

Design Review 2:

Microgrid Team

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EE Senior Design/EE 41440

25 March 2021

Table of Contents

Introduction	p. 2
Generation Subsystem	p. 2-3
Distribution Subsystem	p. 3-4
Battery Storage Subsystem	p. 5-7
Control System Subsystem	p. 7-10
Power Monitoring Subsystem	p. 10-13
Display Subsystem	p. 14
Preliminary Board Design	p. 14-18
Conclusions	p. 18

1 Introduction

In this design review, we will explore each of our subsystems working independently. This includes describing our testing process for each of the subsystems, and then describing our results. After that, we will look at the initial work we have done in creating our board design for the power monitoring and switching components of our project.

2 Generation Subsystem

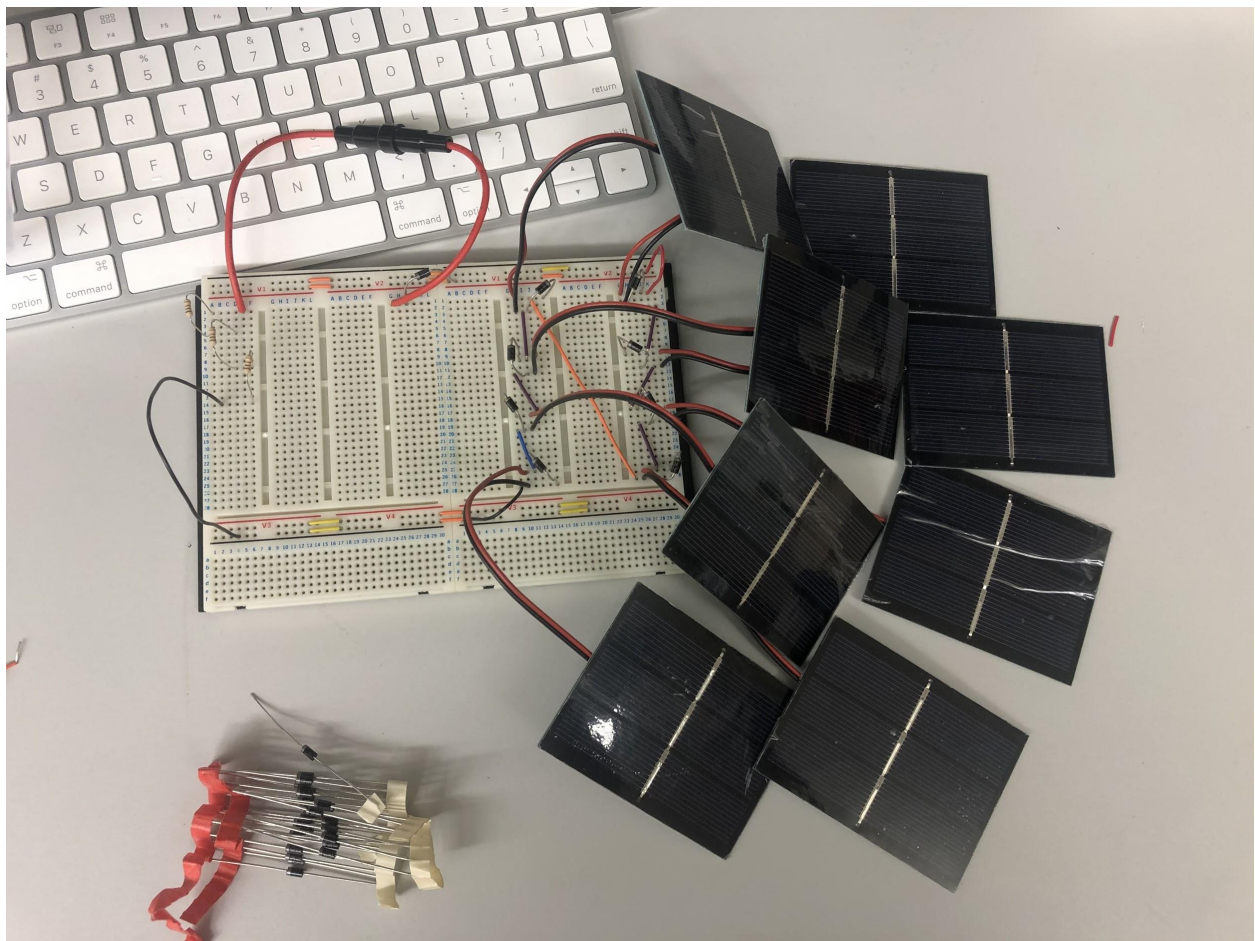


Figure 1. Generation Subsystem Assembled and Ready to Test

Description of Testing Process

The panels were connected in series so that their voltages would add. Since the rating for each panel is 1.5V and 8 panels were connected in series, 12V would be expected at the output. Then, to simulate a sunny day, a full-spectrum lamp was held extremely close to the panels.

To test this subsystem, the panels were connected to three 1kohm resistors wired in series, and the voltage drop across these resistors was measured. With the lamp turned on and held close

to the panels, the voltage drop across the resistors measured approximately 11.15V. This is close to the ideal value of 12V, with a small amount of the difference due to approximately 200mV dropped across the blocking diode and approximately 100mV dropped across the fuse. This results in an efficiency of approximately 93% which is very reasonable!

