An Analysis and Recreation of the VESC Motor Controller

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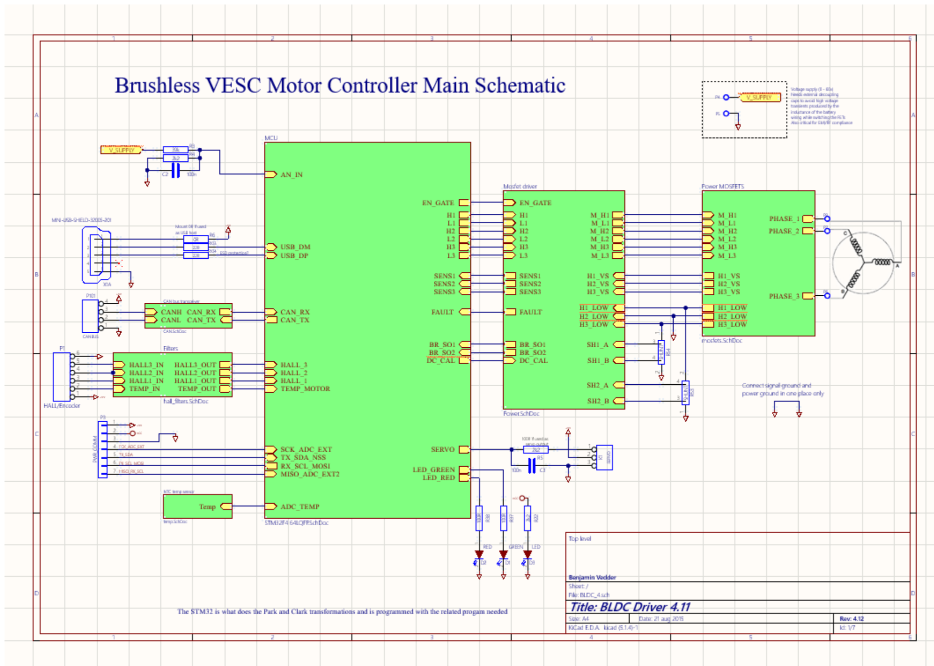
1 Purpose of Project

The purpose of this project was primarily to learn about motor controllers and understand how one functions schematically speaking. Personally, I don't have very much experience with motor controllers and didn't know much of anything before this class, so I wanted to take the time and understand them since I use them in projects blindly.

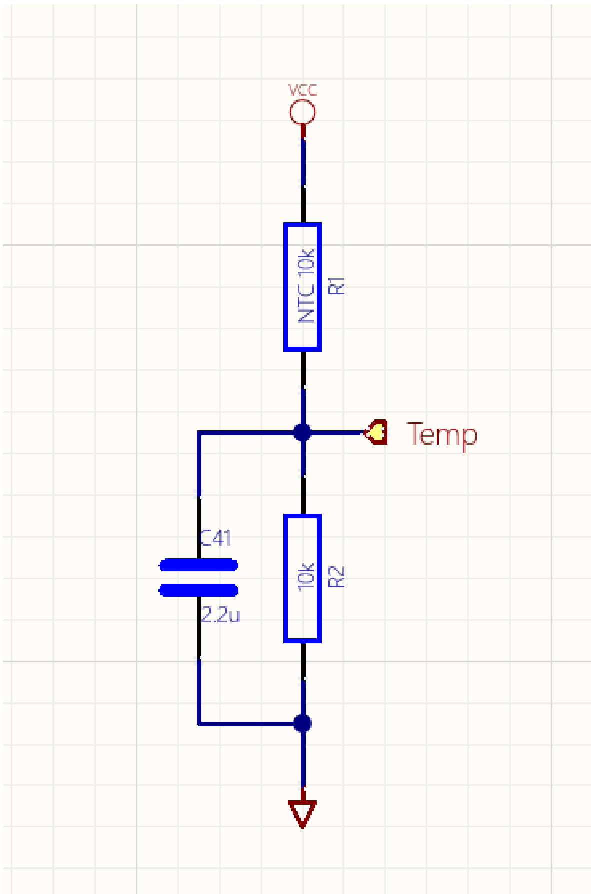
2 Purpose of a motor controller

The purpose of a motor controller is usually to control the speed or torque of a motor that can be attached to a variety of different things. Motor controllers could be applied to an electric vehicle, machinery, or any other application that involves motors. Controlling a motor in general is a complicated process and changes depending on what type of motor you are using. Using a motor controller, you can make this complicated process and turn it into something simple just using a potentiometer.



