Control System Architecture for the PACCAR E-Truck Program

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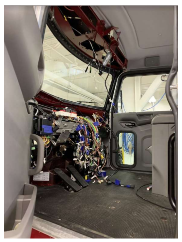
The PACCAR E-Truck Program

- The University of Washington E-Truck Registered Student Organization (RSO) is undertaking a four-year project to convert a Class 7 Peterbilt 337 truck into a fully battery electric vehicle (BEV) by 2027.
- Our team is one of four capstone teams collaborating to tackle this project. The teams include Controls Architecture, Electrical Architecture, Systems Modeling, and Retrofit Packaging.
- For Year 1, our team focused on laying the foundations for the controls architecture in Simulink for the new electric vehicle functions needed for the converted truck.

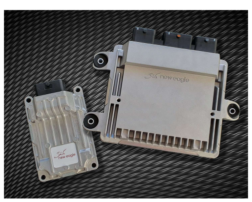
Our Peterbilt 337

- PACCAR provided a Class 7 Peterbilt 337 for us to convert. The diesel engine, as well as the Alison transmission, the driveshaft, and most accessories had already been removed. Four inches of frame rail was cut to fit the truck into our shop.

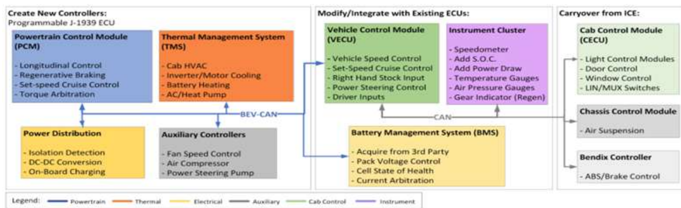
Objective and Requirements

- Produce a controls architecture, developed in Simulink, that had high-level logic for a single electronic control unit (ECU) that handles major BEV-specific functions including power distribution, thermal management, high-voltage battery pack interfacing, and fault management.
- We did not need fully modeled controllers. Instead, we only needed to parse inputs, perform simple calculations, and send signals to actuators as outputs.
- Create a controller area network (CAN) diagram that specifies how our ECU and other components in the truck will communicate through specific CAN lines, ensuring that there is enough bandwidth on each CAN line to support each component.
- Any software-in-the-loop (SIL) simulations needed to demonstrate basic user stories of a truck driver, such as engaging the accelerator and brake pedal.
- A stretch goal was to test our controls using hardware-in-the-loop (HIL) testing using a NewEagle Raptor ECU (shown to the right) provided by our industry mentors at Kenworth R&D.



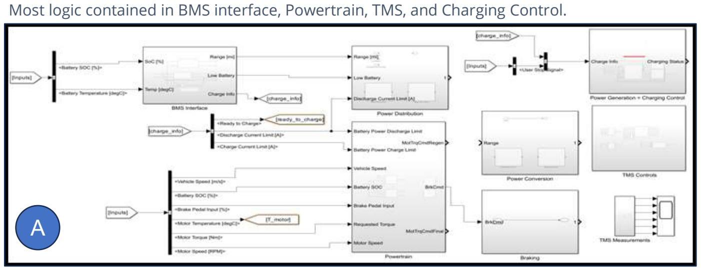
Design Approach

- Focused on the high-level implementation of BEV-specific controls.
- **Assumptions and Constraints:** (1) The Bendix Brake ECU and Cab Control Module (CECU) are part of the original truck and outside our control system boundary. (2) New components such as the e-axle, inverter, and high-voltage battery pack needed interfacing logic. (3) The battery pack will have its own battery management system (BMS) that needs to be interfaced with. (4) A new thermal management system (TMS) needs to be designed. (5) Integrate the Vehicle Control Module (VECU), the instrument cluster, and new battery management system (BMS) into our controls architecture. (5) Specific components for the truck conversion were not yet selected, so models had to be generic and easily modifiable by future teams. (6) ECUs and components will communicate via the J-1939 CAN protocol. (7) Our system requirements and assumptions needed to align with other teams.

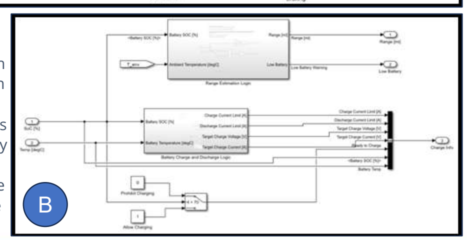


Simulink Model Results

A: Overall Simulink model divided into Powertrain, Thermal Management, Charging Control, Power Distribution, Power Conversion, BMS Interface, and Regenerative Braking subsystems. Most logic contained in BMS interface, Powertrain, TMS, and Charging Control.

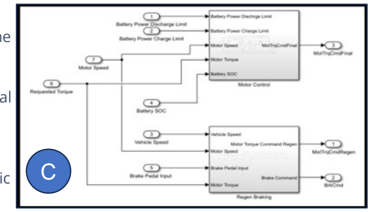


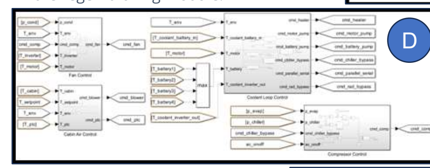
B: Part of BMS interfacing logic. Assumes that the battery pack will not contain range estimation logic for the truck or information about charge and discharge current limits. Logic also includes an indicator for when the battery pack will accept charge or not from regenerative braking or the charger, dependent on the state of charge (SOC) of the pack.



Simulink Model Results (cont.)

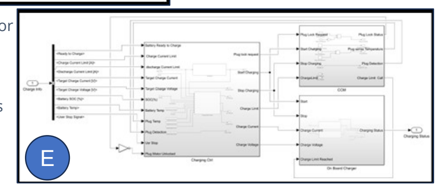
C: Component of the powertrain logic responsible for translating the position of the accelerator pedal into a torque value. This torque value is then processed within the Motor subsystem to ultimately provide a final torque command to the motor. It manages the regenerative braking logic by operating the motors/inverters in reverse. The model also incorporates overcharge protection logic in the regen braking module.

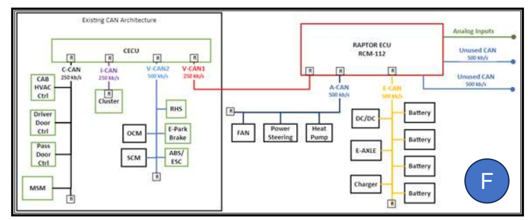




D: Part of TMS logic. The thermal management system's control subsystem comprises controllers for the various components, including pumps, compressors, fans, blowers, and valves, which collectively regulate the system's operations.

E: Part of charging control logic built for CCS1 charging. The charging control logic will find the right time to charge and discharge considering a series of operations of environmental variables and charging information.





F: The CAN wiring layout. CAN signals are sent between ECU's and device. The existing truck's main ECU is the Cabin Control Module (CECU), which interacts with various controllers such as the Master Switch Module (MSM), Instrument Cluster Chassis Modules, Right-Hand Stalk, and Brake controllers. The new, programmable ECU will interface with one of the truck's existing CAN lines (V-CAN1), as well as with our battery electric systems. These include high voltage systems (Batteries, E-Axle, Onboard Charger, DC/DC Converter) on one line, and auxiliary systems (High-speed intake fan, Power Steering Pump, and Heat Pump) on the other.

Future Work, References, and Acknowledgements

- Refine models and add provisions for NREL drive cycle analysis.
- Perform thorough SIL and HIL testing to debug and validate control architecture.

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