Final Report

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Proposal Statement

This project aims to develop an autonomous vehicle capable of obstacle detection and moving around the perimeter of a room. By processing input data, creating a finite state machine processing unit, and powering motors using output logic, the vehicle will accurately move in order to traverse the perimeter of a room. The vehicle will be equipped with two ultrasonic sensors on its front and left sides to detect whether there are obstacles in its path. These sensor inputs will be processed to determine how the vehicle should proceed with its movement, whether that is turning in a certain direction or moving forward. Our vehicle will use the car chassis provided in ECE 110 and the main shell to hold our processing, input, and output units. We plan to use CAD to create a 3D model that we can print in order to extend this chassis. Our print will include a multi-decker design to hold all the circuits used for our vehicle.

Milestones

Originally our milestones timeline in our midterm report mentioned utilizing the infrared sensor as a part of the input unit. But we changed our milestones to not utilize the infrared sensor at all due to facing complications with integrating it into the processing unit. We explain our complication in detail in the processing unit part of the communication, design, and analysis section. We also originally mentioned utilizing the buzzers and EEPROM for the output unit, however due to all the challenges with the input unit, processing unit, and with integrating them together this causes us to spend more time on those units leaving us with less time to complete the output unit. Due to this, we decided to just connect our processing unit to our 110 vehicle motors for our output unit and unfortunately not utilize the buzzer and EEPROM outputs.

Milestone 1: Parts Acquisition- Deadline: 02/16 ✔ (completed)

We have acquired all of the required physical components for this project (Ultrasonic sensors, Infrared Sensors, Buzzers, EEPROM, etc.)

Milestone 2: Complete Processing Unit - Deadline: 04/05 ✔(completed)

We complete building, testing, and debugging processing unit circuit with correct output logic (tested with LEDs).

Milestone 3: Complete Input Unit - Deadline: 04/12 ✔(completed)

We have completed building, testing, and debugging two ultrasonic sensor input modules with Schmitt Trigger clock, resistor-capacitor unit, and comparator unit.

Milestone 4: Build Vehicle Frame - Deadline: 04/12 ✔(completed)

We have completed developing a CAD design for vehicle frame to hold input, process, and output units of the final project. We laser cut wood for the plates in our CAD design and 3D printed the connectors holding up the plates.

Milestone 5: Complete Output Unit - Deadline: 04/21 ✔(completed)

We need to connect vehicle motors to processing unit outputs and ensure proper function of the motors.

Milestone 6: Complete Integration and Testing - Deadline: 04/28 ✔(completed)
We need to integrate the input, processing, and output units together and mount them on the vehicle. We will revise the design and make adjustments as necessary to get the vehicle to the desired state.
Milestone 7: Polishing & Presentation Prep - Deadline: 04/28 ✔(completed)
We need to add finishing touches to the project and compile documentation to prepare for our final presentation.

Tools

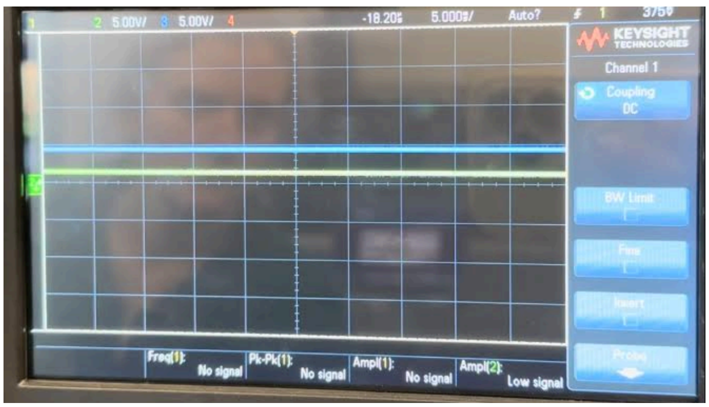


Figure 1: The output voltage when an object is not within a distance of the ultrasonic sensor determined by the voltage divider potentiometer. The voltage signal is green. There is a slight offset in the oscilloscope but the amplitude voltage measurement is 0 V

