## Lab 7: Projects

For my final project I will make a bot that follows the brightest lights source. ZL 12/8/22
I will be building my circuitry onto an available chasis that has 2 12V DC motors connected to treads. The first step is to design the sensor controls. I will use two light sensors to determine Left and Right controls. The light sensor has a lower resistance the brighter a light shines on it. With a voltage divider between the sensor and a resistor and the sensor on top then the brighter the light the higher the voltage output. We can compare each sensor output to each other and a set threshold above ambient light.
We can combine the OP-AMP comparator outputs to create three output signals, "Left" sensor and above threshold AND brighter than "Right" for "Left" control. "Right" sensor above threshold AND brighter than "Left" for "Right" control. When Left AND Right sensors are above the threshold will be the "Forward" output. Next I will design logic to control two H-Bridge drivers to control each motor. One will drive in Forward while the other in Reverse to turn one direction and vise versa to turn the other way. Lastly, I will need to design logic for the "forward" signal to drive both motors forward. In addition to driving the motors we want Indicator lights for Turning Left, Turning Right, and Move forward. Finally, I want to select between three modes: Indicator: where the motors don't activate but the LED Indicators show desired operation, Turning: where the lights Indicate and the motors turn the robot but won't advance forward, and Drive: where the lights Indicate, motors turn, and the bot moves forward toward the light.

- First lets take a closer look at the functionality of the light sensor (Photo Resistor)

## GMQ-5506

The 5506 is a PhotoResistor where it's Resistance is Dependent on the amount of Light Present. A PhotoResistor's Resistance Decreases When Light Increases.

### 5506 Max Ratings

$V_{max} = 100V$ Photo Resistance (10 Lux) ≈ 2k-6k Ω
$P_{max} = 90mW$ Dark Resistance = 150k Ω
Ambient Temp = -30°C – +70°C
Response Time: Rise = 30 ms ; Decay = 40 ms

### PhotoResistor Schematic Symbol

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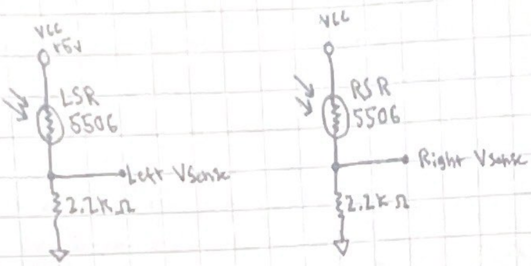
- We will start by measuring the Resistance of the 5506 in Different conditions.
  - Ambient Light @ Lab Desk ≈ 2.5kΩ
  - Flashlight: 6" distance ≈ 500Ω; up close ≈ 60Ω
  - Thumb Coverage ≈ 18KΩ

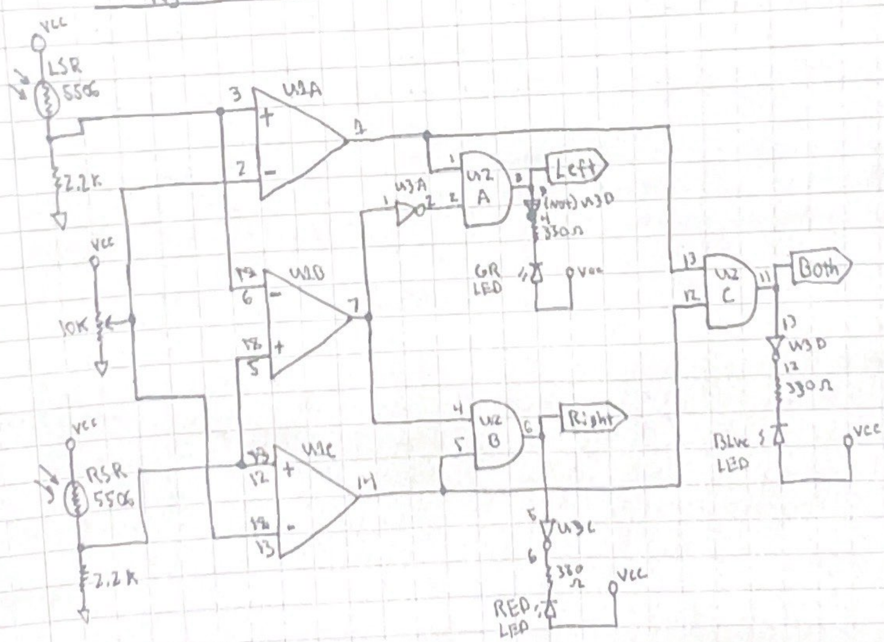
- To sense light we will make a voltage divider with the PhotoResistor and a 2.2KΩ Resistor. As the PhotoResistor is ≈2.5K at Ambient, the voltage split will be ≈ 50/50 in ambient light. As the light Increases the Voltage on the output will increase.

