Logic Gates Lab – Instructions

Overview

This laboratory has five parts:

- Part 1: Transistor NOT gate
- Part 2: NOT gate 74LS04 chip
- Part 3: AND gate 74LS08 chip
- Part 4: OR gate 74LS32 chip
- Part 5: XOR gate 74LS86 chip

You will create a simple NOT gate using a transistor and resistor. Then, you will test the operation of integrated circuit chips with NOT, AND, OR gates, and XOR gates, and verify correct operation.

Preparation

1. Make sure you have your lab kit that you purchased from the bookstore.
2. Watch this video: How to Use a Breadboard (12 minutes).
3. Watch this video: Getting Started (6 minutes).
4. Optional videos:
    - A walkthrough video of an *older version* of the lab: Logic Gates Lab Walkthrough (22 minutes).
    - A video to help you find problems with your circuit if your circuit doesn't seem to work: Debugging the EXOR Circuit (8 minutes).

Required Equipment and Materials

- 74LS04 NOT Gate Integrated Circuit (1)
- 74LS08 AND Gate Integrated Circuit (1)
- 74LS32 OR Gate Integrated Circuit (1)
- 74LS86 XOR Gate Integrated Circuit (1)
- Solderless breadboard (1)
- Red LED (1)
- 220 Ohm resistor (2)
- Male-to-male jumper wires (20)
- NPN Transistor [PN2222] (1)
- For Method 1 below:
    - Power Supply Module LAFVIN Super Starter Kit for Uno R3 (1)
    - 9V battery (1). **NOTE**: Sometimes this is included in the kit and sometimes it is not.
    - Battery connector (1)
- For Method 2 below:
    - Arduino Uno (1)
    - USB cord (1)

Required Data Sheets

These data sheets show the pin connections and electrical characteristics of electronic components. Engineers use these data sheets; the instructions in this worksheet cover all the information you need to know, but you are welcome to review the data sheets for additional learning opportunities.

- 74LS04 Hex Inverter Gates
- 74LS08 Quad 2-Input AND Gates
- 74LS32 Quad 2-Input OR Gates
- 74LS86 Quad 2-Input Exclusive-OR Gates

Background

The **74LS04 NOT gate**, also called an inverter, is an electronic circuit that implements the NOT function. The output is the opposite of the input. If the input is HIGH, the output is LOW and vice versa. This integrated circuit (IC) contains six NOT gates.

A	F
0	1
1	0

Figure 1

The **74LS08 AND gate** implements the AND function. The output is HIGH only if all the inputs are HIGH. If any input is LOW, the output is LOW. This IC contains four AND gates.

A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

Figure 2

The **74LS32 OR gate** implements the OR function. The output is LOW only if all the inputs are LOW. If any input is HIGH, the output is HIGH. This IC contains four OR gates.

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

Figure 3

The **74LS86 XOR gate** implements the Exclusive OR (XOR) function. The output is HIGH when an odd number of the inputs are HIGH. Otherwise, the output is LOW. This IC contains four XOR gates.

A	B	F
0	0	0
0	1	1
1	0	1
1	1	0

Figure 4

Connect Power and Ground to the Breadboard

There are two methods to supply power to the breadboard: (1) the power supply module, or (2) the Arduino UNO. Method 2 is generally more reliable because the batteries die quickly.

Method 1: Use the Power Supply Module

1. Plug the power supply module into the solderless breadboard as shown in Figure 5.

2. On the power supply module, there are two yellow jumpers. The yellow jumpers are adjustable brackets on the edge of the module. There are four prongs which provides the jumpers three positions to be in: 3.3V, Off, or 5V. Move the two yellow jumpers to the 5V position, as shown in Figure 5.

3. Insert four male-to-male jumper wires across the middle of the negative and positive lines of both busses as shown by the red wires in Figure 5. This step is important to extend the 5V and GND busses along the entire length of the board.

> **NOTE**: The male-to-male jumper wires from your kit will look different than the wires shown in Figure 5, but they can be used for this.

4. Connect the 9V battery to the power supply module using [cord]. Ensure it is correctly connected by pressing the white button next to the green LED. This will turn the power on and the LED will turn on.

5. Turn the power supply module off by pushing the button again. The LED will turn off. Do not continue the project until you have the power off.