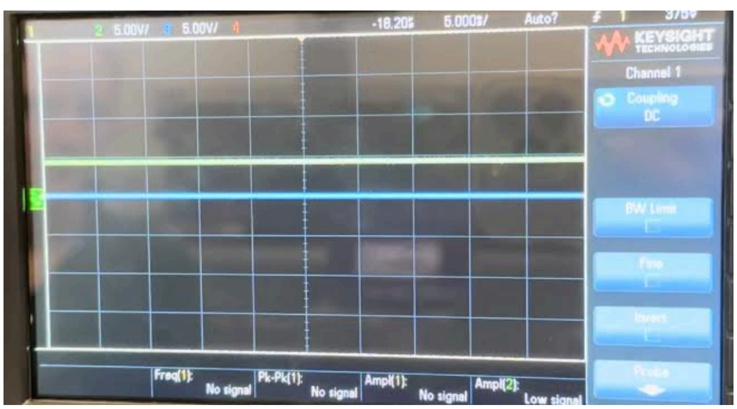


Figure 2: The output voltage when an object is within the distance determined by the voltage dividing potentiometer. The voltage signal is green and approximately 5 V, which is the supply voltage

Figure 1 and 2 display the functionality of the input unit. The unit correctly processes the ultrasonic sensor signal. As displayed, when an object is within a certain distance determined by the voltage dividing potentiometer, the signal is high or approximately 5V. Alternatively, when the object is not within this predetermined distance, the voltage is low, or nearly 0 V.

To provide power to the circuit we used the power supply. We used two 5V on the input and processing unit power rail, one to be positive voltage and another to be negative voltage. We attempted to use batteries, but found that the DC power supply gave us much more consistent and accurate voltage.

For the testing of our processing and output unit we did not need to use the oscilloscope. The state of our FSM is displayed by the LEDs, which are color coded to represent the state. The input values are also represented by LEDs. They are turned on when the voltage is high. For the output unit, we use the motors to understand the state of the BJT.

Communications, Design & Analysis

Input Unit

The schematic for the input unit is the same as the one used in the progress report. Our goal with the input unit was to use the PWM wave output from the ultrasonic sensor to create a high and low signal when an object was within a certain distance. The schematic in figure 3 demonstrates this, by displaying how we used filtering, comparators, and inverters to create a desired output. When this was completed, we found that the signal output of this unit was 5V when high was compatible with the processing unit and the output unit. The only adjustment made to the input unit is that we switched out the voltage divider for a potentiometer to control V_{set}. V_{set} is the voltage that is compared to the processed ultrasonic sensor. This voltage is the voltage output from the process ultrasonic sensor when an object is within a certain distance of the sensor. By controlling V_{set} we can easily change this distance by changing the resistance values of the voltage divider. We found that this was needed because when testing the motors of the vehicles, we found that the vehicle can’t turn fast enough without hitting an object at the current distance. We simply adjusted the potentiometer and increased the proximity detection of the input unit.

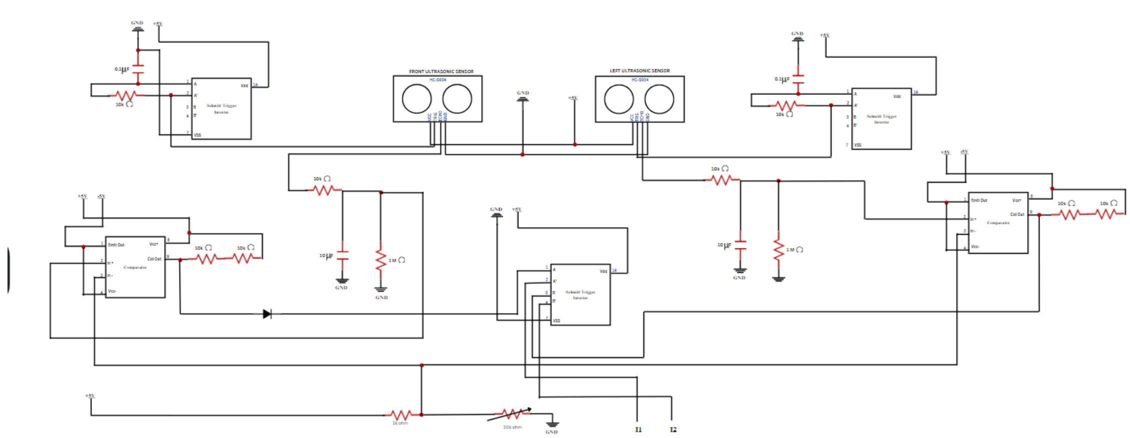
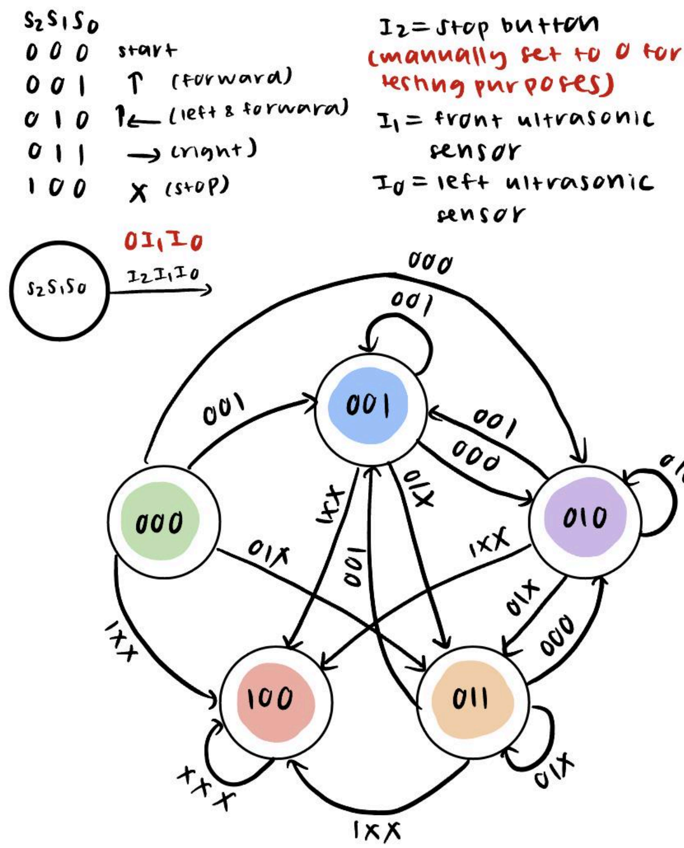


