Network Power for Automobiles

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4/28/24

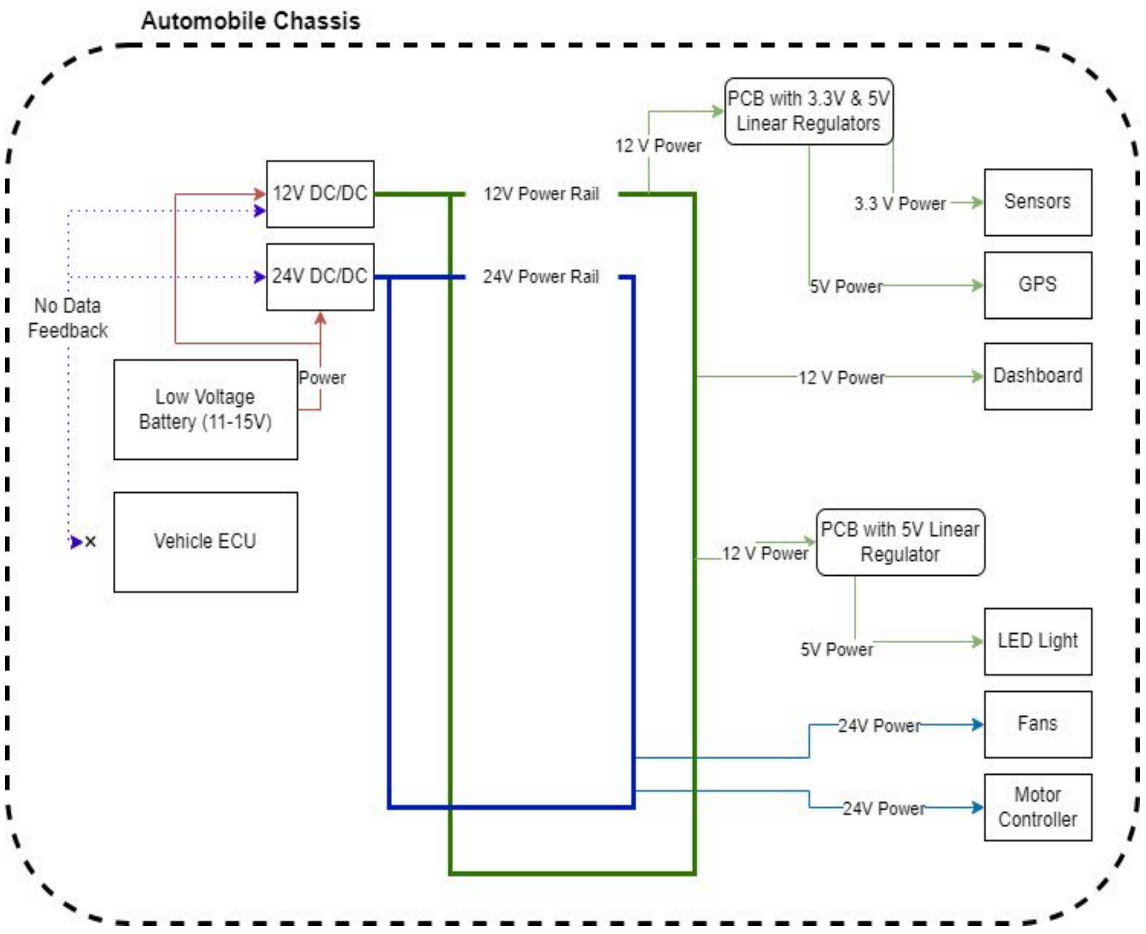
Introduction

- Solve a problem we experience on the Formula SAE team building prototype EVs

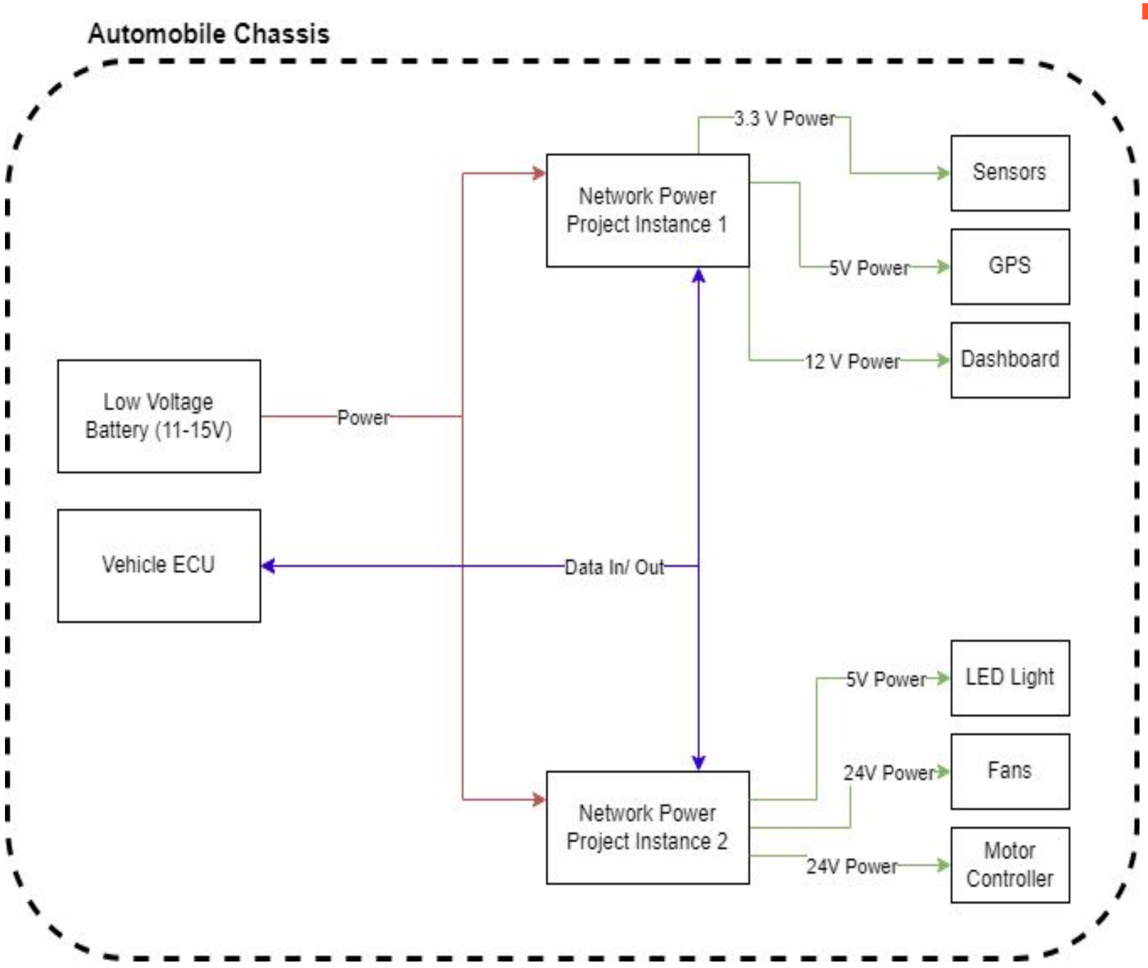
- Manufacturers are trying to move to a “one power one communication” arrangement

Objectives

- Provide power output at different voltage levels in an automotive setting
- Simplify the existing power distribution networks on EVs
- Superior data collection



