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Advanced Multi-Cell Lithium Battery Load Analyzer

2CE1EE

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Contents

1 Background Research

Lithium ion batteries are very energy dense batteries which makes them able to store a lot more energy in the same amount of volume compared to other forms of batteries like lead-acid. Specifically, lithium ion batteries can store 330 Watt-hours per kilogram whereas the lead acid can only store 75 Wh/kg. Each cell can be charged up to 3.6 V which makes lithium ion batteries very effective for high power applications like transportation. In addition, lithium ion batteries discharge at a rate of 1.5% to 2% per month which is a very low discharge rate compared to other batteries, and this gives it a long lifespan [1] (JL).

Given the usefulness of lithium ion batteries, it is used extensively nowadays in electric vehicles made by manufacturers like Tesla and General Motors. However since it is being incorporated into more devices and vehicles, it needs to be well maintained to ensure the health of the battery is not compromised [1]. A lithium ion battery is made of many cells, for a 12 V battery this usually requires 4 batteries in series, each with around 3 V. During acceleration, a lot of current is pulled from lithium cells and this causes the voltage levels on each of the cells to drop. However, due to inconsistent manufacturing, each cell responds to load differently and some sag more than others. This can be a hazard if one cell discharges too much since it can comprise the performance of the whole battery (JL).

The goal of the battery load analyzer is to automate the process of measuring the voltages of a quad cell battery with and without a load applied, then comparing these values to determine whether there is a significant difference between the voltages. Depending on the significance of the discharge, the analyzer will report a rating for each cell and catalog this information in memory which can be viewed remotely. To accomplish this, several components are needed including a carbon pile to apply a load, a shunt to measure the current drawn from the battery, an operational amplifier to amplify the voltages, voltage sensing wires that can measure the voltages of each cell in the battery, a motor to automatically adjust the current through the carbon pile, and a microcontroller that is able to process the measured data and interpret what these values are telling about each cell in the battery. Additionally, an LCD and push buttons are needed to allow for user input and output and a UART bridge is required to communicate with and send data to a personal computer. A safety buzzer will provide audio feedback to the user to remind them to turn down the current (JL).

Some possible loading elements for the battery are high power resistors, high power, transistors, or carbon disks. In order to measure voltages and display them on an LCD, the group determined that an analog-to-digital converter (ADC) is necessary to convert all analog voltages to digital values that can be processed by software. The battery cell voltages are differential rather than single-ended, therefore, a differential ADC or some form of differential-to-single-ended conversion may be needed. The battery cell voltages may need to be attenuated if they exceed the input range of the ADC. In general, ADCs can only convert analog voltage inputs, therefore, some form of current to voltage conversion in order to measure the load current drawn from the battery. A current resistor (shunt) placed in series can be used to create a differential voltage proportional to the current through the shunt. This differential voltage may need to be amplified before conversion if the ADC resolution is not sufficient (OM).

2 Statement of Work and Testbed for Verification

As the adoption of electric vehicles becomes more widespread, batteries will become increasingly more important for storing energy to power them. Electric vehicles use multiple battery cells connected in series to form a battery-pack. In order to maximize the performance and lifespan of an electric vehicle, it is important to consistently monitor the health of the battery pack as well as the health of each one of the individual cells. A battery load analyzer is an important test instrument for assessing battery health and state of charge. Unfortunately, most commercially available automotive battery testers are not designed to sense the voltage of each individual cell in the pack. This means that most battery testers cannot detect if all the cells are balanced at the same voltage. Imbalanced cells can degrade the performance and lifetime of a battery so identifying and balancing these cells can be useful in extending the lifetime of the pack (OM).

3 Innovation - Uniqueness of Proposed Solution

Most of the components involved in the final design, including the microcontroller, the motor, operational amplifier, voltage sensing wires, buzzer, pushbuttons, LCD, and the UART bridge will be directly ordered from online manufacturers like Digikey or obtained from Stony Brook's electrical engineering laboratories. The carbon pile load, shunt, and the rest of the hardware associated with adjusting it cannot be directly ordered online. It can be indirectly ordered by purchasing a device that already contains the hardware or independently manufactured. To save time, the faculty advisor has purchased a manually operated battery load analyzer that already contains the carbon pile load and the hardware needed to adjust it. The group will disassemble the load analyzer to extract the components needed and use that as part of the project (TS).

The carbon pile load acts as a variable resistor, as it is made of many disks of graphite, and its resistance decreases as it is pressurized and squeezed together. The carbon pile load needs to be able to pull as much as 500 A from the battery at high pressure and act as an open circuit when not pressurized. This way, the voltages of each battery cell can be measured using the voltage sense wires before and after applying a load. A diagram of this is shown below in figure 1. A motor can be incorporated to adjust the resistance of the carbon pile by contracting it to a desired resistance. This motor can be controlled by the microcontroller. The voltage drop across the shunt can be measured and the current through the battery can be calculated using Ohm's Law. The user or motor can use this current measurement to determine how much the current needs to be adjusted. The voltage drop across the shunt is very small, so it will need to be amplified using an operational amplifier with a gain of 20 before it can be fed into the microcontroller (JL).

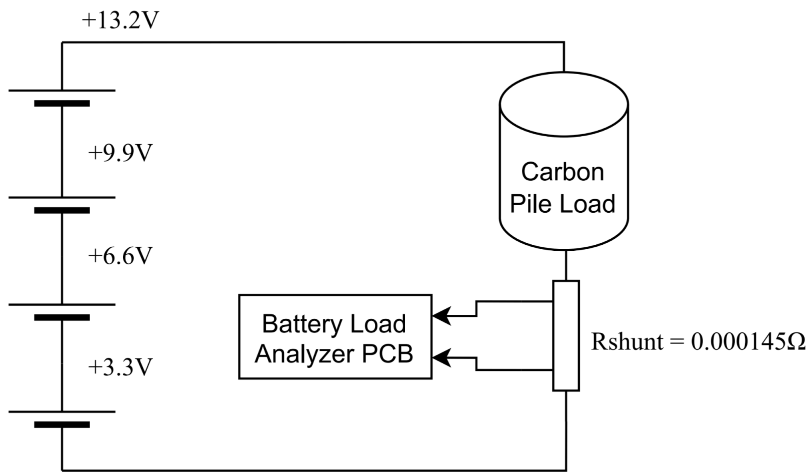


Figure 1: Schematic of Electromechanical Components (OM)

The microcontroller contains internal hardware for an analog to digital converter (ADC), allowing the analog inputs from the battery to be digitized and processed in a microprocessor. It can then be displayed on an LCD in readable format, cataloged into memory, and provide feedback in a control system [2]. Pushbuttons will be used to take in input from the user. The buzzer will sound when the desired current is reached to remind the user to immediately turn down the current. The microcontroller will send data to the UART bridge using its internal UART module. The UART bridge connects to a personal computer using a USB port connector cable (JL).

4 Constraints and Applicable Standards

The faculty advisor has given several constraints for this project. The battery load analyzer must be designed to read the loaded and unloaded voltages of four batteries (one quad pack) at once using sense wires. After measuring the voltages, they should be displayed on an LCD screen and stored digitally on a PC. Additionally, the system must be able to draw up to 500 A of current from the quad pack. The prototype must have a variable load that can be automatically adjusted to draw any current between 0 A and 500 A from the battery. The loaded and unloaded voltages displayed to the user should have a maximum error of 0.01 V and the current measured by the system should be accurate within 1 A. The user should have the option of programming the current value and for the test procedure to be performed automatically with the press of a button. Once the test procedure is complete, each battery cell in the quad pack must be assigned a health rating according to the following figure 2 (TS).

Loaded Voltage Range (with a 500 A load current)	Health Grade (~70°F Ambient Temp)	Description
2.90 and Up	A+	Near Perfect
2.80-2.89	A	Excellent Plus
2.70-2.79	A-	Excellent
2.60-2.69	B+	Near Excellent
2.50-2.59	B	Very Very Good
2.40-2.49	B-	Very Good
2.30-2.39	C+	Good Plus
2.20-2.29	C	Good
2.10-2.19	C-	Near Good
2.00-2.09	D+	Retest at Lower Current
1.90-1.99	D	Retest at Lower Current
1.70-1.89	D-	Retest at Lower Current
1.69 and down	F	Retest at Lower Current

* Retest at Lower Current may mean that the battery is still good for an Accy Battery Cell

Figure 2: Health Ratings Measurement System Developed by Scott Tierno and Modified by TS

A status inductor, such as a buzzer, must inform the user when the test is complete and all of the results must be readily available to the user. Visual feedback during the test must also be available for the user to see the battery current changing in real time. Finally, there must be a remote and local user interface that allows for running tests and viewing and storing results via push buttons or from a PC [3] (TS).

Additionally, the faculty advisor has requested the group to minimize the use of external hardware and use the AVR128DB48's internal microcontroller modules instead. The AVR128DB48 has many internal modules like an Analog to Digital Converter (ADC), Operational Amplifier (OPAMP), and Universal Synchronous/Asynchronous Receiver/Transmitter (USART). This has caused challenges for the design team because of several technical limitations of the microcontroller's modules. For example, the ADC can only support a maximum voltage of approximately 3.6 V [4], but the maximum battery voltage is 13.2 V. As a result, the team decided to add an external voltage divider circuit that scales the battery voltages down to an acceptable range before being read by the microcontroller (TS).

Another challenge is the degraded and inconsistent performance of several hardware modules compared to using an external integrated circuit (IC) chip to perform the same function. For example, when the AVR128DB48's internal OPAMP modules are configured to form an instrumentation amplifier, the gain drops off exponentially as the input voltage drops below 100mV. Since high precision is needed even at low voltages, an external high performance current sense amplifier was used instead in the final design (TS).

The goal of this project is to design a prototype battery load analyzer for personal use by the faculty advisor. Since the prototype will only be used by the advisor and not released to general consumers, there are no specific standards that need to be met or followed. That said, the group will follow general safety standards when designing and implementing the prototype to minimize the risk of accidents. This device involves drawing a 500 A current from the battery. If touched by the user, a high current could lead to burns, permanent brain damage, or death. Additionally, high voltages could damage the device's microcontroller (TS).

The group will take several measures to mitigate these risks. The team will develop a User Manual by the end of the year that details step by step how to use the device properly. The User Manual will include warnings about the high current and voltage and the possible risks of the device if the device is used improperly. The prototype will include a fan to cool down the electrical circuitry and reduce the risk of burns. Additionally, the prototype will be enclosed to further reduce the risk of exposure to high currents and voltages. Finally, the device will incorporate a warning buzzer that will be turned on to remind the user to reduce the current (TS).

5 Best Worst Case Design, Theoretical Analysis, and Simulations

The goal of this design is to have a fully automated test procedure which only requires the user to initiate by a pushbutton press. The key components of this design are as follows (OM):

Liquid Crystal Display (LCD):

A 4 x 16 SparkFun AVR Serial Based Liquid Crystal Display (LCD) is used to display information to the user. The LCD is configured to the microcontroller using the SPI1 module, therefore, it requires SCK, MOSI, and /SS pins. MISO is not used because the LCD does not output any data. This LCD is also compatible with UART, SPI, and I2C. The group chose to use SPI, as it is generally faster than I2C and UART, allowing for quicker LCD updates. An image of the LCD and the schematic of the LCD are shown below as figures 3 and 4 respectively (JL).

Figure 3: LCD Top View (JL)

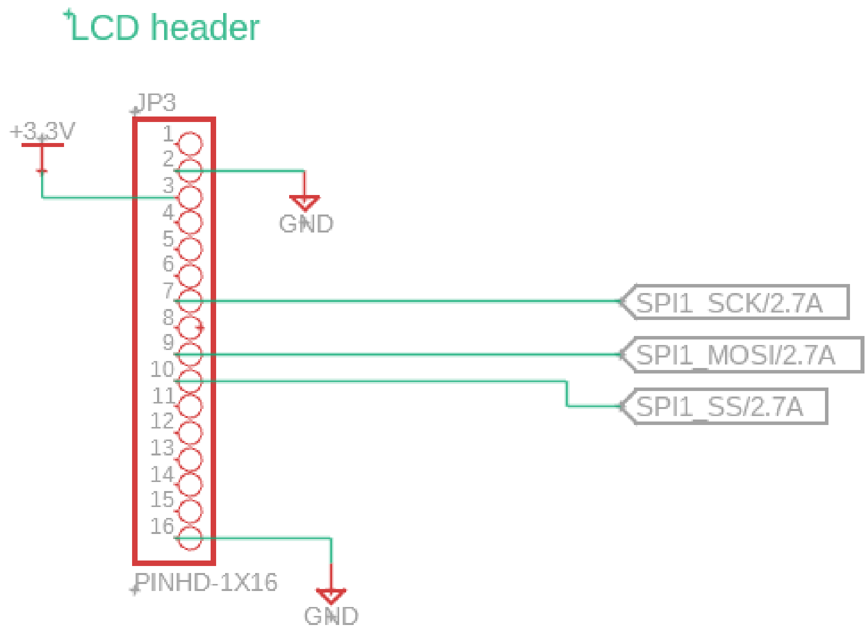


Figure 4: LCD Schematic (OM)

Load Resistor:

The total nominal voltage across the quad-pack is 13.2 V with a maximum load current of 500 A, therefore the load resistor must have a dynamic range of between 26.4mΩ and an open-circuit. The group looked at three possible implementations of a variable resistor: traditional potentiometers, transistors, and a carbon pile (OM).

Traditional mechanical and digital potentiometers are generally not rated for current levels anywhere near 500A so using them for the design would require using multiple potentiometers in parallel to distribute the 500 A load current among them. Additionally, mechanical potentiometers would also require having to mechanically adjust each potentiometer's wiper position until the load resistance has the correct value. All of this would require too many components and excessive overhead for the user and software, therefore, the team decided not to use traditional potentiometers in this design (OM).

A MOSFET can be used as a variable resistor because its conductance is a function of the voltage between the gate and source. Many transistors are generally not rated for 500A so using them for the design may require using multiple transistors in parallel to distribute the load current among them. Additionally, the transistors may not be well matched due to variations in the manufacturing process so a different control voltage may be required for each transistor. These individual differences are not specified in component datasheets, so manual testing and calibration would be necessary to determine the exact control voltages needed for a given load current. Figure 5 shows a general schematic of how multiple MOSFETs with different gate voltages can be connected in parallel to load a battery pack (OM).

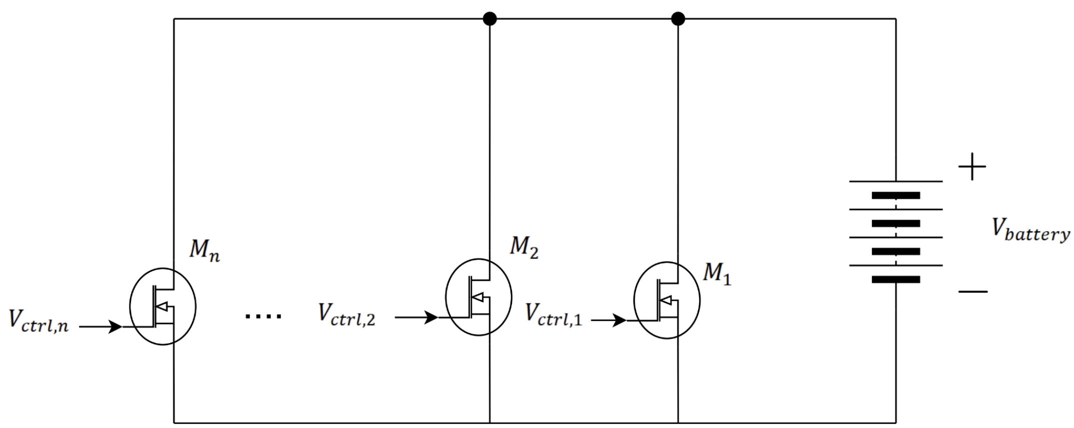


Figure 5: Multiple Parallel Transistors Used to Load a Battery Pack (OM)

Transistors are also nonlinear devices with an exponential increase in conductance as the control voltage increases so small variations due to noise may result in larger variations in the load resistance depending on how the transistor is biased. For example, figure 6 shows the transfer characteristic of the Infineon IPT004N03L Power MOSFET. The transistor has a very large transconductance at 500 A, therefore a small change in gate-to-source voltage can cause a large change in drain current. This is undesirable because we would like to have very precise control over the load current [5] (OM).

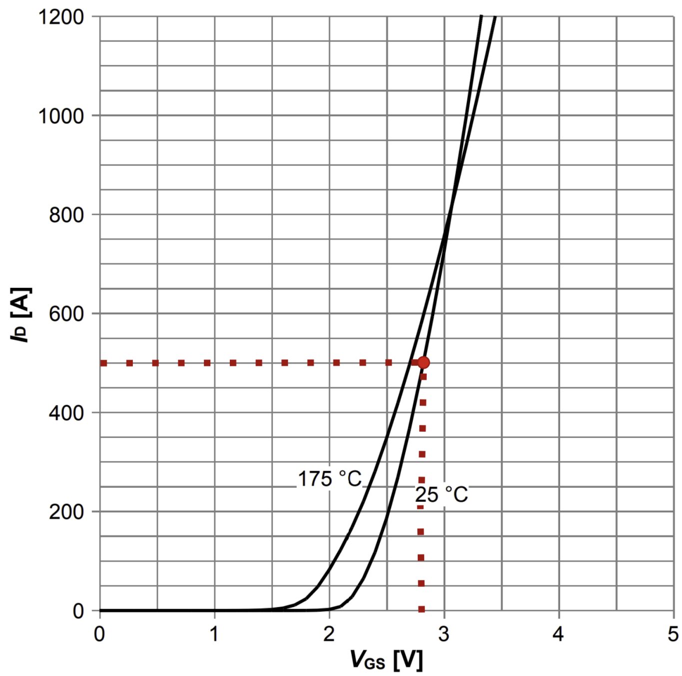


Figure 6: Id vs Vgs for the IPT004N03L Power MOSFET (Diagram 7) [5]

The nonlinearity of the transistor's IV-characteristics also requires more software overhead to calculate the correct control voltage that should be applied to the gate terminal. Additionally, negative feedback in the form of hardware or software may be needed to prevent any variations in the load current due to large transconductances. Another issue with this approach is if the transistors are mounted on a printed circuit board, it will be very challenging to have the PCB traces not burn due to the excess current passing through them. For all of the reasons stated above the team has decided not to use transistors as loading elements for the battery pack (OM).

Using a fixed high-power resistor in series with a high-current relay is theoretically possible, but impractical. To draw 500 A from a 13.2 V battery, the resistor would need to be both extremely low in resistance and capable of dissipating 6600 W of power. Finding a component that meets both the high power and current ratings while maintaining such a low resistance is highly improbable and unfeasible for our application. Additionally, a fixed resistor provides very little control over the loaded current—it would simply be determined by the ratio of the quad pack voltage to the resistor value (OM).

Carbon disks are able to handle the 500A current requirement and their resistance can also be controlled by compression to close or open air gaps in the material. Only one single carbon pile needs to be used as a variable load resistor for this application. Additionally, it is easy to control the resistance of the carbon pile by compressing it mechanically without too much overhead. For these reasons, the group has decided to use a carbon pile as the load resistor. A schematic of the carbon pile load and its connections to the rest of the circuit is included below in figure 7 (OM).

