Task 2: Input Protection Circuitry (Reverse polarity and inrush)

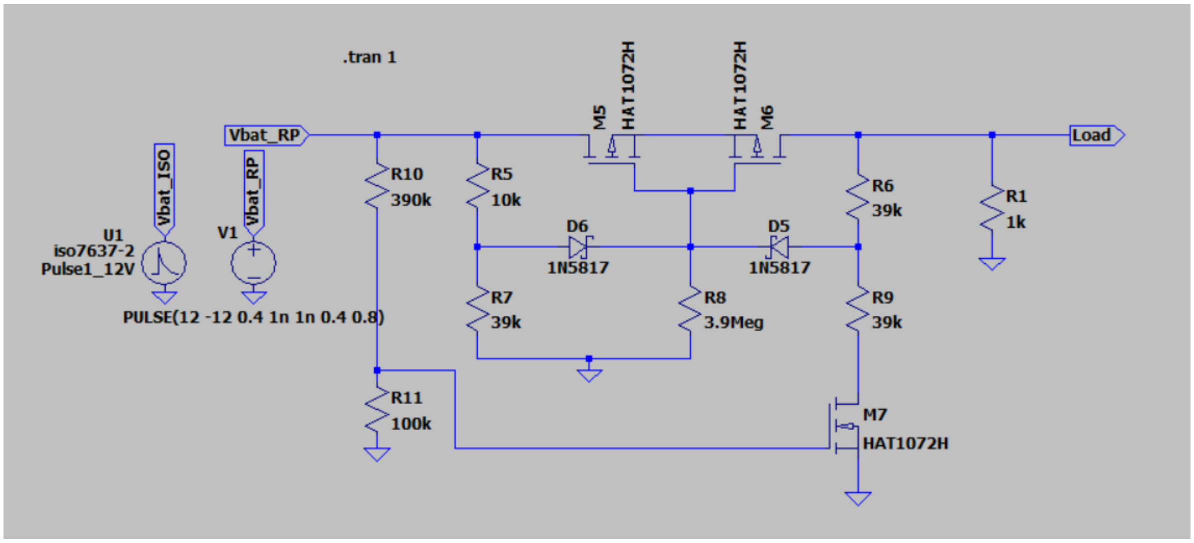


Figure 1. Circuit schematic

The circuit, built around 2 back-to-back PMOS, is first tested in a reverse polarity scenario where 12V and -12V are alternatively applied at its input.

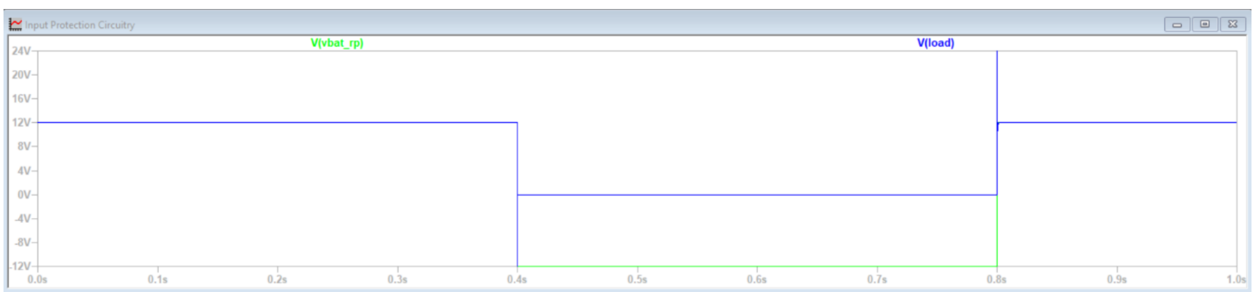


Figure 2. Reverse polarity transient response

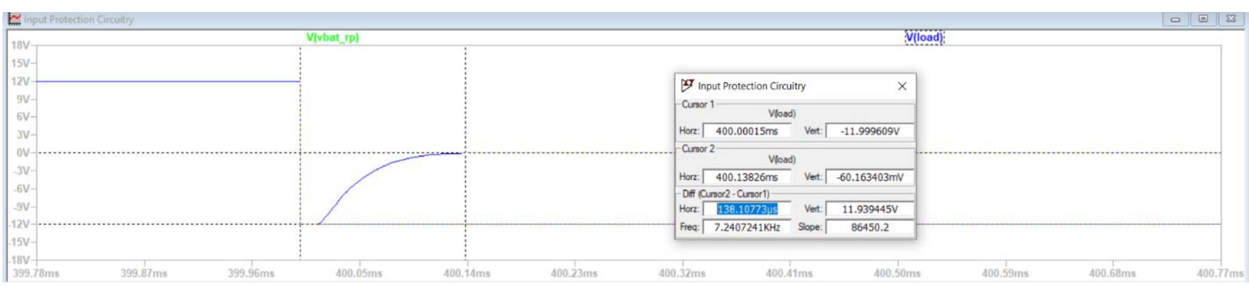


Figure 3. Negative step recovery time

Even though the output is pulled down to -12V initially, it stabilizes at 0V after almost 140µs.

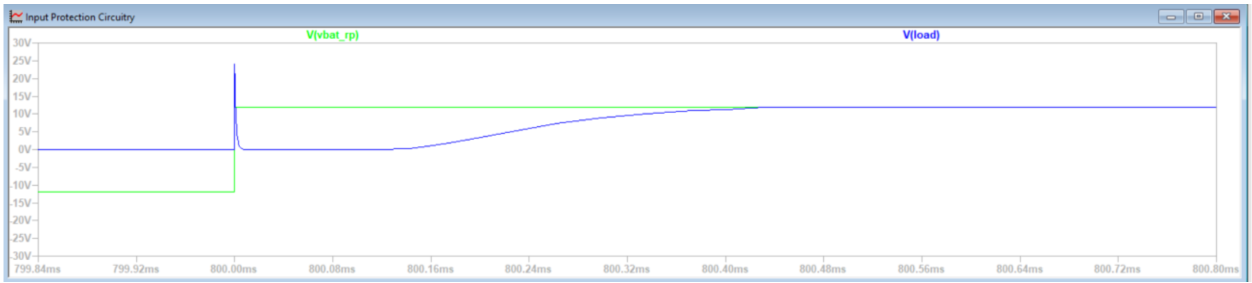


Figure 4. Positive step recovery time

When the supply is reversed from -12V to 12V we can observe a sudden overshoot to 24V that lasts less then 1µs, after which the output slowly rises to a steady 12V over 400µs.