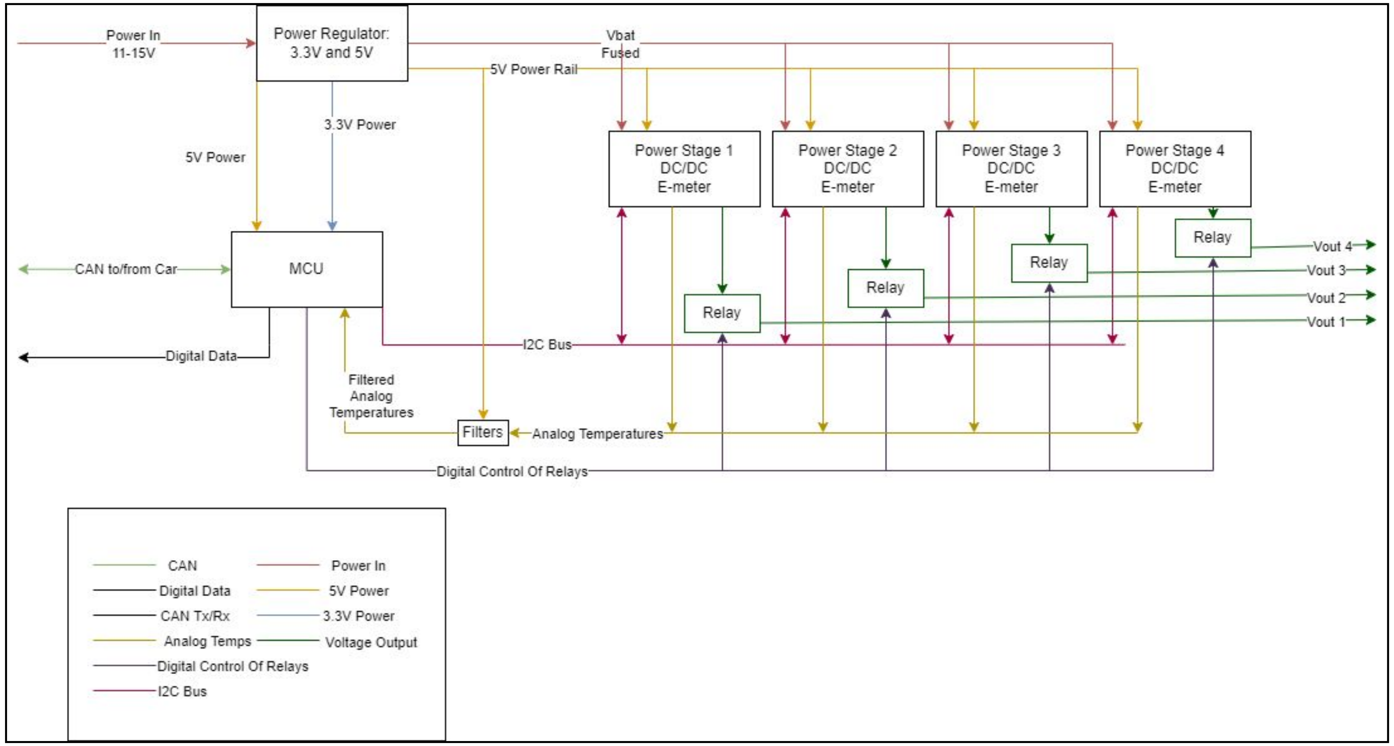
Status Quo

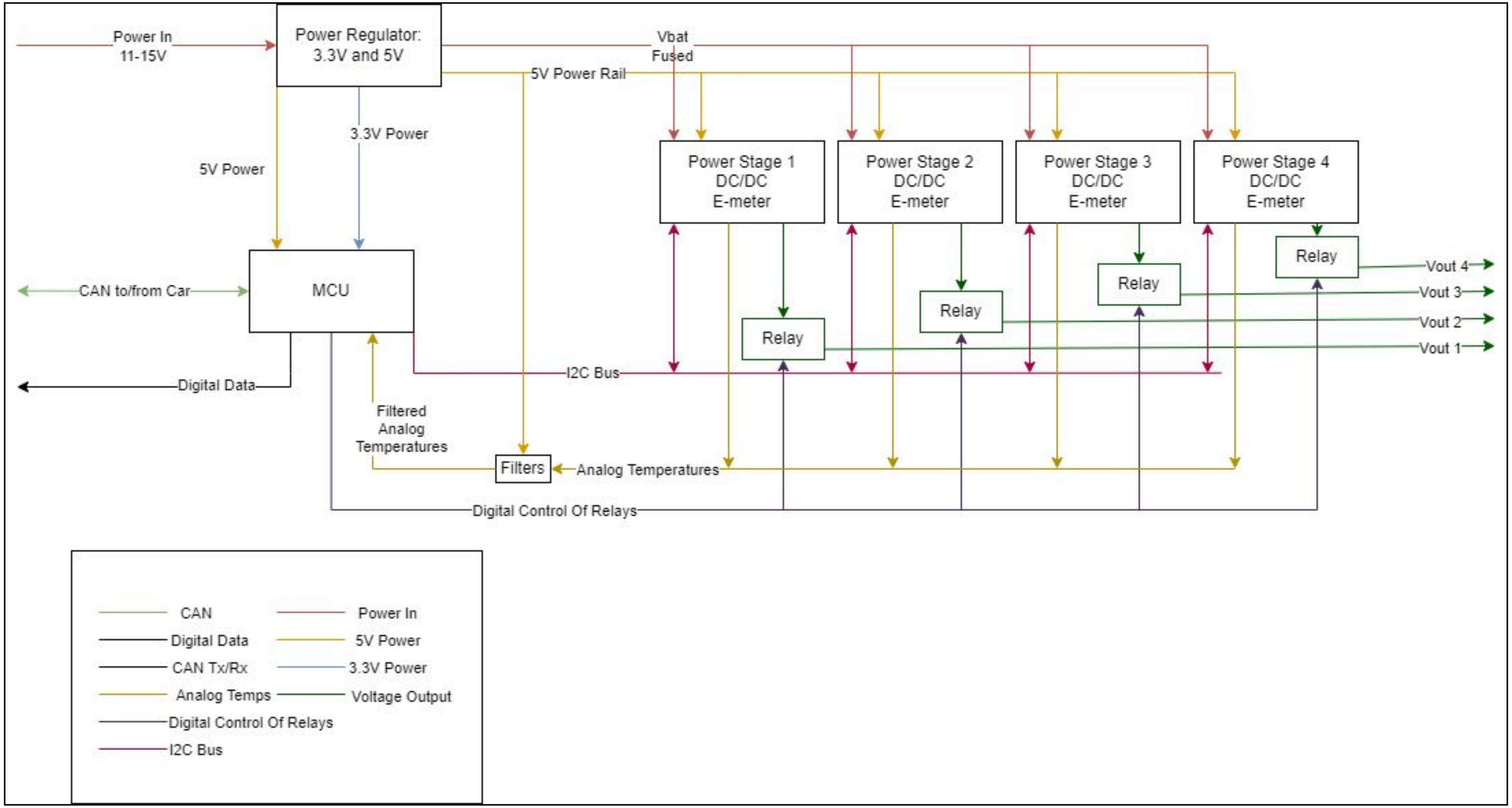


Our Design

High Level Requirements

- 4-switch DC/DC controller
- STM32 microcontroller used for high level control
- CAN communication to the rest of the car, I2C to talk to the DC/DCs and E-meters