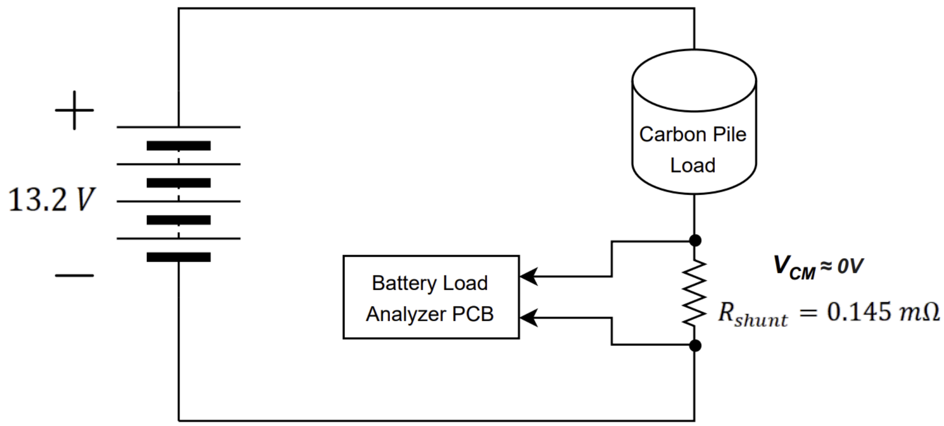


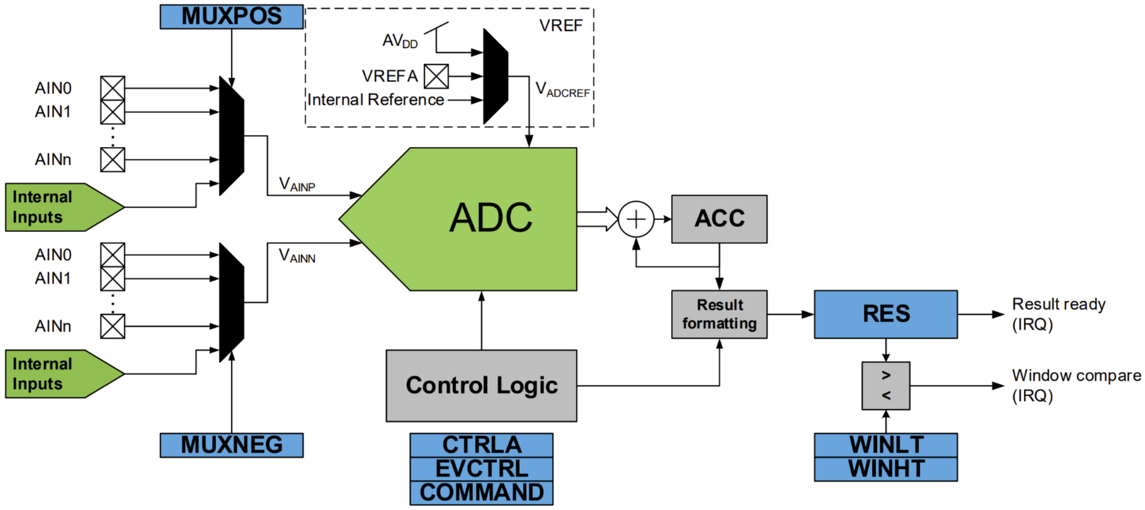
Figure 7: Schematic of Electromechanical Components (OM)

Analog-to-Digital Converter (ADC):

The ADC will be used to measure the battery cell voltages and measure the voltage across the current sensing resistor. These are all differential measurements so either a differential ADC or a single-ended ADC with a front-end differential amplifier can be used. Additionally, the group must decide whether to use an ADC that is internal to our microcontroller or an external ADC integrated circuit. Since this project does not require a particularly high sample rate or resolution the group has decided to use the AVR128DB48's internal ADC because it requires less support circuitry and it can be configured to make either single-ended or differential measurements.The ADC of the AVR128DB48 has up to 22 different input channels that can be multiplexed using software commands [4]. For this design, the group will select the ADC input pin using software rather than using an external analog multiplexing scheme. A block diagram of the internal ADC is shown below in figure 8 (OM).

33.2.1 Block Diagram

Figure 33-1. Block Diagram



33.2.2 Signal Description

Pin Name	Type	Description
AIN[n:0]	Analog input	Analog input to be converted
VREFA	Analog input	External voltage reference pin

Figure 8: AVR128DB48 ADC Peripheral Block Diagram (Datasheet Section 33.2.1) [4]

The internal ADC of the AVR128DB48 can also be configured to have 12-bit or 10-bit resolution. If the ADC is configured to make differential measurements, the most-significant-bit (MSB) is used as a signed bit [4]. Additionally, the reference voltage options of the ADC are shown below in figure 9 (OM).

Bits 2:0 – REFSEL[2:0] Reference Select

This bit field controls the reference voltage level for ADC0.

Value	Name	Description
0x0	1V024	Internal 1.024V reference[1]
0x1	2V048	Internal 2.048V reference[1]
0x2	4V096	Internal 4.096V reference[1]
0x3	2V500	Internal 2.500V reference[1]
0x4	-	Reserved
0x5	VDD	VDD as reference
0x6	VREFA	External reference from the VREFA pin
0x7	-	Reserved

Note:

1. The values given for internal references are only typical. Refer to the *Electrical Characteristics* section for further details.

Figure 9 - AVR128DB48 ADC0 Reference Voltages (Section 21.5.1 of Datasheet) [4]

The reference voltages are generated from a bandgap reference which is stable over a wide range of operating conditions. A block diagram of the internal reference voltages is shown in figure 10 (OM).

21.2.1 Block Diagram

Figure 21-1. VREF Block Diagram

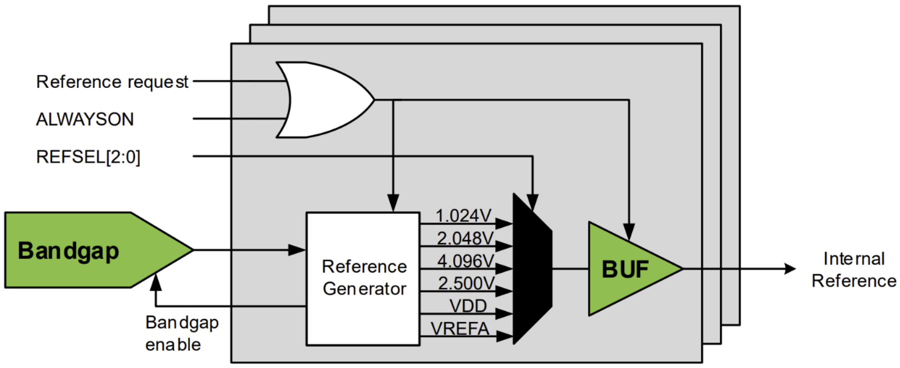


Figure 10: AVR128DB48 Analog Voltage References (Section 21.2.1 of Datasheet) [4]

Additionally, the integer result of the ADC in various configuration modes is shown in figure 11. Resolution is defined as the smallest measurable voltage increment (quantization step). It is equal to the voltage corresponding to an integer result of 1 or one least-significant-bit (LSB) (OM).

33.3.3.5 Conversion Result (Output Formats)

The result of an analog-to-digital conversion is written to the 16-bit Result (ADCn.RES) register and is given by the following equations:

Single-ended 12-bit conversion: $RES = \frac{V_{\mathrm{AINP}}}{V_{\mathrm{ADCREF}}} \times 4096 \in [0, 4095]$

Single-ended 10-bit conversion: $RES = \frac{V_{\mathrm{AINP}}}{V_{\mathrm{ADCREF}}} \times 1024 \in [0, 1023]$

Differential 12-bit conversion: $RES = \frac{V_{\mathrm{AINP}} - V_{\mathrm{AINN}}}{V_{\mathrm{ADCREF}}} \times 2048 \in [-2048, 2047]$

Differential 10-bit conversion: $RES = \frac{V_{\mathrm{AINP}} - V_{\mathrm{AINN}}}{V_{\mathrm{ADCREF}}} \times 512 \in [-512, 511]$

Figure 11 - AVR128DB48 ADC Resolution (Section 33.3.3.5 of datasheet) [4]

The equations in figure 8 show that there is a clear tradeoff between resolution and input range when selecting the reference voltage. If the input range is defined as the difference between the minimum and maximum allowable inputs (single-ended or differential) and it is assumed that an

LSB is negligible in comparison to the full scale value, the following relationships can be observed in equations 1 and 2 (OM).

$$RESOLUTION = \frac{V_{ADCREF}}{2^N} \quad (1)$$

$$INPUT\ RANGE \cong V_{ADCREF} \quad (2)$$

Note that the input is V_{AINP} for single-ended signals and V_{AINP} - V_{AINN} for differential signals. Additionally, note that N is the number of bits and that a smaller resolution is more precise and has better accuracy. For a fixed number of bits, the input range is *proportional* to the reference voltage and the resolution (precision) is *inversely proportional* to the reference (OM).

Most of the battery terminal voltages are above the microcontroller power supply voltage, therefore, they must be attenuated as to fit within the input range of the ADC. Too much attenuation will reduce the input signal level and decrease the signal-to-noise ratio of our measurement. For this reason the group decided not to use the 1.024V reference as the input signal would require too much attenuation to fit within the ADC input range. After experimenting in the lab, the team found that the 2.048V reference gave the most accurate ADC measurements. The experimental results are shown below in table 1 (OM).

Table 1: Voltage Measurements Using Different ADC Reference Voltages (TS)

Battery Voltage from Multimeter (V)	Battery Voltage from MCU's ADC Using 2.048 V Voltage Reference (V)	Battery Voltage from MCU's ADC Using 3.3 V Voltage Reference (V)
3.32	3.307	3.307
3.34	3.350	3.355
3.33	3.328	3.334
3.32	3.307	3.313

In order to measure the voltage across each battery cell, the ADC is configured in differential mode and the resolution is chosen to be 12 bits. All of the battery cell voltages in this circuit are positive, therefore, the MSB (sign bit) will always be 0 because $V_{AINP} \geq V_{AINN}$. As a result, the resolution with respect to *positive* input signals where $V_{AINP} \geq V_{AINN}$ is effectively 11 bits, since the 12th bit will always be 0. Therefore, when the ADC is in differential mode, the effective voltage resolution of the ADC for *positive* input voltages will be 1 mV, as shown in equation 3 (OM).

$$RESOLUTION = V_{min} = \frac{V_{ADCREF}}{2^{11}} = \frac{2048\ mV}{2048} = \mathbf{1mV} \quad (3)$$

Current Sense Resistor (Shunt):

For the current sensing resistor, the group is using a simple shunt with a series resistance value of 0.145 mΩ. When the shunt is placed in series with the carbon pile load, then the current that passes through the shunt is equal to the load current drawn by the carbon pile. This shunt resistance is small enough to not affect the load current being drawn and it will allow the team to measure the load current with the ADC by dividing the voltage across it by the known resistance in software. The shunt can be placed on the high-voltage side in between the carbon pile and the positive quad-pack terminal as shown in figure 9 or it can be placed on the low-voltage side in between the carbon pile and ground as shown in figure 10. For high-side current sensing, the common-mode voltage across the shunt is defined as the average of the voltages at the two terminals of the shunt resistor. Neglecting the small voltage drop across the shunt, this common-mode voltage is approximately equal to the quad-pack voltage of +13.2 V. Because the voltage drop across the shunt is minimal, both terminal voltages will be close to +13.2 V. Therefore, external voltage dividers are required to scale the voltage levels down to fall within the ADC's input range. To accurately amplify the small differential voltage across the shunt in the presence of a large common-mode voltage, an amplifier with a high common-mode rejection ratio (CMRR) is necessary (OM).

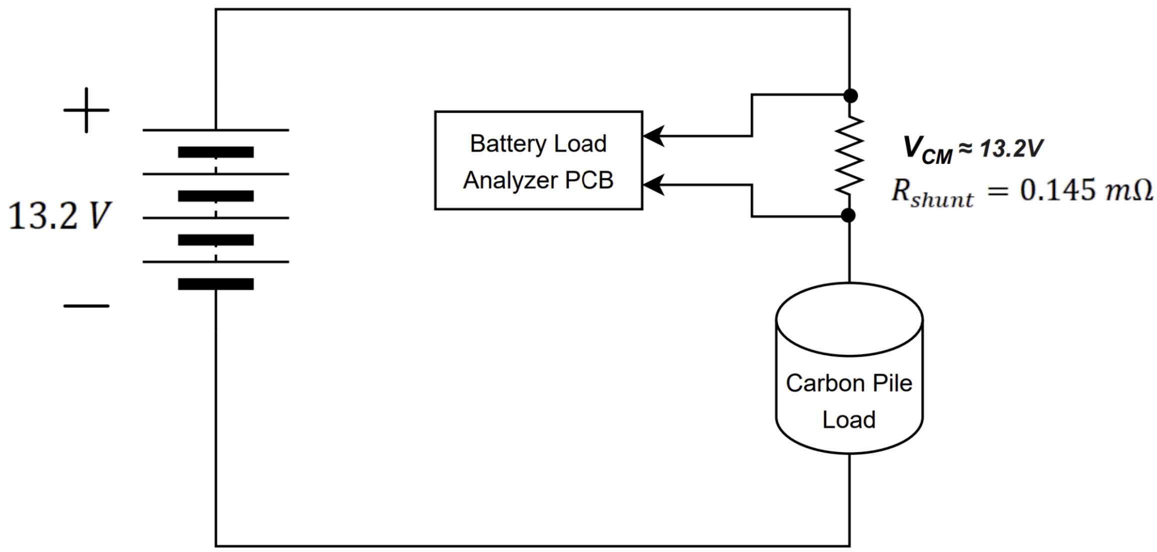


Figure 9: High-Side Current Sensing (OM)

In order to eliminate the need for external voltage dividers and a large CMRR, low-side current sensing can be used. Neglecting the small voltage drop across the shunt, this common-mode voltage is approximately equal to 0 V (ground). Because the voltage drop across the shunt is minimal, both terminal voltages will also be close to 0 V which is within the input range of the ADC (OM).

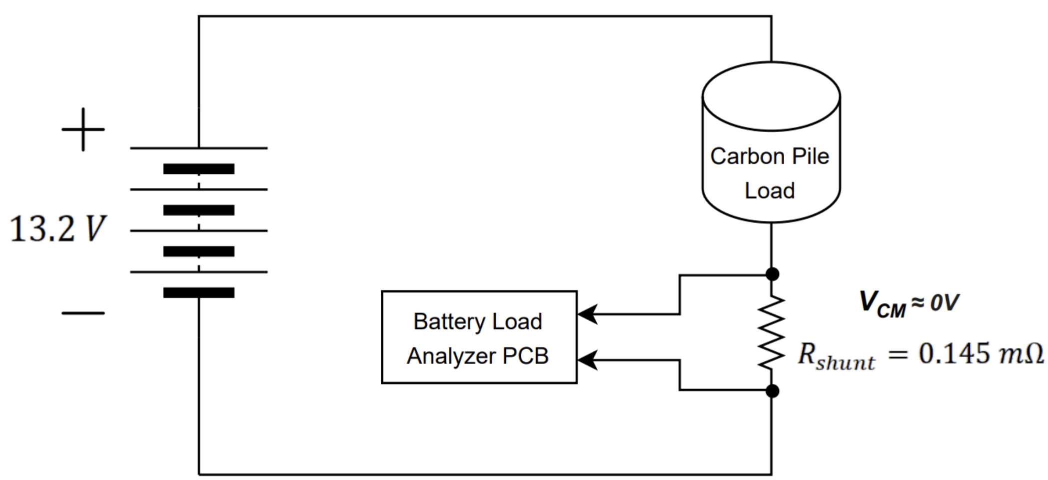


Figure 10: Low-Side Current Sensing (OM)

Analog Ammeter:

In addition to digital current readings, the design also features an analog ammeter as shown in figure 11 below to display current measurements (TS).

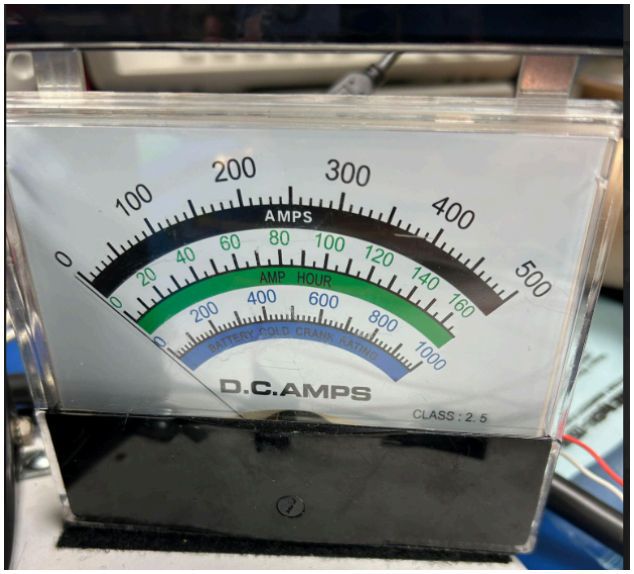


Figure 11: Ammeter to Measure Current (TS)

The analog ammeter is connected in parallel with the shunt resistor, as shown in figure 12 below. Note that the battery load analyzer PCB is excluded from this figure (OM).

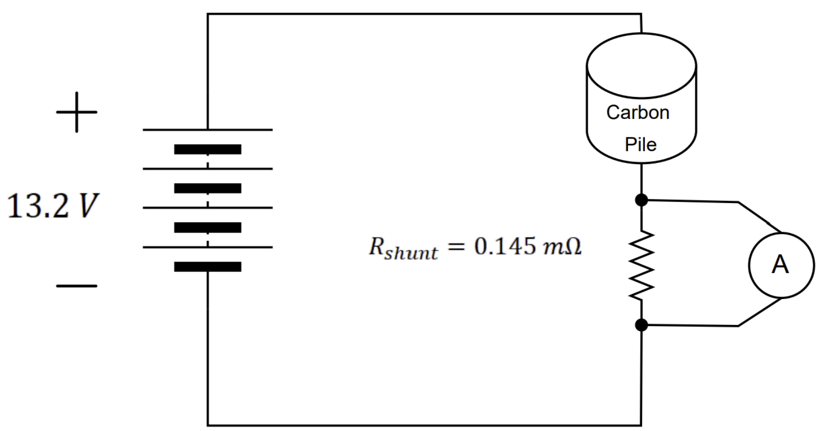


Figure 12: Analog Ammeter Connection (OM)

It draws a small amount of current from the voltage drop across the shunt resistor and generates a magnetic field. The magnetic field causes a mechanical deflection of the needle at an angle that is proportional to the current. The scale markings on the meter translate the needle's deflection angle into a current value in amperes. In order to calibrate the ammeter, a current limiting resistor is placed in series to fine tune the deflection angle of the needle until the current indicated by the scale markings exactly matches the current through the shunt. The calibration setup is shown in figure 13 below (OM).

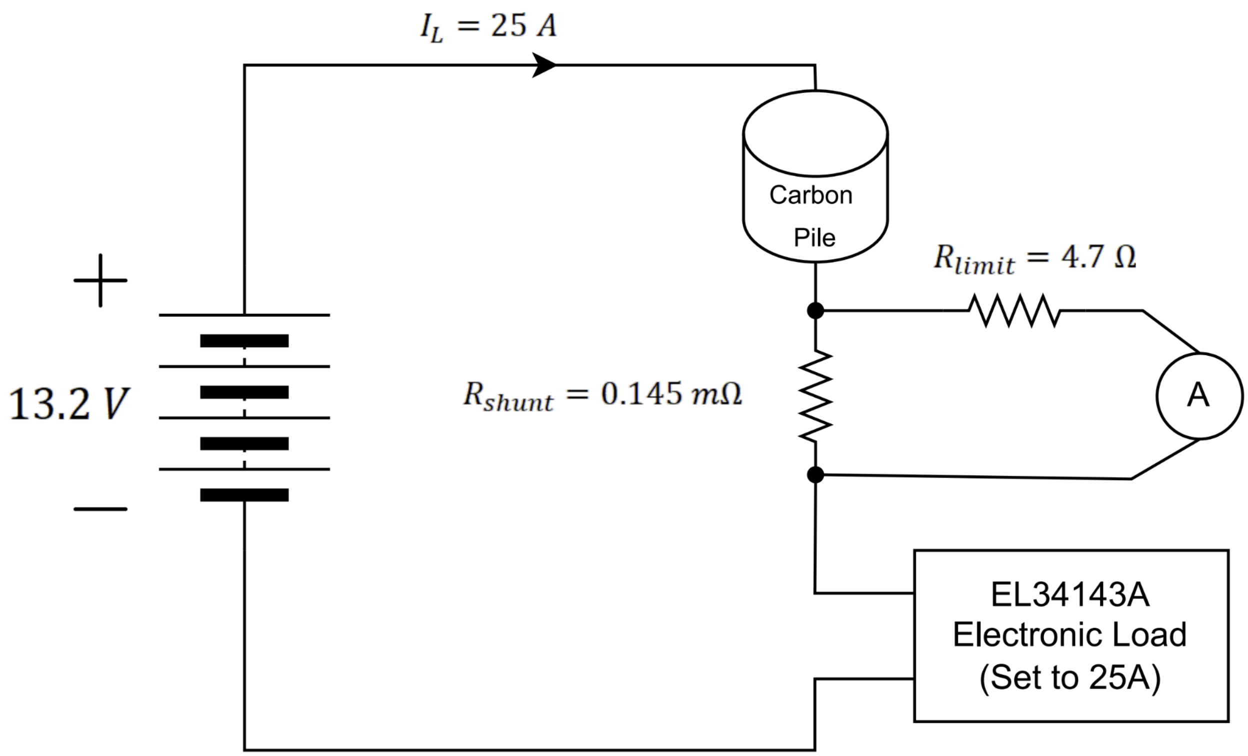


Figure 13: Analog Ammeter Calibration Setup (OM)

The EL34143A electronic load is connected in series with the quad-pack and is configured to set the current drawn from the quad-pack to exactly 25A. The current limiting resistor is adjusted until the current reading on the analog ammeter is exactly equal to 25A, which is the value set by the electronic load. Note that the carbon pile was fully compressed to act as a short-circuit during the calibration. After performing the calibration in the lab, the current limiting resistor value was determined to be 4.7 Ω (OM).