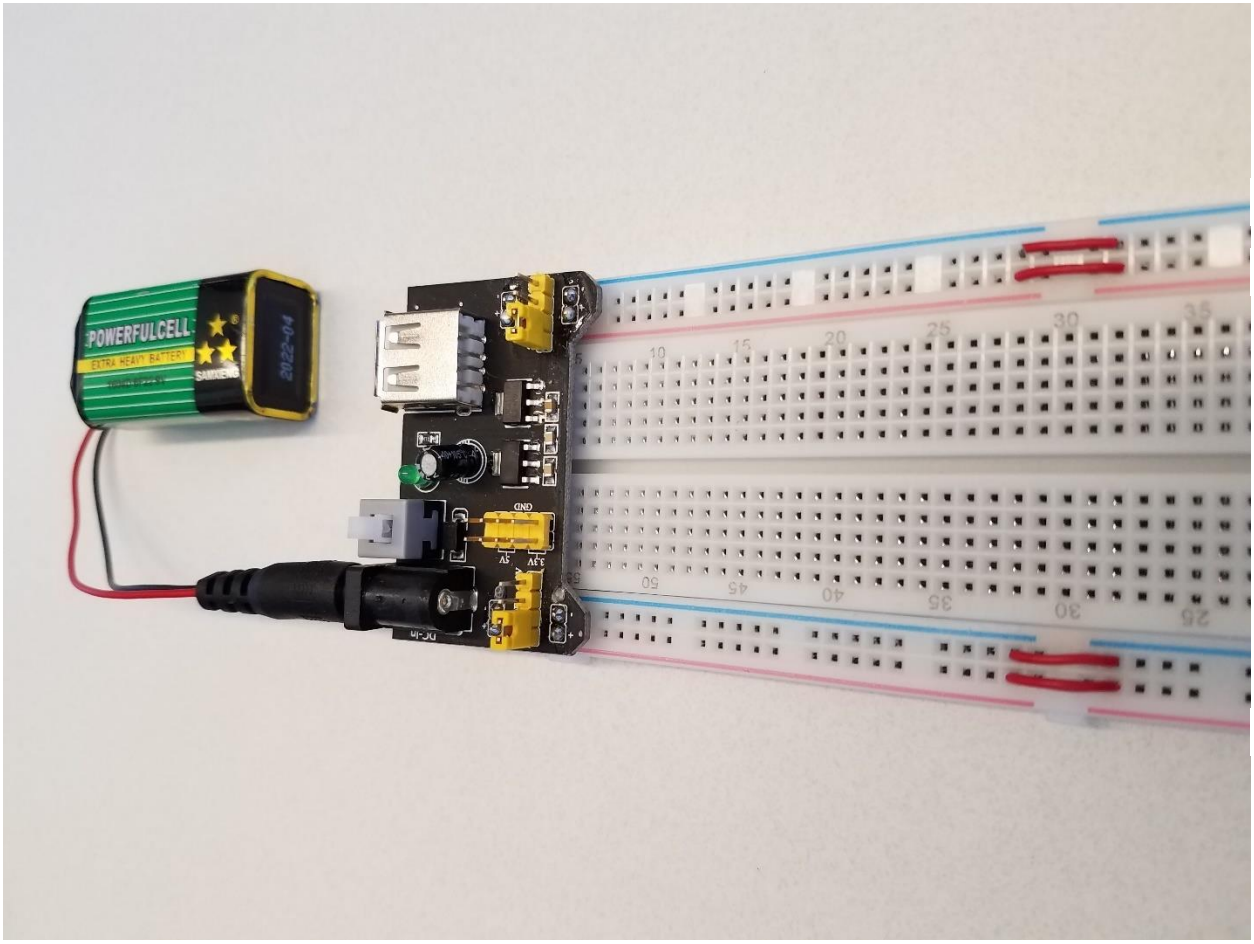


Figure 5

Method 2: Use the Arduino UNO

1. Connect a male-to-male jumper wire from the **5V pin** on the Arduino Uno to the **5V bus** (near the red line) on the solderless breadboard as shown by the diagonal red wire in Figure 6.

2. Use a male-to-male jumper wire to connect the **5V bus** on the top side of the board to the **5V bus** on the other side of the board as shown by the vertical red wire in Figure 6.

3. Connect a male-to-male jumper wire from the **GND pin** on the Arduino Uno to the **GND bus** (near the blue line) on the solderless breadboard as shown by the diagonal black wire in Figure 6.

4. Use a male-to-male jumper wire to connect the **GND bus** on the top side of the board to the GND bus on the other side of the board as shown by the vertical black wire in Figure 6.

5. Insert four male-to-male jumper wires across the middle of the negative and positive lines of both busses as shown by the horizontal black and red wires in Figure 6. This step is important to extend the 5V and GND busses along the entire length of the board.

> **NOTE**: The male-to-male jumper wires from your kit will look different than the wires shown in Figure 6, but they can be used.

6. Cut the power from the solderless breadboard before continuing. Do so by unplugging the Arduino board from your computer before proceeding.

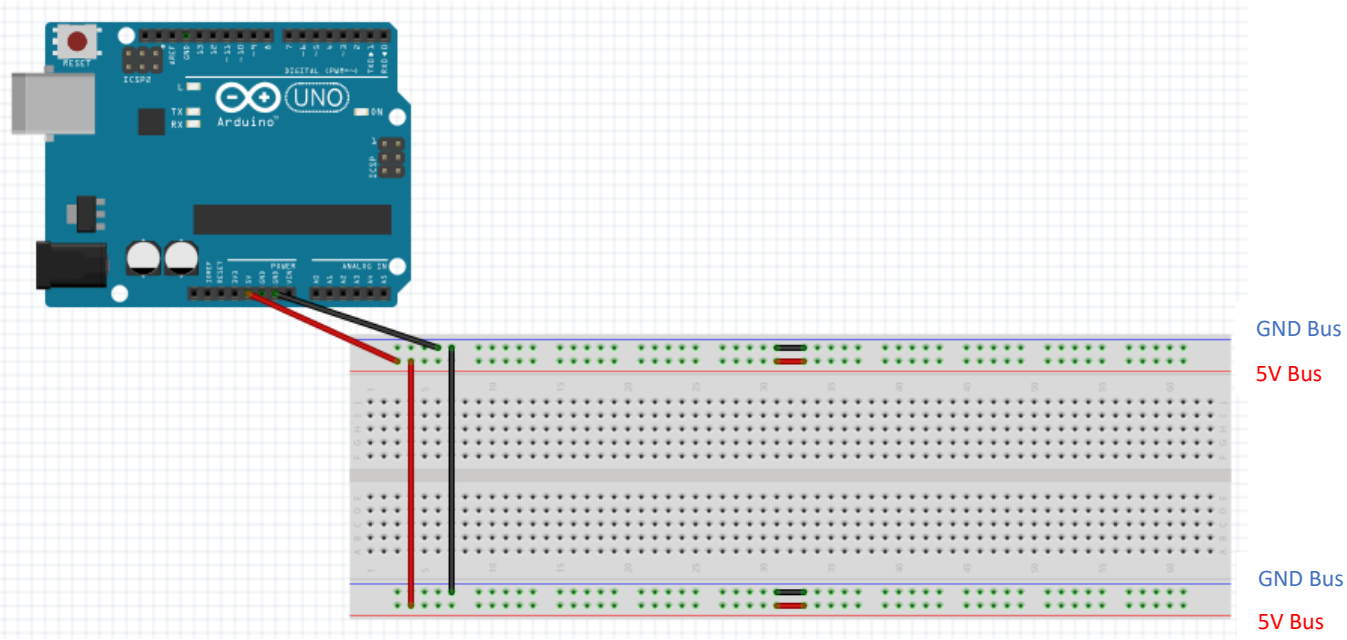


Figure 6

Note: For the rest of the lab, whenever you test one of your circuits, it will need power using either Method 1 or Method 2.