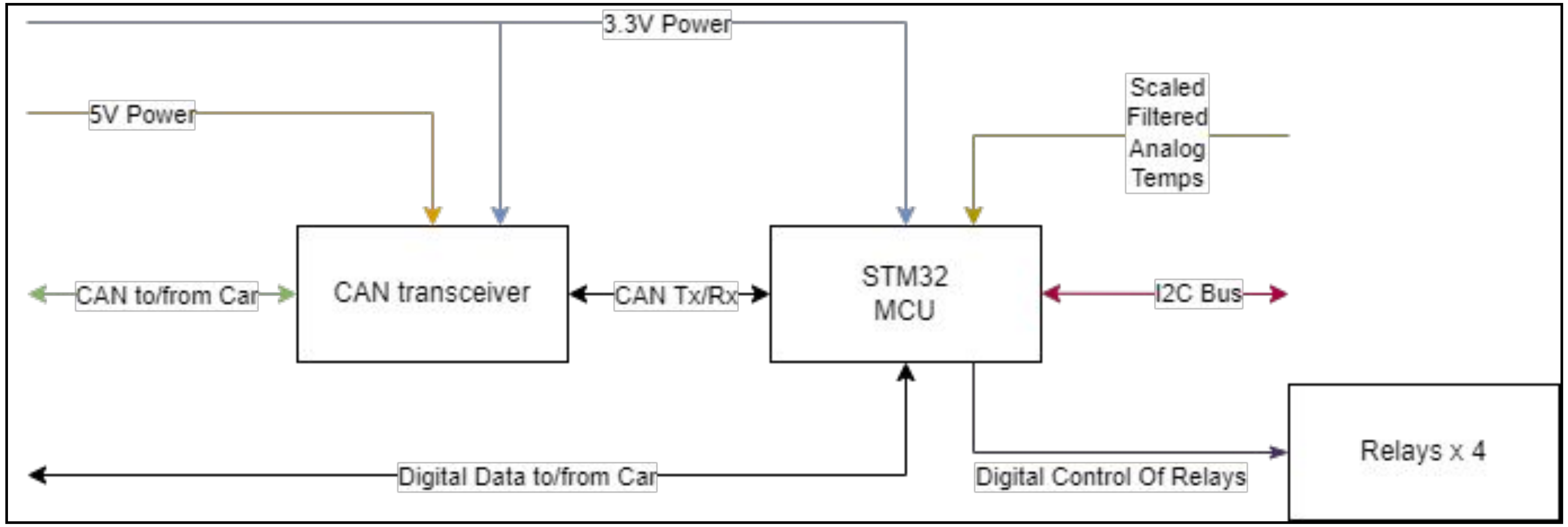




High Level Design

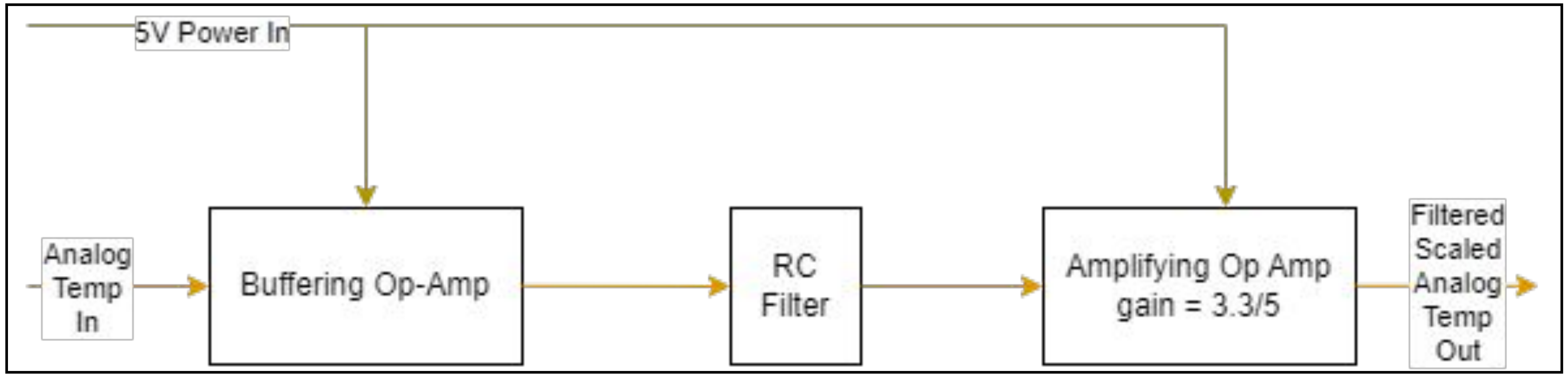
MCU Subsystem

- I2C communication with E-meter and DC/DC controller
- CAN communication with the vehicle
- Temperature sensing
- Alarm signal for ensuring safety



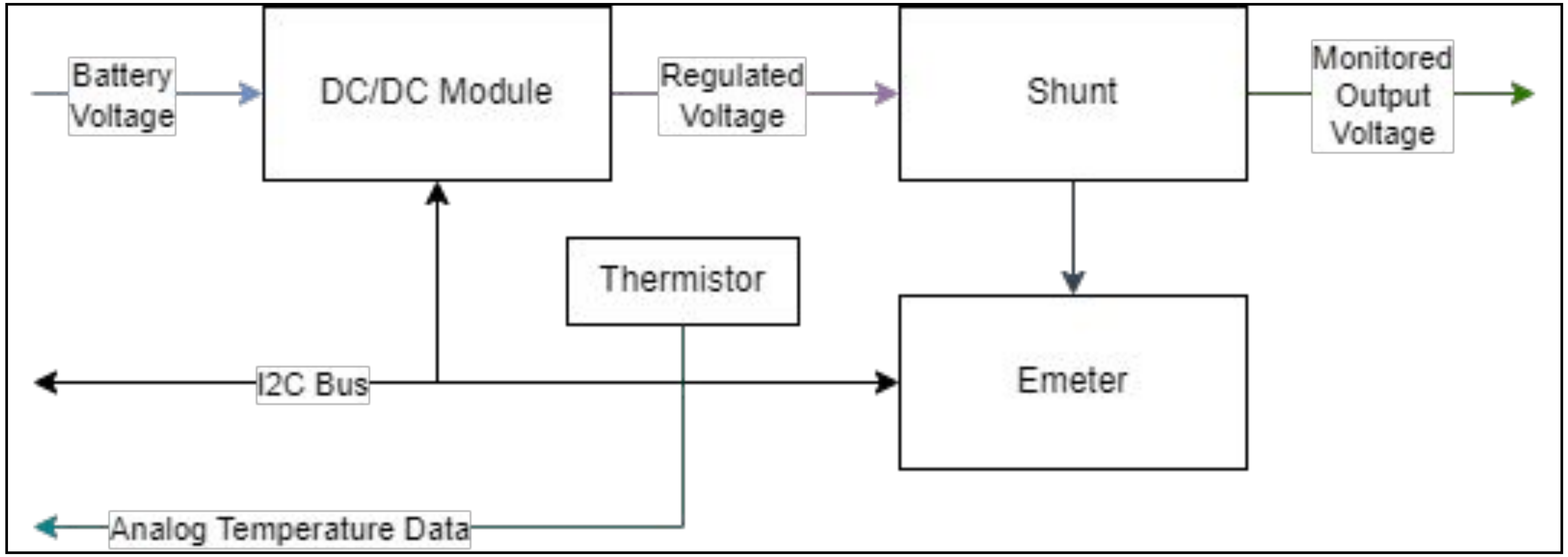
Filter Subsystem

- Powerstage hot swapping/presence detection
- Scale 5V signal to 3.3V to allow MCU to read
- Temperature sensing

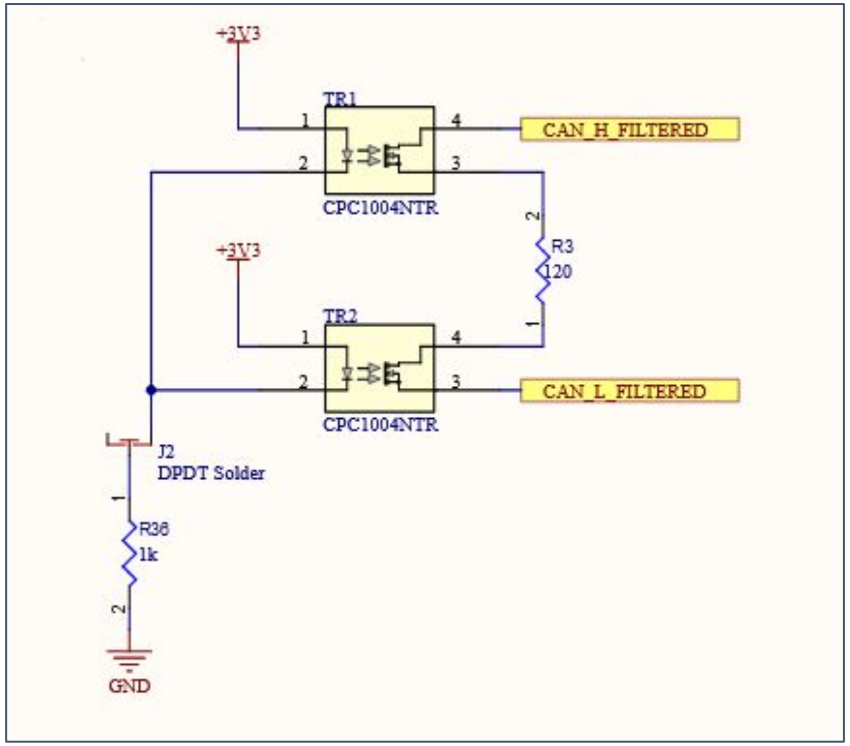


Powerstage Subsystem

- Follow I2C commands from MCU to modulate output voltage
- Provide voltage and current feedback to the MCU over I2C
- Supply maximum 2A on the output
- Maintain temperature below 60°C

