

# WISCONSIN RACING

## 223C ELECTRICAL DESIGNS

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# Public Release Foreword

## Overview

This is an overview of the unique electrical designs for the 2023 Combustion FSAE car from Wisconsin Racing (UW-Madison). Some of the combustion car’s designs are not documented here, and can be found in the electric car documentation, found here <https://www.wisconsinracing.org/e-documents/>. This “design binder” is what we prepared for the competition's design event. Wisconsin Racing’s previously-released design documentation on our website (<https://www.wisconsinracing.org/e-documents/>) have been a useful reference for other teams looking to design custom hardware. In that spirit, we are releasing the designs of the entire electrical system of both our 2023 electric and combustion vehicles, including our BMS, inverter, steering wheel electronics, LV power distribution, and more.

## Correctness, Iteration and Rules Changes

This is a snapshot of the state of these designs last year, and all of them are being improved this year. Therefore, the correctness and rules compliance of these designs cannot be guaranteed. Some designs call out problems found within the design, just referencing schematics may lead to missing those callouts.

## Custom System Notes

Wisconsin Racing has a highly custom electronics system, and it has not been sunshine and rainbows to get to this point. It has been a 7-year team effort. If you're a new team, it is more important to have a car that moves than a car with a bunch of custom PCBs. Don't underestimate the challenge of designing reliable and rules-compliant hardware.

## 2023 Combustion Competition Results

Event	Placement
Design	12th
Acceleration	31st
Skidpad	67th
Autocross	44th
Efficiency	DNF
Endurance	DNF (0 laps completed)
Overall	56th

## Incompleteness/ Systems Integration

This document is incomplete in that it is missing many details of integration, manufacturing and testing. The document is mostly focused on the design of the custom PCB systems on the car, which is not what makes a team win. Reliability and a well tested car wins competitions, not the fancy circuit boards.

## Special Thanks

This document and the 2023 race cars would not be possible without the many contributions of the engineers who worked on it and the alumni that set the stage for this car. I would also like to thank the mentors from the 2022 season, Quinn Sabin, Kai Linsenmeyer and Evan Wildenberg. Special thanks to Alex Groteluschen (High Voltage Lead) as he helped spearhead the creation, formatting and push for this document. Isaac Hewett was my counterpart on the mechanical side, and none of this would be possible without the car to put the electronics in (be nice to your mechanical engineers). Thank you to the subsystem leads and all the team members that put in a large amount of effort to make this document and this car:

- Alex Groteluschen, High Voltage Lead
- Calvin Geishirt, Low Voltage Co-lead
- Pratham Sarvaiya, Low Voltage Co-lead
- Shrey Patel, Controls Co-lead
- Surya Raghavendran, Controls Co-lead
- Eric Li, Firmware Co-lead
- Sean Staggs, Firmware Co-lead

Additionally, thank you to our sponsors who can all be found on the website. The sponsors take the idea of a car and help turn it into the real thing. Finally, thank you to our faculty advisor, Glenn Bower whose wisdom and assistance has kept these cars being built year after year.

## Questions/Contact Information

From my personal experience, being in charge of the electrical system of two race cars is an extraordinary challenge, and documentation may not be readily available. If you have questions, feel free to email me at [c.schusterr@gmail.com](mailto:c.schusterr@gmail.com) or add and message me on LinkedIn. I may not have the answer, but I will attempt to find someone who does, or provide some direction.

Thank you and good luck designing,  
Christian Schuster  
2023 Electrical Technical Director for Wisconsin Racing

## Team Photo



## Car Photo



# DynoPDU

Engineer: Calvin Geishirt, LV Electronics Lead

Revision 2023.1

Dimensions: 100mm x 110mm

Steady State Current Draw: 50mA

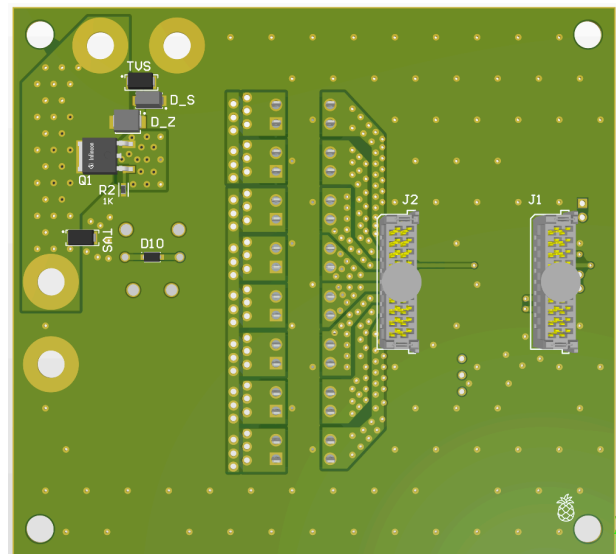
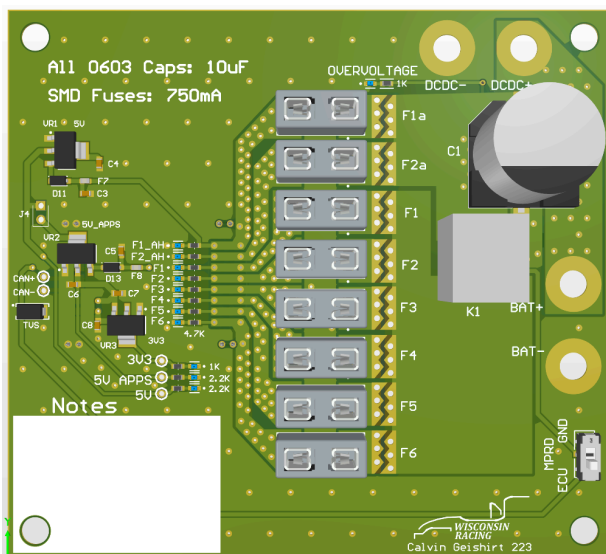
## Overview

The goal of this design was to have a simple and reliable power distribution unit (PDU) to aid the development process of our cars. This board mates with the CCar Carrier board or the ECar Battery Main board and is a fully functional drop-in replacement for our Smart Power Distribution Unit (see ECar Documentation section for more details). While this design is relatively simple, the reasons for making it were very clear and important:

- We needed to have a simple and reliable PDU done by September 1st for engine dyno development.
- Having the design early also allowed us to easily rapid-prototype the carrier board which ended up needing a few revisions.
- Having a blade fuse design allows for more accurate electrical characterization of our system without any smart circuitry interfering with measurements
- The DynoPDU is very robust and is fast, easy, and cheap to fix or fully assemble compared to our SmartPDU. This meant that we were able to use the DynoPDU during times in development that may put the SmartPDU at risk.
- The DynoPDU is also a drop in replacement for the SmartPDU on both cars, and uses standard automotive blade fuses that could be easily found at a parts store, or borrowed from our personal cars in the parking lot in a worst case scenario.

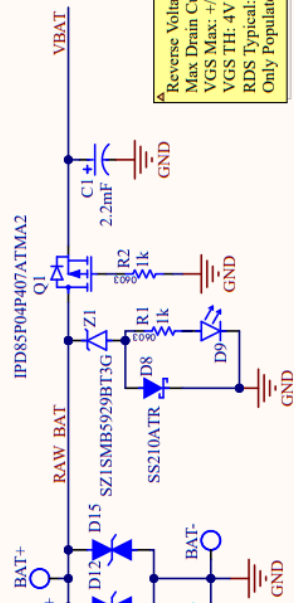
## Features:

- Reverse and overvoltage protection
- Optional inrush protection via ntc thermistors
- Standard automotive blade fuses
- 5V and 3V3 LDOs



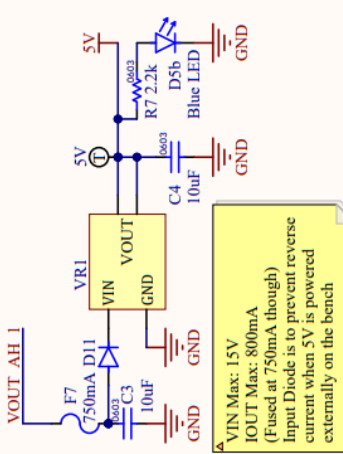


## LV Battery Connection and Protection



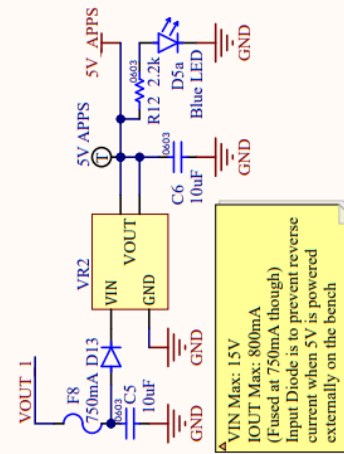
Reverse Voltage Mosfet:  
 Max Drain Current: 85A  
 VGS Max: +/- 20V  
 VGS TH: 4V  
 RDS Typical: 5mOhm  
 Only Populate 1 Capacitor

## 5V Regulation



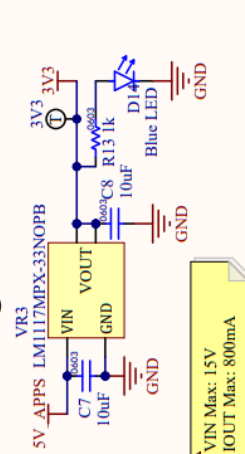
VIN Max: 15V  
 IOUT Max: 800mA  
 (Fused at 750mA though)  
 Input Diode is to prevent reverse current when 5V is powered externally on the bench

## 5V Regulation



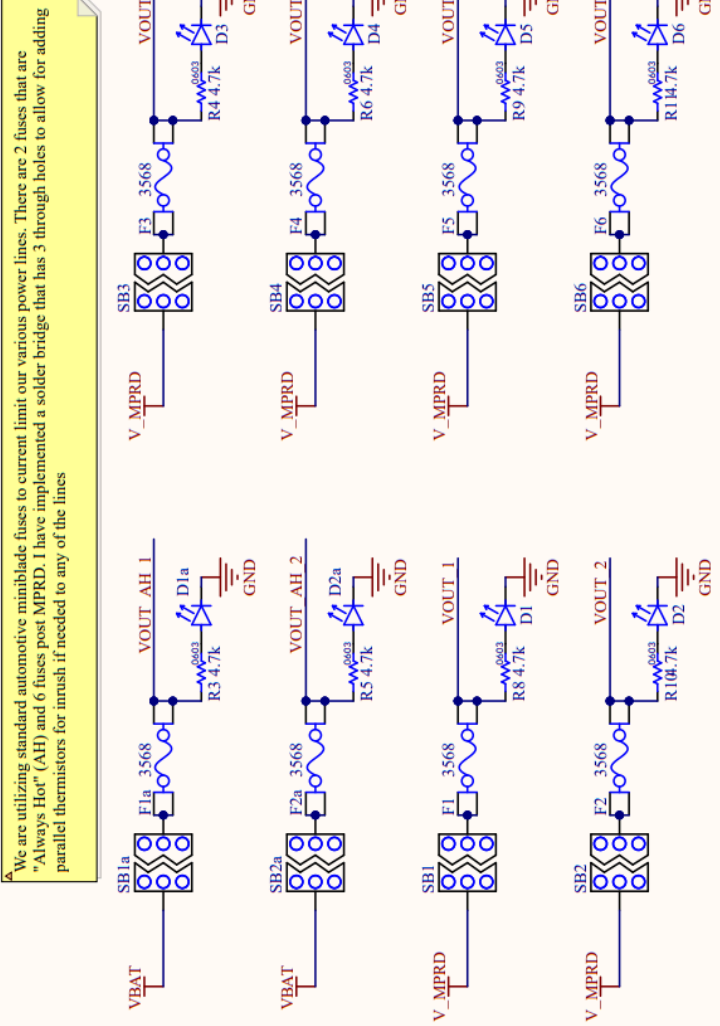
VIN Max: 15V  
 IOUT Max: 800mA  
 (Fused at 750mA though)  
 Input Diode is to prevent reverse current when 5V is powered externally on the bench

## 3V3 Regulation



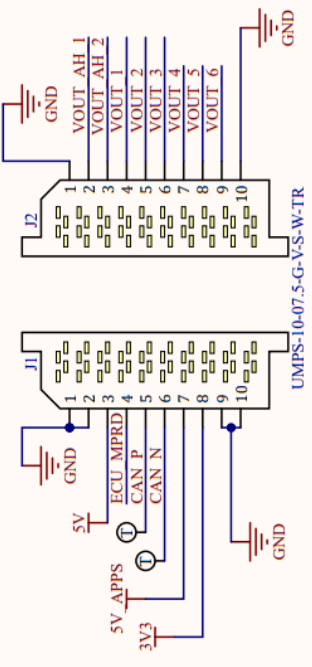
VIN Max: 15V  
 IOUT Max: 800mA

## Fuses



We are utilizing standard automotive mini-blade fuses to current limit our various power lines. There are 2 fuses that are "Always Hot" (AH) and 6 fuses post MPRD. I have implemented a solder bridge that has 3 through holes to allow for adding parallel thermistors for inrush if needed to any of the lines

## Board to Board Connectors



Connector Notes

Fairly standard blade style board to board connector. Each pin can hold a max of 9.4A but the manufacturer says that is derated by at least 20% so fusing at 10A should be fine.

Misc Notes

Optional jumper to bridge 5V lines if needed

## Jumpers

ECU\_MPRD (Main Power Relay Driver) is a normally high signal that goes low when the ECU determines that it is safe to power the auxiliary systems.

