CubeSat Power Distribution System

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Abstract

Satellites require intelligent power distribution systems to manage the loads and sources onboard. A power distribution system is necessary to mitigate the effects of radiation. These highly energetic particles can FETs to latch in the circuitry, possibly causing a short circuit within a subsystem. This short circuit could drain the battery of the satellite within a matter of minutes. Therefore, the UW CubeSat team requires a power distribution system to provide overcurrent protection, current measuring, and current limiting ranging from 500 mA to 8 A for 6 different subsystems on their satellite as well as buck converters to create 5V and 3.3V power rails. Overall, this power distribution system must be able to shut off the current to a subsystem if the current rises above a certain threshold.

Furthermore, upon being launched into low-earth orbit, our board will be subjected to abnormal conditions. These problems include sub-zero temperatures, vacuum environment, and rigorous vibrations during launch and landing. Therefore, it is vital for our board to be fully functional at -40°C within a vacuum and be able to endure aggressive vibrations.

Approach

Figure 1 below is a block diagram of the CubeSat power system which details the location of the power distribution board as well as its input and outputs. After research, we concluded that the TPS24750 chip, manufactured by Texas Instruments, was the most affordable and efficient solution. An important feature of this chip is its ability to monitor and report current to an external MCU. We then designed and tested a PCB of the TPS24750 for a single subsystem through EagleCAD software.

In order for the battery voltage to be stepped down from 5-7.2V to either 5V or 3.3V, we also had to research an appropriate buck converter and found that the LTC3624 was the best candidate. We then designed and tested a successful iteration of a PCB for the LTC3624.

Once each of the nine switches and two converters are functioning individually, the final 10x10cm PCB will be designed, assembled, and tested. Finally, the complete PCB will be subjected to thermal, vacuum, and vibrational tests.

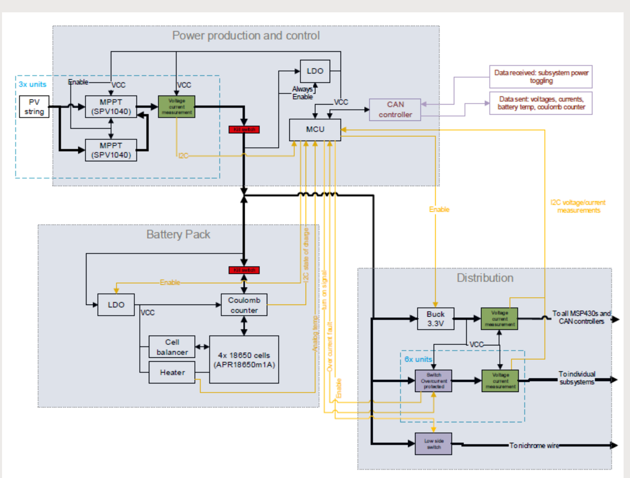


Figure 1. Overall power system diagram of the cube satellite. The power distribution system is the lower right block.

Design

Power Switch

- Equations to determine R_{sense}, R_{set}, R_{Imon}, C_{timer}:

$$I_{LIM} = \frac{.675\,V\ X\ R_{SET}}{R_{IMON}\ X\ R_{SENSE}}\ ;\quad C_{Timer} = \frac{10\mu A}{1.35\,V}\ X\ (Fault\ Time)$$ [1]