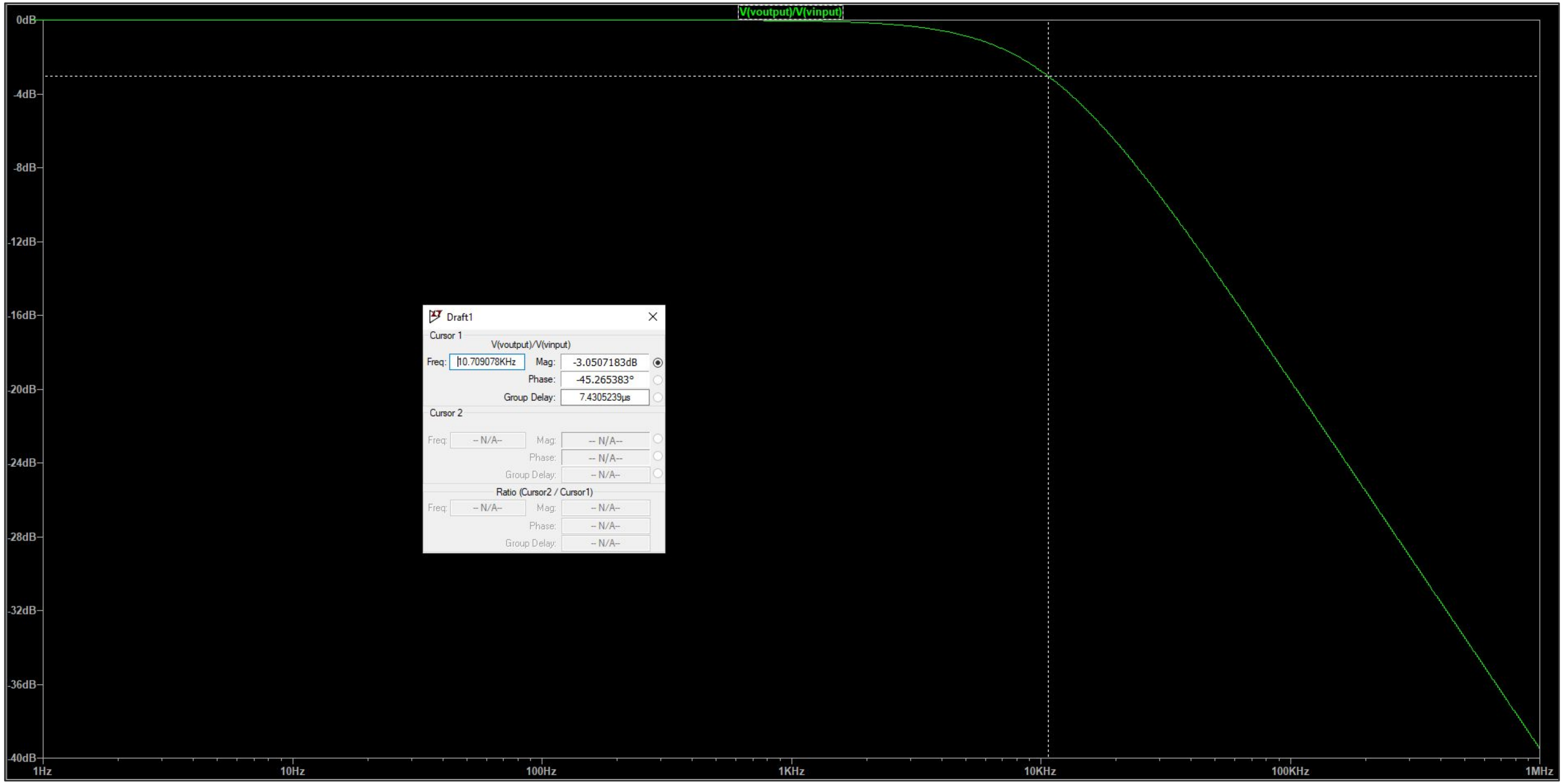


Backplane PCB



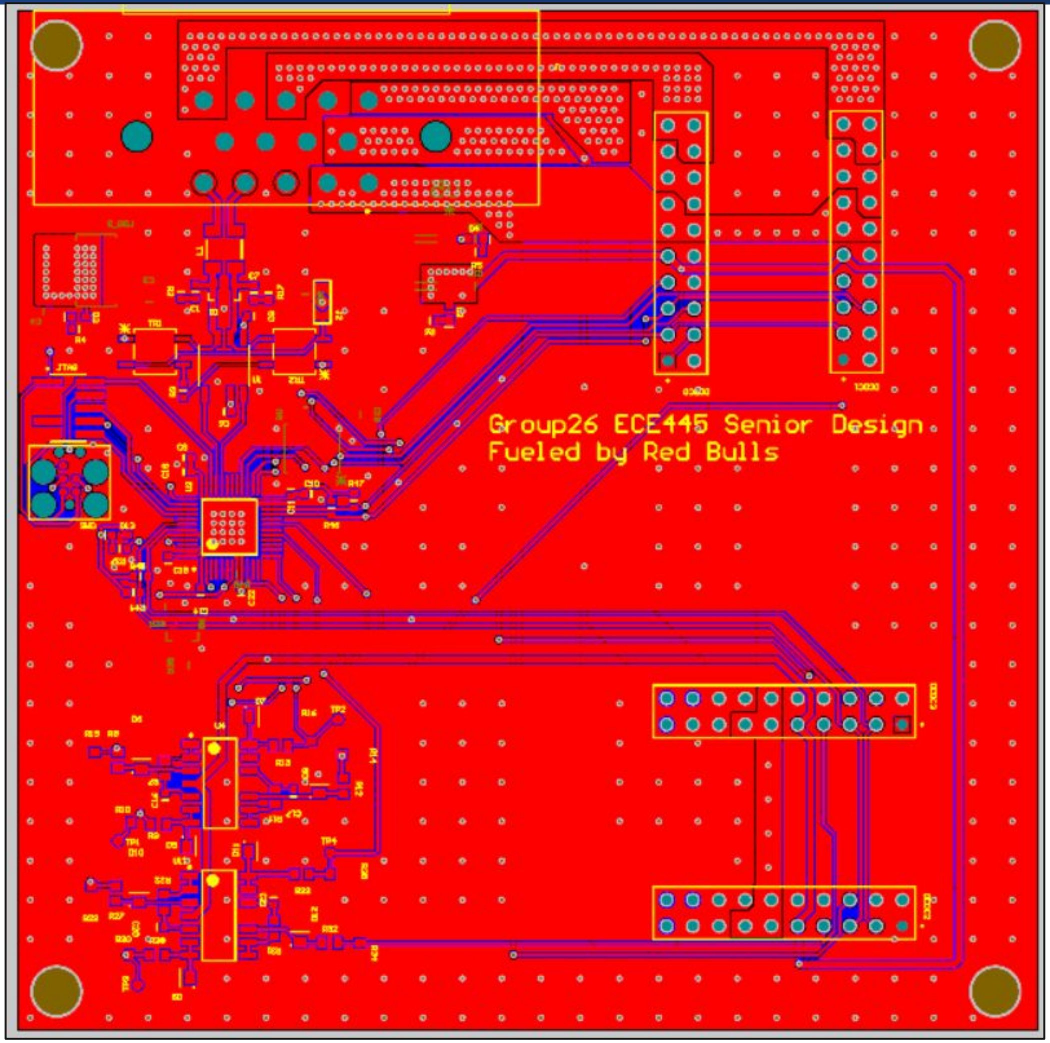
- MCU: STM32F103
- CAN Transceiver: TCAN1044A
- 10kHz low-pass filter for thermistor voltage
- Configurable CAN termination setup