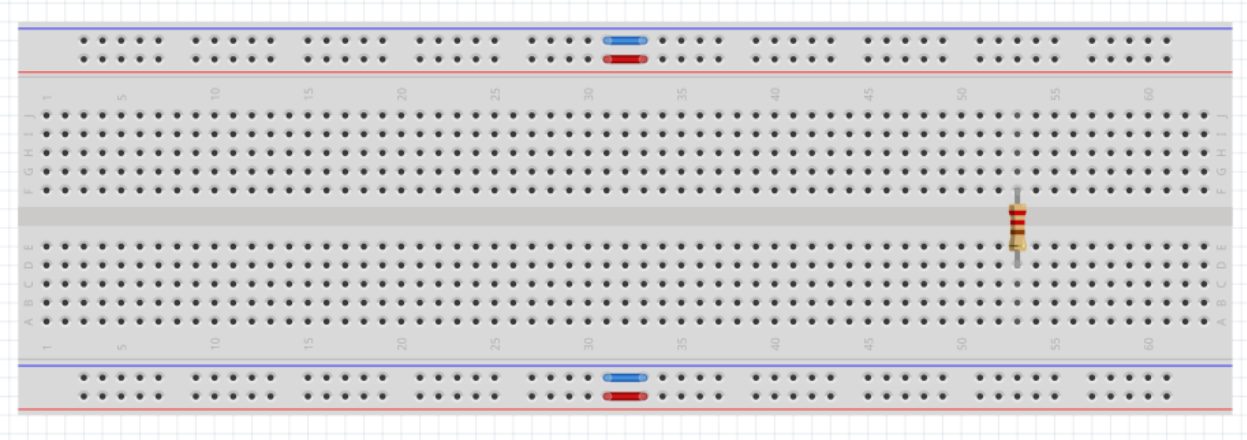
Testing the LED

The first steps help you set up the LED that will we will using as the “output” of our circuits. The negative side of the LED will always be connected to ground (low voltage). The positive side of the LED will have a high (True) or low voltage (False) depending on if we want to turn on or off the LED. LEDs require resistors to not burn out.

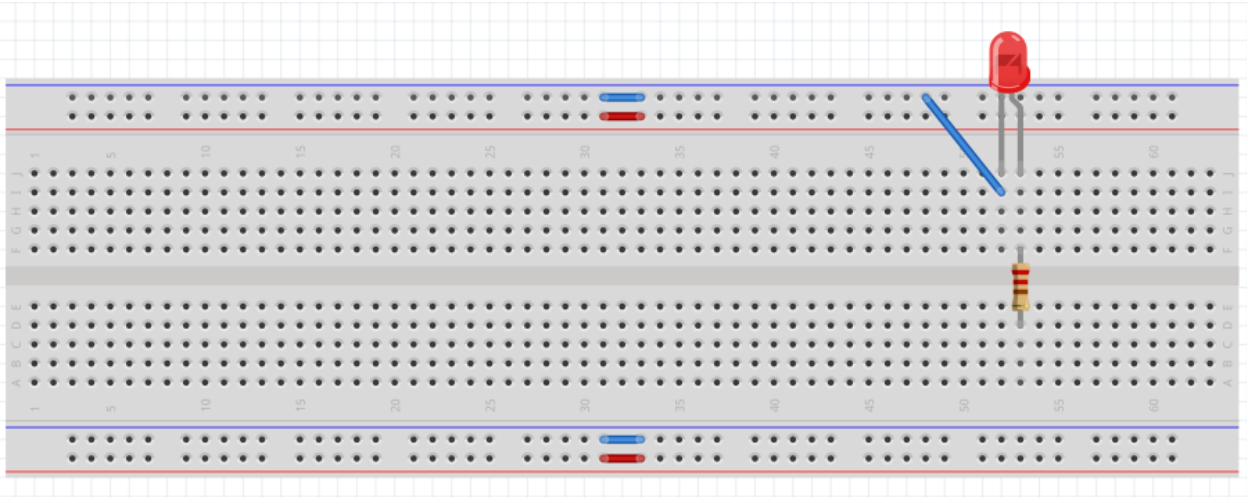
1. Find your 220 Ohm resistors. The color bands are red, red, black, black, brown (or reversed).

   Note: The resistors in the diagrams have slightly different colors. Use the colors listed above.

2. Plug a 220 Ohm resistor into the breadboard across the gap. Place in on the right side of the breadboard to leave room on the left for the chips we will add later.

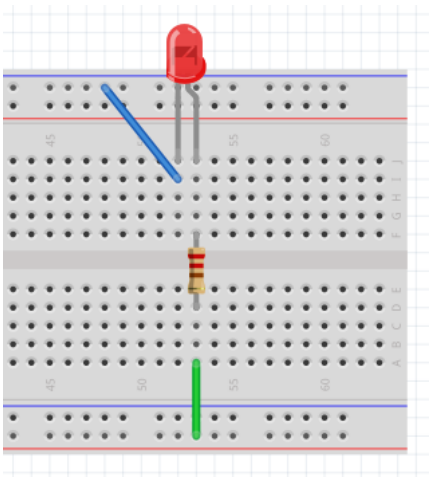


3. Find a red LED. Plug the red LED with the long lead in the same column as the resistor. The “bent” leg in the diagram below is the long leg. It is the positive side.
4. Connect the short lead of the LED to the GND bus with a jumper wire.

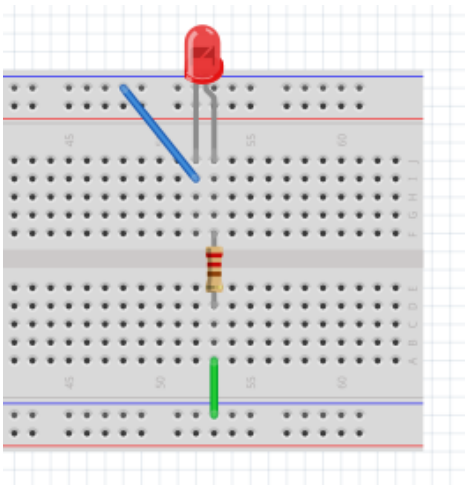


5. Connect the resistor to a high voltage to turn on your LED by plugging one end of a jumper wire to the same column as the resistor and the other end to a High Voltage bus (see the left image in the next image). This is sending a “True” signal to the LED.

6. Turn on power (the LED should turn on).
7. Move the jumper wire you just added back and forth between the Ground Bus (False) and the High Voltage Bus (True). The light should turn off, indicating “False,” when connected to the Ground Bus, and the light should turn on, indicating “True,” when connected to the High Voltage Bus.