- Schematic and Board layout

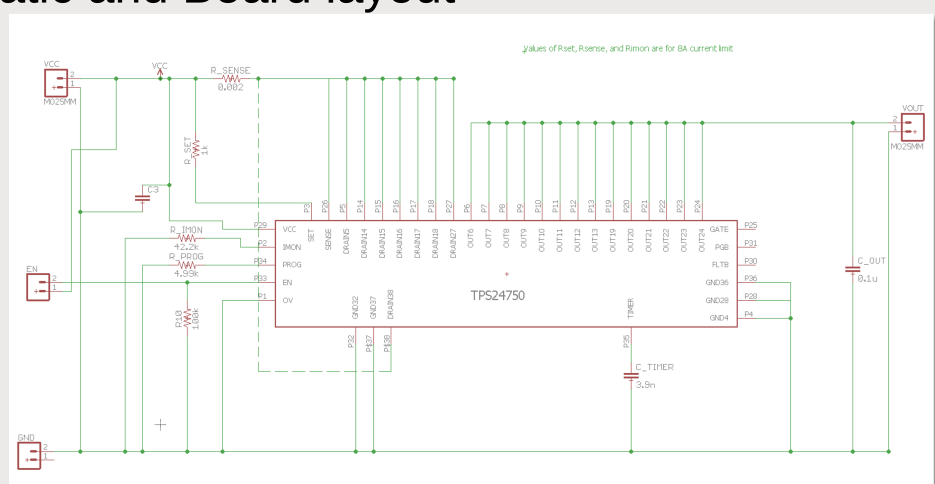


Figure 2. Schematic for the power switch.

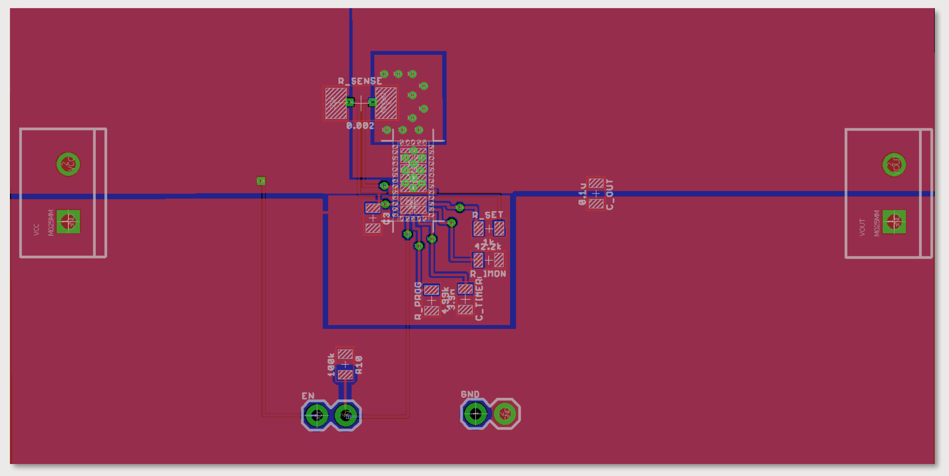


Figure 3. Board layout for the power switch.

Buck Converters

- Equations to determine inductor size

$$L = \frac{V_{OUT}}{f\ X\ \Delta I_{L(MAX)}}\left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right)$$ [2]

- Schematic and Board layout

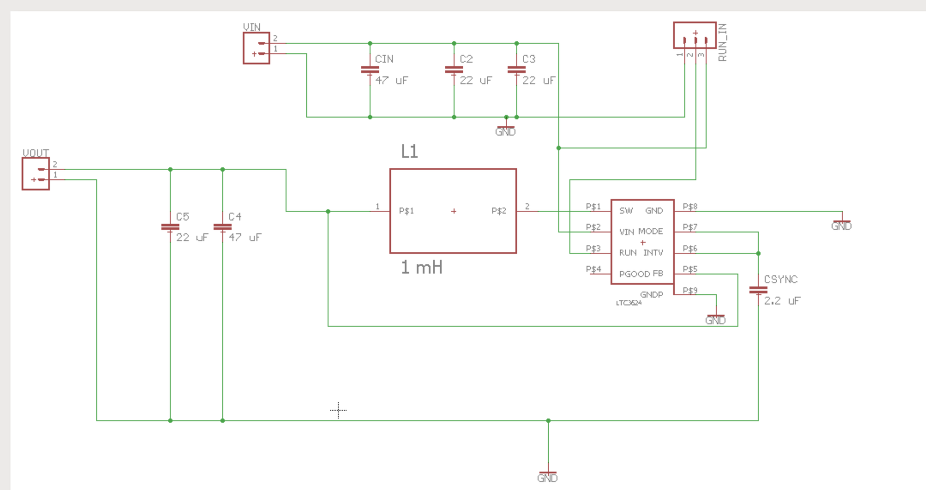


Figure 4. Schematic of the buck converter circuit for both 3.3V and 5V iterations.