Current Sense Amplifier (AD8410A):

If no amplification is used and a differential ADC measurement is made directly on the voltage drop across the shunt, then the smallest measurable current increment (current resolution) is

$$I_{min} = \frac{V_{min}}{R_{shunt}} = \frac{1\ mV}{0.183\ \text{m}\Omega} \cong \mathbf{5.46\ A} \tag{4}$$

Additionally, if we assume that the minimum current is negligible in comparison to the full-scale current, then the maximum measurable current is

$$I_{max} \cong \frac{V_{ADCREF}}{R_{shunt}} = \frac{2048\ mV}{0.183\ \text{m}\Omega} \cong \mathbf{11,191\ A} \tag{5}$$

If the input current range is between 0A and 11,191A then the resolution expressed as a percent of the maximum allowable input is about 0.05%

$$I_{res} = \frac{I_{min}}{I_{max}} = \frac{5.46}{11{,}191} \cong \mathbf{0.0488\%} \tag{6}$$

For our application, the current is limited to between 0A and 500A, therefore, the resolution as a percentage of the full-scale value is about 1.1%.

$$I_{res} = \frac{I_{min}}{I_{max}} = \frac{5.46}{500} \cong \mathbf{1.092\%} \tag{7}$$

It is now clear that without amplification, less than 5% of the available ADC resolution would be used if the current is limited to between 0 and 500A. In order to make effective use of the ADC's input range and increase measurement precision, a differential amplifier must be used to amplify the voltage drop before it is measured by the ADC. The group has decided to use the AD8410A current sense amplifier in the configuration shown in figure 14 (OM).

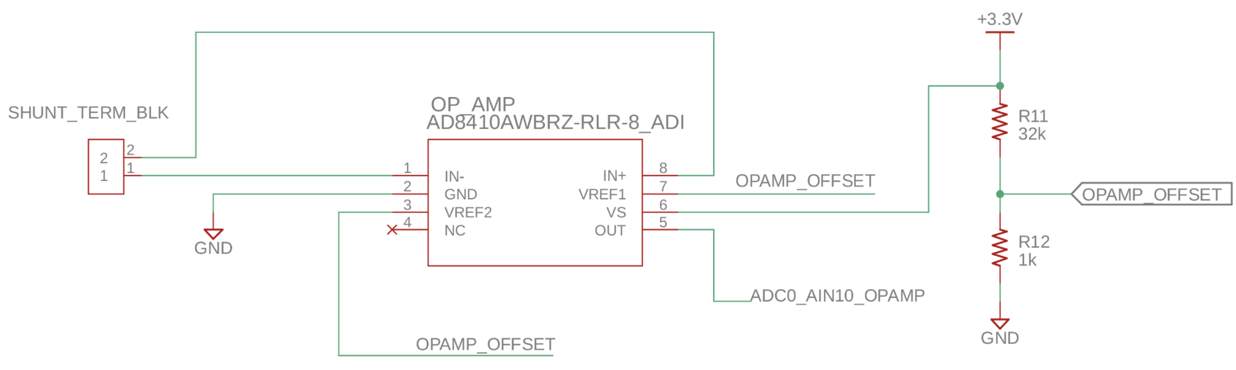


Figure 14: AD8410A Current Sense Schematic (OM)

The AD8410A is a differential-input, single-ended-output current sense amplifier with a fixed differential voltage gain of 20 V/V. After experimenting with the amplifier, the group found that the output voltage could not go below 3 mV even with 0 A of current passing through the shunt. This resulted in a nonzero current being measured even when the load current through the shunt was 0 A. Figure 15 shows how an external voltage source can be used to add a reference offset to the output of the AD8410A (OM).

External Referenced Output

Tie $V_{REF}1$ and $V_{REF}2$ together and to a reference to produce an output equal to the reference voltage when there is no differential input (see *Figure 53*). The output decreases with respect to the reference voltage when the input is negative, relative to the −IN pin, and increases when the input is positive, relative to the −IN pin.

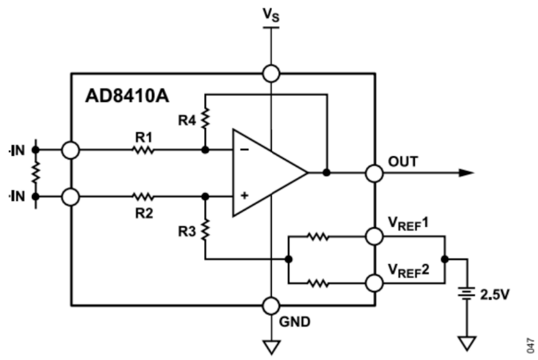


Figure 53. External Referenced Output

Figure 15: AD8410A External Reference Output (Datasheet page 22) [6]

Due to limited time and resources, we decided that the resistive voltage divider in figure 14 was the simplest and most efficient way to generate the offset voltage source. Adding too much offset would reduce the input range, therefore, a 100mV reference voltage was determined sufficient for our design. According to the resistor values in figure 10, the reference voltage is

$$V_{OFFSET} = 3.3\left(\frac{R_{12}}{R_{11} + R_{12}}\right) = 3.3\left(\frac{1}{1 + 32}\right) = 0.1\ V \tag{8}$$

The output voltage of the AD8410A was experimentally determined to have the following relationship as a function of the voltage difference across the shunt.

$$V_{out} = 20 I_{shunt} R_{shunt} + 0.1 \tag{9}$$

The output of the AD8410A is a single-ended voltage, therefore, the ADC is now configured in single-ended mode for current measurements. If 12-bit single-ended ADC measurements are made with the 2.048V reference voltage, the new voltage resolution is 0.5mV.

$$RESOLUTION = V_{min} = \frac{V_{ADCREF}}{2^{12}} = \frac{2048\ mV}{4096} = \mathbf{0.5\ mV} \tag{10}$$

Consequently, the smallest measurable current increment is now 0.137A and full-scale current is now 532 A (OM).

$$I_{min} = \frac{V_{min}}{A \times R_{shunt}} = \frac{0.5\ mV}{20 \times 0.183\ \text{m}\Omega} \cong \mathbf{0.137\ A} \tag{11}$$

$$I_{max} \cong \frac{V_{ADCREF} - V_{ref}}{A \times R_{shunt}} = \frac{(2048 - 100)\ mV}{20 \times 0.183\ \text{m}\Omega} \cong \mathbf{532\ A} \tag{12}$$

After using the signal conditioning circuit in figure 10, the new current resolution expressed as a percentage of the full-scale value is:

$$I_{res} = \frac{I_{min}}{I_{max}} = \frac{0.137}{532} \cong \mathbf{0.0257\%} \tag{13}$$

This is a tremendous improvement compared to when a differential voltage measurement was performed on the voltage drop across the shunt without amplification. Additionally, the single-ended to differential conversion performed by the amplifier allowed us to configure the ADC in single-ended mode which has 12-bit resolution for positive unipolar input voltages. Note that the ADC is assumed to be ideal in these calculations. Inaccurate ADC measurements will not permit the current resolution to be equal to the theoretical value. Since the user interface only allows the current to be programmed with a minimum increment of 1A, the current resolution is rounded up to 1A (OM).

Current Sense Amplifier (AVR128DB48 Internal OP AMP Peripheral):

Originally, the internal OP AMP peripherals of the AVR128DB48 were configured to form an instrumentation amplifier with a gain of 15 as shown in figure 16 (OM).

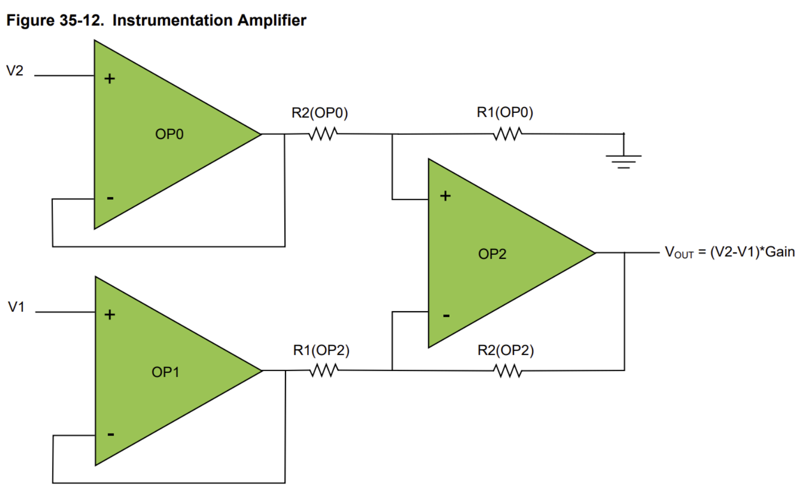


Figure 16: AVR128DB48 Internal OP AMPs used as Instrumentation Amplifier (Figure 35-12 of datasheet)[4]

The first drawback is that the maximum voltage gain is limited to 15, which results in lower current resolution compared to the AD8410A with a gain of 20. However, the resolution would still remain within 1 A, and this approach reduces the need for additional external hardware, making it potentially more desirable. After programming the AVR128DB48 OP AMP peripheral to form an instrumentation amplifier with a gain of 15, the group obtained the following relationship between the input differential voltage and the gain of the instrumentation amplifier shown in figure 17 (OM).

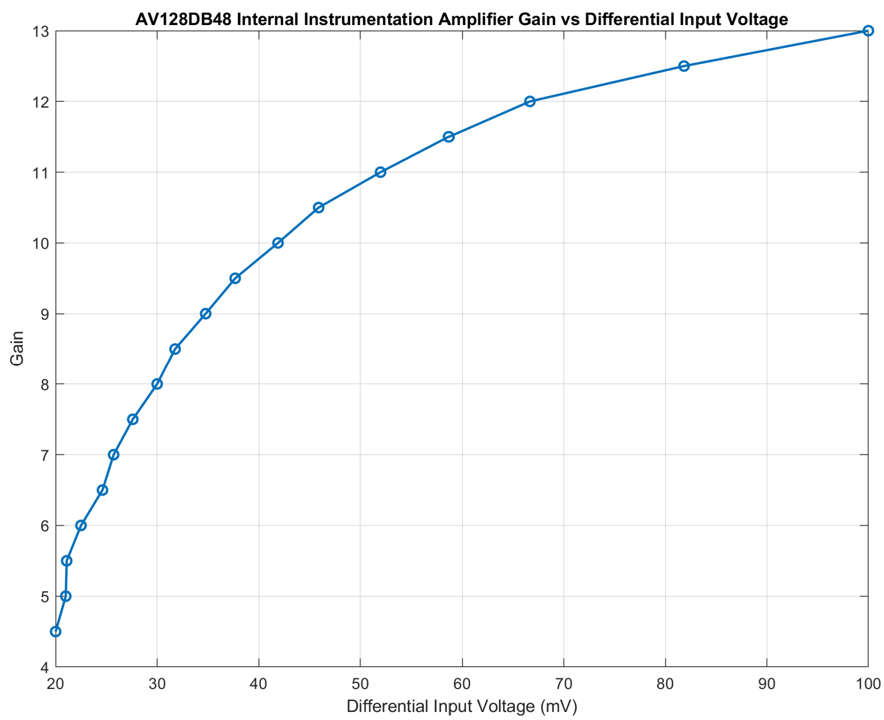


Figure 17: Voltage Gain vs Input Voltage for AVR128DB48 Instrumentation Amplifier (OM)

This clearly shows that the gain decreases exponentially for differential inputs below 100mV. At 500 A, the differential voltage across the shunt is only 72.5 mV, meaning that the current measurements would be highly inaccurate below 500 A.

$$V_{shunt} = I_L R_{shunt} = (500)(0.000145) = 0.0725V \quad (14)$$

This is exactly what experiments confirmed as the group was unable to measure any currents below 100 A, and even above 100 A, the measurements showed significant variability and very poor accuracy. Consequently, the team decided to use the external AD8410A as a front-end differential amplifier rather than working with the internal op amps of the microcontroller (OM).

Battery Voltage Measurements:

The total voltage across the battery pack is 13.2V and the microcontroller input pins have a maximum rated voltage of 3.6V when a 3.3V power supply is used [4]. Additionally, as previously discussed, the ADC is configured in differential mode, therefore, all differential input voltages must be scaled to fit within the ADC input range for accurate measurements. If the differential input voltage exceeds the ADC reference voltage, then the result will be clipped at the full-scale value. For the faculty advisor's quad-packs, the nominal differential voltage across each battery cell is 3.3V, therefore, the minimum voltage divider ratio required to ensure the differential voltage is within the ADC input range is about 1.6 (OM).

$$\frac{V_{OUT}}{VIN} \geq \frac{3.3V}{2.048V} \cong 1.612 \quad (14)$$

However, the positive terminals of the battery cells are above the absolute maximum rating of 3.6V. In order to prevent damage to the microcontroller, a larger voltage divider ratio is required to scale the positive battery terminal voltage down to within the maximum rating of the microcontroller input pins. In order to simplify the software and hardware assembly, the group has decided to use the same voltage divider ratio for all of the battery cell measurements. The maximum voltage across the entire quadpack is 13.2V, therefore, the minimum voltage divider ratio to ensure that all microcontroller pin voltages remain within the maximum rating 3.6V is about 3.67

$$\frac{V_{OUT}}{VIN} \geq \frac{13.2V}{3.6V} \cong 3.67 \quad (15)$$

To provide an additional safety margin, a voltage divider ratio of 5.3 was chosen with the following resistor values.

$$\boldsymbol{R_1 = 1\ k\Omega} \quad (16)$$

$$\frac{R_1}{R_1 + R_2} = 5.3 \rightarrow \boldsymbol{R_2 = 4.3\ k\Omega} \quad (17)$$

The battery cell terminals are connected to the PCB with terminal blocks. A schematic of the voltage dividers used to scale the battery cell voltages to within the rated voltage levels is shown below in figure 18. Additionally, 100nF capacitors to ground are connected to each battery cell input in order to filter noise and prevent the voltages from dropping during the conversion process. During layout, the capacitors should be placed as close to the ADC as possible (OM).

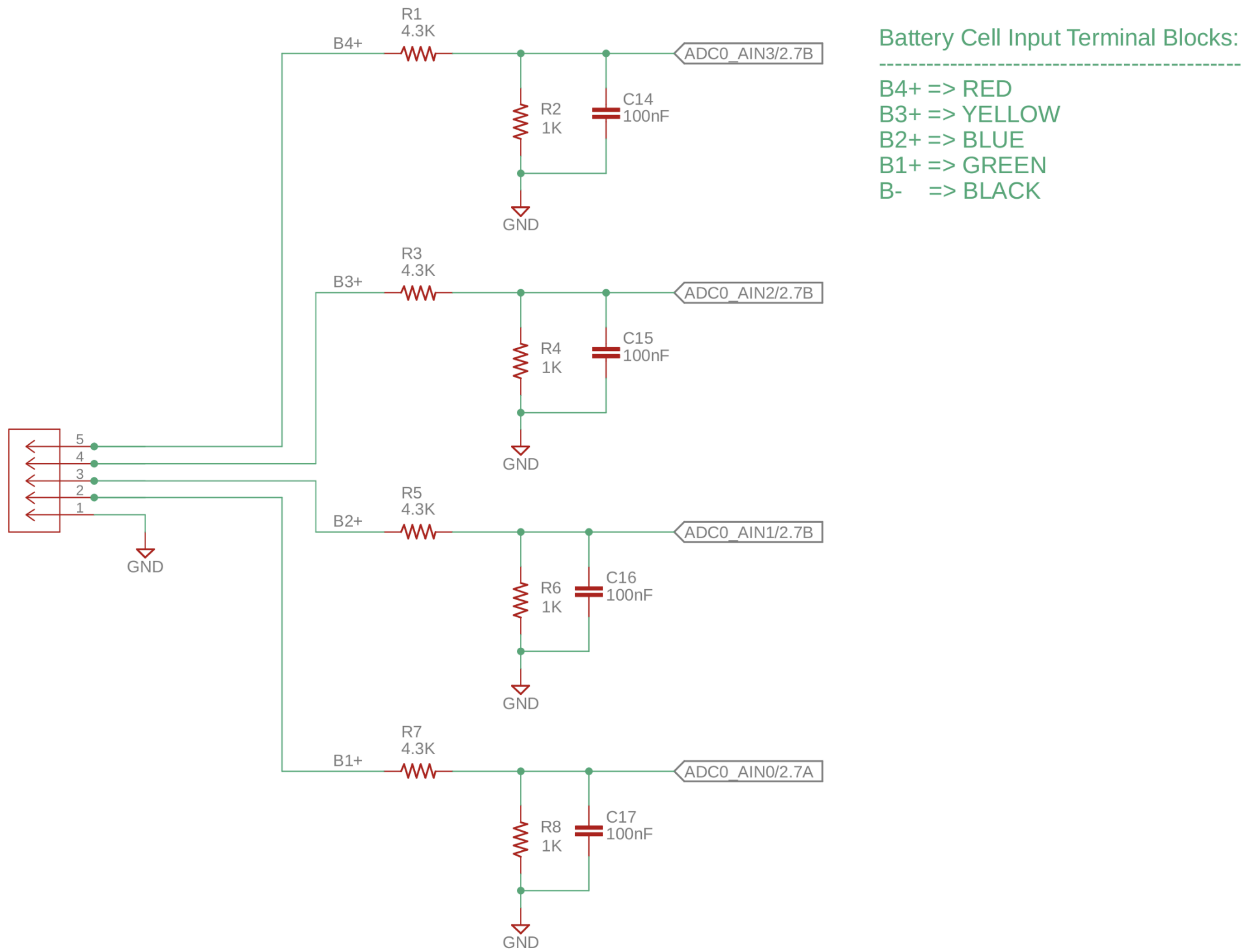


Figure 18: Input Voltage Dividers (OM)

Since all of the positive battery terminal voltages are divided by 5.3, the differential voltages are also divided by 5.3 due to the distributive property.

$$\left(\frac{V_2}{5.3} - \frac{V_1}{5.3}\right) = \frac{V_2 - V_1}{5.3} \quad (18)$$

As a result the input voltage of the ADC is divided by a factor of 5.3 and the voltage resolution for the differential battery cell measurements is 5.3 mV

$$V_{min} = \frac{V_{ADCREF}}{5.3 \times 2^{11}} = \frac{2048\ mV}{5.3 \times 2048} = \mathbf{5.3\ mV} \quad (19)$$

Note that inaccuracies can occur if the resistor values are not properly matched, therefore 1% tolerance resistors are used. This is because software multiplies the measured ADC input voltage by the voltage division ratio to calculate the original value. If the resistors are different from their nominal value, then the actual voltage divider ratio will not be equal to the value written into software (OM)

.

Stepper Motor:

The carbon pile load resistance is controlled by the compression force on the carbon pile. The battery tester that the team has dismantled for its carbon pile already has a linear actuator with all of the mechanical components that are needed for this design. However, the linear actuator requires the user to manually turn a knob to adjust the force on the carbon pile and the faculty advisor would like a fully automated test that only requires a single pushbutton press [3]. Therefore, the linear actuator that clamps down on the carbon pile needs to be electronically controlled. Since the battery tester already has a manually controlled linear actuator, the group decided to remove the knob and plug the shaft directly into a NEMA-17 stepper motor via a shaft coupler (OM).

The stepper motor can then rotate the shaft as if the user was manually rotating
the knob with their hand. The team has decided to use the current reading from the shunt as feedback for the microcontroller to adjust the stepper motor position until the error between the programmed load current and the measured load current read from the shunt is minimized to within a steady-state error tolerance. A block diagram using negative feedback to electronically program the load current drawn from the battery pack is shown in figure 19 below (OM).