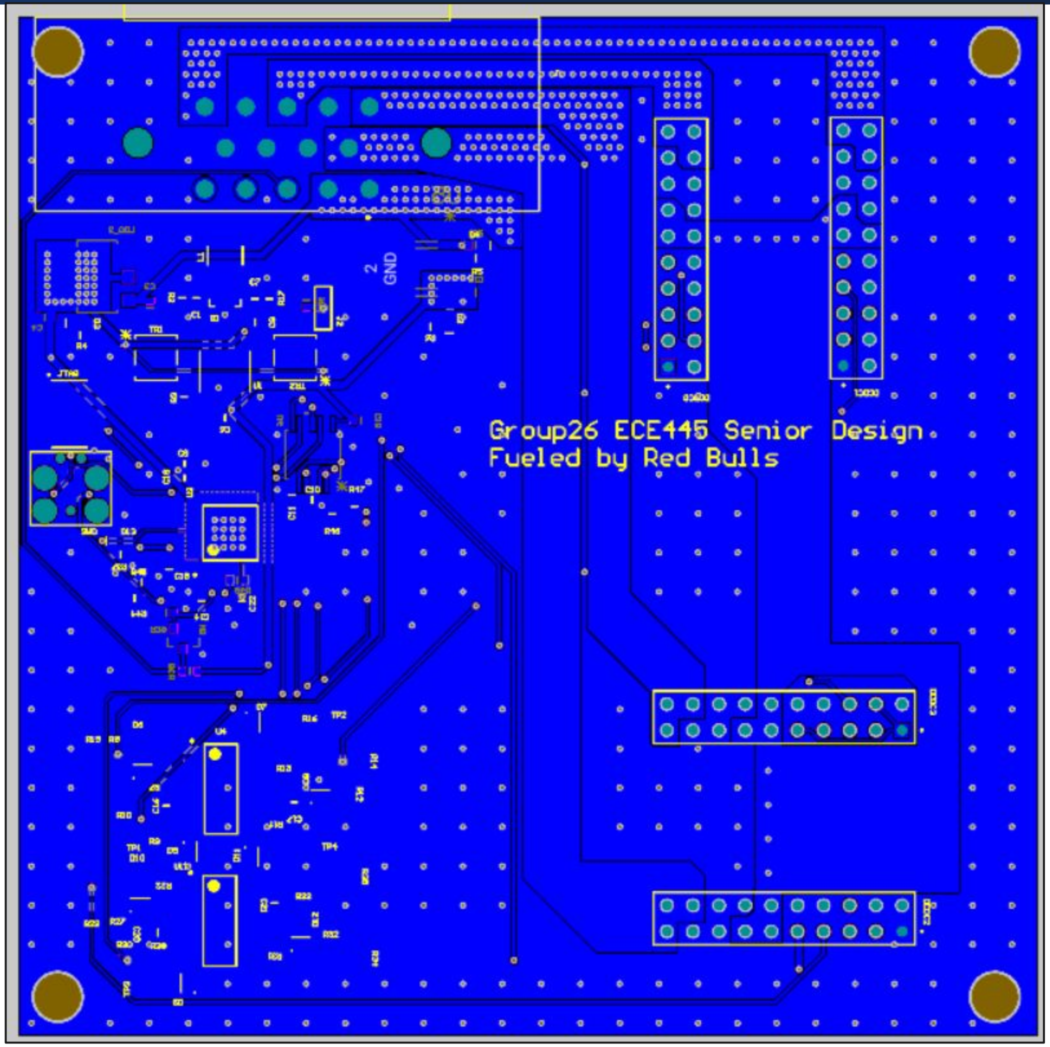
Bode Plot of Filtering Circuit



This bode plot shows that the cutoff frequency of the filter is 10.709 kHz

Backplane PCB layout

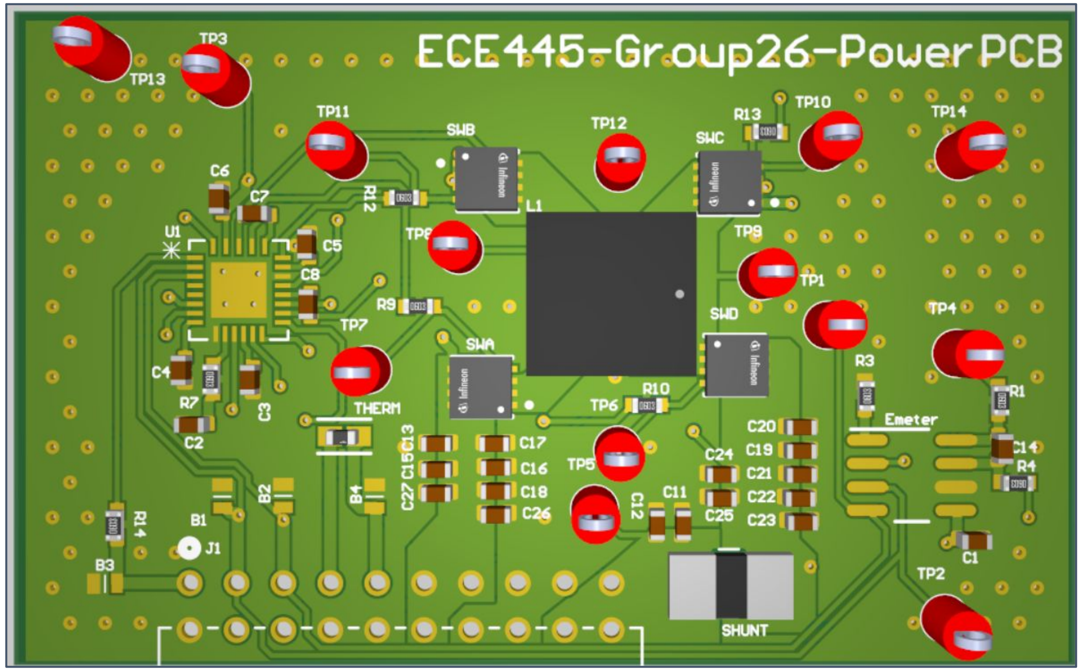




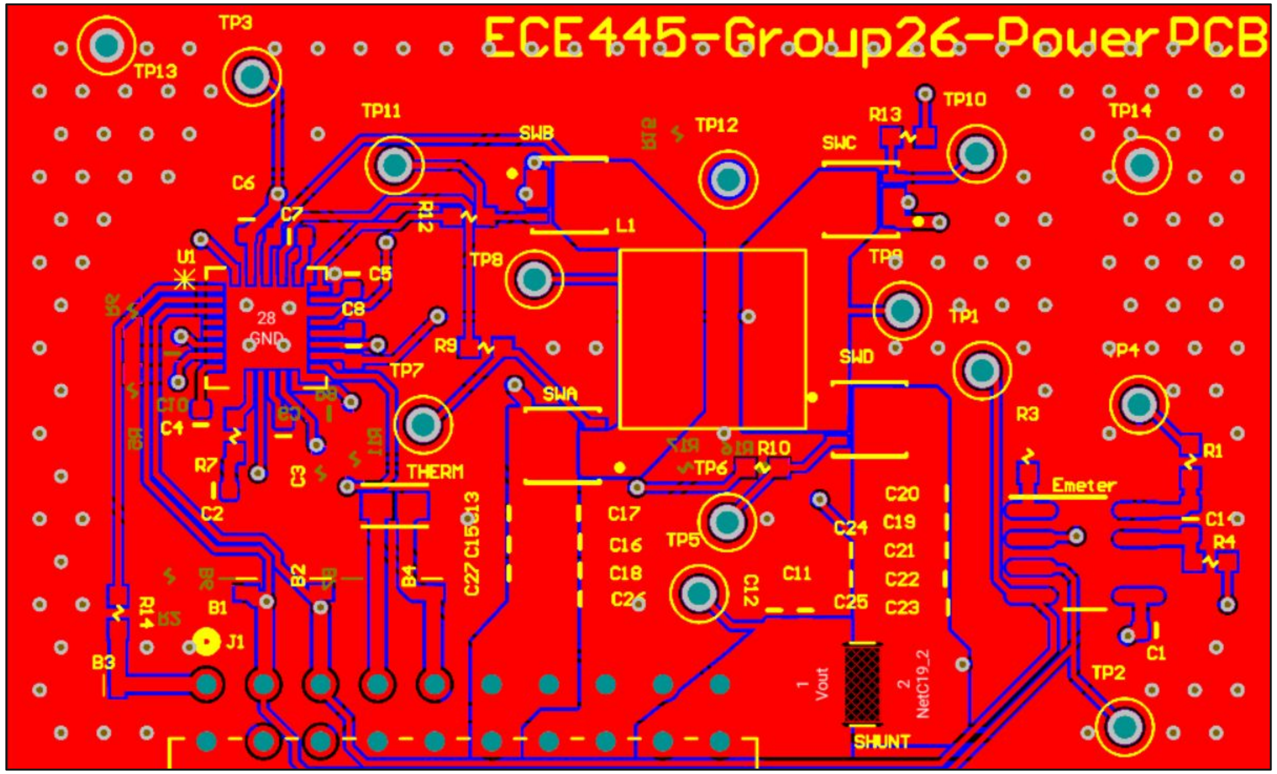
The 1 oz double sided 2 layer PCB that houses the microcontroller

