Lab 10: **Decomposing State machines: Traffic Light Controller**

**Primary Objectives:**

1. Design and build a clocked synchronous state machine of moderate complexity.
2. Design the control unit for the project.

**Design**

Diagram

Description automatically generated

Using this state diagram, I made the following table

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Reset | CarDetect | trightofway | tyellow | Default safety | Highway Priority | Car Detected | Green Farmroad | Back to highway |
| 0 | 0 | 0 | 0 |  |  |  |  |  |
| 0 | 0 | 0 | 1 |  |  |  |  |  |
| 0 | 0 | 1 | 0 |  |  |  |  |  |
| 0 | 0 | 1 | 1 |  |  |  |  |  |
| 0 | 1 | 0 | 0 |  |  |  |  |  |
| 0 | 1 | 0 | 1 |  |  |  |  |  |
| 0 | 1 | 1 | 0 |  |  |  |  |  |
| 0 | 1 | 1 | 1 |  |  |  |  |  |
| 1 | 0 | 0 | 0 |  |  |  |  |  |
| 1 | 0 | 0 | 1 |  |  |  |  |  |
| 1 | 0 | 1 | 0 |  |  |  |  |  |
| 1 | 0 | 1 | 1 |  |  |  |  |  |
| 1 | 1 | 0 | 0 |  |  |  |  |  |
| 1 | 1 | 0 | 1 |  |  |  |  |  |
| 1 | 1 | 1 | 0 |  |  |  |  |  |
| 1 | 1 | 1 | 1 |  |  |  |  |  |
|  |  |  |  | 0 | 4 | 5 | 6 | 7 |

Where the rows in this table decide the values in the 4-bit mux that decide which code goes to the output. Numbers at the bottom row below the colored columns define the 3-bit values (in their decimal value) of each state. Each colored cell determines the value that went into each position (given by the 3-bit decimal value in the bottom row) in each mux with unlisted values tied to 0.



Control unit that was described below the colored table. The reset counter was also moved from the data path to the control unit to lower timing delays.

The data path was redesigned to send a signal to reset the system if it ended up in a state that is unexpected. It was also redesigned to move the reset counter into the control unit as mentioned above.



The error checking sends a reset signal in all cases except if all lights are off and if it’s in a valid state.

**Implementation**



Both control units and data paths put together with the lights exchanged with leds.

**Testing**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CarDetect | Reset | Clock(90,440) | HL | HLG | HLY | HLR | FR | FLG | FLY | FLR |
| 0 | 0 | 0 | 000 | 0 | 0 | 0 | 000 | 0 | 0 | 0 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 001 | 1 | 0 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 1 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 010 | 0 | 1 | 0 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 1 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 1 | 1 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 1 | 1 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 1 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 1 | 1 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 1 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 1 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 1 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 1 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 010 | 0 | 1 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 100 | 0 | 0 | 1 | 100 | 0 | 0 | 1 |
| 0 | 0 | 1 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |
| 0 | 0 | 0 | 001 | 1 | 0 | 0 | 100 | 0 | 0 | 1 |

Testing that shows the codes work as expected.

**Conclusion**

The device works as expected.