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ECE 302
11/2/2023

NAVIGATION LAB REPORT

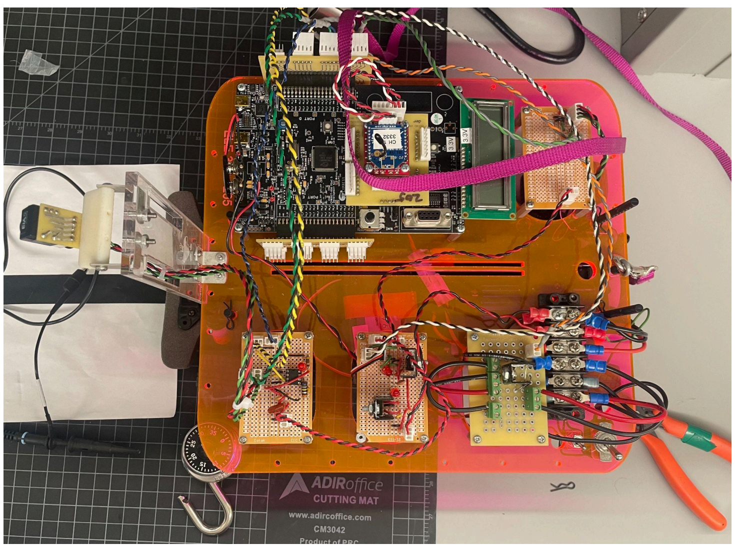
STATEMENT OF OBJECTIVE

The objective of this project was to design and build an autonomous car that can maintain a constant speed whilst navigating a black race track using a camera.

To implement this, we used a P controller where our parameter Kp was tuned on the basis of the direction of steering as well as errors made while following the black line.
We also tuned the PWM_Motor_CMPR on the basis of how fast/slow our car was moving on the track.

KEY SUB-SYSTEMS AND COMPONENTS

From the image above, the following are the key subsystems used:



(1) Motor Board:

- **PWM MOSFET**: A PWM-driven MOSFET is used to control the motor by converting the Pulse-Width Modulated (PWM) signal from the PSoC into a switching action. Since we are using an N-channel MOSFET, when the PWM signal is high, the gate-source voltage (V_GS) becomes positive, turning the MOSFET on and allowing current to flow from drain to source, thereby powering the motor. When the PWM signal is low, V_GS is zero (or negative in some cases), turning the MOSFET off and stopping the motor. This switching mechanism enables speed control of the motor by adjusting the duty cycle of the PWM signal.

- **100 ohms resistor**: A 100-ohm resistor is placed at the gate terminal of the MOSFET to limit the inrush current during switching. This helps in controlling the charging and discharging rate of the gate capacitance, thereby preventing excessive power dissipation and reducing electromagnetic interference (EMI). While a lower gate resistance allows for faster switching, it can also lead to high current spikes that may cause ringing and switching losses. The chosen value of 100 ohms balances switching speed with power efficiency and circuit stability.

- **A diode**: We connect a diode parallel to the motor so as to invert the digital signal from the PWM MOSFET as well as allow unidirectional movement of current. When the digital signal is high, then voltage flows across the path of least resistance, the diode path, leaving the motor OFF. When T. When the digital signal is low, then voltage flows across the motor and drives the motor. The diode also helps avoid any induced current back to the MOSFET.

(2) Power Board:

- **Voltage regulator, 7805**: This is a voltage regulator chip that helps output 5V no matter the input voltage. The output of this voltage regulator is fed into the Hall Effect board.

- **Voltage regulator, 7806**: This is a voltage regulator chip that helps output 6V no matter the input voltage. The output of this voltage regulator is fed into the servo motors.

- **LED**: LEDs on the power board serve as visual indicators to confirm power delivery and assist in troubleshooting. This helps quickly diagnose issues such as power supply failures, short circuits, or incorrect voltage levels, making debugging more efficient.

(3) Hall Effect Board:

- **LED**: The LED on the Hall Effect board serves as a status indicator, providing visual confirmation that the sensor is powered and operational. It helps in troubleshooting by indicating whether the board is receiving the correct voltage and whether the Hall sensor is detecting a magnetic field.

