LAFAYETTE COLLEGE

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Power Board Preliminary Design

1. Features

- 12V DC input from Battery
- 4 outputs of 5V
- 2 outputs of 12V

2. Applications

- Powering Arduino with 5V power supply
- Powering Touchscreen
- Two extra power outputs to power anything else
- Powering two motors

3. Description

The Power Board boasts a high-performance design, offering reliable output capabilities of 5V and 12V. The 5V power supply unit is capable of delivering up to 2A of current, while the 12V power supply unit offers a nominal output of 5A and the capability to handle surges up to 10A during motor activation. Additionally, the board is equipped with comprehensive short circuit protection for all output channels, ensuring reliable and safe operation. The easy-to-replace fuses further enhance the board's user-friendly design, ensuring seamless maintenance in the event of a fault.

4. High-Level Block Diagram

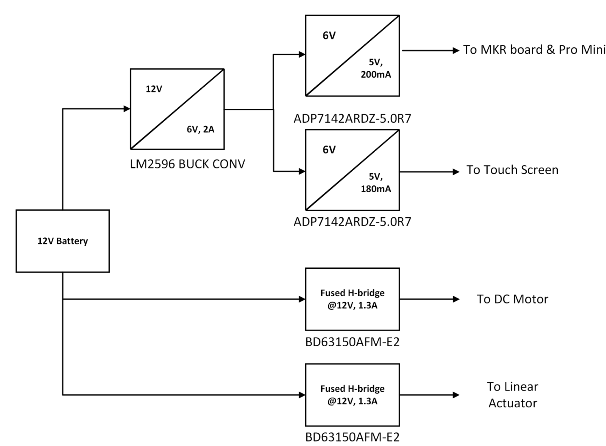

Fig 1: High Level Block Diagram of Power Board

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5. Deep Dive

5.1 H bridge

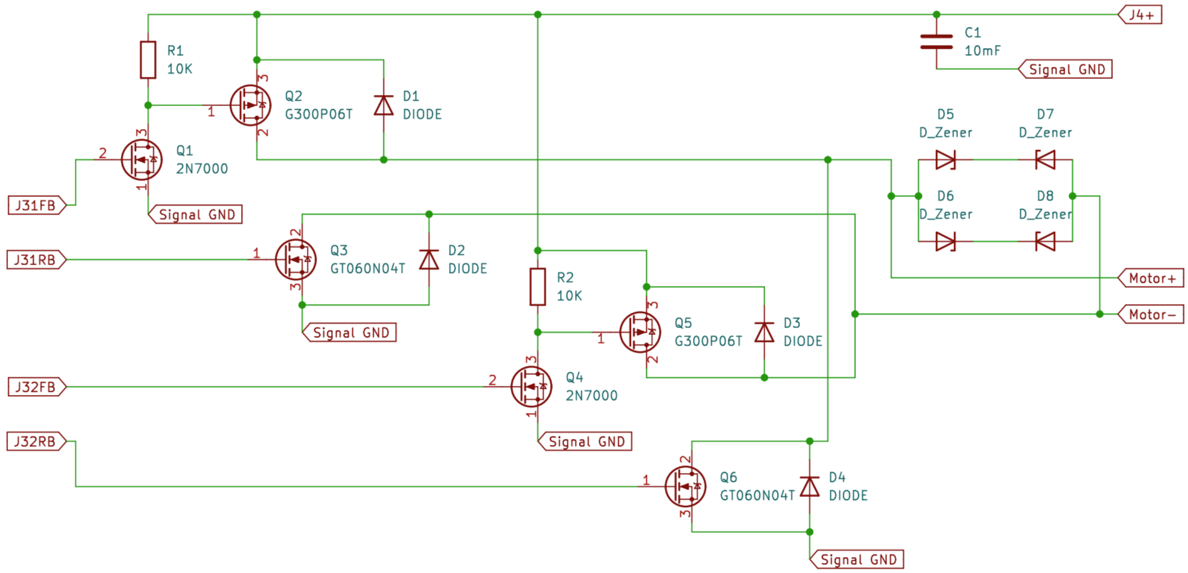


Fig 2: H-Bridge Control Module

The Motor Control Module is constructed using a H-bridge circuit, employing MOSFETs to achieve high performance and reliability. The bridge consists of two P-channel MOSFETs (Q2 and Q5) for the high side, with their gates connected to a pull-up switch incorporating a 10k resistor and N-channel MOSFETs (Q1 and Q4) from the schematic. Additionally, two N-channel MOSFETs (Q3 and Q6) are used for the low side, with all N-channel MOSFET gates connected to the Arduino. The control signal guide table is shown below.