Switch for bypassing MPRD

DynoPDU

Designer Calvin Geishirt

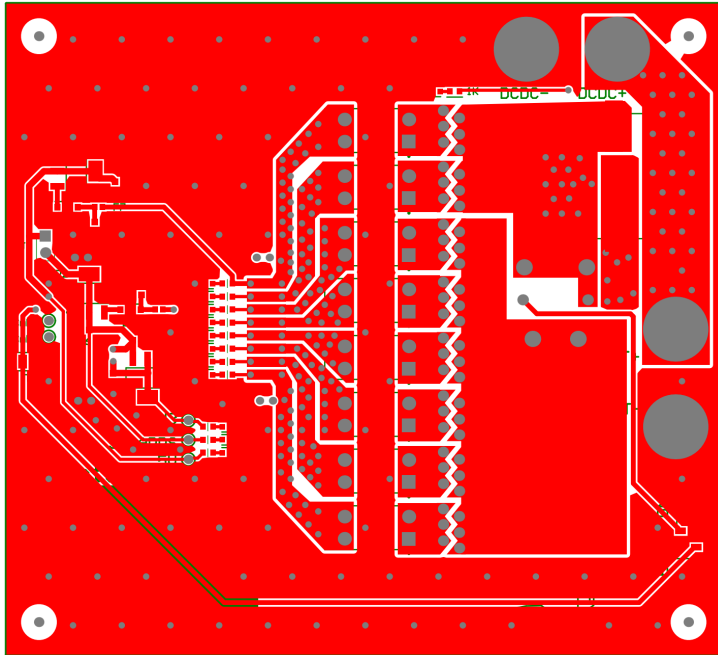
Date: 5/14/2023

File: 223\_DynoPDU\_SchDoc

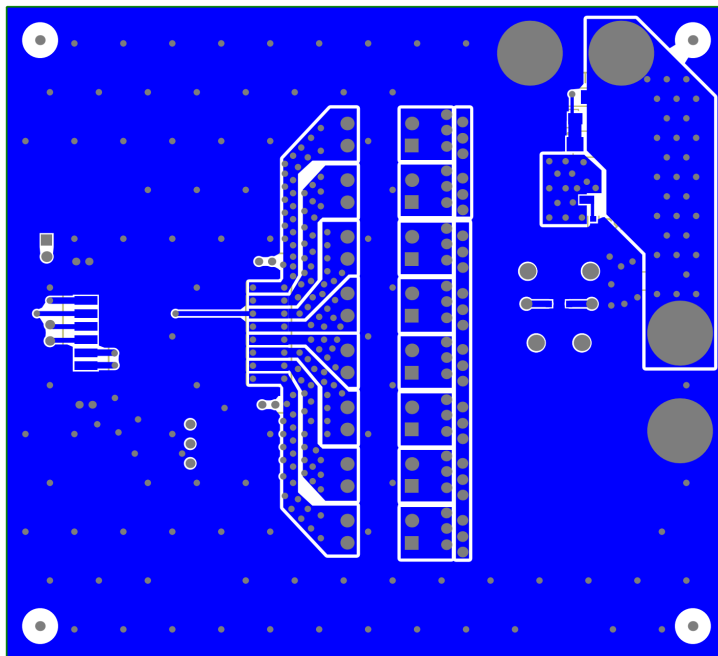
Revision 223.1

## PCB Layers

### Top Layer



### Bottom Layer



# C-Car Carrier Board

Engineer: Calvin Geishirt, LV Electronics Lead

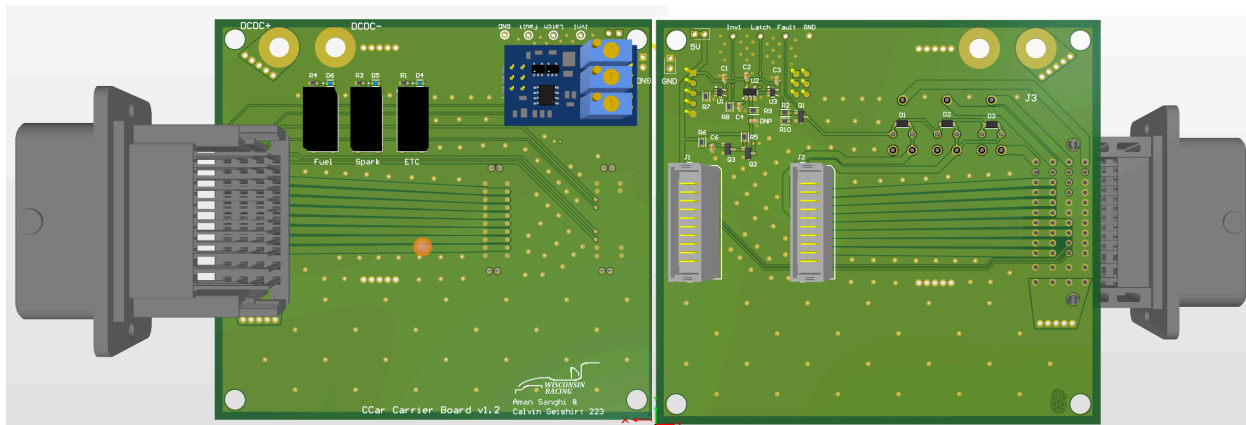
Revision 2023.2

Dimensions: 110mm x 100mm

Steady State Current Draw: 110mA

## Overview

The C-Car Carrier Board was a new design this year to allow for complete compatibility of our Power Distribution Unit (PDU) between our electric and combustion cars. It's main purpose is to house our Brake System Plausibility Device (BSPD) with its non-programmable logic circuitry, Electronic Throttle related Power Relays for the BSPD to control, as well as passing power and signals between the PDU and the rest of the car. Separating out the combustion car specific circuitry also allows for space saving on the electric car, as well as easy rapid iteration on the combustion car while retaining the use of our current PDU.

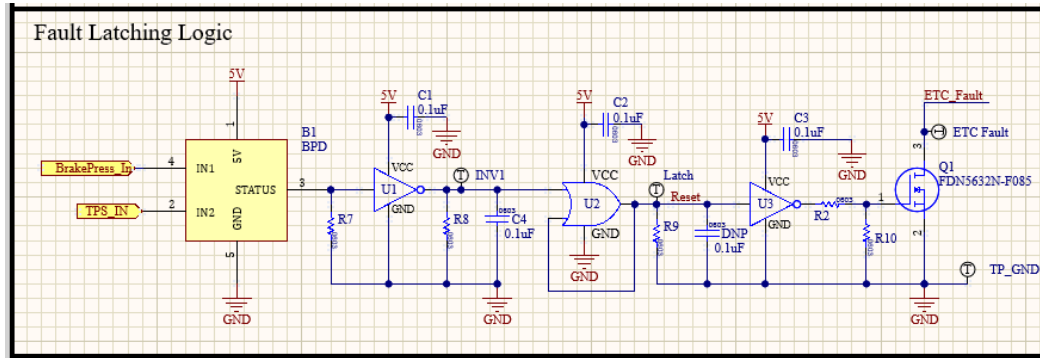


C-Car Carrier Board PCB Layout top and bottom

## Features:

- Houses BSPD with latching logic circuitry
- Houses Power Distribution Unit
- ETC Power Relays
- 48 Pin Molex Connector

## BSPD Logic Circuitry



### Operation

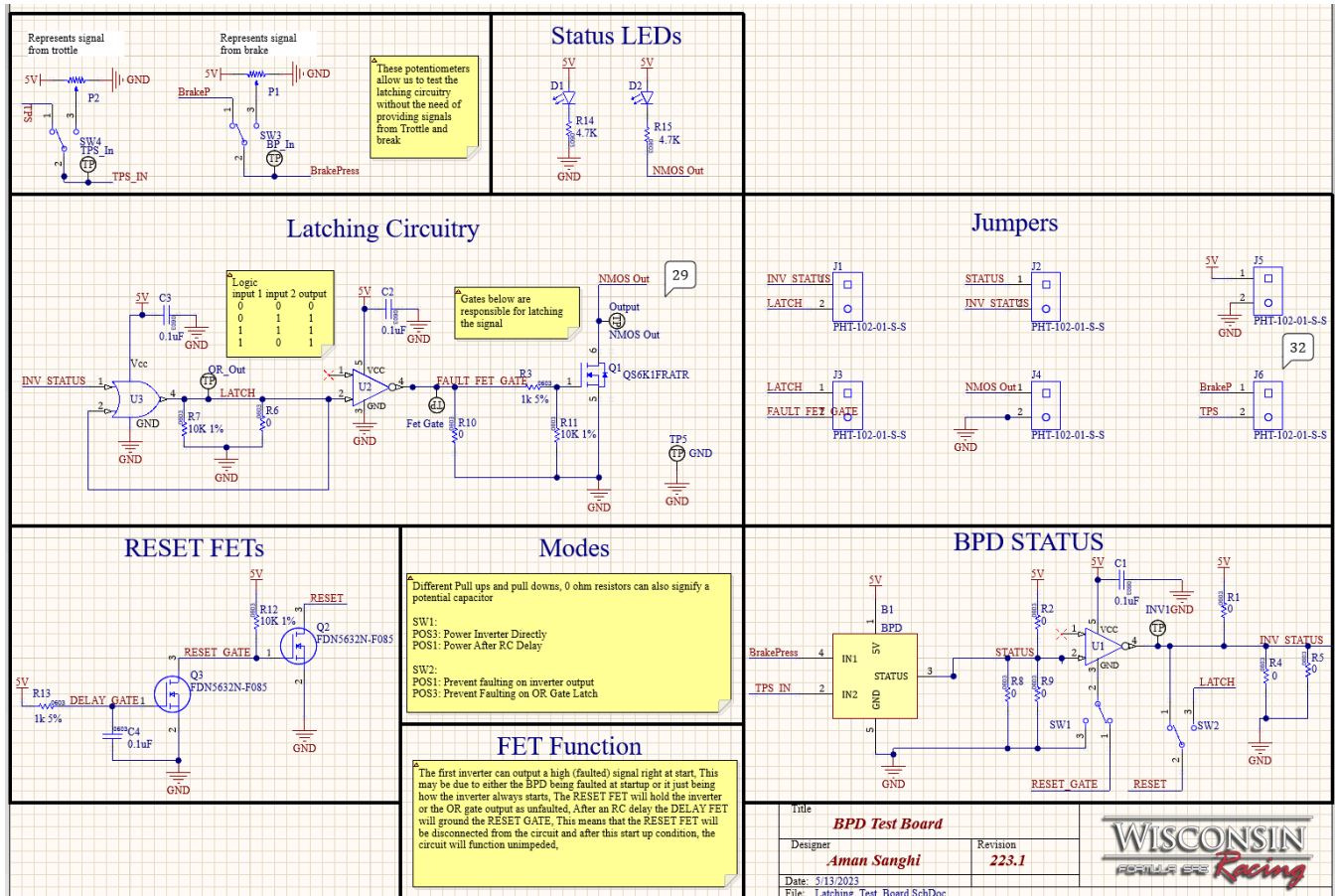
Our BSPD operates such that a low signal means that it is faulted so that if it were to lose power, the system would operate as though a fault condition was present. Using simple logic gates, we first send the BSPD fault signal to a NOT gate which would turn a faulted low signal into a high signal. That high signal would then go to an AND gate, with its output fed back into one of its inputs, which is how the system stays in a latching fault state because if the BSPD were to become un-faulted, the AND gate feedback would keep the system faulted. The AND gate output is then fed into a final NOT gate that controls an n-channel mosfet that acts as a low side switch for the relay coils of our Ignition, Throttle, and Fuel Pump.

### Molex Connector

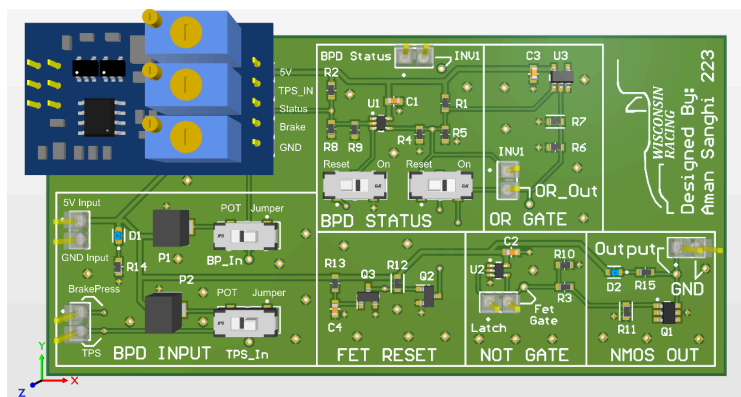
We chose this connector because it is the same style as the connectors we use for our vehicle controller. Using a common connector reduces the number of different types of pins and tools that we need to have with us at all times and streamlines the process of creating wiring harnesses. This connector has 48 contacts, 8 of which are rated for 13A, and 40 rated for 6A.

## Latching Test Board

Our first attempt at the latching logic circuitry failed due to startup issues. We made a test board that was modular to allow us to ensure that the next revision would pass all tests.



This test board allowed us to quickly test potential solutions to the startup problem. We landed on the solution that is implemented above.

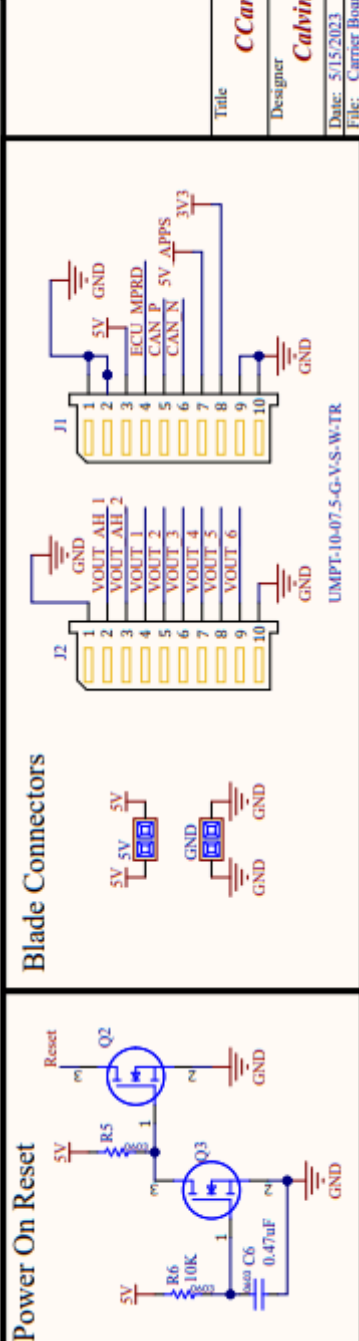
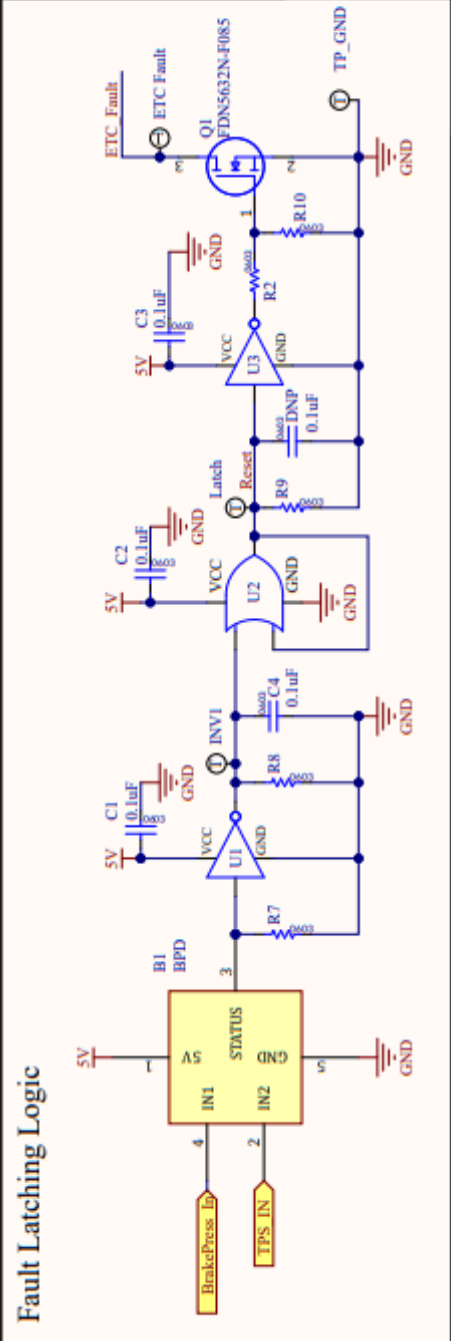
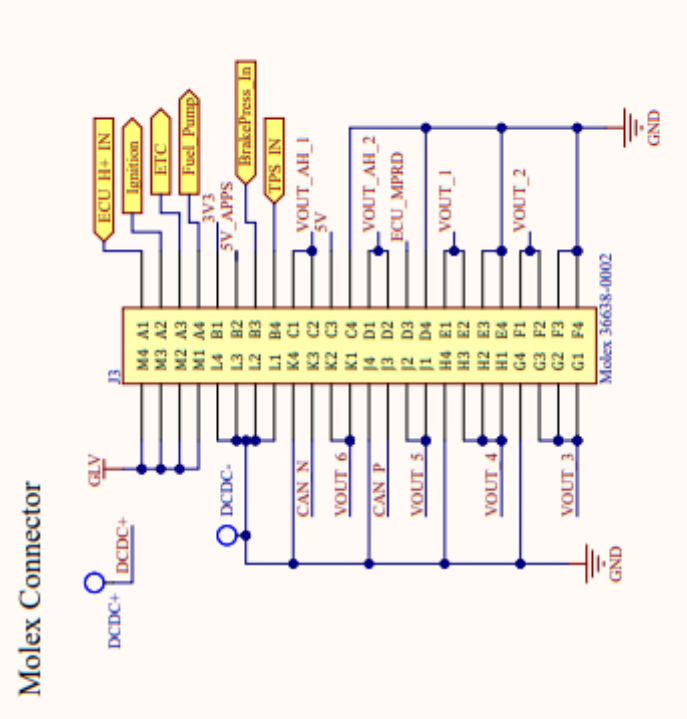
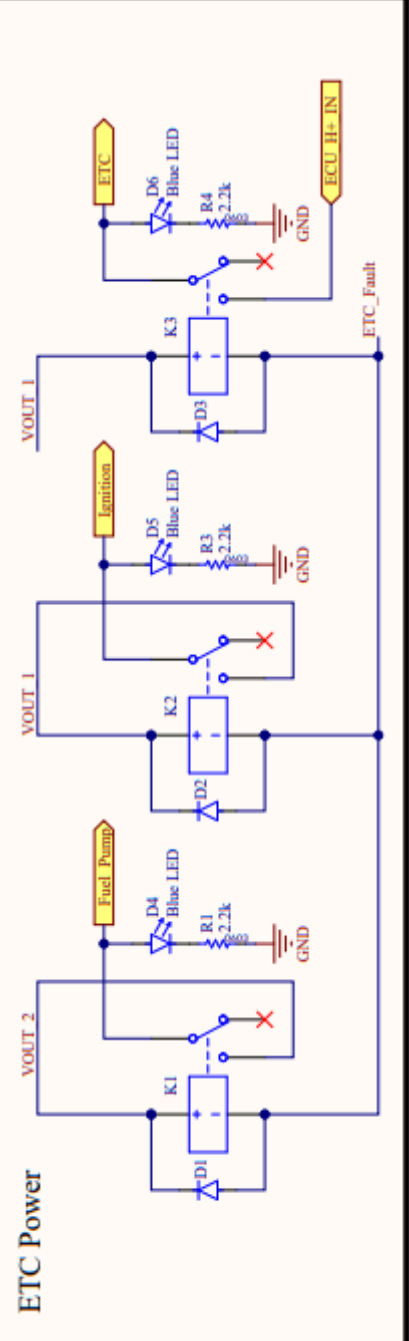