Figure 7.1: Left and Right Light Sensors




- Then we can compare these two signals to each other and against a variable threshold. We will create 3 signals from these outputs: Left, Right, and Both. Indicate with LEDs.

Figure 7.2: Left and Right Sensor Circuit



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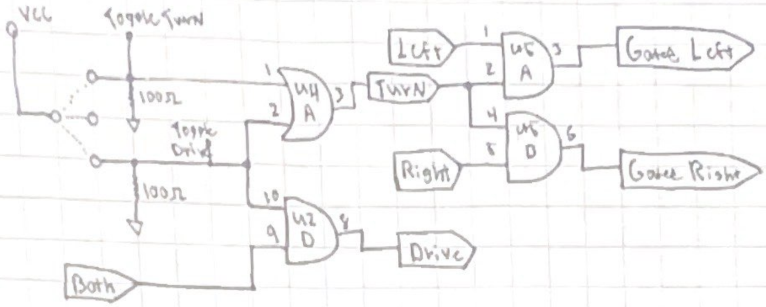
•Before we use these signals we want to gate them to a switch for the 3 independent Modes. We can use a 3 state switch to select between Indicate, neither input high; Turning, to gate the Left and Right Inputs; and Drive, to gate Left, Right, and Both Inputs.

Figure 7.3: Mode Toggle Gating Circuit




•Lets summarize what we have so far. We have two light sensors that can give us three signals to control our Motors: Turn Left (Left side is Brighter than Right side), Turn Right (Right side is Brighter than Left), and Drive forward (Both sides are Bright). These control signals are then going to give us control over our three modes. Indicate (Always On), Turning (Robot will turn), and Drive (Robot will move toward the light). We need to now look at how we want the motors to move to achieve this kind of motion. With the two track chassis provided this will be a tank steering system. In other words, To turn Right the Right motor should go in Reverse; ~~to turn Left~~ while the Left motor continues to go forward; To turn Left the Left motor should go in Reverse while the Right motor goes forward. We have two motors (12v DC) that need to operate in forward and Reverse, so we'll need 2 separate H-Bridge driver circuits that are isolated. Keep in mind the Optocouplers will be active Low but our current signals are active high, so we will Invert the signals before the Opto Couplers. For now, we will focus on the turning motion and Implement forward motion Later. We will use our two Input Signals (Gated Left and Gated Right) to control our four Outputs: Left Motor Forward (LMF), Left Motor Reverse (LMR), Right Motor Forward (RMF), and Right Motor Reverse (RMR). Because of the design of the Left and Right Inputs they will flip-flop or toggle and never be active at the same time. We can then connect Gated Left to Left Motor Reverse and Right Motor Forward. We can connect Gated Right to Right Motor Reverse and Left Motor Forward. Again, this is only to turn the chassis Left and Right we will Implement the Drive signal to override the turn controls After displaying the connections to control turning.