Input				Output		
J31FB	J32FB	J31RB	J32RB	Motor+	Motor–	Mod
L	L	L	L	0V	0V	Motor off
H	L	L	H	12V	0V	Motor On forward biased
L	H	H	L	0V	12V	Motor On reverse biased

Table 1: H-bridge control signal guide table

The circuit is equipped with advanced protection mechanisms to ensure safe and reliable operation. A fuse is placed after the power source to prevent high current drain, and four zener diodes are installed in parallel with the motor to block reversing current flow. Moreover, four optional regular diodes are placed in parallel with the power MOSFETs to protect them from reversing current flows. A 10mF capacitor is connected in parallel with the power source after the fuse for effective decoupling.

Two identical control circuits are included, each designed to support either a warm gear motor or a linear actuator. Fig2 shows this connection.

The final PCB design is shown below.

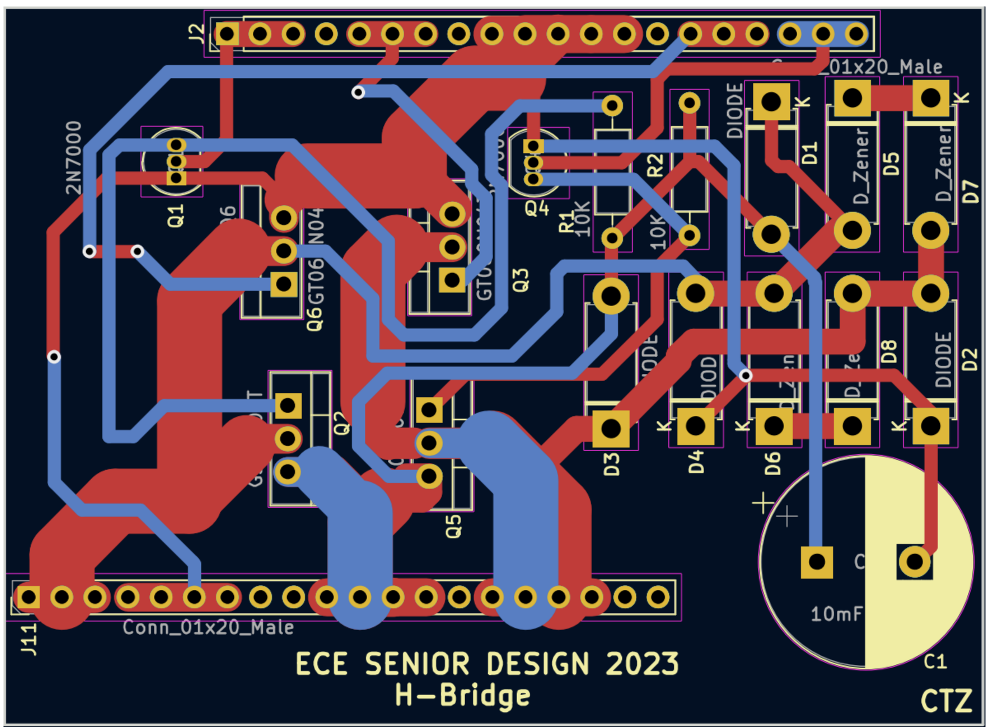


Fig 3: H-Bridge PCB circuit schematic

The inductive nature of motors opposes any instantaneous change in the current flow in itself. Therefore, after current is terminated by MOSFETs, the energy/current remaining inside the motor is needed to be re-circulated and decayed in order to protect the MOSFETs. To achieve that, when a half-bridge(one N-MOSFET and one P-MOSFET) is turned on and then off to complete a step, the N-MOSFET remains on for an extra time after P-MOSFET is turned off.