## Layout Notes

The size of the board (110mm x 100mm) was chosen to match the size of the Power Distribution Unit that will sit above it. A two layer stackup was used with no issues of fitting all the circuitry on the board.. A 2 oz outer copper weight was used to make high current trace size manageable.

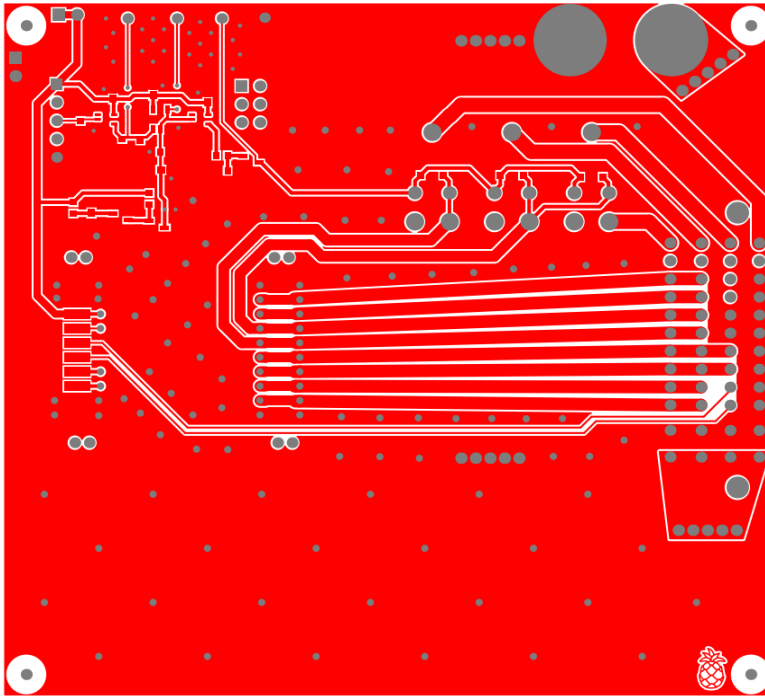
Manufactured by JLCPCB

#	Name	Material	Type	Thickness	Weight	Dk
	Top Overlay		Overlay			
	Top Solder	Solder Resist	Solder Mask	0.01016mm		3.5
1	Top Layer		Signal	0.07mm	2oz	
	Dielectric 1	FR-4	Dielectric	0.32004mm		4.8
2	Bottom Layer		Signal	0.07mm	2oz	
	Bottom Solder	Solder Resist	Solder Mask	0.01016mm		3.5
	Bottom Overlay		Overlay			



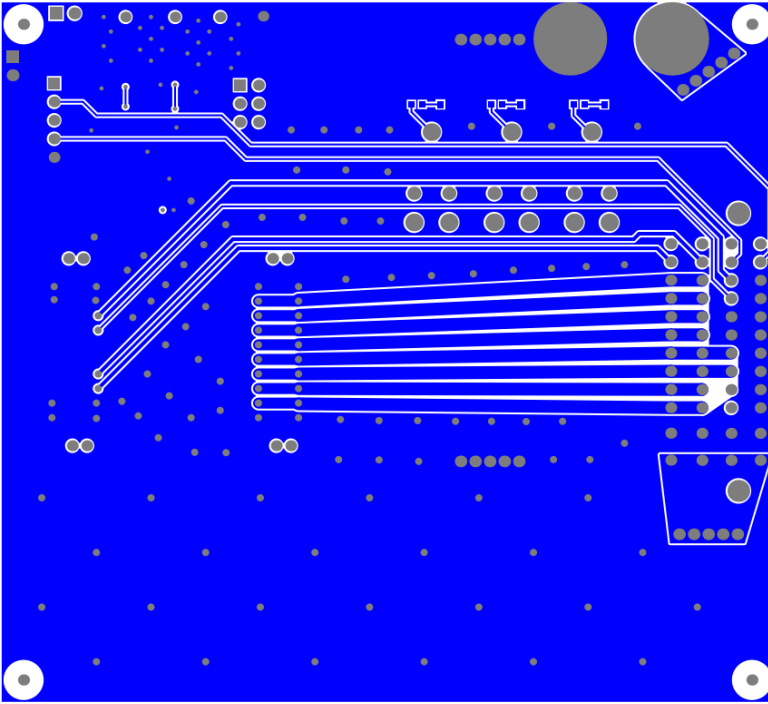
## PCB Layers

### Top Layer



### Bottom Layer





# Eddy Current Dynamometer

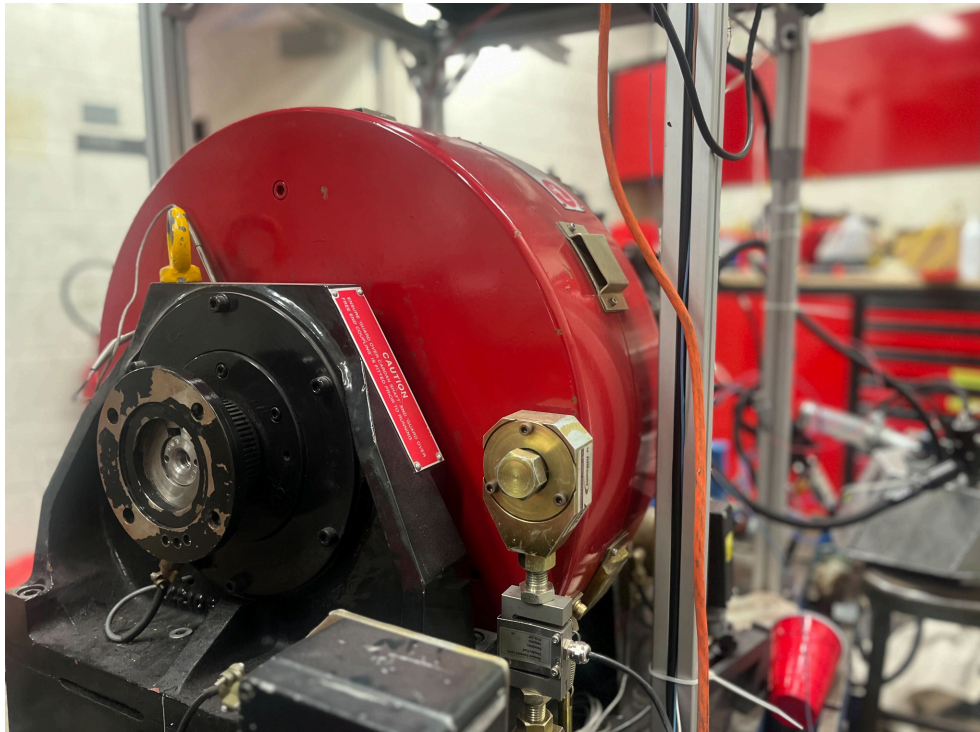
Engineers: Shrey Patel, Controls Lead and Romit Bhatnagar, Controls Team Member

## Overview

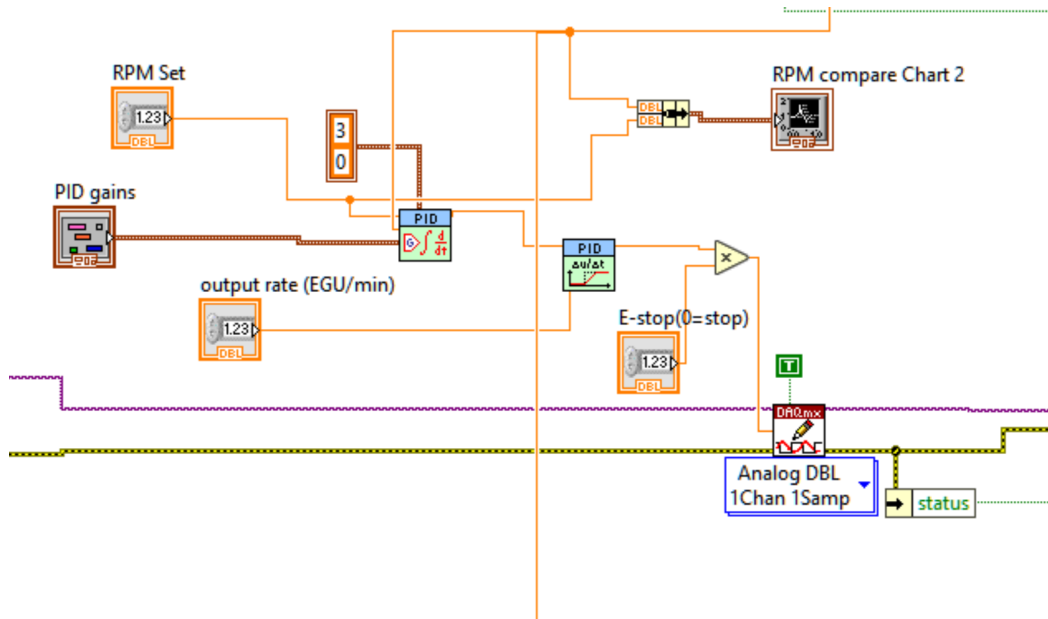
Custom Eddy Current Dynamometer Controller via Labview designed to calibrate new powertrain package. Design includes multiple modes of operation including constant torque, speed, and acceleration. A load cell is used to accurately measure torque off the engine. There is also additional support for high speed sensors such as in-cylinder pressure transducers.

## Features:

- CAN data acquisition
- Multiple modes constant speed and torque
- High precision Load Cell
- Thermocouples support
- Additional Engine sensor support
- Support for high speed logging
- Fault monitoring



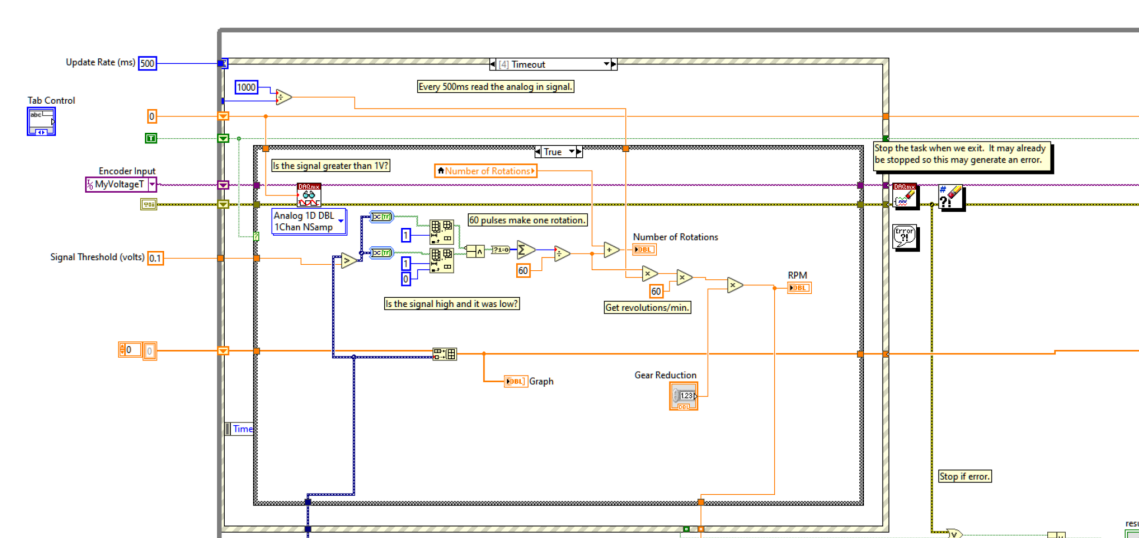
## Constant Speed Controller



### Operation:

Given a set RPM by the operator, this program uses a PID controller with a rate limited output to adjust the load created by the dyno until the actual RPM (derived from the RPM logic) matches the set RPM. A rate limiter is there to protect the powertrain from instantaneous load changes.