ISO 7637-2 and ISO 16750-2 are the most common specifications encountered by engineers who design automotive electronics. These two specifications describe potentially destructive transients and the recommended test procedures to ensure that the electronics are suitably protected. For this purpose, the circuit was tested using a 12V pulse from the ISO 7637-2 library.

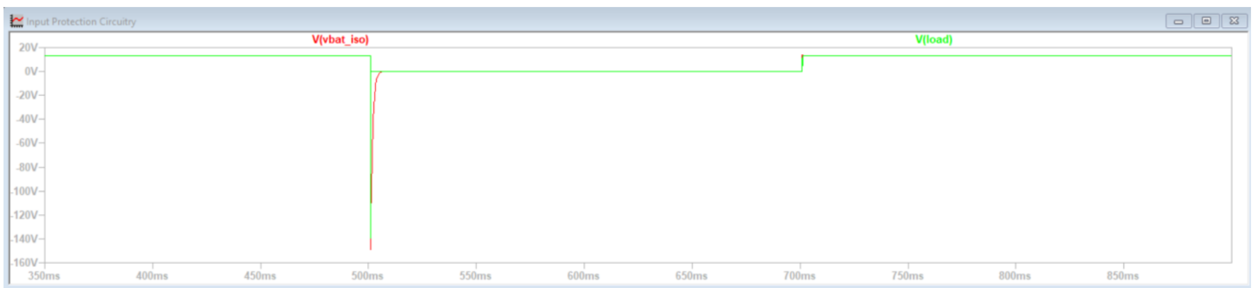


Figure 5. ISO 7637-2 transient response

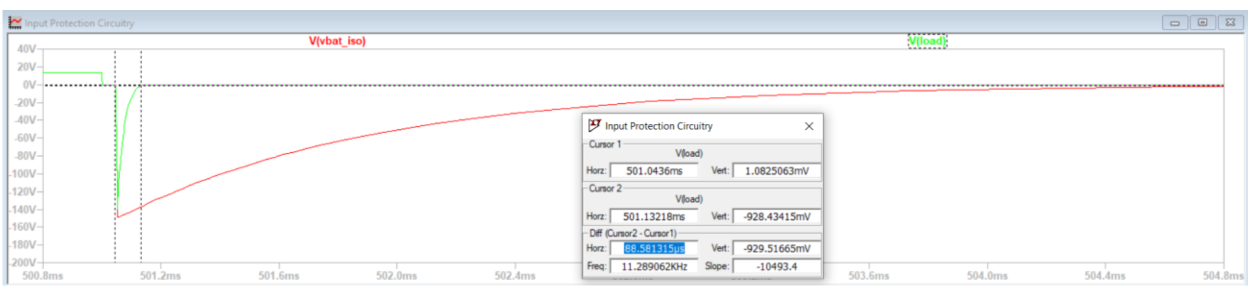


Figure 6. Negative step recovery time

During a -150V surge, the output of the circuit is able to bounce back to 0V in less than 90µs.

Figure 7. Positive step recovery time

This time, we can observe the output steadily stabilizing at 12V over 300µs.

