

Pre-Lab 1

Carefully read the entirety of Lab 1, then answer the following questions. Attach a separate sheet of paper, if necessary, to show all work and calculations.

1. Is there a built-in connection on the breadboard between the binding posts and the power rails? If not, how can we make that connection?

2. What two things can happen if the power supply is dialed to a value greater than +5 V?

(a)

(b)

3. Why do we use red wires for power and black wires for ground?

4. What might happen if the exposed contacts of red and black wires touch each other?

5. How should you disconnect the power supply from your breadboard during class if you want to temporarily remove the voltage from your circuit?

6. How should you disconnect and turn off the power supply at the end of lab?

7. Why are DIP chips inserted into a breadboard in such a way that the two columns of pins straddle the trench?

8. Why is it important to be careful when inserting and removing DIP components from a breadboard?

9. What are the two purposes of pull-down resistors?

(a)

(b)

Lab 1: Introduction to Digital Labs

In this introductory lab, you will learn how to use the lab equipment required to build digital logic circuits. The most important pieces of equipment, that will be used in almost every lab in this class, are the breadboard, power supply, and DIP switch.

For lab resources and information, go to the following URL or scan the QR code. doctor-pasquale.com/digital-systems-lab-1



1.1 Breadboards and Power Supplies

In days before modern breadboards, people who worked on electronics projects had to find a way to conveniently prototype circuits that allowed them to create removable electrical connections between components. Many folks found that using an actual breadboard (a piece of wood that you cut bread on) was useful. People would drill holes in them and then insert screws or nails in regular spacings in those holes. By wrapping the different legs of different components around the nails, they could achieve electrical connections at each individual nail.

The name “breadboard” continues to be used, even in modern versions that are no longer built out of pieces of wood. Breadboards have a bunch of built-in electrical connections. These electrical connections use terminal strips that are hidden on the back side of the breadboard. Along the sides of each panel run power rails. These long columns can be connected to Vcc and ground for easy access along the entire breadboard. In-between, rows of holes are connected by terminal strips, with a large trench running between two sets of rows. A terminal strip is a strip of exposed wire that connects each of the input holes. The trench provides electrical isolation between adjacent rows of pins, and is ideal for use with digital logic chips.

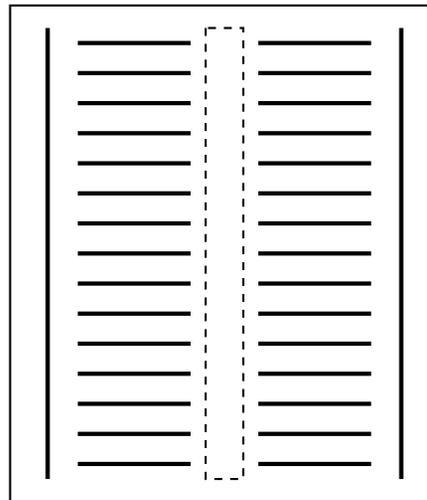


Figure 1.1: Diagram of the electrical connections (thick solid lines) and trench (dashed lines) on a breadboard.

Figure 1.1 shows a simplified layout of a breadboard. The dashed rectangle indicates the trench.

1.2 Digital Logic Signals

A digital logic signal can take on one of two values. This is why the binary number system is used in digital electronics. Binary represents two states, and those two states correspond to electrical signals in a circuit. These values can be represented as a binary value (with the numerals 0 and 1), as a signal (LOW and HIGH), as the positioning of a switch (OFF and ON), as a voltage value (0 V and 5 V), or using circuit notation (GND and VCC). These terms may be used interchangeably. This is shown in table 1.1.