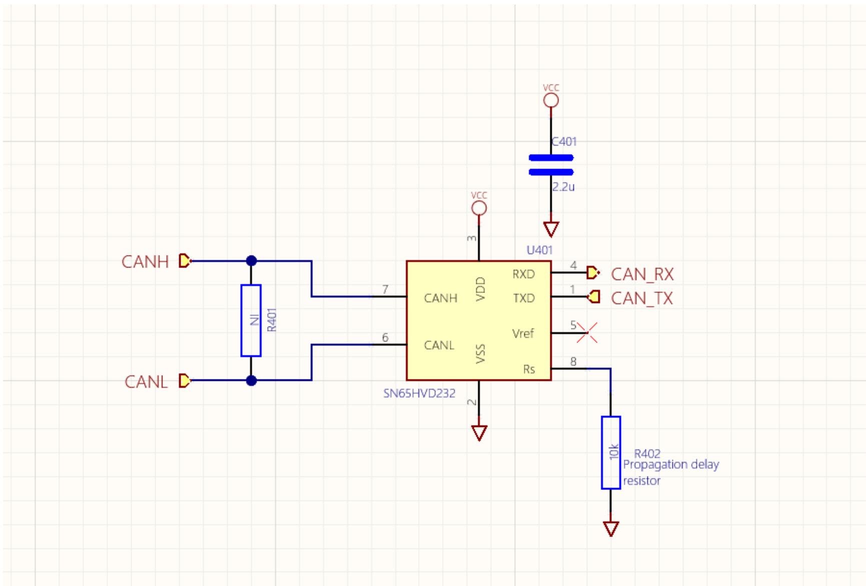
3 Different parts of the VESC Motor Controller

There are a few main parts of the VSEC motor controller. First, there is the "Brain" of the system, or the MCU. In this situation the part is called an STM. Next, there are the MOSFETs and the MOSFET driver. The MOSFETS are three pairs of N Channel MOSFETs that make the motor turn. The MOSFET Driver is a chip that runs these MOSFETs. Next, there is the CAN Transceiver. This transceiver is meant to take in CAN signals from other parts of the EV that it's designed for and translate them into actions performed by the STM. Lastly, there are the Hall filters and the temperature sensor. The hall filters take in the data from the Hall sensor and filter it out and clean the data. The temperature sensor takes the temperature and sends it along to the STM just like all the other parts of the schematic.



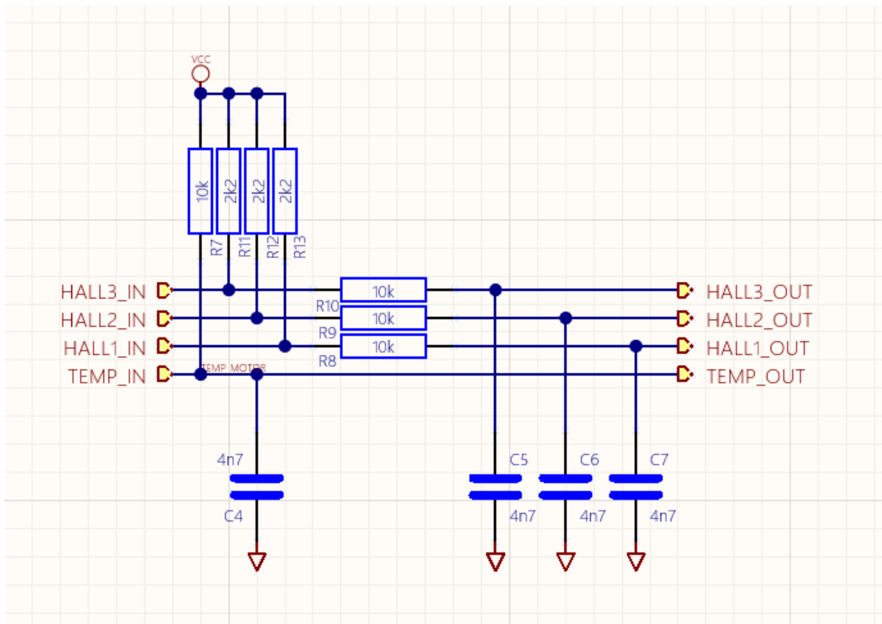
4 Temperature Sensor

The temperature sensor is the simplest part of the schematic and is in the form of a basic resistor divider. It follows the equation of a resistor divider and uses a thermistor to take the temperature and send it to the Microcontroller.



