Pre-Lab 2

Carefully read the entirety of Lab 2, then answer the following questions. Attach a separate sheet of paper, if necessary, to show all work and calculations.

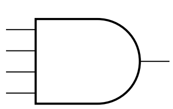
1. How many resistors will you need to use when wiring up Circuit 7? The circuit has three inputs and one output signal.

2. What will happen to a digital logic chip if the power and ground connections are swapped?

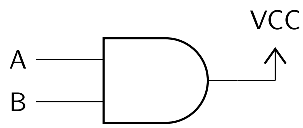
3. What is meant by a floating input?

4. What will happen to the output of a logic chip that has a floating input?

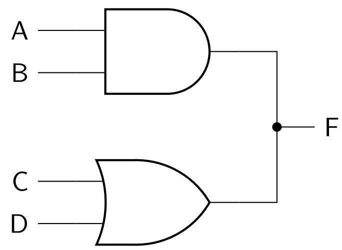
5. What is the fan-in of the following AND gate?



6. Describe the problem with the following circuit.



7. Describe the problem with the following circuit.



8. Identify each of the following logic chips.

   (a) T74LS283B1

   (b) SN74LS02N

   (c) 74LS00PCQR

   (d) SN74HC595N

   (e) SN74ALS08N

9. Derive a truth table for a 3-input OR gate.

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

10. Derive a truth table for a 3-input AND gate.

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

Lab 2: Digital Circuits

This lab focuses on digital circuits, and will introduce basic logic functions. These logic functions will be described using circuit diagrams, truth tables, and expressions. The digital logic chips that contain logic functionality will also be introduced. These logic chips are part of a "family" of logic gates known as TTL. You will learn about how to use these logic chips, and then connect them together in several different circuits.

For lab resources and information, go to the following URL or scan the QR code. doctor-pasquale.com/digital-systems-lab-2

2.1 Digital Logic Functions

There are three basic universal logic functions that can be used to build any digital circuit, regardless of its complexity. These logic functions are AND, OR, and NOT, and each is explained in detail in the class textbook.

Any digital circuit can be described using a circuit diagram, a truth table, or a Boolean expression. In labs, each of these has a valuable purpose. A circuit diagram provides the blueprint of how a circuit should be built using each individual logic gate and logic chip. The truth table can be used to either verify that a circuit is working as expected (if the circuit is already well-understood), or to record the information about how a circuit functions (if the circuit is not already well-understood). A Boolean expression acts as a convenient shorthand to describe a circuit in a manner that takes up less physical space than a circuit diagram or a truth table.

You will derive truth tables for three of the most fundamental logic gates by using circuits created out of switches on a printed circuit board (PCB). When the switch is in the left-hand position, it is off (0). When it is in the right-hand position it is on (1).

Circuit 1: Record the truth table for the NOT gate. When you have finished recording data, demonstrate it to your instructor to receive a stamp.

A	F
0	
1	

Instructor Stamp: ______

Circuit 2: Record the truth table for the AND gate. When you have finished recording data, demonstrate it to your instructor to receive a stamp.

A	B	F
0	0	
0	1	
1	0	
1	1	

Instructor Stamp: ______

Circuit 3: Record the truth table for the OR gate. When you have finished recording data, demonstrate it to your instructor to receive a stamp.

A	B	F
0	0	
0	1	
1	0	
1	1	

Instructor Stamp: ______

2.2 Transitor-Transistor Logic

The digital logic chips that will be used in this class are part of the Texas Instruments 7400 series, which are members of the TTL (Transistor-Transistor Logic) family. TTL devices use a particular type of transistor to create the logic gates internal to each chip. TTL chips have particular voltage values that must be present on the input in order to be registered as a logic HIGH or logic LOW value. When these conditions are present, the circuitry will generate a logic LOW or logic HIGH output value within certain voltage values specified by the TTL electronics. These input and output voltage ranges are provided in table 2.1. Note that the output values have tighter voltage values, which enables compatibility when the output of one logic chip is connected to the input of another logic chip.

Signal Type	LOW voltage values (V)	HIGH voltage values (V)
input	0–0.8	2–5
output	0–0.4	2.4–5

Table 2.1: Voltage values present on the input and output of a 5 V TTL logic chip given a logic HIGH or logic LOW condition.