HIGH - Light should be ON



LOW - Light should be OFF

If your LED doesn’t turn on:

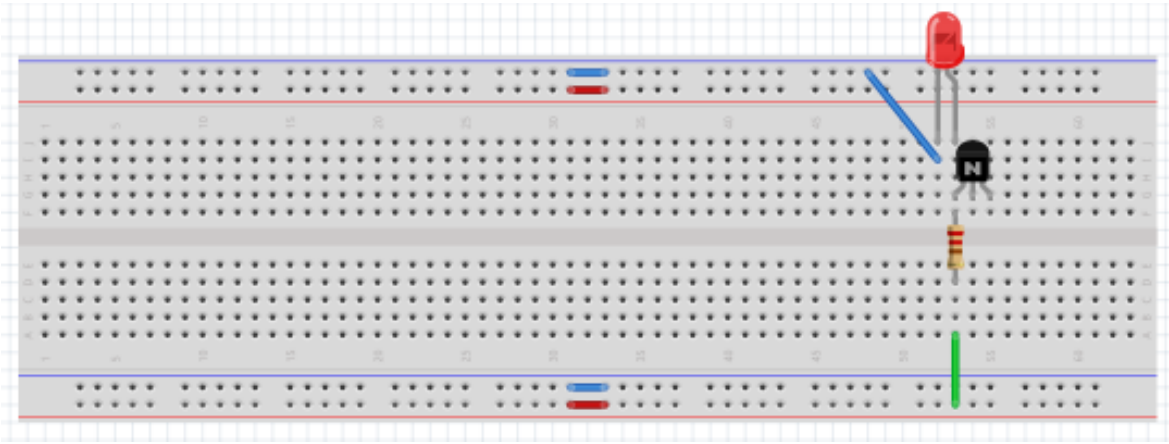
- Make sure that you have powered your board using either Method 1 or Method 2 from earlier.
- Make sure that you connected the power busses across the gap.
- Make sure the LED is not backwards.
- Make sure you have the right resistor (red, red, black, black, brown).
- Ask a T.A. or the instructor for help.

8. To get ready for the next section, move the jumper wire back to the High Voltage Bus (True).
9. Disconnect power to prepare to build the circuit in the next section.

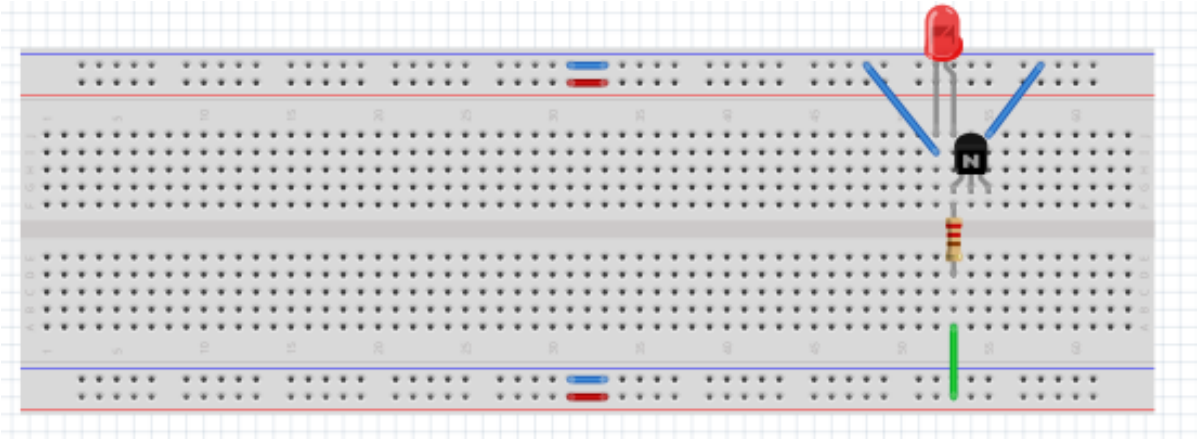
Note: When building logic circuits, a HIGH voltage is considered a TRUE, which maps to a Binary 1. A LOW voltage is considered a FALSE, which maps to a Binary 0.

Part 1: Building a Transistor NOT Gate

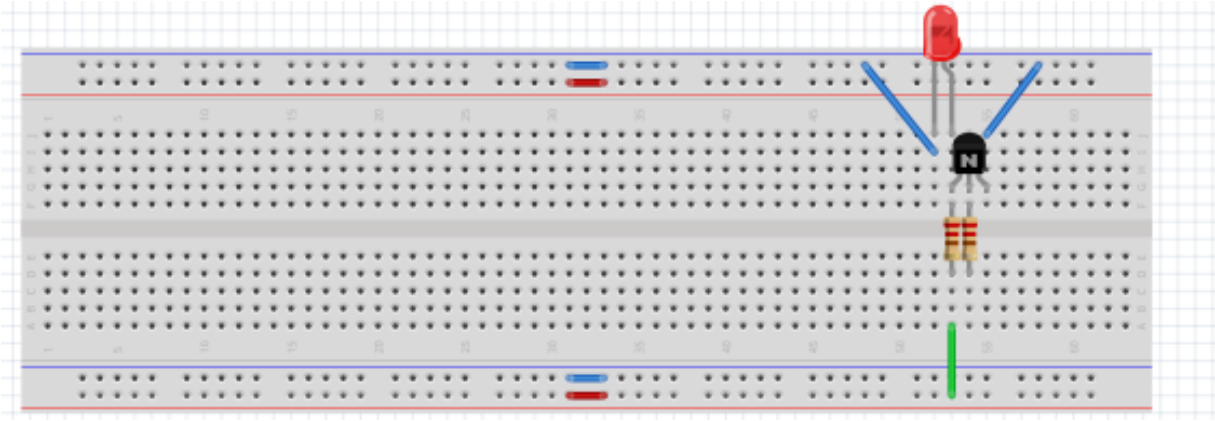
1. Find an NPN transistor. It is probably labeled “PN2222” or “PN 2222A.”
2. The transistor has three legs. With the flat side towards you, plug the left leg into the same column as the long leg of the LED with the other two legs being in the two columns to the right (see image below).