- **Hall Effect Sensor**: The Hall Effect sensor (A110), which has three pins (VCC, GND, and Output), is connected to the Hall Effect board to detect magnetic fields. It operates as a digital switch, toggling its output voltage between high (5V) and low (0V) in response to the presence of a magnetic field. When the sensor detects a magnet, the output switches to 0V, and when no magnet is present, the output returns to 5V. This behavior makes it useful for our autonomous car applications i.e motor speed sensing.

(4) PSOC(Programmable System on Chip)

- Programmed using a PSOC Creator
- **XBee**: Used for communication between the PSOC and the UART output, that is emitted into the computer.

(5) Video Board:

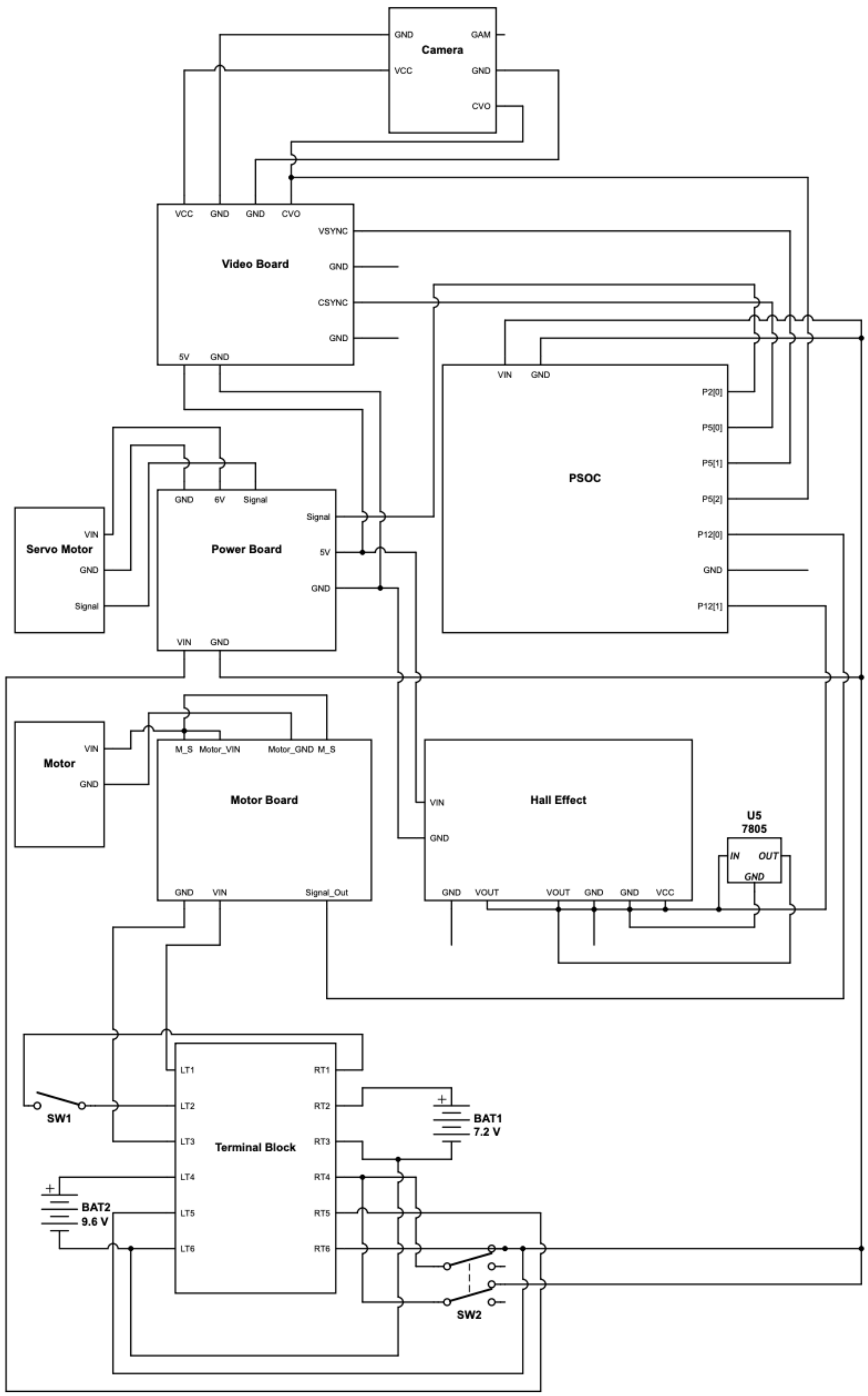
- **LED:** LEDs on the video board serve as visual indicators to confirm power delivery and assist in troubleshooting. This helps quickly diagnose issues such as power supply failures, short circuits, or incorrect voltage levels, making debugging more efficient.