[Link to Video of Working Subsystem](#)

3 Distribution Subsystem

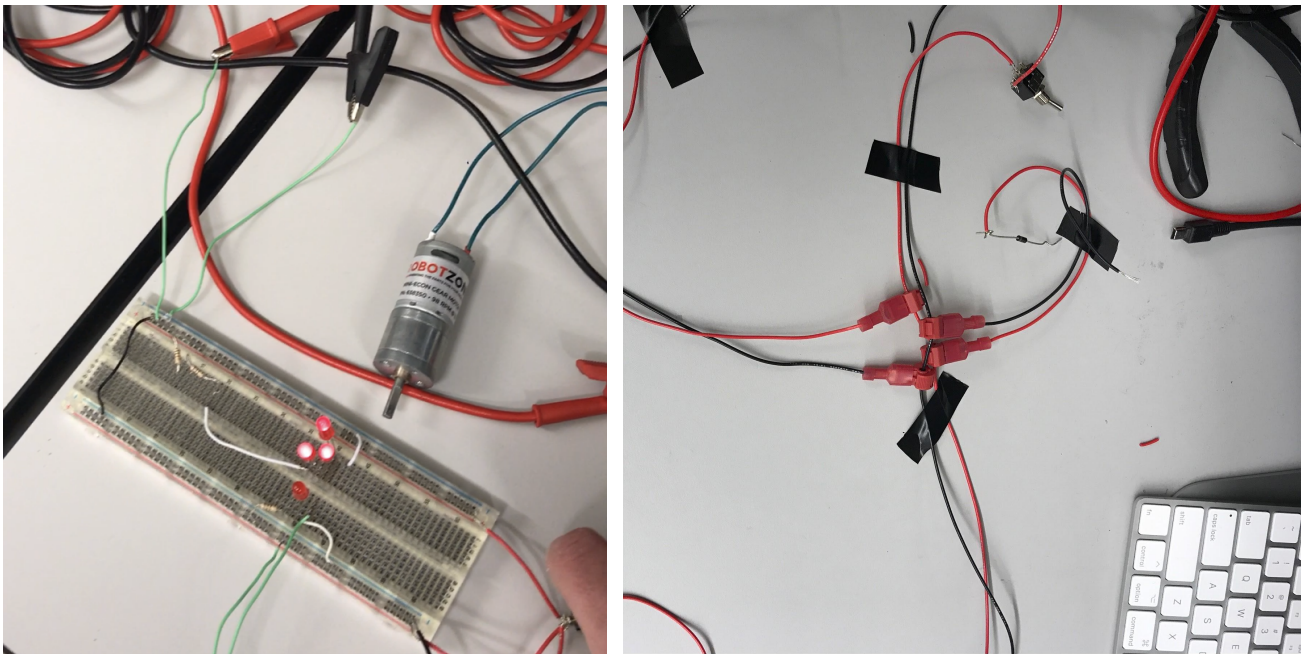


Figure 2. Distribution Subsystem Loads and Generation/Load Input

Description of Testing Process

DC Distribution System

In order to have a subsystem set up for testing simultaneous load and generation inputs into the system, a design pivot was made from an AC distribution system to a DC one. The system consists of 22 AWG wire, tapped 10 times to provide connections for Load 1, Load 2, Generation 1, Generation 2, battery input, and battery output. At each generation input and the battery input, a blocking diode was added to stop reverse current flow into the sources. Load 1 consists of a 1W DC motor, and load 2 is variable between 250 Ω and three red LEDs, or 100 Ω and one red LED. Both loads have a physical toggle switch at their input that allows the load to be switched on or off, or in the case of the variable load, between off and the high or low-power load.

The system was tested first by running 12V DC at max 300mA (predicted output from the solar panels) from a power supply connected to the Generation 1 input with all the switches open. The switch to the DC motor was then closed, and once it was confirmed that the motor was running, the switch to the motor was opened and the switch to the high-power load was closed. An input of 12V DC at max 300mA was then added to the second generation system, and it was observed that the total current through the system dropped by half (from about 90mA to 60mA). To test the battery input into the system, generation 1 was disconnected and the power supply was reconnected at the battery input, where the same phenomenon was observed, confirming that the electrical connections in the system are sound.

System Part	Input Voltage (V)	Input Current (max mA)	Measured Voltage (V)	Measured Current (mA)
1W DC Motor	12	300	11.19	89
250Ω Load	12	300	11.26	45
100Ω Load	12	300	11.26	10

Link to Videos of Working Subsystem

[Demonstration of working subsystem with one generation input](#)

[Demonstration of working subsystem with two generation inputs](#)

[Demonstration of working subsystem with one generation input and battery input](#)

AC Distribution System

The AC distribution system described in Design Review 1 was also constructed and tested. This system uses 12 AWG wire tapped 10 times to account for all system inputs/outputs, with 2-prong plugs and outlets wired as necessary to the inverters, transformers, and rectifier. With one generation on and one load turned on, the system works as expected, but with multiple loads and only one generation on, the inverter sees an overloaded input and turns off. If two inverters are turned on simultaneously, they see a short circuit between each other and both turn off. This was not something accounted for in the original system design, and the wiring configuration of the system will need to be redesigned for the potential of the AC distribution system being reimplemented later. Independent tests of the AC system's reactive and resistive loads, as well as the overloaded and short-circuit issue cases, can be found in the videos linked below.

Link to Videos of AC Subsystem

[Reactive load test](#)

[Resistive load test](#)

[Electrical connection test](#)

[Overload failure](#)

[Short-Circuit failure](#)

4 Battery Storage Subsystem

Description of Testing Process

The SP1250 12V 5Ah batteries(2) rest at a nominal voltage of about 13.3V each. They are able to charge and discharge successfully. Below are the load characteristics of the batteries.

