Aastha Grover (aasthag4)
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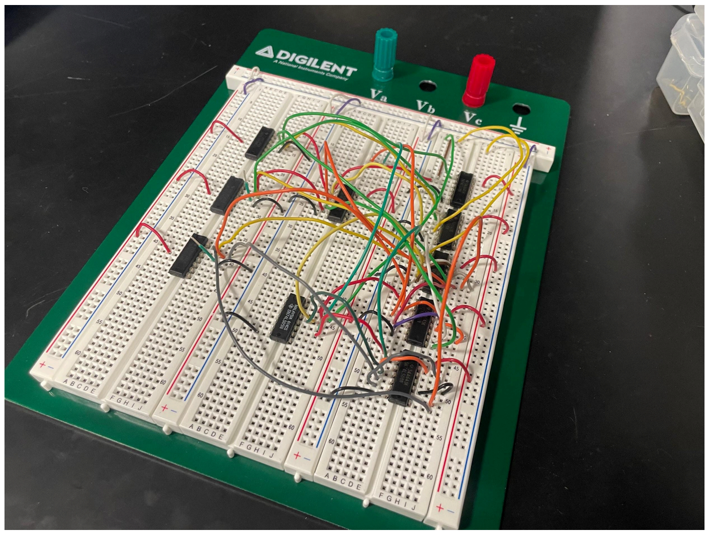
EchoNav Journal

Week of Monday, February 19

Progress Since Last Week:

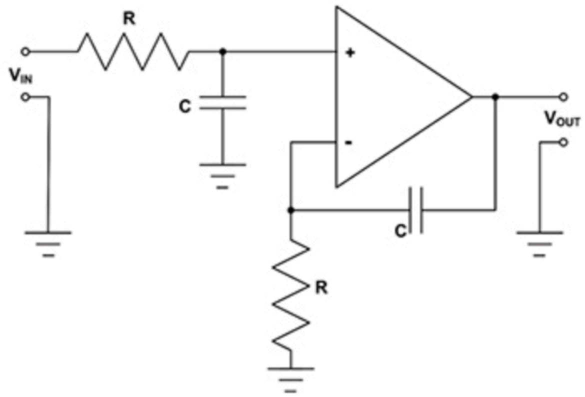


We completed the processing unit circuit for our project. We tested the output signals from the ultrasonic sensors that will be sent as input to our processing unit and noticed that we will have to modify the ultrasonic sensor outputs to fit our processing unit's requirements. The ultrasonic sensor produces a square wave with varying frequency based on the proximity of an object in the sensor's detection area (~4 meters). Our processing unit expects a high input from the ultrasonic sensors when an object is detected within 6 inches of the sensor and a low input otherwise.

Challenges:
We tested the ultrasonic sensor provided to us by the instructors, and found that the frequency of the ultrasonic sensor square-wave output changed based on the distance of an object from the sensor. Since we want our ultrasonic sensor to output that there is an object only after a certain distance, we have to solve the problem of how to read the ultrasonic sensor output and convert it into a digital output we could use. After conducting research and asking feedback from the instructors on how to approach this problem, we found one method is utilizing a non-inverting integrator (that is made out of an op amp inverter, resistors and capacitors) to measure the area of the ultrasonic sensor's square wave output and check if that area meets a certain threshold. To check if the area meets a certain threshold, we can use a LM311P comparator. We will compare the value of the output of the integrator to a voltage source. We plan to use a battery and then change the resistance and capacitance in the integrator schematic to properly compare the output of the ultrasonic sensor to some threshold voltage

value. Since the ultrasonic sensor needs a clock signal, we also plan to do more research on whether a 555 timer or Schmitt trigger would provide a more effective signal, but for now we are leaning towards utilizing the 555 timer.

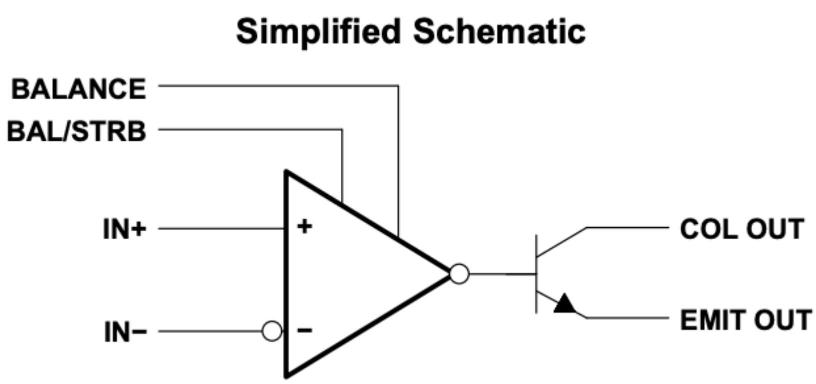
Integrator Circuit:



$$V_{OUT} = \frac{1}{RC}\int V_{IN}\,dt$$

Figure 4: A non-inverting integrator based on a difference amplifier op amp configuration can ensure the output phase matches that of the input. (Image source: DigiKey)

Comparator Schematic:



- Op Amp Inverter: https://www.electronics -tutorials.ws/opamp/opamp_2.html
- Non inverting integrator: https://www.digikey.com/en/articles/analog-integrators-how-to-apply-them-for-sensor-interfaces
- Schmitt Trigger vs. 555 timer: https://www.ednasia.com/should-you-use-a-555-or-a-schmitt-trigger/ https://www.electronicshub.org/555-timer-as-schmitt-trigger/

Proposal for Next Week:

Since it took a week for our project proposal to be graded, our current progress is a week behind our original milestone. As a result, we now plan to acquire new parts during the coming week and assemble the input and output circuits and the vehicle itself by the end of the week of