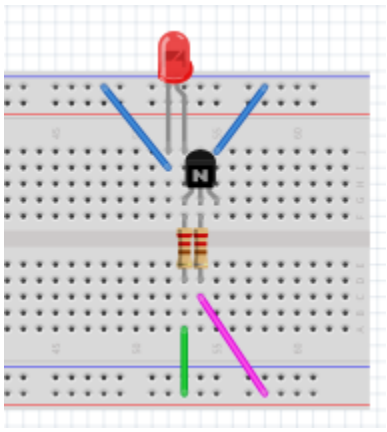
3. Connect the right leg of the transistor to Ground by plugging one end of a jumper wire into the same columns as the right leg and the other end into the Ground Bus.



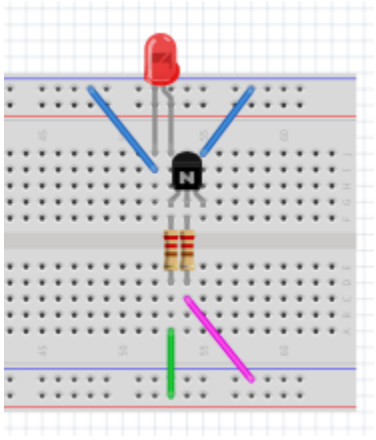
4. Add another 220-ohm resistor to the same column as the middle transistor leg, across the gap.



5. Using a jumper wire, connect the middle-leg resistor (the resistor on the right) to either a High or Low voltage. This will be the input to your NOT gate (shown in magenta below).
6. Power on the circuit.
7. Switch the input wire (shown in magenta below) back and forth between high and low voltage. When the input is HIGH, the output (LED) should be LOW (off). When the input is LOW, the output (LED) should be HIGH (on).



Input (magenta wire) HIGH
Light should be OFF (LOW)



Input (magenta wire) LOW
Light should be ON (HIGH)

Congratulations! You have built a NOT gate using a transistor and resistor.

Record – Photo: Take a photo of the NOT gate you built with a transistor and resistor. You will upload this to I-Learn.

Record – Truth Table: In your report (in I-Learn), enter the values you observed with your LED into the truth table for Part 1. "A" is your input (magenta wire). For the row where "A" is 0, that means your magenta wire was connected to Ground Bus. For the row where "A" is 1, that means your magenta wire was connected to the High Voltage Bus. The "Actual Output" is the LED. It should match the truth table of a NOT gate.

Part 1: Transistor NOT Gate

Please enter in the values you observed after building a **NOT** gate with a transistor:

A	Actual Output
0	
1	

Enter 1 for the light being on (true). Enter 0 for the light being off (false).

In future ECEN courses, you can learn how to build other Logic Gates using transistor. For the remaining portions of this lab, you will be using pre-built logic gates which have the transistors inside of *integrated circuit* (IC) chips.

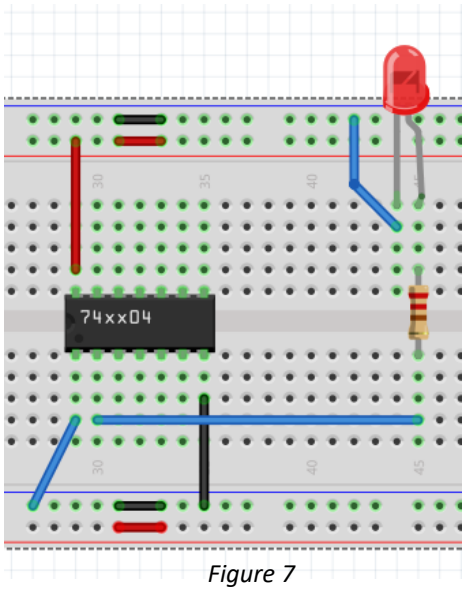
Part 2: 74LS04 NOT Gate

The first three steps construct the output circuit that will be used with all the other circuits in this laboratory.

1. Plug a 220 Ohm resistor into the solderless breadboard (Figure 7).

2. Plug in a red LED with the long lead in the same column as the resistor (Figure 7).

3. Connect the short lead of the LED to the GND bus with a jumper wire (Figure 7).



← The 220 Ohm resistor in the LAFVIN Super Starter Kit for UNO R3 has five color bands: red, red, black, black, brown.

Figure 7

Continue with connecting the NOT gate.

4. Plug the 74LS04 into the breadboard. You may have to carefully bend the pins slightly inward to line them up with the holes in the solderless breadboard (Figure 7). Be sure the 74LS04 is plugged into the board with the notch marking toward the power supply module. See the pin diagram for a 14-pin integrated circuit (IC) in Figure 8.

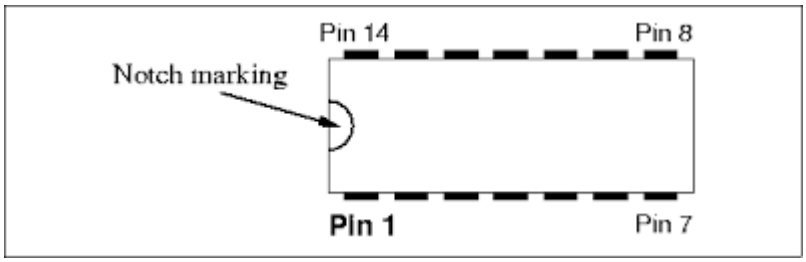


Figure 8

5. Connect **pin 7** to **GND bus** as shown by the vertical black wire in Figure 7.

6. Connect **pin 14** to **5V bus** as shown by the vertical red wire in Figure 7.

NOTE: There are six NOT gates inside the 74LS04 IC (Figure 9).