Figure 3: Schematic of the Input Unit

One issue we encountered involved implementing the infrared sensor as I_2 for the input unit. We wanted to create a third input for the processing unit that would force the FSM to the stop state, but we ran into many issues when attempting to do so. The infrared sensor processing design that we created involved an infrared sensor that had a built-in collector and emitter, a comparator to compare the infrared value with the color we wanted detected, and an inverter to output the voltage we desired. When testing the circuit with only the input unit and DC power supplies the infrared did output a high signal when detecting a white sheet of paper, which is what we planned on the vehicle detecting when it should be stopped. But, when connected to the processing unit, the output of the infrared sensor was always around 3 V, forcing the circuit into the stop state at all times, regardless of the infrared sensor values. We know that the issue does not lie with our processing unit because the FSM behaves correctly when directly connected to power or ground. We tried resolving this issue by adding a buffer, but this did not fix or change the issue. Because of time constraints, we were not able to resolve this issue.

Processing Unit

To create our processing unit for deciding the direction our vehicle should move given two ultrasonic inputs and an infrared sensor input, we utilized next-state tables and 6-variable K-maps. Our five states for our processing unit represented by 3 values $S_2S_1S_0$ are start (000), move forward (001), turn left and move forward (010), turn right (011), and stop (100). Originally we had planned our first input I_2 to be the infrared sensor input, however we faced problems with the infrared sensor input when connected to our processing unit always being high, so our FSM was always in the stop state. We attempted using a buffer and a comparator to solve this challenge, but we still faced the same issue. Since the stop state and infrared sensor is not the most essential part of our processing unit, we decided to set I_2 to 0 or ground for the purposes of testing since the robot will move through the other states when I_2 is 0. Another solution we had instead of utilizing the infrared sensor was to utilize a button that when pressed would set I_2 to 1 which would cause S_2 to be 1 and the FSM to be in the stop state. Originally we had a reset button for S2 as wel1 since we need the flip flip to store 0 originally to go through



all the moving states before we push the stop button. The problem with this was that the S2 reset button sent power to the input of the flip flop even when not pressed which caused the FSM to go back to the stop state immediately in the next clock signal when the reset button wasn't being pressed. After discussing with the TAs, we realized that the solution to this was to utilize a reset switch for S2 instead of a button. We did not have time to fully implement and test this, but we have included this design solution in figure 4.

The second input is the front ultrasonic input (I_1) that is high when the ultrasonic sensor on the front of the vehicle detects an object. The third input is the left ultrasonic input (I_0) that is high when the ultrasonic sensor on the left of the vehicle detects an object.

