

Physics 4700 Experiment 7  
Digital Circuits

Almost all of the circuits in this part of the course will be built using the “DIGI DESIGNER” and tested using a logic probe. You should become familiar with both of these tools before you start the lab. The bookshelf contains bounded copies of spec sheets for the chips used in this lab. In the lab report, draw the schematic diagram (lines are straight and make 90-degree turns) of each circuit with electronic symbols, **not** the pin connections. You should strive for the **simplest** circuit design to receive the full credit.

1) Verify the truth table for a NAND gate (7400 chip), NOR gate (7402), AND gate (7408), OR gate (7432) and Exclusive OR gate (7486). Use the lamp switches on the DIGI DESIGNER to signal a high or low state. What is the output voltage of a high or low state from the above gates? Include a truth table for each gate.

2) A small company has 100 shares of stock divided among 4 people. Each share entitles its owner to a vote. The shares are divided as follows:

Mr. A 10 shares

Ms. B 20 shares

Mr. C 30 shares

Ms. D 40 shares

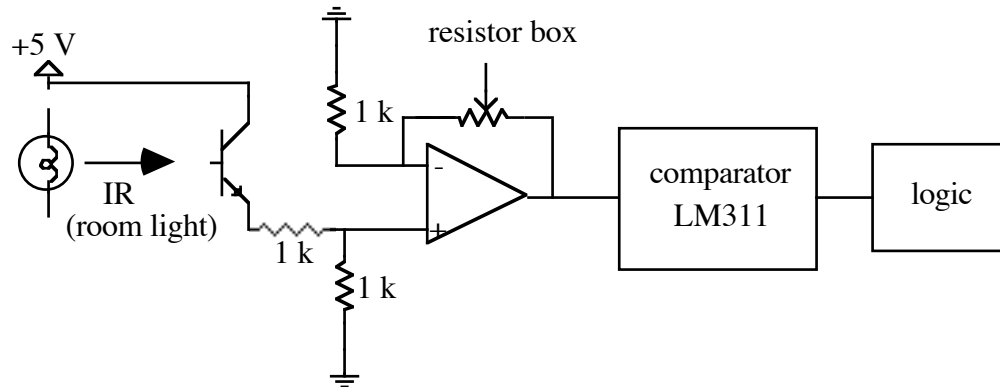
A measure that has been voted on passes if there is a two thirds majority. Each person votes with all of their shares (1) or none of their shares (0). Write out the truth table for all possible votes. **Construct** the logic equation for the votes and use Boolean algebra (**show work**) to simplify the equation. Design a circuit using logic gates which lights a lamp whenever a measure passes. Hint: To simplify your equation, you might wish to use  $C = C + C$ , i.e.  $ABCD = ABCD + ABCD$ .

3) Verify the truth table for the JK flip-flop (74S112) including the preset and clear options. Note: a low PRESET or CLEAR has higher priority over the J and K inputs, i.e. the PRESET or CLEAR (low) command will get executed regardless of the J or K inputs and hence the J and K inputs should be used when PRESET and CLEAR are both high. Include the truth table in the report.

4) Using 3 JKFF's build a circuit that counts from zero to seven, i.e. 0,1,2,3,4,5,6,7,0,1... After you have verified that the above circuit works using the LED lights on the DIGI DESIGNER, hook up the LED display (see Appendix) to your circuit and verify that the circuit counts from zero to seven. There is no need to include the connections to the LED display in the lab report.

5) Add components to the circuit in Part 4 such that it now counts from zero to nine. You will have to use the reset on the flip-flops.

6) Build the infrared (IR) burglar detector shown below. The room lights are used as a source of IR radiation. The IR light is received by a photodiode receiver sensitive to IR light. A burglar is detected when the IR beam is interrupted. The photodiode (see diagram below) acts like a transistor where the base current is replaced by a photoelectric current proportional to the input light. The photodiode thus has an emitter current proportional to the input light. The op amp converts this current into a voltage. A resistor box is used to set the sensitivity of the circuit's light collection.

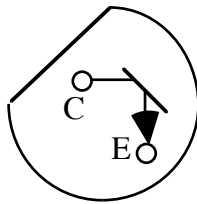
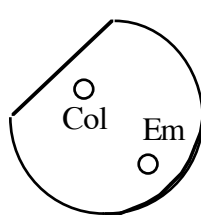
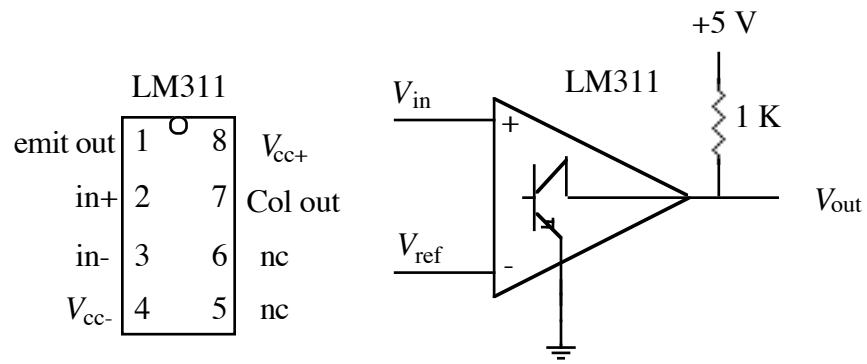


A comparator is used to turn the op amp's voltage into a digital pulse. For a comparator use an LM311 (see below for details on this device). The comparator should “fire” (give 0 V) when the IR beam is interrupted. Finally, design and hook up a flip-flop so that if the beam is interrupted a display diode remains lighted, indicating an intruder has broken into your house and disturbed the IR beam. The flip-flop circuit should contain a reset so that you can clear the alarm. Include the circuit in the report and summarize the following info in a table:

- Emitter voltage with and without IR light impinging on the photodiode.
- Positive (+) and negative (-) input voltages of the op-amp with and without IR light impinging on the photodiode
- The feedback resistance of the op-amp.
- Positive (+) input voltages of the comparator with and without IR light impinging on the photodiode.
- The reference voltage of the comparator.
- The output voltage of the comparator with and without IR light impinging on the photodiode.

### **LM311 Comparator**

Connect the LM311 up as outlined in the figure below. Use +5 V for  $V_{cc+}$  and -5 V for  $V_{cc-}$ . If the positive (+) input terminal of the LM311 is at a higher voltage than the negative (-) input, the output will be 5 V, otherwise the output will be zero Volt. The 1 kΩ resistor (external to the chip) is called a “pull-up” resistor. For the burglar detector  $V_{ref}$  must be determined by looking at the output of your op-amp.



Infrared Photodetector