Battery 1:

Time(min)	Resistance (ohms)	Watts(W)	Ampere Hours (mAh)	Starting Voltage	Final Voltage
20	96.66	1.79	45.8	13.17	12.75
20	96.66	1.68	43.97	12.75	12.67
20	50.88	3.15	83.0	12.67	12.5

Battery 2:

Time(min)	Resistance (ohms)	Watts(W)	Ampere Hours (mAh)	Starting Voltage	Final Voltage
20	96.66	1.79	45.42	13.17	12.8
20	96.66	1.68	44.17	12.8	12.75
20	50.88	3.15	83.3	12.75	12.7

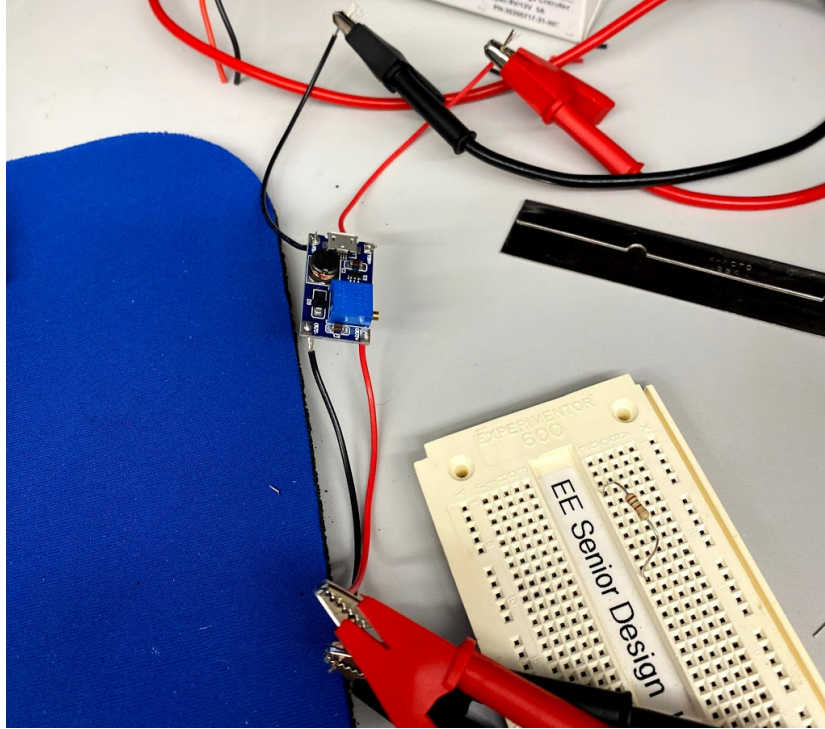


Figure 3. Boost Converter

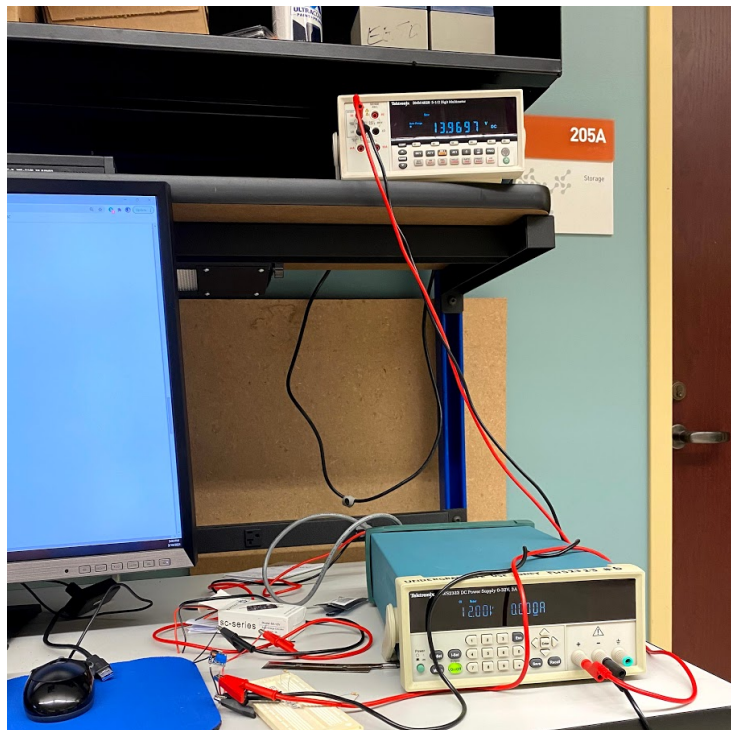


Figure 4. The Boost Converter Attached to a 12 V Power Source

Charge Controller:

There were two trials for the charge controller. The first used the power source for a 14V source. The charge controller was put in series with the battery and ran for one hour. The batteries were charged immediately after their discharged testing

Trial 1:

Battery	Starting Voltage(V)	Final Voltage (V)	Time (hours)
1	12.5	13.33	1
2	12.7	13.22	1

Trial 2 involved the entire system, the battery was connected in series with the charge controller then the boost converter then the 12V power source. The battery was loaded for 1 hour with a 3.50 W load then charged for 1 hour. (See video)

Battery	Starting Voltage(V)	Final Voltage (V)	Time (hours)
1	12.58	12.80	1

Link to Video of Working Subsystem

[Demonstration of working battery storage system](#)

5 Control System Subsystem

Description of Testing Process

The Control System Subsystem was tested to ensure that the team could successfully control switching behavior of the solid state relays with the input of microcontroller digital output signals. To test this, switching logic based on pseudo-power monitoring data on the microcontroller was generated using a random number generator between the lower and upper limits of the expected power output of the final system at both generation points and loads. In the final build, this data will be sent via UART connections from each load/generation point to the microcontroller that will be performing the switching logic, and this microcontroller will then send switching signals to the SSRs via digital outputs. Data on the voltage, and hence charge level, of the battery will be monitored via the Power Monitoring Subsystem, and I2C data will be sent from a power monitoring chip to the microcontroller of the Control System Subsystem (the same microcontroller that will be receiving power data via UART from the loads/generations). However, for testing purposes, this power and voltage data was randomly generated. Then, the

power/battery voltage data was used in the switching control logic, and the microcontroller sent digital output signals to either open or close the SSRs based on the power/battery voltage data. The C code for this test is attached in the Appendix.

The schematic in Figure 5 was used to model the solid state relay (SSR) testing, with the addition of a 150Ω resistor at the input of the SSR.

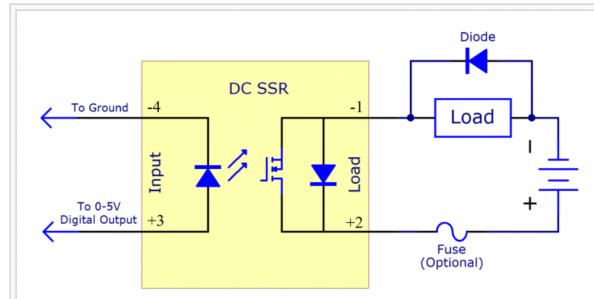


Figure 5. Schematic of Solid State Relay

The safety information in Figure 6 was used to create the final 3-wire system test breadboard.