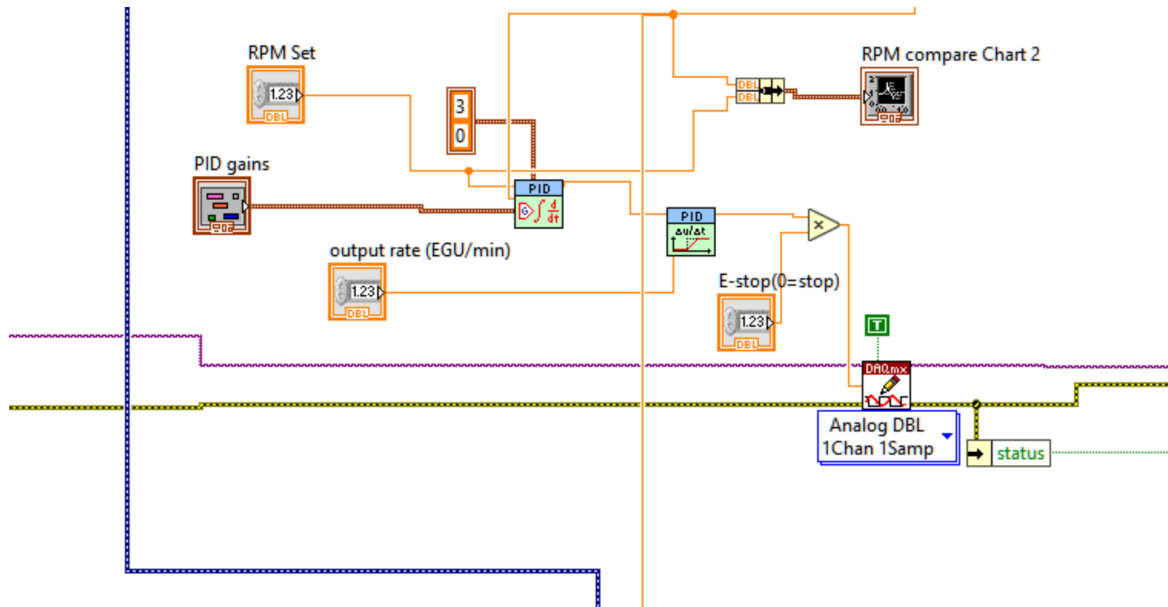
## RPM Logic



## Operation

The RPM logic is written to convert an analog signal from a hall effect sensor into speed. This code converts the sine wave into a digital signal. The digital signal is then used in a counter which is then used to convert into rotations.

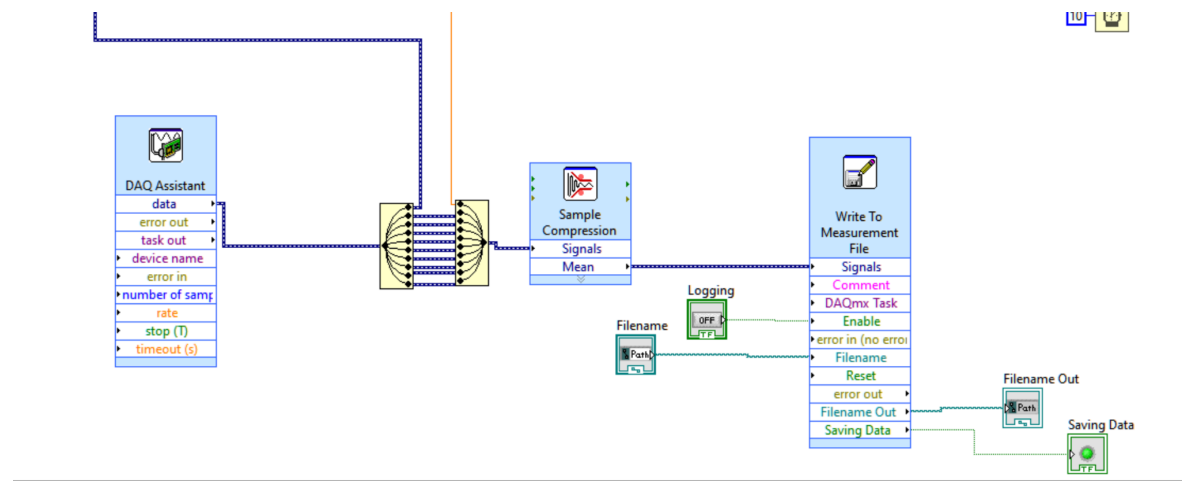
## Speed/Load Controller



## Operation

The speed controller on the Dyno is a simple PID controller with a rate limited output. The PID controls the output torque of the Dyno exerted on the engine in response to the speed derived from the RPM logic. The rate limiter is implemented as a safety precaution as instantaneous changes in load are not safe for the engine. This controller can also be configured to be used as constant load that is determined by the operator.

## Data Acquisition



## Operation

The data acquisition of the dyno is all controlled by a NI-cDAQ. This allows for very high speed logging up to 100K Hz. High speed logging allows support of in-cylinder pressure transducers and O2. All low speed sensors are logged via CAN. This allows for ease of use as engine parameters and dyno data are all on the same CAN Bus.

# ETC Switch Panel

Engineer: Krish Isserdasani, Electrical Hardware Team Member

Revision: 2023.1

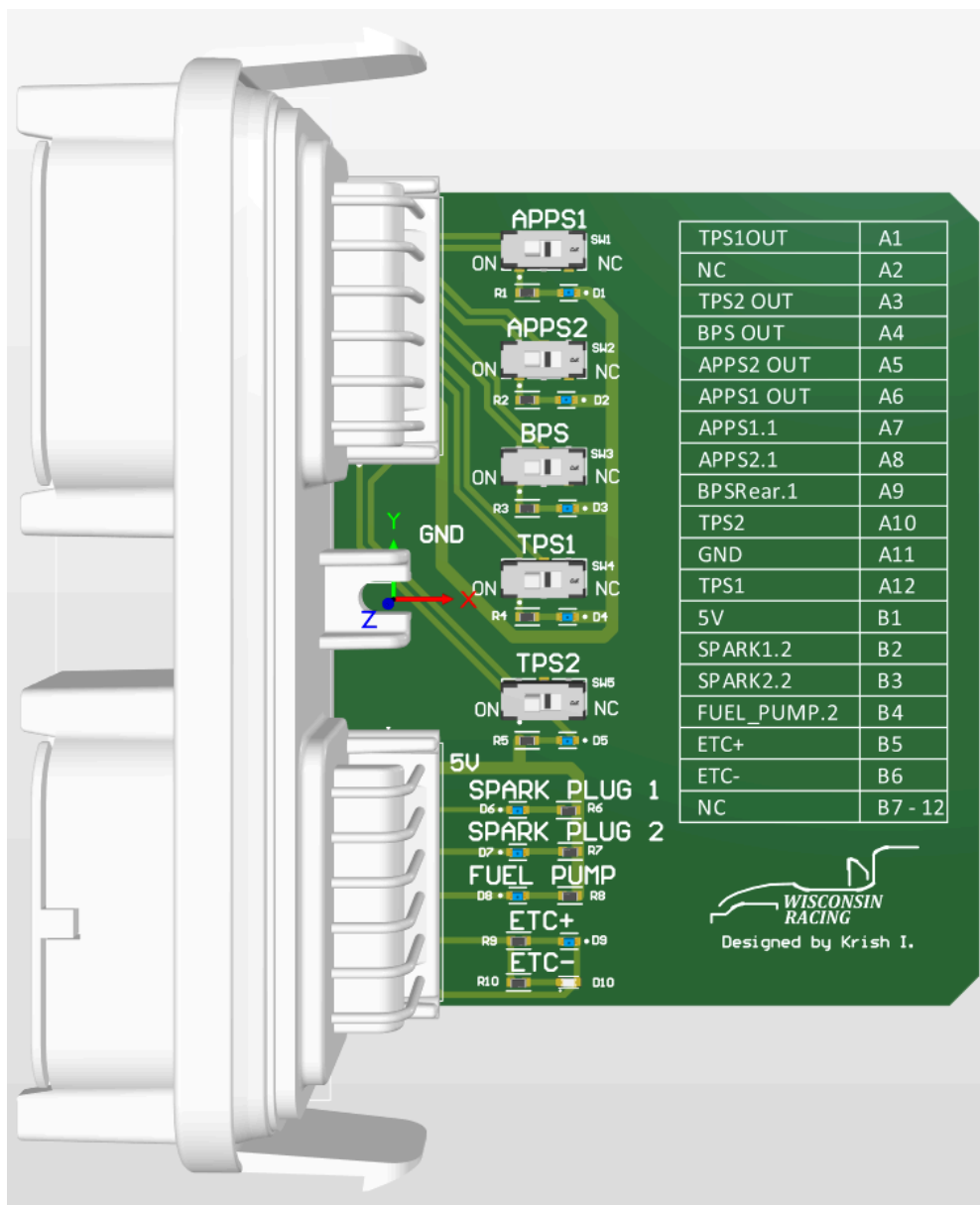
Dimensions: 65mm x 82mm

## Overview

The purpose of this board is to verify the rules compliance of our electronic throttle controls. By adding an inline switch and LED, it allows a clear representation of signals or power being cut to show compliance with the Electronic Throttle Controls rules.

## Features:

- Switches to connect and disconnect sensors
- LED indicators for power and signals
- 1 layer board and big traces to avoid suspicion



# Controls Systems Board

Engineers: Ishan Rai, Electrical Hardware Team Member and Tyler White, Electrical Hardware Team Member

Revision: 2023.1

Dimensions: 48.641mm x 28.321mm

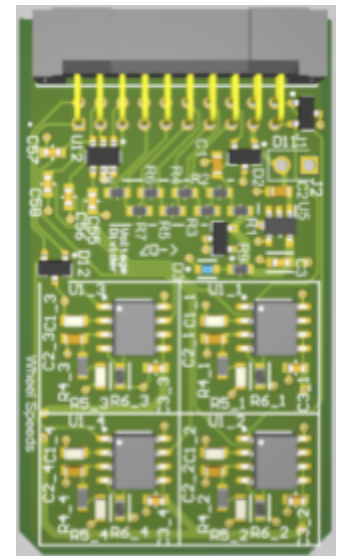
Steady State Current Draw: 120mA

## Overview

The controls systems board is one of several boards with the purpose of gathering information about the performance of the combustion car. This board integrates a gear position circuit and wheel speed conversion circuit onto one PCB. Wheel speed input to the board is a square wave from the sensor for each wheel's tone wheel, and the frequency of each square wave is converted to an analog output. The gear position side of the board has seven inputs but only one analog output to represent which input is currently grounded from the gear position sensor.

## Features:

- Voltage divider for gear position that changes output voltage depending on which input is grounded
- Frequency to analog converters for each wheel speed, which use the TI LM2907 IC
- 12V to 5V linear regulator so that variance in input voltage doesn't change the analog output of either the voltage divider or frequency to analog converter
- Every input and output has TVS diodes and wheel speed outputs also have filtering capacitors

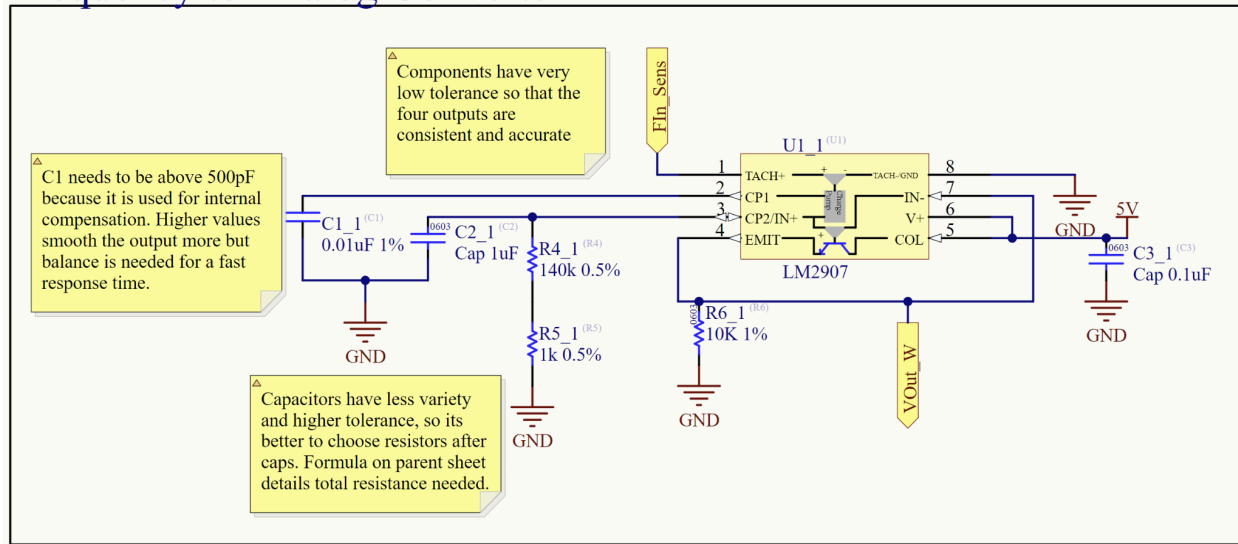


Controls Systems Board 3D Layout

## Frequency to Analog Converter

The frequency-to-analog converter makes use of the TI LM2907 IC, where the input frequency is first put through a comparator before entering the charge pump, which has one external capacitor so that the output resolution (Hz/V) can be tuned to a desired value. The voltage output by the charge pump is mirrored at the output of the IC via the op amp driving a BJT which altogether has negative feedback. The key equations for the operation of this system are  $I3 = C1 \times Vcc \times f$  and  $Vout = I3 \times R1$ , where  $C1$  is the external capacitor for the charge pump,  $I3$  is current out of the charge pump, and  $R1$  is the resistance to ground of the output of the charge pump, which for this specific board was broken into two resistors to achieve a more accurate resistance and precise outputs. To ensure each of the four ICs has the same output voltage for a frequency, components were chosen with small tolerances that also kept the response time high.

## Frequency to Analog Converter



Equation for Vo:	
$V_o = I_3 \times R_1$	
$I_3 = C_1 \times V_{cc} \times f$	
$f / 25 \text{ (Hz)} *$	$V_o$
1	0.176
5.68	1.000
10	1.761
11.36	2.000
17.04	3.000
22.72	4.000
28.4	5.000
* $f / 25$ is wheelspeed in rps	

## Gear Position Analog Converter

The gear position analog converter is responsible for converting the grounded input signals from the Gear Position sensors to an analog signal which is then fed into the ECU. This information is then relayed to the driver through displays on the steering wheel.