- **Connection to a Voltage Regulator (7805):** Since the video board operates at **5V**, we used a **KK connection** from the output of the **7805 voltage regulator** to ensure a stable 5V power supply. This allowed us to reliably power the video board while protecting it from voltage fluctuations.

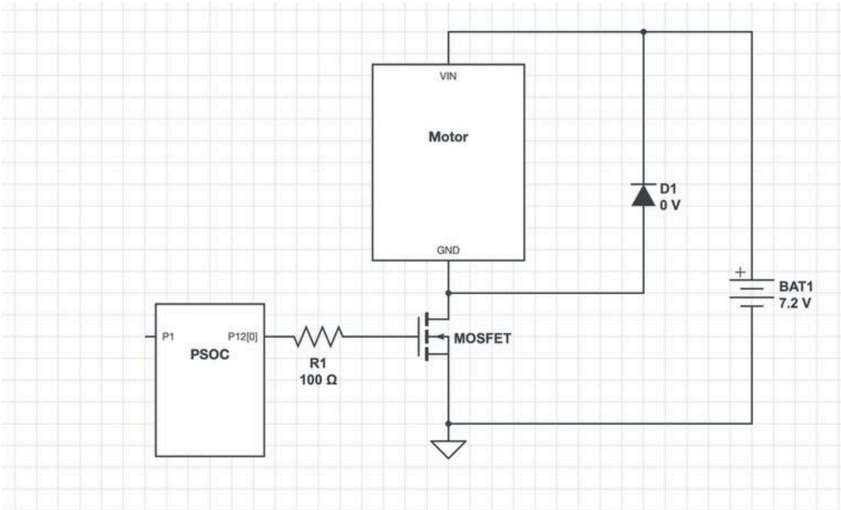
- **LM1881 Video Sync Separator:** The **LM1881** video sync separator, mounted on an **IC socket**, was used to extract timing information, primarily **composite sync** and **vertical sync** data outputs.
    - Connections for the **inputs and outputs** of the LM1881 were made according to the specifications provided in the **datasheet**.
    - Additional circuit modifications included:
        - **An LED on VCC** to provide a quick visual indicator of power status.
        - **A 75Ω resistor in parallel with a 0.1μF capacitor** to ensure the video circuit impedance matched that of the camera, improving signal stability and performance.

<u>**SCHEMATIC DIAGRAM OF CIRCUITS**</u>

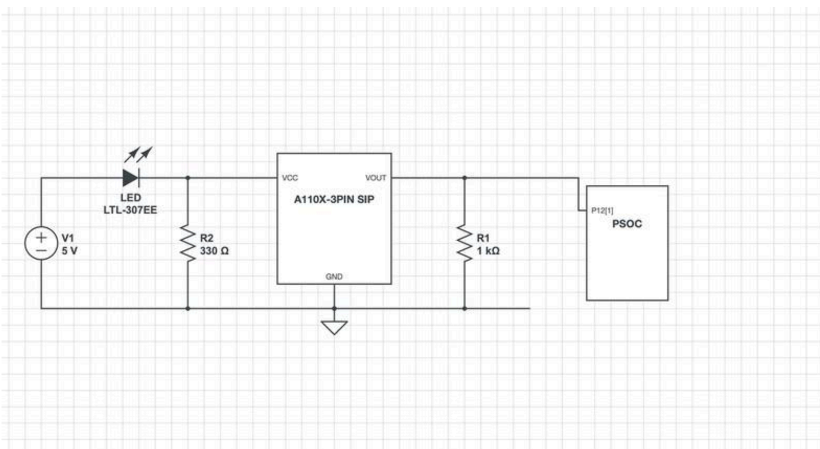
OVERVIEW SCHEMATIC:



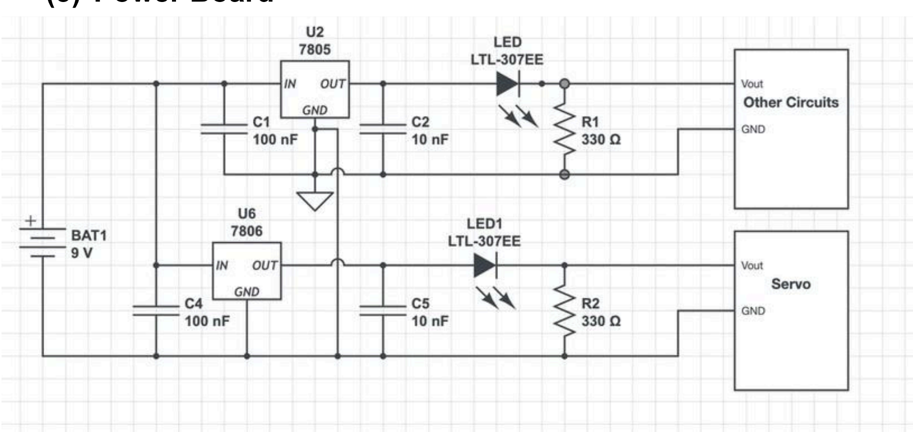
(1) Motor Board



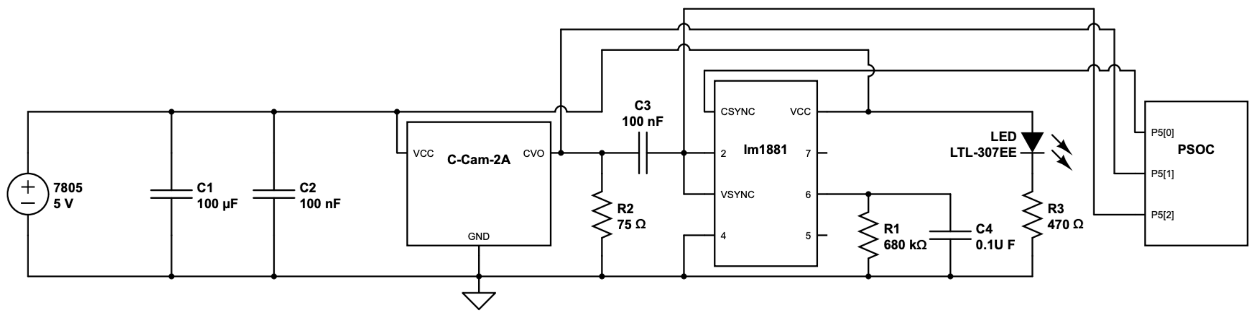
(2) Hall Effect Board



(3) Power Board



(4) Video Board

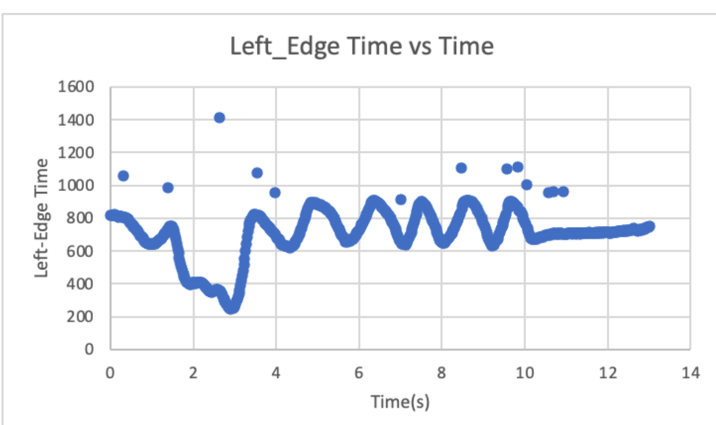


Data

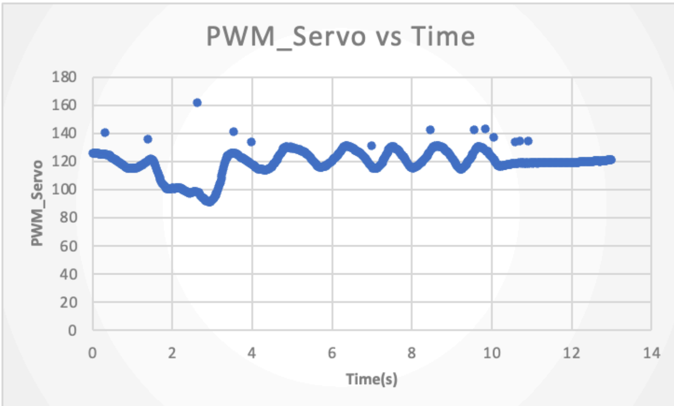
Telemetry Data

1. Graph indicating error vs time(s) on a small portion of the race track. Data extracted from PUTTy.

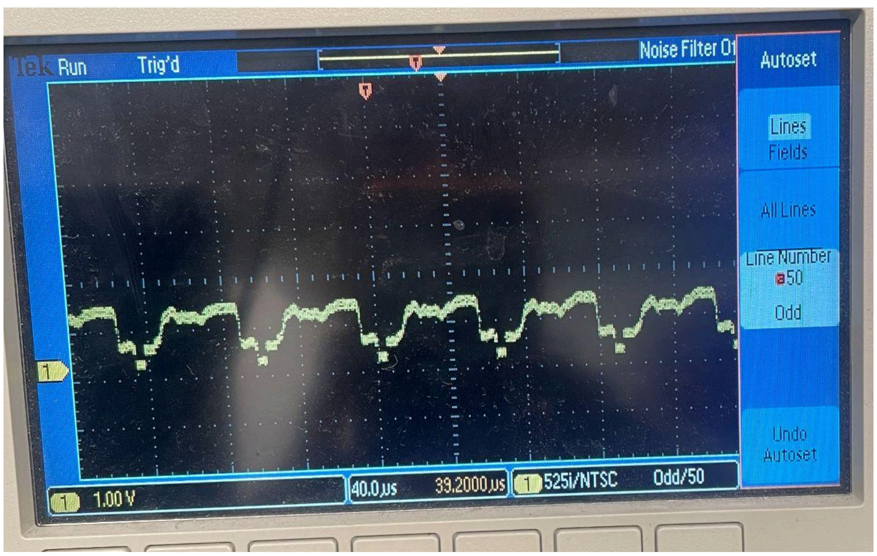