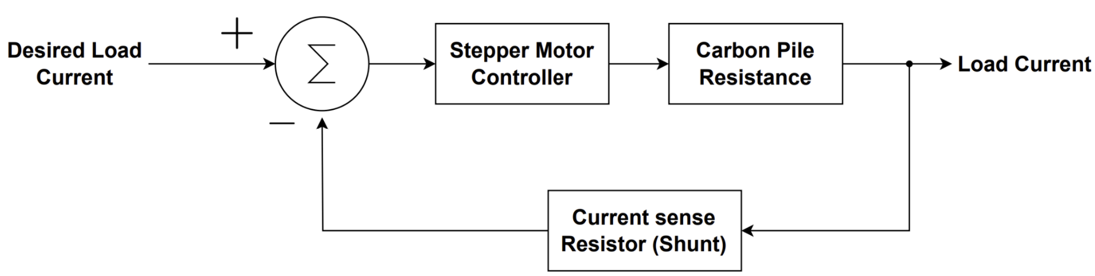


Figure 19: Stepper Motor Control Diagram (OM)

Additionally, an algorithmic flowchart for the software used to set the current equal to the target value is shown in figure 20 below:

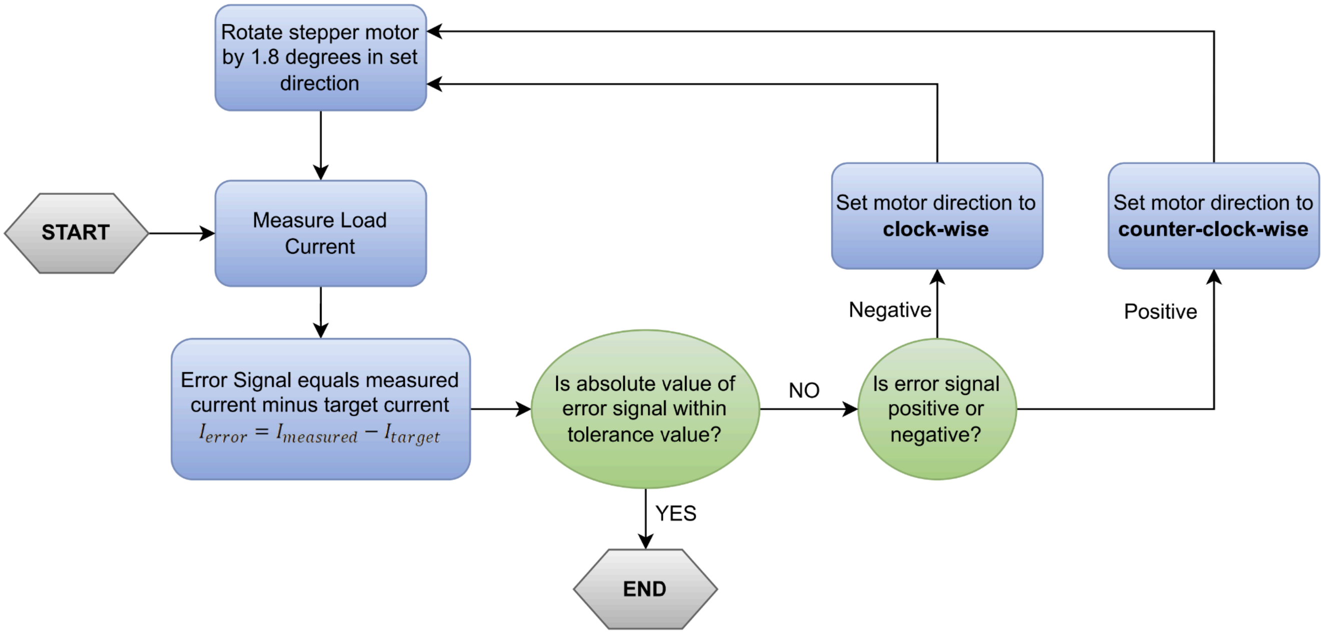


Figure 20: Stepper Motor Software Flowchart (OM)

The stepper motor is controlled using an A4988 driver with two MCU pins:

- One for direction control (1 = CW, 0 = CCW)
- One for generating step pulses

The A4988 is configured in full-step mode so that each step moves the motor in the set direction by 1.8 degrees. Since one full rotation is 360 degrees, 200 steps results in one full rotation. During automatic testing, the MCU uses a negative feedback loop to send STEP pulses to the motor and adjust its direction based on whether the measured load current is above or below the programmed target amount. The MCU remains in this feedback loop until the measured current level settles at the desired amount within a steady-state error tolerance. The NEMA-17 stepper motor is powered by a +12 V power supply and is currently limited to 500 mA. The group decided to use a separate carrier board to host the stepper motor driver. A schematic of the stepper motor board is shown in figure 21 (OM).

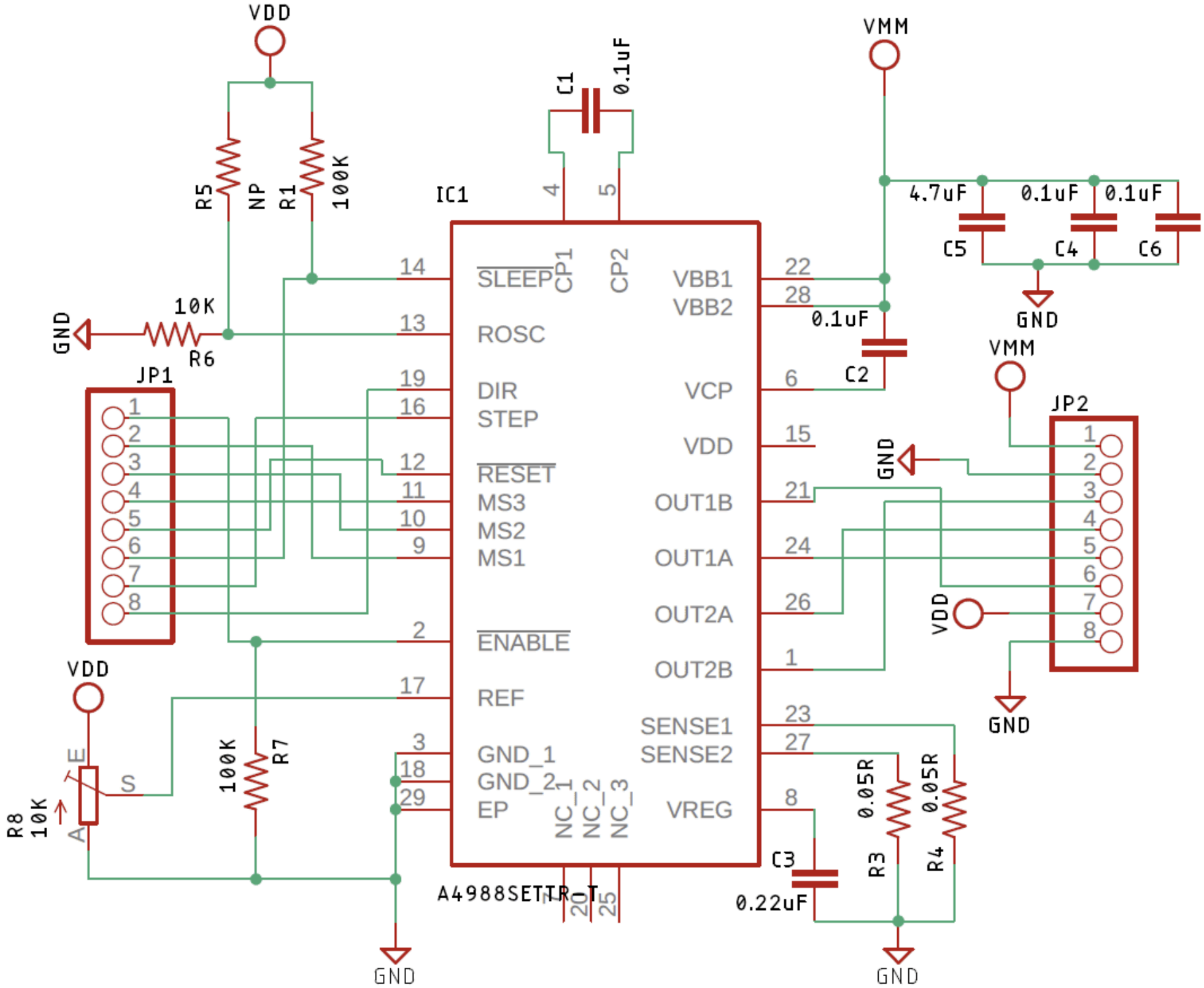


Figure 21: A4988 Stepper Motor Carrier Board [7]

The stepper motor carrier board is mounted on the main PCB with female headers. The MS1, MS2, and MS3 pins are all tied to ground so that A4988 is operating in full-step mode with a step resolution of 1.8 degrees. In order to prevent the stepper motor from causing power supply ripple, a 100 uF decoupling capacitor is used to isolate the motor from the main power 12 V power supply. A 100 nF decoupling capacitor is also included to isolate the A4988 logic from the main 3.3 V power supply used to power the microcontroller. Additionally, a SLEEP control pin is connected to pin PC6 of the microcontroller in order to save power when the motor is not being used for an automated test. A schematic of the main PCB interface to the A4988 stepper motor driver board is shown below in figure 22 and an image of the stepper motor mechanically coupled to the carbon pile is shown in figure 23.

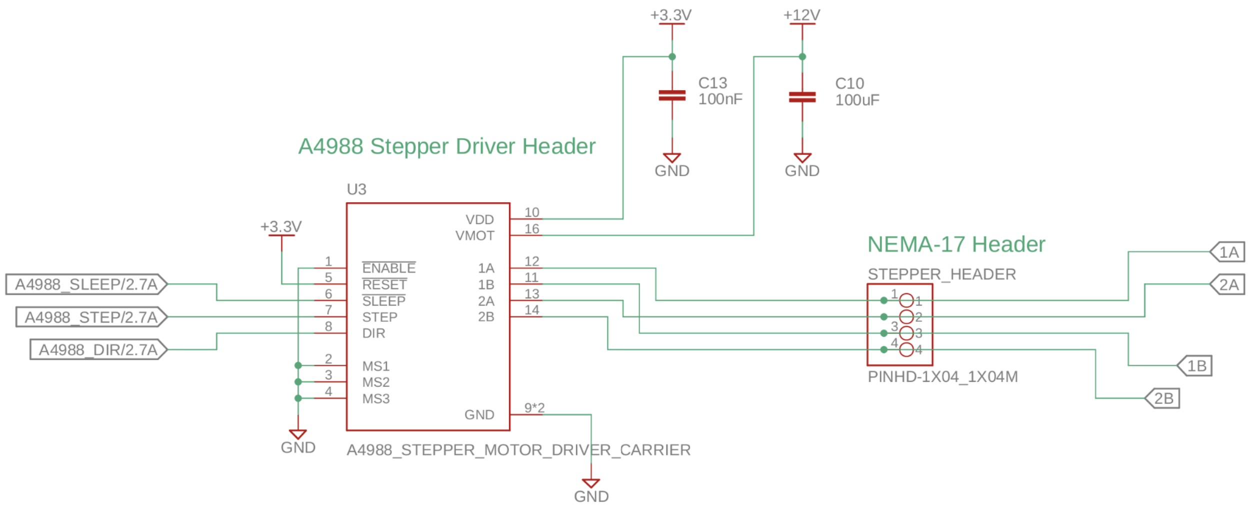


Figure 22 A4988 Stepper Motor Driver PCB Interface (OM)

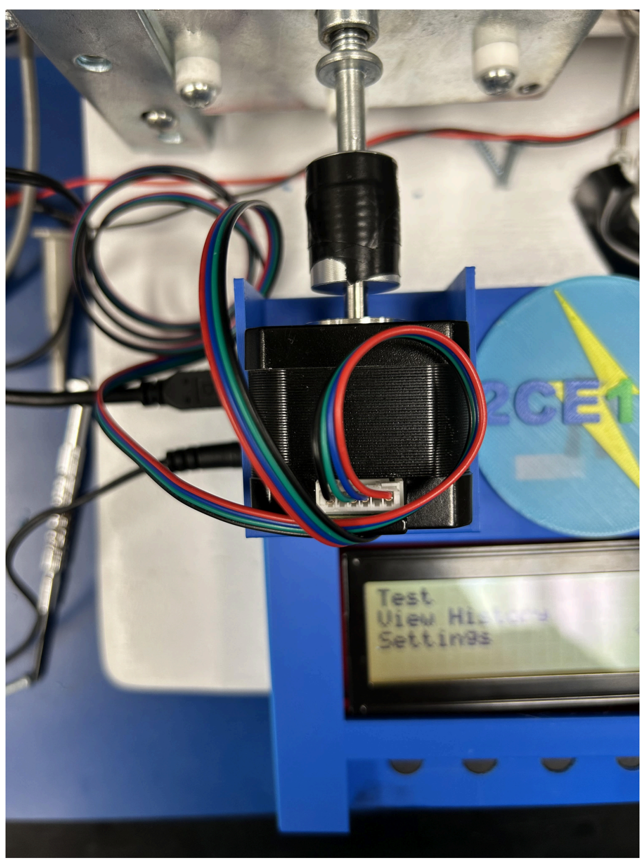


Figure 23: Stepper Motor Mechanical Coupling (TS)

Section 4.3 Power Supply Board:

The power supply board is shown below in the yellow box in figure 24. It is integrated into the main Printed Circuit Board (PCB) and uses the LM2596 buck converter. The schematic is shown below in figure 25. R2 is the upper resistance of the potentiometer and R1 is the resistance of the lower half of the potentiometer. The potentiometer is used to adjust the output voltage. This power supply is used to generate 3.3V for the circuit, and two additional wires from the 12V line will be used to power the fan and stepper motor (JL).

Figure 24: Power Supply Board (JL)

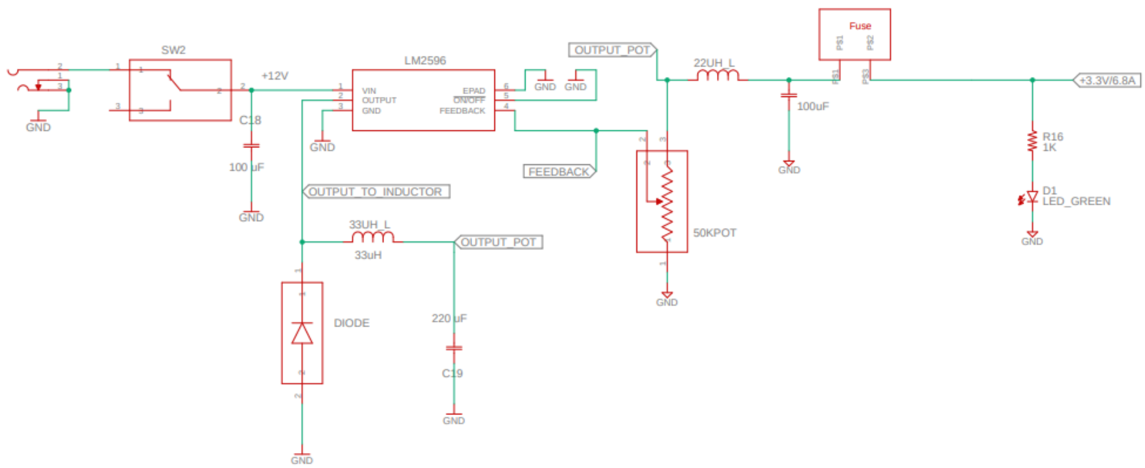


Figure 25: Power Supply Board Schematic (JL)

Table 2 shows the performance of the power supply circuit with different input voltages and resistances (JL).

Table 2: Power Supply Circuit Performance with Different Input Voltages and Resistances (JL)

Vin (V)	R2 (ohms)	R1 (ohms)	Expected Vout (V)	Vout (V)	% Error
4	3047	1903	3.21	3.3	2.8
4	1321	3629	1.67	1.71	2.4
4	0	4950	1.23	1.65	34
4	4850	100	4	3.85	3.75
5	4850	100	5	4.82	3.6
6	4850	100	6	5.78	3.7
8	4109	841	7.34	7.6	3.5
20	4850	100	20	19.45	2.75
20	3047	1903	3.21	3.3	2.8

System Block Diagram:

A high-level diagram of the design selected is shown in figure 26. The voltage dividers will attenuate the battery cell voltages so the microcontroller's internal ADC can multiplex them via software commands. Once the battery cell voltages are measured differentially, using the ADC, software will undo the attenuation and calculate the original voltages. As the load current passes through the shunt, it will create a small voltage drop across the shunt which a current sense amplifier will amplify for the ADC to convert. The amplifier is implemented using the AD8410A with a voltage gain of 20. The current measurement is used as feedback to help the microcontroller adjust the stepper motor position so the carbon pile has the correct resistance to draw a programmed load current. Additionally, the current is displayed as visual feedback to the user during manual testing in order for the user to adjust the control knob appropriately. At all times that the system is powered on, the fan is blowing air into the carbon pile in order to prevent overheating during load tests. Lastly, data can be logged and viewed using the local user interface on the LCD display or with the remote PC interface.

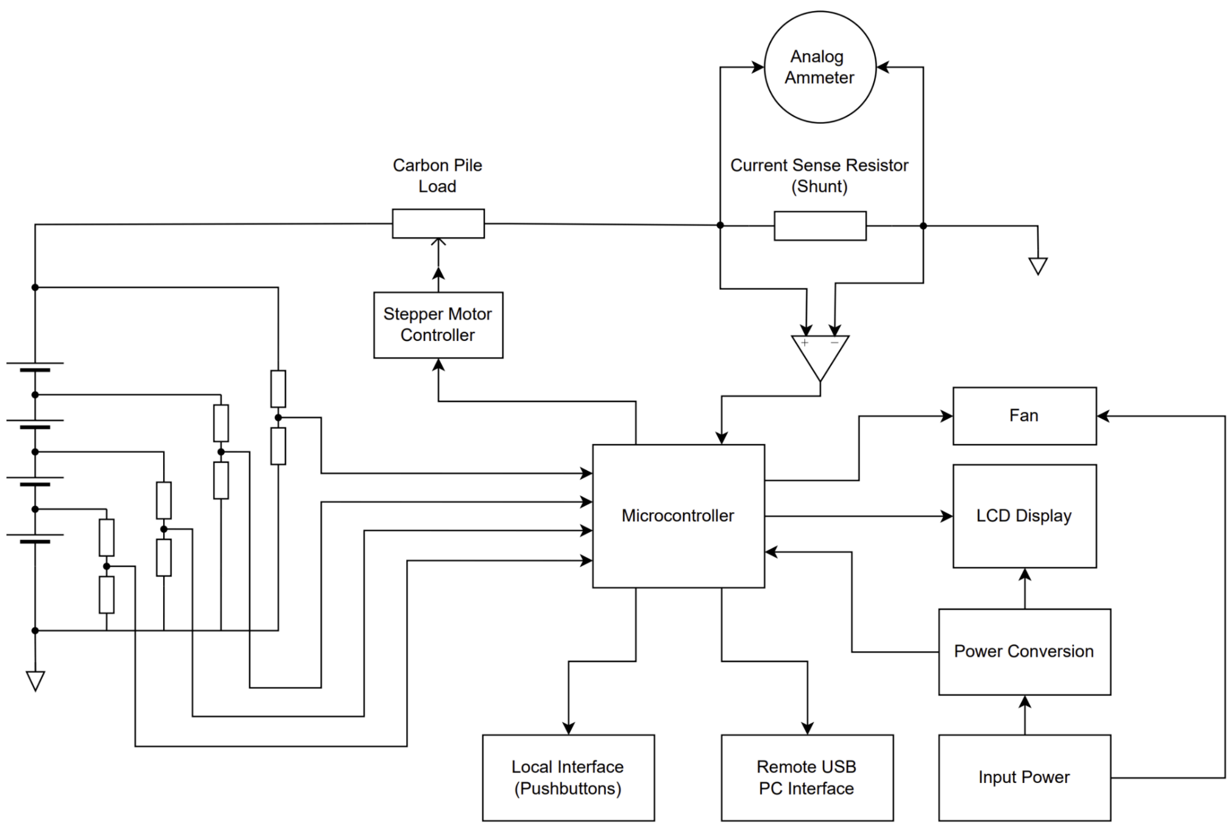


Figure 26: System Block Diagram (OM)

6 Social, Environmental, and Societal Impact Considerations

There are important societal safety concerns addressed by the help of the battery load analyzer. Developing an embedded battery load analyzer that can be controlled remotely, has a user-friendly interface, and that can store a report of a battery's health will streamline the detection of bad cells within a multi-cell lithium ion battery. When overcharging or severely discharging a lithium ion battery, a phenomenon known as thermal runaway can occur. This is when a single cell overheats and causes nearby cells to overheat and create a chain reaction that results in an explosion. In this case, spotting the bad cell early on can prevent a catastrophic explosion. Electric vehicle owners can find the battery load analyzer very handy to swiftly test the voltages of each cell within their battery to identify the bad cells. In fact, the owner doesn't need to know what voltages are within the safe limit, since the battery analyzer is incorporated with this knowledge. This can prevent further degradation of the lithium ion cells and vehicle accidents. The battery load analyzer can be used for testing the integrity of the production and research of lithium ion batteries. Lithium ion batteries used in electric vehicles undergo various stresses including extreme temperatures, exposure to moisture, stress from bearing weight of passengers, and shocks from uneven roads all of which can affect a lithium ion battery. Test engineers can utilize the battery load analyzer to ensure their batteries can withstand these conditions before sending them to consumers [8] (JL).

