Digitally-Controlled Synchronous Battery Charger

Crane Aerospace Mentors: Jacob Shannon, Gregg Stavig
Faculty Advisor: Brian Johnson
Students: Jonah Au, Cooper McBride, Thaniel Schrimshire

Problem Statement:

As the complexity of aircraft avionics continues to grow and become an integral part of flight, so does the modern day pilot's dependency on these systems for safety of flight. Flight-critical avionics powered by DC power include communication, navigation, and monitoring systems. During normal operation, the aircraft's turbine-generated AC power is converted by the transformer rectifier unit (TRU) to DC power. To ensure continuous power delivery to these essential avionics in the event of aircraft low voltage or power loss during flight, secondary backup power sources must be available.

Project Description

To design a power converter capable of charging an aircraft's battery during normal operation and sustaining DC loads in the event of a loss of generation.

System Requirements

- Supply 700 Watts (20 Amps @ 35 Volts) to either the battery or bus.
- Be at least 95% efficient in converting power.
- Generate less than 2 Volts peak-to-peak ripple under any load as a result of conversion.
- Accept commands from supervisory controller regarding operating mode and output.
- Implement operating modes such as constant voltage battery charging, constant current battery charging, and bus-sustain at constant voltage (TRU).

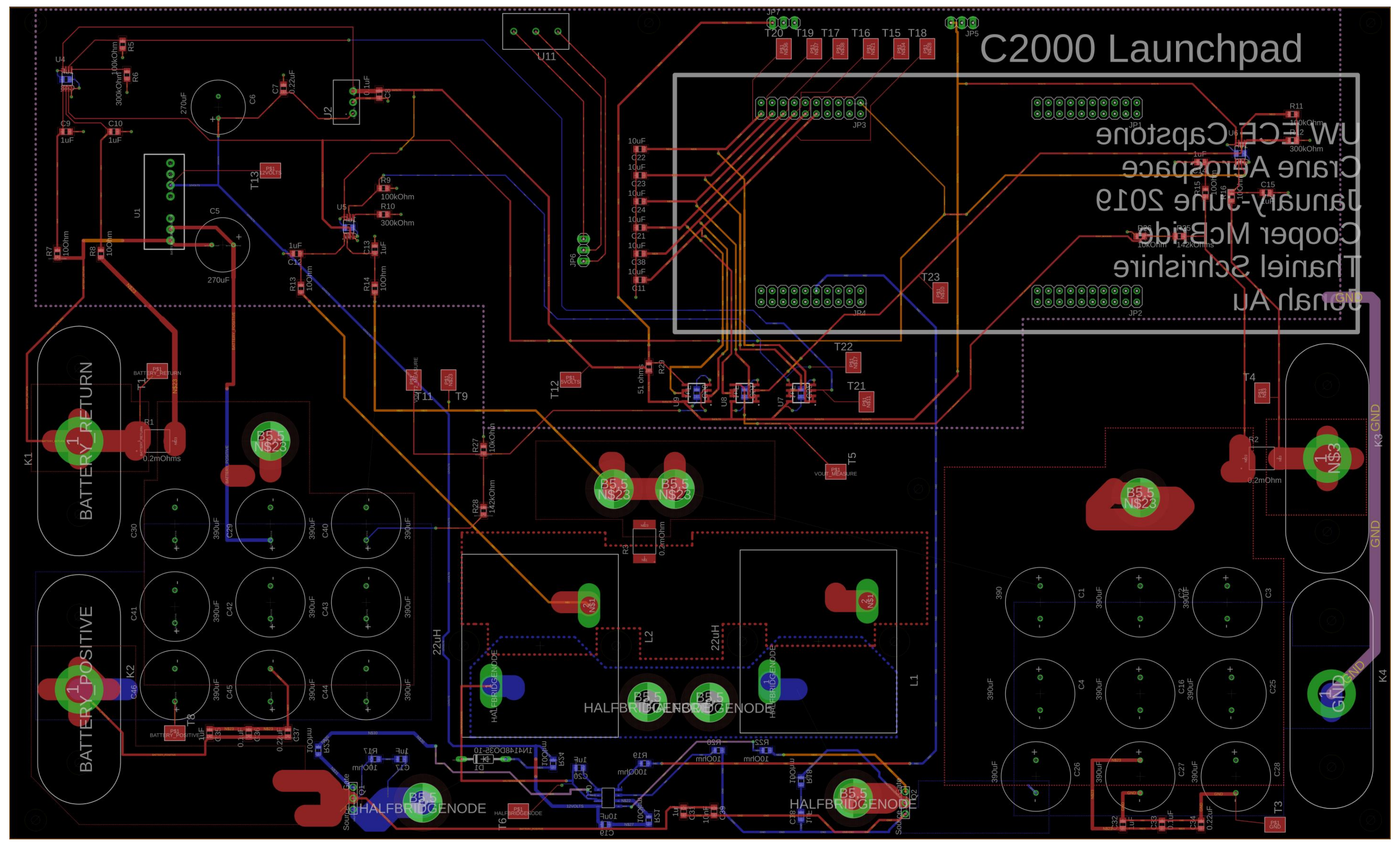

Figure 1: Eagle CAD PCB Design

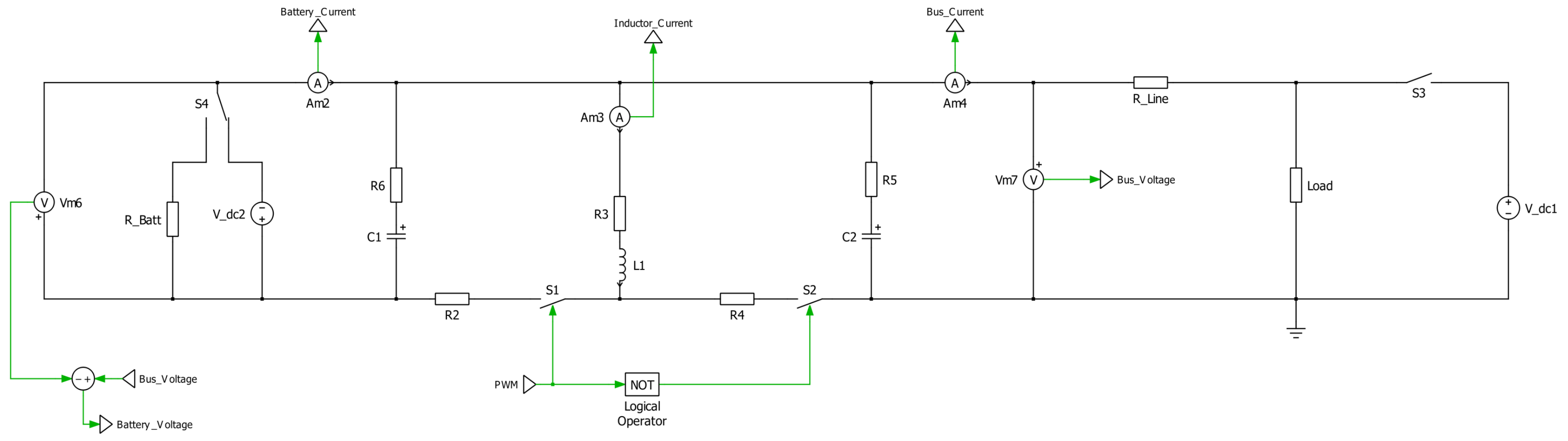

Figure 2: Schematic of the Buck-Boost Converter

System Overview

A conventional buck boost topology was chosen for our converter design due to its robust design and ease of controllability. This was implemented as a two-switch converter to allow for synchronous operation.

The TI C2000 Piccolo F280049C was chosen to control the circuit. It possessed all necessary I/O for the project and enabled the team to use an associated HIL simulator for initial tests. It also included a CAN transceiver, which we used for communication with the supervisory controller.

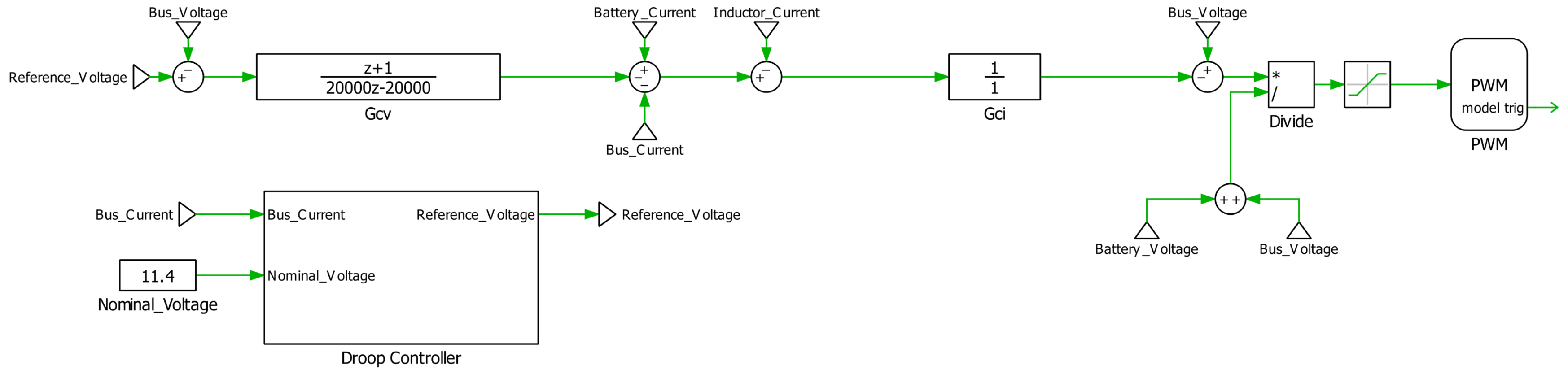

Figure 3: Block Diagram of the controller. Gcv is the output voltage controller and Gci is the inductor current controller. In addition to the standard feedback blocks, there are also blocks for feedforward control which offers enhanced disturbance rejection.

