ENGS 28 Laboratory Exercise 1

All kinds of variations on Blinky

Objectives

- Gain experience reading data sheets.
- Become proficient with multimeter measurements of voltage, current, and resistance.
- Design and prototype an embedded system with LED outputs.
- Practice writing clear, correct, and well-documented C code.

Equipment (from student kits)

- Arduino + breadboard
- Three LEDs (use both red and green)
- Three 332 Ω resistors[1]
- One 1 kΩ resistor
- Jumper wires
- Digital multimeter

BEFORE THE LAB

Review the readings for this week (see the daily pages). Note the checkpoint questions in the readings from the ENGS 31 eBook. Read through the supplementary material. The problems in the supplementary material must be turned in on Canvas with the Prelab 1 Quiz.

DURING THE LAB

Technical Study

1. Light Emitting Diode Properties

On Canvas, navigate to Files > Data Sheets, and find the datasheets for the Kingbright LEDs you will be using this term. There are separate datasheets for the red LED and the green LED. Pick one and answer the following questions:

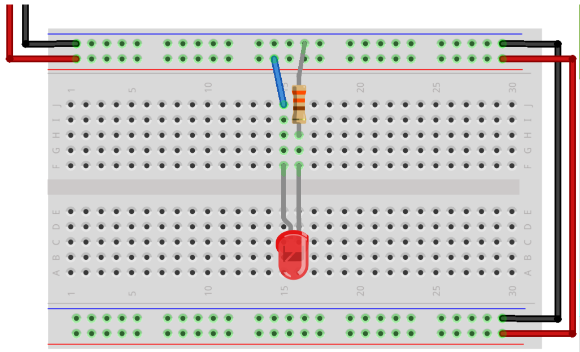
(1a) Record the typical forward voltage for your LED.
(1b) Record the maximum forward current (I_f) for your LED.
(1c) Record the material which your LED is comprised of.
(1d) Is the color of your LED light emitted determined solely by the color of the plastic housing?
(1e) Assume V_{OH} for the Arduino is V_{CC} (5V). Using I_f Ifrom above, what is the smallest resistor that will keep the current safe for your LED? Show your work.

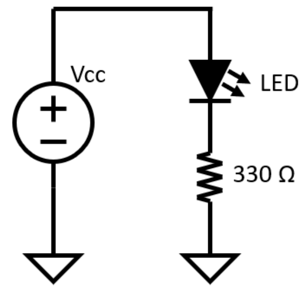
2. Light Emitting Diode Measurements

With the Arduino unplugged, wire up an LED and a 332 Ω resistor in series as shown in the diagram below.

- The anode of the LED will be connected to the red 5 V power rail on the breadboard, also called *V_{CC}*. ***Always use red ONLY for wiring for connections to this power rail.***
- Connect the cathode of the LED to one leg of the 332 Ω resistor.
- Connect the other leg of the 332 Ω resistor to the circuit ground reference (0 V), also called *GND.* ***Always use black ONLY for wiring for connections to ground.***

[1] Your kit may contain 330 Ω ohm resistors instead. These are fine too.





(2a) Measure the following with your multimeter (refer to the multimeter video):

1. V_{CC}, the voltage measured across the high-power rail and ground.
2. V_F, the voltage measured across the LED, from anode to cathode.
3. V_R, the voltage measured across the resistor.

Your measurements should agree quite well with Kirchoff's voltage law, $V_{CC} = V_{LED} + V_R$. If they don't, think about what you might have done wrong (reversing the positive and negative probes is a common error --- in this circuit, all your measured voltages should be positive). Keep at it until you have a good result, then write down your three voltages.

(2b) Ohm's law states that the voltage across a resistor is proportional to the current flowing through the resistor multiplied by its resistance, or $V = IR$. Using the voltage across the resistor you measured in part (a), calculate the current flowing through the 332 Ω resistor (Milliamps are the appropriate units.). How much current flows through the LED? Compare this current to the maximum indicated by your LED's datasheet. Is the current limiting resistor doing its job?

3. Light Intensity of an LED

(3a) Replace the 332 Ω resistor with a 1 kΩ resistor and repeat the measurements from before.

1. V_{CC}, the voltage measured across the high-power rail and ground.
2. V_F, the voltage measured across the LED, from anode to cathode.
3. V_R, the voltage measured across the resistor.