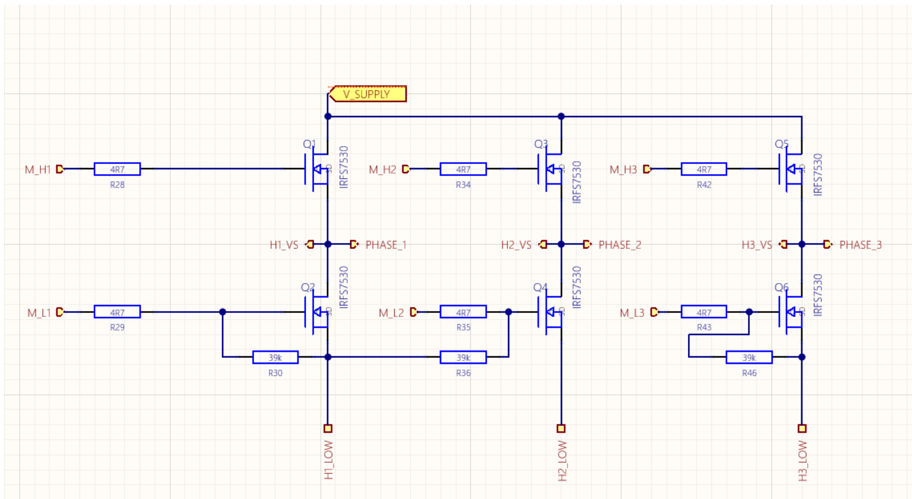
5 CAN Transceiver

The CAN Transceiver is not seen on all Motor controllers. In this situation, this VESC motor controller is being used in an Electric Vehicle, so a CAN transceiver is appropriate to install. Even in actual cars and full size electric vehicles, CAN is a commonly used communication protocol. In this schematic, the inputs are CANH and CANL. When data is being transmitted, the voltage of CANH is greater than the voltage of CANL. When data is not being transmitted but the connections are still present, the voltage between CANH and CANL is the same. Another thing in the schematic that can be seen in the top right corner is a capacitor between VCC and Ground. The purpose of this capacitor is to be a bypass capacitor and prevent noise from entering the system since noise could disrupt the data.