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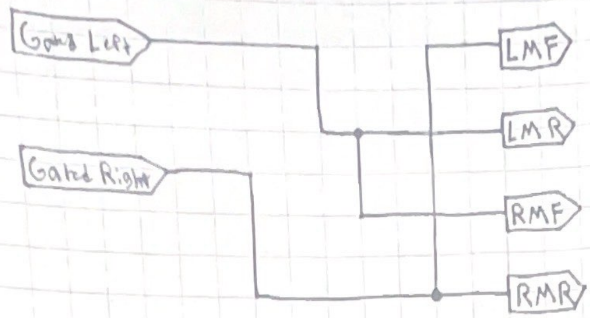
## Figure 7.4: Turning Motor Signal Connections




- We can now look at implementing the drive signal to move both motors forward. To do this we will look at how the Drive signal should effect the forward and Reverse signals for both motors.

### Forward

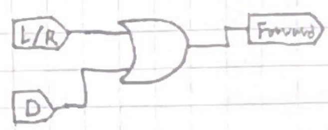
When Drive is Ø it should buffer the Left/Right signal. When Drive is 1 the forward signal should be 1.

Table 7.1: Forward Signal Drive Gating Truth Table

| Inputs | | | Outputs | |
|---|---|---|---|---|
| Drive(D) | GLeft | GRight | LMF | RMF |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 |

D or L/R

$D + L/R$



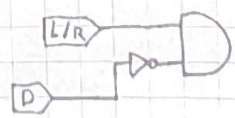

### Reverse

When Drive is Ø it should buffer. When L/R is 1 it should be Ø and if L/R is Ø is should Remain Ø, When Drive is 1.

Table 7.2: Reverse Signal Drive Gating Truth Table

| Drive(D) | GLeft/Right (L/R) | Motor Reverse |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

$\overline{D} \cdot L/R$



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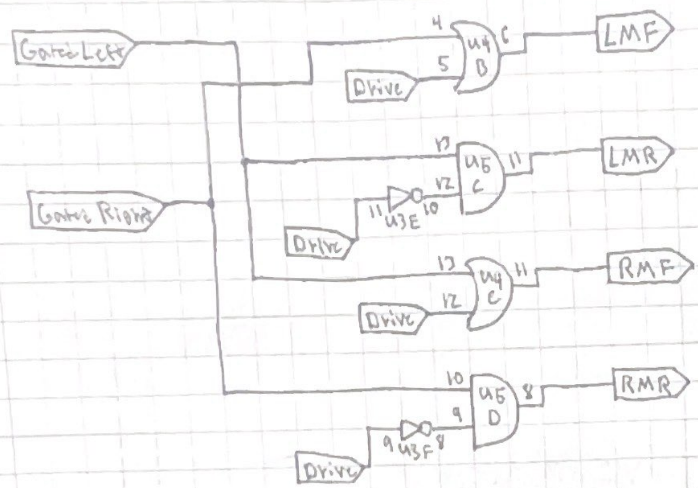
• We can now combine these two gating techniques to have the Robot turn when Drive is 0 and move forward when Drive is 1.

Table 7.7: Left and Right with gated Drive Truth table (fig 7.5)

| Inputs | | | Outputs | | | |
|---|---|---|---|---|---|---|
| Drive | GLeft | GRight | LMF | LMR | RMF | RMR |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 |

Figure 7.5: Left, Right, and Drive Motor Connections




• We now have circuitry that can control the two H-Bridge Drivers in the proper manner to turn towards the light and drive towards it as well. We will now go over how to connect these signals to two H-Bridge Drivers while providing Isolation from the control circuitry.

• H-Bridge Drivers and Opto-Isolation covered in depth on Pg. 39 & 40.
(important current loading update to figures 6.3.12 and 6.3.14)

In the previous figures we inverted the signal and used a Not gate to drive two Optocoupler Inputs. This caused the $I_{OL}$ of that Inversion gate to exceed $I_{OL}$ Max (16mA): $V_{CC} - V_D = V_R$ $5v - 2v = 3v$ $3v/330 = 9.09mA \cdot 2$ inputs $= 18mA$
to prevent this we will use two Not Gates (one for each Input) moving forward.