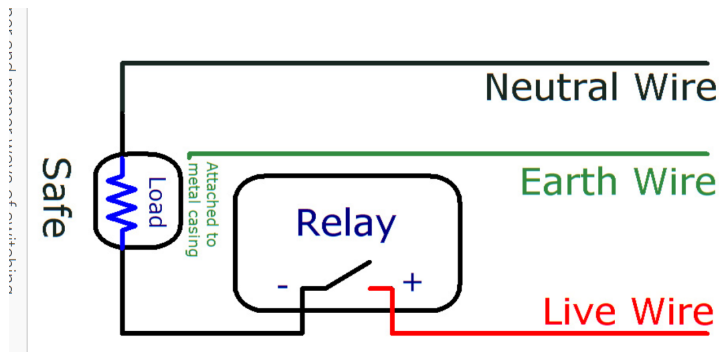


Figure 6. Safe 3-Wire Setup of Solid State Relay

Given this information, two separate SSR circuits were set up on one breadboard, each with its own power supply of 12V DC and an output current of 100mA at the output of the SSR. These model the charging and discharging branches of the battery, respectively. In the actual system to be built, the output current will be around an average of 400mA with a maximum of 650mA, however, this higher current was not modeled because the available resistors did not have a power rating high enough to withstand the higher currents with 12V. Appropriate resistors will be ordered. Instead, 3W rated resistors were found in the closet in 205 Stinson Remick, and those were used for the modeled output load of the SSR. The resistors were 6.8kΩ, which is higher than the team would like in the actual build and caused the current of the output circuit to be lower than ideal, but these resistors sufficed for the purposes of testing the Control System independently of other subsystems. The testing setup with both breadboard and microcontroller for the Control System Subsystem is shown in Figure 7, and Figure 8 shows the labeled breadboard setup. Note that in Figure 8 only the left-side circuit is labeled for simplicity, as the right-side circuit is the exact same setup.

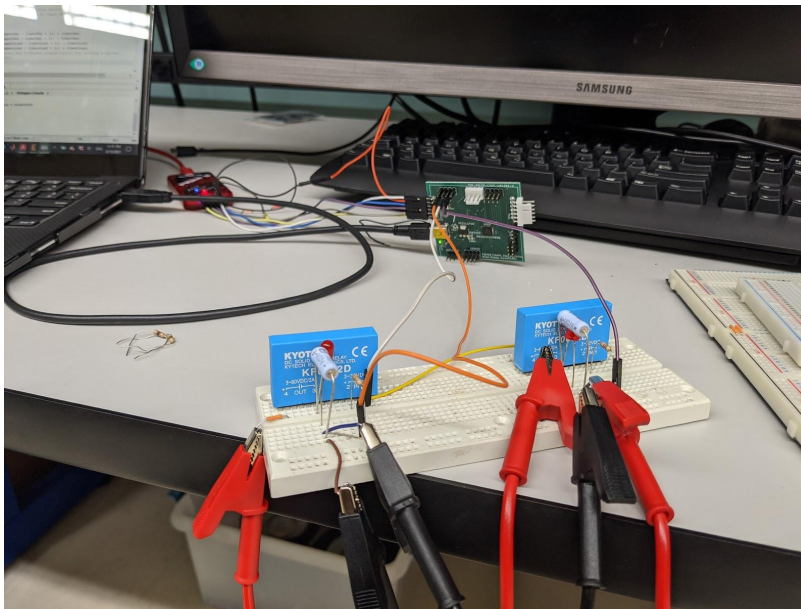


Figure 7. Microcontroller and Breadboard Testing Setup for Control System Subsystem