2.2.1 Power Connections

Power connections must be made to every digital logic chip. This establishes the logical HIGH and logical LOW values used on the chip, and also power the internal circuitry, allowing it to function properly. Switching these two connections **will** cause a chip to overheat, and possibly melt. Therefore, special care must be taken to ensure that the chip is inserted properly and that all power connections are made to the correct power rail on the breadboard.

2.2.2 Floating Inputs

All inputs to a TTL logic circuit must have a clearly defined value, as given in table 2.1. Importantly, a logic circuit input cannot be floating. A floating input means that there is no electrical connection at all, either to VCC or GND. If there are any floating inputs on a logic gate (or even a more complicated logic device), the output may behave unpredictably. For this reason, all inputs must be connected to a properly wired DIP switch, or directly to VCC or GND.

2.2.3 Outputs

While inputs must be connected properly, different considerations must be made with logic circuit outputs. All logic circuit outputs will assert themselves (establishing either a logical HIGH or logical LOW output value) based on the input values and device functionality. For this reason, an output signal should **never** be directly connected to another signal value, such as VCC, GND, or another logic chip output. If this were to happen, a short circuit could result. This could cause (in the best case) the circuit to malfunction or (in the worst case) could damage the chip, possibly irreversibly.

2.2.4 Reading Part Numbers

The 7400 series of digital logic chips all have part numbers that indicate what the device is used for. These part numbers contain multiple parts. Each follows a similar format: XX74YYZZZPP. Each of these parts is explained below.

- **XX** – manufacturer (optional)
- **74** – 7400 series
- **YY** – device family (optional)
- **ZZZ** – part number

- **PP** – packaging (optional)

The most important value given is the part number. This provides the identity of the chip and its functionality. The part number of every chip used in your digital logic circuits should be verified before placing it into your breadboard.

As an example, consider the part number 74LS126N. This part number does not contain a manufacturer label. The 74 indicates that the device is part of the 7400 series of TTL logic devices and will be compatible with other TTL chips. The device family is LS, which explains exactly how the device is fabricated, and dictates its electrical properties, power consumption, and switching characteristics. The part number is 126. Looking at the list of 7400 chips, that identifies the chip as a Quad, 3-state buffers chip. Finally, the packaging is given by N, which indicates that the device is packaged in a plastic DIP format.

2.3 DIP Chips

As discussed in Lab 1, DIP stands for dual in-line package. DIP switches were used to create connections to digital logic signals. The chips containing digital logic gates also have a DIP architecture. As mentioned, the pins on a DIP chip are very fragile and can be bent and broken quite easily. Visually verify that all of the pins are present and in good shape before inserting a DIP chip into your breadboard. Each pin has a particular function. For this reason, it is important to understand how a DIP chip is oriented and how the pins are numbered. A DIP chip is shown in figure 2.1.

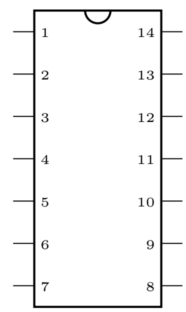


Figure 2.1: Diagram of a DIP chip with 14 pins.

The notch on the DIP chip indicates which end is up. When placing a DIP chip into a breadboard, ensure that the notch points to the top of the breadboard. The pin numbering starts at the pin in the upper left, and continues counter-clockwise around the chip.

A pinout diagram is used to determine the purpose of each of the pins on a logic chip. First, the part number must be established. Second, the notch must be placed in the correct orientation. The pinout diagram can then be used. Pinout diagrams for all of the chips used in your labs are provided in appendix A. An example pinout diagram is provided in figure 2.2 for the 7408 chip.

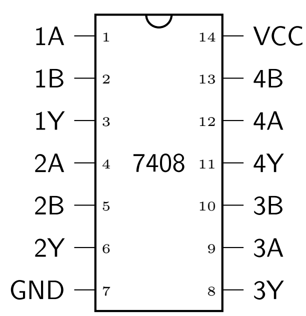


Figure 2.2: Pinout diagram of the 7408 chip.

A datasheet is a more complete set of information describing a digital logic chip. The datasheet contains a pinout diagram, but also a complete description, logic diagrams, electrical properties, switching characteristics, and other important information. A datasheet must be consulted if more detailed information about a digital logic chip is required than just the label corresponding to each pin.