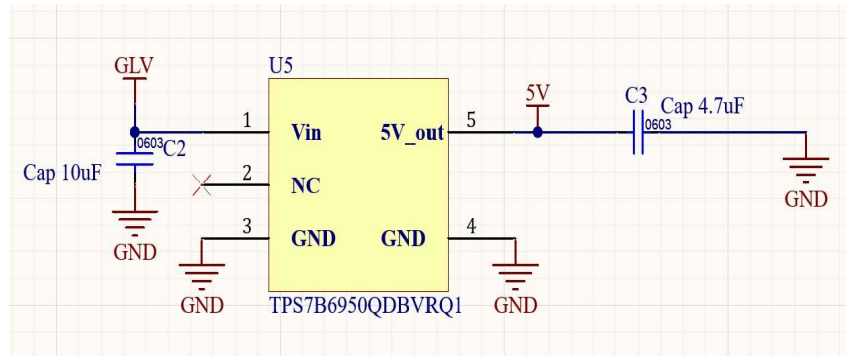
### Operation

The converter uses an LDO to regulate voltage from 12V to 5V. When the car is in a certain gear position, the gear position sensor grounds the input corresponding to that gear. When this occurs, the resistance value in the voltage divider circuit changes, and a different output voltage is relayed for every gear position.



### LDO Circuit

GLV is the Vin signal for the LDO. The LDO outputs a stable 5V signal which is then used as the input voltage for the voltage divider circuit. Capacitors C2 and C3 are decoupling capacitors and their values are based on manufacturer's recommendations given in the datasheet.

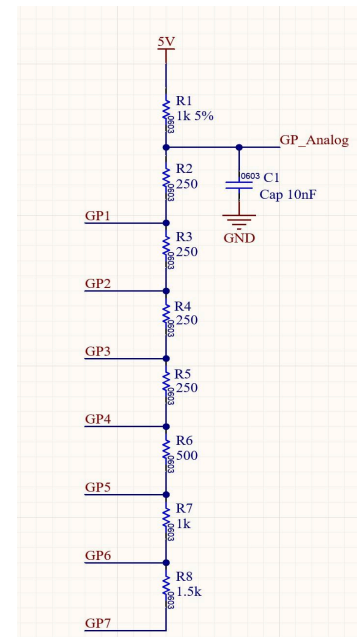


### Voltage Divider Circuit

This is a typical voltage divider. GP1-GP7 are the gear position outputs and GP\_Analog is the output signal. Capacitor C1 is a noise filtering capacitor. The value of the output voltage is determined using the following equation:

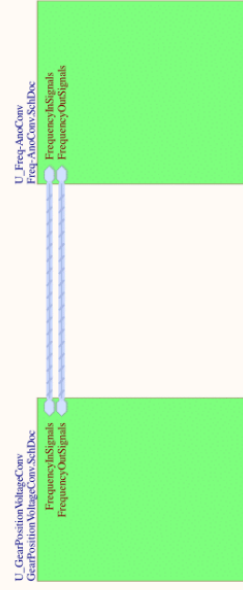
$$V_{out} = \frac{V_s \times R_2}{R_1 + R_2}$$

Vs is the input voltage with a value of 5V. R2 varies based on the output of the gear position sensor and R1 is a fixed resistor with a value of 1k ohm.

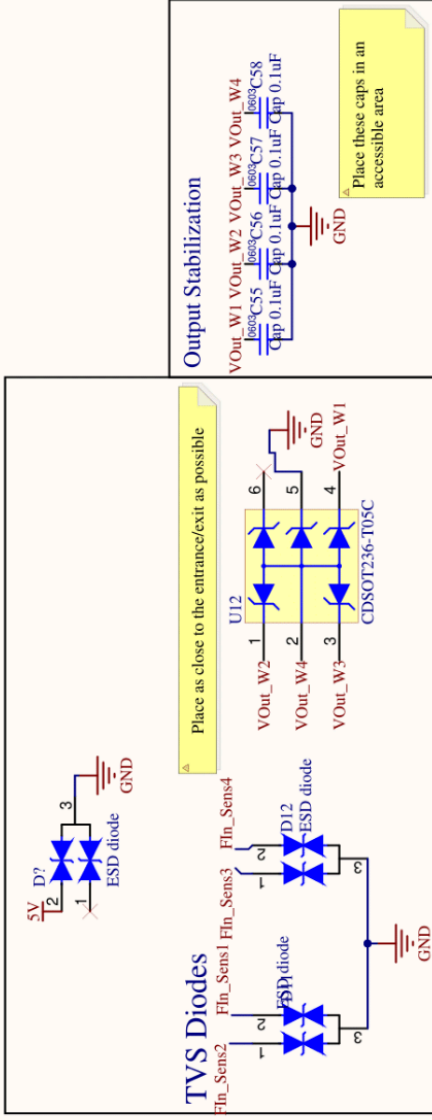


Gear Position	Voltage Range
1	(0,1]
2	(1, 1.66]
3	(1.66, 2.143]
4	(2.143, 2.5]
5	(2.5, 3]
6	(3, 3.57]
7	(3.57, 4]

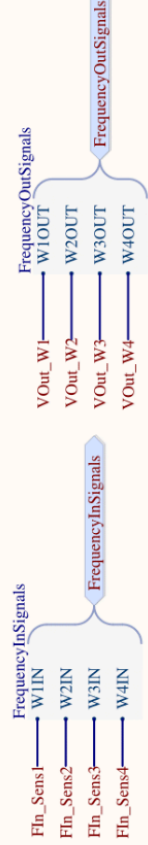
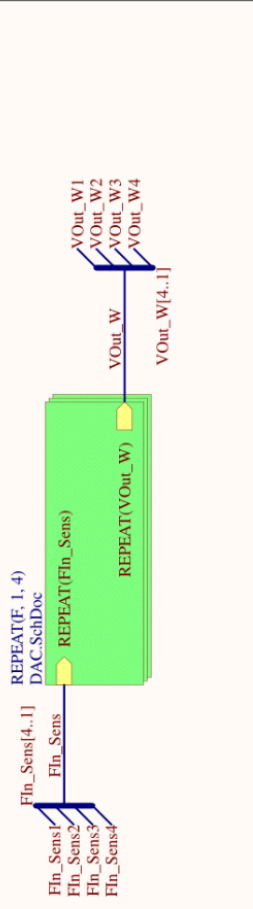
Output voltage range of every gear position has been provided in this table.



Title	<b>TopLevel</b>
Designer	<b>Ishan &amp; Tyler</b>
Date	5/15/2023
File	TopLevel.SchDoc
Revision	*



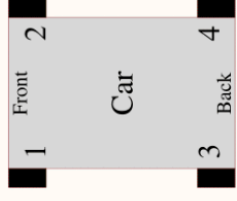
### FAC Circuit



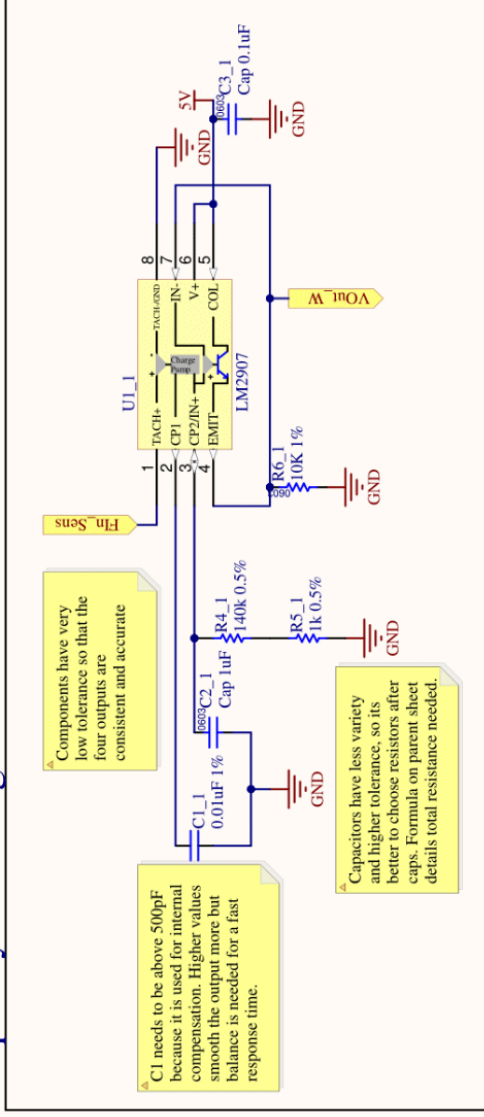
Equation for Vo:  
 $V_o = I_3 \times R_1$   
 $I_3 = C_1 \times V_{cc} \times f$

f / 25 (Hz) *	Vo
1	0.176
5.68	1.000
10	1.761
11.36	2.000
17.04	3.000
22.72	4.000
28.4	5.000

\* f / 25 is wheelspeed in rps



## Frequency to Analog Converter



Title **Wheelspeed DAC**

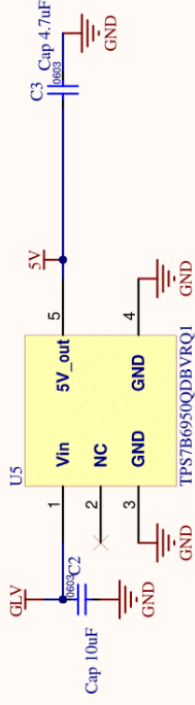
Designer **Tyler White**

Revision **223.3**

Date: 5/15/2023

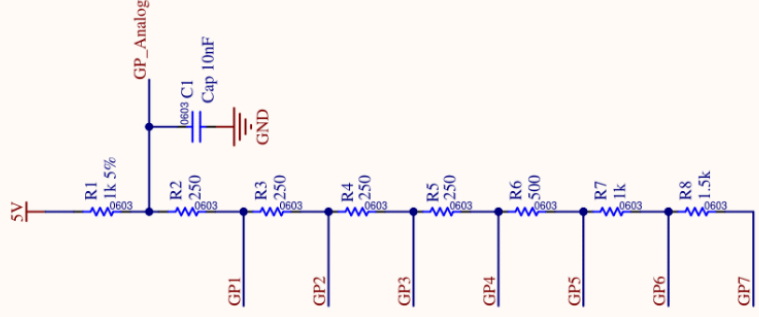
File: DAC.SchDoc

# LDO



U5 has an output current of 150mA  
 C2 and C3 are decoupling capacitors with values recommended by the datasheet

# Voltage Divider for analog output



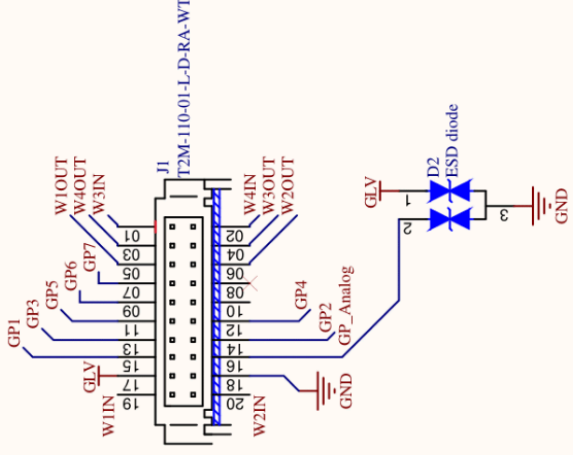
When gear is not in position, GPx (x is 1-7) is floating. When it is in position, it is grounded.

C1 is a noise filtering capacitor

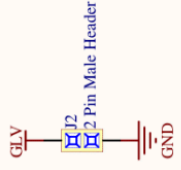
# Voltage range and formula used

Cannot open file  
 C:\Users\ishan\Downloads\2023-01-25 102623.png: File does not exist.  
 C:\Users\ishan\Downloads\2023-01-25 101310.png: File does not exist.

# Connector



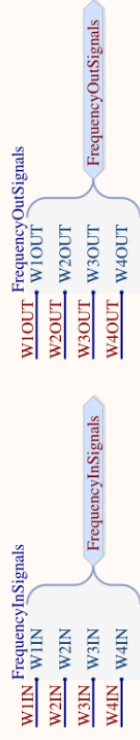
# Header for power and ground



# Indicator LED



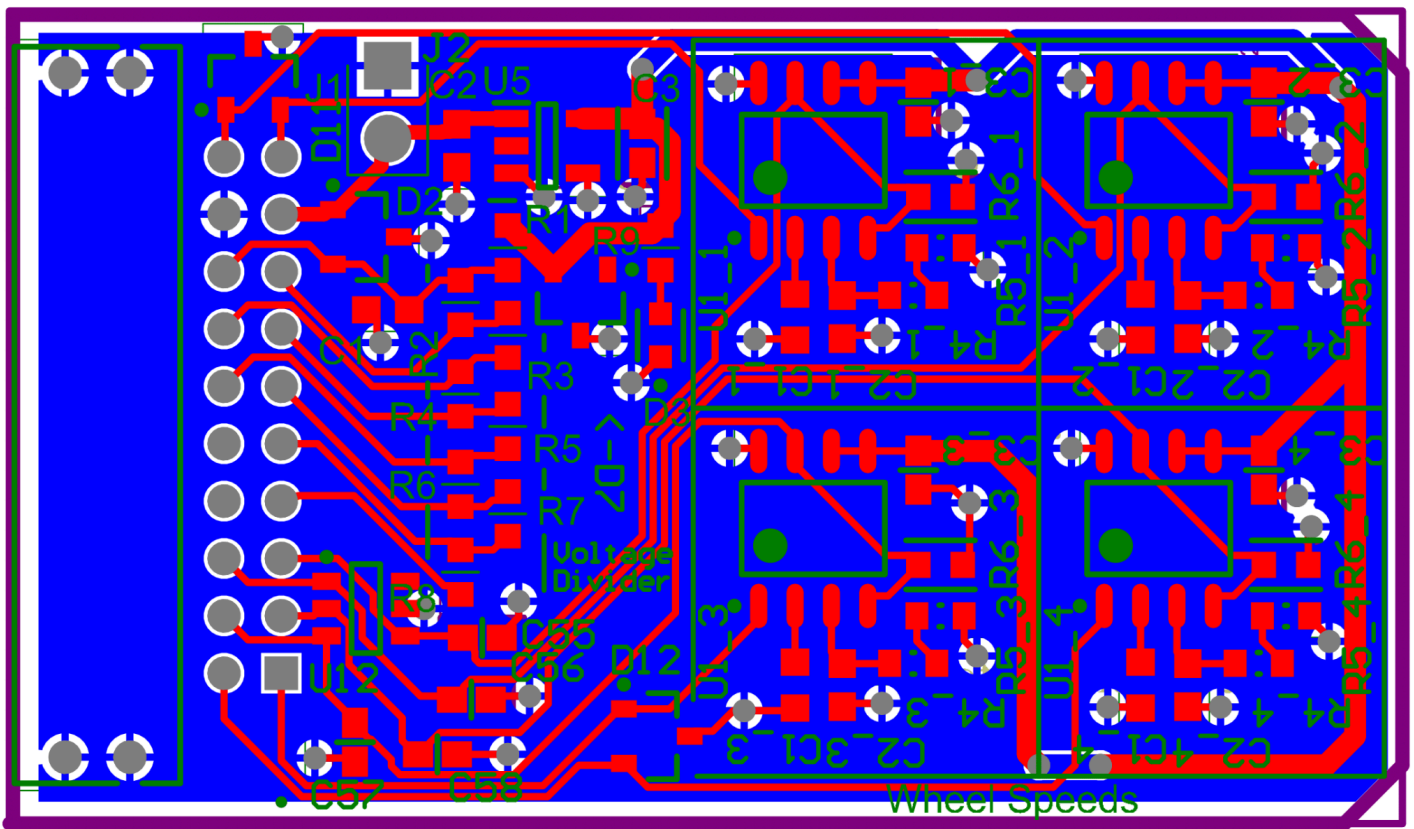
# Freq Input and Voltage Output harness



Title		<b>Gear Position Voltage Converter</b>
Designer	<b>Ishan Rai</b>	Revision
Date	5/15/2023	<b>223.1</b>
File:		GearPositionVoltageConv.SchDoc



# PCB Printout



# Tire Temp Sensor

Engineer: Joshua Cobian

Revision: 2023.2

Dimensions: 64mm x 23mm

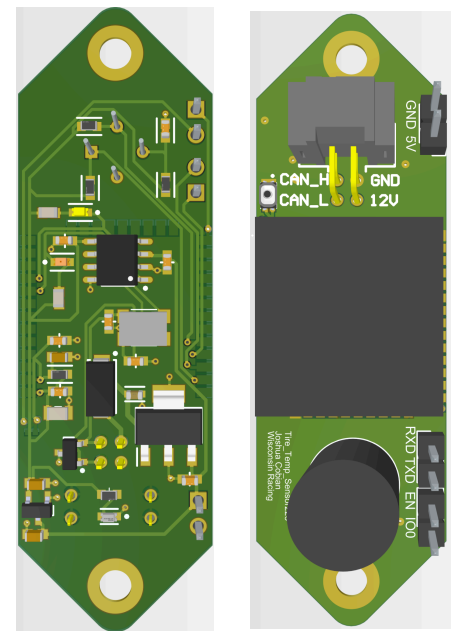
Steady State Current Draw: 115mA

## Overview

The Tire Temperature Sensor board is a programmable circuit board that will take the real time temperatures of the tires. The board uses an ESP32-WROOM microprocessor to read data from an IR sensor and sends that data over CAN to the steering wheel, vehicle controller, and the data logger. The circuit board is split between top and bottom. The top is where the microprocessor, IR sensor and all the headers needed to run or flash the board live. The bottom is where the power delivery, CAN, and other supportive circuitry for the IR sensor and microprocessor are. Other than read temperatures, the main goal of the board is to prove that the ESP32-WROOM could be used as a main microprocessor for a board that communicates with CAN.