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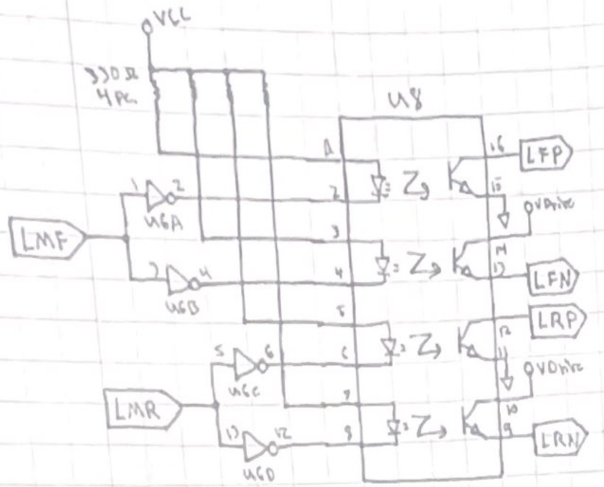
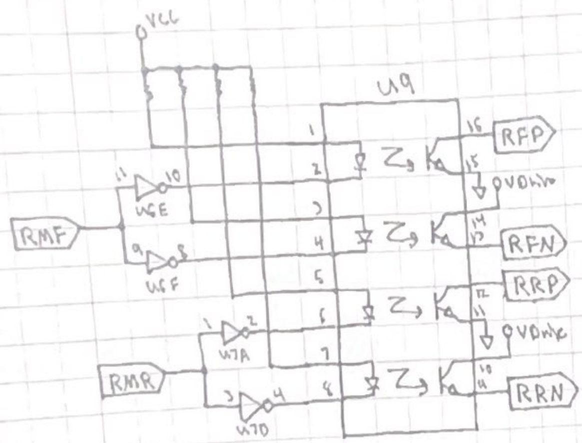
• Next we will input our 4 motor control signals into 2 Optocouplers (LTV-847) to control our 2 H-Bridge Driver circuits.

Figure 7.6: Left and Right Motor Optocoupling




• These 8 output signals will control our 8 MOSFET Gates between the two H-Bridge Drivers. Left Forward P-channel (LFP) and Left Forward N-channel (LFN) to control left motor forward. Left Reverse P-channel (LRP) and Left Reverse N-channel (LRN) to control Left Motor Reverse. Right Forward P-channel (RFP) and Righ Forward N-channel (RFN) for Right Motor forward. Lastly, Right Reverse P-channel (RRP) and Right Reverse N-channel (RRN) for Right Motor Reverse. H-Bridge Driver connections shown in figure 7.7 Pg. 49.