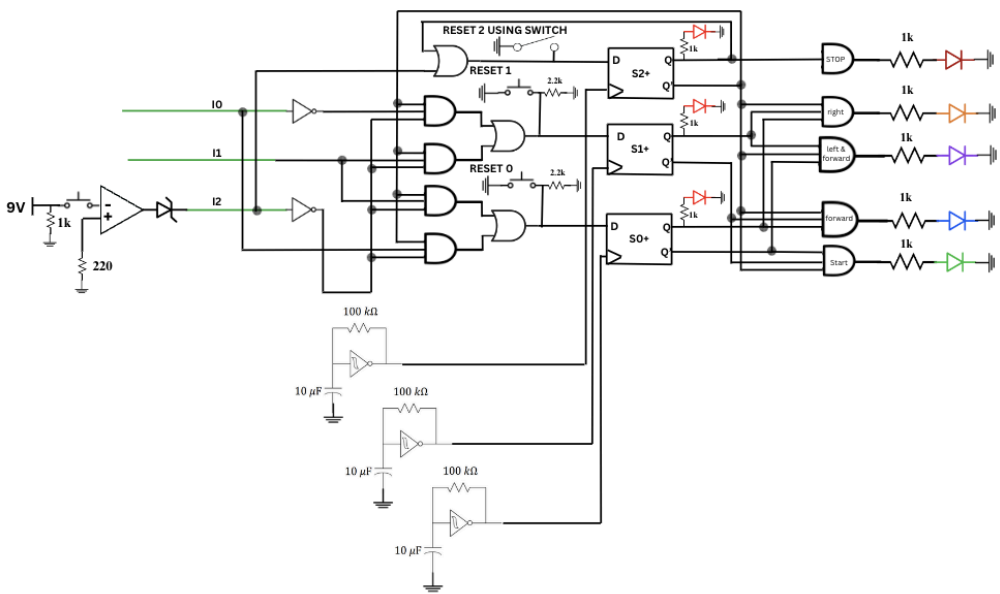
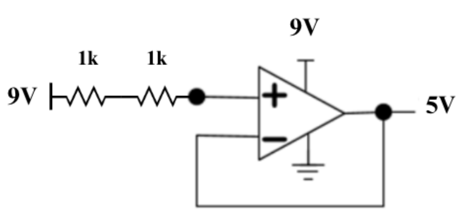


Figure 4: Schematic of the Processing Unit



Since our processing unit would be mounted onto our 110 car, we needed a way to get 5V given a 9V battery. Figure 5 showcases a schematic with a voltage divider and buffer to get 9V to the 5V needed for the flip flops and schmitt triggers for the processing unit.

Figure 5: Schematic of Getting 9V to 5V

To test our processing unit we utilized the leds to let us know which FSM state our processing unit was in. We also used light red leds connected to each of the outputs of the flip flops to make sure the FSM state corresponded to its $S_2S_1S_0$ state encoding. The blue led represents the move forward state and the purple led represents the turn left and forward state. Initially we used the orange led to represent the turn right state. But, while testing our final car we replaced it with the dark red stop led as it had burnt out and stopped working.

Output Unit

For the output unit, we designed a circuit to run the motors in the corresponding directions based on the outputs from the processing unit as shown below. There is low resistance between the Drain and Source of the left MOSFET when the output of the processing unit is either in the move forward state or the turn right state and there is low resistance between Drain and Source of the right MOSFET when the output is either in the move forward or turn left state. This makes it so only the left motor will run when the output of the FSM is the turn right state, enabling the vehicle to turn right, and only the right motor will run when the output is the turn left state, making it so the vehicle turns left. Both motors will run when the output is the move forward state, making the vehicle move forward. Figure 6 showcases the circuit schematic we utilized for our output unit. To test this we connected our logic to our 110 car and examined the movement of the left and right car motors.