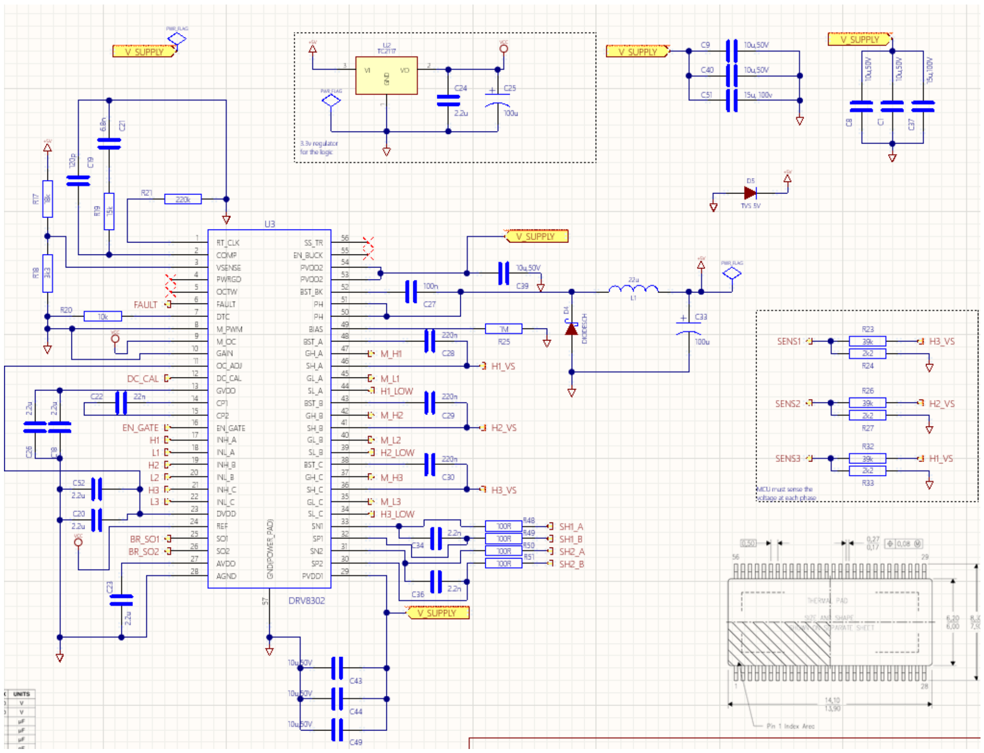
6 HALL Filters

A Hall effect sensor uses the Hall Effect to locate the position of a magnet inside of a motor and relay that information to the Microcontroller. With this information, the STM32 is able to spin the motor correctly and know which coils to activated at exactly what time. This block of code is taking in the hall effect sensor data and cleaning it for the MCU. It uses a series of capacitors and resistors to remove any noise or signal issues that the STM might have taking in the data.



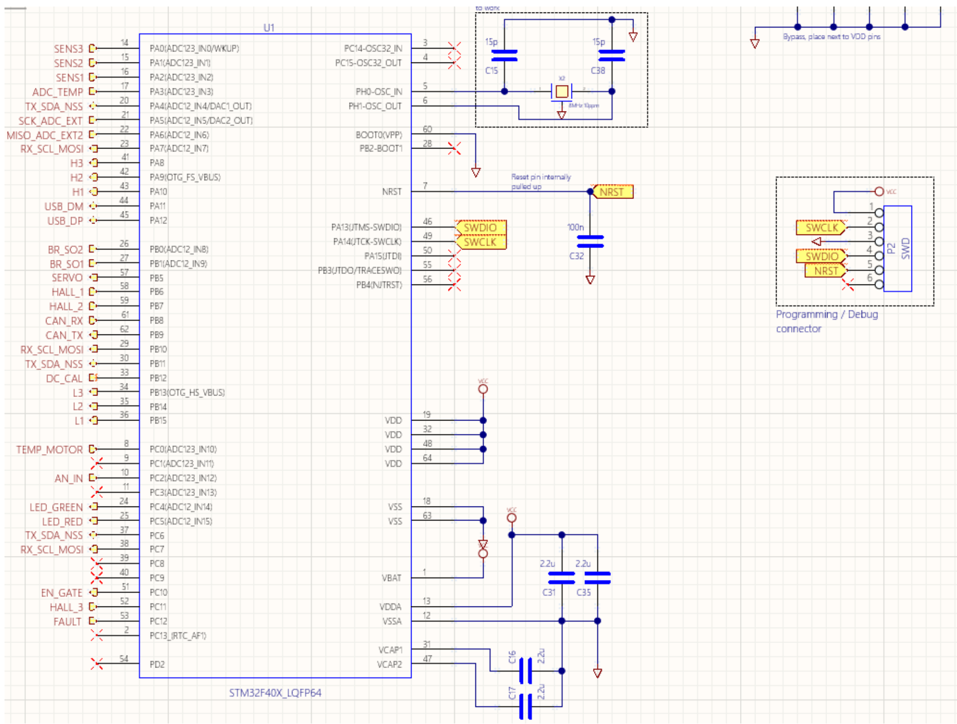
7 The MOSFETs

In order to make the motor spin, we need to do what's called 6-step commutation. This process involves activating and deactivating 3 pairs of N-Channel MOSFETs to make the coils activate at the proper time. The schematic shown has the 6 N-Channel MOSFETs and their proper data they need to turn on. In this situation, the N-Channel MOSFET is being used as a switch to turn the coils off and on.