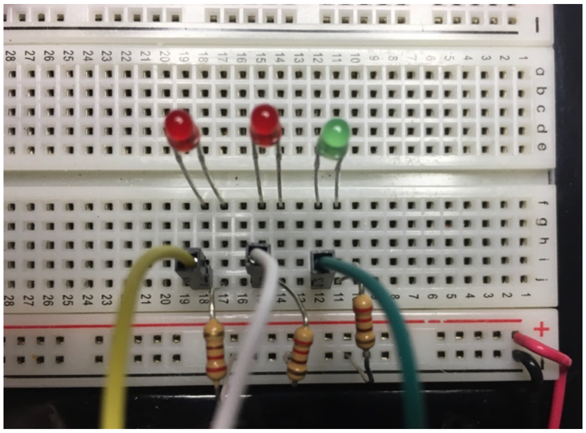
(3b) Analysis.

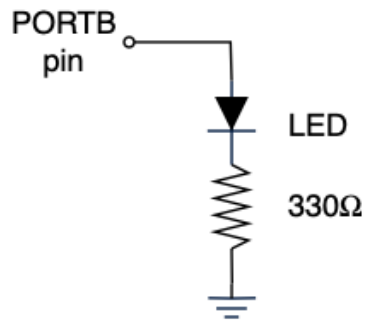
1. Did the forward voltage drop across your LED change?
2. Did the voltage drop across the resistor change? If so, what does this tell us about the circuit?
3. How did the intensity of the light created by the LED change? Why?

Scan your solutions to these questions (last page of this handout) into a PDF document and upload to Canvas.

Design Challenges

There are three closely related design challenges in this week's lab. Begin by wiring up three LEDs (any color), with three 332 Ω resistors, to Port B, bits 0 through 2. Shown below is a photo of the layout on the breadboard, alongside a schematic diagram of the wiring for one LED. As I wired it, the three LEDs are connected, from left to right, to bits 2, 1, and 0.





After wiring it up, design, implement, and test each of these modified blinky designs. The first two were introduced in Wednesday's class.

1. blinkySIM: Flash all three LEDs simultaneously.

2. blinkySEQ: Flash the three LEDs in sequence, one at a time: 0, 1, 2, 0, …

3. blinkyCNT: Design and implement a three-bit counter (0 to 7), displaying the three bits with the three LEDs. This is harder. You can use a uint8_t variable to represent the count, but you have to figure out how to isolate bits 0, 1, and 2 so they can be displayed on the LEDs (consider a bit mask). Make sure the counter counts slowly enough that you can easily see the lights flash in binary sequence: 000, 001, 010, ..., 111, 000...

Use your best C programming style. Be sure to clearly document your code with inline comments and a descriptive header, as in the main.c template file.

As you work through these problems, think about the build and test philosophy described in class and how it applies to this system. Also think about how you are organizing your file system so you can refer to these three programs at a later date with ease.

Demonstrate each of your designs to a TA or instructor. If you are unable to demonstrate the design to a TA or instructor, upload a video of each challenge working to Canvas.

Upload each of your C files to Canvas.

Clean Up

If you wish, you may choose to "permanently" attach a couple of LEDs with their current limiting resistors to your breadboard. These are very useful and will be used in later labs. Choose an out of the way spot near the narrow edge of your breadboard to place the LEDs. Trim the legs of the LED and the resistor so they fit tightly to the board. Be sure to leave room to connect a jumper so you can control the LED later! Figure 1 shows one possible layout. Feel free to take some of the hookup wire from the cabinet to form jumper wires like those seen in the figure. (Ask for help if you aren't sure which tools to use!)

