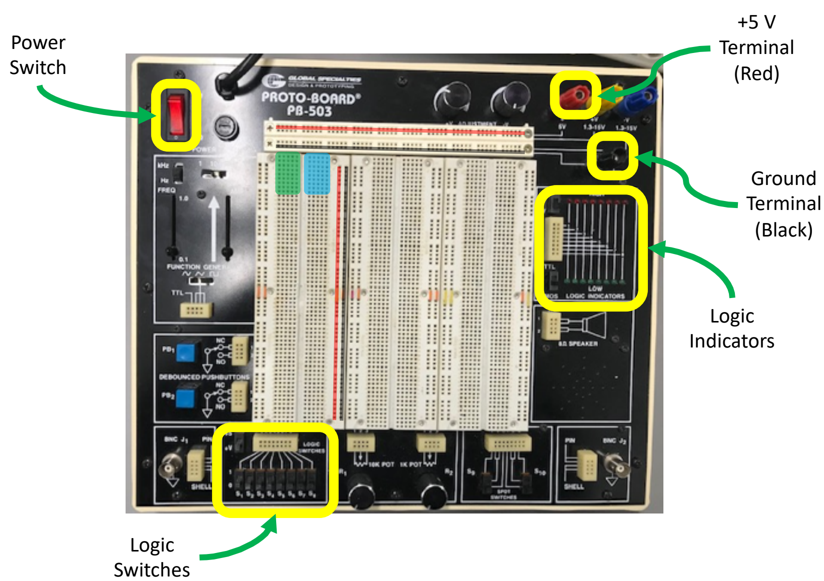
NAMES: ____

COMP256 – Computing Abstractions
Dickinson College
LAB #1
Introduction to Digital Electronics and Switching

Introduction:

In this lab you will be introduced to some of the equipment used for prototyping electronic circuits. Each station is equipped with a Proto-Board (Figure 1) and a Digital Multimeter (DMM) (Figure 2) and a box holding wires, tweezers, a wire stripper and a pair of plyers. In addition, you will find a small box containing the electronic components that we will be using.



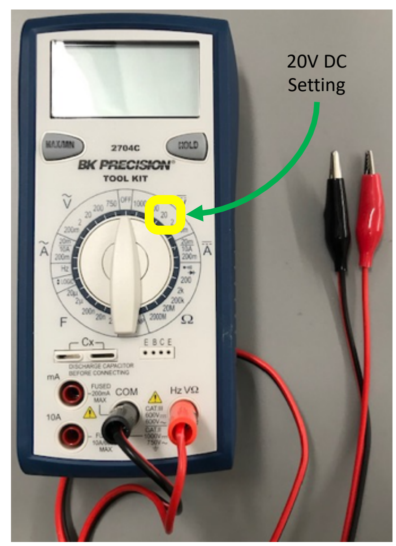


Figure 1: The Proto-Board with the essential elements labeled. **Figure 2:** Digital Multimeter

1’s and 0’s are Voltages:

It is common to hear the phrase “computers only understand 1’s and 0’s.” In the circuits that make up the computer these 1’s and 0’s are logical values associated with electrical potentials (or voltages). Positive voltages indicate a logical 1 (or a true value), while voltages near 0 represent a logical 0 (or a false value). In the circuits we work with voltages between 3 and 5 volts will be called “high” and will indicate a logical 1 (or true). Voltages between 0 and 2 volts will be called “low” and will indicate a logical 0 (or false). Notice that there is a gap between the ranges that are considered logical 0 and 1. This is done to make it unlikely that small variations in components or electrical interference will change 0’s into 1’s or vice versa.

1. The digital multimeter has a wide variety of functions, but for our purposes we will only need to use it to measure direct current (DC) voltages less than 20 volts (V). Turn the dial on the multimeter to the 20V DC setting. What is displayed in the LCD display?

2. Turn on the Proto-Board using the power switch. Then touch the black lead of the DMM to the Ground Terminal and touch the red lead to the +5V Terminal. What does the DMM read? Is that a logical 0 or a logical 1?

Exploring the Proto-Board:

3. Using the red lead of the DMM and a wire, measure the voltage between some of the holes on the protoboard with the horizontal red line on them in Figure 1 and the Ground Terminal. To do this the black lead should remain in contact with the Ground Terminal. This will be the case for all voltages that you are asked to measure.

What voltage do they read?

Is that a logical 0 or a logical 1?

4. Repeat question 3 for the holes on the protoboard with the horizontal black line on them in Figure 1.

What voltage do they read?