For instance, Arduino signal 1 which controls the P-MOSFET turns low after 10ms while the Arduino signal 4 which controls the N-MOSFET should remain ON for 300ms. Such procedure makes N-channel MOSFETs on to decay the current remaining in the motor after it is energized and expected to be off/de-energized. The example signal timeline plot is shown on Figure 14 and the actual effect on the H-bridge circuit is shown in Figure 3.

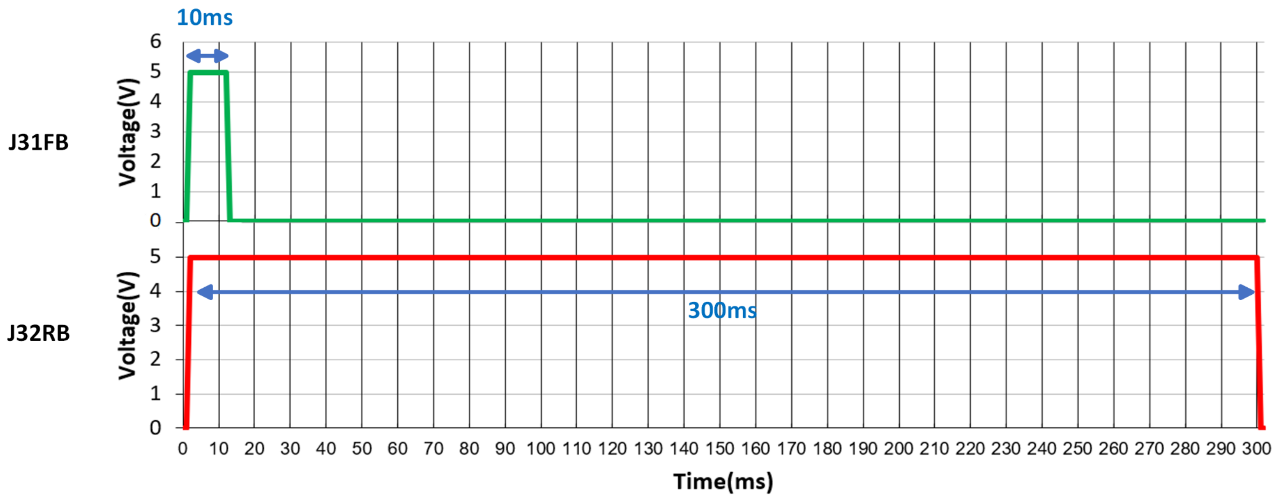


Fig 3: The signals controlling P-MOSFET(green) and N-MOSFET(red)

5.2: Step down Circuit

The Step-Down Circuit is primarily built around the LM317 Linear Regulator, which steps down voltage from 12V to 5V - the ideal voltage requirement for most system components.

The circuit comprises several key components, including capacitor C2 to improve ripple rejection, C3 to improve stability, and a protection diode D1 to provide a low-impedance discharge path that prevents the capacitor from discharging into the output of the regulator.

The output is controlled by resistor R1, whose value is calculated from the formula:

$$R1 = \frac{V_0}{I_{adj}} - V_{ref}(1 + \frac{R1}{R3}),$$

where $V_{ref} = 1.25V$,

$I_{adj} = 50uA$

$V_0 = 5V$

This circuit is equipped with a user-replaceable fuse that serves to protect it from any potential damage. Outputs of this circuit are:

a. 5V Arduino power supply
b. 5V Touchscreen power supply
c. 2 standby 5V power supplies.