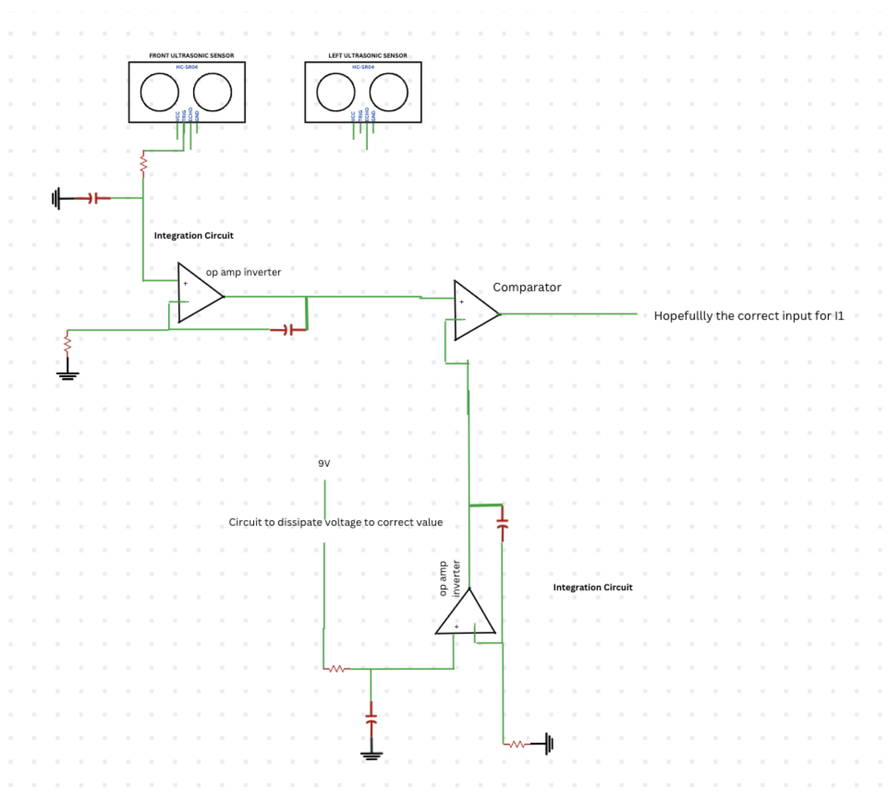
03/09/24. Before we proceed to assemble the input/output circuitry and the vehicle, we will test the processing unit circuit that we completed this week to ensure that it has been correctly assembled. During this coming week, we also plan to update our circuit diagram to account for utilizing a non inverting integrator to measure the area of the ultrasonic sensor output and using a 555 timer to compare that area value to a set threshold.

<u>Contributions:</u>
Aastha: Processing Unit Circuit, Research on Ultrasonic Sensor Input Issue
Maya: Processing Unit Circuit, Research on Ultrasonic Sensor Input Issue
Rina: Ultrasonic Sensor Testing, Research on Ultrasonic Sensor Input Issue

Week of Monday, February 26

<u>Progress Since Last Week:</u>
This week we tested our processing unit circuit from last week to check if we assembled it correctly. Originally we tried testing it without a clock signal, but later realized that it was necessary so after consulting with the TAs we decided to simply use a button as the clock signal for testing purposes. For testing we also used different buttons for the I2, I1, and I0 sensor inputs and LEDs of different colors for the state outputs. We added 1k resistors to test with the LED output because the LEDs would burn out if we used no resistors and a 5V battery. We faced challenges with our testing processes as the outputs were not properly displaying. The steps we took after facing these challenges with our processing unit circuit are in the challenges section of this week's journal.

This week we also updated our circuit schematic to utilize a non-inverting integrator to measure the area of the ultrasonic sensor output and using a comparator to compare the value to a threshold. We are still considering which capacitance and resistance values are best suited for the integrator. Also, the "circuit to dissipate voltage to the correct value" will be implemented once we get data on what that voltage should be based on the distance



that we want objects to be detected.

<u>Challenges:</u>
Through our testing process and after ensuring we wired everything correctly, we realized that there may be ways to simplify our original FSM schematic to mitigate any potential mistakes. To solve this problem, we decided to remake our schematic for the FSM using next state tables and 6 variable K-Maps. The original FSM schematic outputted zero in the event of an unreachable state. This design uses the same implementation, but uses don't cares in the event of an unreachable state. Although using zero outputs in this case may have more security, we hope this implementation will simplify our schematic and design. Our work to build the new schematic including our K-Maps and final FSM schematic is shown below.

States:

s_2, s_1, s_0
$\downarrow \ \downarrow \ \downarrow$
u, v, w

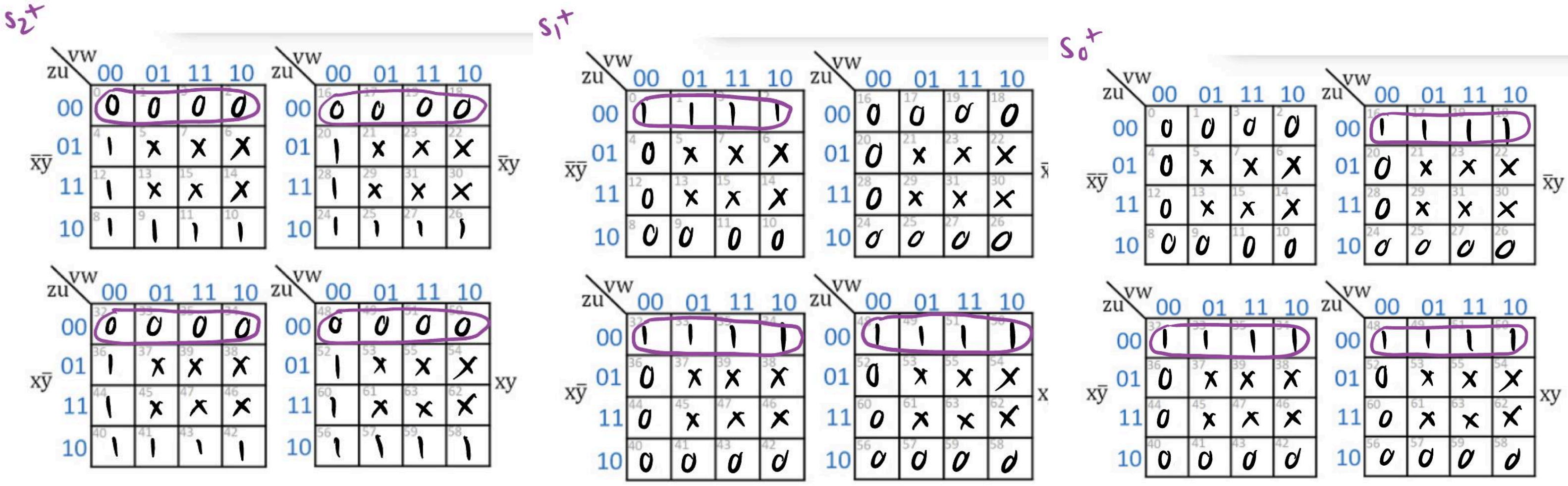
Inputs:

