Laboratory 6: Traffic Signal State Machine

Learning Objectives

- Design and synthesis of state machines

1. Goal

In this lab, you are asked to design a traffic signal controller. This traffic signal is on a high-traffic main road, at an intersecting cross road. One signal faces the main road, the other signal faces the cross road. The light is "demand driven", so when there is no cross road traffic (or pedestrian), the main road light stays green, and the cross road light remains red. The functional specification is as follows:

- When a pedestrian pushes the "Walk" button, the Main Road goes to Amber for 4 seconds.
- Then the Main Road goes to Red and the Cross Road goes to Green for 8 seconds.
- Then the Cross Road goes to Amber for 4 seconds.
- Then the Main Road goes to Green and Cross Road goes to Red (back to the default state).

2. Pre-Lab

Note that you need to submit individualized pre-lab report for this lab.

In order to build a working circuit in this lab session, you will need to do some design work before coming to the lab. For your prelab, please complete the following tasks and hand in a copy at the start of your lab section.

1- Explain your understanding of the design problem and describe the goal of the experiment in your own words.

2- Describe your own understanding of what a state diagram is, how it is being constructed, and how it generally can help in designing finite state machines.

3- Draw a state diagram for the described traffic signal controller, showing all the discrete states of your system, and the conditions for transitioning between states.

4- Propose a design solution. Provide a preliminary schematic of your proposed circuit. Identify the logic gates needed.

3. Experiment

Implement and test your proposed traffic signal controller circuit. There are numerous resources available describing this problem and its solution. Feel free to discuss your design with your lab partner and divide up the design and work together, or even discuss your designs with other students in the class. You can utilize all these resources, however each student in each team must build their own circuit, and the circuit must work and operate the lights to the specifications. Given the moderate complexity of the circuit, you will very likely need to perform some troubleshooting to get your circuit to function properly

The traffic signal is controlled through a 10-pin connector. Each bench has a 10 pin adapter cable (Figure 2) - one end plugs in to your breadboard (Figure 1), and the other end plugs in to the traffic signal interface connector. This is how you test your circuit. Pin 1 is identified by the small triangle depression in the connector housing plastic at one end (Figure 3). DO NOT BEND THE PINS! THEY WILL BREAK!

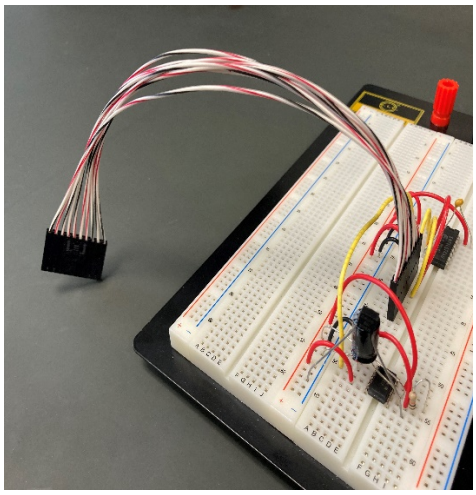

Figure 1
Example controller that just blinks some lights.

Figure 2
Bottom plugs in to breadboard.

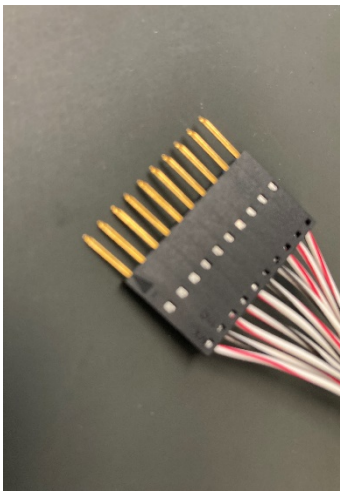

Figure 3
Pin 1 on left.
DO NOT BEND PINS!

The pin functions are as follows:

Pin 1 - Ground reference
Pin 2 - 5 volt power to your circuit - Max 250mA.
Pin 3 - Main Road Red Light (active low)
Pin 4 - Cross Road Red Light
Pin 5 - Main Road Amber Light
Pin 6 - Cross Road Amber Light
Pin 7 - Main Road Green Light
Pin 8 - Cross Road Green Light
Pin 9 - Cross Road Pedestrian Button N.O. (Normally Open)
Pin 10 - Cross Road Pedestrian Button N.C. (Normally Closed)

Light control pins are TTL logic level inputs. 0 Volts light is ON, +5 Volts light is OFF.

Cross Road Pedestrian Button is a momentary pushbutton SPDT (Single-Pole, Double-Throw) switch, with COMMON terminal wired to ground.

Note the following:

- The circuit can be built in sections, so team members could work in parallel to help get things done faster.

- In addition to the logic gates we have in the labs (AND, NAND, OR, NOR, XOR, NOT, Flipflops), we also have 74LS10 3-input NAND, 74LS11 3-input AND, 74LS20 4-input NAND, and 74LS27 3-input NOR gates.

- Your design will have to generate its own clock signal to drive the state machine. One way of doing this is with a "555 Timer" circuit. This is a popular chip which can be easily wired up to produce a 1 Hz (or whatever frequency you want) square wave. Google "LM555 timer circuit".

- The circuit could also be tested in sections. For example, the combinational logic that translates state machine states into the bits that drive the 6 lights could be tested separately.

- While the logic probe is useful in most situation, don't be afraid to connect up the oscilloscope when your circuit is behaving strangely. The scope can show you problems the logic probe can't. For example, if a logic level is around 1.6V, it can mean there is no output gate driving that node (wiring error).

Trouble-Shooting

Your design will be of moderate complexity, so again it is important to build and test it in stages to avoid dealing with a large trouble-shooting challenge. If you do end up having to trouble-shoot the entire design at once, the best strategy is to break the design down into smaller parts and make sure each one is working independently, and then connect them back together one at a time. For example, the state machine without the feedback logic should cycle through all the states; the combinational logic that drives the 6 lights should map states to lights; the clock source (LM555 maybe) should output a 1 Hz (or whatever your design requires) square wave.

4. Lab 6 Report

Note that you need to submit individualized post-lab report for this lab.

Your final report for Lab 6 should include the following:

1- Your individual prelab report

2- Final schematic of your circuit and the images of the circuit that you implemented in the lab.

3- Describe how you planned the experiment.

4- Discuss any challenges you had with your design. Did you have to modify your original design? Was there a particularly difficult part? How did you solve the problems?

5- Did you use other resources (e.g., online/textbook/etc) to complete the tasks in this lab? What new knowledge/skills did you have to learn to complete this design that wasn't directly covered in the course?

6- Explain those new knowledge/skills in your own words.

7- Describe how you utilized those new knowledge/skills in your design.

8- Discuss any challenges you had with getting your design to work as it should. Did you have any wiring problems? Failed components? Troubleshooting challenges? What steps did you go through to find any problems?

9- Can you think of any safety or reliability issues with your design?

10- What would happen if the power at the intersection failed very briefly and the state machine was reset while cars were going through the intersection? Can you suggest a solution?

11- Please provide any comments or feedback relating to this lab/design project. For example, did you feel like you had adequate theoretical knowledge to solve the problem? How was the difficulty level of the problem? Would you change anything? Would you add anything?