This device involves drawing a 500 A current from the battery. If touched by the user, a high current could lead to burns, permanent brain damage, or death. To address this, the team will develop a User Manual that details step by step how to use the device properly. The User Manual will include warnings about the high current and voltage about the possible risks of the device if the device is used improperly. The prototype will include a fan to cool down the electrical circuitry and reduce the risk of burns. Additionally, the prototype will be enclosed to further reduce the risk of exposure to high currents and voltages. Finally, the device will incorporate a warning buzzer that will be turned on if the device is very hot (TS).

7 Methods and Materials

Implementation Problems and Improvements:

Initially, voltage dividers were used to step down the battery voltages to safe levels for the MCU. The MCU's ADC read these values and recalculated the actual voltage by multiplying the measured voltage by the voltage divider ratio in software. After transitioning from the AVR128DB48 Curiosity Nano evaluation board to a new AVR128DB48 MCU on a breakout board, the team observed discrepancies in voltage readings. Suspecting resistor tolerance issues, the group replaced them with 1% tolerance resistors, but the voltage readings still varied by approximately 0.05 V. Even when measuring the voltages differentially and in single-ended mode, the measurements yielded similar inconsistencies (JL).

To improve accuracy, the internal ADC reference voltage was adjusted from 3.3V to 2.048V, allowing more precise measurements of small voltage variations. This adjustment improved accuracy to within 0.03V, but occasional 0.05V discrepancies remained for batteries 1 and 4. Further investigation revealed that the issue stemmed from the short pin length of wires used in the circuit, causing voltage fluctuations. Once replaced, the voltage readings stabilized. Capacitors were also added in parallel to all voltage inputs for additional noise filtering (JL).

Additionally, the group originally wanted to use the AVR128DB48 microcontroller's internal operational amplifier (OPAMP) as the current sense amplifier. However, as mentioned earlier, the internal OPAMP had poor current accuracy. As a result, the group decided to use an external amplifier intended for current sensing, the AD8410A. This is discussed more in detail in section 5 of this report under the Current Sense Amplifier Section (JL).

Final Implementation:

The final implementation of the system is discussed in detail in section 8 of this report.

8 Results and Discussion

The faculty advisor, Scott Tierno, brought in his own quad pack batteries for the group to test the system on. The main data measured were the battery voltages and currents. The battery voltages measured by the system were compared with the voltages measured using a handheld multimeter. The currents were compared with the current on the analog ammeter which was precisely calibrated using the Keysight EL34143A electronic load. The current and voltage measurements were collected by running loaded and unloaded tests on quad pack batteries and recording the measurements from the microcontroller that were produced from the test. Both manual and automated tests were performed to compare how the system performs according to the original specifications. Note that due to concerns about the long-term health of the quadpack, all loaded tests were limited to 100 A at the time of writing (TS).

Figure 27 shows the voltages measured by the MCU displayed on the LCD for a manual test performed with a load current of 100 A and figure 28 shows the voltages measured for an automated test performed with a load current of 100 A. The unloaded voltages are shown in the left column and the loaded voltages in the right column. The battery cells are labeled from top to bottom in ascending order, for example, “B1” corresponds to the bottom battery cell in the quad-pack with a nominal positive terminal voltage of 3.3V and “B4” corresponds to top battery cell in the quad-pack with a nominal positive terminal voltage of 13.2 V (TS).

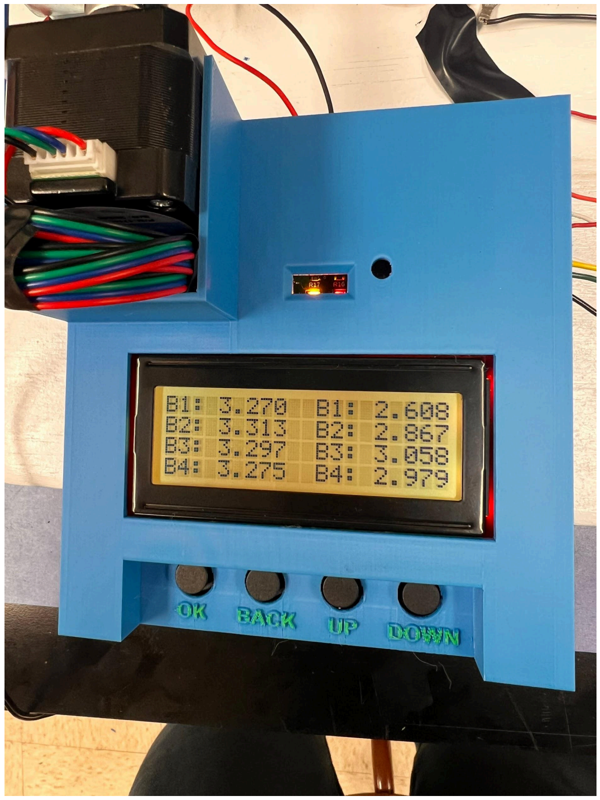


Figure 27: Measured Unloaded and Loaded Voltages for Manual Test (JL)

Figure 28: Measured Unloaded and Loaded Voltages for Automated Test (JL)

Tables 3 and 4 compare the unloaded voltages measured by the MCU with the voltages measured by a multimeter during a manual and automated test respectively (JL).

Table 3: Comparison of the MCU and Multimeter Measured Voltages for Manual Test (JL)

Battery Voltage from MCU's ADC Using 2.048 V Voltage Reference (V)	Battery Voltage from Multimeter (V)
3.270	3.300
3.313	3.290
3.297	3.300
3.275	3.290

Table 4: Comparison of the MCU and Multimeter Measured Voltages for Automated Test (JL)

Battery Voltage from MCU's ADC (V)	Battery Voltage from Multimeter (V)
3.270	3.300
3.313	3.290
3.297	3.300
3.275	3.290

The unloaded voltages are generally accurate within about 0.03 V, which is slightly higher than what the faculty advisor originally asked for. The reason for this discrepancy in voltage is because the accuracy of the microcontroller's ADC is limited in precision to 5mV when the external voltage dividers are used. Additionally, the microcontroller ADC is not ideal and there is a non-deterministic error between the voltage measured by the ADC and the actual input voltage. Table 5 compares the voltages measured by the ADC with the input voltage measured using a multimeter. This is the voltage of the battery cell after it has been stepped down by a factor of 5.3 from the voltage divider network (OM).

Table 5: Comparison of Input Voltage and Voltage Measured by ADC (JL)

ADC Input Voltage (V)	Voltage Measured by ADC (V)
0.617	0.620
1.242	1.244
1.864	1.865
2.482	2.482

The voltage reference could be decreased to increase precision, but then the input range would be reduced and the current reading would not be able to reach 500A since the full-scale voltage would be decreased. As a result, the voltage reference could not be decreased further than 2.048 V (TS).

Another source of error is that the resistor values used to create the voltage dividers are not exact, even though 1% tolerance resistors were used. Therefore, when software calculates the battery voltages based on the ADC value, the voltage divider ratio may not be exactly 5.3. Table 6 shows the input and output voltages for the voltage dividers used to scale down each battery cell voltage (OM).

Table 6: Voltage Divider Ratios (JL)

Voltage Divider Input (V)	Voltage Divider Output (V)	Voltage Divider Ratio (V/V)
3.280	0.620	5.290
6.580	1.244	5.289
9.870	1.865	5.292
13.17	2.482	5.306

Another source of error is thermal noise due to the resistors used in the voltage dividers. According to page 26 of the Tektronix document “Noise Figure - Overview of Noise Measurement and Methods”, any current that passes through the resistors, causes the physical matter to undergo molecular vibrations as a result of the thermal energy. The raw ADC measurements are accurate to within the theoretical 5mV and the voltage divider ratios are very close to the nominal values. As a result, it appears that the main source of battery voltage measurement inaccuracy is thermal noise generated by the resistive voltage dividers. The equivalent noise voltage caused by the thermal noise of each resistor is given by the following equation (OM).

$$e_{nR=\sqrt{4KTBR_0}} \quad (20)\ [9]$$

Table 7 shows currents measured by the MCU and compared with the ammeter measurement. Note that the currents were set by turning the control knob manually (JL).

Table 7: Comparison of the MCU and Ammeter Measured Currents (JL)

Current from MCU (A)	Current from Ammeter (A)
38.6	38
100.9	100
200.4	200
340.6	340

The remote and local user interfaces only support current settings in whole-ampere increments and the currents are experimentally determined to be accurate within about 1 A. The maximum current that could be obtained from the batteries was 350 A and not 500 A as originally specified. This is due to the dynamic range of the carbon pile resistance shrinking overtime. Repeated use of the carbon pile form when it was first purchased it has resulted in the minimum resistance increasing from about 19 mΩ when first used to 37 mΩ at the time of writing. The increased series resistance limits the current drawn from the battery to about 350A. The maximum current can be increased by shaving down or removing some of the carbon disks in the stack so that their resistance is decreased (OM).

The current accuracy is determined by the precision of the AD8410A current sense amplifier and by the accuracy of the ADC. Since the output characteristic of the AD8410A with a reference offset was near ideal it is not a primary source of any current measurement inaccuracy. The current measurements are subject to the same ADC measurement inaccuracies that limit the accuracy of the battery cell voltages. Therefore, the primary source of current measurement inaccuracies is the inaccurate ADC conversions and thermal noise due to resistances (OM).

The analog ammeter calibration also influences whether the results are interpreted correctly. The scale markings on the analog ammeter only have a precision of 10 A, therefore, the group had to rely on visual judgement to interpolate in between the scale markings. This method of calibration is subject to human error as it is difficult to reliably estimate the current to within 1A of precision when the ammeter dial is in between scale markings that are 10A apart. Nevertheless, the system only allows current settings with 1 A precision, therefore, any inaccuracies less than 1 A are not significant (OM).

The current for automated tests was limited to 200 A because the torque needed to compress the carbon pile began to exceed the stepper motor's capability. As a result, the motor would get jammed and the current would remain stuck at 200 A while the stepper motor is unable to deliver the torque necessary to rotate the knob any further. An additional feature was added to cancel the automated test and have the stepper motor open circuit the carbon pile with a pushbutton press (OM).

The final version allows the manual and automated tests to be initiated with the local interface or with a PC via the remote interface. An image of the final prototype is provided in figures 29-32 below. An image of the final remote interface is shown below in figure 33. The results of up to 13 quad-packs can be uploaded to a PC and stored into the microcontroller's internal EEPROM which retains the data even if power is disconnected. Additionally, the maximum current measured during the test is recorded, along with an indication of whether the test was manual or automatic (OM).

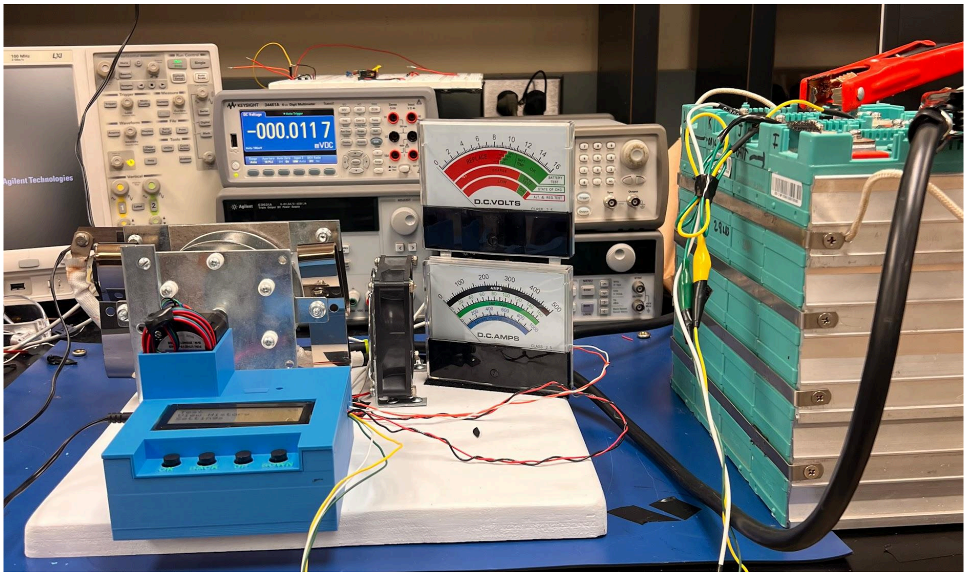


Figure 29: Final Prototype with Battery Connected Front View (JL)

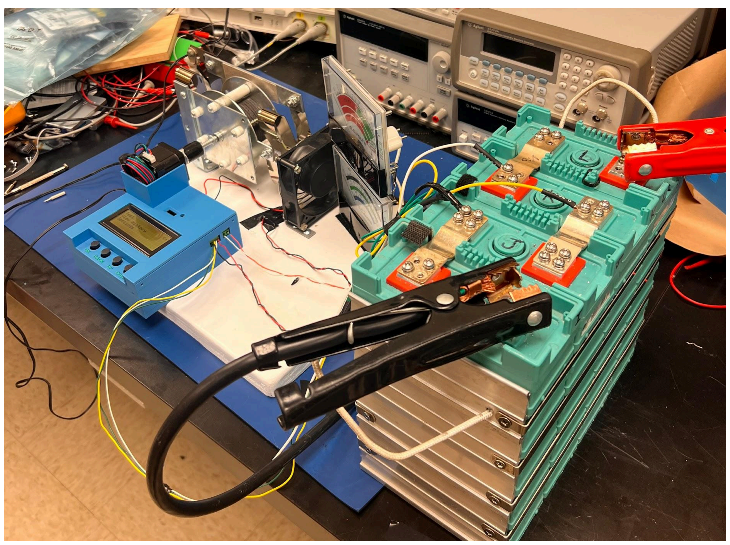


Figure 30: Final Prototype with Battery Connected Side View (JL)

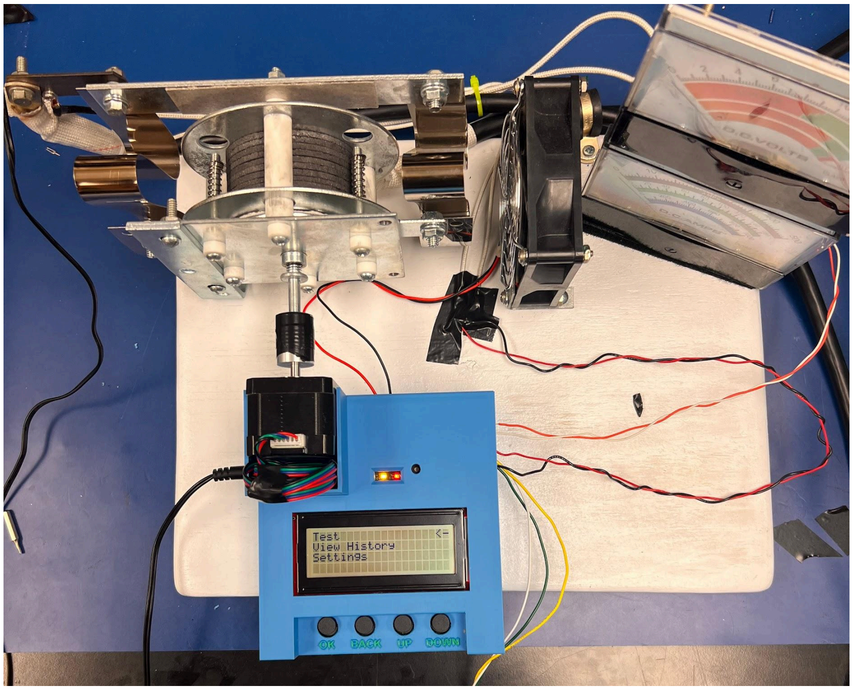


Figure 31: Top View of Prototype (JL)

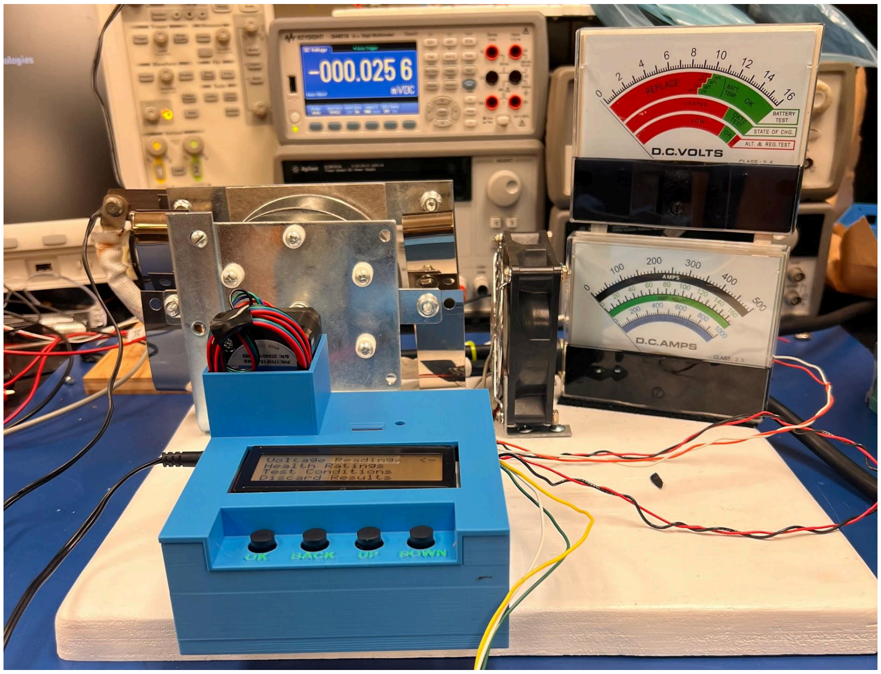


Figure 32: Side View of Prototype (JL)

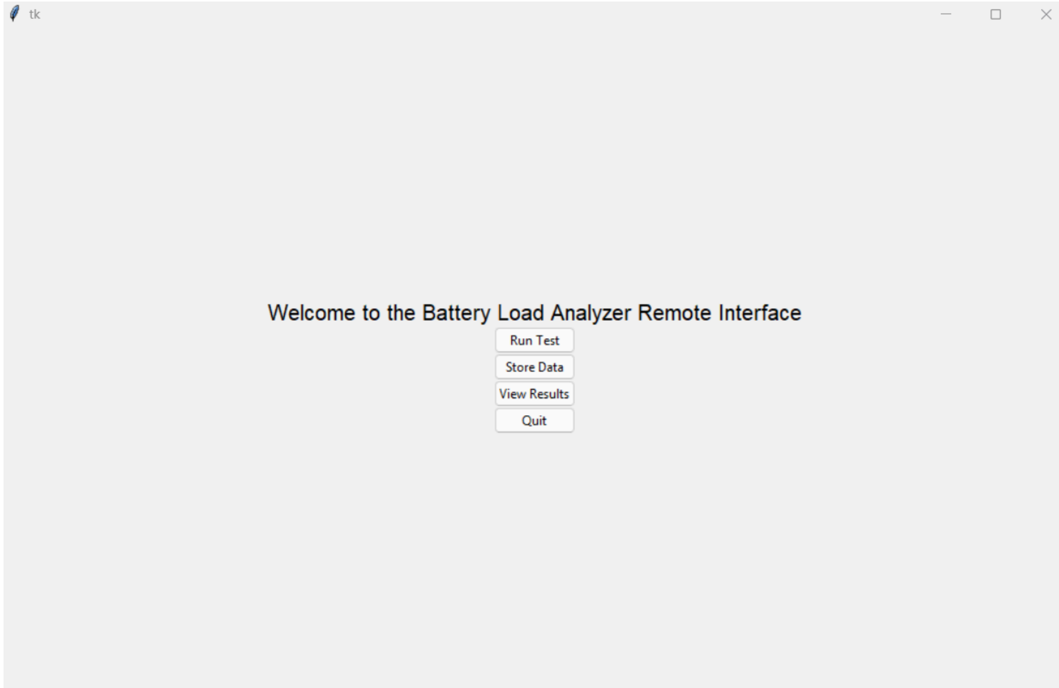


Figure 33: Remote Interface

9 Bibliography

[1] University of Washington Clean Energy Institute. *Lithium-Ion Battery*. [Online]. Available: https://www.cei.washington.edu/research/energy-storage/lithium-ion-battery/#:~:text=In%20addition%2C%20Li%2Dion%20cells,to%20maintain%20their%20battery%20life.

[2] Nick. General Technologies Corp. (2018, Oct. 16). *How to Use a Battery Tester*. [Online]. Available: https://gtc.ca/blog/how-to-use-a-battery-tester/.

[3] F. S. Tierno, "Advanced Multi-Cell Lithium Battery Load Analyzer Project Description," Stony Brook University, Stony Brook, NY, USA, Aug. 2024.