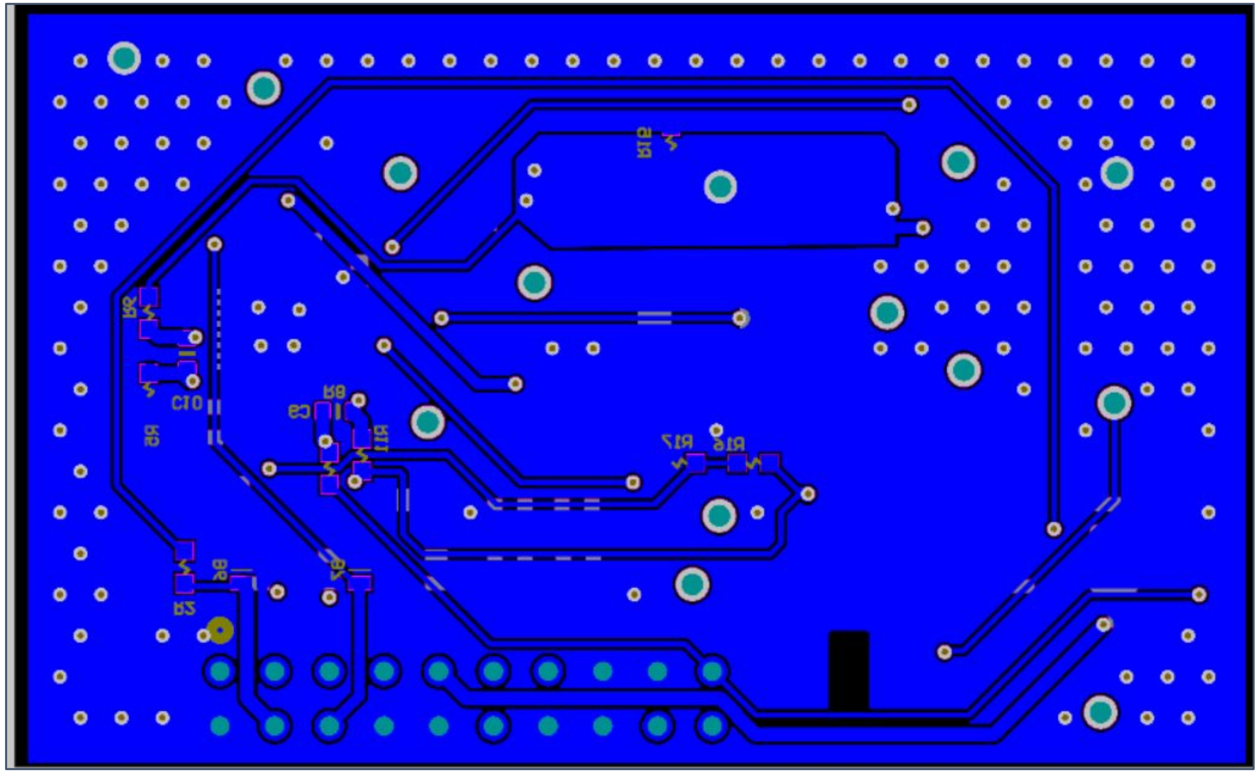
Powerstage PCB

- DC/DC Controller IC: MPQ4214-AEC1
  - Changed from the original design due to supply shortage
- E-meter: INA219
- 40 V, 7.2 mOhm 40 A NMOS used as switches
- 15 uH shielded inductor
- 28.2 uF input and output capacitance
- Test points added to help with verification and testing
- 2nd layer dedicated mostly to the ground plane
- Polygons used to conduct power with minimal losses
- Stitching vias added to dissipate heat created by switches and inductors



Powerstage PCB

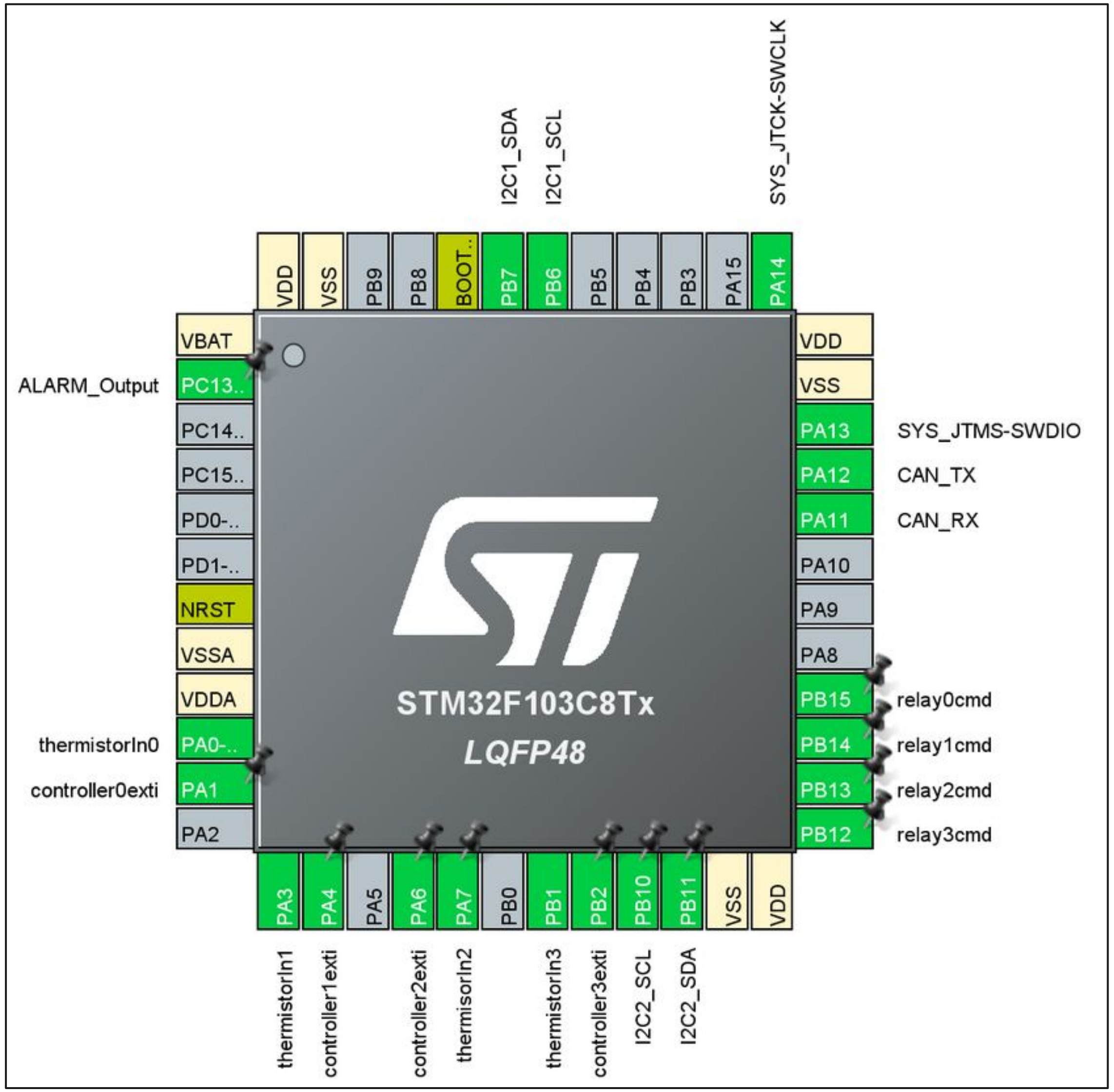




The double sided, 2 layer, 1 oz PCB that houses the DC/DC Controller IC and the Emeter

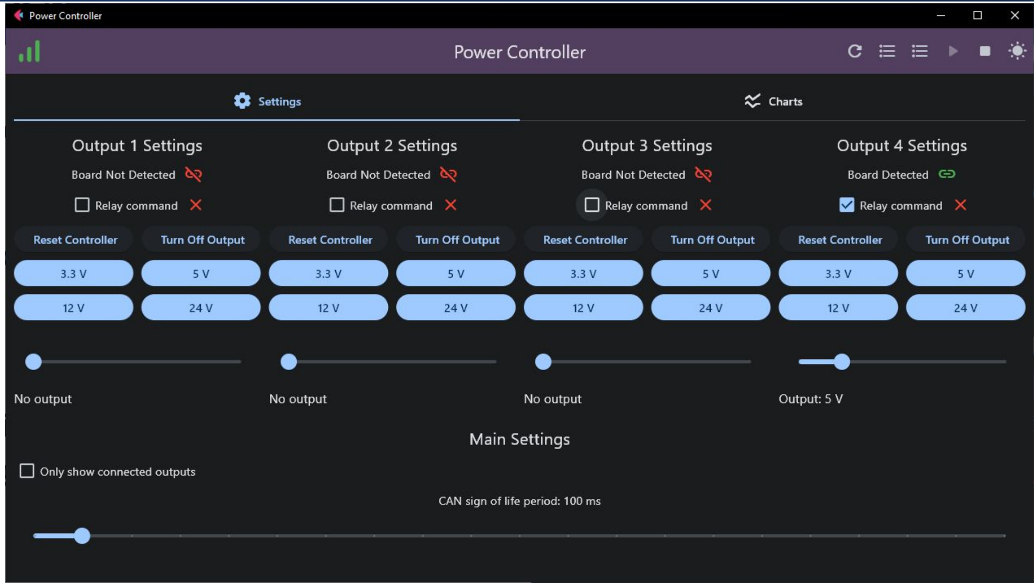
Embedded Software Design

- I2C communication with emeter and DC/DC chips
- ADC thermistor readings, with Direct Memory Access for extra speed
- Alarm output pin to signal output or communication errors
- CAN communications with ECU
- Detection of secondary boards using the thermistors