Circuit 4: Refer to the pinout diagram for the 7404 chip. Use it to wire up a NOT circuit, using a DIP switch as the logic circuit input and an LED as the logic circuit output. Draw the circuit diagram. When you have completed your circuit, verify that it works. Then, demonstrate your results to your instructor to receive a stamp.

Instructor Stamp: ______

Circuit 5: Refer to the pinout diagram for the 7408 chip. Use it to wire up an AND circuit, using a DIP switch as the logic circuit input and an LED as the logic circuit output. Draw the circuit diagram. When you have completed your circuit, verify that it works. Then, demonstrate your results to your instructor to receive a stamp.

Instructor Stamp: ______

Circuit 6: Refer to the pinout diagram for the 7432 chip. Use it to wire up an OR circuit, using a DIP switch as the logic circuit input and an LED as the logic circuit output. Draw the circuit diagram. When you have completed your circuit, verify that it works. Then, demonstrate your results to your instructor to receive a stamp.

Instructor Stamp: ______

2.4 Fan-In

Fan-in corresponds to the number of inputs that a logic gate contains. The 7408 and 7432 chips used in the previous circuits have a fan-in of two, as each individual logic gate only has two inputs. In this class, the fan-in of all logic chips will be two, due to a limited inventory of parts. Therefore, it is important to understand how to use logic gates with a fan-in of two to act as logic gates with larger fan-in (such as three or four, which could be necessary for a 3-input gate or a 4-input gate).

Circuit 7: Determine how to wire up a 3-input OR gate. When you are finished, draw the circuit diagram and wire up the circuit on your breadboard. Use an LED to determine the output values. Demonstrate its functionality to your instructor to receive a stamp.

Instructor Stamp: ______

Circuit 8: Determine how to wire up a 3-input AND gate. When you are finished, draw the circuit diagram and wire up the circuit on your breadboard. Use an LED to determine the output values. Demonstrate its functionality to your instructor to receive a stamp.

Instructor Stamp: ______

2.5 XOR and XNOR

XOR and XNOR logic gates are not part of the family of universal logic gates (NOT, AND, OR), meaning that they cannot be used to build any logic circuit. However, they may still provide a useful function in reducing the complexity of a circuit that you need to build. The XOR chip (7486) is available to use in lab. However, there is no XNOR chip. Understanding how to wire this up using the components that are available will be helpful in future labs.

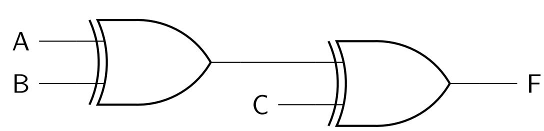
Circuit 9: Determine how to wire up a 2-input XNOR gate. (There is no XNOR chip available to use, so another way to build this will need to be determined.) When you are finished, draw the diagram and wire up the circuit on your breadboard. Use an LED to determine the output values. Fill out the corresponding truth table. Demonstrate its functionality to your instructor to receive a stamp.

A	B	F
0	0	
0	1	
1	0	
1	1	

Instructor Stamp: ______

Circuit 10: Wire up the following circuit on your breadboard. Use an LED to determine the output values. Fill out the corresponding truth table. Demonstrate its functionality to your instructor to receive a stamp.

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



Instructor Stamp: ______

Lab 2 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.

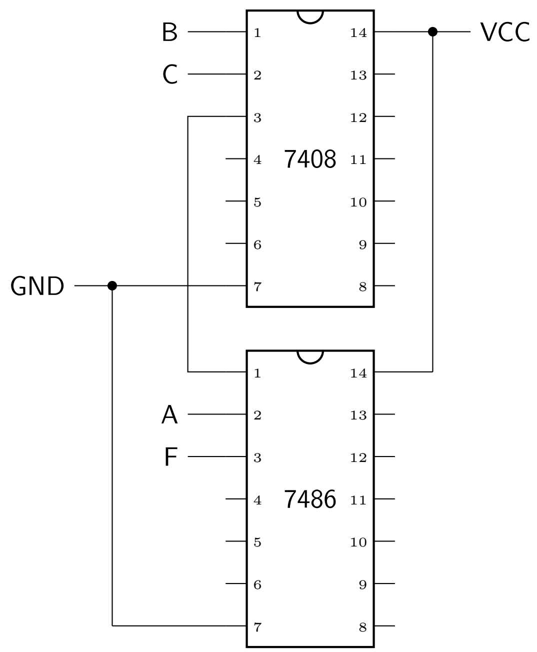
1. The 4069 integrated circuit is an inverter chip using CMOS technology. The logic levels that it uses are shown in the table below.