[4] Microchip. *AVR128DB28/32/48/64 Datasheet,* (2020). [Online]. Available: https://ww1.microchip.com/downloads/en/DeviceDoc/AVR128DB28-32-48-64-DataSheet-DS40002247A.pdf

[5] Infineon. *IPT004N03L Datasheet,* (2014 Oct. 8). [Online]. Available: https://www.infineon.com/dgdl/Infineon-IPT004N03L-DS-v02_00-EN.pdf?fileId=db3a30433e9d5d11013e9e0f382600c2

[6] Analog Devices. *AD8410A Datasheet,* (2025). [Online]. Available: https://www.analog.com/media/en/technical-documentation/data-sheets/ad8410a.pdf

[7] D. Das. Circuit Digest. (2023, Mar. 8). *Stepper Motor Control with A4988 Stepper Motor Driver and Arduino Uno.* [Online]. Available: https://circuitdigest.com/microcontroller-projects/interface-a4988-stepper-motor-driver-with-arduino

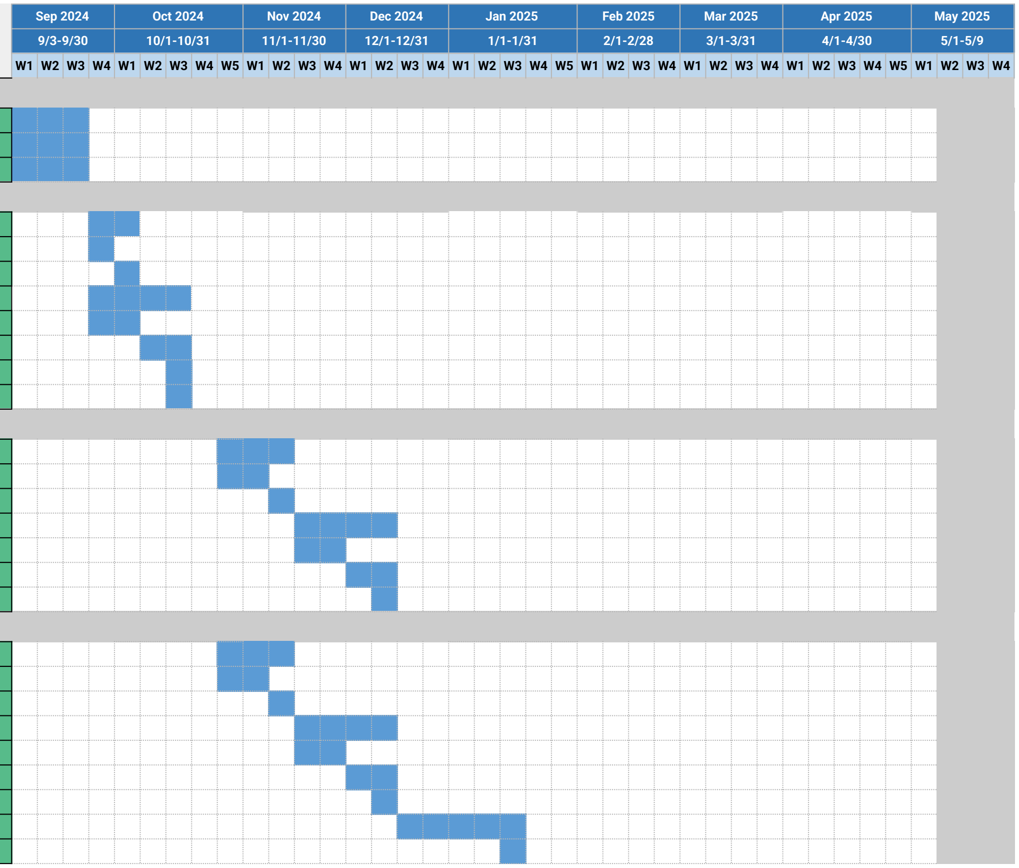
[8] Associated Environmental Systems. (2023, May 19). *The Importance of Battery Testing*. [Online]. Available: www.associatedenvironmentalsystems.com/blog/the-importance-of-battery-testing.

[9] Textronix. (2014). *Overview of Noise Measurement Methods*. [Online]. Available: https://download.tek.com/document/37W-30477-0%20Noise%20Figure%20WP.pdf

GANTT CHART

PROJECT TITLE	Advanced Multi-Cell Lithium Battery Load Analyzer	**COMPANY NAME**	2CE1EE
PROJECT MANAGER	Tyler Shaw	**DATE**	5/9/25

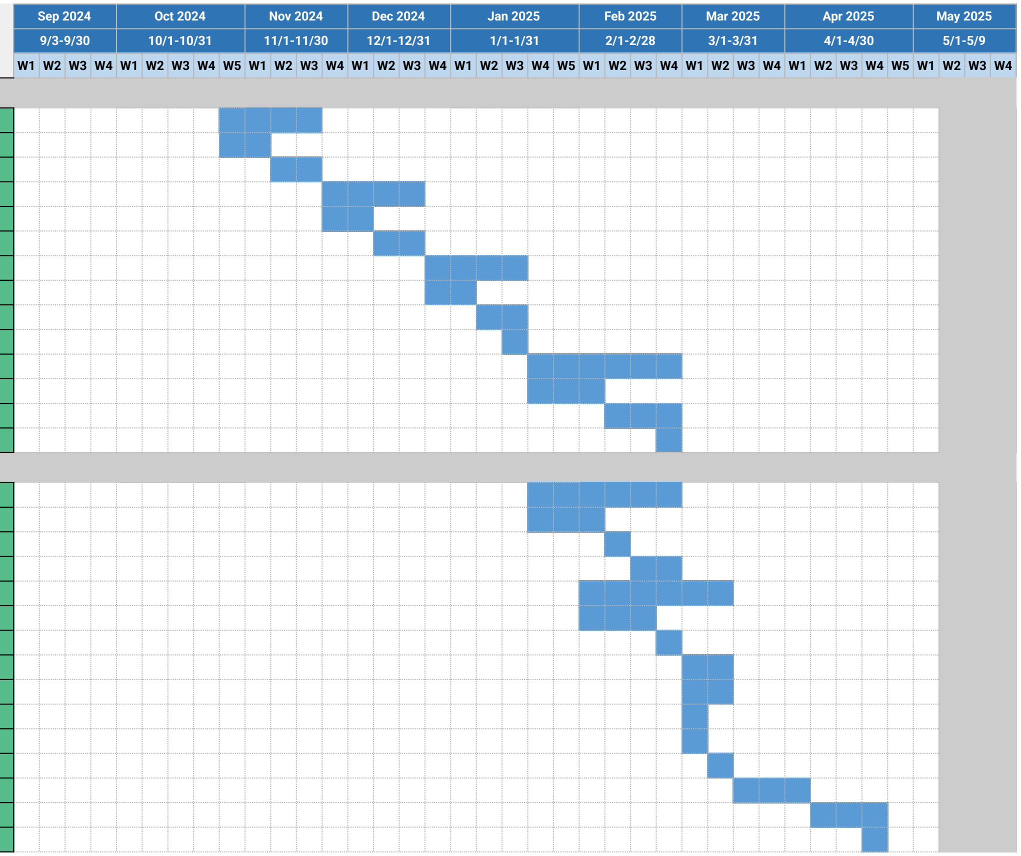
Milestone Number	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Research**	**Everyone**	**9/3/24**	**9/21/24**	**18**	
1.1	Circuit Research	Omar	9/3/24	9/21/24	18	100%
1.2	Electromechanical Research	Omar	9/3/24	9/21/24	18	100%
1.3	Software, Microcontroller Research	Jake, Tyler	9/3/24	9/21/24	18	100%
2	**Simple Voltage Reading Circuit**	**Everyone**	**9/22/24**	**10/25/24**	**33**	
2.1	Circuit and Hardware	Omar	9/22/24	10/5/24	13	100%
2.1.1	Circuit Development	Omar	9/22/24	9/29/24	7	100%
2.1.2	Circuit Implementation and Testing	Omar	9/30/24	10/5/24	5	100%
2.2	Software	Tyler, Jake	9/22/24	10/17/24	25	100%
2.2.1	Software Development	Tyler, Jake	9/22/24	10/6/24	14	100%
2.2.2	Software Debugging	Tyler, Jake	10/7/24	10/17/24	10	100%
2.3	Full System Integration and Testing	Everyone	10/18/24	10/24/24	6	100%
2.4	Demo to Advisor	Everyone	10/25/24	10/25/24	0	100%
3	**High Power Resistive Load**	**Omar**	**10/26/24**	**12/13/24**	**47**	
3.1	Circuit and Hardware	Omar	10/26/24	11/16/24	20	100%
3.1.1	Circuit Development	Omar	10/26/24	11/9/24	13	100%
3.1.2	Circuit Implementation and Testing	Omar	11/10/24	11/16/24	6	100%
3.2	Software	Omar	11/17/24	12/12/24	25	100%
3.2.1	Software Development	Omar	11/17/24	11/30/24	13	100%
3.2.2	Software Debugging	Omar	12/1/24	12/12/24	11	100%
3.3	Demo to Advisor	Omar	12/13/24	12/13/24	0	100%
4	**Local Interface**	**Jake, Omar**	**10/26/24**	**1/17/25**	**81**	
4.1	Circuit and Hardware	Jake	10/26/24	11/16/24	20	100%
4.1.1	Circuit Development	Jake	10/26/24	11/9/24	13	100%
4.1.2	Circuit Implementation and Testing	Jake	11/10/24	11/16/24	6	100%
4.2	Software	Jake	11/17/24	12/12/24	25	100%
4.2.1	Software Development	Jake	11/17/24	11/30/24	13	100%
4.2.2	Software Debugging	Jake	12/1/24	12/12/24	11	100%
4.3	Initial Demo to Advisor	Jake	12/13/24	12/13/24	0	100%
4.3	Full System Integration and Testing	Jake, Omar	12/14/24	1/16/25	32	100%
4.4	Final Demo to Advisor	Jake, Omar	1/17/25	1/17/25	0	100%



GANTT CHART

PROJECT TITLE	Advanced Multi-Cell Lithium Battery Load Analyzer	**COMPANY NAME**	2CE1EE
PROJECT MANAGER	Tyler Shaw	**DATE**	5/9/25

Milestone Number	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
5	**Remote Interface**	**Tyler**	**10/26/24**	**2/28/25**	**122**	
5.1	Send Results to the PC	Tyler	10/26/24	11/23/24	27	100%
5.1.1	Software Development	Tyler	10/26/24	11/9/24	13	100%
5.1.2	Software Debugging	Tyler	11/10/24	11/23/24	13	100%
5.2	PC Control of Test Run	Tyler	11/24/24	12/21/24	27	100%
5.2.1	Software Development	Tyler	11/24/24	12/7/24	13	100%
5.2.2	Software Debugging	Tyler	12/8/24	12/21/24	13	100%
5.3	Analyzer Health Ratings	Tyler	12/22/24	1/16/25	24	100%
5.3.1	Software Development	Tyler	12/22/24	1/4/25	12	100%
5.3.2	Software Debugging	Tyler	1/5/25	1/16/25	11	100%
5.4	Initial Demo to Advisor	Tyler	1/17/25	1/17/25	0	100%
5.5	Graphical User Interface (GUI)	Tyler	1/18/25	2/27/25	39	100%
5.5.1	GUI Design and Development	Tyler	1/18/25	2/8/25	20	100%
5.5.2	GUI Integration	Tyler	2/9/25	2/27/25	18	100%
5.6	Final Demo to Advisor	Tyler	2/28/25	2/28/25	0	100%
6	**Project Finalization**	**Everyone**	**1/18/25**	**4/25/25**	**97**	
6.1	Printed Circuit Board	Omar, Jake	1/18/25	3/1/25	43	100%
6.1.1	Printed Circuit Board Design	Omar, Jake	1/18/25	2/8/25	20	100%
6.1.2	Printed Circuit Board Verification	Omar, Jake	2/9/25	2/15/25	6	100%
6.1.3	Printed Circuit Board Order	Omar, Jake	2/15/25	3/1/25	16	100%
6.2	Enclosure	Omar, Jake	2/1/25	3/15/25	44	100%
6.2.1	Enclosure Design	Omar, Jake	2/1/25	2/22/25	21	100%
6.2.2	Enclosure Verification	Omar, Jake	2/23/25	3/1/25	8	100%
6.2.3	Enclosure Order	Omar, Jake	3/1/25	3/15/25	14	100%
6.3	Document Preparation	Everyone	3/2/25	3/16/25	14	100%
6.3.1	Software Theory of Operation	Everyone	3/2/25	3/9/25	7	100%
6.3.2	Hardware Theory of Operation	Omar, Jake	3/2/25	3/9/25	7	100%
6.3.2	User Guide	Everyone	3/9/25	3/16/25	7	100%
6.4	Assembly	Everyone	3/16/25	4/7/25	21	100%
6.5	Testing and Refinement	Everyone	4/8/25	4/24/25	16	100%
6.6	Submit Project to Advisor	Everyone	4/25/25	4/25/25	0	100%



2CE1EE Meeting Notes
Advisor Meeting 1
Friday September 6th, 2024
10:00am-11:30am (90 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Team Member Backgrounds
    a. Scott asked if analog to digital converters were covered in ESE 280/381
        i. No, analog to digital converters were not covered in either class
    b. Jake asked if it was okay to take ESE 323 at the same time as senior design
        i. Scott said that is okay since we will not be making PCBs until the second semester.
    c. Scott commented that the team members' backgrounds are excellent
    d. Scott recommended that Omar collaborate with Romano from the other senior design team working on this project to find a solution on how to deal with the carbon pile resistors, as both have electromechanical backgrounds.
        i. The first task will be to determine the carbon pile's resistance
        ii. We will later need to depressurize the carbon pile so that it has a low resistance
2. Senior Design Policies and Expectations
    a. Scott mentioned the following policies and expectations related to senior design
        i. The group may discuss ideas with other senior design groups, including the other group working on the same senior design project. However, code, circuitry, writing, and diagrams may not be shared between groups.
        ii. Generative AI tools may be used as resources, but not to write code or any other writing required for the class. All writing will be checked for plagiarism
        iii. All code must be commented
        iv. Everyone must contribute to writing assignments. Each person should put their initials next to sections that they write
        v. Send Scott emails at any time with questions
        vi. Let Scott know if the group needs any time off due to exams or other reasons
        vii. Schedule a block of time each week that the whole group can collaborate on the project
        viii. Follow ESE 280/381 wiring standards
        ix. Double check each other's work. It's okay to make mistakes.
    b. Omar asked if block diagrams would be provided.

        i. Scott said he would provide diagrams, but they may not be copied and the group must make their own.
        ii. Scott recommends using Visio for block diagrams and flow charts.
    c. Jake asked about the expected workload for the project
        i. Scott responded that the workload would be however many hours each member can contribute every week.
    d. Scott confirmed that he received a copy of the project selection form.
        i. Omar asked if the project selection form was submitted yet.
            1. Tyler responded that he submitted it.
            2. Omar requested the Brightspace submission email and all future submission emails be sent to him.
            3. Tyler will send submission emails to all teammates
3. Project Discussion
    a. Scott mentioned that the block diagram provided in the project description is not good
        i. Missing shunts
        ii. The sense wires should be measuring the voltage at the battery instead of at the battery analyzer due to the resistance of the wires
    b. Analog ammeter demonstration
        i. Scott explained that the analog ammeter will be used in our project because of its reliability
            1. Works even if the microcontroller crashes as it does not depend on the microcontroller
    c. Jake asked about the purpose of a shunt
        i. Scott graphed the voltage to current relationship of a shunt, which is linear
        ii. Omar noted that a shunt is like a fixed resistor
        iii. Scott added that shunts can handle large amounts of power and can measure the current without producing a large voltage
    d. Scott drew the block diagram of the system, including the analog ammeter, DOG LCD, JTAG, and several push buttons
        i. The LCD can be changed later on if the group finds a better one
        ii. Scott demonstrated a previous project to show how we could use soft keys to save on buttons by having the function of the buttons change over time.
4. First Design Task
    a. Measure the voltages and display on the DOG LCD using the AVR128DB48 microcontroller
    b. The group will start breadboarding in about a week or 2
    c. Jake asked if there are any strict specifications like the ESE 280 and 381 labs
        i. Scott clarified that the senior design project have more flexibility than the 280 and 381 labs

   d. Tyler asked if the group could use premade breadboards from ESE 280 and 381 for the DOG LCD
      i. Scott said this was alright for now, but in the future, the circuitry would likely need to change to fit with the printed circuit board
   e. This task should be completed within 1 month
5. Lab Tour
   a. Scott showed us the senior design space and where different tools and equipment would be stored
   b. Scott discussed the following lab rules
      i. Ask Bryant for help with lab equipment or if anything needs to be taken out of the lab
      ii. The group can take equipment from the other groups' drawers, however breadboards and components should not be touched
      iii. Don't leave parts out. Store them in the designated drawers when not in use.
      iv. Try not to touch the big battery. It is very dangerous if not used properly
6. Meeting Conclusion and Next Steps
   a. No meeting next week. Next meeting in 2 weeks.
   b. Next week, the group should work on the proposal for ESE 440. Use the project description as the starting point for the proposal
   c. In 2 weeks, the group will discuss the work division plan for the first design task.

2CE1EE Meeting Notes
Advisor Meeting 2
Friday September 20th, 2024
11:00am-12:10pm (70 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

Note: meeting rescheduled to 11am due to Omar needing to attend a job fair event from 9am-11am

1. Proposal Questions
    a. Jake and Tyler had questions about what should be included in each section of the proposal.
        i. Scott said to ask Professor Dhadwal for all questions related to senior design administrative work.
        ii. It's best to ask in class, since he might not see all emails
    b. Scott asked that each section be clearly labeled for grading.
2. Partitioning the Design
    a. Scott said that the design will be partitioned in the next meeting
    b. Omar will do most of the hardware work
    c. Jake and Tyler will do most of the software work with some help from Omar
3. Presentation
    a. Scott went over his presentation
    b. There were several graphs showing the battery performance under different conditions
        i. The batteries perform differently due to inconsistent manufacturing processes
        ii. The group's task is to figure out which batteries perform poorly, so they can be removed and replaced with higher performance versions
4. Carbon Pile Load Considerations
    a. The problem is that the initial state of the carbon pile is unknown, so all cases must be taken into account
    b. Scott drew some schematics of circuits we could use to address this problem
        i. Use the microcontroller's internal pull-up resistor
        ii. Use a diode as a switch to block current from always flowing
5. Demo of Battery Load Analyzer
    a. Scott demonstrated the battery load analyzer
    b. The group examined the interior of the analyzer to look for the carbon pile resistor, shunt, and sense wires.

c. Scott explained the importance of safety features and asked the group to include some, like a buzzer that sounds when the device is very hot

6. Discussion of Omar's Email
   a. Omar asked about Scott's thoughts on the email he sent
   b. Scott asked which program Omar uses for schematics and block diagrams
      i. Draw.io - is free to use and easy to download
   c. Scott gave feedback on Omar's block diagram
   d. Scott recommended using as much internal microcontroller hardware as possible
7. Schedule
   a. Jake asked about the project schedule
   b. Scott recommended starting with the 3.3 V curiosity nano board
   c. Later, the group can wire directly to the chip
   d. The first semester is mostly breadboarding
   e. PCB design will not start until the 2nd semester, but the group can start learning how to make schematics in Eagle now
8. Conclusion
   a. Scott let the group know he would leave the battery load analyzer in the lab for further examination and testing.
   b. Scott said that if the group needed to purchase any parts, they could let him know and he would do the purchasing.