Task 3: Power Supply PCB Integration

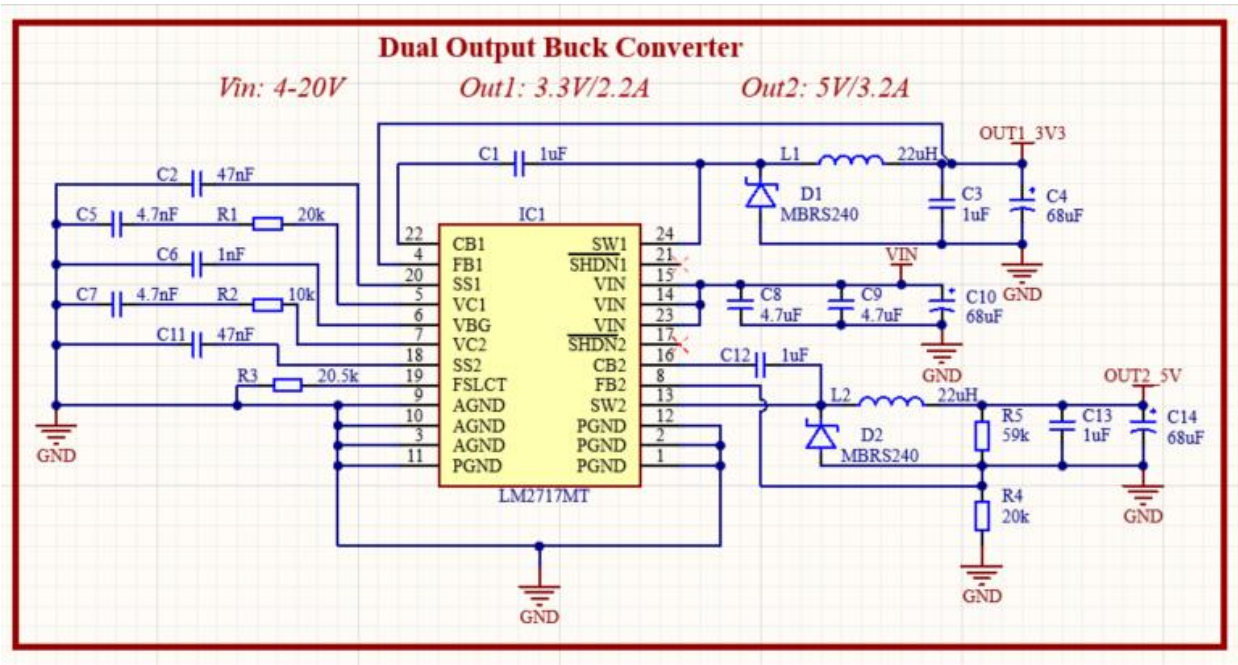


Figure 1. Circuit schematic desgned around LM2717 dual output buck converter

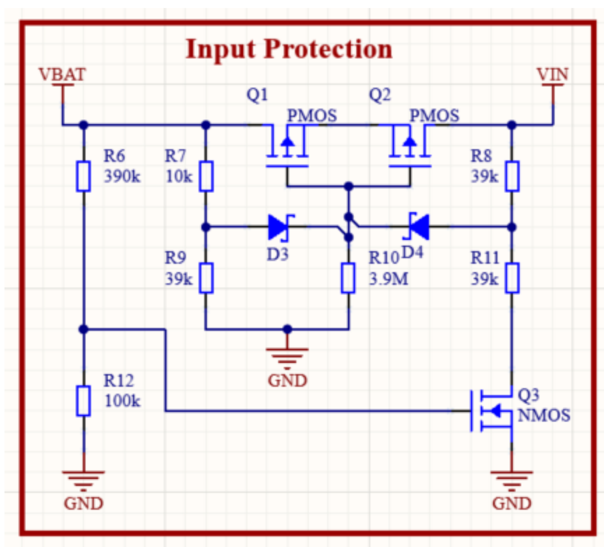


Figure 2. Input protection circuitry designed in task 2

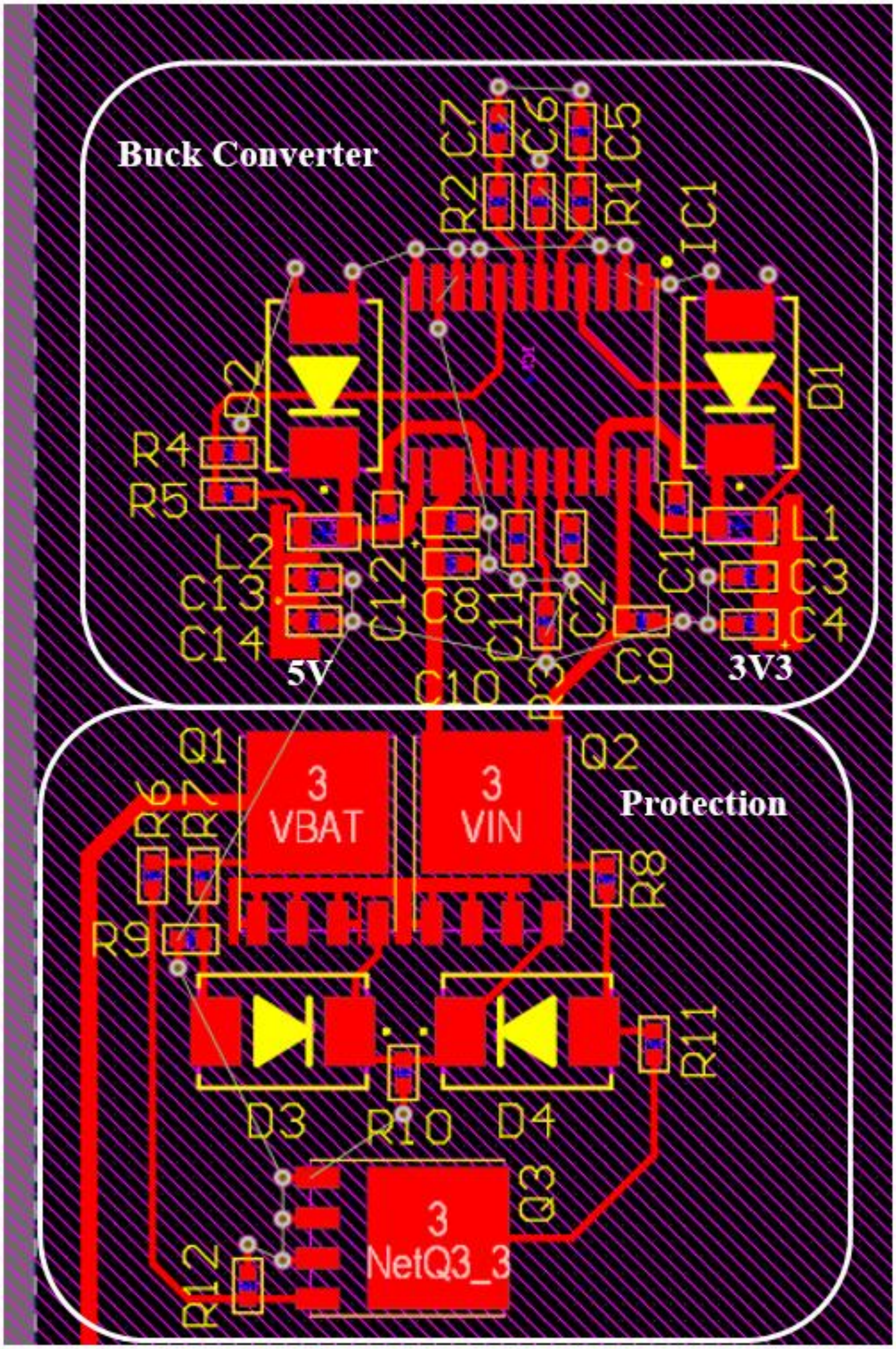


Figure 3. PCB layout

Task 4: DC Pump Driver

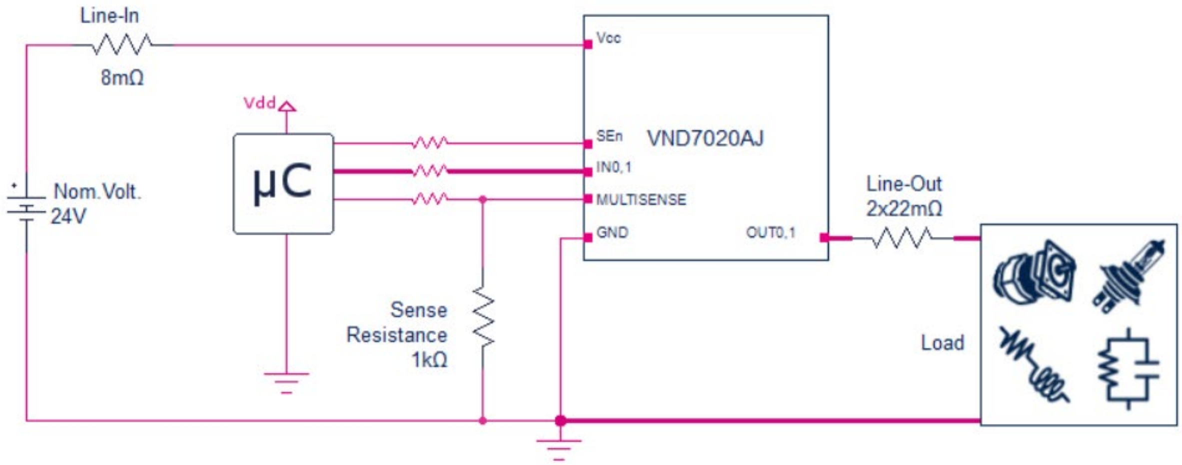


Figure 1. TwisterSIM Circuit

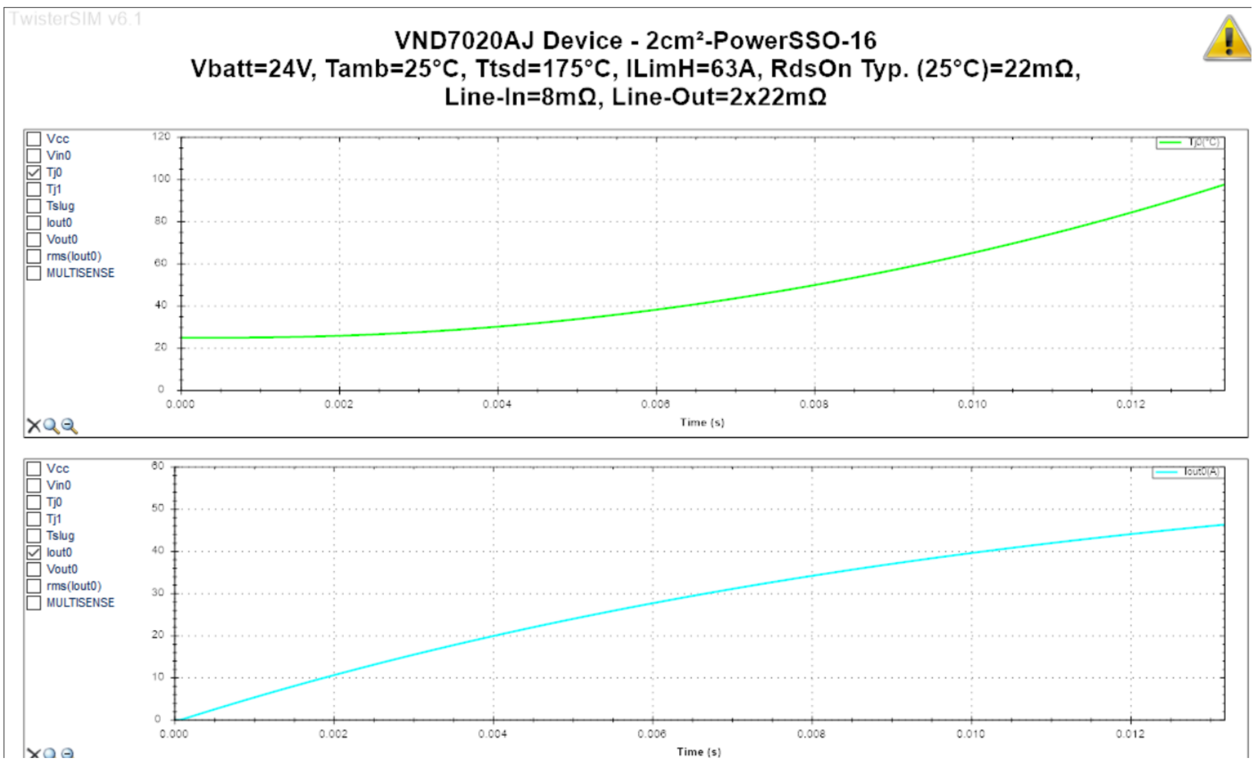


Figure 2. Thermal/Electrical Simulation

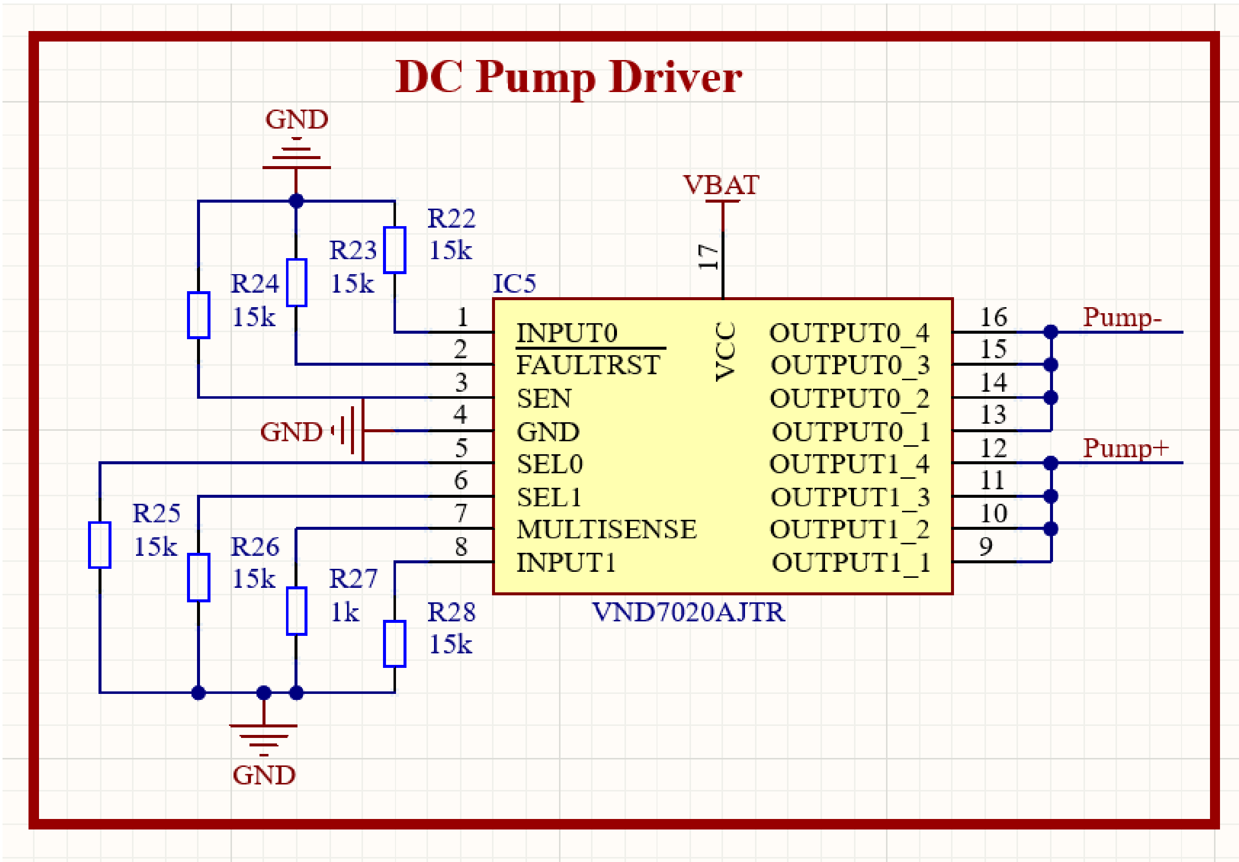