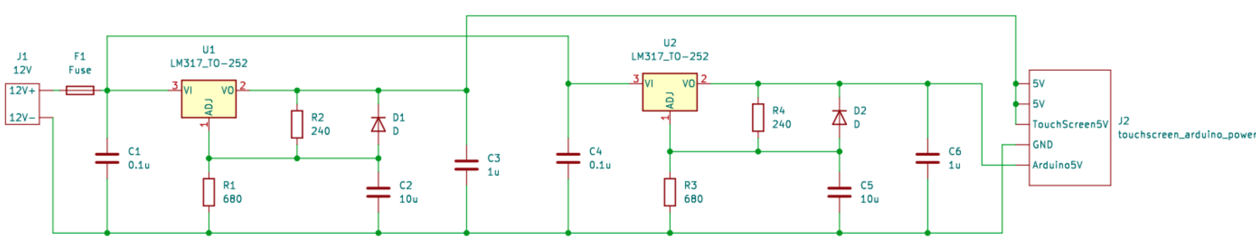


Fig 5: Step Down Circuit

6. Simulation

The circuit was simulated using LTSPICE to verify functionality. Fig 4 below shows the simulation results for the step down:

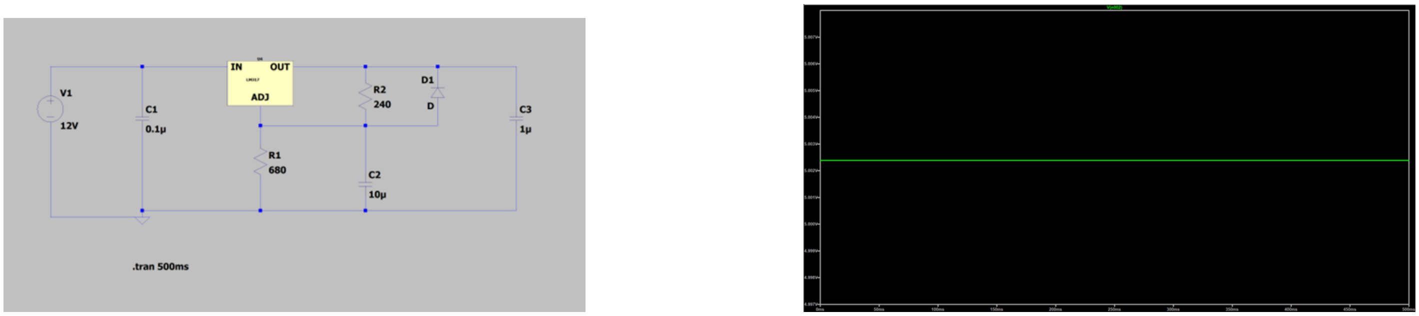


Fig 6: Step down simulation showing expected voltage of 5V

A pull-up switch built with a 10k resistor and a N-channel MOSFETs (BS170) is implemented to switch the power P-channel MOSFETs. As the plot shows, when the voltage source feeds BS170 with 5V, the Vds of it turns to 0V which will turn on the P-channel MOSFETs.

