**EGR24L Fall 2023 Project 1**

**Total points: 100**

Extra credit (50) available for the optional challenge version

**Problem statement**

You are to design a controller for an outdoor light that functions both as an ordinary light, and also as a motion activated light and alarm. This is how the controller should operate:

1. If the manual light switch S is switched on, then the outdoor light L will be turned on.
2. In addition to the manual switch input, there is a motion detector M. When M is activated, the light L will be turned on.
3. If motion is detected while the manual light switch S is already switched on, then a second output A, an alarm, will be turned on.
4. The disable switch D disables both the motion-activated light output and the alarm output, but it still allows the manual control operation of the light output using the manual switch S.

Also, your circuit should be implemented with NAND gates only. Use **as few NAND gates as possible**.

**Circuit design procedure – to be included in your project report write up**

1. Make a **truth table** for the two outputs (L and A) from three inputs (M, S, and D). The inputs and outputs are 1 when they are active or ON (high), and 0 when they are not active or OFF (low). List all possible combinations of input values for M, S, and D.
2. Complete the truth table: for each input combination in the truth table, determine what the output should be from the operational description of the controller function. It is helpful to use the **ascending binary order** to organize the input values in the truth table.
3. Design the logic circuit by using NOT, OR, and AND gates to obtain the outputs. Draw the **logic gate schematic** for your design.
4. Convert this circuit into to a **NAND-only circuit**, and draw its logic gate schematic.

**Building the physical circuit**

1. General guidelines
   1. You will be using three slide switches to control the three inputs M, S, and D.
   2. You will be using LEDs of different colors to indicate the two outputs (L and A), and to optionally indicate the three inputs (M, S, and D).
2. Construct the circuit on a breadboard.
3. Test the various combinations of the inputs to make sure the circuit works correctly. Record the outputs observed from the LED states for the various input combinations. If the outputs do not agree with the truth table, you need to debug the circuit until it works properly.

**Optional challenge version –** building the circuit with a NOR only circuit

You may choose to build your circuit with NOR gates only (instead of using NAND gates). If you successfully do this, you may receive an extra 50 points beyond the 100 points of this project. The extra 50 points will be applied to your labs to replace a low score lab (which means you may drop the 3 lowest score labs).

There are some challenging aspects for building a NOR-only circuit. First, you need to figure out how to build NOT, OR, AND gates with NOR gates. Second, you need to figure out how to use the SN7402 NOR IC chip. This chip has its own pin-out scheme. More importantly, it has its own power rail voltage requirement, which is different from the NAND gates that you have used before. Look up the product sheet (in this Canvas module) of the NOR IC for **pin-out specs**. Also look up the product sheet for this chip’s **power rail voltage requirement**. If the rail voltage is too high, the IC chip may be damaged. If the rail voltage is too low, the IC chip may not receive sufficient power to operate normally. Design a **portable solution that is suitable to supply the requisite voltage rail** for this NOR IC chip. A helpful hint is to use a 9V battery and a voltage divider such as a suitable potentiometer with a proper setting.

**Deliverables**

1) **Demo and turn in** your product (the breadboard circuit). Clearly mark the input switches (LEDs are optional for the input nodes) and output LEDs on your circuit product.

2) **Brief project report** should include:

a) How you come up with your design – your thought process

b) Truth table organizing the 3 inputs (ascending binary order) and the 2 outputs

c) Preliminary circuit diagram using AND, OR, and/or NOT

d) Final circuit diagram using NAND only (for extra challenge, using NOR only)

e) What you have learned in this project