Figure 3. Altium Schematic Document

Task 5: Shunt Measurement Circuit

The task is to evaluate 2 shunt measurement circuits, one based on a dedicated instrumentation amplifier and one based on a differential amplifier side-by-side. The chosen IA is INA333 and the selected DA is LM2904. The goal is to design for a 10mΩ shunt resistance up to 15A.

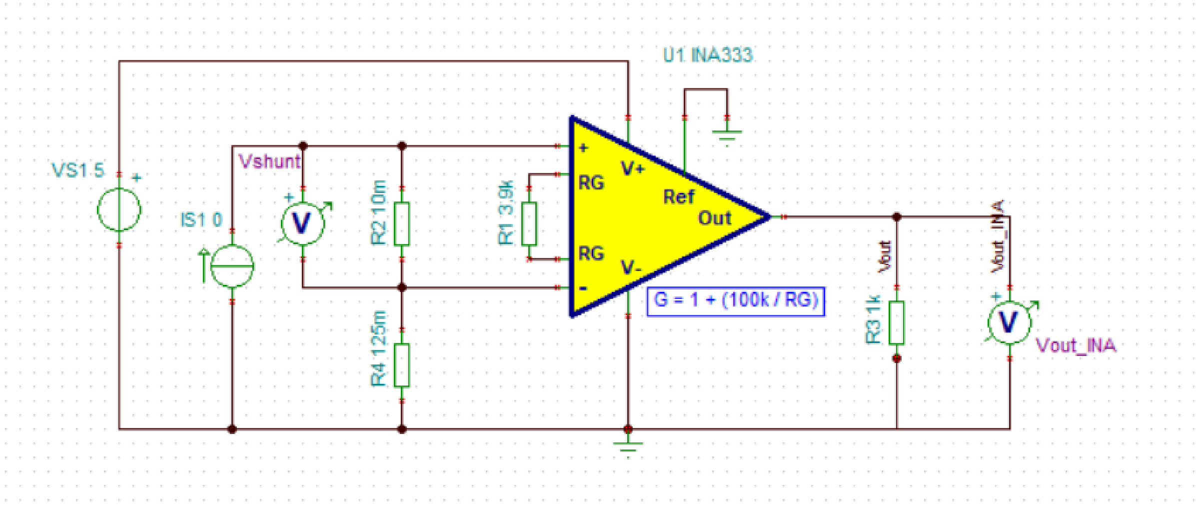


Figure 1. Shunt Measurement Circuit with INA333

A unipolar 5V supply is used, along with a generic 1kΩ load resistance – R3. R4 is used to raise the common mode voltage above 0 due to the unipolar supply. The value of the gain resistance RG is calculated according to the formula in Figure 1 in order to use as much of the available output voltage domain without getting clipped. A 3.9kΩ value results in a gain of 26.64. Considering that the maximum input voltage is given by a 15A current flowing through a 10mΩ resistance, resulting in a 150mV maximum value, the maximum possible output voltage will be close to 4V, which is well within the 5V limit without being too close. This fact is confirmed through simulation in Figure 2.