2CE1EE Meeting Notes
Advisor Meeting 3
Friday September 27th, 2024
10:00am-10:35am (35 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Meeting Time
    a. Scott asked Omar if moving the meeting later would be more convenient since he has a long commute every Friday
    b. The team agreed to meet at 10:30 every week
2. Group Progress
    a. Scott asked about the group's process
        i. Tyler said that the group wired the voltage divider circuit
        ii. The group would write code after the meeting
    b. Scott asked the group to send him any code that we wrote for review
        i. He also emphasized the importance of modularity: making subroutines for small tasks
        ii. He also recommended using flow charts and schematics
3. Report Feedback
    a. Reports looked good so far on first glance
    b. Scott will give grades soon based on Professor Dhadwal's rubric
    c. One piece of feedback is to give citations for specific measurements and records
4. Upcoming Dates and Tasks
    a. In the next few days, partition the work and email to Scott
        i. Tyler asked what would be specific tasks to partition
        ii. Scott gave examples of the carbon pile load, local interface, and remote interface
        iii. However, the group should make their own partitions using the given examples for reference
    b. Send parts to Scott to be ordered
        i. Send the 4 line LCD DOG display soon to be ordered
    c. No meeting 10/12
5. Demo of Milli Ohm Meter
    a. Carbon pile is 1.42 m Ohm
    b. We need many discs with similar low resistance so they can be stacked

2CE1EE Meeting Notes
Advisor Meeting 4
Friday October 4th, 2024
10:30am-11:30am (60 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Electromechanical Research
    a. Omar updated the group on electromechanical research and asked for feedback
    b. Scott recommended finding 2-3 methods and not always picking the first one
    c. Omar showed some actuators he was thinking of purchasing for the project
    d. Scott commented that the actuators needed springs for compression
2. Advisor Demo
    a. Scott used the milliohm meter from the last meeting to find the resistance of nichrome wires
    b. Nichrome wires have low resistance and can support high currents, making them ideal for the project
    c. The resistances measured were 38 ohms and 6 ohms, too high for the project
    d. The resistance should be around 24 milliohms
    e. Using several nichrome wires in parallel might work
3. Partition of Work
    a. Scott gave feedback on the partition of work submitted by the team
    b. It will be impossible to switch the load between different batteries
    c. Omar has too much work with the carbon pile load and all of the different software functions related to it
    d. The collecting voltages part should be given to someone else
    e. Tyler's part looks good
    f. Tyler asked about what kind of GUI Scott wanted for the remote interface
        i. Scott said a website or desktop application is fine
        ii. He asked for a GUI layout sketch before beginning the software development
    g. Scott asked the group to make changes and resubmit a new proposal in the next couple of days
4. Power Supply
    a. Scott mentioned that the group can cannibalize the load testers he purchased for parts or to use as an example
    b. Scott went over the different wires needed for the final design
    c. Jake asked if a printed circuit board was needed for the power supply

        i. Scott drew a diagram on the board of a potential circuit solution for the power supply
        ii. Scott mentioned that the group should do research on power supplies with multiple source inputs to determine if a printed circuit board was needed
        iii. Scott mentioned that potentially power could also be drawn from the computer
    d. Scott suggested using micro fuses to check the current load and prevent frying components
5. Team Demo
    a. The team presented their four battery voltage reading circuit to Scott
    b. Scott was impressed by the low error
    c. He asked if the group could find a way to get rid of the voltage divider circuit and feed the input directly into the microcontroller pins
6. Conclusion
    a. There will be no meeting next week because Scott is out of town
    b. Email Scott any questions and he will respond on the same day

2CE1EE Meeting Notes
Advisor Meeting 5
Thursday October 31st, 2024
4:00pm-4:30pm (30 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Electroteers Design Team

Note: Jake Lin and Omar Mohamed could not attend as this meeting was scheduled last minute and both had prior scheduled commitments

1. Distribution of Materials
    a. Scott gave both teams the following materials to share
    b. Fans
    c. Platforms
    d. Screws
    e. Angled brackets
    f. An AVR microcontroller
        i. Tyler asked why this microcontroller was needed when the group already had one from Bryant Gonzaga (the lab manager)
        ii. Scott replied that it was better to use a microcontroller with no external circuitry for the final design
2. Updates
    a. Use islandpatent.com/EDE for pictures of Scott's car for the presentations
    b. The reports looked good
        i. There are no page limits.
        ii. Write as much as necessary to convey the information
3. Hardware Discussion and Demonstration
    a. Scott distributed block diagrams of the system and circuitry and stated how there was no ground for the battery circuit
    b. He proposed using optoisolation to isolate and control the fan
    c. Scott demonstrated the use of a temperature sensor to check the temperature of the battery load analyzer
4. Next Steps
    a. No meetings for at least two weeks due to Scott's surgery
    b. After the procedure, both design teams will have a meeting with Scott to discuss the flow operation including error messages and screen layouts
    c. The biggest LCD screen size used will be 4 lines x 20 characters
    d. Tyler asked about if the remote interface should store data on the computer itself or on a remote server

    i. Scott said he prefers just storing on the computer for not
    ii. We can move to cloud storage and websites later if time permits
e. At the end of the project, the groups will measure each battery and compare the results
f. Tyler asked if the completed schematic should be done on OrCAD or Fusion 360
    i. Scott prefers Fusion 360

2CE1EE Meeting Notes
Advisor Meeting 6
Thursday December 19th, 2024
11:00am-12:00pm (60 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Omar Mohamed, Jake Lin

1. Updates
    a. The group presented the disassembled load analyzer to Scott to examine
    b. Scott measured the resistance and noted it was off
        i. Jake noted that one of the ceramic standoffs broke
        ii. Scott noted that it probably wasn't a problem but the group should either glue together the pieces or buy a new part from McMaster-Carr
        iii. Scott noticed that the reassembled load analyzer created a short circuit which would destroy the analyzer if a battery was connected to it
        iv. Jake realized he incorrectly reassembled the load analyzer and fixed it to match the other group's assembly
    c. Scott recommended using the other group's project as a model
2. Batteries and Safety
    a. Jake asked Scott about the different batteries for testing
    b. The quad pack already distributed is very safe and good for testing the battery measurements for 4 batteries
        i. Tyler asked if the batteries need to be recharged
        ii. Scott said they can be replaced
    c. Scott distributed a larger 12 V battery
        i. A larger current can be drawn from this battery which allows the group to test the loaded current state
    d. The next battery to be tested is the quad pack
        i. Scott needs to be present for safety reasons
        ii. Scott recommends buying and wearing safety glasses while testing the quad pack
    e. Scott wants to test both quad packs and single batteries so there will need to be functionality for both
        i. Option 1 is the device can automatically detect which battery is being used
        ii. Option 2 is to have the interface ask the user which battery to test
        iii. The other group is using option 2
3. Assembly Demo
    a. Scott showed the group different materials that could be used for assembly
    b. He also showed the group the tools the lab has for assembly

c. Next, he demonstrated how to connect the bracket to the platform

4. Next Steps
    a. Scott wants the group to start transitioning to using the microcontroller with external circuitry
    b. Scott also asked the group to send a parts list to him
        i. Tyler asked for a UART chip and debugger to program the microcontroller with external circuitry
    c. Tyler asked if Scott still wants a demo by December 31st
        i. Scott said he could extend the deadline to the middle of January, but no later than that
        ii. Scott can come in if the group needs additional lab time while Bryant is out but
    d. Jake asked what the demo would include
        i. Scott wants to see the assembly and manual operation of the carbon pile
        ii. Everything should be mounted on the platform
        iii. Send Scott a picture of the assembly progress at the end of the day
    e. Scott will return on Friday with a wall transformer for the group

2CE1EE Meeting Notes
Advisor Meeting 7
Friday January 24th, 2025
10:30am-12:00pm (90 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Omar Mohamed, Jake Lin

1. Updates
    a. Scott asked the group how much progress was made since the last meeting
        i. The other group has not completed the demo yet, so it's ok if the demo isn't ready yet
        ii. Omar replied that he thought the group was ready to the demo
    b. Scott asked if the group tested with the quad pack yet
        i. Jake replied that the group did not use the quad pack yet, as per Scott's instructions
    c. Scott reminded the group that there would be documentation due in April
        i. He sent out an email with directions last week.
        ii. He asked if there were any questions regarding the documentation.
        iii. Nobody had questions.
        iv. Scott emphasized the importance of the documentation because the group can still earn a good grade if the project is not working but the documentation is good
2. Safety
    a. Scott detailed the following safety protocols that need to be followed when using the quad pack of batteries
    b. Safety glasses should be worn when testing
    c. The quad pack is safe to touch but metal tools should not be dropped on top of the battery because they can cause an explosion
    d. Carefully and quickly tap the high current leads on the battery before attaching them to the battery
    e. Ensure the fan is turned on when the carbon pile is being used to prevent overheating
        i. The other group has the fan on all the time. Scott recommends this approach
3. Remote Interface Demo
    a. Tyler presented the preliminary design of the remote interface to Scott
    b. He asked Scott how the data should be saved and presented
    c. Scott said to send him an email presenting the different options
4. Manual Operation of Carbon Pile Load Demo

a. Scott pointed out that there were not enough connector leads to the battery
b. The group added the connector leads
c. The demo did not work properly
d. Omar noticed that the leads were switched
e. Scott will give the group time to modify the design and the demo can be completed at the next meeting

2CE1EE Meeting Notes
Advisor Meeting 8
Wednesday February 24th, 2025
12:15pm-12:45pm (30 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin

Note: Omar Mohamed could not attend due to an injury

1. Demo
    a. The group presented the demo of the manual operation of the carbon pile load to Scott
    b. Scott asked if the group had any issues with the alligator clips welding, as the other group is currently having this problem
        i. The group does not have this problem
    c. Scott noted the results were slightly off when he tested the battery voltages with a multimeter but everything else looked good
        i. Tyler noted it was probably due to using 4% precision resistors which caused the measurements to be slightly off
        ii. Scott asked the group to try to use resistors with greater precision to ensure the measured voltages are within 0.01% of the actual voltages
    d. Scott also would like to see the load current that the batteries were tested under
        i. Jake commented that while cranking up and down the carbon pile, the load current is displayed on the LCD
        ii. Scott would like to see the maximum load current on the LCD and suggested using another push button that can display the load current on a separate screen from the results
        iii. Tyler will also include this information on the remote interface as well
2. Printed Circuit Boards
    a. Jake asked when the group should start the PCB layout design, as he asked the other group and they already started it
        i. Scott suggested starting in the next few weeks around the beginning of March
        ii. He also recommended having the group members solder on the components instead of the manufacturer, as it reduces the manufacturing time by several weeks
    b. Scott asked if the group had a master schematic and bill of materials
        i. Tyler commented that Omar had completed both and would send them to Scott shortly

c. Jake presented his power supply PCB to Scott and asked how the different power domains should be dealt with, as his PCB only provides one 3.3 V power domain, but 12 V is needed to power the fan and another power domain will be needed for the stepper motor
    i. Scott showed Jake a circuit that could be built to counteract this problem
3. Remote Interface and UART Chip
    a. Scott responded to Tyler's email on saving results in the remote interface by saying he preferred creating separate time stamped files for each test
    b. Tyler noted that the FT232 UART chips Scott gave the group did not come with a USB port
        i. Scott said that the USB port would have to be separately installed
        ii. He pulled up the FT232 schematic to illustrate where the USB pins would connect to the FT232
    c. Tyler asked Scott what the health ranking criteria would be
        i. Scott hasn't thought about this yet and asked Tyler to email him about this
4. Next Steps
    a. Scott would like to see another demo with the new resistors installed and the LCD displaying the load current with the results next week
    b. Once the manual operation is done, the group can start working on the stepper motor
        i. Tyler noted that Omar is already working on the stepper motor
    c. Scott would like all of the hardware and software to be completed by late April with a final demo by the end of that month
    d. May will be used to complete all documentation requested by Scott and Professor Dhadwal
    e. Tyler asked what the April 14th deadline for Scott's documentation is for if the group will continue working on the documentation in May
        i. Scott said he would like a completed draft version by April 14
        ii. In May, the group will revise and finalize the documentation

2CE1EE Meeting Notes
Advisor Meeting 9
Friday March 7th, 2025
11:30am-12:00pm (30 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin

Note: Omar Mohamed could not attend due to an injury

1. Schematic Feedback
    a. The schematic was very good, but Scott had some feedback on ways the schematic could be improved
    b. Ensure hardware is properly labeled (female JTAG header should be male)
    c. Ensure hardware is consistently labeled (Fan_PWM signal has different names)
    d. Replace IC chips with circuit (OPAMP IC should be replaced with an actual OPAMP)
    e. Include decoupling capacitors where possible to reduce noise
    f. Clarify functions of the minor circuits off to the side of the main circuits
2. ADC Debugging
    a. Jake and Tyler presented the voltages they were getting and Scott confirmed the voltages had too much error and were changing too quickly
    b. Scott examined the circuit and noted the decoupling capacitors on the ADC inputs, but also recommended decoupling capacitors between the microcontroller's VDD and ground
    c. Scott also noted that the VDD and ground connections were too long and there should be connections between power rails at both the top and bottom of the breadboard to reduce the distance travelled
    d. Scott examined the power supplied to the microcontroller using an oscilloscope and noted that the noise was normal and the voltage was at the correct level
    e. Scott checked the wires and noted that the leads were too short. The wires need to be longer to reach the bottom of the breadboard
    f. Scott recommended fixing the wiring and adding more decoupling capacitors and seeing if that fixed the problems with the ADC
3. Next Steps
    a. Contact Scott next week for another meeting after the wiring is fixed
    b. The group should send Scott a revised schematic by the end of the weekend
    c. Jake presented his board to Scott and asked if it should be redone to support different power domains, as the fan runs at 12 V, while the rest runs at 3.3 V
    d. Scott agreed and said Jake should add a 12 V output for the fan
    e. Tyler asked if Scott brought in the EEPROM chips

f. Scott replied that he wants the ADC and all other necessary components fixed before starting on the EEPROM, stepper motor, and temperature sensor
g. The EEPROM, stepper motor, and temperature sensor are all time consuming components and it would take away too much time from the rest of the project
h. The group should add the EEPROM, stepper motor, and temperature sensor to the PCB board and can work on those components if they have time
i. If there is no time left at the end of the semester, Scott will have a future senior design group integrate those components using the documentation submitted by the group at the end of the semester.

2CE1EE Meeting Notes
Advisor Meeting 10
Wednesday April 9th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Presentations
    a. The presentations were very well done
    b. Scott asked for a copy of the presentation
2. Remote Interface Demo
    a. Tyler presented a demo of the remote interface, but it was not working fully because the UART pins were fried
    b. Scott asked Tyler to schedule another demo meeting later in the week or next week when it is fixed
3. Case
    a. Jake asked Scott for feedback on his draft of the case
    b. Jake's case will enclose the PCB and internal circuitry components but not the carbon pile or fan like the other group's
    c. Jake's design will still make use of the vinyl board, which could make testing inconvenient to the user
    d. Scott said that both options were fine with him and that Jake should just choose whatever he thinks will work the best
4. Stepper Motor
    a. Jake and Romano both had concerns about the stepper motor coupler needing calibration when it is attached to the carbon pile knob
    b. Scott agreed with these concerns
    c. However, he thinks it is best for both groups to skip the stepper motor portion of the design because it will take several weeks to get the assembly done
    d. The manual load test is fine for him
5. Meeting on Friday
    a. Scott asked if anyone was available on Friday
    b. Tyler and Omar will be available on Friday
    c. Scott would like to bring batteries up to be tested by both groups
    d. He wants the unloaded and loaded voltages, current, and health ratings taped onto the side of each battery
    e. Tyler will email Scott his availability for Friday
6. Documentation
    a. A draft of the documentation is due on Monday

b. Scott will have feedback returned by the end of next week
c. Scott wants detailed descriptions of everything, including many graphical images
d. He recommended a more detailed table of contents with subcategories and subsections
e. He complimented the group's schematics made by Omar and recommended blowing up subsections of the schematic to include in the documentation

2CE1EE Meeting Notes
Advisor Meeting 11
Wednesday April 30th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Scott Tierno (faculty advisor), Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Group Progress
    a. Tyler has updated the remote interface with the ability to name batteries and can present a demo
    b. Jake and Omar have added a resistor to the ammeter so the current is now being correctly read
    c. Omar is working on the automated test
    d. Jake built a new PCB incorporating Scott's feedback and ordered it. It will arrive in the afternoon
    e. Jake also built a case for the first PCB and will make another one for the new PCB
    f. Scott was impressed by the case
2. Current Issues
    a. Scott noted that the battery testers he bought were not meant for drawing 500 A out of the battery
    b. Jake mentioned how he could get over 450 A of current out of the battery but it sparks so the group has stopped testing at such high currents
    c. Scott believes that too much current is being drawn out of the battery for too long
    d. He asked the group to immediately turn down the current once the desired current is reached
    e. Jake noted that the loaded voltages were not stable right away so a 1 second delay was added before reading the loaded voltages
    f. Scott said that it is fine if the voltages are not accurate and to remove the delay so the current is read right away
3. Automated Tests
    a. Omar is working on the automated test right now
    b. Jake and Omar are having trouble connecting the stepper motor to the carbon pile knob
    c. Scott recommended looking at the other group's prototype as an example
4. Updated Remote Interface Demo
    a. Tyler presented the updated remote interface demo that provided for naming batteries

b. Tyler’s design provides a list of letters and numbers that can be combined to create a battery identifier
c. Scott asked if it would be possible for him to choose the names instead
d. He wants to create battery names of about to 3 characters, which will be a combination of letters and numbers
e. Tyler will add a text box functionality so the user can input their own battery identifiers

5. Documentation
    a. Tyler asked about what Scott thought was too technical about the Remote Interface section of the User Manual
    b. Scott said that the test procedure, in particular, setting up the test program and connecting to the UART bridge was too technical for most consumers
    c. Typically, consumer products would use an executable file that performs all of the functions automatically for the user
    d. However, since the project is almost completed, there is no time to add those features
    e. Scott said the report is good for him as is and does not need any changes to be made
    f. The rest of the documentation was very good and exceeded Scott’s expectations
6. Final Written Report
    a. Tyler asked about the “Innovation-Uniqueness of Proposed Solutions” section of the written report and what the skills, techniques, and tools refer to
    b. Scott is not sure and said to use AI for possible topics to write about
    c. He also recommended speaking to Professor Dhadwal regarding what he is looking for

2CE1EE Meeting Notes
Team Meeting 1
Thursday September 12th, 2024
5:30pm-6:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Regularly Scheduled Meeting Time
    a. The team agreed to meet on Friday mornings starting 9/20 after our faculty-team meeting in the Embedded Systems Design Lab (Light Engineering 228)
    b. Tyler informed the team that material can be taken out of the lab by speaking to Bryant Gonzaga and filling out the form
2. Division of Work for Project Proposal
    a. Jake will work on the background research and the social, environmental, and societal impact sections on the report.
    b. Omar will work on the statement of work, testbench for verification, and potential risks and mitigation strategies sections of the report.
    c. Tyler will work on the solutions, project team, meeting schedule, budget, and Gantt chart sections of the report. He will be responsible for formatting everyone else's work to fit the proposal specifications and submitting the assignment.
    d. Everyone should list all sources used in the bibliography section. Tyler will generate the works cited entries based on the sources used.
    e. Assigned sections should be completed by 11:59pm on Sunday September 22nd. Tyler will work on the formatting on September 23rd and 24th and submit the report from there.
    f. The final deadline for the proposal is Tuesday September 24th at 11:59pm
3. Discussion of Design Task 1
    a. Design Task 1 is to read a voltage from the four cell battery and display it on the LCD DOG.
    b. Scott wants the project completed in one month. He will teach us more material relevant to the project next Friday
    c. Before the next meeting, we should have the schematic, wiring, and code done for the DOG LCD. Available team members will start breadboarding early next week.
    d. Omar said he can work on the board design and help with the software
    e. The team agreed to use the microcontroller's built-in ADC module
        i. Tyler and Jake will do research on the ADC over the weekend
    f. Omar explained how differentials worked with an op-amp.
        i. Omar proposed connecting the positive terminals to one multiplexer and the negative terminals to another multiplexer.

2CE1EE Meeting Notes
Team Meeting 2
Thursday September 19th, 2024
10:00am-11:00am (60 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed (virtually)

Notes: Meeting originally scheduled for Friday September 20th was rescheduled to Thursday September 19th due to career fair events on the 20th. Omar attended virtually.

