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ECE 302
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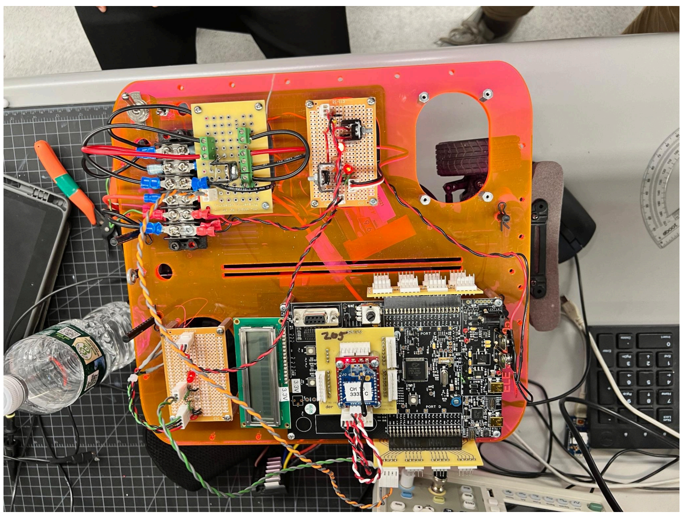
SPEED CONTROL LAB REPORT

STATEMENT OF OBJECTIVE

The objective of this project was to design and build an autonomous car that can maintain a constant speed on both a flat surface, as well as up and down a ramp.

KEY SUB-SYSTEMS AND COMPONENTS



From the diagram 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.

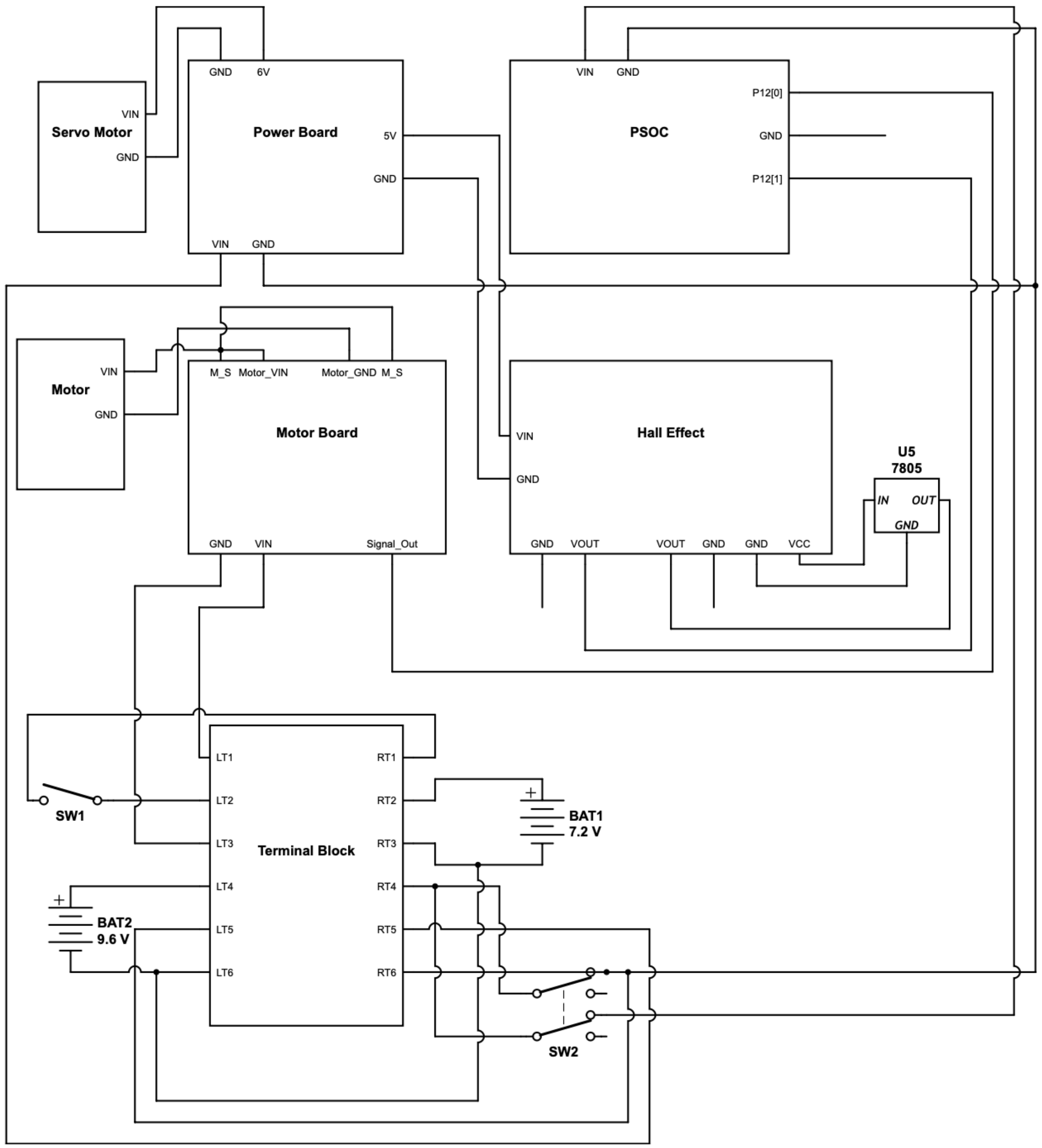
- **Hall Effect Sensor**: The Hall Effect sensor (A110), which has three pins (VCC, GND, and Output), is connected to the Hall Effect board to detect magnetic fields. It operates as a digital switch, toggling its output voltage between high (5V) and low (0V) in response to the presence of a magnetic 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)