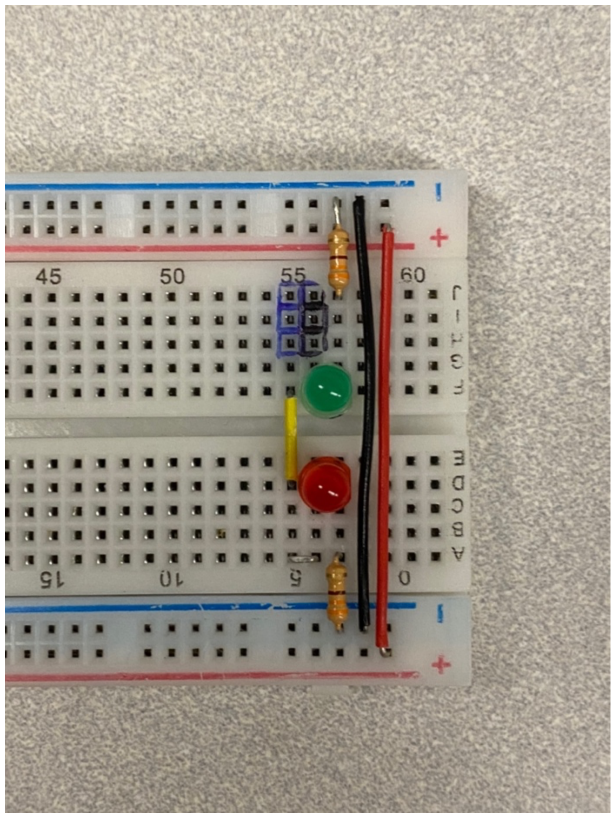


Figure 1 Sample LED Layout

Lab 1 Answer Recording Sheet

Name: ____________________________

Technical Study

Light Emitting Diode Properties.

You need only answer for the color LED you selected.

(1a) V_F typical, red LED = __________________ OR V_F typical, green LED = __________________

(1b) Maximum allowable I_F,
red LED = __________________ OR green LED = __________________

(1c) Red LED material = __________________ OR Green LED material = __________________

(1d) Based on your discussion, is the color of the LED light emitted determined solely by the color of the plastic housing?

(1e) Rmin, red LED = _____________ OR Rmin, green LED = ________________.

Show your work:

Light Emitting Diode Measurements

(2a) V_{CC} = __________________, V_{LED} = __________________, V_R = __________________.

(2b) I_{LED} = __________________.

Compare this current to I_F typical for your LED. Is the current limiting resistor doing its job?

Light Intensity of an LED

(3a) V_{CC} = __________________, V_{LED} = __________________, V_R = __________________.

(3bi) Did the forward voltage drop across your LED change?

(3bii) Did the voltage drop across the resistor change? If so, what does this tell us about the circuit?

(3biii) How did the intensity of the light created by the LED change? Why?

Design Challenges

1. Staff initials that blinkySIM works well: _________________________.

2. Staff initials that blinkySEQ works well: _________________________.

3. Staff initials that blinkyCNT works well: _________________________.

$$\frac{}{220+220} \quad \frac{440}{2}$$

$= 2.5\ V$

Lab

1. a. Typical forward voltage = ~~V~~ 1.85 V

b. Maximum forward current = 30 mA

c. Material = Gallium Aluminium Arsenide Red LED

d. No. The LED produces red light too.

e. $V_{cc} = I_f R$

$$R = \frac{V_{cc}}{I_f} = \frac{5\ V}{30\ mA} = \frac{5}{\frac{30}{1000}} = \frac{500}{3} = 166.67\ \Omega$$

2. a. 1. $V_{cc} = 5V$

b. 2. $V_F = 2V$

c. 3. $V_R = 3V$

~~2b.)~~ ~~a)~~ a).

$V_R = I_R R \qquad V = \overset{3}{\cancel{8}}V \qquad R = 332\ \Omega$

$I = \dfrac{V}{R} = \dfrac{\cancel{8}\,3}{332} \approx \overset{0.009}{\cancel{0.015}}\ A \ / \ \overset{9}{\cancel{18}}\ mA$

$\overset{9}{\cancel{18}}$ mA flows through the LED. Since the LED & resistor are connected in a series circuit, same amount of current flows through both. The current limiting resistor is doing ~~its~~ its job, as max current on the datasheet for the LED is 30 mA.

3. a. $V_{cc} = 5V$

$V_F = 1.86\ V$

$V_R = 3.14\ V$

b. 1. The forward voltage did change. There is more resistance in the circuit so, we so a drop in voltage from 2V to 1.86 V.

2. The voltage drop across the resistor increased from 3V to 3.14 V. This shows that the circuit follows Kirchoff's Voltage law. Since voltage in the circuit decreased, voltage drop across the resistor would have to increase to make ~~x~~ voltage across circuit components equal to voltage source.

3. Intensity of light decreased because of the increase in resistance in the circuit. This led to less power flowing to the ~~Vech~~ LED.