1.2.1 Connecting Power to a Breadboard

Binding posts are used to connect to a power supply to supply digital logic signals. There is no inherent connection between the breadboard power rails and the binding posts. These connections must be made

Binary Value	Signal Value	Switch Status	Voltage	Circuit Notation
0	LOW	OFF (open)	0 V	GND
1	HIGH	ON (closed)	5 V	VCC

Table 1.1: Binary values, signal value, switch status, voltages, and circuit notation in digital logic.

manually. Each binding post can be unscrewed. When unscrewed, there is a hole that can be used to place a wire inside. Place the metal end of a jumper wire in this hole and screw the binding post back down to create a firm electrical connection. (Be careful that the plastic insulating part of the jumper wire isn't inserted into the binding post, only the metal end.) Lightly tug on the wire to ensure that it stays in place. Then, place the other end of the jumper wire into a power rail. Connections from that power rail can then be made to other places on the breadboard as needed. Use a banana plug (named due to the shape of the wire coming out of the end) to connect the power supply to the binding post.

Circuit 1: Connect a power supply to the breadboard. Do not turn the power supply on yet. Use a red banana plug for the power connection (+ terminal on the power supply), and a black banana plug for the ground connection (− terminal on the power supply). Use a red jumper wire to go from the red binding post to one of the power rails on your breadboard. Use a black jumper wire to go from the black binding post to a different power rail on the breadboard.

Note: it is important not to connect red and black wires into connected sections of the breadboard. This would create an electrical short circuit, creating a lot of current which generates heat and can melt the wire, the breadboard, or other circuit components.

When the power supply has been properly connected to the breadboard, demonstrate your setup to your instructor to receive a stamp. When you get the OK, you will be instructed to turn your power supply on and slowly dial it up to 5 V. This is how you will get every circuit started in this class.

Instructor Stamp: _____

1.2.2 Disconnecting and Turning Off the Power Supply

If the power supply needs to be temporarily disconnected from a circuit, do not turn the power supply on and off, as this will stress the power supply. In addition, when the power supply is turned on, the voltage may spike into the tens of volts before settling back to zero. Therefore, if the power supply is turned on and off when connected to a circuit, those voltage spikes may cause damage to anything connected to the supply.

To temporarily disconnect the power supply from the breadboard, either disconnect one of the banana plugs (it doesn't matter which one as any break in the connection to or from the power supply will interrupt the flow of current) or dial the voltage back to zero. When dialing back to 5 V again, do so slowly, as an over-voltage may damage components or melt the breadboard.

At the end of lab, when completely finished using the power supply, follow the indicated steps to turn the power supply off correctly.

1. Dial the voltage knob down to zero.
2. Unplug the banana plugs from the front of the power supply.
3. Turn the switch on the power supply to the OFF position.

1.3 Light-Emitting Diodes

Light-emitting diodes (LEDs) will be used in labs to determine whether the output of a logic functions is a 1 or a 0. A lit LED will correspond to 1 (ON), and an unlit LED will correspond to 0 (OFF). The LED is simply a convenient way to determine logic levels without having to use a voltage probe.

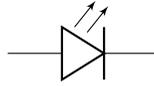


Figure 1.2: Circuit schematic of a light-emitting diode (LED). Current will flow in the same direction as the triangle (from anode to cathode), but will not flow in the opposite direction.

A diode is a semiconductor device that allows the flow of electrons in only one direction. Schematically, current flows in the same direction of the triangle in the circuit symbol (shown in figure 1.2) for the diode or LED. This means that high potential must be present on the anode (left side of the circuit diagram) and low potential must be present on the cathode (right side of the circuit diagram) for the LED to light up.

There are two ways to distinguish the anode from cathode in a physical LED, depicted in figure 1.3. The anode has a longer leg and is connected to the epoxy cap in a section where the cap has a rounded edge. The cathode has a shorter leg and is connected to the epoxy cap in a section where the cap has a flat edge.

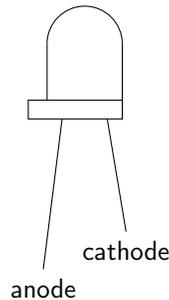


Figure 1.3: Depiction of an actual light-emitting diode (LED). The anode corresponds to the long leg connected to the round end of the epoxy cap. The cathode corresponds to the short leg connected to the flat end of the epoxy cap.