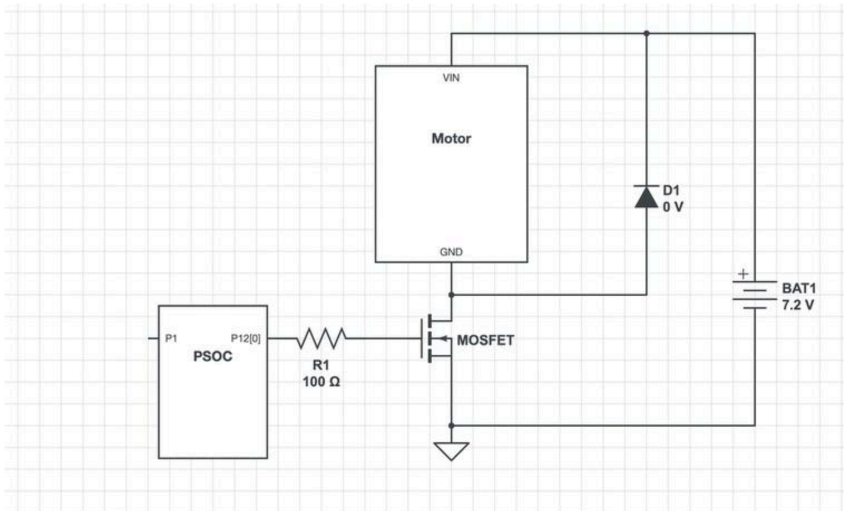
- Programmed using a PSOC Creator
- **XBee**: Used for communication between the PSOC and the UART output, that is emitted into the computer.

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

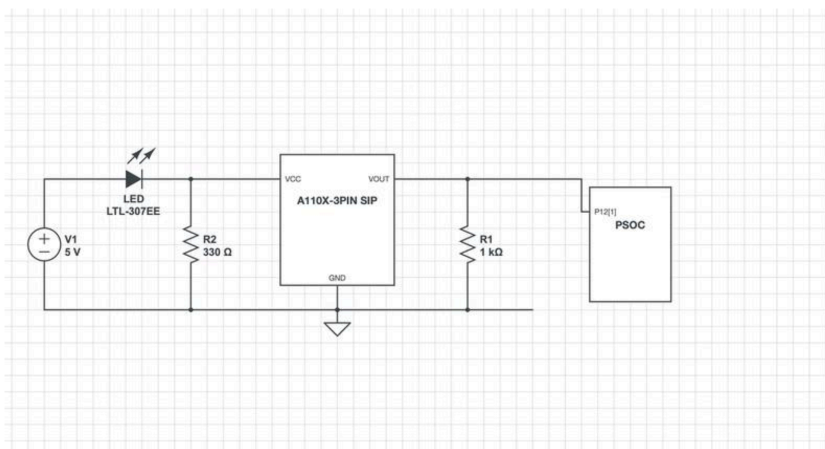
OVERVIEW SCHEMATIC:



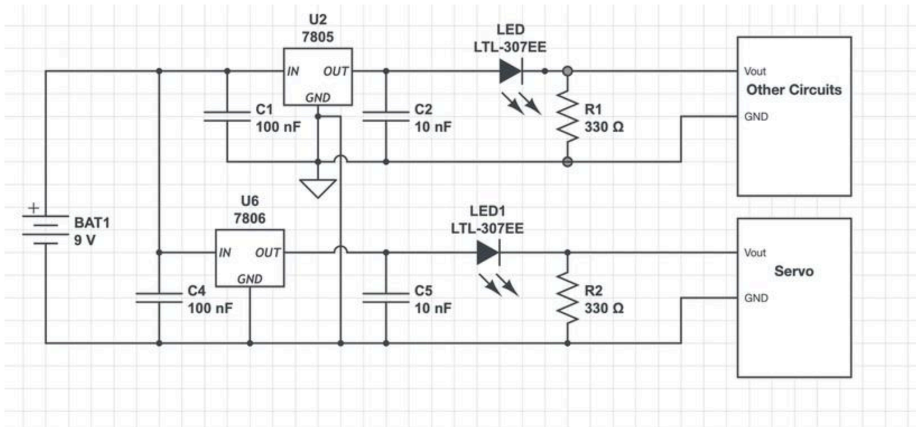
(1) Motor Board



(2) Hall Effect Board



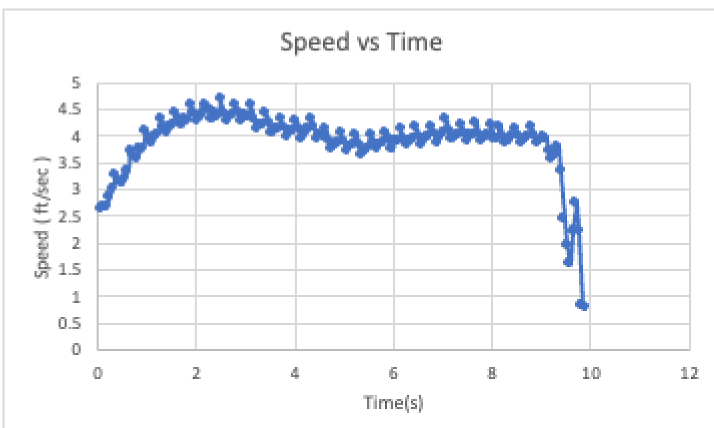
(3) Power Board



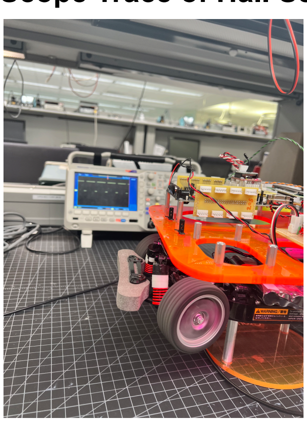
DATA:

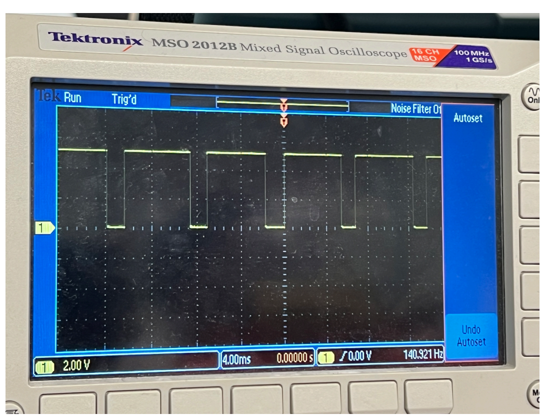
Telemetry Data

Graph indicating variation of speed vs time on a flat surface. Data extracted from PUTTy.