I_2, I_1, I_0
$\downarrow \ \downarrow \ \downarrow$
z, x, y

I_2 = infared sensor
I_1 = front ultrasonic sensor
I_0 = left ultrasonic sensor

	s_2	s_1	s_0
start/check	0	0	0
↑	0	0	1
↰	0	1	0
→	0	1	1
x	1	0	0
	x	x	x
	x	x	x
	x	x	x

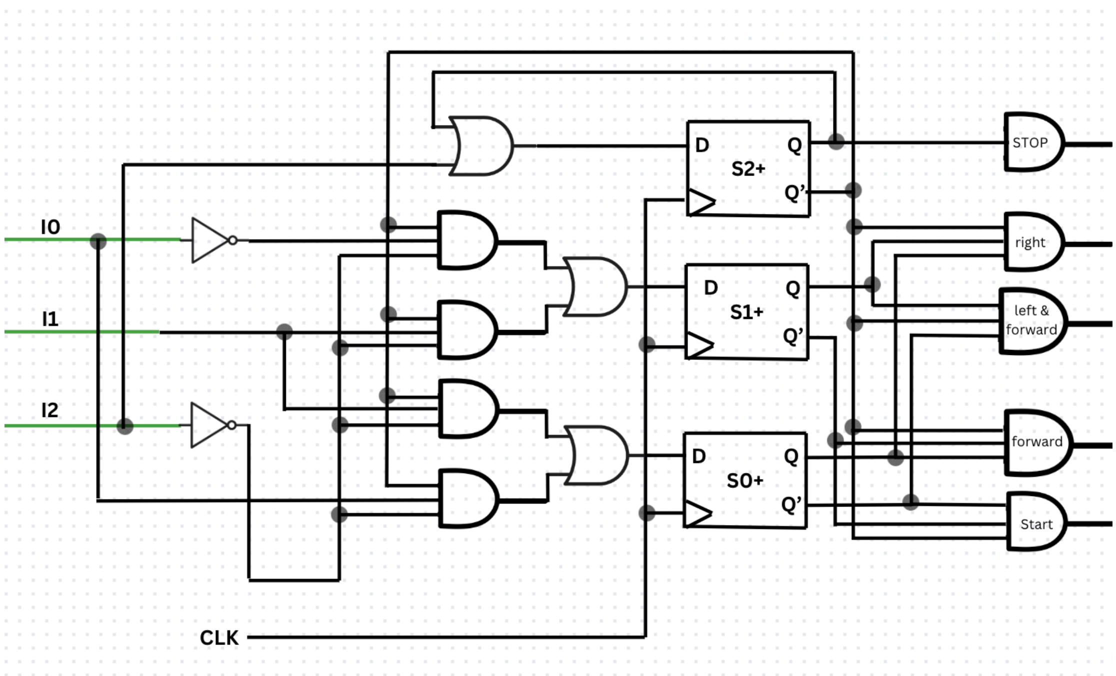
$(\overline{s_2} \cdot \overline{s_1} \cdot \overline{s_0}) \rightarrow$ start
$(\overline{s_2} \cdot \overline{s_1} \cdot s_0) \rightarrow$ forward
$(\overline{s_2} \cdot s_1 \cdot \overline{s_0}) \rightarrow$ left & forward
$(\overline{s_2} \cdot s_1 \cdot s_0) \rightarrow$ right
$(s_2) \rightarrow$ stop



$S_2^+ = (z+u) = (I_2+S_2)$

$S_1^+ = (\bar{z}\,\bar{u}\,\bar{y}) + (\bar{z}\,\bar{u}\,x)$
$= (\bar{I_2}\cdot\bar{S_2}\cdot\bar{I_0}) + (\bar{I_2}\cdot\bar{S_2}\cdot I_1)$

$S_0^+ = (\bar{z}\cdot\bar{u}\cdot y) + (\bar{z}\cdot\bar{u}\cdot x)$
$= (\bar{I_2}\cdot\bar{S_2}\cdot I_0) + (\bar{I_2}\cdot\bar{S_2}\cdot I_1)$



Proposal for Next Week:

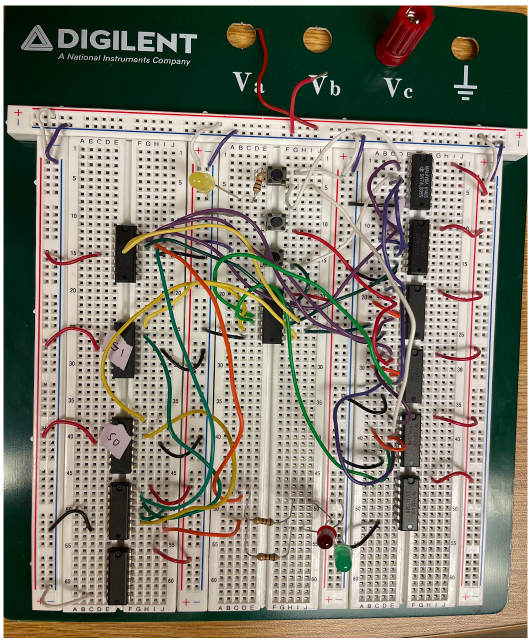
Next week we plan to build and test our new processing unit schematic again using buttons for the clock signal and sensor inputs as well as LEDs for the state outputs. We also plan on doing more testing with the ultrasonic sensor to make sure there are no issues with the frequency.