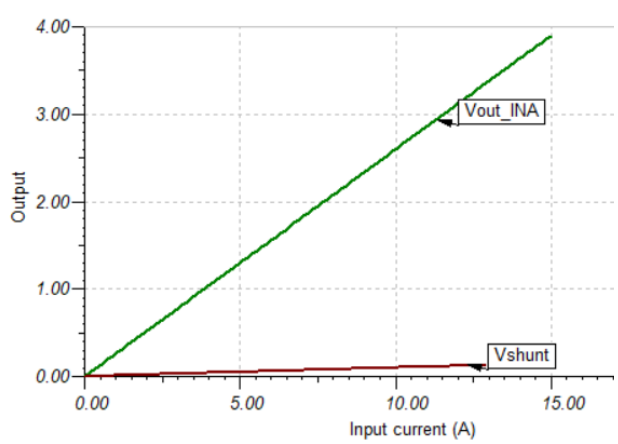


Figure 2. Input current vs. output voltage – INA333

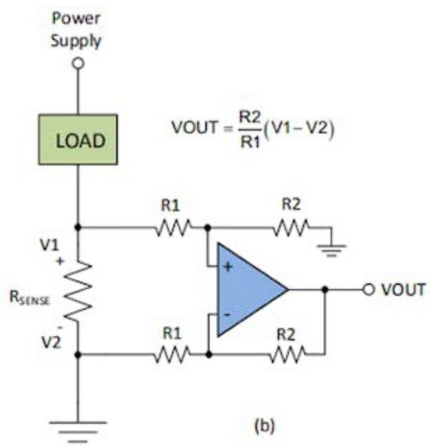


Figure 3. Differential Current Sense Amplifier

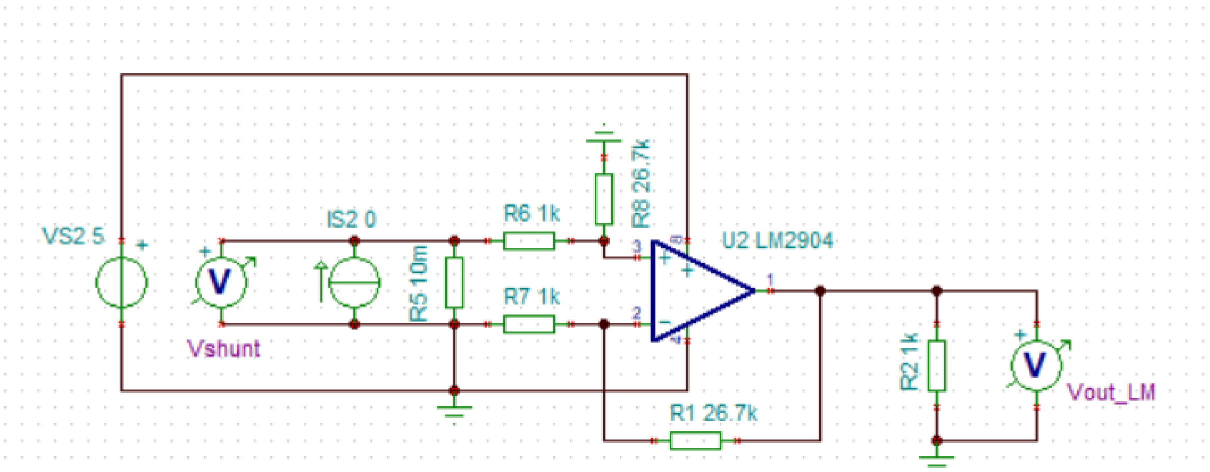


Figure 4. Shunt Measurement Circuit with LM2904

The gain is calculated using the formula in Figure 3 so that it matches the one in the first circuit as close as possible. The closest available value for the feedback resistor is 26.7kΩ, which results in a gain of 26.7, which is nearly identical to the previous 26.64 in order to maintain the same conditions for both circuits.

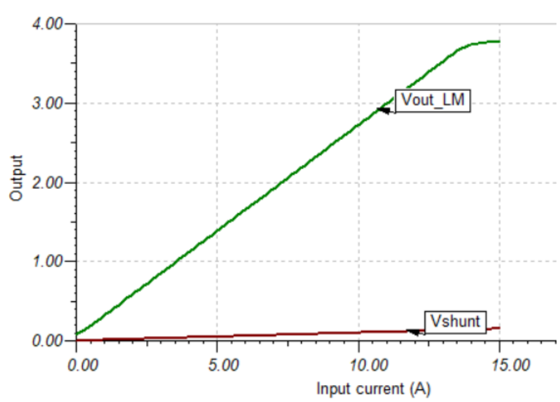


Figure 5. Input current vs. output voltage – LM2904

It can be observed that the output of the LM saturates a little faster than in the case of the INA. This makes sense when we consider that the INA is of type rail-to-rail and can get as close as 50mV to the supply voltage value, while the voltage output swing of the LM from the positive rail is no smaller than 1.35V under any test condition.

Up next the behavior of the output of both circuits will be compared when subject to temperature variations. The range for the simulation is chosen as the range of temperatures most commonly used in automotive applications: between -40°C and +125°C.

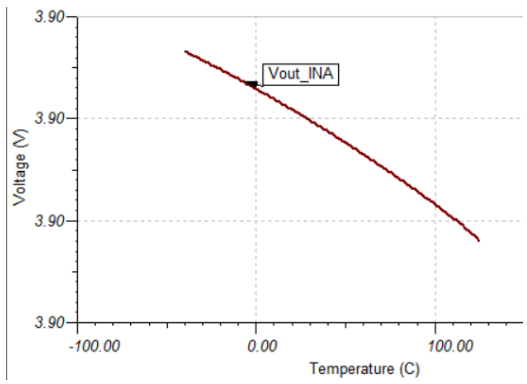


Figure 6. Output voltage vs. temperature - INA333

The output voltage of the INA only varies from 3.898V to 3.899V over the entire temperature interval.

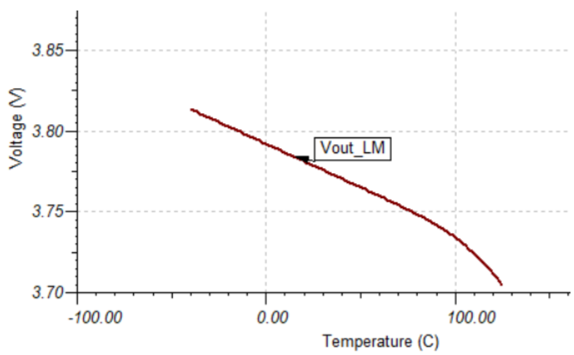


Figure 7. Output voltage vs. temperature – LM2904

The LM varies significantly more, from 3.71V to 3.82V, which is still acceptable but it performs 110 times worse than the INA by comparison.

