Electrical Engineering at FSAE

An overview of the electrical work involved in building an EV

COLUMBIA UNIVERSITY

FORMULA RACING

COLUMBIA | ENGINEERING

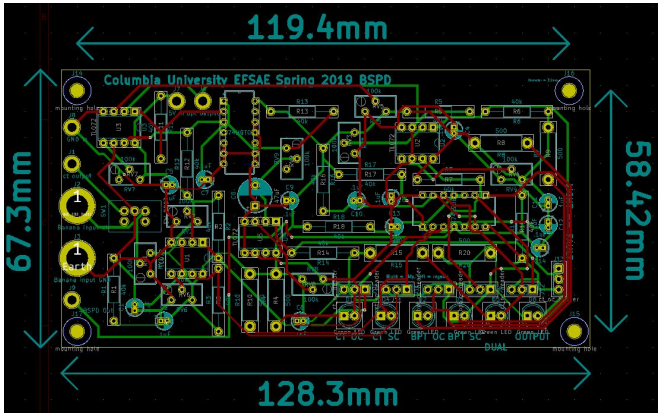
The Fu Foundation School of Engineering and Applied Science

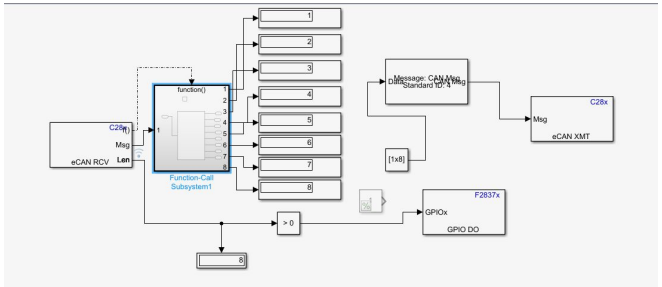
What do we do?

Completely design, manufacture, and drive a formula-styled electric vehicle to compete at an intercollegiate Formula SAE competition!

Why Join FSAE?

- Apply skills that will be useful in industry including:
  - PCB Design (using KiCad)
  - Code, model, and simulate using MATLAB Simulink
  - LTSpice modeling and simulation
  - Electronics hardware testing
- Connect with experts in the automotive industry
- Hands on experience with real engineering problems
- Be part of a highly motivated and passionate team





Electrical Engineering Team

Team → Electrical Engineering

Subteams →

High Voltage	Low Voltage
Tractive System	*Wiring Harness*
HV Electronics	*Shutdown System*
Battery Pack	*Enclosure Boards*
Charging	*MCU Software*
	Telemetry

