**Purpose**

This project was performed as a laboratory exercise for the MOOC "UT.6.01x Embedded Systems - Shape the World" (available on courses.edx.org). This project had these major objectives: 1) the understanding and implementing of indexed data structures; 2) learning how to create a segmented software system; and 3) the study of real-time synchronization by designing a finite state machine controller. Software skills covered include advanced indexed addressing, linked data structures, creating fixed-time delays using the SysTick timer (of the Tiva TM4C123G Launchpad microcontroller), and debugging real-time systems.

**System Attributes**

Consider a 4-corner intersection as shown in Figure 10.1. There are two one-way streets are labeled South (cars travel South) and West (cars travel West). There are three inputs to the LaunchPad, two are car sensors, and one is a pedestrian sensor. The South car sensor will be true (3.3V) if one or more cars are near the intersection on the South road. Similarly, the West car sensor will be true (3.3V) if one or more cars are near the intersection on the West road. The Walk sensor will be true (3.3V) if a pedestrian is present and he or she wishes to cross in any direction. This walk sensor is different from a walk button on most real intersections. This means when testing the system, walk sensor must be pushed and held until the FSM recognizes the presence of the pedestrian. Similarly, the car sensors have to be push and held until the FSM recognizes the presence of the car. In this simple system, if the walk sensor is +3.3V, there is pedestrian to service, and if the walk sensor is 0V, there are no people who wish to walk. In a similar fashion, when a car sensor is 0V, it means no cars are waiting to enter the intersection. 6 LEDs were interfaced to represent the two Red-Yellow-Green traffic lights, and green LED (connected to PF3 port of the LaunchPad) was used for the "walk" light and the red LED (connected to PF1 port of the Launchpad) was used for the "don't walk" light. When the "walk" condition is signified, pedestrians are allowed to cross. When the "don't walk" light flashes (and the two traffic signals are red), pedestrians should hurry up and finish crossing. When the "don't walk" condition is on steady, pedestrians should not enter the intersection.

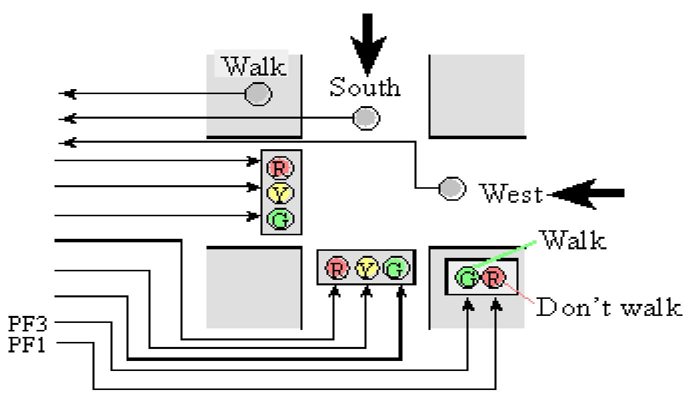


*Figure 10.1. Traffic Light Intersection.*

At all times, there is exactly one of the {red, yellow, green} traffic lights active on the south road. At all times, there is exactly one of the {red, yellow, green} traffic lights active on the west road. The "walk" and "don't walk" lights are never both on at the same time.

Cars are not allowed to crash into each other. This means there can never be a green or yellow on one road at the same time as a green or yellow on the other road. Pedestrians are not allowed to walk while any cars are allowed to go. This means there can never be a green or yellow on either road at the same time as a "walk" light. Furthermore, there can never be a green or yellow on either road at the same time as the "don't walk" light is flashing. If a green light is active on one of the roads, the "don't walk" should be solid red. If just the south sensor is active (no walk and no west sensor), the lights adjust so the south has a green light. The south light stays green for as long as just the south sensor is active. If just the west sensor is active (no walk and no south sensor), the lights adjust so the west has a green light within 5 seconds. The west light stays green for as long as just the west sensor is active. If just the walk sensor is active (no west and no south sensor), the lights adjust so the "walk" light is green. The "walk" light should stay green for as long as just the walk sensor is active. If two or more sensors are active at the same time, the system cycles through the requests servicing them in a round robin fashion.

The state transition table is given below. 8 different input values are possible through the three push-button switches. The column titled "6-LED" shows the output of the vehicle traffic lights at a particular state where "W" represents the output of the traffic lights for vehicles bound westward and "S" represents the output for the traffic lights for vehicles bound southward. 10 different states were considered for this finite state machine.

**Traffic Light FSM State Transition Table**

| State # | Name | 6-LED | Pedestrian Lights | Time (s) | In=0 | In=1 | In=2 | In=3 | In=4 | In=5 | In=6 | In=7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | goW | W=Green S=Red | Red | 3 | goW | goW | wtW | wtW | wtW | wtW | wtW | wtW |
| 1 | wtW | W=Yellow S=Red | Red | 2 | allR | allR | goS | goS | walk | Walk | goS | goS |
| 2 | goS | W=Red S=Green | Red | 3 | goS | wtS | goS | wtS | wtS | wtS | wtS | wtS |
| 3 | wtS | W=Red S=Yellow | Red | 2 | allR | goW | allR | goW | walk | walk | walk | walk |
| 4 | walk | W=Red S=Red | Green | 3 | walk | wkOn1 | wkOn1 | wkOn1 | walk | wkOn1 | wkOn1 | wkOn1 |
| 5 | wkOn1 | W=Red S=Red | Red | 0.5 | wkOf1 | wkOf1 | wkOf1 | wkOf1 | wkOf1 | wkOf1 | wkOf1 | wkOf1 |
| 6 | wkOf1 | W=Red S=Red | Off | 0.5 | wkOn2 | wkOn2 | wkOn2 | wkOn2 | wkOn2 | wkOn2 | wkOn2 | wkOn2 |
| 7 | wkOn2 | W=Red S=Red | Red | 0.5 | wkOf2 | wkOf2 | wkOf2 | wkOf2 | wkOf2 | wkOf2 | wkOf2 | wkOf2 |
| 8 | wkOf2 | W=Red S=Red | Off | 0.5 | allR | goW | goS | goW | allR | goW | goS | goW |
| 9 | allR | W=Red S=Red | Red | 2 | allR | goW | goS | goS | walk | walk | walk | walk |