After we make sure there are no problems with the ultrasonic sensor output we will build and test the circuit with the non-inverting integrator after doing calculations to find the proper R and C values.

<u>Contributions:</u>
Aastha: Testing Processing Unit Circuit, Making New Schematic
Maya: Testing Processing Unit Circuit, Making New Schematic
Rina: Ultrasonic Sensor Testing, Research on Ultrasonic Sensor Frequency Issue

Week of Monday, March 4

<u>Progress Since Last Week:</u>



We built the new circuit for the processing unit and began testing it this week. In this circuit we have modified the FSM and added the output logic to correspond with the directions of motion to be expected as output. We began testing this circuit but ran into some issues with the resistors not providing enough resistance in the circuit as the LEDs would light up initially and then eventually dim down. This hindered us from properly testing our FSM and we plan on addressing this issue first in the coming week before proceeding with testing this design.

<u>Challenges:</u>
We ran into some challenges with the resistors as we were using a 9V battery to test our circuit and 1k resistors were not providing enough resistance for the LEDs through the logic gates. We will need to calculate the proper amount of resistance that will need to be provided in this circuit and appropriately add resistors to make sure the LEDs do not burn out during testing.

This week, we continued testing and collecting information on the input components. Our original design for the integrator circuit using ultrasonic sensors included resistance and capacitance values that when implemented in the formula for the op amp inverter integrator created a coefficient of one and would therefore provide us an approximate value for the area under the voltage square wave of the ultrasonic sensor output. Although this process was logical in theory, we didn't consider the voltage ratings of the circuit components. If the voltage is too high the circuit outputs an unexpected voltage and could potentially harm the circuit components.

Proposal for Next Week:

We will measure the current flowing through different parts of the circuit and use the given supply voltage to calculate the amount of resistance required to keep the LEDs properly lit during our test trials of the processing unit. Once this is achieved, we will test the processing unit and proceed accordingly– if it works as expected, we will move on to integrating the output unit of the circuit with the processing unit and assemble the vehicle to mount the entire circuit on. However, if we continue to run into issues with the processing unit, we will revisit our design and continue to adjust it until it works.

Using the new information we know about the integrator circuit, this week we will implement small capacitor and resistance values that should mitigate any risks of exceeding voltage ratings of the circuit components. We also plan to take data on the voltage output of the integrator when an obstacle is at a distance from the ultrasonic sensor where we would want the vehicle to make a turn (currently this distance is 6 inches, but is subject to change). This data will allow us to create a circuit that outputs this voltage and can be used with a comparator so the circuit outputs a high voltage when an object is at this certain distance. If we successfully complete this, all we then need to do is replicate this schematic for the left ultrasonic sensor and implement the infrared sensor with a similar integrator/comparator circuit. This will complete the input circuit.

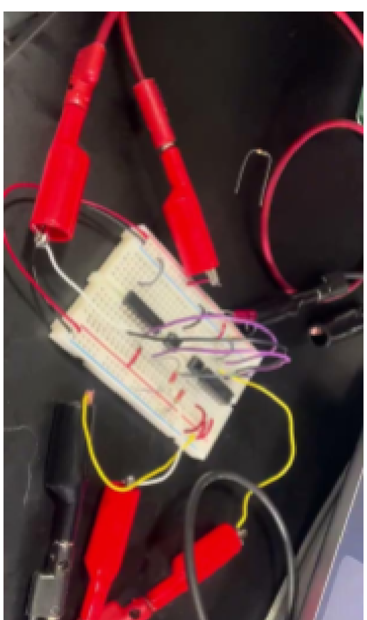
Contributions:

Aastha: Testing and Debugging new Processing Unit Circuit
Maya: Testing and Debugging new Processing Unit Circuit
Rina: Implementing Input Circuit Using Ultrasonic Sensor Input

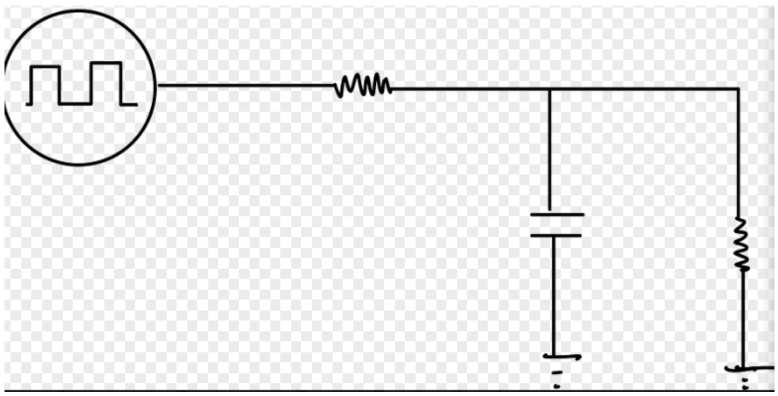
Week of Monday, March 18

Progress Since Last Week:

Video Link:
https://drive.google.com/file/d/1BzeU_i2MdMC27VIdyMIghYi01emyhZRr/view?resourcekey