Is that a logical 0 or a logical 1?

These holes all have the same voltage because they are all connected together inside the Proto-Board. The ones with the red line are also connected to the +5 Terminal and the ones with the black line are connected to the Ground Terminal. This connection is indicated by the white lines painted on the Proto-Board case. Other white lines on the Proto-board case indicate other connections.

5. What is the voltage at the holes under the vertical red and black lines?

Like the holes under the horizontal lines the holes under each vertical line are also connected (as are those in each of the other small 2-hole wide vertical columns). However, these vertical lines are not yet connected to the +5V or Ground Terminals.

6. Connect the column of holes under the vertical red line to +5V by inserting a wire between the row connected to the +5V Terminal and the column. Now what is the voltage in the holes under the vertical red line?

7. For each of the 6 pairs of vertical columns, connect the left column to +5V and the right column to ground. By convention a red wire should be used when connecting to +5V and a black wire should be used when connecting to ground. Ideally these colors will only be used for those purposes. It may not seem important now, but in more complex circuits this color coding can be very helpful. Use the DMM to confirm that each column is connected correctly. **Have the instructor verify that your Proto-Board is properly connected before going on.**

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8. The green and blue highlights of Figure 1 indicate some of the holes in the wider columns of the Proto-Board.

Are the holes in these wider columns internally connected horizontally or vertically?

Are the holes under the green highlight connected internally to those under the blue highlight?

Explain, in a few complete sentences, how you determined your above answers.

Switching:

Almost as common as "computers only understand 1's and 0's" is the phrase "computers only understand on and off." This can get confusing, because sometimes people really mean logical 1 (or a positive voltage) when they say on and logical 0 (or ground) when they say off. But other times, people mean on and off like we think about with a light switch. This second interpretation is consistent with the fact that everything in the central processing unit (CPU) and memory (RAM) of a computer is based on turning switches on and off.

In the next several sections you'll learn about circuits with switches and how some switches (relays and transistors) can be turned on and off using voltages. You'll see how these switches can perform a very basic logical computation. Then, in the next lab, you'll use transistors to build circuits that perform other logical computations.

A Manually Switched Circuit:

In this section you will experiment with a circuit containing a resistor (Figure 3) and a manual "knife" switch (Figure 4).

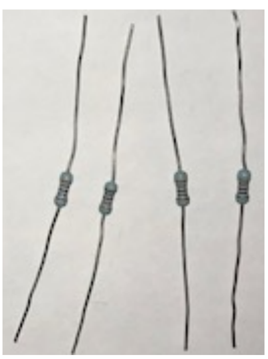

Figure 3: Four resistors

Figure 4: A Knife Switch in the open position.

Figure 5 shows a diagram, called a schematic, of the circuit you are to build. The squiggly line represents a resistor, the part that looks like the knife switch, well… that represents the switch. The small triangle represents ground. The same ground symbol can be seen painted on the Proto-Board case near the Ground Terminal.

Figure 6 shows one way that this circuit can be wired-up on the Proto-Board. Notice how the resistor is connected to the switch using the row connection of the Proto-Board. The connections from the resistor to +5 V and from the switch to ground are made in similar ways.

9. Before wiring this circuit, **turn off the Proto-Board power switch**. You should always turn off the power when making wiring changes to a circuit. Connect up the circuit as shown in Figure 6. **Have the instructor inspect your circuit before continuing.**

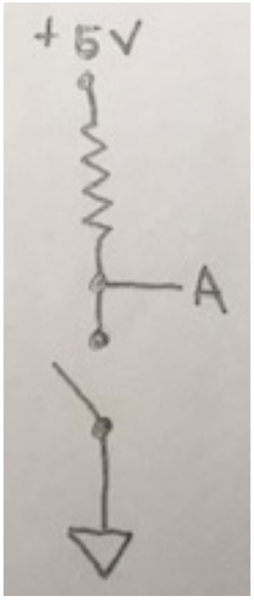

Figure 5: Knife switch circuit schematic

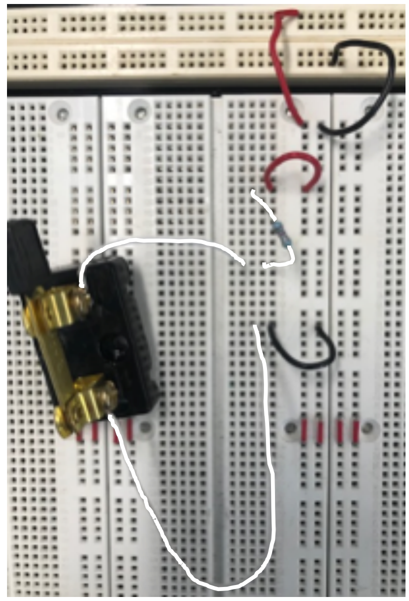

Figure 6: Knife switch circuit on the Proto-Board.