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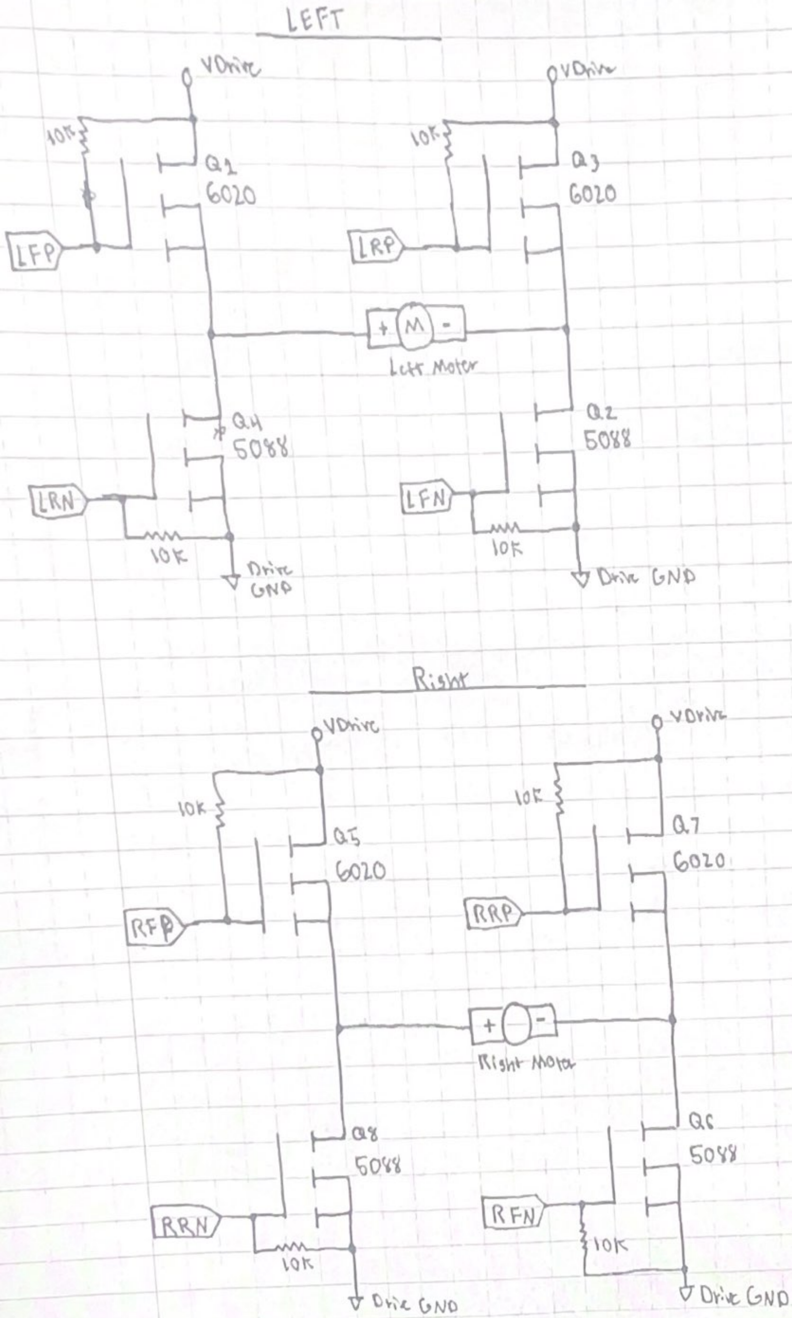
- We can now assemble our two H-Bridge Driver circuits. Remember it is important to ensure only the correct MOSFETs saturate at once (2 per H-Bridge). If two MOSFETs saturate that short the load to ground, high current will pass through the MOSFETs and can damage components.

Figure 7.7: Left and Right H-Bridge Drivers



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- We now have the full circuit to operate the Robot as intended. Lets take a Look at the Integrated Circuits used and the Current Loading of the whole circuit and each figure. Z.C. 12/13/22 12/14/22

## ICs used

- U1 - Rail to Rail OP-AMP: MCP6004
- U2 - AND: 7408
- U3 - NOT: 7404
- U4 - OR: 7432
- U5 - AND: 7408
- U6 - NOT: 7404
- U7 - NOT: 7404
- U8 - Optocoupler: LTV-847
- U9 - Optocoupler: LTV-847

## Worst Loading Calculations

fig 7.2 (Pg. 44)

| | |
|---|---|
| IOL = 3.2 mA | - U2: Pins 3, 6, & 11 - U3 Pins: 2, 7, 8, 14 |
| IOH = 80 µA | - Same as IOL |
| VIH = 5v | - All OP-AMP inputs/Ins |
| VIL = 0v | - Same as VIH |

fig 7.3 (Pg. 45)

| | |
|---|---|
| IOL = ~~3.2~~ 6.4 mA | - U2D: Pin 8 |
| IOH = 160 mA | - U2D: Pin 8 |
| VIH = 5v | - U2D: Pin 10 - U4: Pins 1 & 2 |
| VIL = 160 mV | - Same as VIH |

fig 7.5 (Pg. 47)

| | |
|---|---|
| IOL = 3.2 mA | - U4: Pins 6 & 11 - U5: Pins 8 & 11 |
| IOH = 80 mA | - Same as IOL |
| VIH/VIL = N/A | - All voltage inputs are Logic Out |

fig 7.6 (Pg. 48)

| | |
|---|---|
| IOL = 9.09 mA | - U6: Pins 2, 4, 6, 8, 10, & 12 - U7 Pins 2 & 4 |
| IOH = 0 | |
| VIH/VIL = N/A | - Same as fig 7.5 |
| Sink current = 500 mA | - All outputs U8 & U9 |

Figure 7.7 (Pg. 49)

Max current through the MOSFETs is dependent on the Load it is driving. VDrive / R Load = ID. VDrive can be up to 12V for the motors but can also function w/ 5V. VGS max = ± 20v.