Testing GUI Design

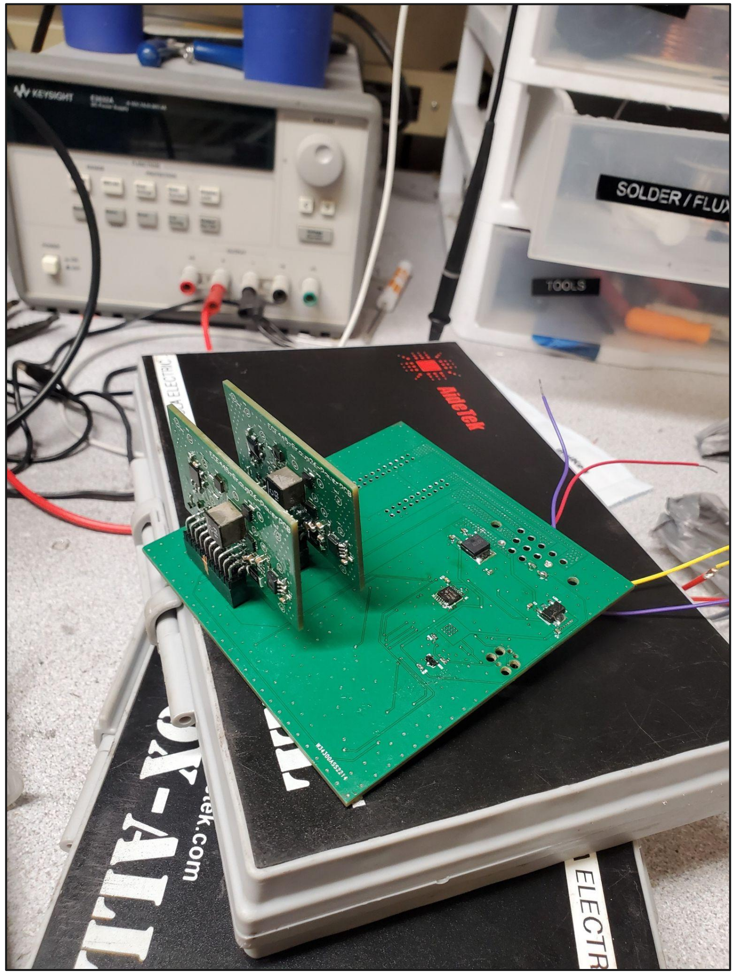
- Written in Python using the Flet library
- CAN communications through KVaser/Peak system drivers
- Easy testing without needing to control the system through debugger
- Displayed thermistor and emeter data on custom plots

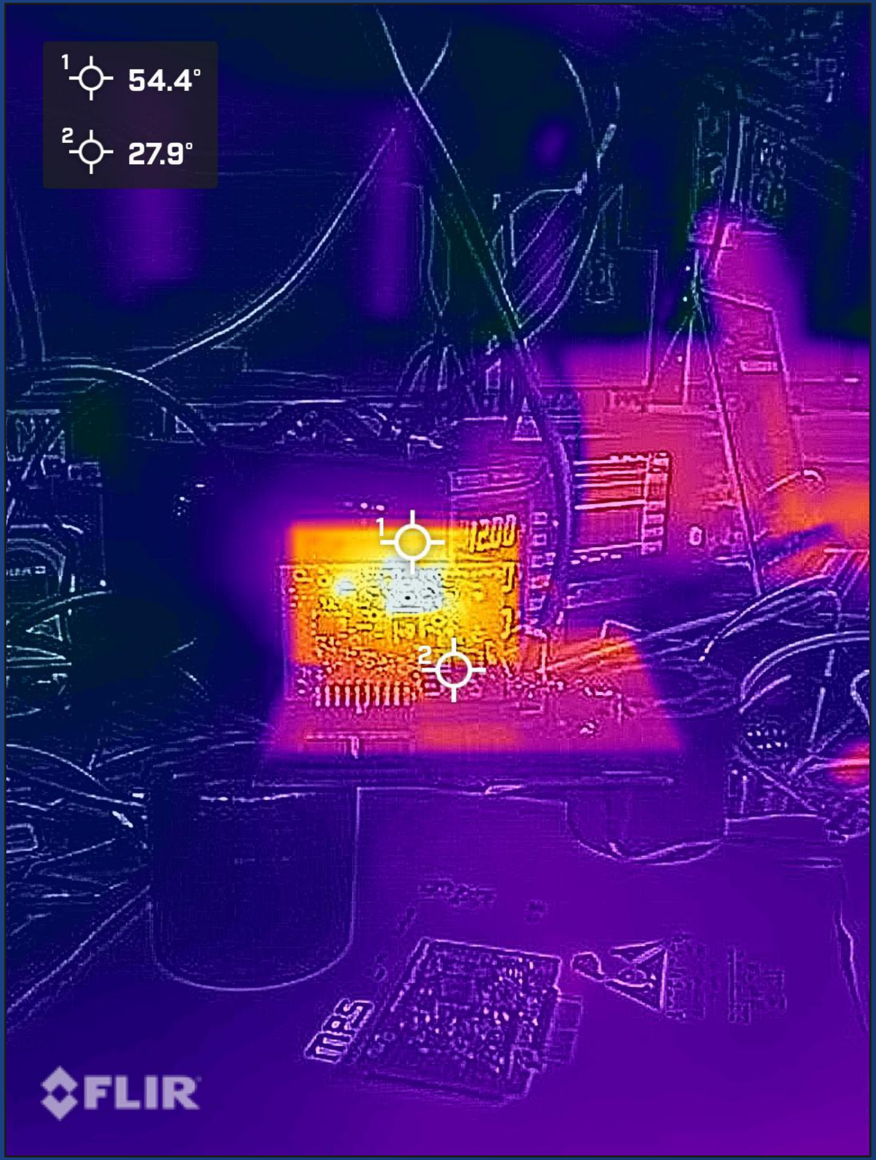


Manufacturing and Testing

- Backplane I/O testing before power boards

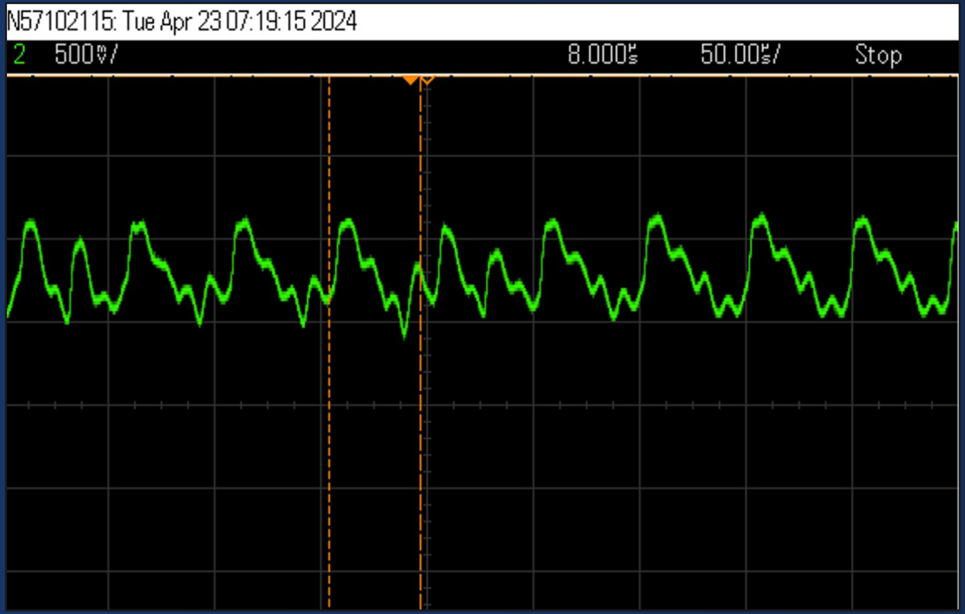
- Power rail isolation issues led to internal short in MCU and LDO