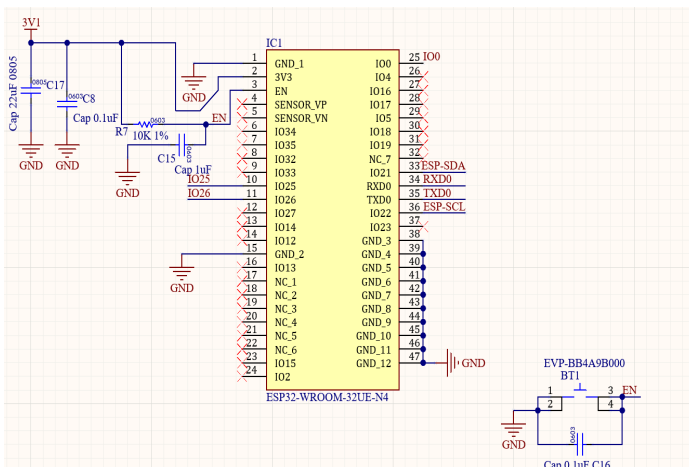
## Features:

- Uses a programmable ESP32-WROOM
- Uses a matrix based IR sensor
- Is powered by 12V but can also be powered by 5V for flashing code
- Communicates over CAN
- Small enough to fit in an enclosure
- Rate for high temperatures and shaking
- Expected current draw is 120mA - 140mA



Bottom of Board 3D

Top of Board 3D



ESP32-Wroom

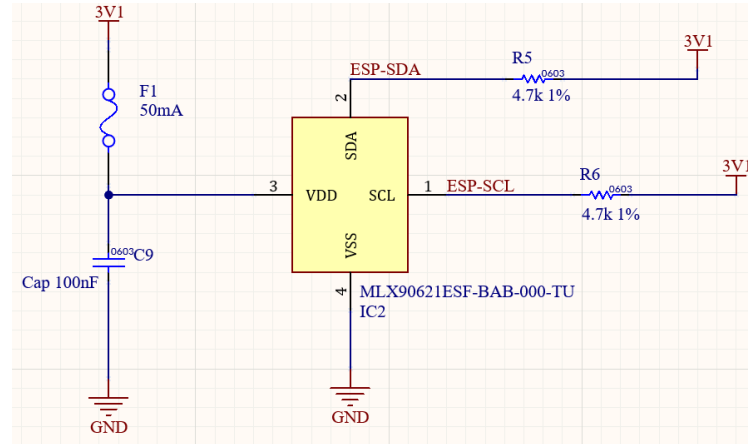
## Microprocessor

The ESP32-Wroom is the main processor for this board. It will read data from the IR sensor through I2C and transmit it to the CAN circuitry through CANRXD and CANTXD. The ESP32-WROOM was chosen because it would work with CAN, the team had a reliable way to flash it with code, it worked with Arduino, and it was relatively inexpensive. The

Custom circuit around it is taken directly from the ESP32-WROOM's datasheet. It recommends a RC circuit on enable for startup and also filtering capacitors for the power input.

## IR Sensor

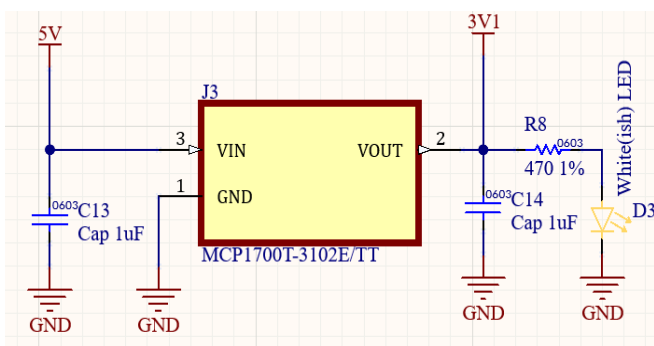
The IR sensor collects temperature data from the wheel and sends it to the microprocessor using I2C. The specific model is MLX90621ESF-BAB-000-TU. It was decided to use this model because it was in use by the earlier iteration of the temperature sensor board, and the sensors were quite expensive. Also because it was expensive a 50ma fuse was added to protect the sensor.



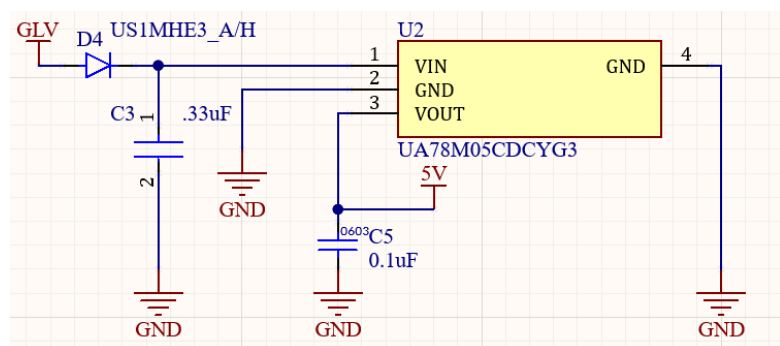
IR Sensor

## Power Delivery

The board is powered by 12V from the Low Voltage Battery and requires a 5V for the CAN transceiver and 3.3V for the microprocessor and 2.7V for the IR sensor. In order to compromise and to make the circuitry small enough, it was decided to run the ESP32-WROOM and IR sensor at 3.1V which is within the operational range of both. For both voltage drops a linear dropout regulator (LDO) was used. The 12V to 5V LDO is significantly bigger than the 5V to 3.1V LDO because there is expected to be more heat due to the larger amount of voltage dropped. In order to make the board capable of being powered by a 5V input, a rectifier diode was added to the 12V to 5V LDO. A LED was also added to the 5V to 3.1V LDO so it is known when the board is powered.



5V to 3.1V LDO

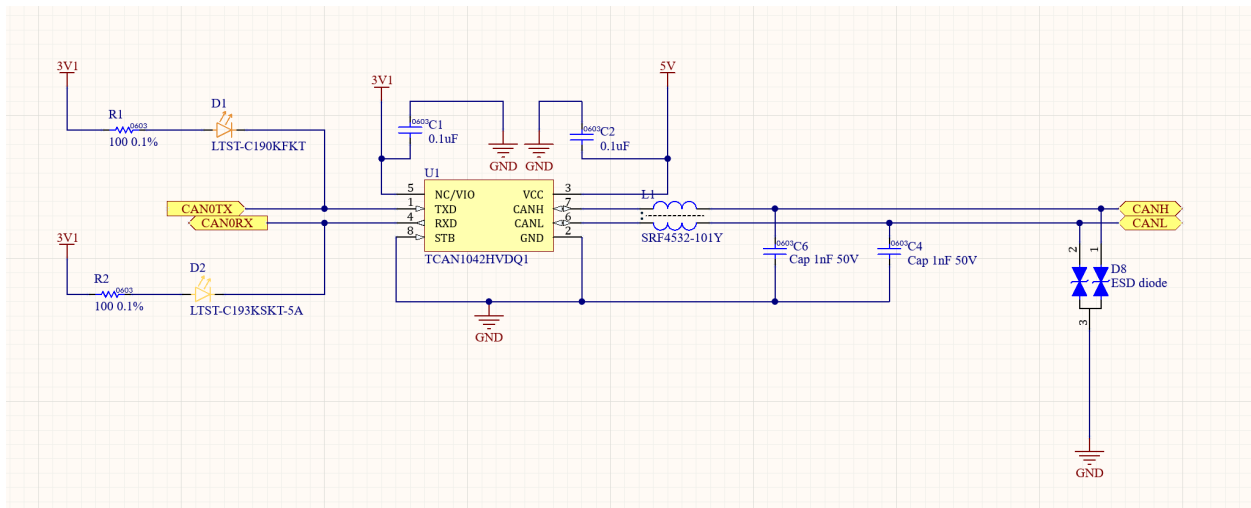


12V to 5V LDO

## CAN

The team uses the TCAN family of CAN transceivers with integrated level shifters. The CAN circuit is used across both cars and features LEDs to show when CAN communication is occurring, a common mode choke for noise rejection and ESD diodes. This circuit is common on all PCBs that use CAN on the car.





TCAN

## Code

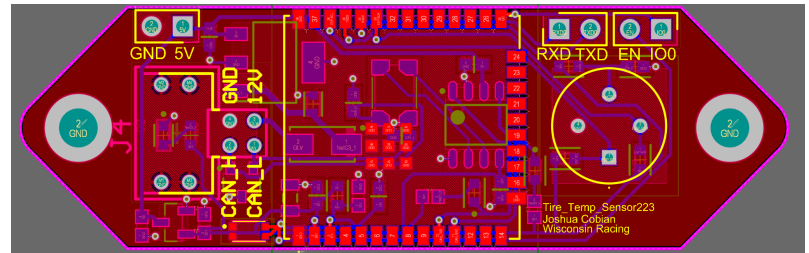
The code the microprocessor uses is written in Arduino. It takes in the data from the IR sensor which is a 4x16 temperature data matrix and compresses it into a 1x8 temperature data matrix by averaging down the four rows to one row. It then sends this smaller package over can to the various places in the car that needs it. The team flashes the ESP32-WROOM with code using a by hooking up the TXD, RXD, IO0, and EN broken out pins to a ESP-32-WROVER devkit.

## Layout Notes

The layout of this board is split between top and bottom. The top is where the microprocessor, IR sensor and all the headers needed to run or flash the board live. The bottom is where the power delivery, CAN, and other supportive circuitry for the IR sensor and microprocessor are. The board dimensions are 62.5997mm X 19.5mm

## Top

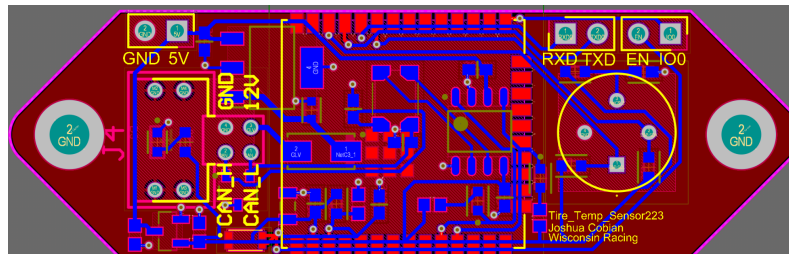
The centerpiece of this board is the microprocessor and it is in the middle of the top. It was put there because it required the most space underneath it to put the surrounding circuitry and traces that were required to make it operate correctly. The other components are placed in such a way to get the maximum space underneath the board. The large round holes on the sides of the board are for mounting near the wheel in an enclosure. The top layer is a nearly fully continuous ground plane except for the ESP32 microprocessor.



Top of Board 2D

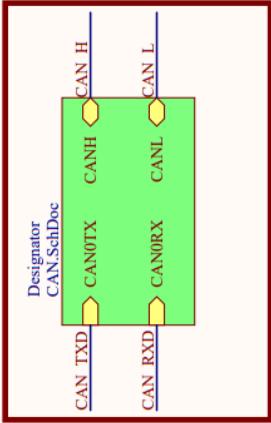
## Bottom

The bottom is laid out as follows from left to right. Power delivery, microprocessor, TCAN, and IR Sensor. This was done so that the components on the bottom are arranged to support the components on the top as close as they can be to ensure signal integrity.