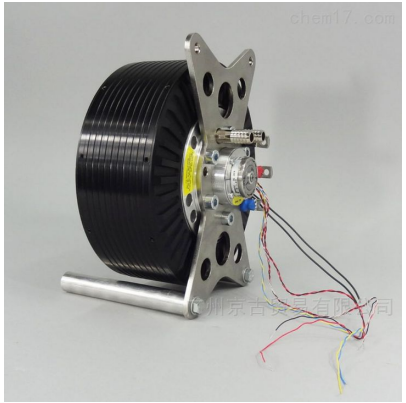
Systems

*High Voltage is any voltage that is 60V or greater as per the FSAE rules

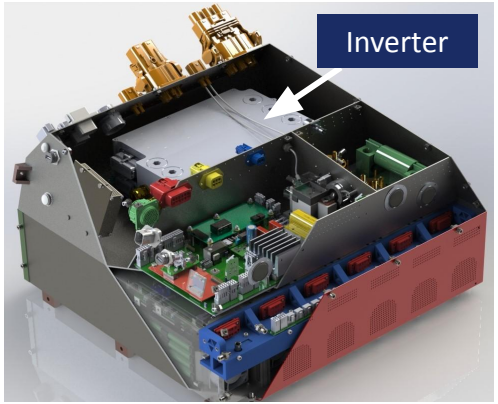
High Voltage Subteams

Tractive System

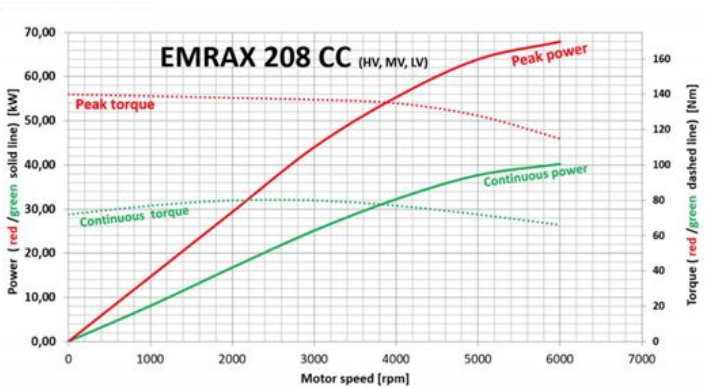
- The tractive system converts the DC output of the battery pack into spinning of the motor
- Includes the isolation relays, inverter, tractive system measuring points, and the motor
- Works closely with the drivetrain system on the mechanical side which converts the spinning of motor to motion of the vehicle