10. Turn on the Proto-Board power and experiment with your circuit to complete the blanks in the sentences below:

When the switch is open the voltage at point A is ________ which is a logical ____.

When the switch is closed the voltage at point A is ________ which is a logical ____.

11. Make sure the small switch next to the “Logic Indicators” on the Proto-Board is set to CMOS. Then, use a wire to connect point A in the circuit to one of the Logic Indicators. Experiment with your circuit to complete the blanks in the sentences below:

When the switch is open the Logic Indicator is __________ indicating a logical ____.

When the switch is closed the Logic Indicator is __________ indicating a logical ____.

<u>An Electromagnetic Relay:</u>

An electromagnetic relay is an electrically controlled switch. That is, it works like the knife switch, but it can be opened and closed using an electrical signal instead of manually. Figure 7 shows an electromagnetic relay with some of its parts labeled. The green wires control the electromagnetic coil, similar to the electromagnet you probably made using wire and a nail in a science class a long time ago. The white wires connect to two ends of a switch, just like those that were connected to the knife switch. Figure 8 shows the schematic symbol for an electromagnetic relay.

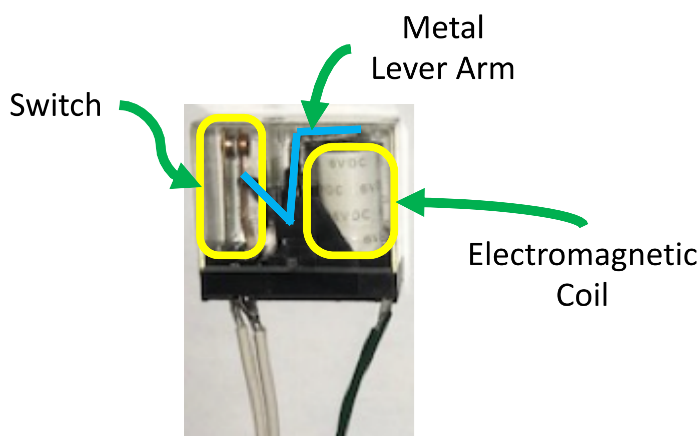

Figure 7: Electromagnetic Relay

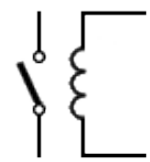

Figure 8: Relay schematic symbol

12. Make sure the little switch next to the Logic Switches on the Proto-Board is set to +5V and set one of the Logic Switches to logical 0 (i.e. ground or 0V). Connect one of the green wires to ground and connect the other to the Logic Switch that you just set to 0. Turn on the Proto-Board power (you did remember to turn it off right?) and flip the Logic Switch from 0 to 1 and back to 0. Describe, in a few complete sentences, what happens in the relay when the input to the electromagnetic coil is a 0 (low or ground) or a 1 (high or +5V).

13. Now remove the knife switch from the circuit on the protoboard replace it with the relay by connecting the white (switch) wires in place of the knife switch leads (wires). The green wires should remain connected to Ground and the Logic Switch. **Have the instructor inspect your circuit before continuing.**

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14. Fill in the blanks in the sentences below:

When the Logic Switch is a 0 the switch in the relay is __________ and

the Logic Indicator is ________.

When the Logic Switch is a 1 the switch in the relay is __________ and

the Logic Indicator is ________.

15. Use the schematic symbol for the relay shown in Figure 8 to draw a schematic diagram for your new circuit. Your diagram should not contain the Logic Switches or the Logic Indicator. Instead, simply label those wires as input and output, as appropriate.

An N-Type Transistor:

One of the big advantages of using of vacuum tubes and subsequently transistors as switching devices in computers (as compared to relays), is that they have no moving parts. Of course, with no moving parts is not an actual switch inside the transistor. Rather the electrical properties of the materials (silicon dioxide semiconductors) from which the transistor is made cause it to behave like a switch. Because they have no moving parts, transistors can turn on and off much faster than relays (billions of times per second vs hundreds of times per second).