When we were testing our FSM circuit we noticed that the Q output of the D flip flops were not the same as the D input to the flip flops. In order to figure out the issue we decided to isolate a part of the circuit onto a small breadboard and test there. We decided to test only the S2 flip flop because the next state logic for this flip flop was the most simple with it being S2+ = I2 OR S2. I2 is the infrared sensor input and S2 is 1 whenever the car has already stopped or the infrared sensor is high. After hours of debugging and working with the TAs, we realized that the since we were only using one side of the flip flop chip for one flip flop the second flip flop on the other side of the chip had floating values for $\overline{PRE}$ and $\overline{CLR}$. In order to fix this we connected $\overline{PRE}$ and $\overline{CLR}$ of the other flip flop we weren't using to ground. While testing our circuit we also realized that the flip flops randomly store a 0 or 1 when we turn them on. To solve this problem we added a button to the D input of the flip flop that connected to ground so that it cleared the D input and set it to 0 manually whenever pressed. The video linked showcases our working circuit for our S2 flip flop with the Q output connected to a dark red led that lights up when S2 is 1 or the car is stopped.



This week we made major progress for the input circuit. First, instead of creating an op amp circuit to create an integrator, we opted for a simple resistor/capacitor circuit that would perform similar functions to the integrator. In our new design the output signal moves substantially lower as an object is moved closer to the ultrasonic sensor, which was the goal of this circuit: to create a signal that changes based on the period of the ultrasonic signal.

<u>Challenges:</u>

While testing our revised circuit, we did not receive the output we expected. This seemed to be fueled by a few issues. The first was that the flip flops were initialized to random values upon being powered. In order to receive the expected output, we would need each of the flip flops to start in a state of storing 0. Ideally this would be solved by using the CLR and PRE pins on the flip flop chip. However, despite wiring these pins to GND as described on the datasheet, we were still not receiving the expected output. We suspected that this may have been due to floating voltages somewhere on the chip. We were correct, as when we wired the CLR and PRE pins on the other unused side of the flip flop to GND, the chip no longer stored random values upon being powered. To further ensure that each of our flip flops started in a state of storing 0, we wired a reset button to the chips that would store 0 in the flip flops upon being pressed.

Some challenges that we encountered with the input circuit are the implications of the integrator circuit design. After further analysis, we realized that the integrator would continuously integrate the area under the input signal, while we only want to integrate over a finite time and then to reset the output signal of the integrator. We found that this could still be achieved with an integrator if we connected a high resistance resistor, but we decided to simplify our design with the capacitor/resistance method.

<u>Proposal for Next Week:</u>

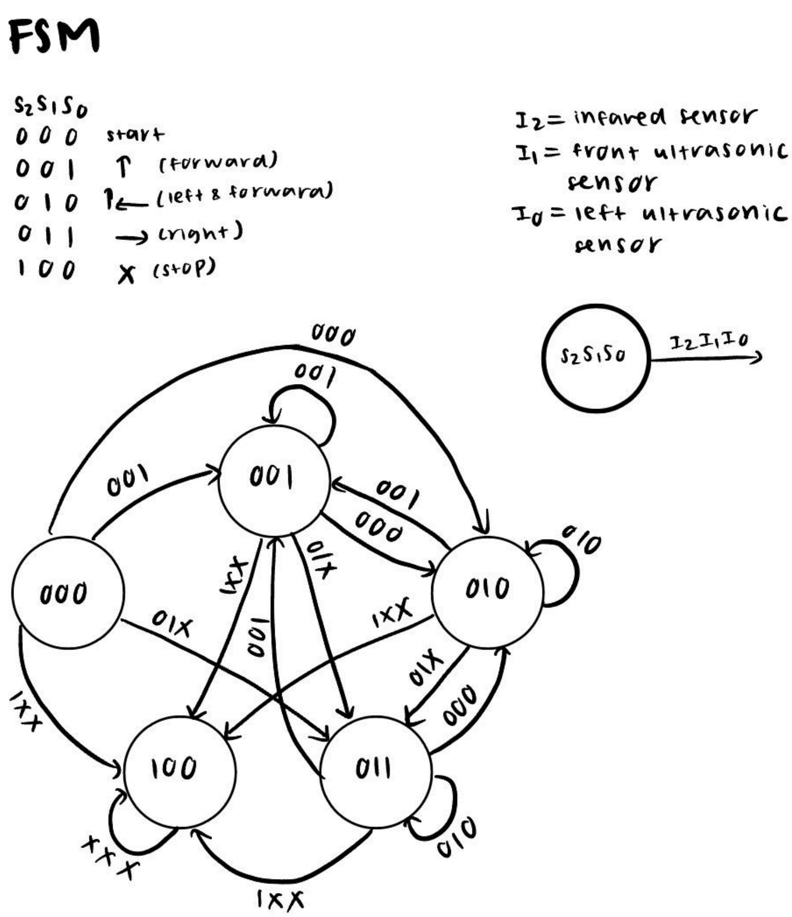
We have gotten a single flip flop to work correctly in an isolated circuit. Next week, we plan to reintegrate this flip flop with the rest of the processing unit and check if it still produces the desired output in this larger environment. Then we will debug the rest of the components of the processing unit in a similar manner, by isolating components until they individually work if needed.