Emrax 208 PMSM Motor

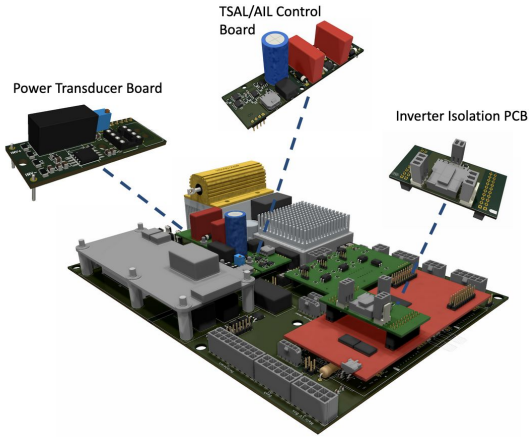


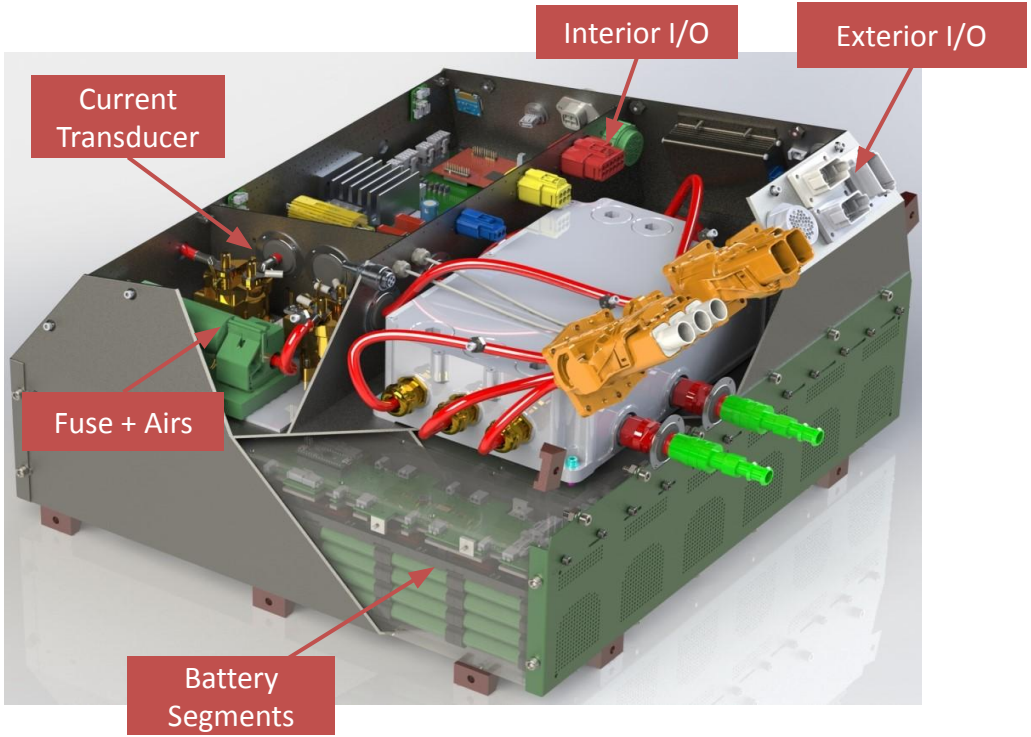
Cascadia PM100DX Inverter



HV Electronics

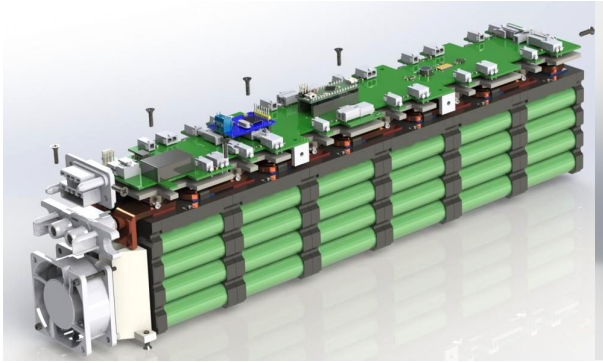
- Various circuits responsible for monitoring and controlling high voltage in the vehicle
- Some of these electronics are:
  - Insulation monitoring device
  - Tractive System Active Light
  - Accumulator Indicator Light
  - Precharge/Discharge circuit





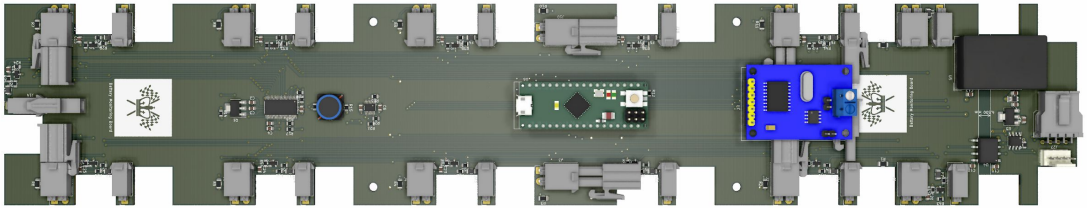
Battery Pack

- Assembling the battery pack and building a battery management system
- In house battery management system design with individual breakout PCBs for each battery segment each communicating with an MCU
- 6 battery segments contain 12s8p configuration of 18650 Li-Ion cells



Batter Segment

Battery Pack



BMS Breakout Board

Charging

- Designing and building the charging circuitry on the accumulator charging cart
- ElCon PFC5000 charger used to charge the battery pack with a maximum power output of 5kW
- Charger and accumulator communicate through the CAN Bus