Signal Type	**LOW voltage values (V)**	**HIGH voltage values (V)**
input	0–1	4–5
output	0–0.05	4.95–5

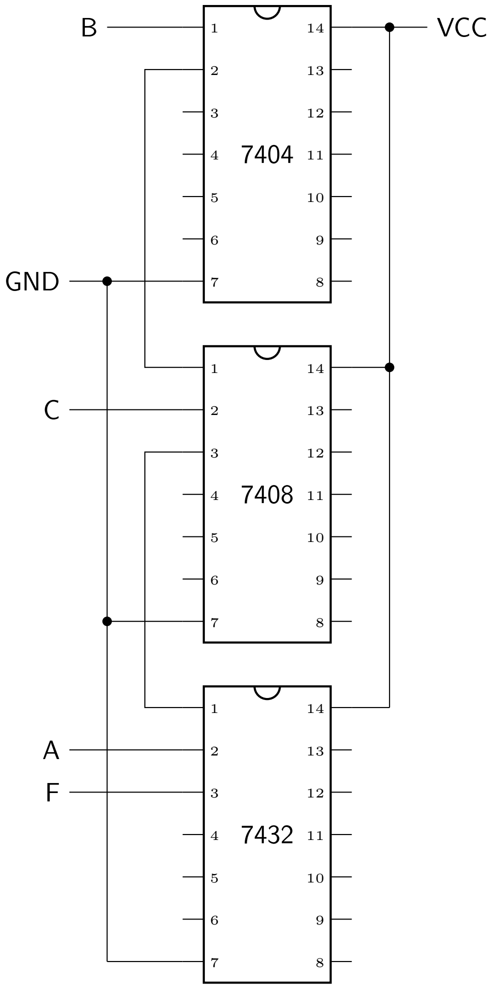
   (a) Can you use the 4069 chip as an input to a TTL logic gate and be certain that the circuit will function correctly? Why or why not?

   (b) Can you use a TTL logic gate as an input to the 4069 chip and be certain that the circuit will function correctly? Why or why not?

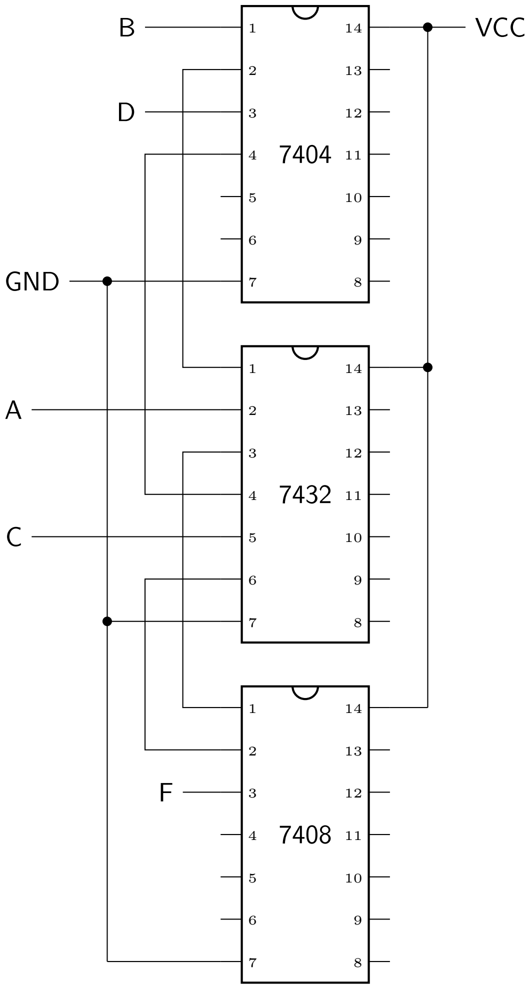
2. What digital logic expression is being implemented by the circuit shown below? Draw a circuit diagram and write an expression.



3. What digital logic expression is being implemented by the circuit shown below? Draw a circuit diagram and write an expression.



4. What digital logic expression is being implemented by the circuit shown below? Draw a circuit diagram and write an expression.



5. What digital logic expression is being implemented by the circuit shown below? Draw a circuit diagram and write an expression.