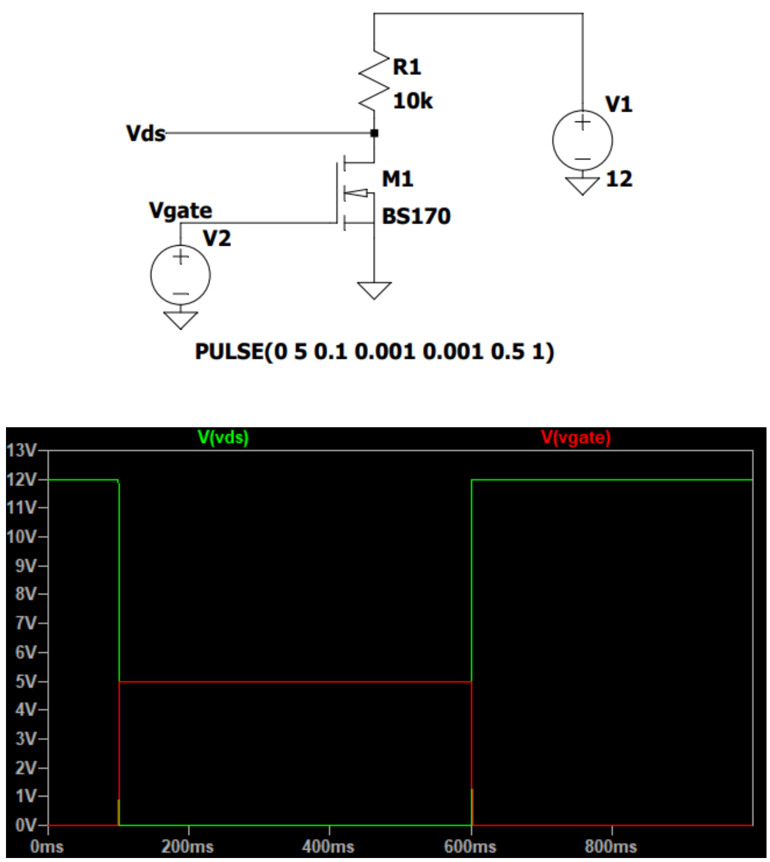


Fig 7: Pull-up switch schematic & signals timeline

Considering the inductance of the long wire used to connect between battery and powerboard, a decoupling capacitor is desired to provide extra voltage making up the one lost by the wire. By assuming the wire has 16AWG with 50cm long, the inductance of the wire is calculated as 660nH. The following calculation shows the appropriate value of the decoupling capacitor needed in this case.

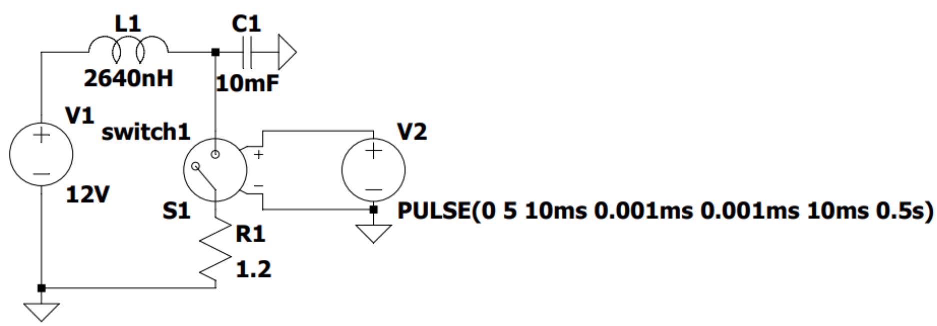
$$V_L = L\frac{dI_L}{dt} = 660nH \times \frac{10A}{2ms} = 0.0033$$

$$I_C = C\frac{dV}{dt} \qquad dV = V_L$$

For $I_C = 1mA$,

$$C = I_C\frac{dt}{dV} = 6mF$$

Furthermore, by the result of simulation, 10mF is a sufficient value of decoupling capacitor to do the job.



.model switch1 SW(Ron=0.001 Roff=1Meg Vt=3 Vh=0)
.tran 0 60ms 0.1ms 0.001ms

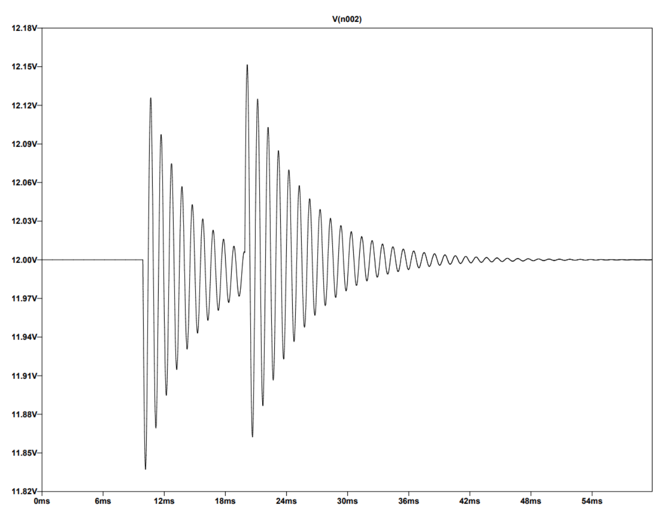


Fig 8: Decoupling capacitor simulation circuit & output voltage plot

7. Floor Plan

The power board was built on a circuit board that measures 20x30. To fit in the whole system design, it was modified to measure as shown in Fig 5 below:

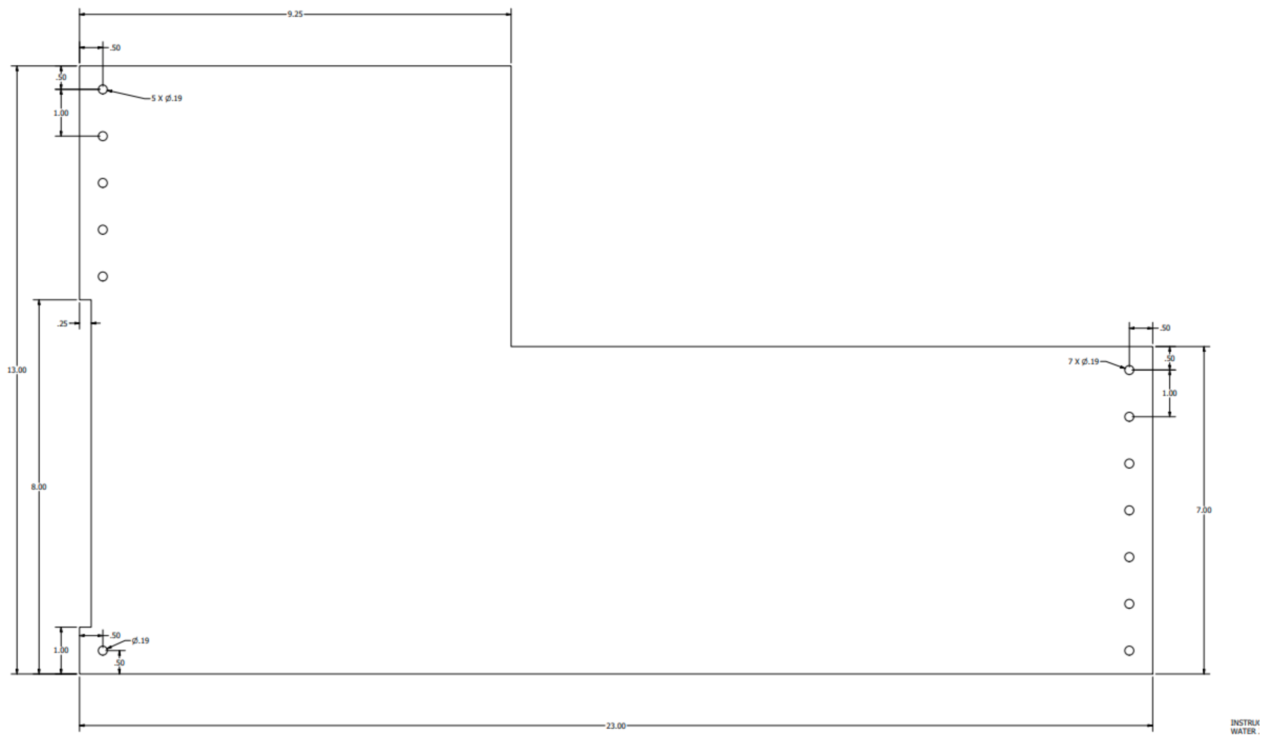


Fig 5: Modified power board with dimensions

9. Performance

Equipped with an ability to supply more than 1.5A, the LM317 regulator works well to supply the required currents to the devices. The current requirements of each component is as follows:

a. Arduino Pro Mini: 32mA
b. Arduino MKR: 120mA
c. Touchscreen: 180mA

It is worth noting that linear regulators often suffer from overheating issues. However, the LM317 has a recommended operational temperature range of 25 degrees Celsius to a maximum of 125 degrees Celsius. It is important to verify that the regulator operates within this temperature range in the current implementation.