ElCon PFC5000

CAN Communication with Charger

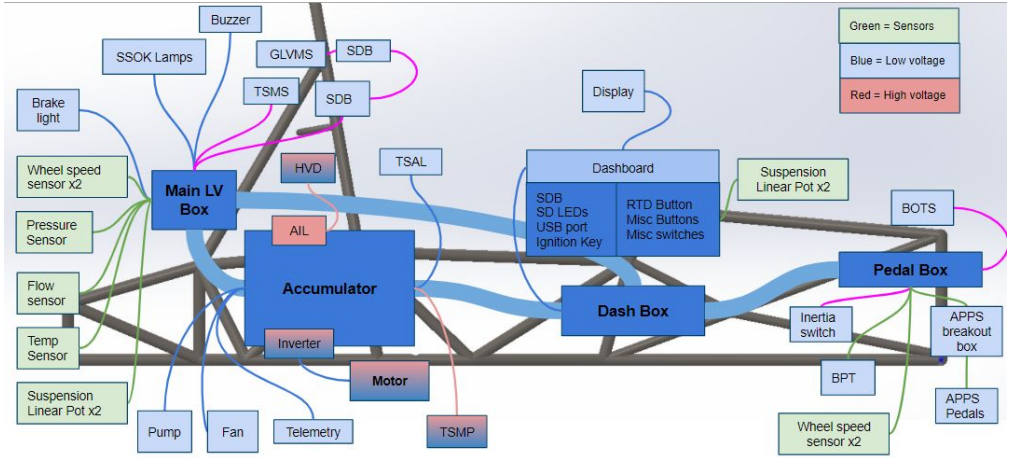
Rolling Trace

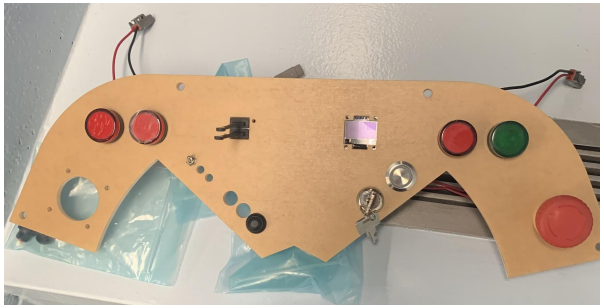
TRACE	ID	DLC	DATA 0	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6	DATA 7	TIME STAMP (sec)	TIME DELTA (sec)
TX	0x1806E7F4x	8	0x00	0x78	0x00	0x05	0x00	0x00	0x00	0x00	21.8902	3007.743
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1309.1150	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1308.6150	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1308.1150	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1307.6149	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1307.1149	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1306.6149	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1306.1149	1284.238
TX	0x1806E7F4x	8	0x00	0x78	0x00	0x05	0x00	0x00	0x00	0x00	21.8771	3011.229
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1305.6149	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1305.1149	0.501
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1304.6140	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1304.1140	0.500
RX	0x18FF50E7x	8	0x00	0x57	0x00	0x00	0x00	0x00	0x00	0x00	1303.6140	0.500

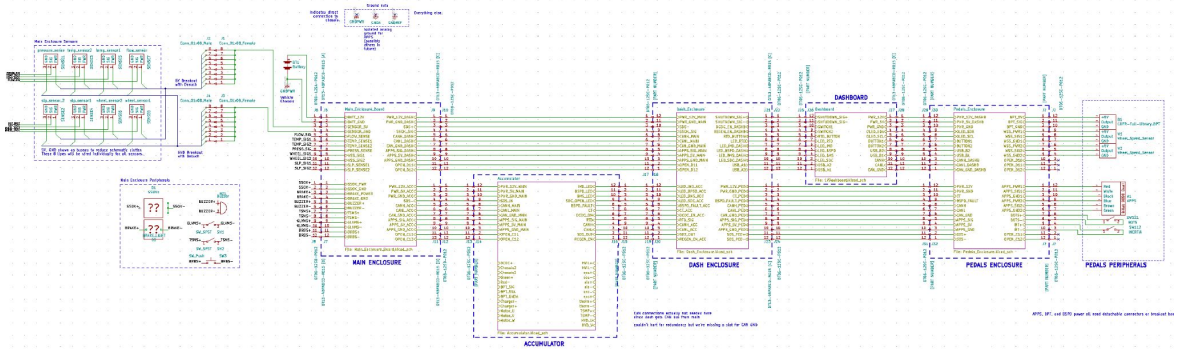
Low Voltage Subteams

Wiring Harness

- Design and assembly of all of the conduits between LV enclosures, the accumulator, and peripherals
- Responsible for sensor placement and dashboard electronics as well

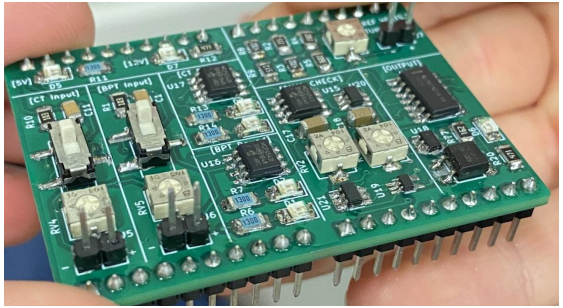




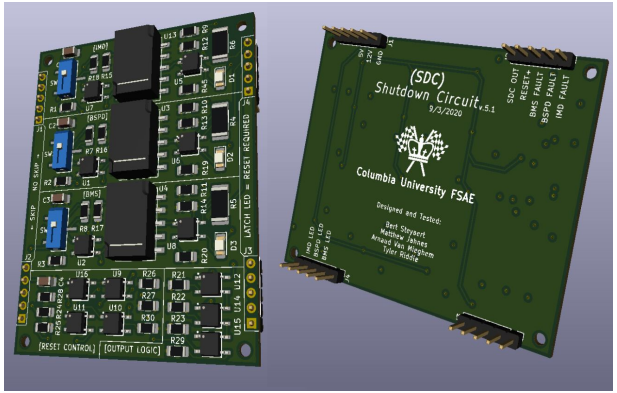


Shutdown System

- Cuts the supply of high voltage from the battery pack to the inverter in the case of a fault