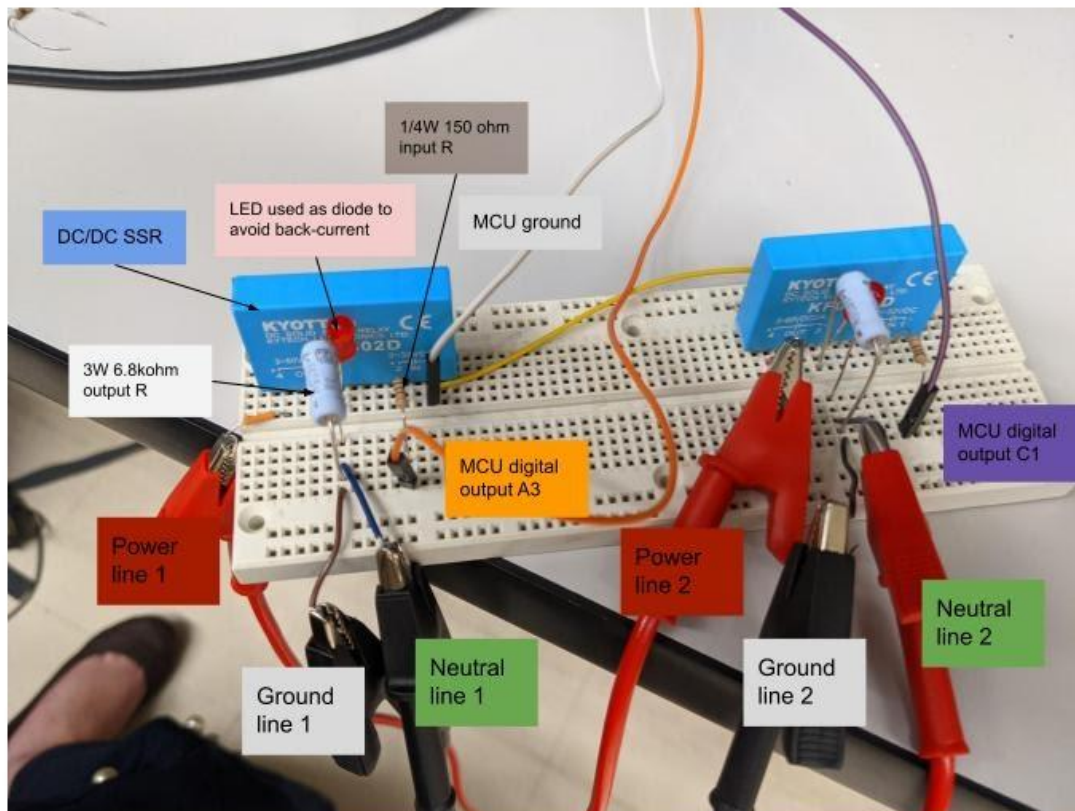


Figure 8. Labeled Control System Subsystem Breadboard Circuits

Link to Video of Working Subsystem

[Independently Functioning Control System Subsystem](#)

Note: the addition of battery voltage logic was added after this video was taken, but functionality of the subsystem remains the same