Total Circuits (Pg. 44-49)

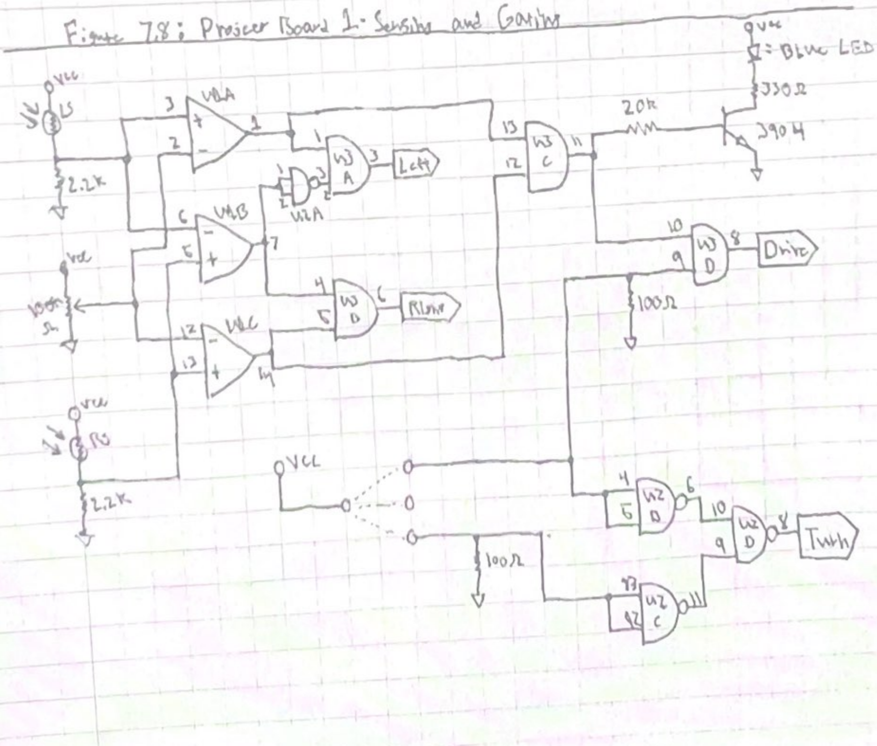
| | |
|---|---|
| IOL = 9.09 mA | - U6: Pins 2, 4, 6, 8, 10, & 12 - U7: Pins 2 & 4 |
| IOH = 160 mA | - U2: Pin 8 |
| VIH = 5v | - U2: Pin 10 - U4: Pins 1 & 2 - U1: All OP-Amp Inputs |
| tp ≈ 110 ns | U3A → U2A → U5A → U5C → U6C (excluding OP-AMP and Opto coupler) |

With the circuit fully designed and tested, lets take a look at the schematic when soldered onto the PCB board. The changes made do not effect the logic or function of the previous circuit. The changes that were made were done in order to minimize the data transfer between project boards and to use the minimal number of components / unused gates per board. Due to the limited space on each project board, this circuit will be split among three project board PCBs. The first board will contain the OP-AMP comparator sensing circuitry and the mode selection gating. The second board will contain the logic to control the motors Left, Right, and Straight. While the final board will house the dual H-Bridge drivers and optical isolation. Let's look at each board and the changes made during assembly. Z.C. 12/18/22

## Project Board 1: Sensing and Gating

This board had the most changes to the schematic. For this section of the circuit we required two inversions and a single OR gate. To prevent empty gates when using a 7432 and 7404 we utilized a NAND gate to create OR logic with 3 of the NAND gates and the last as a NOT gate. The final inversion was to light an indication LED on low logic. Instead we will use a BJT driver to light the LED on High logic without overloading current specs. The revised schematic is a follows in fig 7.8. With 4 outputs to Board 2.