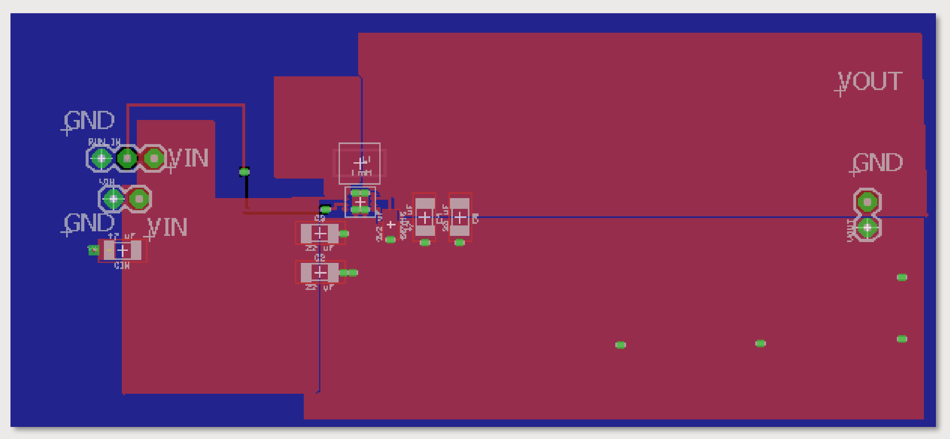
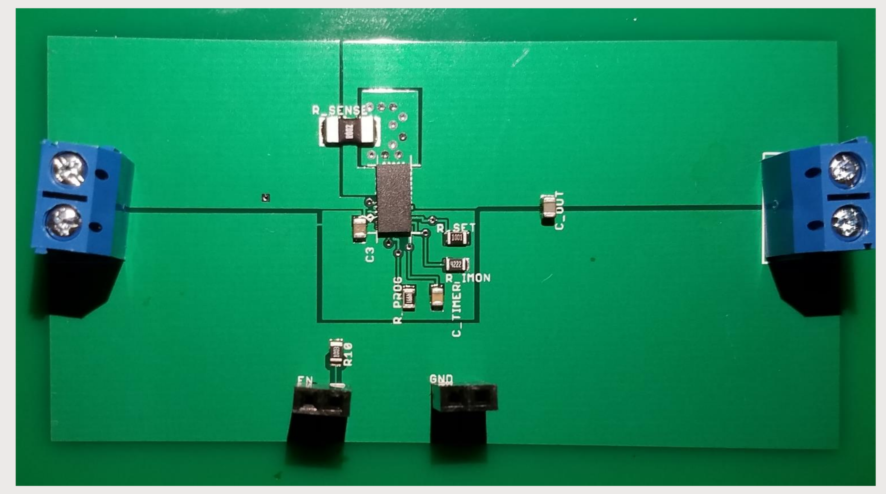


Figure 5. Board layout of the buck converter for the 3.3V and 5V circuits.

