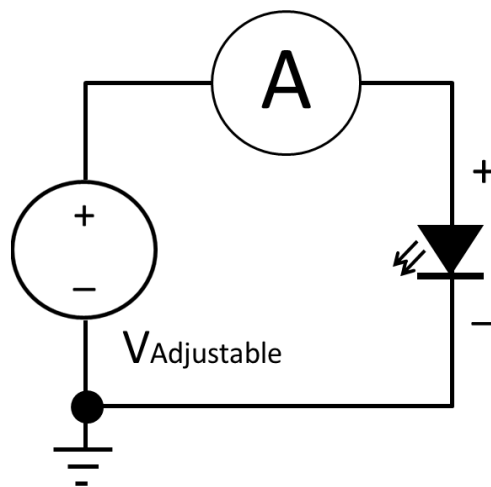


Figure 2: Measuring I-V characteristic of an LED

- e) Using the 25 Volt power supply, starting at 1 volt, measure the current in the LED and record the voltage and current in a table. Then increase the voltage across the LED in 0.1 volt steps until at least 3 volts, recording both voltage and current at each step. Then increase in steps of 1 volt until at least 8 volts or until it reaches the point of failure as indicated by the LED no longer lighting up. The LED you used is now damaged and we suggest discarding it to keep it from being used accidentally in a 'good' circuit.
- f) Plot the results of your experiment with a computer. The graph will have volts on the horizontal axis and current on the vertical axis. See **figure 3** for an example plot. **Figure 3** is not the proper curve for a red LED but the shape is similar. You can use any program you want. Excel, Sheets, R, and MATLAB are some that come to mind. It isn't necessary to print the plot, you can save it electronically. Be sure to show it to the teaching assistant since it is part of your results.
- g) How do the maximum values you measured compare to the datasheet values? Did your LED burn out at a similar current and power as the datasheet stated? Does your I-V curve look similar to the datasheet version?

LEVEL 2: UI (user interface) design:

- a) Be sure level one is completed.
- b) Powering LEDs near their maximum current value results in them losing efficiency over time. Thus they become dim and customers become dissatisfied with the product. To prevent this engineers often run LEDs at a current lower than their maximum, yet high enough that they are obviously lit. Your task is to use the I-V curve and burnout measurements from level one to determine the safe operating voltage and current you would use if you were designing a commercial product.
- c) Assume you are integrating one of these LEDs into a product as a status indicator. When the status is 'good' there is 12 volts available across a terminal. If the status is 'not good' the voltage across the terminal is zero. We learned in level 1 that directly applying 12 volts to LEDs will damage them or at least shorten their life. A simple solution is to connect a resistor

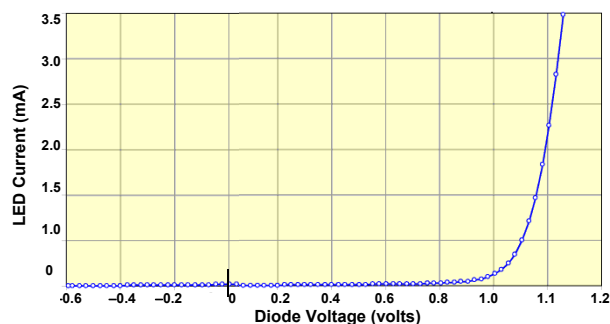


Figure 3: Example I-V Curve for an LED ³

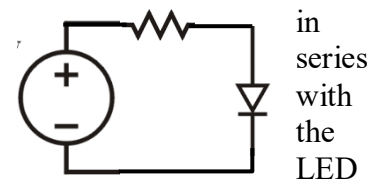


Figure 4: I-V Current limited LED circuit

to limit the current to the LED as seen in **figure 4**. Hint: If you use the terminal voltage (12 volts), and the LED voltage, and current as constraints in the circuit, you can determine the proper resistance for the resistor by using KVL and $V=IR$.