Task 6: CAN transceiver with wake-up

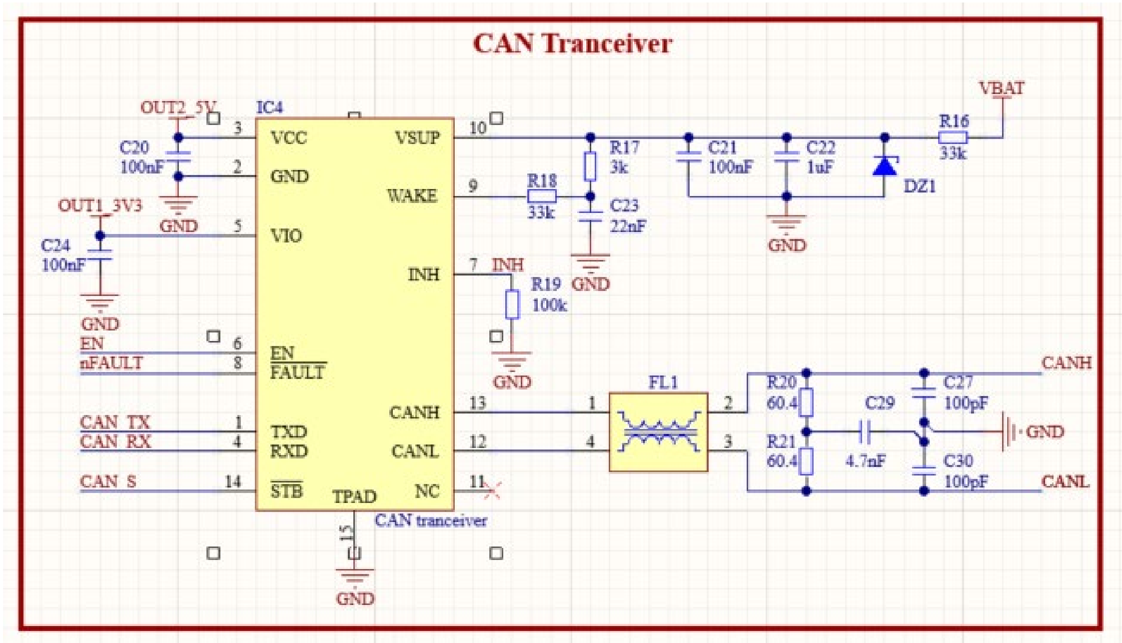


Figure 1. CAN tranceiver schematic

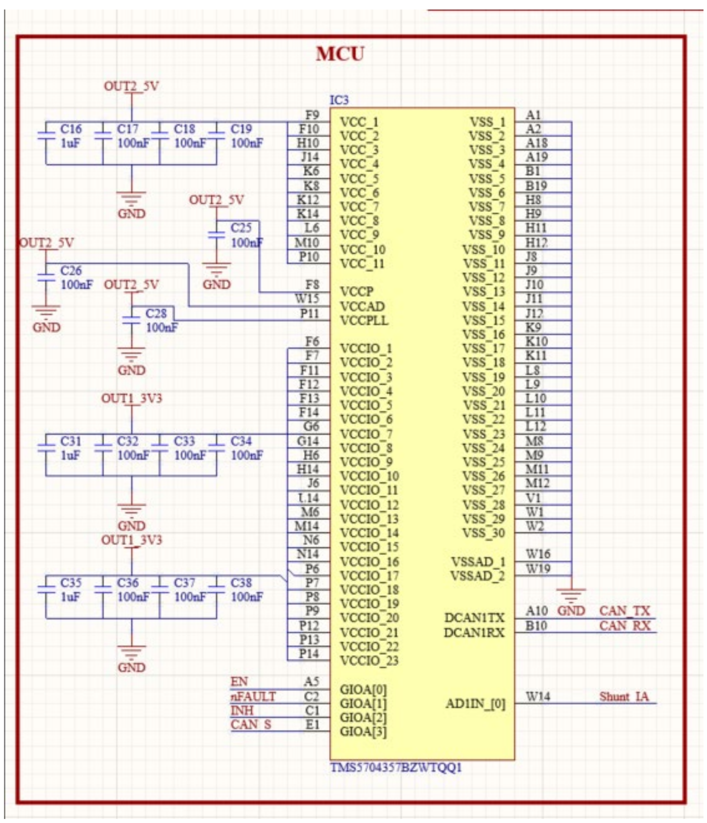


Figure 2. MCU schematic