Figure 9 shows a discrete solid-state (i.e. no moving parts) transistor. Inspecting the transistors in your parts bin you will see that, unlike with the relay, it will be impossible to visually check if the transistor "switch" is open or closed. Instead, we will have to deduce whether the transistor "switch" is open or closed based on the behavior of a circuit.

Figure 9: A transistor

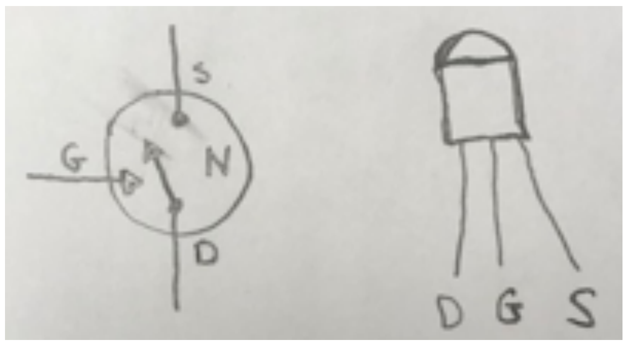

Figure 10: N-Type transistor heuristic symbol and pin map

Figure 10 shows a heuristic symbol for an N-Type transistor and a pin map for the physical device. This is a heuristic (not a schematic) symbol because it illustrates the behavior of the transistor as a switch, even though there is not an actual switch inside the transistor. We will see the more formal schematic symbol for a transistor in class. The letters D, G and S stand for the three contact points for the transistor: Drain, Gate and Source. The gate, like the electromagnetic coil input on the relay, controls the transistor "switch". The source and drain are like the switch leads of the knife switch or the relay.

16. Remove the electromagnetic relay from your circuit and insert the N-Type transistor into the circuit as shown in the schematic in Figure 11. Connect the input of the circuit (i.e. the gate) to one of the Logic Switches and the output of the circuit (A) to one of the Logic Indicators. **Have the instructor inspect your circuit before continuing.**

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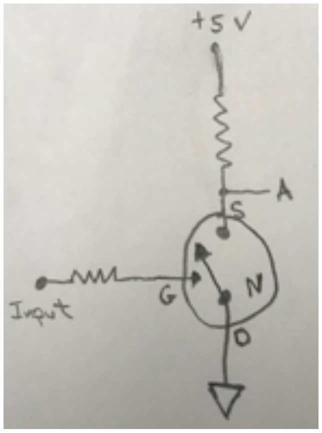

Figure 11: Schematic for circuit containing an N-Type transistor.

17. Experiment with your circuit to complete the blanks in the sentences below.

When the input is a 0 the output is a ____.

When the input is a 1 the output is a ____.

18. Given your answer to question #17, what logical function does this circuit compute? Explain. (Hint: Recall that 0 = low = false and 1 = high = true.)

19. Write a rule for an N-Type transistor that explains the “switch” position (open or closed) as a function of the value (0 or 1) on the gate.

A P-Type Transistor:

There are two primary types of transistors used in the construction of computers. You learned about the N-Type transistor above. In this section you will experiment with a P-Type transistor. The N and P used to name these transistors refer to two different types of impurities that are added to the silicon dioxide during manufacturing (a process called doping) to produce the desired switching behavior.

20. Replace the N-Type transistor in your circuit from Figure 11 with the P-Type transistor. The source, gate and drain of the P-Type transistor have the same orientation as the N-Type transistor. Be sure to keep them in the same configuration in the circuit. Draw a schematic diagram of your new circuit using the heuristic symbol for a P-Type transistor shown in Figure 12.

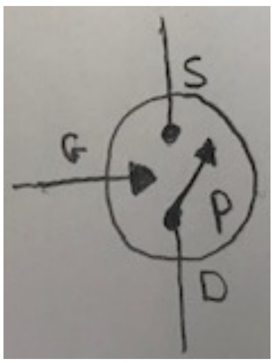

Figure 12: Heuristic symbol for a P-Type transistor

21. Experiment with your circuit to complete the blanks in the sentences below.

When the input (gate) is a 0 the output is a ____.

When the input (gate) is a 1 the output is a ____.

22. Given your answer to question #21, what logical function does this circuit compute? Explain. (Hint: Recall that 0 = low = false and 1 = high = true.)

23. Write a rule for a P-Type transistor that explains the “switch” position (open or closed) as a function of the value (0 or 1) on the gate.

24. Which transistor (N-Type or P-Type) behaves more like an electromagnetic relay? Explain.