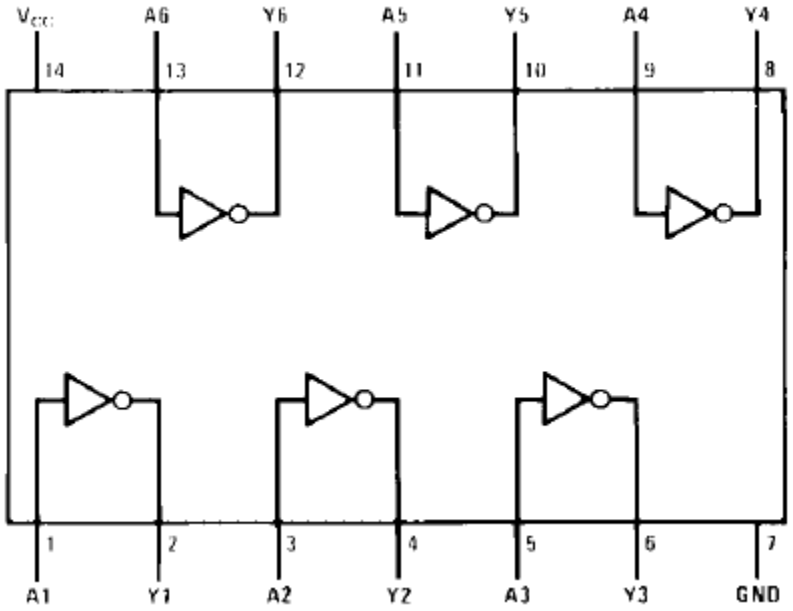


Figure 9

7. Connect the output **Y** of the first NOT gate (**pin 2**) to the **resistor** as shown by the horizontal blue wire in Figure 7.

8. Connect the input **A** of the first NOT gate (**pin 1**) to **GND bus** (logic 0) as shown by the diagonal blue wire in Figure 7.

9. Connect power to the solderless breadboard by pushing the button on the power supply module or connecting the Arduino board to your computer.

10. Observe the LED. If the LED is on, the output is HIGH (logic 1). If the LED is off, the output is LOW (logic 0).

In I-Learn, there is a table like the table in Figure 10. This is where you will record your results for Part 2.

Part 1: NOT gate Truth Table

A	Actual Output
0	
1	

Figure 10

11. Record the output's value (0 or 1) in the first row of your truth table for Part 1 (like the table in Figure 10).

12. Connect the input **A** of the first NOT gate (**pin 1**) to **5V bus** (logic 1) as shown by the diagonal blue wire in Figure 11.

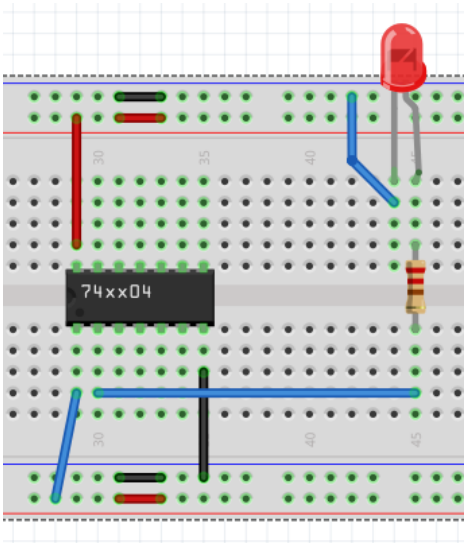


Figure 11

13. Record the output's value (0 or 1) in the second row of your truth table for Part 1.

14. Verify that the outputs you obtained are the same as what you expected.

15. Disconnect power from the solderless breadboard.

16. Carefully remove the 74LS04 by prying up both ends with a pencil or pen. You must lift it straight out to avoid bending and breaking the pins. The 5V and GND wires remain in the same place for the 74LS08.

You have now completed Part 2 of the lab. Continue onto the next page for Part 3.

Part 3: 74LS08 AND Gate

1. Plug the 74LS08 into the solderless breadboard (Figure 12).

2. Connect **pin 7** to **GND bus** as shown by the vertical black wire in Figure 12.

3. Connect **pin 14** to **5V bus** as shown by the vertical red wire in Figure 12.

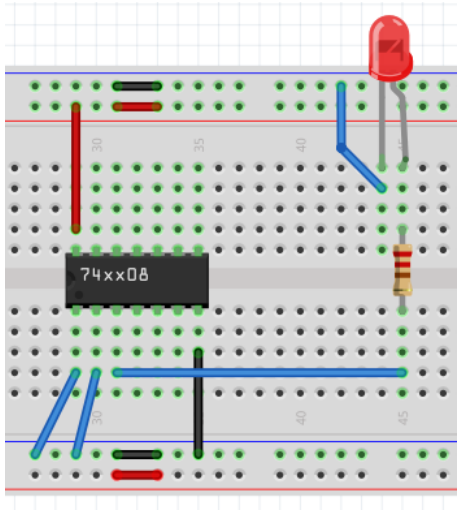


Figure 12

Note: There are four AND gates inside the 74LS08 IC. You can see them below in Figure 13.

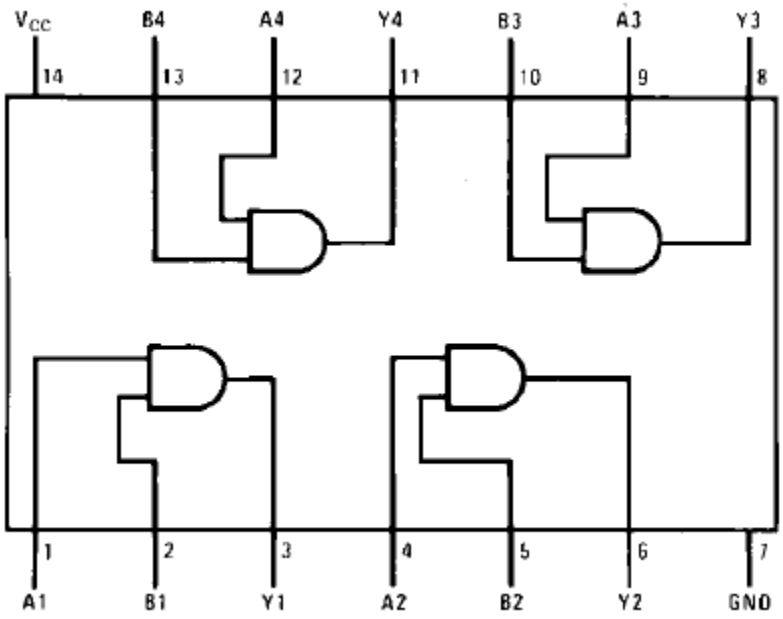


Figure 13

4. Connect the output **Y** of the first AND gate (**pin 3**) to the **resistor** as shown by the horizontal blue wire in Figure 12.

5. Connect input **A** of the first AND gate (**pin 1**) to **GND** (logic 0) as shown by the diagonal blue wire in Figure 12.