2. Graph indicating the time for the camera to detect the Left_Edge of the black line vs time(s) on a small portion of the race track. Data extracted from PUTTy.



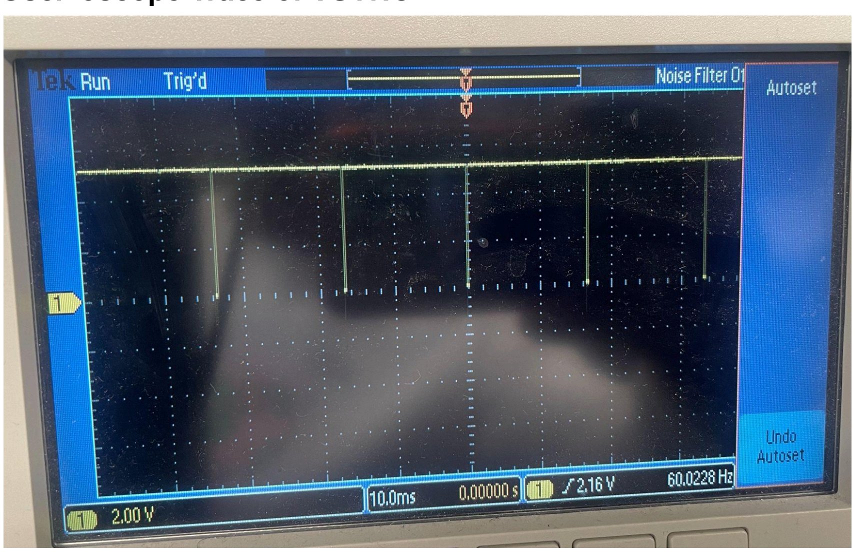
3. Graph indicating the PWM signal of the servo motor vs time(s) on a small portion of the race track. Data extracted from PUTTy. The shape of this graph is very similar to graph 2 as expected.



