Formula Hybrid Proposal

Senior Design 2021-2022

Jason Joehlin

Maxwell Coil

Elizabeth Mathy

Hanna Gagnon

Luke Nordman

Introduction

- Collaborating with Notre Dame Formula SAE Hybrid Racing Team
  - Improving and expanding electrical subsystems in the vehicle
  - Working off of and continuing development from previous EE Senior Design groups
- The car is a series hybrid vehicle powered by an ultracapacitor bank in series with an internal combustion engine
  - The generator motor converts mechanical energy from the ICE to electrical energy
  - The capacitor bank serves as an energy buffer between the generator and the two electric hub motors

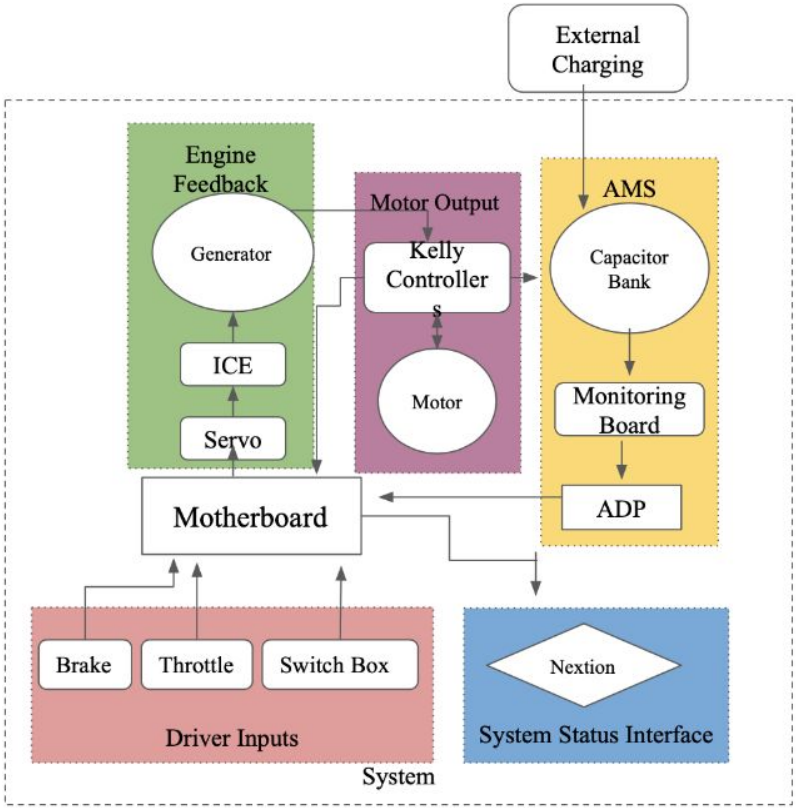

Figure 1. Complete System Diagram

Problem Description

Previous EESD teams have worked on various subsystems, identified future improvements needed:

- Accumulator Management System (AMS)
  - The current AMS does not incorporate temperature sensors in the capacitor bank
  - The battery monitors have a 5V single-transistor power supply that shuts off with an input voltage below 11V
  - The current capacitor balancing system only works when the bank is fully charged
- Motherboard Design
  - The current motherboard does not have the processing power or available connections needed for the current system
  - The Nextion display controlled by the motherboard currently requires an external power supply
- System Status Interface
  - The current System Status Interface does not consist of a complete off-track monitoring system
  - Data displayed on Nextion is not communicated by an RF transmitter to an off-track RF receiver
- Engine Feedback Loop
  - Current Engine Feedback Loop cannot operate with motor running due to noise
  - Engine RPM is always set a maximum ICE efficiency no matter capacitor charge
  - No idle-state

Proposed Solution

- AMS
  - Incorporate temperature sensors into the capacitor bank
  - Replace the single-transistor power supply with a low-dropout 5V supply
  - Implement an active cell balancing system to equalize the capacitor charge at any voltage
- Motherboard Design
  - Redesign the main motherboard incorporating a new more powerful microprocessor, more UART connections to support vehicle systems
  - Add a 12V-5V converter to supply power to the Nextion display
- System Status Interface
  - Coding adjustments to the 2019 team's MATLAB GUI to complete off-track monitoring system
  - Implement an RF transmitter
- Engine Feedback Loop
  - EMI shield wires + Modify controller constant for load conditions
  - Algorithm that decreases RPM setpoint if capacitors are above a given SOC or increases RPM is capacitors are below a given SOC + Introduce idle-state into Algorithm

Demonstrated Features

- AMS
  - The AMS can detect high temperatures and send relevant errors to the motherboard
  - The monitor boards can function below an input voltage of 11V
  - The balancing system can correct a voltage imbalance between capacitors
- Motherboard Design
  - The new motherboard will interface with both the RF Transmitter and the Nextion display that were implemented by previous EESD teams.
- System Status Interface
  - Displays similar data to Nextion
  - Can send data to a PC using a MATLAB GUI
- Engine Feedback Loop
  - The RPM is correct with the motor running
  - The RPM of the engine adjusts based on voltage in the capacitors
  - The vehicle can idle

Available Technologies

- AMS
  - Thermistors, power supplies, fuses, transistors
- Motherboard Design
  - 12V-5V DC-DC converters, microprocessors
- System Status Interface
  - RF Transmitter
- Engine Feedback Loop
  - Shielded Wires

Engineering Content

- AMS
  - Circuit board modification and design, programming microcontrollers.
- Motherboard Design
  - Board Design
  - Microprocessor Software
- System Status Interface
  - UART communications
  - Signals sent and received at specified baud rate
- Engine Feedback Loop
  - New PCB design, new interface with voltage signals
  - More complex algorithm to respond to voltage signals
  - Measuring engine and capacitor response to load

Conclusion

- Working with the Formula SAE Hybrid Racing Team
  - Many project requirements come from the needs that are defined by the team
- Completing work on multiple different subsystems of the vehicle
  - AMS that monitors capacitor voltage and temperature
  - Motherboard capable of interfacing to both an RF transmitter and the Nextion display
  - Systems Status Interface that implements off track monitoring via an RF transmitter
  - Engine Feedback Loop that addresses the issues of noise and modifying the RPM setpoint based on capacitor charge level