Results

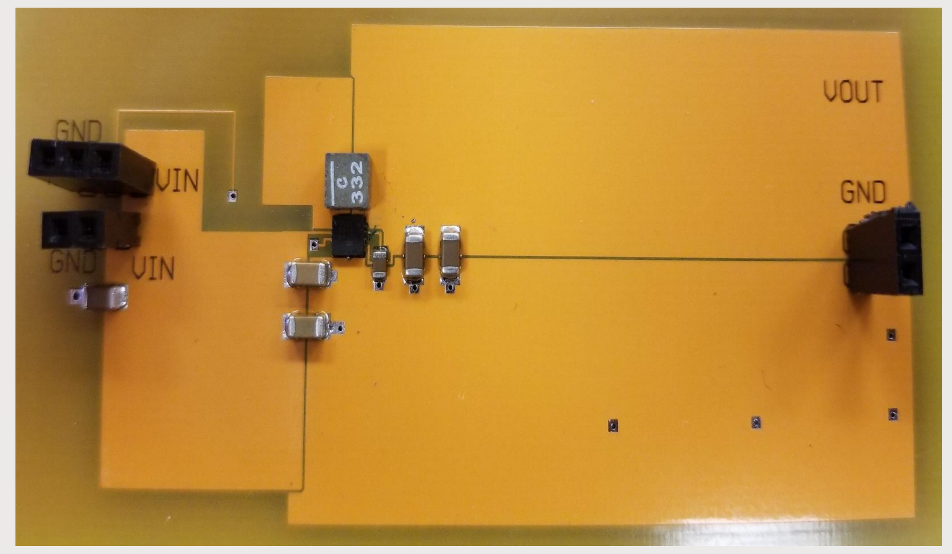
Power Switch



Out of the multiple boards we built, only ~25% operated properly. Hand placing surface mount components is proving to be rather difficult due to the complexity and size of the power switch.

Figure 6. Completed TPS24750 power switch.

Buck Converters



Both buck converter prototypes successfully holds the output voltage at 5V and 3.3V, respectively, for a battery input of 5.2V – 7V.

Figure 7. Completed buck converter circuit.

Future Plans

- Assemble final board with nine switches and two buck converters

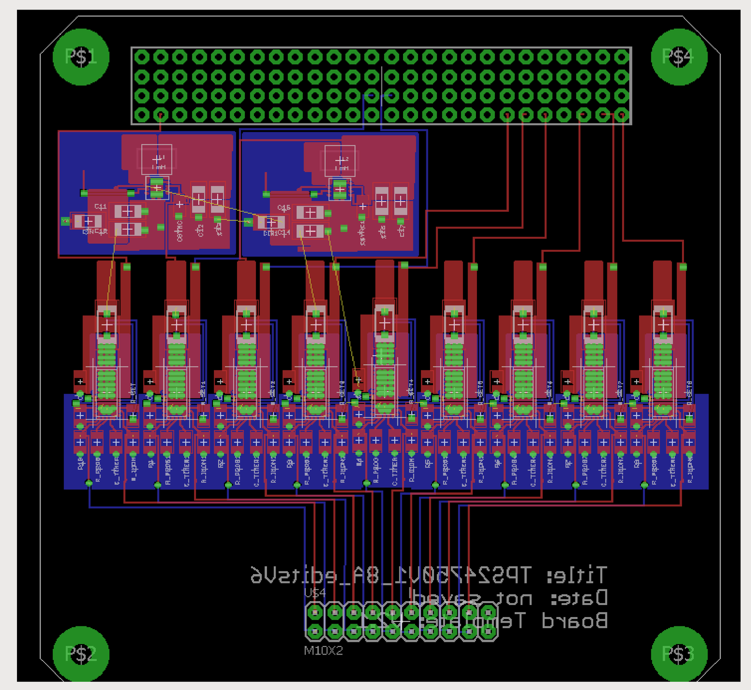


Figure 8. Completed layout of final board

- Test the final board to meet NASA regulations:
  - Operate at -40 degrees Celsius
  - Function in a vacuum
  - Endure rigorous vibrations
- Launch the CubeSat, with our board, into low-earth orbit in August 2018

Acknowledgments

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Works Cited

[1] Texas Instruments, "12-A Integrated Load Switch Using TPS24750/51" TPS24750 datasheet, April 2015.

[2] Linear Technology, "17V, 2A Synchronous Step-Down Regulator with 3.5µA Quiescent Current", LTC3624 datasheet, 2014