1.3.1 Current-Limiting Resistors

An LED can only tolerate a limited amount of current flowing through it before it overheats and possibly melts. It is therefore important to use a current-limiting resistor in every circuit path that contains an LED. A current-limiting resistor should be connected in series with an LED, and can be connected to either the anode or cathode, as depicted in figure 1.4.

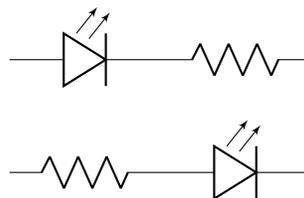


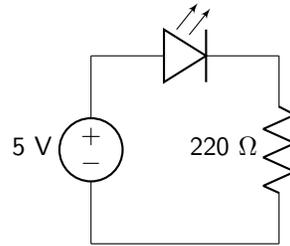
Figure 1.4: A current-limiting resistor can be connected to either the cathode (top) or anode (bottom) of an LED.

While different LED displays may require some calculation to determine the appropriate value of current-limiting resistor to be used, all of the LEDs used in these labs will work with a 220 Ω resistor. Resistors are

identified by reading the colored bands around the ceramic coating. Each color corresponds to a number. 220 Ω resistors are colored RED-RED-BROWN, which means 22×10^1 , or 220. The gold-colored stripe indicates the tolerance of the resistor, which means that the actual value of the resistor will fall between 5% of the indicated resistance value.

It is important to note that, unlike LEDs, resistors do not have a polarity to them. In other words, it does not matter which end is connected to high potential and low potential in a circuit.

Circuit 2: Connect the following circuit, which contains the power connections that you wired up previously to the power supply, and an LED with current-limiting resistor. If this successfully works, then you should see the LED light up.



When you have completed your circuit, verify that it works. Then, demonstrate your results to your instructor to receive a stamp.

Instructor Stamp: _____

1.4 DIP Switches

DIP stands for dual in-line package. Any component that has a DIP configuration contains two sets of pins set in parallel (in-line) columns. Each of the pins on a DIP component will be unique. That is, each pin has its own particular function, that depends on the device being used. This fact means that a DIP component must be inserted onto a breadboard such that the columns of pins straddle the isolating trench in the center of the board. This prevents the pins that would otherwise share a row from being shorted together. Virtually all of the components used in this class will be of DIP architecture.

Because the pins in any DIP component are set vertically, they can be very easily bent. For this reason, it is important to be very careful when inserting and removing DIP chips from the breadboard. Use the dental probe to gently wedge the DIP component out from top and bottom, and then pull vertically upward to remove the DIP switch. Do not apply a large force to the DIP component from only one side, as that tends to cause the pins on the opposing side of the pins to bend (for example, if levering up strongly from the bottom, the top pins may bend outward).

DIP switches are a convenient package of toggle switches that are used to control the input signals of a digital logic circuit, which can correspond to the two logic states defined in table 1.1. This allows signal inputs to a digital logic circuit to be controlled in one location without having to continuously move wires from one place to another on the breadboard. A diagram of a DIP switch containing four toggle switches is shown in figure 1.5. The position of the slider indicates the value of each switch. In

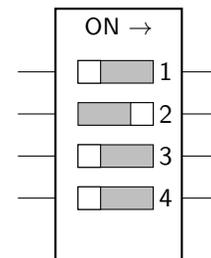


Figure 1.5: Diagram of a DIP switch containing four toggle switches. Switches 1, 3, and 4 are OFF. Switch 2 is ON.

figure 1.5, switches 1, 3, and 4 are in the OFF (open switch) position. Switch 2 is in the ON (closed switch) position.