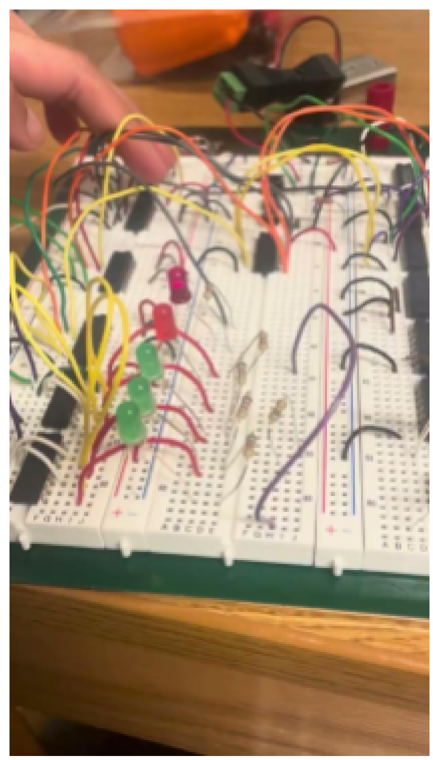
Now that we have completed the signal for the period of the ultrasonic sensor signal, we now face the challenge of comparing that to another variable voltage dictated by the distance we want between any given object and the ultrasonic sensor. Once we determine the output voltage of the period of the ultrasonic sensor that is desired, we will need to replicate that voltage with a voltage divider and use a comparator to finally output I_0 the input for one of the FSM states that is dictated by the left ultrasonic sensor.

<u>Contributions:</u>
Aastha: Testing and Debugging new Processing Unit Circuit
Maya: Testing and Debugging new Processing Unit Circuit
Rina: Implementing Input Circuit Using Ultrasonic Sensor Input

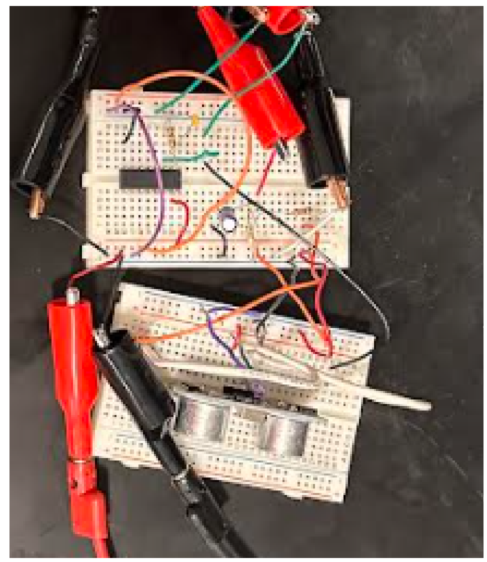
Week of Monday, March 25

<u>Progress Since Last Week:</u>
Video Link:
https://drive.google.com/file/d/1MCF0cp7PmS0MlThp6fzElXX0ZHWbLIYH/view?resourcekey





This week we used our knowledge from last week about using buttons to set the flip flops to 0 and about setting the floating values on the other side of the flip flip to power to build the rest of the FSM. When testing the circuit we only had a 9V battery, so we had to figure out which resistors to use in order to get the supply voltage down to between 4.5-5.5 V as that is the voltage all of the chips needed. After a process of trial and error since, we found that using a 47 ohm resistor dropped the supply voltage from 9V down to between 4.5-5.5 V. When testing the circuit we found that the stop and start states were correctly outputted as can be seen in the video with the dark red LED for stop and light red LED for start. The dark red LED lit up initially before resetting everything and when the I2 (infrared sensor) button was pressed. The light red LED lit up when the reset button was pressed to set the flip flops to 0 (so the state was 000). Although these two states worked, pressing the other I1 and I0 (ultrasonic sensors) buttons did not change the states to the ones represented by the green LED as it was supposed to. After probing around with the multimeter, we found that the OR gate inputs for the S1 and S0 flip flops were not working properly. We assume that this is due to the presence of floating values in the OR gate similarly to the flip flop, so we plan to add 2 separate OR chips to our circuit in lab for the S1 and S0 inputs respectively to hopefully correct this.



This week, we implemented a comparator that will take the output of the period of the output of ultrasonic sensor signal voltage and the voltage of a voltage divider that creates the threshold for the distance that we wish an object to be detected. First we tested the output voltage of the period of the ultrasonic sensor output circuit at a 6 inch object detection and found that the voltage was at about 5 V. Then, we used a voltage divider to create an approximately 5V voltage. Not only is this voltage useful as an input for the comparator, but many of our other circuit components have a 5V supply voltage rating, which is useful when implementing these components without a DC power supply. We also created a clock signal for the ultrasonic sensor and the d flip flops in the processing unit. To do this we filled a schmitt trigger inverter circuit and successfully created this signal that worked with the ultrasonic sensor and its intended functionality. Finally, we began implementing the comparator based on the circuit provided in the data sheet of the specific comparator we are using. The image above contains the circuitry for the ultrasonic sensor, the circuitry used to create a signal dependent of period of the output signal of the ultrasonic sensor, and the schmitt trigger implementation of a clock signal.

<u>Challenges:</u>
When reconnecting our S2 flip flop with the larger circuit and testing the FSM, we faced issues in receiving the expected output. We probed each of the levels of our circuit to determine where the issue lied and discovered that the input and output voltages of the OR gate supplying input to the flip flop acted as expected with only the logic for S2 connected to it. However, when we added the inputs for S1 and S0, the output voltage was significantly lower to the point where it

did not meet the minimum voltage threshold to be supplied as input to the flip flops. We predict this is due to a case of floating voltages in the OR gate chip as we are not using all of the pins on the chip. To solve this problem, we plan on using separate OR gate chips to handle the logic for each of our three flip flops.

Another issue we faced that will become more prevalent as we move further in our project was during remote testing. As we did not have access to the DC power supply from the lab, we had to use a 9V battery to power our circuit. However, as many of the chips in our circuit have a threshold voltage of 5V, we had to use a voltage divider to lower our input voltage to these chips. This was a challenge as our batteries were not exactly 9V and the resistors in our kit would not divide our voltage to give us exactly 5V. Although we can continue to use the DC power supply provided in the lab to test our processing unit, we will eventually need to resolve this issue to supply power to our circuit on the final vehicle.

There were several challenges faced with the input circuit. First we needed to create a portable clock signal for many of the circuit components, including the trigger of the ultrasonic sensor. There are two main methods that we had to choose from: 555 timer and a schmitt trigger inverter. There are many considerations for both of these methods, but our decision mainly came down to the applicability and feasibility of the design. A 555 timer would allow us to easily change the clock speed if other components required the different clock speeds, but is more difficult to implement. Currently we want our components to work on the same clock, so we opted for the schmitt trigger method.