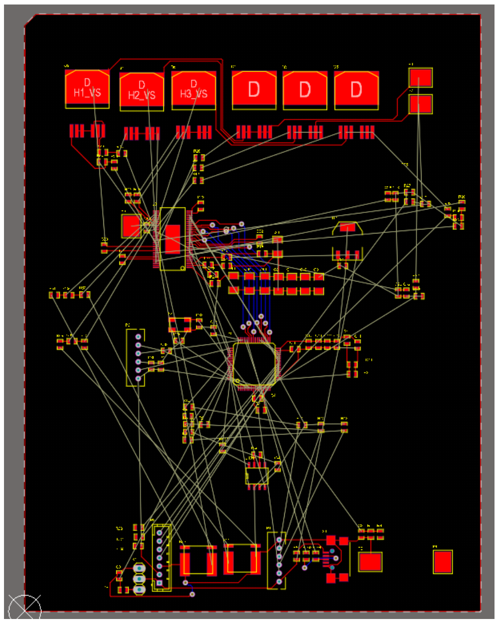
8 The MOSFET Driver

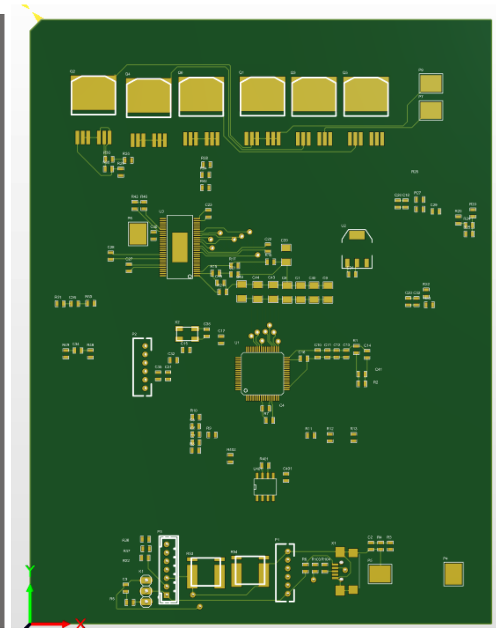
The MOSFETs are the most important part of the system, but without the MOSFET Driver, the MOSFETS would be meaningless. The big block (DRV8302) in the schematic is what drives the N-Channel MOSFETs and allows for 6-step commutation. The outputs in this schematic are MH1, ML1, MH2, ML2, MH3, ML3, H1VS, H2VS, H3VS, H1LOW, H2LOW, and H3LOW. These outputs drive different parts of the MOSFET setup and are critical to the success of the motor rotation. What can also be noticed is many capacitors throughout the schematic of the MOSFET Driver. These are not bypass capacitors like the others, but are in fact bootstrap capacitors meant to help the Driver. The second smaller schematic is a Linear Voltage regulator (TC2117) and provides 3.3V for logic. The reason this is a voltage regulator and not a buck converter is because although the linear voltage regulator is inefficient, using a buck converter would create noise which is not ideal for logic. There are also several miscellaneous bus capacitors to help filter out AC voltage from the DC voltage.



9 The Mictrocontroller Unit: STM32

The Microcontroller Unit, AKA, STM32, has the most complicated job, but happens to be the most straightforward. The STM takes in all the data from the other parts of the system and controls essentially everything. It receives the Hall effect sensor data, the temperature sensor data, the CAN transceiver data, and power and turns it into a functioning package to make a motor turn. Additionally, there are a few small LEDs to indicate the current status of the system.





10 Layout + My Alteration of the Design

For my layout part of the project, I wanted to try making a layout that only used one side of the board. I wanted to apply an assumption that when the board is being used, it will be attached to a face on one side and will therefore make one side unusable for components. The idea is that I can still use vias and routing on the other side, but I can only place components on the one side available. Unfortunately, this part of the project turned out to be a bit more difficult than I thought and didn't get finished, but by breaking the layout into sections, I was able to somewhat neatly organize my board components even though they didn't get completely connected.

This design is definitely not ideal and perfect. Having only one side of the board to work with limits a lot of things in terms of noise in the board, size, and efficiency of the PCB.

11 Takeaways and Conclusion

My main goal in this project was to dissect the VESC Motor controller and play with making my own altered version of the same board. I have learned a lot during this project and my interest in motor controllers has definitely gone up.

Overall, the VESC Motor Controller PCB is a work of art and should be treated as such. I hope to continue dissecting PCBs and learning more.

12 Resources Used

Almost all of my sources were from the pcb.mit.edu class website either under technical resources or in labs. The only other resources I used were past experience, youtube videos, and help from others.