Digital logic signals can only be generated in a DIP switch if it is connected properly. Electrical connections to both GND and VCC are required to do this. The left side of the DIP switch is therefore connected to VCC. Each of the switches that is to be used must have its own connection to VCC made somewhere in the adjoining row on the breadboard.

A connection to GND is also required to avoid floating values (which indicate that no electrical connection exists). The right side of a DIP switch cannot be directly connected to ground (as that would cause a short circuit when the switch is closed), but instead must contain a pull-down resistor. A pull-down resistor connects the right side of the DIP switch to GND, hence the name “pull-down” (pulling down to zero volts.) The pull-down creates an electrical connection without shorting anything out. The signal wire is always connected between the switch and the pull-down resistor. In this manner, a pull-down resistor accomplishes two functions: it prevents short circuits, and prevents floating values.

Figure 1.6 shows a circuit diagram of the proper wiring of a DIP switch. The left side of the switch is connected directly to VCC. The right side of the switch is connected to GND using a pull-down resistor. When the switch is OFF (figure 1.6, left), the switch is open. Current cannot flow, and the DIP switch signal value is LOW. When the switch is ON (figure 1.6, right), the switch is closed. Current flows from VCC to GND, via a pull-down resistor to protect against short circuits. In this case, the DIP switch signal value is HIGH.

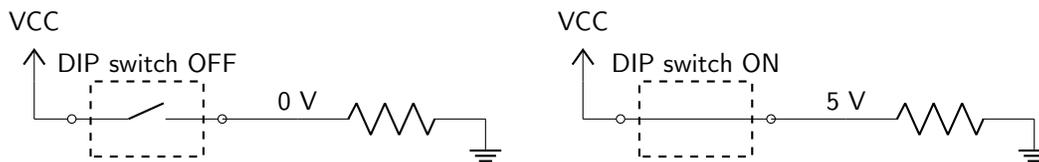


Figure 1.6: Schematic of a DIP switch connected directly to VCC and to GND via a pull-down resistor, both when the slider is in the OFF position (left) and when the slider is in the ON position (right).

Circuit 3: Connect two switches of a DIP switch to two LEDs. In this manner, each of the switches will control one of the LEDs. When you have completed your circuit, verify that it works. Then, demonstrate your results to your instructor to receive a stamp.

Instructor Stamp: _____

1.5 Preparation for Lab 2

Carefully read through lab 2. You will use TinkerCAD to build some of the circuits that will be built in lab 2, giving you practice in completing the circuit in a simulation before building it in real life. Your instructor will provide you with a course access code to sign up for TinkerCAD. Using that access code, your circuit can therefore be viewed by your instructor to provide you with feedback prior to the next lab. **You will not need to obtain stamps for these simulations, as your instructor will view them, grade them, and provide feedback after lab 1 ends and before lab 2 begins.**

Circuit 4: Build a NOT gate circuit in TinkerCAD using the 7404 chip.

Circuit 5: Build an OR gate circuit in TinkerCAD using the 7432 chip.

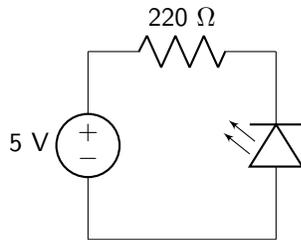
Circuit 6: Build an AND gate circuit in TinkerCAD using the 7408 chip.

Lab 1 Homework

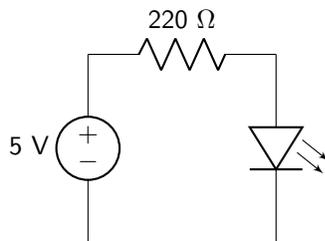
Carefully read each question before answering. Show all work or justify your answers to receive credit. Attach a separate sheet of paper, if necessary, to show all work and calculations.

1. Build the following LED circuits in your TinkerCAD account, using the access code provided by your instructor. For each circuit, indicate below whether or not the LED will be lit. If the LED does not light, explain why.

(a)



(b)



(c)