Another issue we had was the supply voltages of the comparator. One of the supply voltages is a negative voltage, so we had to consider how to implement this with portability. Initially we theorized that switching the polarity from the positive voltage power supply with jumper wires to a nearby power supply would switch the sign of the voltage, but that did not provide a desired output. Instead, we deduced that it was best to use an additional battery and flip the polarity of the input to the power supply, which did provide the desired voltage.

<u>Proposal for Next Week:</u>
We are nearly finished with testing and debugging our processing unit. Next week, we will use separate OR gates to handle the logic being input into each of the three flip flops in our circuit. Hopefully, this solves the issue of floating voltages in the OR gate chips and sends the correct inputs to our flip flops. If we face further issues in the output of our FSM, we will have to re-evaluate our design and continue debugging.
We aim to have our processing unit working by the end of next week. Additionally, we plan on starting work on the output unit of our project and combining the input, processing, and output units into a final comprehensive product.

This week for the input circuit we hope to complete the comparator. Additionally, we want to replicate the left ultrasonic sensor circuitry for a forward ultrasonic sensor circuitry, which will complete the input circuit for two inputs. Our third input will be the infrared sensor which we need to test and design an implementation that fits our needs, but we hope that many of the components used for the ultrasonic sensor can also be used for the infrared sensor.

Contributions:
Aastha: Testing and Debugging new Processing Unit Circuit
Maya: Testing and Debugging new Processing Unit Circuit
Rina: Implementing Input Circuit Using Ultrasonic Sensor Input

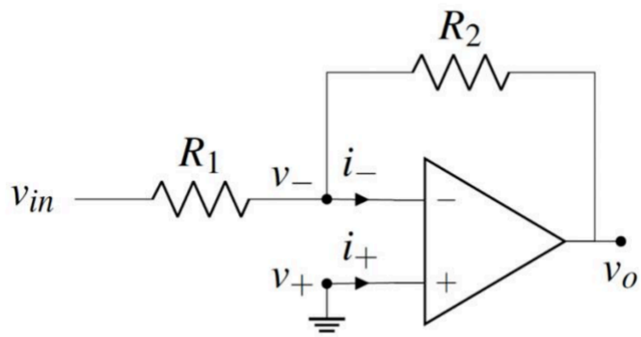
Week of Monday, April 8

Progress Since Last Week:
Video Link:
https://drive.google.com/file/d/1Zb4ztyf1MUdTklVctVQxQEALCvKuTjhv/view?usp=sharing

This week we enabled a joint clock signal for our processing unit FSM using a Schmitt trigger inverter. Previously, we were using buttons to act as clock signal inputs for our D flip-flops, however, this was only a temporary solution and would not be feasible once the circuit boards were mounted on the vehicle as the vehicle needs to operate autonomously. Our primary concern with using Schmitt trigger inverters to implement the clock signal was that in a previous attempt to generate a clock signal with Schmitt triggers, we were unable to produce the desired oscillating signal to enable both the ultrasonic sensors in our input unit with a single Schmitt inverter. We had to thus resort to using separate inverters for each ultrasonic sensor. However, this may have been an issue relating to the integration of the Schmitt trigger inverter with other components in the input unit circuit as we were able to successfully generate a clock signal for all of the D flip-flops in our processing unit using a single Schmitt trigger.

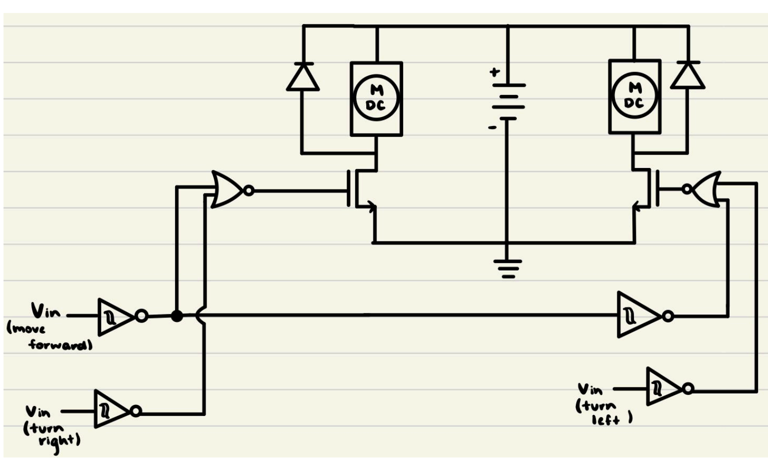
We also began integrating the ultrasonic sensors from our input unit with our processing unit circuit. We successfully connected the output from the left and forward-facing ultrasonic sensors as inputs I0 and I1, respectively, of our processing unit. While testing our integration, we initially received the expected results with the processing unit FSM proceeding to the move forward state when an obstacle was detected by the left ultrasonic sensor. However, during testing, we abruptly stopped receiving input signals from the input unit. We initially hypothesized that this may have been due to loose connections or a short circuit within the input unit, however upon debugging, we believe the issue may lie in the way we are generating negative voltage for the input unit comparators.

We also began integration from the other end, connecting the outputs of our processing unit to the motors on the vehicle. In order to run the motors in the corresponding directions based on the processing unit outputs, we first needed to address the issue that the output voltage from our processing unit lied around 2.5 V, whereas the motors needed voltage closer to 9 V to operate. Our first design consideration was using an amplifier circuit to amplify the 2.5 V output voltage from the processing unit to approximately 8 V with the amplifier schematic, in which we set R1 to 100Ω, R2 to 330Ω, and using the formula $v_{out} = -v_{in}\frac{R_2}{R_1}$, we expected an output voltage of 8.25 V to power the motors.