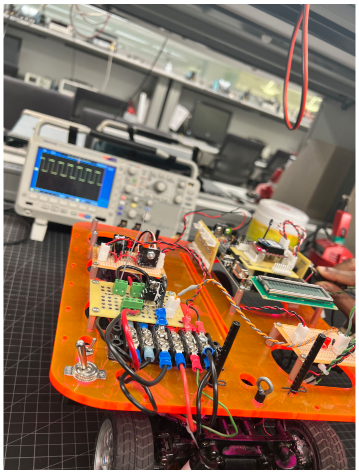


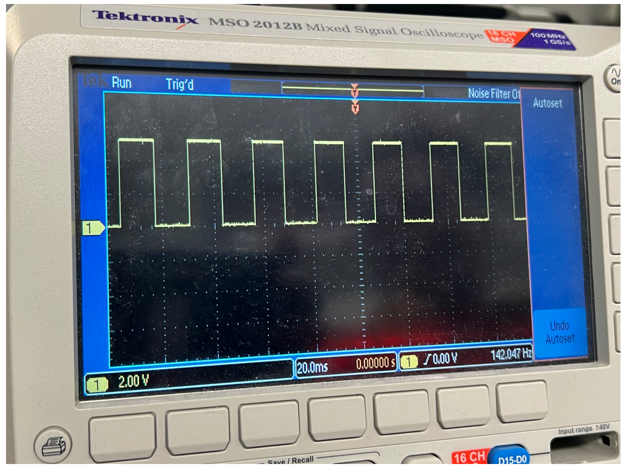
Scope Trace of Hall Sensor





PWM Signal





<u>**CHALLENGES & DESIGN CHOICES MADE**</u>

(1) Optimal Placement of the Hall Effect Sensor

One of the biggest challenges we encountered was efficiently positioning the Hall Effect sensor. If placed too close to the wheel, disturbances such as bumps or inclines would knock the sensor out of alignment, leading to inconsistent readings. Conversely, positioning it too far from the wheel resulted in unreliable data, as observed through noisy, bouncing signals on the oscilloscope. To address this, we carefully adjusted the sensor's placement to strike a balance between stability and reliable magnetic field detection, ensuring consistent and accurate measurements.

(2) Incorporating LEDs for Troubleshooting

Including LEDs on every board significantly improved our ability to troubleshoot issues. The presence of an illuminated LED allowed us to quickly confirm that a board was receiving power, enabling us to rule out power failures when diagnosing circuit problems. This simple yet effective design choice saved valuable debugging time.

(3) Challenges in PI Controller Tuning

Tuning the Proportional-Integral (PI) controller proved to be the most difficult aspect of the project. While the system performed well on both flat surfaces and inclines—achieving a stable time of around 8 seconds—descending a ramp introduced significant challenges. We frequently had to adjust the proportional (Kp) and integral (Ki) gains, sometimes mis-configuring them, which disrupted the consistency of our experimental data. To resolve this, we first determined near-optimal values for Kp and Ki for both flat and uphill conditions. Then, instead of making drastic tuning changes for the descent, we scaled the vehicle's speed by a specific factor. This approach effectively "tricked" the system, allowing the car to maintain stable performance while descending within the desired time.

WHAT COULD BE IMPROVED?

(1) Optimized Capacitor Placement
Capacitors should be soldered as close to the board as possible to minimize resistance between their leads. This reduces unwanted voltage drops and improves circuit efficiency.

(2) Better Wire Management
Crossing wires between boards should be zip-tied to the center of the car to prevent loose wires from getting caught on external objects. This enhances both safety and durability.

(3) Consistent Wire Color Coding
Maintaining a standardized color-coding scheme for wires simplifies troubleshooting and reduces wiring mistakes:

- **RED/YELLOW** → Power
- **BLACK/GREEN** → Ground

(4) Shorter Wire Lengths
Wires should be stripped to the shortest necessary length, especially for internal board connections. Shorter wires reduce resistance and power losses, increasing overall efficiency.

(5) Using a 470Ω Resistor Instead of a 330Ω Resistor
Choosing a **470Ω resistor** over a **330Ω resistor** helps lower current draw and conserves battery power while maintaining proper circuit operation.