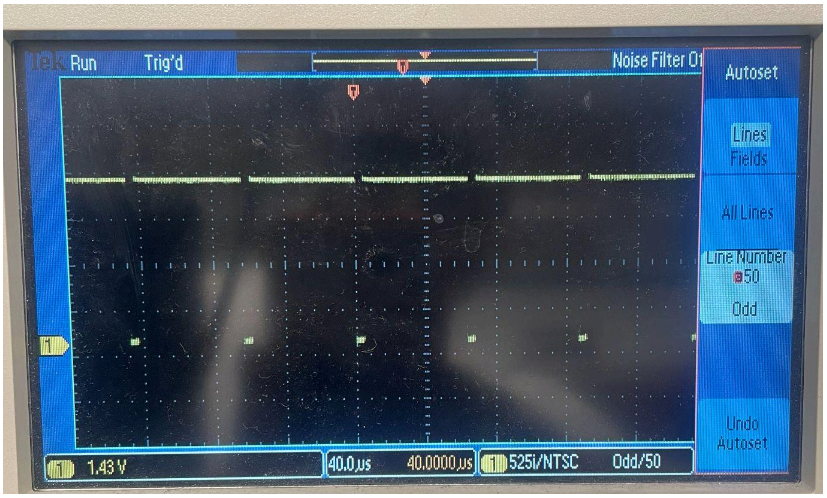
Oscilloscope Trace of Raw Camera Data (CVO)



Oscilloscope Trace of VSYNC



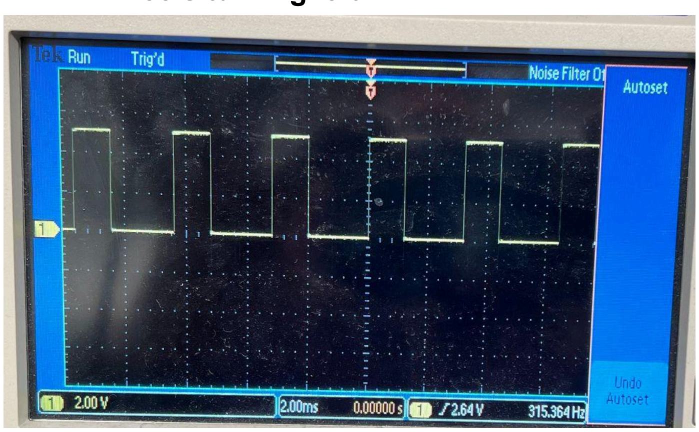
Oscilloscope Trace of CSYNC



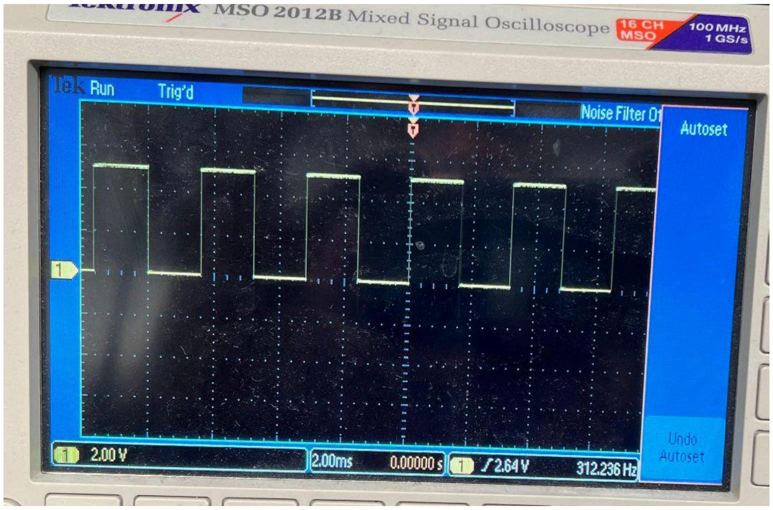
PWM Signal to Motor

PWM Signal to Servo Motor:

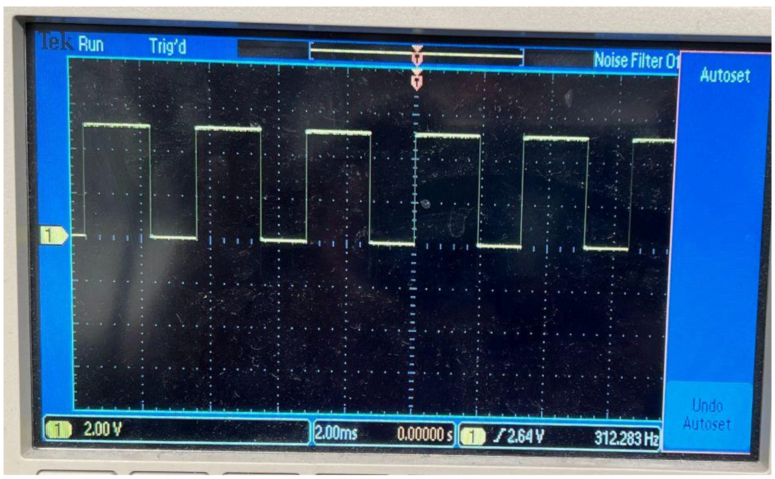
- **Wheels turning left**



- **Wheels straight**



- **Wheels turning right**



CHALLENGES & DESIGN CHOICES MADE

(1) Supplying the Video Board with 5V

To power the Video Board, we created an additional output using **KK connectors** from the **7805 voltage regulator** on the Power Board. This ensured a stable 5V supply without interfering with other system components.

(2) Including an LED for Troubleshooting

We added an **LED on the Video Board** to provide a quick visual indicator of power status. This helped in troubleshooting, as we could immediately rule out power supply issues if the LED was illuminated.

(3) Mounting the LM1881 on an IC Socket

Instead of soldering the **LM1881 video sync separator** directly onto the Video Board, we mounted it on an **IC socket**. This design choice prevented potential heat damage from soldering and allowed for easy replacement if needed.

(4) Fixing Incorrect Timer Readings

We encountered an issue where time values remained constant, even when the **paper race track's** position changed. The problem was traced to our **Timer_ReadCapture function**—we were printing its direct output instead of first saving it to a variable. By storing the captured value in a variable before printing, we resolved the issue and obtained accurate time readings.

(5) Tuning the PWM_Motor_CMPR for Optimal Performance

Adjusting the **PWM_Motor_CMPR** to track the car's timing on the race track was a major challenge.

- A **higher speed** made cornering difficult.
- A **lower speed** risked the car not completing the lap within the desired time.
  Finding the optimal balance required extensive tuning and iterative testing.

(6) Addressing Oscillations on the Race Track

Our car experienced oscillations while navigating the race track due to signal noise. To resolve this, we introduced a **glitch filter** between the **analog comparator** and the **timer**. This effectively eliminated unwanted noise and improved the stability of our car's movement

<u>**WHAT COULD BE IMPROVED?**</u>

(1) Printing a Longer Mast for the Camera

Our initial mast was too short, leading to two key issues:

- A **wider field of vision**, which made the black line on the race track appear thicker than intended, affecting accuracy.
- The **camera being too close to the ground**, causing it to detect small dark spots outside the race track, leading to potential false detections.
  By increasing the mast height, we could narrow the field of view and improve tracking accuracy.

(2) Increasing the Duty Cycle for Faster Lap Completion

By increasing the **PWM_Motor_CMPR** duty cycle, the car could have completed the lap in a shorter time than our **50-second time-lapse**. Fine-tuning this parameter while maintaining control through corners would have improved overall performance.