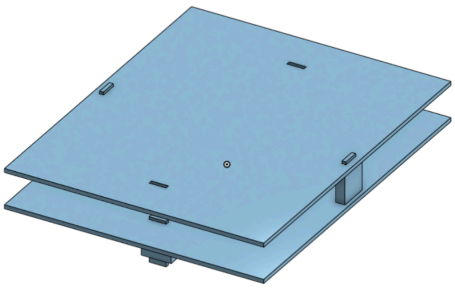
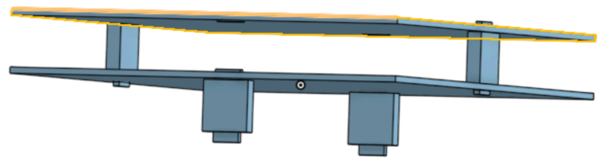
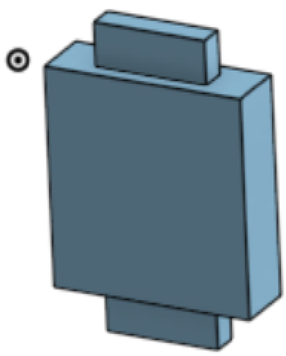
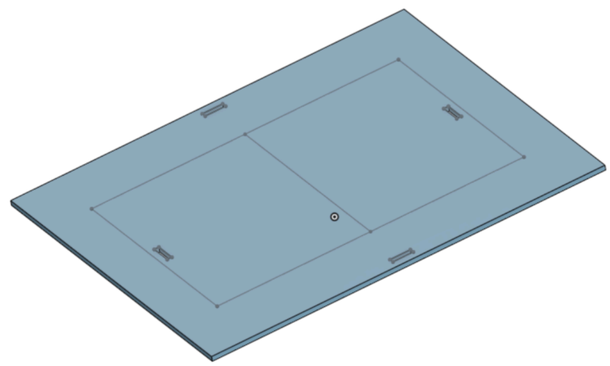


Building this circuit proved to be a challenge as the LM358 op-amp inverter required two voltage sources, one being negative and the other positive, which we were not able to implement properly. Although we could have tried further debugging this issue, we found that an easier and more effective solution would be to use a MOSFET to control motors with the processing unit outputs.

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.

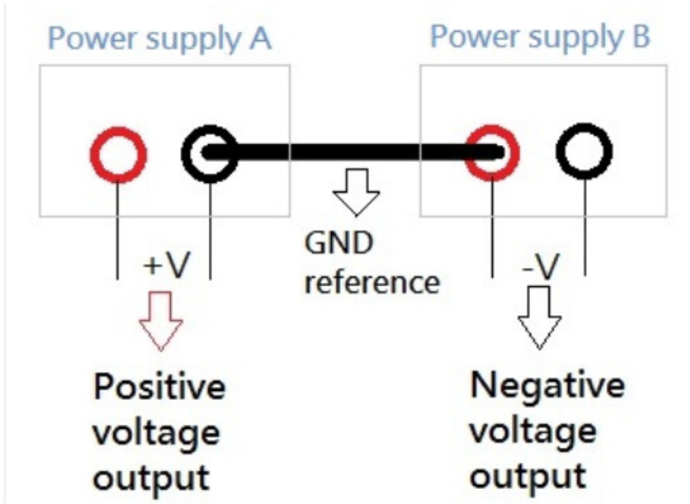


We also completed the CAD design of the mounts for our circuit boards onto the vehicle as shown below. We have developed a two-tier design that allows us to stack our input and processing units on top of each other.

<u>Challenges:</u>
After utilizing a schmitt trigger to generate the clock signal for our processing unit, we faced a challenge with converting the LED output we originally had for our processing unit into an output that will move the car motors. This is because the motors for our 110 car needs 9V in order to run, but the voltage from the output logic was only around 2-3V. Our original solution to this was to use an amplifier to amplify the voltage to 9V, but that solution had complications so our new solution is to utilize a MOSFET and schmitt triggers similar to the way we built circuits for 110 lab.

One major challenge we need to solve as soon as possible is creating a negative voltage power rail. Throughout the semester we have had issues with this and likely prohibited our ability to build the integrator that we wanted at the beginning of the semester and the comparator and op amp we attempted to implement this past week. We verified that this was our issue because when measuring the output of the comparator with a multimeter, we do not measure the negative and positive voltage we expected based on the theoretical supply voltage, but a voltage that varies between -1 V and -2 V. Some of our initial ideas to solve this problem is to create a negative voltage relative to ground on the positive voltage power rail. Currently the oscilloscope is outputting our desired output signal, but only if the negative pin is connected to the negative voltage rail's ground. This has proven to be an issue with the rest of our circuitry because we wired all the ground IC chips to the positive rail's grounds.



This image shows one way to implement a negative voltage and the method we plan to try in next week's lab. Currency we just flipped the power and ground pins on a power rail, but using this method, we hope that when connecting a multimeter's positive pin to the positive rail of the negative power rail the the negative pin to the ground of the ground rail of the positive power rail we will receive our desired negative voltage.

<u>Proposal for Next Week:</u>
Our plan for the next week will be to complete the output unit by connecting the left and right 110 car motors to the output logic using the MOSFETs and schmitt triggers. After successfully connecting the output unit to the processing unit, we will connect the input unit to the processing unit (and test to make sure it works properly) so that all three units are integrated together. We will 3D print our CAD mount design and utilize it in order to place our input and processing unit onto the car in such a way that the car motors connect properly to the output logic and the ultrasonic sensors each face in the correct direction. We also plan on beginning testing the vehicle next week.

<u>Contributions:</u>
Aastha: Integration of processing unit with input and output units, vehicle mounts CAD designs
Maya: Integration of processing unit with input and output units
Rina: Integration of processing units with input and output units, completing input circuit