6 Power Monitoring Subsystem

MCP39F521

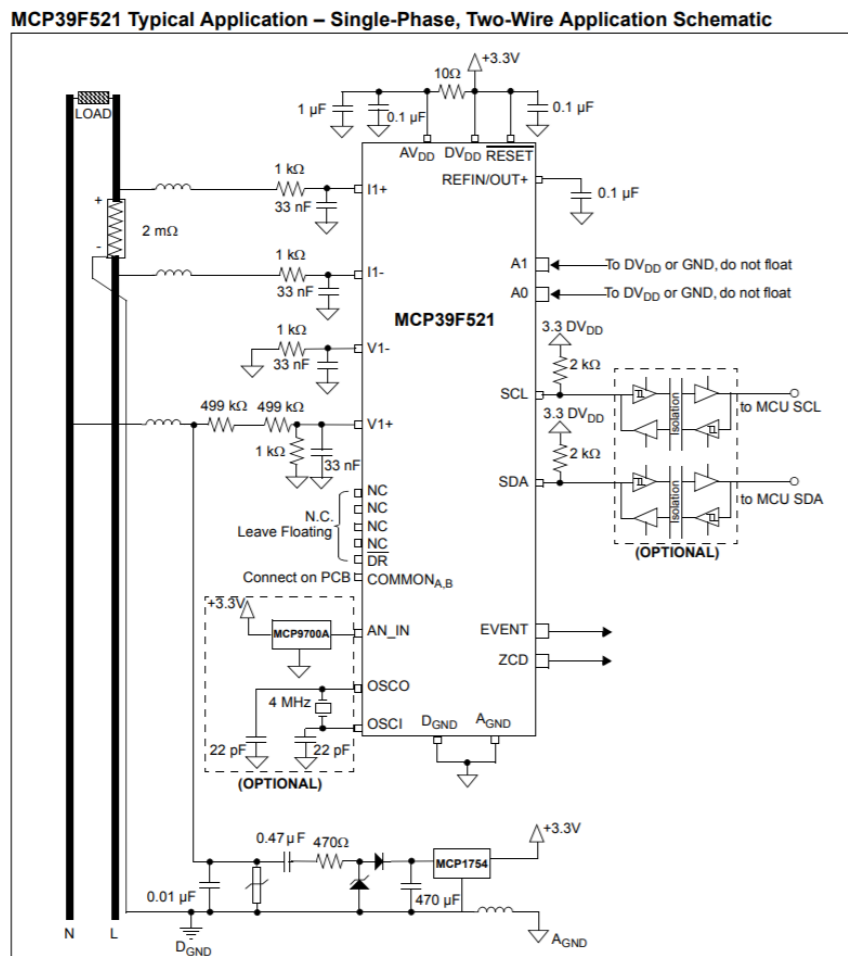


Figure 9. Power Monitoring Subsystem Model Circuit from MCP39F521 Datasheet

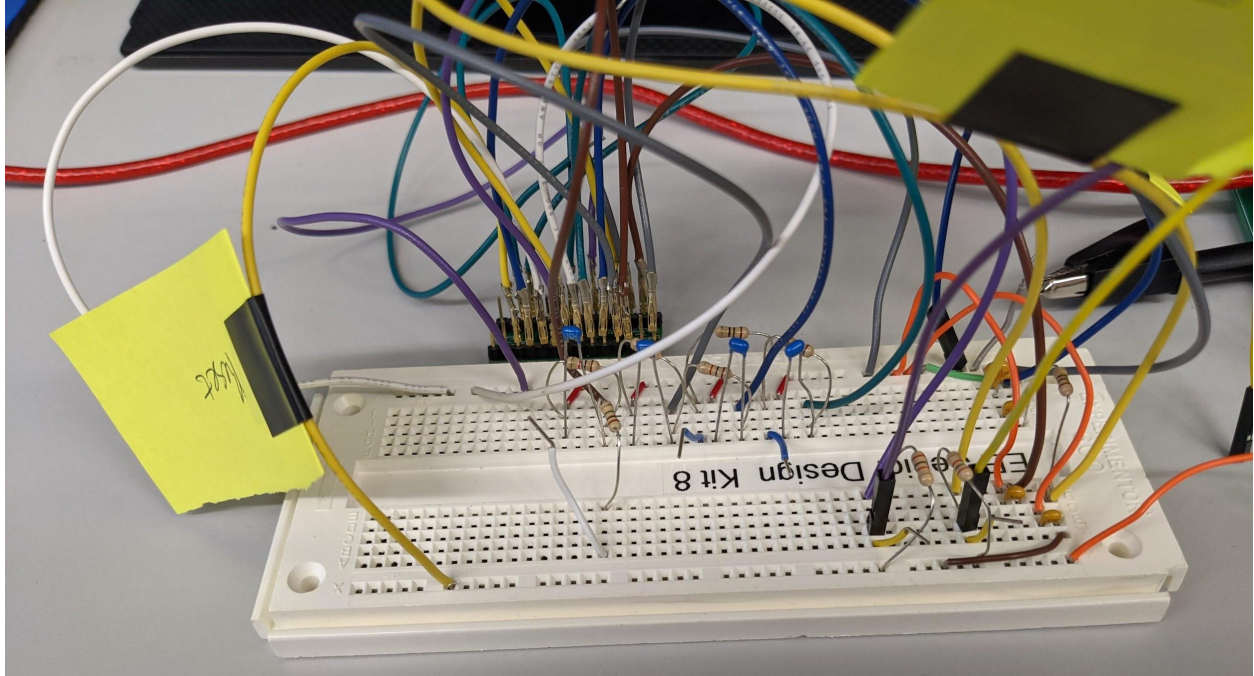


Figure 10. Power Monitoring Subsystem Breadboard Circuit Setup

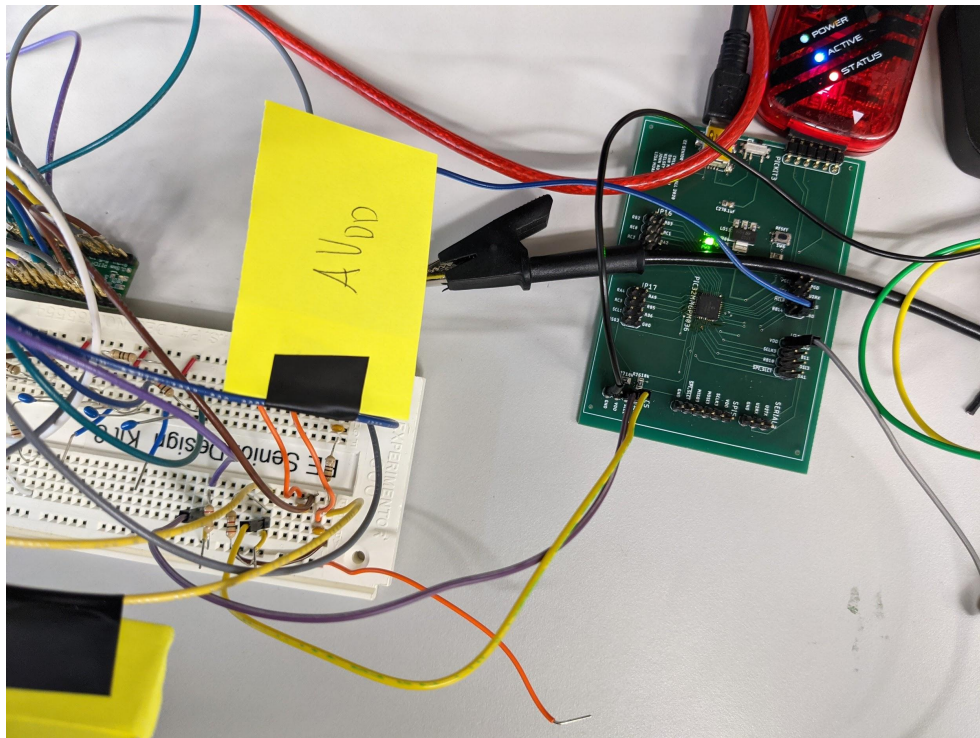


Figure 11. Power Monitoring Subsystem Connection to SCL1 and SDA1 on the PIC32MM

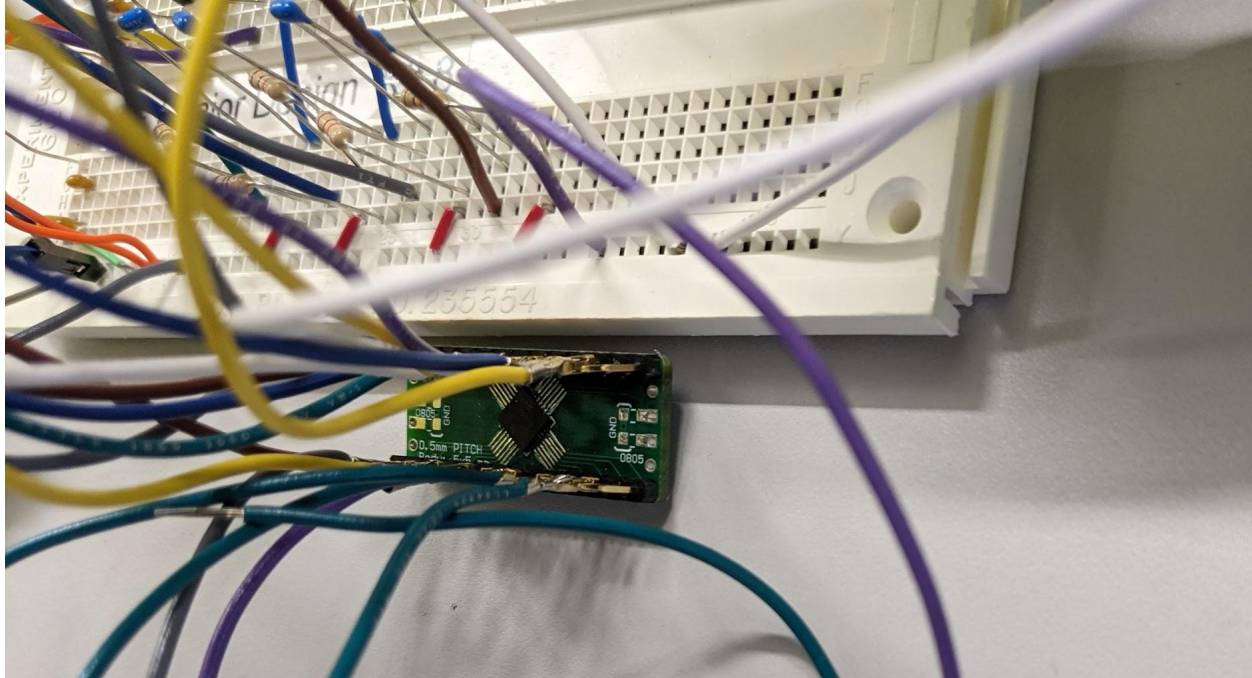


Figure 12. Power Monitoring Chip on Adapter PCB with Connections to Breadboard

Description of Testing Process

To test the power monitoring subsystem, it was established that the team needed to use I2C communication between a PIC32MM microcontroller and the power monitoring chip (MCP39F521). A PCB adapter board was purchased, and the chip was soldered onto it. Next, the circuit matching the suggested circuit from the datasheet was constructed via breadboard, with connections to the pinheaders of the power chip adapter board. Meanwhile, functioning I2C code was written independently of a connection with the chip to ensure that this could be done successfully. Then, SDA1 and SCL1, along with the ground pin of the PIC board, were connected to the power chip & breadboard setup. The power chip breadboard, including the power chip itself, was hooked up to an independent power supply of 3.3VDC and 13mA, the typical operating characteristics.

Ultimately, the team was unable to successfully complete a reciprocal I2C communication with the power monitoring chip given the time constraints. It is very likely that there is a loose connection somewhere on the breadboard circuit that resulted in the loss of signal once SDA and SCL were linked to the breadboard. The I2C connection was working initially, with the need to debug, but it