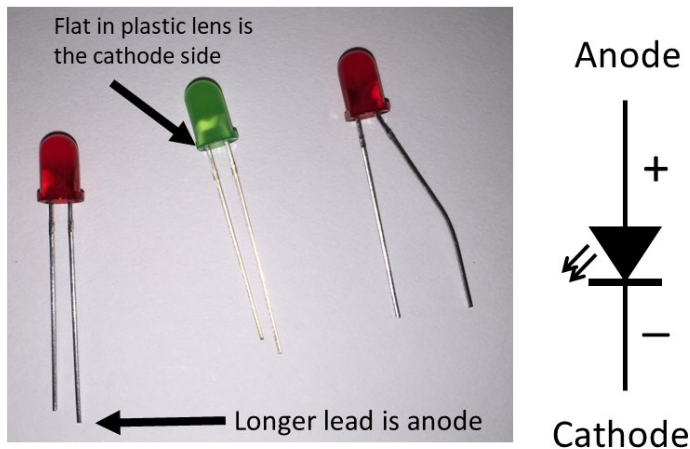
- d) Build and test your circuit on your breadboard. Note that you may not be able to find the exact calculated resistor value. It is OK to use the next value up. For example if you calculated 42 ohms but it is not available you can use a 43 ohm resistor.
- e) Record the voltage and current of the LED. How do the results compare to the theory?

Suggestions for Things to Record in Your Logbook:

- Circuit diagrams for all tests
- Voltage at which LED begins to emit visible light.
- Power at which LED burns out
- Spreadsheet of data used for plotting LED $i-v$ curve

This is the end of level 2. Read below for more in depth information.

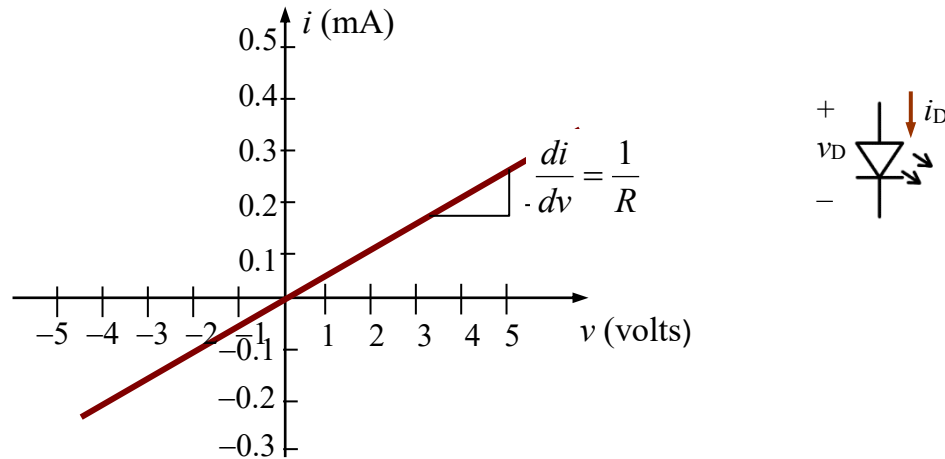
LED connections



Leds are polarized meaning they need to be connected in the proper orientation to emit light. The longer lead is the anode. The shorter lead is the cathode. If the leads are cut or bent the polarity can be determined by looking for the flat spot in the annulus of the plastic lens.

The current-voltage characteristic of a two-terminal circuit element, often called its “ i - v curve”, describes the amount of current that flows through the element versus the voltage applied across it. The i - v curve is usually plotted with voltage on the horizontal axis and the current on the vertical axis.

A resistor has a very simple i - v curve defined by Ohm’s Law: $i = v/R$. This curve is actually a straight line because Ohm’s law is a linear equation. The plot below shows the i - v “curve” for a resistor of value $R = 10 \text{ k}\Omega$. Note that the line has slope $di/dv = 1/R = 0.1 \text{ mA/V}$.



In contrast to a simple resistor, the light-emitting diode (LED) has a more complicated i - v equation:

$$i_D = I_S (e^{v_D/V_T} - 1)$$

Here i_D and v_D are the LED voltage and current, respectively, and I_S and V_T are constants. This formula is plotted below for LEDs of several different color types and values of I_S .

The i - v curve of an LED can be approximated using two straight lines: A horizontal line for voltages below the forward voltage, where no current flows; and a line having positive slope over the region where current does flow. The location where these two lines meet is called the “knee” of the i - v characteristic.