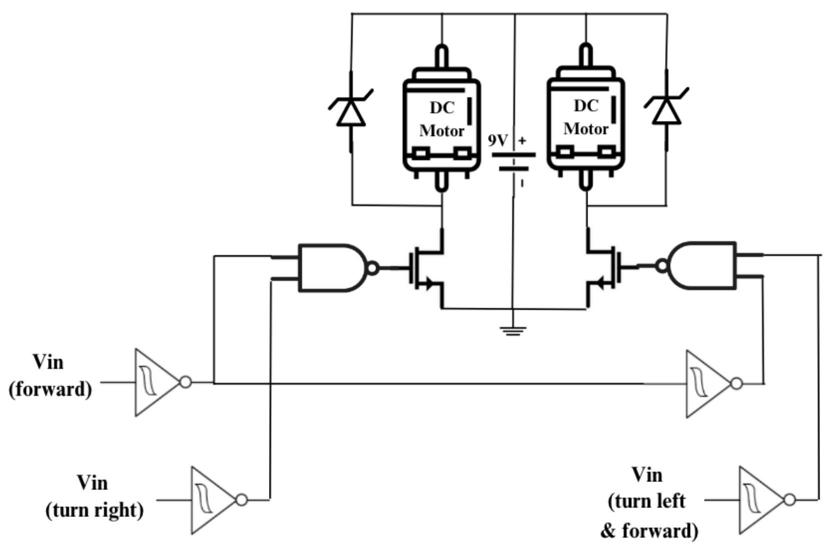


Figure 6: Schematic of Output Unit

Final Product

For our final product, we integrated our input, processing, and output unit together by mounting it on our 110 car and connecting everything together. Our final car product has a double decker design with 3 layers as we laser cut 2 wood plates each to hold the input and processing unit big breadboards. Figure 7 showcases a picture of our integrated car. The top layer contains the processing unit, the middle layer contains the input unit, and the bottom layer, not fully visible in the picture due to being directly on top of the 110 car, contains the output unit. Originally we were testing our circuit using batteries, so we connected two 9V batteries to the small left breadboard (containing the stop button logic) on the top layer, a 5V battery to the middle layer to get a -5V power rail (5V power rail was obtained by connecting to the processing unit), and a 9V battery to the small breadboard for output logic on the bottom layer. We faced some complications with our 9V battery dropping in voltage to 7V, so we ended up utilizing the power supply for the purpose of testing our vehicle and for our final report videos.

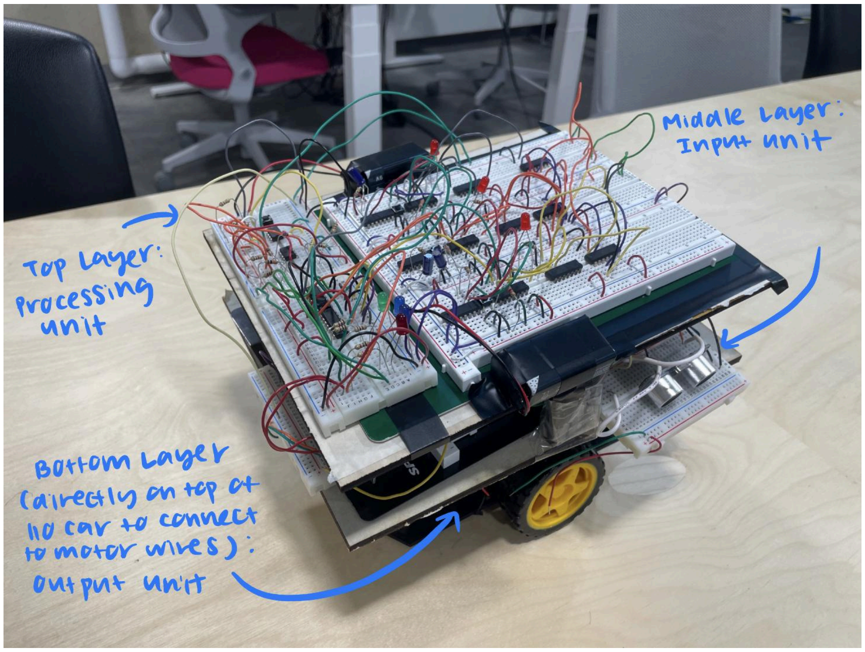


Figure 7: Final Project with 3 Units Integrated

Conclusions & Future Directions

For our final project, our main goal of implementing and testing the logic to allow a vehicle to traverse the perimeter of a room was successfully implemented. Unfortunately, as we met and meticulously solved each challenge while creating the input and processing unit, we could not implement the output logic to store and output our direction data. Through the process of working on this project, we realized the complexity of utilizing ultrasonic sensor inputs without an arduino as we had to utilize a clock signal, filtering, and comparators to end up with a high or low input for the processing unit. The complexity of the infrared sensor input not fully working when integrated led us to face even more challenges as we had to create a new solution to stop the motors using a button. The complexity of the processing unit with the final issue being the flip flop floating values after hours of debugging led it to take more time than initially anticipated to successfully build. In the future, we would have more knowledge on the components that made the processing and input unit challenging to build, so we would have more time to build and integrate an additional EEPROM and buzzer output.