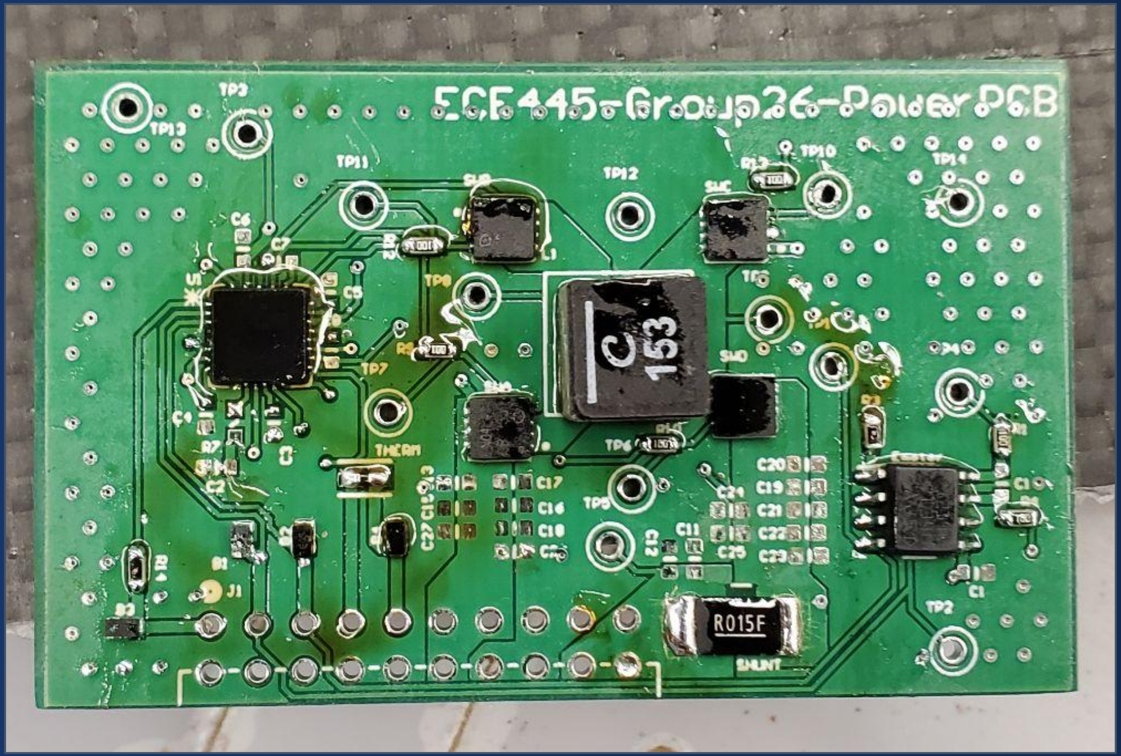
Verification

- Temperature testing allowed us to debug manufacturing issues quickly
- Excessive noise on I2C bus when output enabled



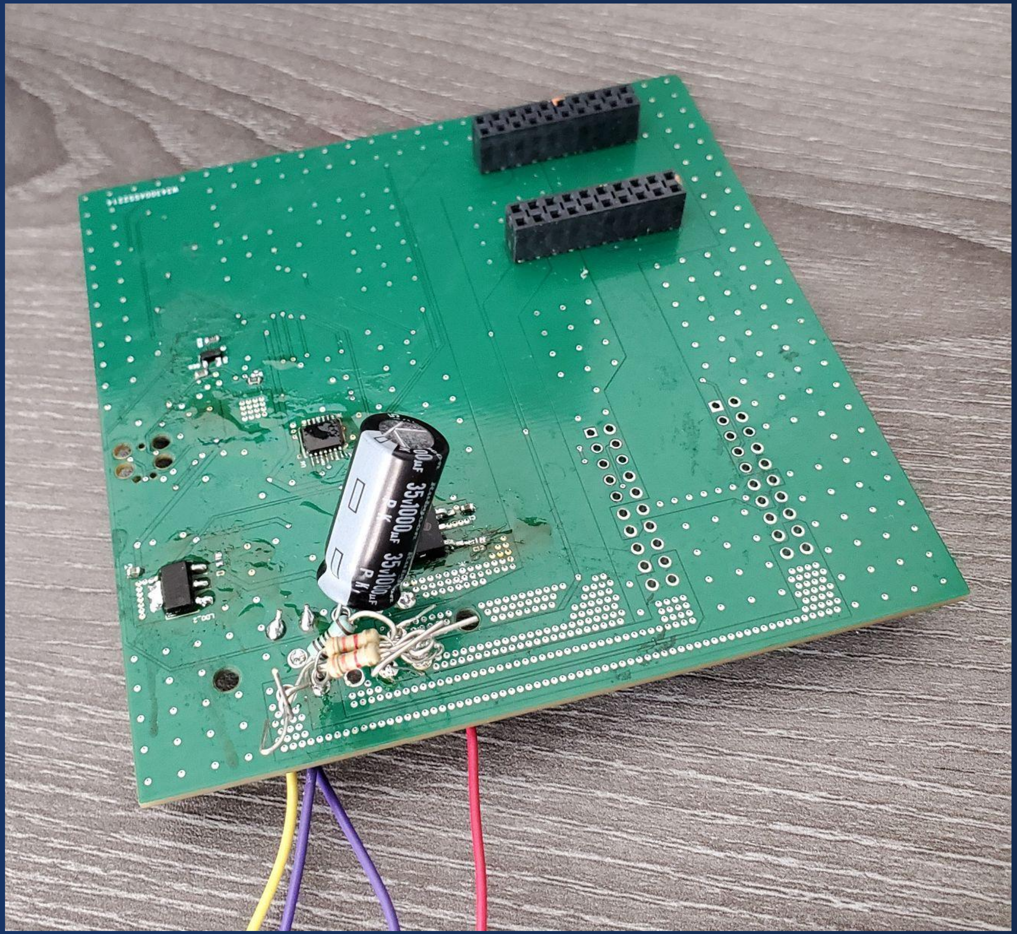
Performance Results

- 100% ripple on DC output
- All microcontroller based subsystems worked without any issues
  - I2C
  - CAN
  - Thermistors
- Missing capacitor buffers on inputs / outputs due to purchasing errors and budget constraints
- Failed NMOS resulted in audible “screaming” for the first DC/DC module



Future Improvements

- Add missing capacitor buffers on inputs / outputs
- Improved manufacturing using easier to solder components with a reflow oven
- Adding thermal relief to ground pads for 0603 components to allow for better manufacturing
- Move to a 4 layer PCB on the backplane to further remove the noise from the I2C and thermistor lines
- Update DC/DC gains for expected load currents

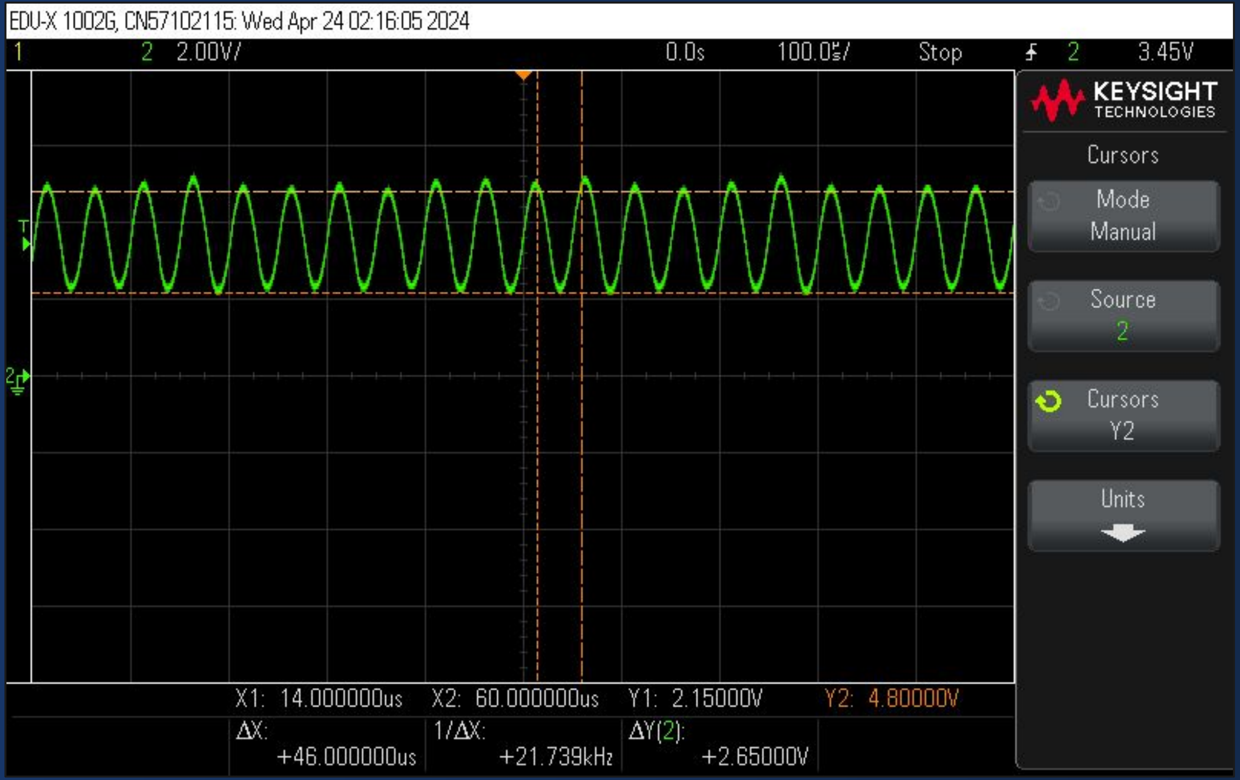


Conclusion

- Our DC output was not stable

- Communication and I/O of the module, as well as the safety systems worked perfectly

- Given more time to test, we are confident that we could solve most of the output issues



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