6. Connect input **B** of the first AND gate (**pin 2**) to **GND** (logic 0) as shown by the diagonal blue wire in Figure 12.

7. Connect power to the solderless breadboard.

In I-Learn, there is a table like the table in Figure 14. This is where you will record your results for Part 2.

Part 2: AND gate Truth Table

A	B	Actual Output
0	0	
0	1	
1	0	
1	1	

Figure 14

8. Record the output's value (0 or 1) in the first row of your truth table for Part 2.

9. Connect input **A** of the first AND gate (**pin 1**) to **GND** (logic 0) as shown by the diagonal blue wire in Figure 15.

10. Connect input **B** of the first AND gate (**pin 2**) to **5V** (logic 1) as shown by the diagonal blue wire in Figure 15.

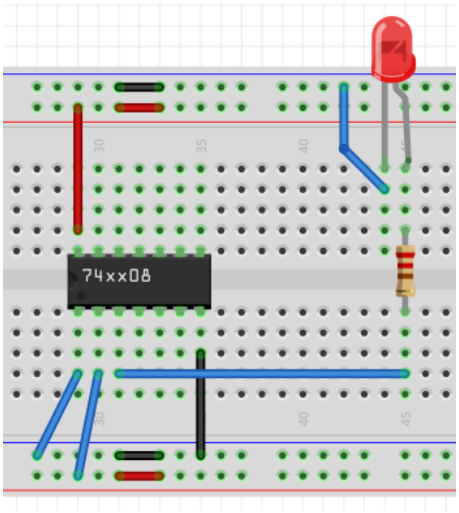


Figure 15

11. Record the output's value (0 or 1) in the second row of your truth table for Part 2.

12. Connect input **A** of the first AND gate (**pin 1**) to **5V** (logic 1) as shown by the diagonal blue wire in Figure 16.

13. Connect input **B** of the first AND gate (**pin 2**) to **GND bus** (logic 0) as shown by the diagonal blue wire in Figure 16.

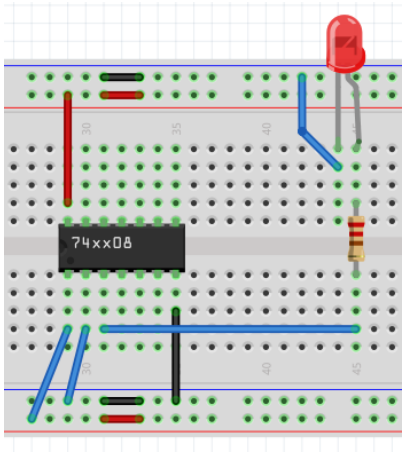


Figure 16

14. Record the output's value (0 or 1) in the third row of your truth table for Part 2.

15. Connect input **A** of the first AND gate (**pin 1**) to **5V** (logic 1) as shown by the diagonal blue wire in Figure 17.

16. Connect input **B** of the first AND gate (**pin 2**) to **5V** (logic 1) as shown by the diagonal blue wire in Figure 17.

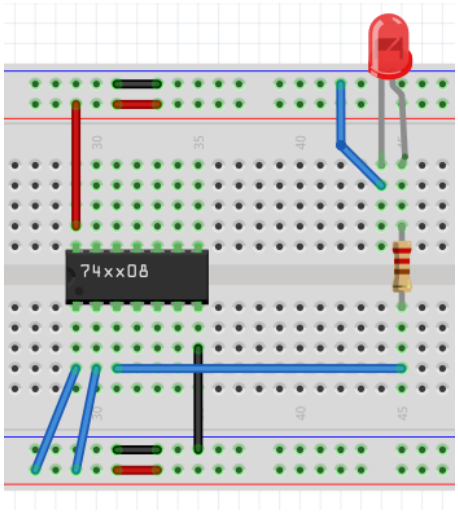


Figure 17

17. Record the output's value (0 or 1) in the fourth row of your truth table for Part 2.

18. Verify that the outputs you obtained are the same as what you expected.

19. Disconnect power from the solderless breadboard.

20. Carefully remove the 74LS08.

You have now completed Part 3 of the lab. Continue onto the next page for Part 4.

Part 4: 74LS32 OR Gate

1. Plug the 74LS32 into the solderless breadboard.

2. Connect **pin 7** to **GND bus** as shown by the vertical black wire in Figure 18.

3. Connect **pin 14** to **5V bus** as shown by the vertical red wire in Figure 18.

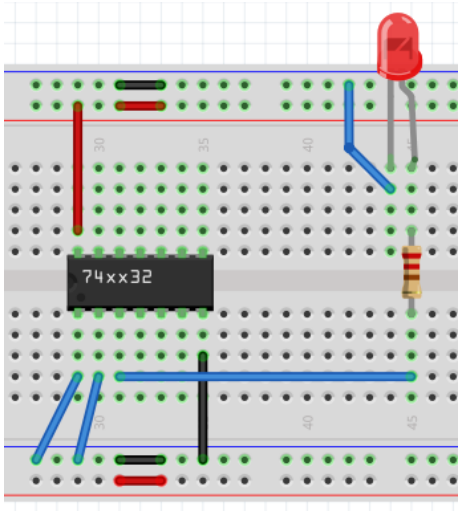


Figure 18

Note: There are four OR gates inside the 74LS32 IC. You can see them below in Figure 19.

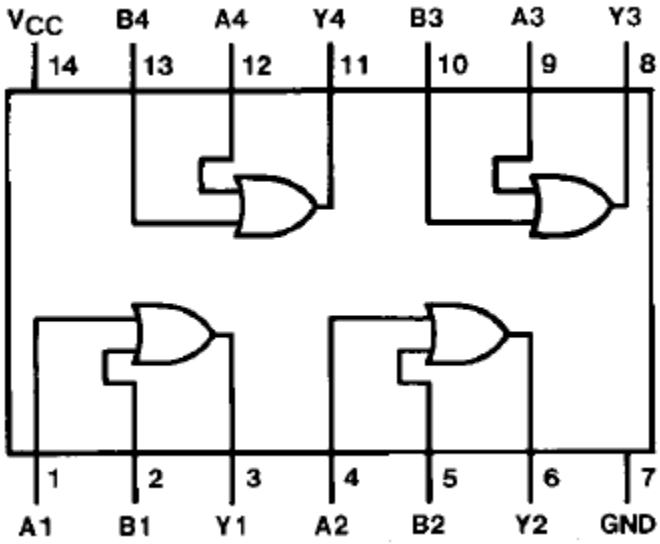


Figure 19

4. Connect the output **Y** of the first OR gate (**pin 3**) to the **resistor** as shown by the horizontal blue wire in Figure 18.