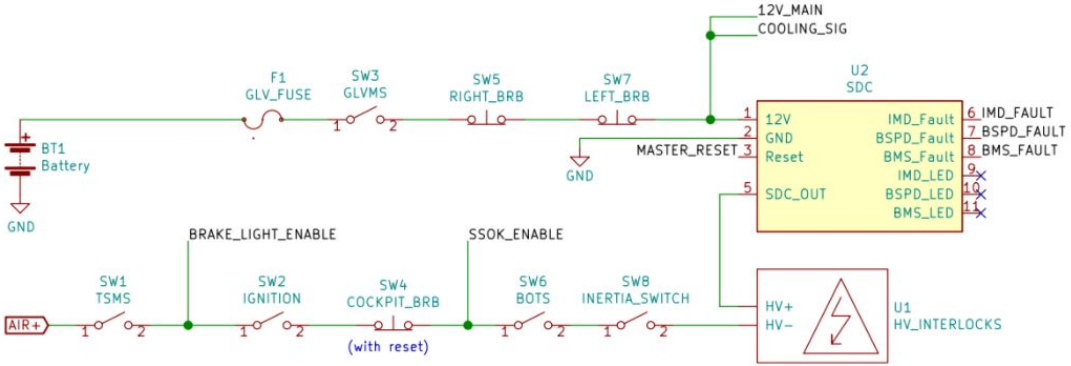


BSPD



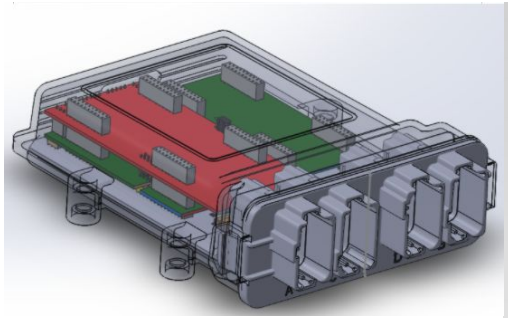
Shutdown Circuit

- Consists of a series of switches, sensors, buttons, interlocks, the Brake System Plausibility Device, and ultimately the Shutdown Circuit

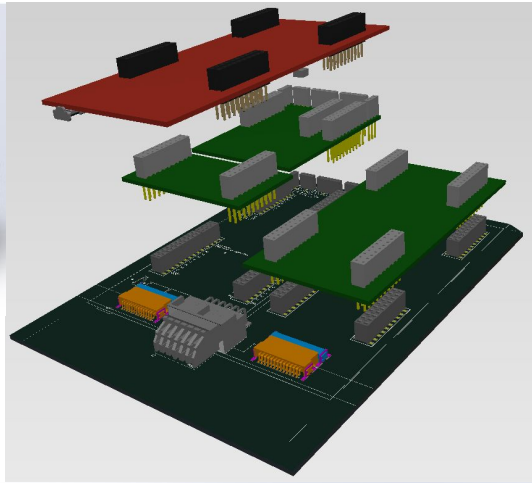


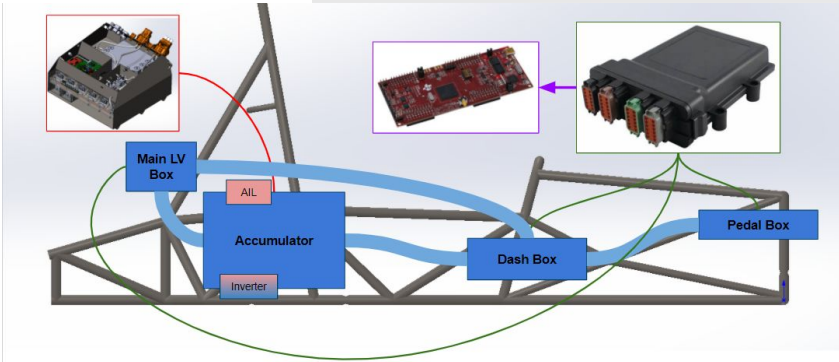
Enclosure Boards

- Design, assembly, and testing of the three LV enclosure boards: Main LV Enclosure, Dashboard Enclosure, and Pedals Enclosure
- Enclosure boards contain a stack of PCBs specific for their purpose and each contains a C2000 LaunchXL MCU
- Enclosures control and distribute power to peripherals, communicate with each other and the accumulator through a CAN Bus, and store telemetry data for further analysis