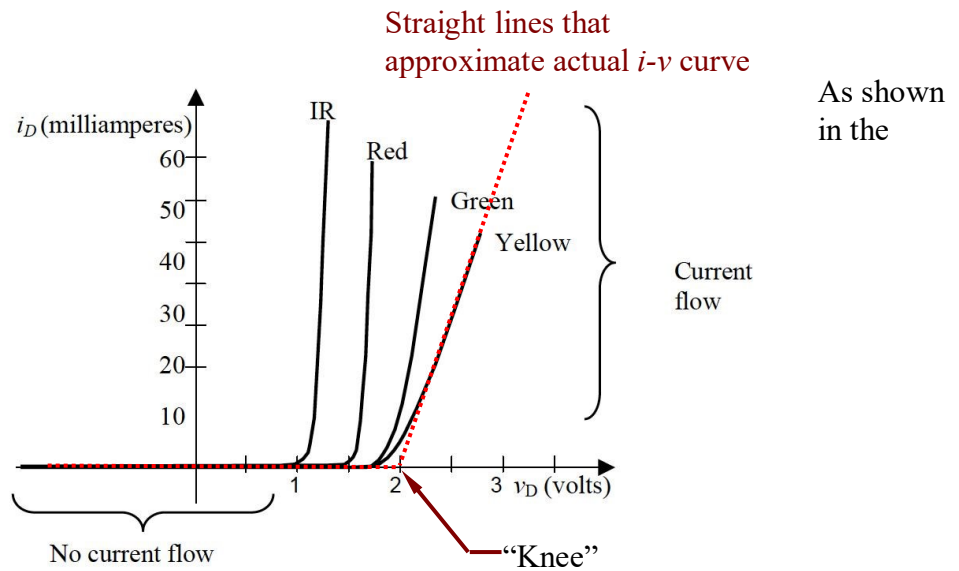
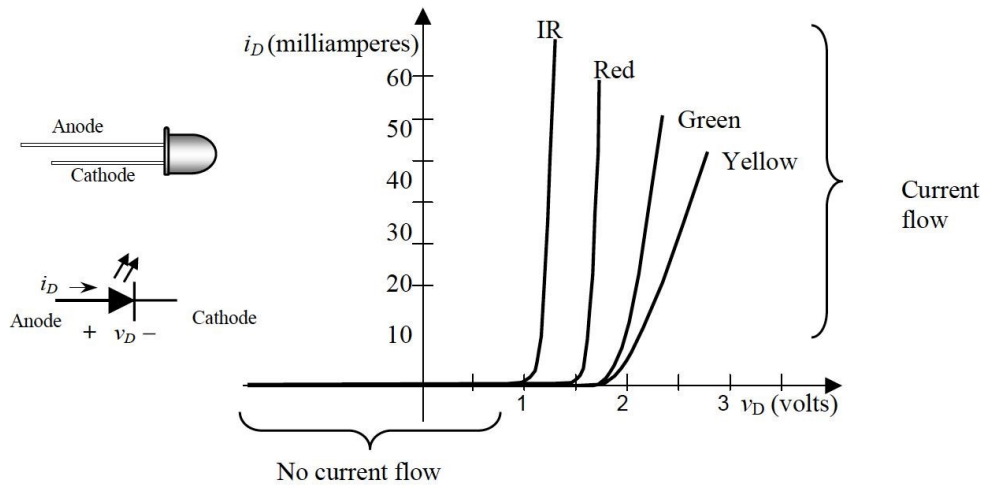


figure above, the current increases very rapidly for as the voltage is increased above the knee. If the applied voltage continues to increase, the current will continue to increase as well until the LED is no longer able to dissipate the inflow of power. At this point the LED sustains damage due to the excessive heat and burns out.

The Anatomy of a Breadboard

Let's forget for a moment the outer strips of the breadboard (commonly referred to as "power strips") and focus on the inner part. The inner part of the breadboard consists of columns and rows.

Columns are usually denoted by letters while rows are denoted by numbers. In this example, columns are denoted by letters A-J and rows are denoted by numbers 1-30.

As seen in the "X-ray" of the breadboard, each row is independent while the columns are separated into two groups, A-E (left side) and F-J (right side). Each row at a given side of the breadboard forms a strip, i.e., a node. For example, A1, B1, C1, D1, and E1 belong to the same node. In other words, if you connect a two terminal device like an LED in A1 and D1, you will create a short circuit. In order to avoid short circuits you should use different rows but not necessarily different columns. So, a possible choice would be A1 and C3. As long as the rows are different, the choice of column is not that important. You can also use the same row but different sides of the breadboard.

Now back to the power strips. These are four completely independent strips that you can use as you deem fit. Because they run through the whole length of the breadboard, it's convenient to use them as power sources, hence their name. But notice that you need to provide power externally using a power source. Some breadboards (like the one in the figure) label these strips with "+" and "-" signs for your convenience.