5. Connect input **A** of the first OR gate (**pin 1**) to **GND bus** (logic 0) as shown by the diagonal blue wire in Figure 18.

6. Connect input **B** of the first OR gate (**pin 2**) to **GND bus** (logic 0) as shown by the diagonal blue wire in Figure 18.

7. Connect power to the solderless breadboard.

In I-Learn, there is a table like the table in Figure 20. This is where you will record your results for Part 3.

Part 3: OR gate Truth Table

A	B	Actual Output
0	0	
0	1	
1	0	
1	1	

Figure 20

8. Record the output's value (0 or 1) in the first row of your truth table for Part 3.

9. Continue testing the other three combinations of inputs and outputs and recording the output values in the corresponding row of your truth table for Part 3.

10. Verify that the outputs you obtained are the same as what you expected.

11. Disconnect power from the solderless breadboard.

12. Carefully remove the 74LS32.

You have now completed Part 4 of the lab. Continue onto the next page for Part 5.

Part 5: 74LS86 XOR Gate

1. Plug the 74LS86 into the solderless breadboard.

2. Connect **pin 7** to **GND bus** as shown by the vertical black wire in Figure 21.

3. Connect **pin 14** to **5V bus** as shown by the vertical red wire in Figure 21.

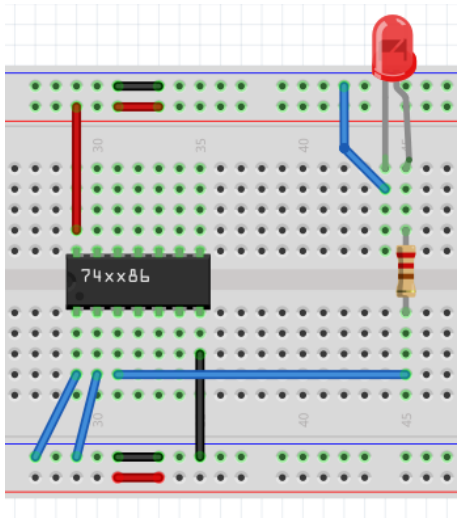


Figure 21

Note: There are four XOR gates in the 74LS86 IC. You can see them below in Figure 22.

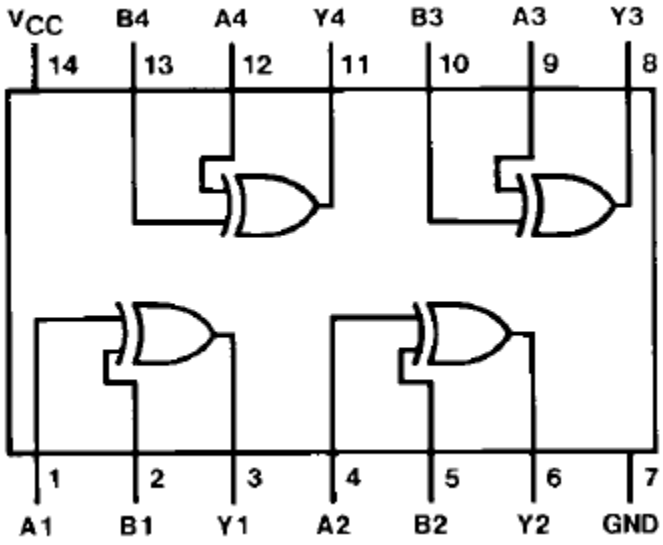


Figure 22

4. Connect the output **Y** of the first AND gate (**pin 3**) to the **resistor** as shown by the horizontal blue wire in Figure 21.

5. Connect input **A** of the first XOR gate (**pin 1**) to **GND** (logic 0) as shown by the diagonal blue wire in Figure 21.

6. Connect input **B** of the first XOR gate (**pin 2**) to **GND** (logic 0) as shown by the diagonal blue wire in Figure 21.

7. Connect power to the solderless breadboard.

In I-Learn, there is a table like the table in Figure 23. This is where you will record your results for Part 4.

Part 4: XOR gate Truth Table

A	B	Actual Output
0	0	
0	1	
1	0	
1	1	

Figure 23

8. Record the output's value (0 or 1) in the first row of your truth table for Part 4.

9. Continue testing the other three combinations of inputs and outputs and recording the output values in the corresponding row of your truth table for Part 4.

10. Verify that the outputs you obtained are the same as what you expected.

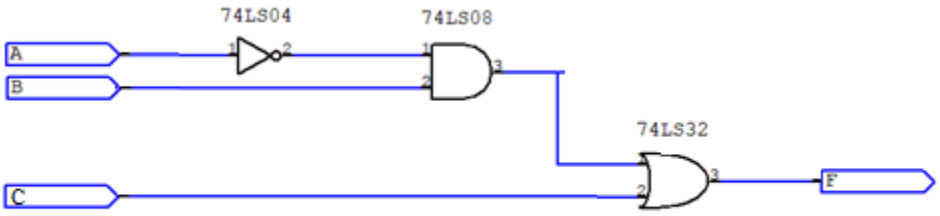
11. Disconnect power from the solderless breadboard.

12. Carefully remove the 74LS86.

You have now completed Part 5 of the lab. Continue onto the next page for an optional activity.

Optional: Logic Circuit

If you finish early, try combining gates into a larger logic circuit. For example, you could build this circuit:



This circuit implements the following Boolean equation: $F = \bar{A} \cdot B + C$

The truth table for this circuit is shown below:

ABC	F
000	0
001	1
010	1
011	1
100	0
101	1
110	0
111	1

Wire it up and verify that you get the same outputs for each input combination as is shown in the truth table.

You have now completed the lab.

Submit Your Laboratory Report

After completing this laboratory go to I-Learn and find the Lab Report assignment for this lab. Enter in the truth table values you recorded for Parts 1, 2, 3, 4, and 5.