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Project Proposal - Formula Hybrid

1. Introduction

For our project we are going to be working with the Notre Dame Formula Hybrid team to improve the electrical system and powertrain in their hybrid vehicle. Two previous senior design teams have worked on this project and have documented their work; this will serve as the foundation for our continued work on the Formula Hybrid car. We will begin by implementing the work done by last year's group, resolve any persistent errors such as error messages related to the High Voltage system, and incorporate improvements leading to a functioning Formula Hybrid vehicle.

2. Problem Description

Our senior design team will be continuing the previous work of last year's Formula Hybrid team. Last year's team was unable to complete some of their goals due to the Covid-19 Pandemic. The electrical system consists of three sections: control, monitoring, and information. The control system takes driver pedal and wheel inputs and produces motor outputs or regenerative braking while also controlling the internal combustion engine (ICE) to maintain efficient operation. The monitoring system measures voltage, temperature, and current values to maintain safe operation. The information system provides the driver and off-track team with live updates of the vehicle diagnostics.

System Status Interface

The current system status interface uses an LCD inside the car to update the driver on fuel level, ultracapacitor charge, vehicle speed, engine speed, and error messages. The system is also designed to have off-track transmission via an RF transmitter. The transmitter uses UART communication to transmit diagnostics of the vehicle to an off-track computer.

Currently the system is unable to transmit data to an off-track computer using UART communication in real time and there is no data logging feature. Also the team last year was unable to fix issues with the LCD display inside the car, such as brightness and color contrast. The off-track RF transmitter needs additional work to determine the baud rate of the transmission system. Signals are determined to be sent and received, but our group cannot decipher such signals without the correct baud rate, which was not documented by the previous year's group.

CAN Drive

The current system is not able to distinguish the difference between the left and right hub controller messages. This is problematic for fine-tuning the torque-vectoring method that has been developed. The CAN contains error messages for the motors, so not being able to distinguish the right from the left delays the debugging process.

Engine Feedback Loop

The current engine feedback loop consists of the ICE, a sensor to measure the motor velocity, a servo to adjust the ICE throttle, and a PID controller implemented in the motherboard. The purpose of the system is to hold the ICE at a set RPM to balance efficiency and output.

The RPM sensor uses an off-the-shelf IC chip along with a low pass RC filter to measure the frequency of the alternator output. This part of the system and the PID controller currently works. The biggest problem with the system is noise that occurs on the two signals, RPM sensor-to-motherboard and motherboard-to-servo. The system works when the motors are turned off, but the EMI generated by the motors and motor controllers cause erroneous RPM readings and random servo settings. The current algorithm is very simple in that it only holds the engine at a set RPM. This algorithm doesn't account for current accumulator charge values. It also must be disabled to run the car in idle mode.

3. Proposed Solution

Fix CAN Drive

To fix the problem with the CAN drive, one of the possible solutions is to use the "Preferred CAN address". Using this method we would set the identifying bits which using the Saleae Logic Analyzer we would identify the addresses. The other possible solution is to implement two separate CAN busses, one for each side. According to the documentation from the previous team, the PIC32MX795, and the motherboard that they were using would be able to accommodate for the additional CAN bus system and thus facilitate the transmission of error messages from the individual motors.

System Status Interface

We plan to solve the transmission problem by fixing the communication protocol. We will attempt to find the baud rate of the UART communication. Alternatively, we can implement other protocols such as SPI and I2C. Last year's project used MATLAB to log data. We plan to improve the GUI and monitor the vehicle in real time, which may require us to use different software tools.

For the LCD display one improvement would be to add a display for motor temperature and controller temperature. We also plan to fix the LCD brightness and color contrast in order to make the display more visible to the drive.

Engine Feedback Loop

Due to the cancellation of in person classes last semester, last year's team was unable to work on the engine feedback system. The primary goal for this year is to continue last year's goal of adding a noise resistant cable between the motherboard and servo motor. The signal noise problem can be solved by simply using shielded cables. In addition, to increase robustness a dedicated PCB should be built for the RPM sensor circuit. Currently, this circuit is realized on a prototyping board. This PCB should be separate from the motherboard to help reduce noise from the high-voltage signals that are inputs to the RPM sensor.

A secondary goal for this year is to implement software that would be able to change the RPM setpoint based on the voltage of the capacitors. Instead of only operating at maximum ICE efficiency, the new system will be able to adapt to the energy needs of the vehicle. If the capacitor voltages were measured to be below a threshold, the RPM setpoint would be increased. If they were measured above a threshold, the RPM setpoint would be decreased.

4. Demonstrated Features

To demonstrate the functionality of the CAN system, RF Transmitter, and LCD interface we need to demonstrate real time vehicle information, including both hub motors individually to the driver, and to the off track team through the RF Transmitter. Also we will demonstrate a data log for the car data sent through the RF Transmitter. As for the engine feedback loop we must be able to maintain the motor RPM stable based on capacitor values without stalling the vehicle.

5. Available Technologies

- Quad/Dual Supercapacitor Auto Balancing (SAB) MOSFET Array
    - http://www.aldinc.com/pdf/ALD810025.pdf

- Fuses
    - https://www.mouser.com/datasheet/2/240/Littelfuse_Smart_Glow_MINI_Blade_datasheet-1291256.pdf

Because this project is a continuation of a previous project, we don't foresee implementation of many new/expensive technologies. Much of our work will be in understanding the technology that was implemented last year in enough depth to allow for improvement. Otherwise, our other costs should be rather minor, such as new circuit boards.

6. Engineering Content

- Embedded systems are crucial to our project since our proposed improvements focus on monitoring and controlling the vehicle. These features require proper communication protocols and programming.
- RF communication is also an important aspect of this project. Our goal is to communicate back and forth between the vehicle and remote RF receiver in real time. We have to find ways to send, receive, and process real-time data.
- This project also involves software skills such as GUI design, since we want to add more features to the GUI.

7. Conclusion

This project drew the interest of our group for multiple reasons. Beyond the engineering aspects, the project is focused on design constraints for an actual customer, the Formula Hybrid Team. This gives us the opportunity to work with the Formula Hybrid Team and receive feedback from them throughout the project. We will be in communication with the club and will have to design around their existing chassis and suspension. The project also gives us experience in working with other engineers in a team environment to create a final product. Our overall goal is to help the hybrid team develop a working vehicle in time for the SAE competition held in the spring.