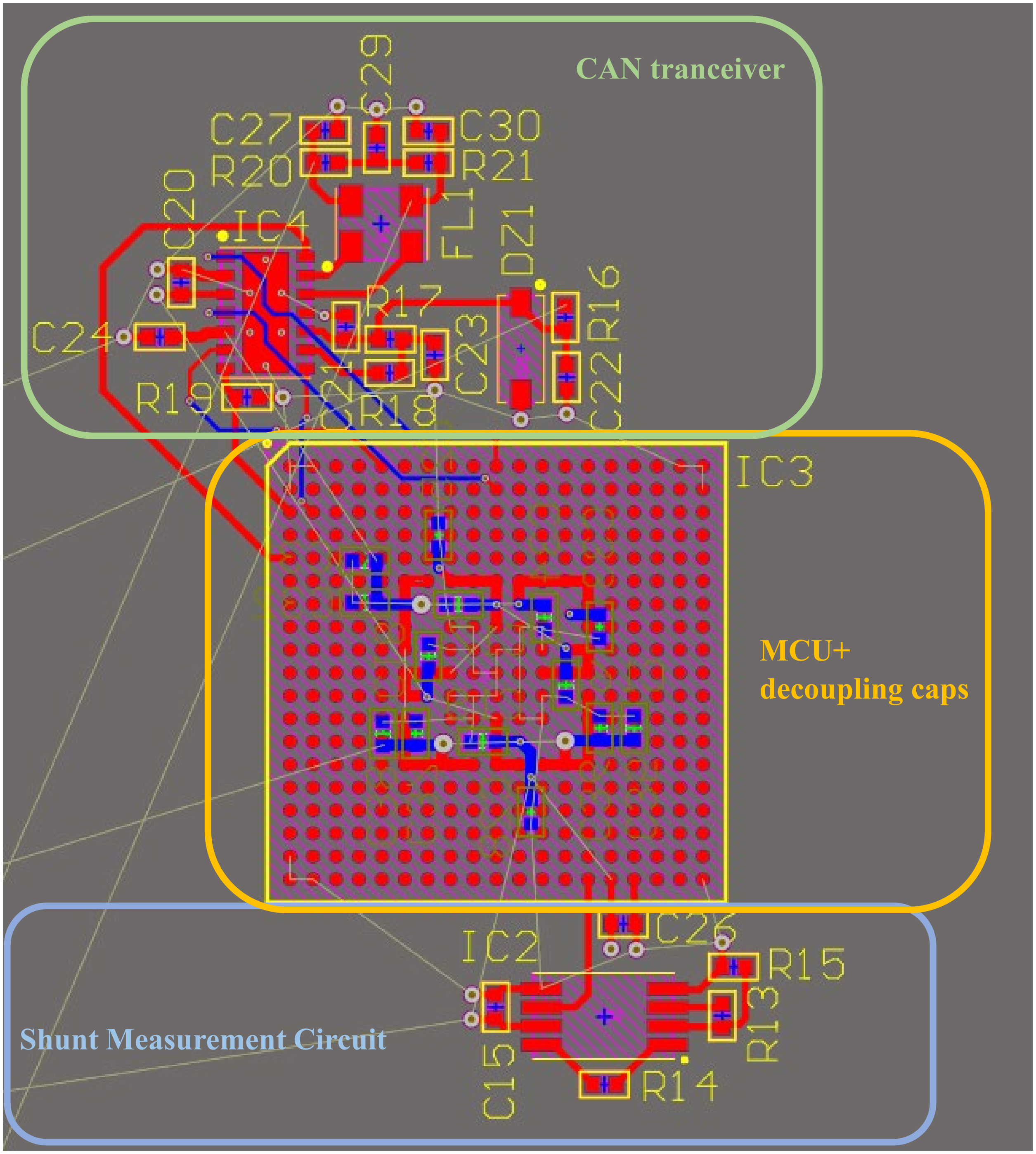
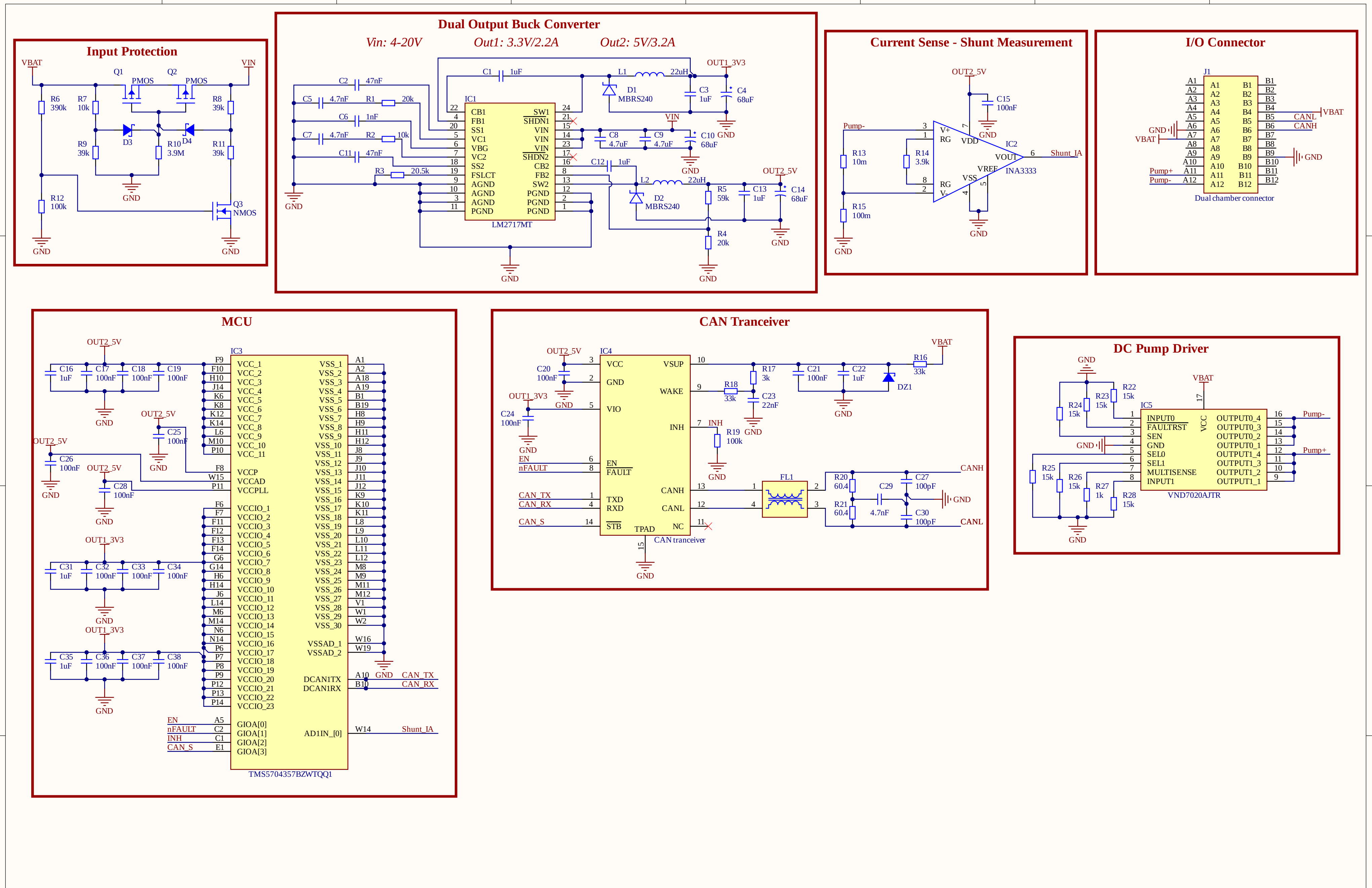


Figure 3. PCB layout



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