Figure 7.8: Project Board 1 - Sensing and Gating



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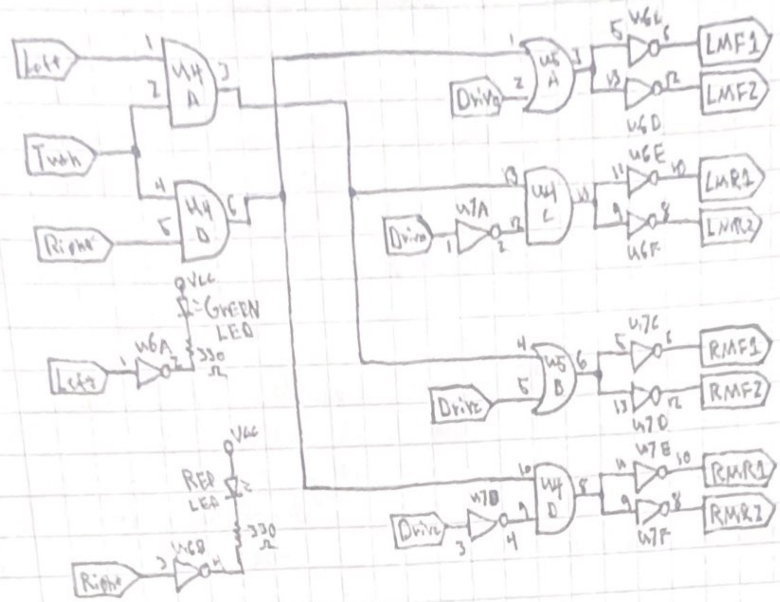
### ...roject Board 2: Motor Control Logic

No significant changes were made to the schematic of this board. *Note U7A and U7B were combined to use a single part leaving one unused NOT Gate.

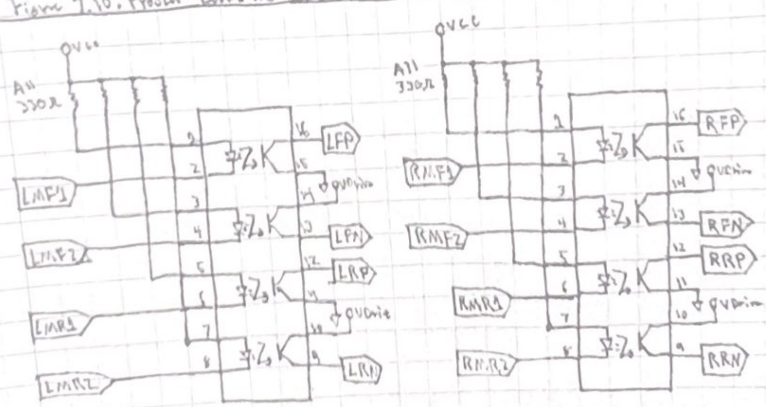
Figure 7.9: Project Board #2- Motor Control Logic




### Project Board #3: H-Bridge Drivers and Isolation

The final board was entirely unchanged from the previous schematic. The H-Bridges inputs are the same as Fig. 7.7. However I will redraw the opto coupler inputs for clarity's sake.

Figure 7.10: Project Board #3- Opto-Isolation Inputs




*Outputs of Fig 7.10 input to Fig 7.7 on the same PCB board.

An Attempt was made to regulate 12v In to 5v So the Motors could run on 12v, while the Logic runs on 5v. The Opto-Isolation is already in Place. However, when Attempting we had lots of current Drawn through the Regulator. The Two H-Bridge PCB seems to be working fine (as of 5/1/23). Next test should be extra grounding as I Beleive there may be grounding Issues on the TTL Logic and 12v H-Bridge.

Zac Christensen

5/1/23