stopped working once the team came back from a break (hence the reasoning of a loose connection that was not able to be identified). However, I2C signals were successfully sent to the SDA and SCL pins of the PIC32 to be received by the power chip; those signals can be seen in Figure 12.

As far as the wireless communication system is concerned, the team purchased incorrect modules to design a full LoRaWAN network and was unable to implement the system. Instead the team will be using wired UART communication to meet the Design Review 3 date and will revisit wireless communication before the final demonstration if time and budgeting allows.

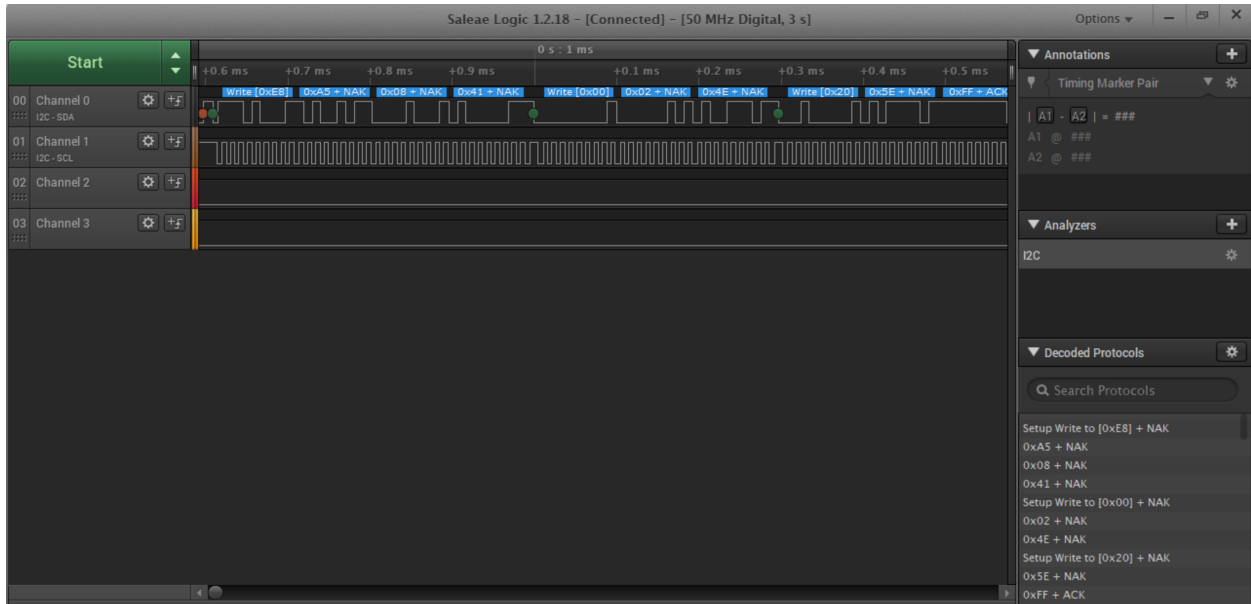


Figure 13. I2C Signals from the PIC32MM Board are Sent Out as Expected

Moving forward, the team still plans to use the MCP39F321 for its intended purpose, despite an unsuccessful independent subsystem test. Further work will be done in an attempt to establish successful I2C communication. Given the nature of the issue that the team is experiencing, where the source of error could come from any number of loose breadboard connections (that were each evaluated thoroughly as is) or potential bad electrical connection on the PCB adapter board, it seems prudent to continue moving forward with the intention to test the power monitoring chip on the more-clearly-laid-out PCB board that the team has designed. More work will, of course, also be undertaken to ensure perfect understanding of the power monitoring chip's functionality, configuration/calibration needs, and communication protocols. Moving forward, this subsystem will be prioritized, with larger time/work commitment expectations from all team members, so the team can work together to achieve a successfully functioning system.