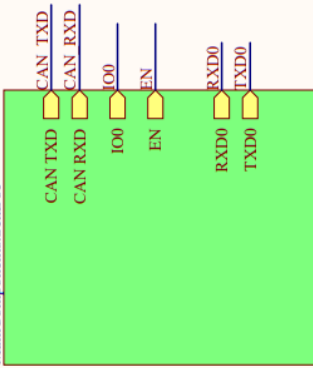


Bottom of Board 2D

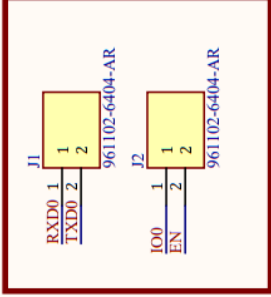
### CAN



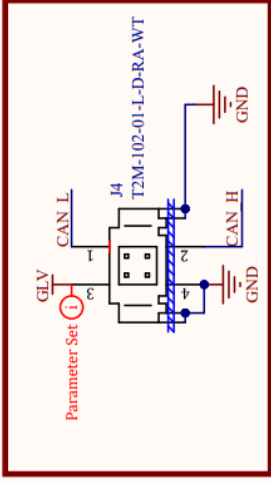
Designator: MainComponents\_SchDoc



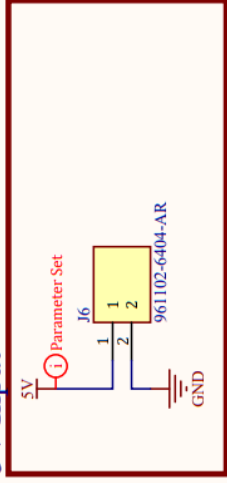
### UART



### Main Connector



### 5V Input



Title

**Tire Temp Sensor**

Designer

**Joshua Cobian**

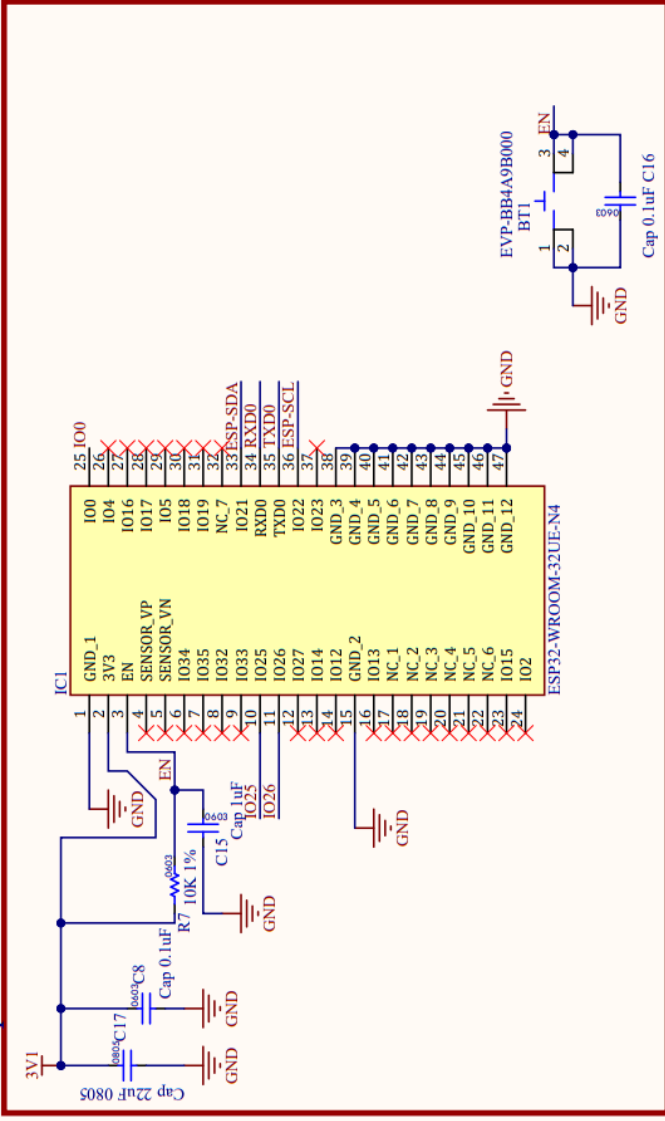
Revision

**223.1**

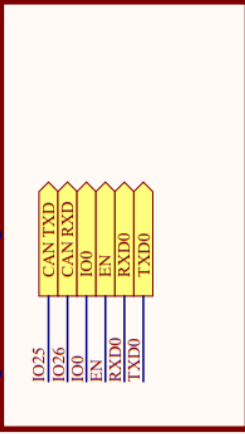
Date: 5/14/2023

File: TireTempSensor\_SchDoc

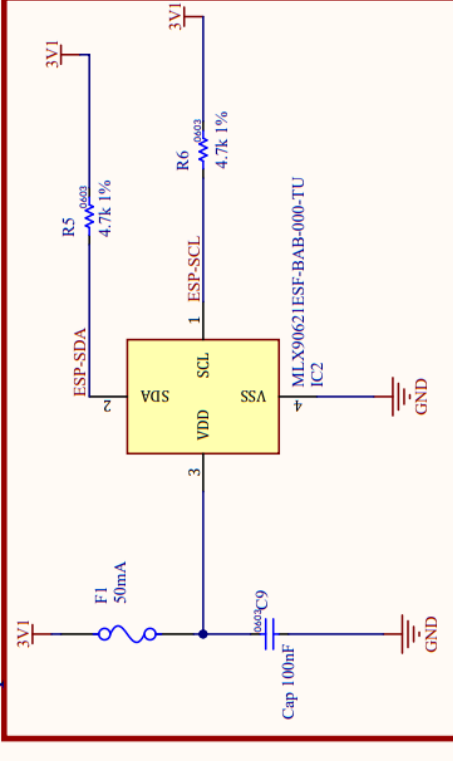
# Microprocessor



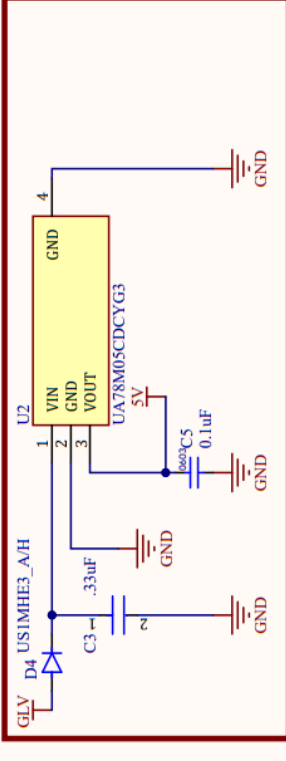
# Output and Inputs



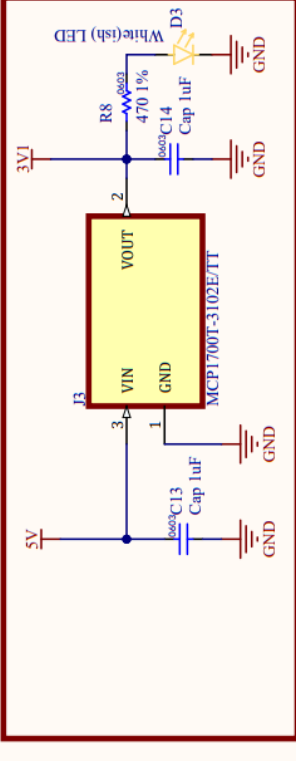
# Temperature Sensor



# 12V to 5V LDO



# 5V to 3.1 LDO



Title

Tire\_Temp\_223

Designer

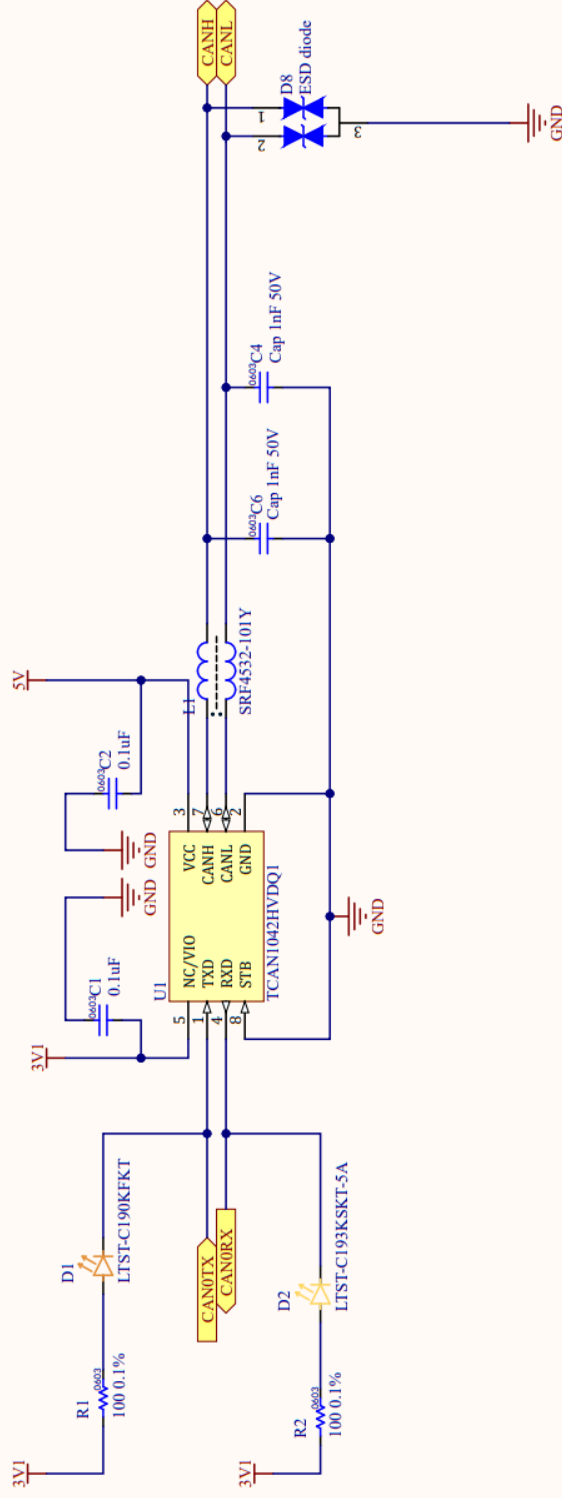
Joshua Cobian

Revision

223.1

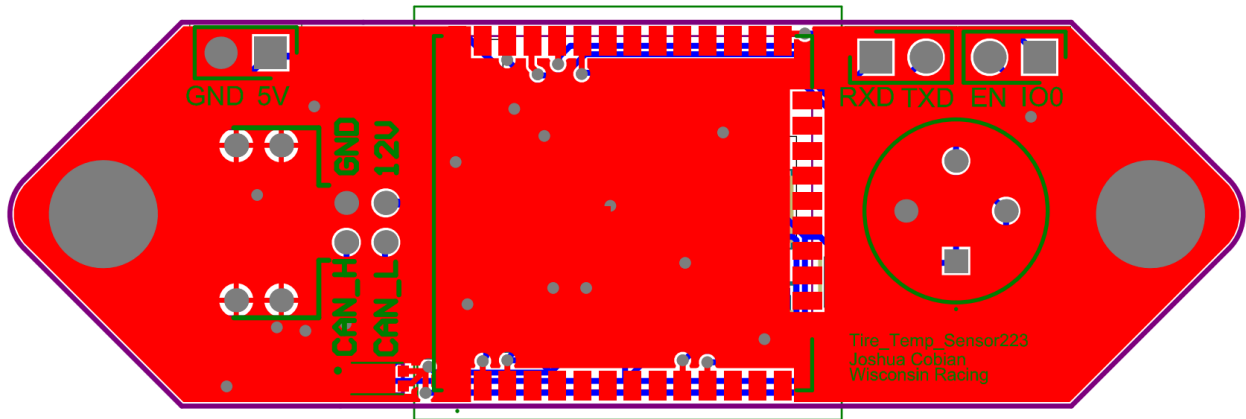
Date: 5/14/2023

File: MainComponents.SchDoc



Title	CAN	
Designer	Joshua Cobian	Revision
Date: 5/14/2023		223.1
File: CAN.SchDoc		

# PCB Printout



## Systems Integration

Engineers: Calvin Geishirt, LV Electronics Lead,  
 Shrey Patel, Controls Lead,  
 Surya Raghavendran, Controls Lead,  
 Krish Isserdasani, Electrical Hardware Team Member, and  
 Shreya Mukherjee, Electrical Hardware Team Member

### Harnessing

Wiring harness design and manufacturing is a cross sub-team effort between the electrical hardware team and the controls team. The team starts by adding every sensor, PCB, ECU, and switch to a centralized excel spreadsheet. Components are then added to a RapidHarness schematic, and signals are connected. Lengths can then be added between nodes, and a wiring table is generated for manufacturing. The team then manufactures the entire harness in house.



### Features:

- Harness is split into 3 sections for ease of manufacturing and maintenance
- Field serviceable Deutsch DTM connectors used as much as possible
- RapidHarness schematics greatly aid in manufacturing process

### Front Harness

The front harness contains everything in front of the driver. This includes dash buttons, APPS potentiometers, brake pressure sensors, the steering wheel, and more. The front harness connects to the central harness with a “bulkhead” connector, a high pin density Deutsch Autosport connector.

### Central Harness

The central harness contains the ECU, which is where almost all signals must go. Bulkheads from the front and rear connect here. Our data logger, the EVO5, also connects to this portion of the harness.

### Rear Harness

The rear harness runs by the engine, and all engine sensors need to be connected to this harness. This is by far the most complicated part of the harness. The rear harness needs two bulkheads to pass all the signals, both from the Deutsch series. Both use the same pins that we use for the Deutsch DTM and DT series connectors, making them easily serviceable.

### Dyno Harness

The dyno harness is a special made harness that only contains the connectors for sensors we would need on the dyno. The harness was split into two sections, one part connects to the engine, and the other half connects to the ECU and control room switches.

Rev	Revisão	Descrição

NOTAS	

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade



Componente

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

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Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade

Item	Descrição	Quantidade	Unidade



Item No.	Description	Unit	Quantity	Material Code	Remarks
1	1.0000	1	1	10000	1
2	1.0000	1	1	10000	1
3	1.0000	1	1	10000	1
4	1.0000	1	1	10000	1
5	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
6	1.0000	1	1	10000	1
7	1.0000	1	1	10000	1
8	1.0000	1	1	10000	1
9	1.0000	1	1	10000	1
10	1.0000	1	1	10000	1

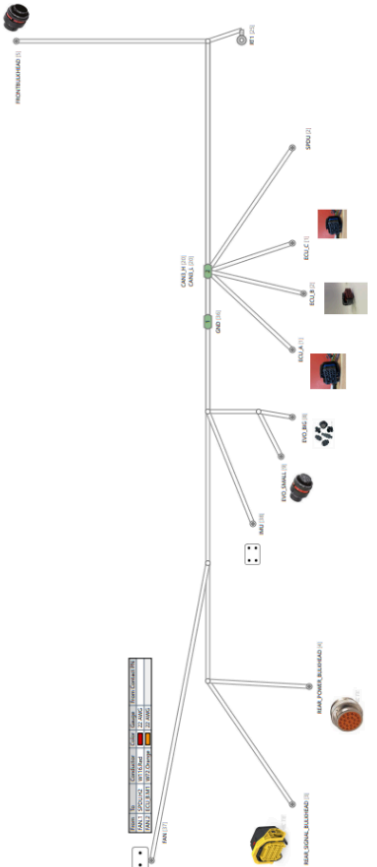
Item No.	Description	Unit	Quantity	Material Code	Remarks
11	1.0000	1	1	10000	1
12	1.0000	1	1	10000	1
13	1.0000	1	1	10000	1
14	1.0000	1	1	10000	1
15	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
16	1.0000	1	1	10000	1
17	1.0000	1	1	10000	1
18	1.0000	1	1	10000	1
19	1.0000	1	1	10000	1
20	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
21	1.0000	1	1	10000	1
22	1.0000	1	1	10000	1
23	1.0000	1	1	10000	1
24	1.0000	1	1	10000	1
25	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
26	1.0000	1	1	10000	1
27	1.0000	1	1	10000	1
28	1.0000	1	1	10000	1
29	1.0000	1	1	10000	1
30	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
31	1.0000	1	1	10000	1
32	1.0000	1	1	10000	1
33	1.0000	1	1	10000	1
34	1.0000	1	1	10000	1
35	1.0000	1	1	10000	1