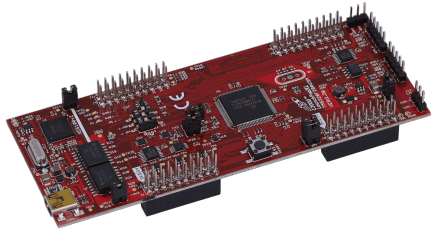
Deutsch DT PCB Enclosure



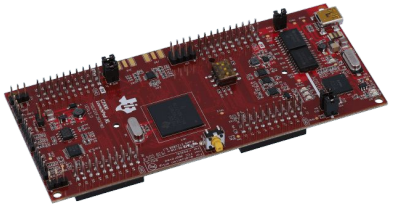


MCU Software

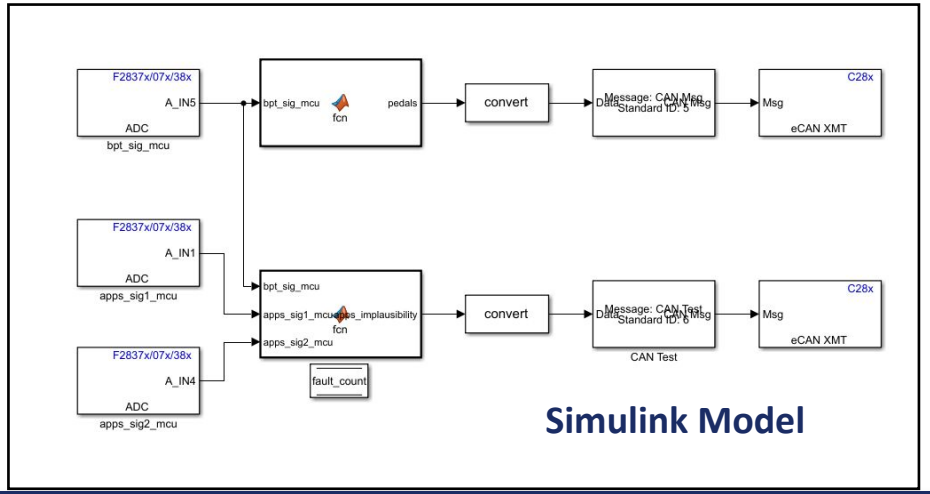
- MCUs used:
  - LAUNCHXL-F28379D
  - LAUNCHXL-F28069M
- Software is developed using MATLAB Simulink, a graphical programming environment
- The MCUs take in sensor data, control LEDs and other peripherals, and send CAN messages



LAUNCHXL-F28069M



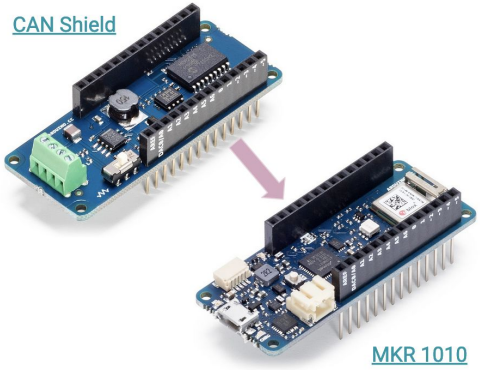
LaunchXL-F28379D



Simulink Model

Telemetry

- Telemetry system will receive sensor data through the CAN messages sent by the MCUs, package the data, and then send it to a Firebase Realtime DB
- Data will be uploaded to the database with an Arduino MKR WiFi 1010
- A user friendly GUI will also be developed to present the data on a laptop




```
58
59  void onReceive(int packetSize) {
60    // CAN packet received
61    Serial.print("Received ");
62
63    if (CAN.packetExtended()) {
64      Serial.print("extended ");
65    }
66
67    if (CAN.packetRtr()) {
68      // Remote transmission request, packet contains no data
69      Serial.print("RTR ");
70    }
71
72    Serial.print("packet with id 0x");
73    Serial.print(CAN.packetId(), HEX);
74
75    if (CAN.packetRtr()) {
76      Serial.print(" and requested length ");
77      Serial.println(CAN.packetDlc());
78    } else {
79      Serial.print(" and length ");
80      Serial.println(packetSize);
81
82      // Only print packet data for non-RTR packets
83      while (CAN.available()) {
84        byte new_value = CAN.read();
85        Serial.print(new_value);
86
87        upload_data(new_value);
88      }
89      Serial.println();
90    }
91
```

Join FSAE

How to get involved

Scan the QR Code to **join our mailing list**:

Expect an email about our **first General Body Meeting**, especially targeted to new members, which will take place on **Wednesday September 14 at 9PM**.

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