Controller

The controller consists of an inductor current loop nested within an output voltage loop. The design also uses feedforward control for enhanced disturbance rejection. This means the converter will be stable across all expected loads. A droop controller determines the reference voltage fed to the voltage controller. The droop controller allows multiple converters to evenly share loads when connected in parallel.

Potential Applications

The droop control architecture allows for the parallelization of multiple converters. The droop controller automatically shares the load among all the converters, allowing each converter to handle less current.

Another feature of stable, parallel converters is the ability to handle higher voltages. Enough converters can be put in parallel such that the power through each converter is within specification. This also adds a layer of redundancy, as if one converter fails, the rest of them will pick up its load.

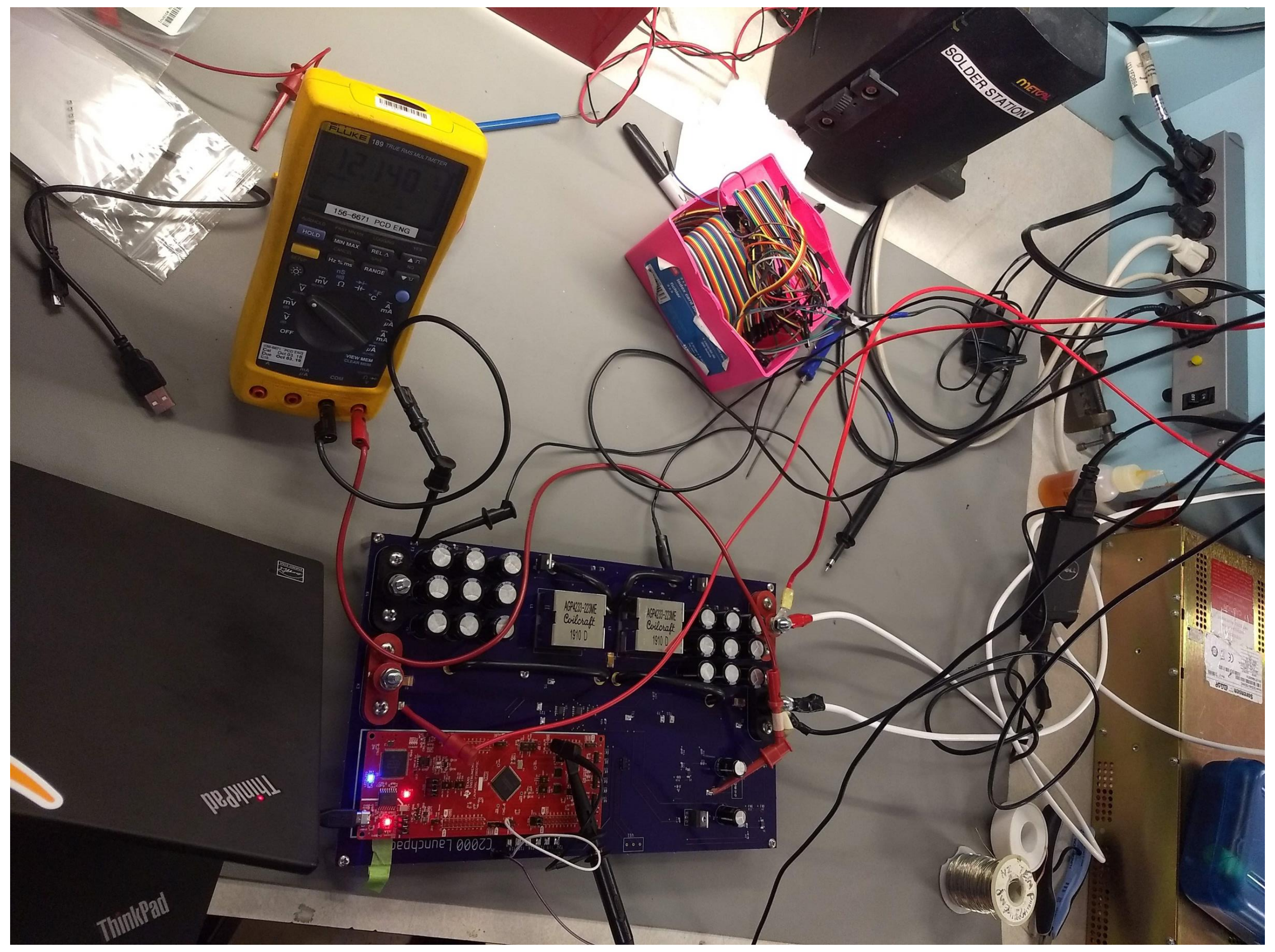

Figure 4: Initial Testing with no load

Conclusion

Testing and validation is ongoing. A real-world demonstration has not yet occurred. Our initial tests show that the converter is working as expected under no-load conditions. Our simulations, however, show that the converter should meet all of the criteria it was meant to. The design provides added redundancy and flexibility due to the ability to put multiple converters in parallel. With refinement and significant testing, this could be turned into a reliable product that increases aircraft safety.

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