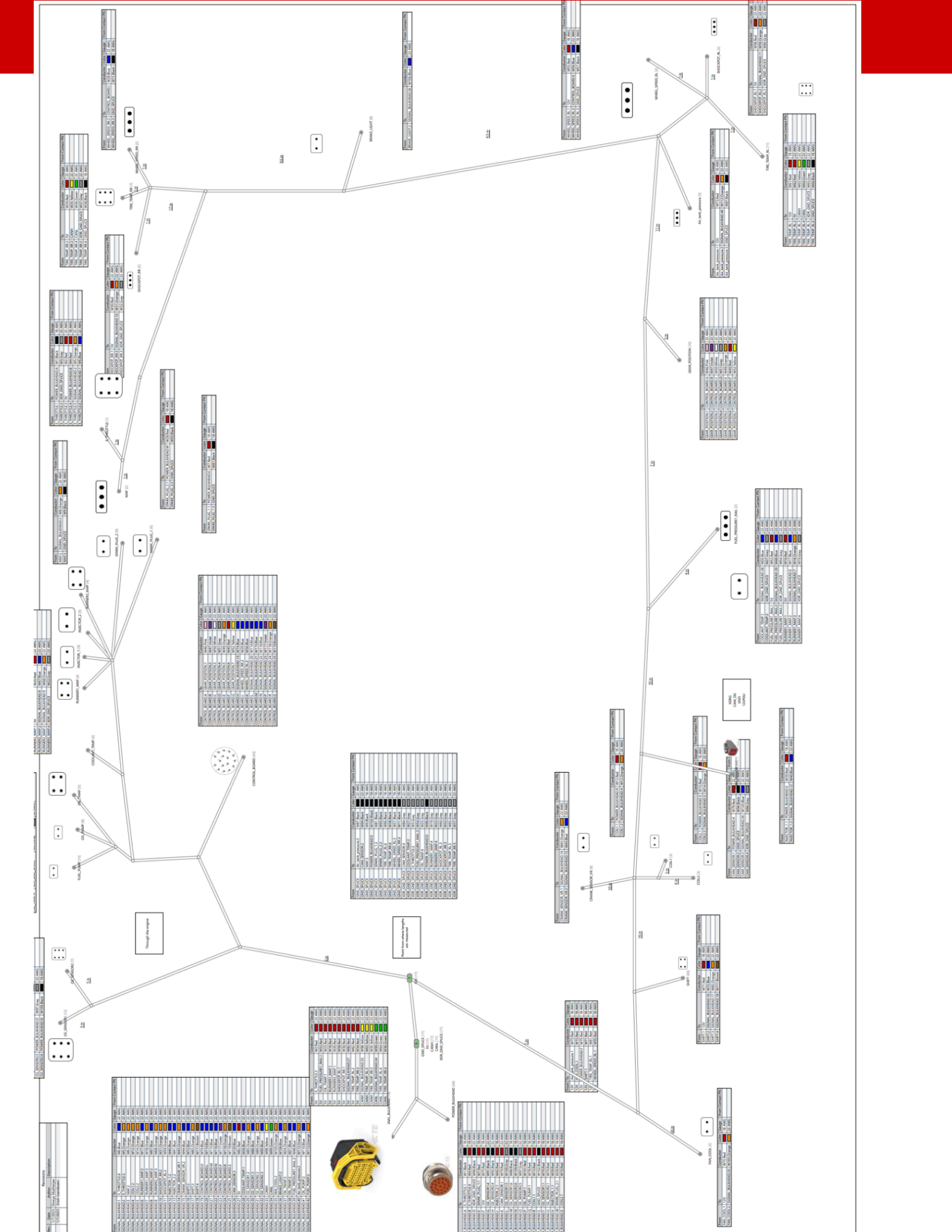


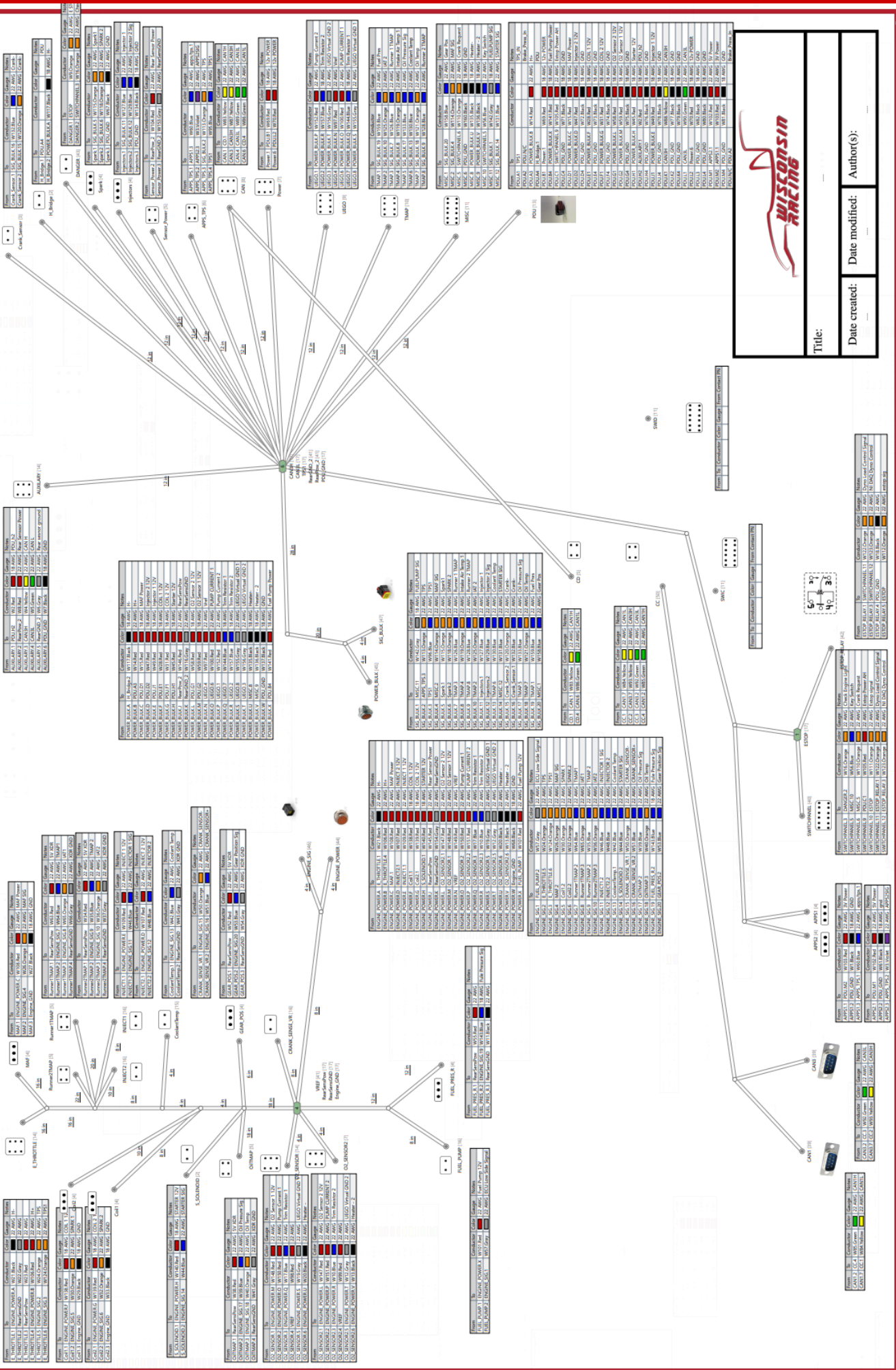
Item No.	Description	Unit	Quantity	Material Code	Remarks
36	1.0000	1	1	10000	1
37	1.0000	1	1	10000	1
38	1.0000	1	1	10000	1
39	1.0000	1	1	10000	1
40	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
41	1.0000	1	1	10000	1
42	1.0000	1	1	10000	1
43	1.0000	1	1	10000	1
44	1.0000	1	1	10000	1
45	1.0000	1	1	10000	1

Item No.	Description	Unit	Quantity	Material Code	Remarks
46	1.0000	1	1	10000	1
47	1.0000	1	1	10000	1
48	1.0000	1	1	10000	1
49	1.0000	1	1	10000	1
50	1.0000	1	1	10000	1







**WILCOSON RACING**

Title: \_\_\_\_\_

Date created: \_\_\_\_\_

Date modified: \_\_\_\_\_

Author(s): \_\_\_\_\_

## Low Voltage Load Characterization

The team characterized load currents from the 8 fuses using the DynoPDU so the smart circuitry didn't interfere with our measurements. This information will help us optimize the fuse panel for future iterations.

The loads on each fuse are as follows:

AH 1	AH 2	Fuse 1	Fuse 2	Fuse 3	Fuse 4	Fuse 5	Fuse 6
ECU AH	EVO	Front Sensors	Steering Wheel	ECU GLV	Injectors	Oil Pump Solenoid	O2 Heater (2)
MPRD Switch	IMU		Fuel Pump	Shifting	Cooling Fan		

### Process

For the testing setup, a current clamp was placed around each fuse output. An oscilloscope trace was taken as GLV was turned on. The test was repeated for each fuse output with the engine off and the engine on. The inrush current peak, steady state for both engine off and engine on was recorded. The cranking current for Fuse 3 was recorded to see how the ECU was affected by it.

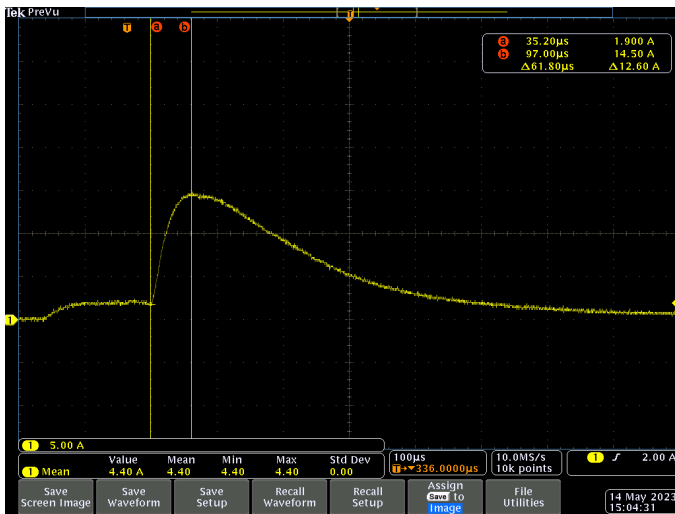
### Results

This table records the results we obtained from running this test. Included are snapshots of the oscilloscope traces of results we found particularly interesting.

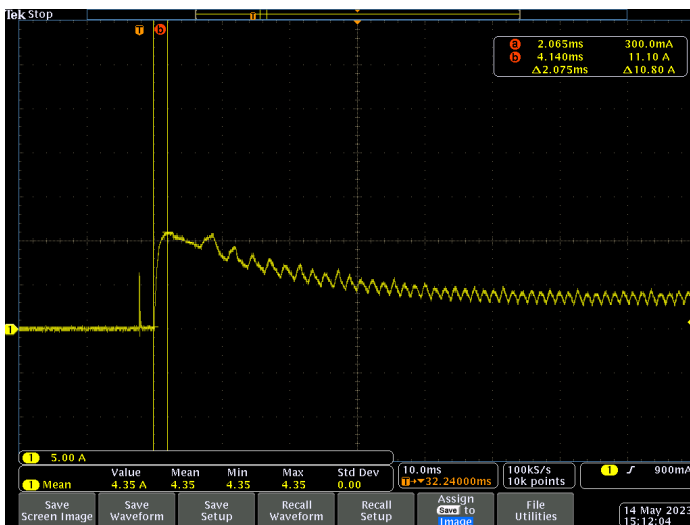
Fuse	Peak Inrush	Steady State (Engine Off)	Cranking	Steady State (Engine On)
AH1		0 100mA		100mA
AH2	14.5A	300mA		300mA
F1		0 100mA		100mA
F2	11.1A	4.5A		4.5A
F3		0 3.3A Peak (Oscillating)	8A	1A Peak (Oscillating)
F4		0	0	1.8A Peak 20Hz Square Wave with d=10%
F5		0	0	4A
F6	3.9A	3.7A		3.5A

Capacitance Equation:

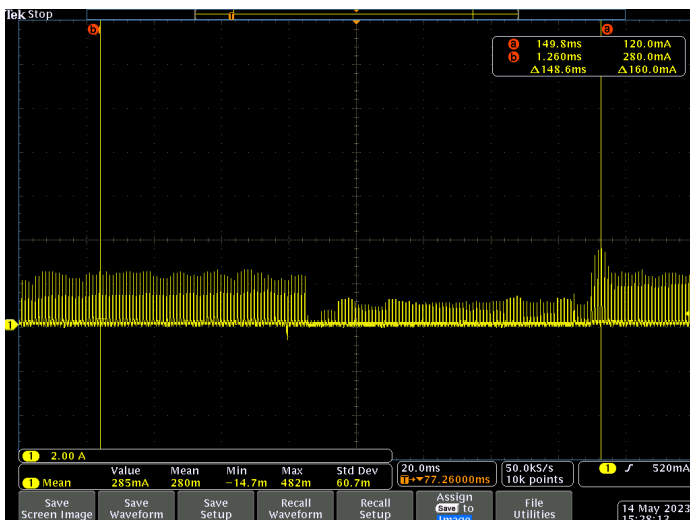
$$C = \int (i dt) / V$$



Always Hot 2 Inrush (Evo)  
 Calculated Capacitance: 40uF



Fuse 2 Inrush  
 Calculated Capacitance: 1.2mF



Fuse 3 ECU Oscillations

It is important to know that this power output pulses like this because it is a source of EMC in our system. To mitigate this, we shielded sensitive signals and routed them away from things powered by the ECU when possible.

## Electric Car Designs

### Overview

Wisconsin Racing also builds a car for the electric competition. The unique electrical designs for the electric car can be found here: <https://www.wisconsinracing.org/e-documents/>.

### Electric Car Specific Designs

- Battery Management System
  - Battery Main Board - Centralized Low Voltage System
  - Battery Sensor Board - LTC6811 battery management IC
  - Battery Trace Board - Muxing System for cell measurement
  - Battery Management Algorithms and code
- 3 phase Quad Inverter (motor controller)
  - Control Card - Houses motor controller, signal and fault processing
  - Gate Driver - Houses the gate drivers and isolated power supplies to drive the gates of the IGBTs
  - Double Pulse Testing - Validation of the inverter switching efficiency
- Precharge
  - Board to control the ramp up of voltage when initially turning on the high voltage system
- Motor Controls
  - Custom motor controls for a 3 phase synchronous motor.
- High Voltage Daughter Board
  - Senses the high voltage bus and controls the Tractive System Active Light
  - Houses the HV to LV DC DC converter
- Systems Integration

### Shared Designs - Only Found in 2023 ECar Design Release

- Smart Power Distribution Unit
- Steering Wheel
- Brake Systems Plausibility Device

## Contact Us

To contact the team, email: [team@go.uwracing.com](mailto:team@go.uwracing.com)

To contact the 2023 Electrical Technical Director with questions related to this document and its designs, email: [c.schusterr@gmail.com](mailto:c.schusterr@gmail.com)

Thank you for reading! Good luck from Wisconsin!