7 Display Subsystem

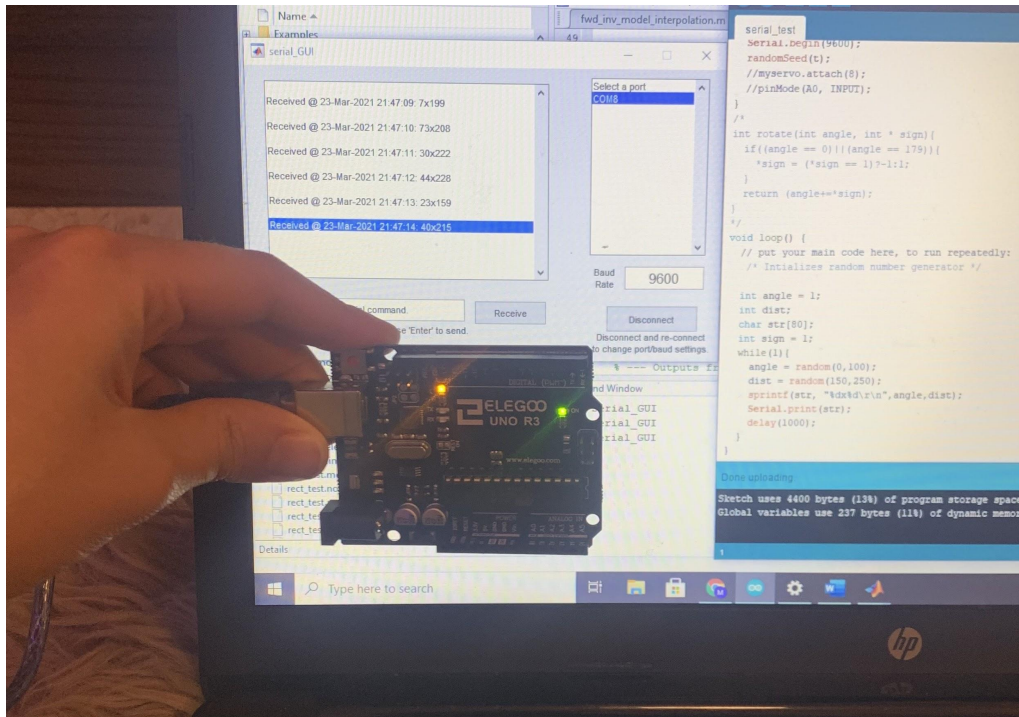


Figure 14. Display Subsystem Assembled and Ready to Test

Description of Testing Process

The current demonstration shows the end-to-end capabilities of the system: its ability to read serial data, select from a list of options and display the data as it flows in.

An arduino is programmed to transmit two random integers per second. The MATLAB file then is able to establish the serial connection and receive the data continuously.

[Link to Video of Working Subsystem](#)

8 Preliminary Board Design

The following figures show our board design to be used for monitoring the generations/loads and the storage. Additionally, the board includes switching capabilities to be used for the storage. This switching capability will be included on the generation/load boards to save money, but on these boards the switching capabilities will go unused.

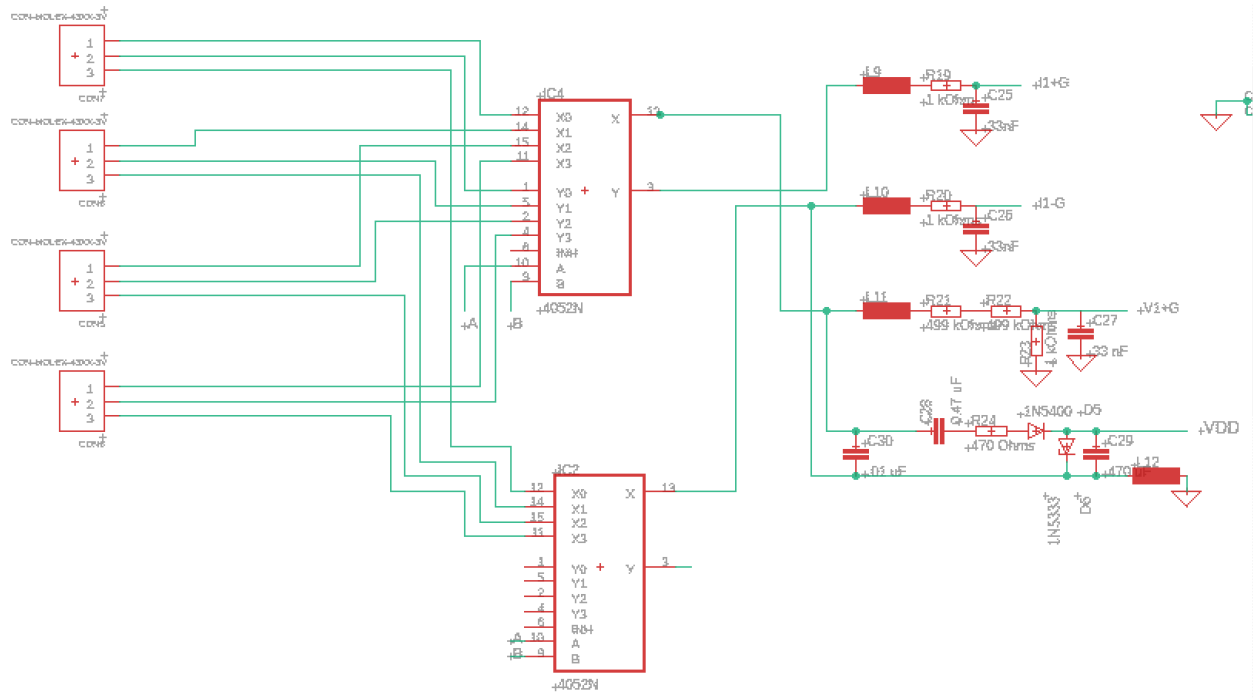


Figure 15. Two Sets of Power Monitoring Inputs

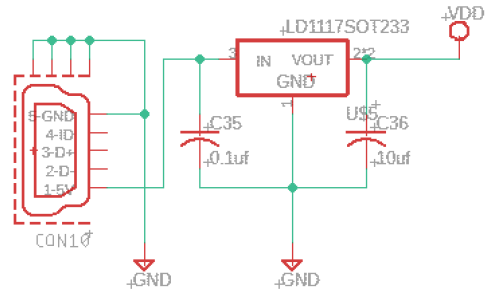


Figure 18. Voltage Input & Voltage Regulator

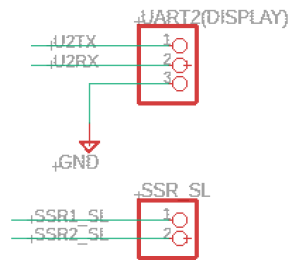


Figure 19. UART and SSR Pin Headers

