Laboratory 6
Diodes and Transistors

Introduction

In this lab, you will build and test circuits using diodes and transistors. You will use a number of different types of diodes, including regular “signal” diodes, red and green light-emitting diodes (LED’s), and a Zener diode. You will also be introduced to a commonly-used NPN bipolar transistor, the 2N3904, and test it in several configurations, including common-emitter, emitter-follower, and a flip-flop. These parts are available in Cabinet 2 as well as Cabinet 1 (which is always open). Power will be supplied as in previous labs, from the MicroBLIP’s +5V (12B) and GND (14B) pins (Fig. 1).

Fig. 1

Parts List

2N3904 Transistors in TO-92 package (2)
1N914 signal diode
2.4V 0.5W Zener diode
SPST momentary push-button switches (2)
red LED (Light Emitting Diode)
green LED
100 KΩ trim-pot
The Diode

You will explore the properties of the diode using the 1N914 signal diode. (“Signal” implies that it is not a “power” diode used to rectify large alternating currents, or other type of specialized diode). Build the circuit shown in Fig. 2, also shown in the photograph, in Fig. 3, taking note of the location of the voltmeter in the schematic, and the forward-biased direction of the diode. The black line on the diode is the cathode or (-) end. Caution: Connecting 5 V directly across the diode will destroy it !!! Based on the current vs. voltage curve for a typical diode, explain why this is so. (A) Measure the voltage across, and (without moving the voltmeter) calculate the current through, the diode, using resistors with values 1 KΩ, 10 KΩ, 100 KΩ, 1 MΩ, 10 MΩ. Graph current vs. voltage. (B) Explain how you determined current. (C) You might have tried, instead, to determine the current by measuring the voltage across R directly. Given that a typical meter has an input impedance as low as 1 MΩ, explain why it does not make sense to do this when R = 10 MΩ. (D)

Change the diode’s direction and measure the current and voltage again, using a 10K resistor. Draw the new schematic. Add this new data point to your graph. (E)

Repeat the entire procedure with a red Light Emitting Diode (LED) with the same resistors as with the 1N914. The pin-out for an LED is shown in Fig. 4. Note the flat bevel on the side of the LED indicates the (-) lead, and the fact that the (+) lead is longer than the (-) lead. Inserted backwards, the LED will not light up. Plot the new data on your previous graph. (F) Repeat the entire process with a green LED and again plot your data. Explain how they differ? (Hint, the energy of a photon is proportional to its frequency). (G)
Bipolar Transistors and the Common-Emitter Circuit

We will now explore some simple circuits using a bipolar transistor. The pin-out for the 2N3904 NPN transistor (in a TO-92 package) is shown in Fig. 5, with the Emitter (E), Base (B), and Collector (C) labeled from the top view. Caution: The B-E junction acts like a diode, so connecting 5V directly across it will destroy it, as before with the signal diode.

For your first circuit, you will use a single-pole single-through (SPST) momentary push-buttons switch, the same kind you used in Lab 2. Again, straighten the pins and observe the proper orientation by inserting it across the central divide of the breadboard (Figs. 6 and 8) so that you can access both terminals of the switch from either the top or bottom half of the breadboard.

Construct the common-emitter circuit shown in Fig. 7. Note that the symbol for the LED is a diode in a circle, and that it is forward-biased in this circuit. The photograph in Fig. 8 shows how to build the circuit neatly on the breadboard. Pushing the button should light the LED. Given the values of the two resistors in the circuit how does this demonstrate the ability to control a relatively large current with a relatively small current? (H)
Calculating the Current Gain of a Transistor

Build the circuit in Fig. 9. Measure and record the voltages at the base and the collector of the transistor relative to ground. From these measurements, calculate the voltage across each of the two resistors. Then Calculate $I_C$ and $I_B$, and determine the $\beta$ ($h_{FE}$ or current gain) of this particular 2N3904 transistor. Repeat the procedure on a second 2N3904 transistor and compare (the value of $\beta$ varies fairly widely between transistors unless they have been intentionally chosen to match). Show your calculations for both transistors. (I)

Next, use the $h_{FE}$ setting on your multimeter, sticking the pins of the two transistors in the appropriate holes (NPN, EBC, see Fig. 10). (“$h_{FE}$” is another way of denoting $\beta$.) How does the result compare to that just calculated from the currents through the resistors? (J)
Zener Diodes and the Emitter-Follower

Using the 2.4V 0.5W Zener diode (1N5221) handed out with in the baggie with your PittKit, construct the emitter-follower circuit shown in Fig. 11. Note the orientation of the black stripe on the Zener diode indicating the cathode (-) end. It is reversed-biased in this circuit (see Fig. 12). Explain the voltages at points “x” and “y” (Zener voltages can vary from diode to diode, and may not be exactly 2.4V). (K) Estimate the power being dissipated by the Zener diode, (ignoring the base current of the transistor). (L)

Construct the circuit in Fig. 13, using your 100 KΩ pot and adjust the pot to make the output 3 V without the 10 KΩ “load” resistor across the output. Then attach the 10 KΩ resistor and measure the resulting output voltage. (M) Calculate what you would expect this to be, as you did in Laboratory 2. (N)

Now construct the emitter-follower circuit shown in Fig. 14. Adjust the output to 3 V. Measure the voltage at the base of the transistor and explain the difference between it and the output voltage. (O) Attach a 10 KΩ resistor across the output and report the new output voltage. Compare the voltage drop caused by the load to previous circuit without the emitter-follower and explain why this is a more perfect voltage source. (P)
The Flip Flop, a Bistable Circuit

Now construct the Flip Flop shown in Figs. 15 and 16 explain its ability to remember which push-button was pressed last. (Q)