1. Circuit Design
    a. The team went over four options for measuring the battery voltage
        i. Option 1: voltage divider, 1 multiplexer
        ii. Option 2: 2 multiplexers, 1 differential amplifier
        iii. Option 3: 1 multiplexer, 4 differential amplifiers
        iv. Option 4: Use internal microcontroller architecture
    b. All agreed that option 4 was the best
2. LCD Code
    a. Omar presented LCD code
    b. Tyler and Jake agreed to start wiring the circuit and test the code out
3. Work Session
    a. Tyler and Jake breadboarded in the lab
    b. When they ran the code, the LCD was backlit, but nothing was displayed
    c. Tyler tried his code from a previous class and it worked
    d. There may be a minor error in Omar's code
    e. We will use Tyler's code as a baseline for future LCD code

2CE1EE Meeting Notes
Team Meeting 3
Wednesday September 25th, 2024
10:30am-12:00pm (90 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Battery Examination
    a. Jake examined the battery circuit and determined that only one five pin header was needed to connect to the microcontroller
    b. Jake determined the header pins were arranged in order from top to bottom of where the voltage was being probed
    c. Jake measured the battery voltages using a digital multimeter to determine what the expected voltages would be
2. Discussion of Voltage Divider Circuit
    a. Omar proposed using three voltage divider circuits with differing resistors to scale all of the voltages down to 3V
    b. Jake asked how we would recalculate the battery voltage after reading from the ADC
    c. Omar noted that we could multiply the voltages by the scaling factor we originally divided each input by
    d. Tyler proposed using the same resistor and scaling factor for each voltage divider circuit
    e. The group agreed Tyler's solution was best
3. Wiring the Voltage Divider Circuit
    a. Jake wired the circuit and tested it
    b. He noticed that the voltages were not as expected
    c. The group realized that two of the resistors had a larger percent error, causing this discrepancy
    d. The two bad resistors were swapped out for resistors with lower percent errors.
4. Discussion of ADC Code
    a. Tyler shared his research on ADC and proposed using the differential ADC mode
    b. Omar proposed using the single ended ADC mode for a higher resolution, as one bit is not used for the sign like in differential mode
    c. The group agreed to use the single ended mode
    d. The group agreed to have code written on the ADC by Friday
    e. On Friday, the group will convene again and test the code during the regularly scheduled faculty-team meeting

2CE1EE Meeting Notes
Team Meeting 4
Friday October 4th, 2024
11:30am-12:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Partition of Work
    a. Tyler prepared a revised partition of work and asked the other group members for feedback
    b. The other group members approved the changes to the partition of work
2. Voltage Reading Circuit with No External Hardware
    a. Tyler proposed emailing Professor Short to see if the microcontroller pins can support such a high voltage
    b. The other group members agreed
3. Power Supply Circuit
    a. Jake asked if Omar thought we needed a printed circuit board for the power supply circuitry
        i. Omar said that a printed circuit board was most likely not needed
        ii. He added that Jake could help make a printed circuit board for his linear actuator circuit
4. Next Steps
    a. Omar will continue researching the carbon pile load
    b. Tyler will email Professor Short about the ADC pins' maximum voltage
    c. Jake will wire the new LCD into the breadboard and interface it into the circuit
    d. No meeting next week due to fall break

2CE1EE Meeting Notes
Team Meeting 5
Friday October 18th, 2024
11:30am-12:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed (virtually)

1. Progress Report 1
    a. Progress Report 1 is due next Thursday
    b. Tyler proposed the following distribution of work
        i. Omar: design description (electromechanical)
        ii. Jake: abstract, design description (hardware/software)
        iii. Tyler: completed tasks and next steps, timeline, record of meetings, formatting, submission
    c. The other group members approved the distribution of work
2. Function Headers
    a. Tyler asked the group to create headers for their portions of the project, as per the email from Scott sent on October 11th
    b. Tyler sent a shared document to place all of the headers
3. Updates
    a. No meetings with Scott until further notice due to family emergencies
    b. Each group member should continue working on their part of the project
    c. Tyler spoke with Professor Short and he said that it was not possible to place a voltage higher than 3.9 V on the microcontroller pins
        i. We will discuss this further with Scott when he returns from his leave

2CE1EE Meeting Notes
Team Meeting 6
Tuesday October 22nd, 2024
4:30pm-5:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Progress Report 1
    a. Omar asked if the group has read his part of the paper
    b. Tyler said yes and he is currently editing the formatting
    c. The page limit is 5 pages and it is unclear what counts towards the page limit
    d. Omar's work is 4 pages, the Gantt Chart is 2 pages, and Tyler's work is 1 page, which already puts the group over the page limit
    e. Jake's work (the abstract) and the appendices likely do not count towards the page limit
    f. Tyler asked if anyone knew if the Gantt Chart counts towards the page limit but nobody knew for sure
    g. Tyler will continue trying to condense Omar's writing to fit in the page limit
2. Electromechanical Updates
    a. Omar showed the group the linear actuator he would like to purchase
    b. He plans to put the carbon pile disks on the compressing part of the actuator
    c. Tyler asked if the linear actuator could be sent to Scott for purchase
    d. Omar mentioned that he will be meeting with Scott on Thursday October 24th and will bring it up with him then
    e. Tyler asked Omar to send the function headers for his part of the project
3. Software Updates
    a. Jake shared that he successfully wired the new LCD to the breadboard and is in the process of writing code to interface it with the rest of the system
    b. Omar asked why we needed a new LCD
    c. Jake responded that Scott wanted to use a 4 line LCD
    d. Omar asked if the LCD is similar to the DOG LCD
    e. Jake replied that it is not a DOG LCD and is an AVR LCD.
    f. Jake shared the datasheet with Omar
4. General Updates
    a. Omar asked about the group's presentation date
    b. Tyler replied that the presentation is scheduled for November 14th
    c. Omar invited Jake and Tyler to attend his meeting with Scott on Thursday October 24th at 4:15pm
    d. Both Jake and Tyler will try and make it

2CE1EE Meeting Notes
Team Meeting 7
Thursday October 31st, 2024
4:30pm-5:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Meeting with Scott Updates
    a. Tyler shared updates from the meeting with Scott, which Jake and Omar were not able to attend
    b. Scott gave components to the group
    c. We will use optoisolation to control and isolate the fan
    d. The reports were good and there are no page limits for future reports
    e. No meetings with Scott for at least 2 weeks
    f. At our next meeting, we will discuss the flow of operation for the battery load analyzer
2. Updates
    a. Jake has interfaced the 4 line LCD to the microcontroller successfully
    b. Omar will need multiple power supplies for high voltage electromechanical components
        i. Jake volunteered to make a PCB for the power supplies
    c. Omar also needs to know the resistance of the shunt
    d. Tyler has a completed schematic in OrCAD for the simple voltage reading circuit
        i. However, Scott wants the schematic on Fusion 360
3. Next Steps
    a. Omar will start writing code for the electromechanical parts of the project
    b. He will also work on the final design schematic on Fusion 360, converting Tyler's schematic and adding components for his part of the project
    c. Jake will start writing code for the local interface
    d. He will also start working on the power supply PCB
    e. Tyler will continue working on the remote interface
    f. He will also measure the resistance of the shunt the next time he is in lab

2CE1EE Meeting Notes
Team Meeting 8
Thursday November 7th, 2024
4:30pm-5:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Schematic
    a. Tyler presented his revised schematic including the new LCD and the AVR without external circuitry
    b. Jake asked what the difference was between the AVR with and without external circuitry
    c. Tyler replied that there is no debugger, push button, or LCD
    d. We will need to get an external debugger to program the AVR
    e. We can get one from Bryant
    f. For the local interface, Jake only needs a couple of pins reserved for any push buttons but it does not matter which pins are used
    g. The push button pins can be moved around based on which pins Omar needs
    h. Omar agreed to add his electromechanical components to the schematic
    i. Omar will also combine his schematic with Tyler's schematic on Fusion 360
2. Oral Presentation
    a. The group will present next Thursday at 5pm in the normal lecture room
    b. Tyler has created a powerpoint document in the shared folder and will start working on it this weekend
    c. Omar will discuss the hardware and electromechanical components of the project
    d. Jake and Tyler will split the introduction, background, software, conclusion, and future work portions of the project.
        i. The division of slides will be decided later
    e. Each person should work on the slides they will be presenting

2CE1EE Meeting Notes
Team Meeting 9
Wednesday November 13th, 2024
2:00pm-4:30pm (150 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Current Progress
    a. Omar has written the code for the analog comparator that he wanted to test in lab
    b. Tyler is working on the USART interface with the PC. He got a breakout board from Bryant that will be used to provide the USB connection to the PC.
    c. Jake has measured the resistance of the shunt as 0.18 mOhm.
        i. Omar commented the resistance is sufficient for the design
        ii. Jake noted that Scott wanted the shunt from the purchased battery load tester used
2. Work Session
    a. The group tested Omar's code on the microcontroller
    b. The results were not as expected
        i. The gain varied at different voltages
        ii. At low voltages, the op amp produced weird results
    c. Omar theorized that the weird results at low voltages were due to noise
    d. Using external op-amps would produce better results, but Scott wants all hardware to be internal to the microcontroller where possible
    e. Omar proposed using a lookup table to store the gains
    f. Jake asked if it would be better to use an equation to increase accuracy
    g. Omar replied that it was not needed since the two main states are the unloaded state (0 A) and loaded state (500 A)
    h. Jake asked why we need to measure the voltages for currents between 0 A and 500 A
    i. Omar replied that we need the other values to use feedback from the shunt to determine how much the stepper motor needs to be turned
    j. The group measured the voltages corresponding to gains with 0.5 precision and stored it in a table
    k. Jake will write the lookup table code
    l. Jake measured the resistance of the purchased battery load tester as 0.392 m Ohm
    m. Omar said the maximum resistance is 24 m Ohm
    n. Jake had concerns about the shunt's ability to hold large amounts of power and preferred using the other shunt
    o. Omar noted this shunt should be okay, as the device is listed for 500 A currents.
3. Overall Progress and Future Plans

a. We have finished the voltage divider network and display module
b. We have almost finished the current sense resistor
c. Omar will work on the carbon pile load and fan next, as well as powering all of the external devices
d. Jake will work on the user interface next
e. Tyler will continue working on the PC interface

2CE1EE Meeting Notes
Team Meeting 10
Thursday November 21st, 2024
4:30pm-5:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Omar has written the code to control the fan using pulse width modulation
    b. Jake has tested the code and it was working properly for several different duty cycles
        i. He noted that the output pin was not configured correctly
        ii. PA0 is used for the internal oscillator of the AVR128DB48
        iii. Jake switched to using pin PB0 instead
    c. Tyler is having trouble with the USART interface transferring the same characters multiple times
2. Next Steps
    a. Omar noted that since the fan code was working properly, the fan module is now complete
    b. The only remaining components are the stepper motor, remote, and local interfaces
    c. Omar will work on the stepper motor
        i. Scott would like the stepper motor to be integrated into the design and manually controlled by the end of the semester
    d. Jake will work on the local interface
        i. Jake will start integrating a push button into the design to determine when the ADC should be read on Friday the 22nd
    e. Tyler will work on the remote interface
        i. Tyler will continue debugging the issue mentioned earlier
        ii. After Thanksgiving, he will also start interfacing the microcontroller with the external USART IC.
    f. No meeting next week due to Thanksgiving
    g. The next written report is due December 10th
        i. Some of the sections are repeated from previous reports
        ii. Tyler will ask Scott if it is okay to reuse sections from previous reports
        iii. After hearing back from Scott, the group can decide which sections each person will write about
        iv. Per Scott's feedback on the last report, the group will need to elaborate on the technical sections of the next report

2CE1EE Meeting Notes
Team Meeting 11
Tuesday December 3rd, 2024
4:30pm-5:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Scott and Professor Dhadwal said reusing sections for the report is okay
    b. The Interim Report is due next Tuesday December 10th
    c. The User Manual is due next Friday December 13th
    d. Scott will be stopping by to see breadboard progress next week
    e. Omar needs to know the carbon pile load's minimum and maximum resistance
    f. Jake has successfully implemented the push button into the design
        i. The button is pressed to update the data on the LCD
2. Interim Report
    a. Tyler proposed the following division of sections
    b. Tyler: Constraints and Standards, Team Discussions, formatting, submission
    c. Omar: Best Worst Case Design, Theoretical Analysis, Simulations, Design Selection
    d. Jake: Preliminary Results, Discussion
    e. The background research section from the proposal can be reused
    f. All group members agreed with the division of writing
3. User Manual
    a. Jake and Omar will write about the local interface
    b. Tyler will write about the remote interface
    c. Tyler will ask Scott if hand drawings as acceptable, as it would make it easier to plan layouts
4. Breadboard Assembly
    a. Tyler asked which components can be assembled before Scott's visit next week
    b. Omar said the fan could be set up
    c. The group will demonstrate the push button, current reading, and fan operation to Scott
5. Next Steps
    a. Each group member will work on their assigned sections for the interim report and user manual
    b. Jake will go to the lab to gather test data for the report and find the carbon pile resistance for Omar
    c. Tyler and Jake will look into connecting the fan to the breadboard early next week before Scott's visit

2CE1EE Meeting Notes
Team Meeting 12
Wednesday December 11th, 2024
5:00pm-5:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Scott wants the load analyzer to be disassembled ASAP
    b. He also wants to see the manual operation of the carbon pile load
    c. The demo scheduled for Friday December 13th is cancelled
    d. Omar stated that Scott wants the demo by December 31st at the latest
    e. The user manual is still due on Friday
2. User Manual
    a. Tyler proposed the following division of sections for the user manual
    b. Omar: testing and operation procedures
    c. Jake: local interface operation
    d. Tyler: remote interface operation
    e. All group members agreed with the division of work
3. Load Analyzer Disassembly
    a. Omar will be on campus on Tuesday the 17th and can pick up the load analyzer then
    b. Jake and Tyler volunteered to disassemble the load analyzer since they are already on campus
    c. Omar said that he needs the carbon pile load, clamp connectors, and voltage sensing wires
4. Manual Operation of Carbon Pile Load
    a. Tyler stated that all laboratories will be closed from December 21st-January 5th so it will be hard to work on the project during that period.
    b. It is best to do the demo with Scott before December 21st to meet the December 31st deadline
    c. Tyler suggested finishing the Manual Operation of the Carbon Pile Load on Tuesday the 17th when Omar is on campus
    d. Then, the demo could be done on December 20th before leaving campus
    e. Everyone agreed on this idea
5. Next Steps
    a. Everyone will work on their respective sections for the user manual
    b. Jake and Tyler will disassemble the load analyzer over the weekend
    c. Everyone will work on assembling the manual operation of the carbon pile load on Tuesday

2CE1EE Meeting Notes
Team Meeting 13
Thursday December 19th, 2024
12:00pm-3:00pm (180 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Initial Updates
    a. Jake has disassembled the load analyzer
    b. Jake and Tyler tried testing the opamp and noticed it has inconsistent performance
        i. Sometimes it works and other times it doesn't work
    c. Jake has also wrote the code for the buzzer and got it working
2. Work Session
    a. Omar debugged the opamp code and then prepared the code for the demo with Scott
    b. Jake worked on assembling everything on the platform
    c. Tyler went to look for the ceramic standoff
3. Final Updates
    a. Omar noted that the opamp wasn't working because PD1 is being used for the ADC and opamp
    b. Omar has written up the code for the demo
    c. Omar would like to use multiple files for the code to make everything more organized
    d. The group members agreed that the demo would most likely be ready by Friday the 20th
    e. Tyler only found one half of the standoff and will need to order one online
        i. He found a possible replacement and emailed Scott to ask if the part is suitable
4. Next Steps
    a. Tyler will contact Scott about the group's progress for the day
    b. Tyler will split the code into multiple files and then continue working on the remote interface
        i. Omar will send Tyler the most updated code
    c. Jake will start working on the local interface
    d. Omar will start working on the automated control of the carbon pile
    e. The ESDL will be closed from December 23rd-January 3rd and January 13th-17th
    f. The senior design lab will be closed from December 23rd-January 3rd
    g. No meetings for the next few weeks due to the holidays and lab closures

2CE1EE Meeting Notes
Team Meeting 14
Friday January 24th, 2025
10:00am-10:30am (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. The parts Omar ordered has arrived and are ready to be used
    b. Jake has finished the carbon pile assembly
    c. Omar has fixed the issue with the opamp and finished the code for reading the load current. He also has the local interface working to store results and run a full test
    d. Tyler has finished the preliminary design for the remote interface
    e. Omar thinks the group is ready for the demo and asked Scott to come in at 10:30
2. Next Steps
    a. Omar will work on the stepper motor code and then the PCB layout board
    b. Tyler will continue working on the remote interface so that it can send and receive data from the microcontroller and run a full test
    c. Jake will write the code to interface with the new four line DOG LCD.
    d. Jake will also help Tyler with the embedded code for the remote interface so the microcontroller can send and receive data from the remote interface and process it.
    e. Omar commented that not much is left to be done and the project should be completed well before the end of the Spring semester.
3. Demo Setup
    a. The group setup for the demo with Scott
    b. The group tested the system using the power supply and everything appeared to be working correctly

2CE1EE Meeting Notes
Team Meeting 15
Monday January 27th, 2025
11:00am-11:30am (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Tyler has started working on connecting the GUI to the internal PC serial port to send and receive data
    b. Jake is working on configuring the microcontroller's UART module to send and receive data
    c. Omar got the opamp working fully
    d. However, he accidentally connected the 13 V leads to the microcontroller's ADC pins and the UART bridge chip and neither are working anymore
    e. Omar noted that once the parts are replaced, the group is ready for the demo of the manual operation of the carbon pile load
2. Part Replacements
    a. The microcontroller and UART bridge chip both need to be replaced
    b. Jake and Tyler remember that Scott brought in spare microcontrollers last week
    c. The group searched the ESDL and Senior Design Lab for the spare microcontrollers but couldn't find them anywhere
        i. It's possible that the other group could have taken them by mistake or Scott took the microcontrollers home
    d. The UART chip is from Bryant Gonzaga.
        i. This chip cannot be easily soldered into the final design, so the group decided it would be better to order a new QFN packaged UART chip
3. Next Steps
    a. Tyler will email the other group and Scott regarding the spare microcontrollers
        i. Scott will be unavailable for most of this week and possibly next week as well, so it might take a while for the parts to arrive
        ii. The group can consider ordering a microcontroller themselves to reduce waiting time
    b. Tyler will also ask Scott to bring in or order the QFN packaged UART chip
    c. Jake and Tyler will continue working on their respective parts of the remote interface
    d. Jake will replace the LCD with the DOG LCD
    e. Omar will start working on the stepper motor code
    f. The group will schedule a demo with Scott once parts arrive, likely in 1-2 weeks depending on Scott's availability

2CE1EE Meeting Notes
Team Meeting 16
Tuesday February 4th, 2025
11:30am-12:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Tyler received the parts from Scott on Friday
    b. Jake soldered the new AVR128DB48 board to the breakout board
2. Testing the New Board
    a. The group tested the new board to see if it is working correctly.
    b. Everything seemed to be working fine, except the LCD was not working properly
    c. Tyler noted that the LCD was working fine last week with the old microcontroller, therefore the issue likely has something to do with the new microcontroller
    d. Jake noted he had some difficulties soldering the board, which may have caused these problems
    e. Omar tested each of the individual SPI pins of the microcontroller and noted that the clock frequency was twice the expected frequency
    f. Omar heard the other group had a similar problem and asked if Jake or Tyler knew how they fixed that problem
    g. Neither knew but Jake said they asked Daniel for help who was able to fix the problem for them
3. Next Steps
    a. Jake and Omar will look into the SPI clock issue further
    b. Jake and Tyler will continue working on their respective parts of the remote interface
    c. Jake will replace the LCD with the DOG LCD
    d. Omar will start working on the stepper motor code
    e. The group will schedule a demo with Scott once everything is resolved with the new microcontroller, likely in a week

2CE1EE Meeting Notes
Team Meeting 17
Tuesday February 11th, 2025
12:30pm-1:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake and Omar fixed the issue with the SPI clock
        i. A wire was loose and not properly connected
    b. Jake was able to configure the UART module to send and receive characters
    c. Tyler has completed the basic design of the GUI
    d. Omar has compiled a basic schematic of all components involved in the design as well as a list of parts needed for the PCB board
2. Demo Meeting
    a. Scott would only be available for a demo meeting on Wednesday
    b. Tyler has not heard from Scott yet, so he is not sure if there will be a demo meeting this week
    c. Scott is not available the rest of the week, so the demo would have to be next week
    d. Tyler asked everyone which day would be most convenient for everyone
    e. Jake and Omar both wanted to meet on Tuesday before senior design as Scott will also be presenting that day but could also do Monday or Wednesday too
    f. Tyler will ask Scott for a meeting on Monday, Tuesday, or Wednesday of next week if he doesn't hear back from Scott tonight
3. Assembly
    a. Jake asked Omar about his progress on the PCB layout design and if he could help with that
    b. Omar hasn't started the layout yet as he's still working on the stepper motor code but could use some help in a couple of weeks
    c. Omar asked Jake to design the case for the prototype
    d. Jake agreed and told Omar to let him know when he's ready to start the PCB layout and case design
4. Next Steps
    a. Jake will start developing the communication scheme control logic for the embedded side of the UART interface
    b. Tyler will start implementing the software UART interface with the GUI
    c. Jake will replace the LCD with the DOG LCD
    d. Omar will continue working on the stepper motor code
    e. Tyler will update the group on the next meeting date and time with Scott

2CE1EE Meeting Notes
Team Meeting 18
Thursday February 20th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake and Tyler have written the code to initiate unloaded and loaded tests from the remote interface
        i. They are currently working on sending results from the microcontroller to the PC
    b. Omar is continuing working on the stepper motor code
    c. Omar will not be on campus for the rest of the week and part of next week
2. Demo Meeting Discussion
    a. The demo with Scott went well but he would like two changes to be made by next week
    b. The voltage measurements need to be more precise
        i. Tyler stated that the resistors could be replaced with higher precision resistors which could be ordered from Scott
        ii. Jake proposed updating the constants used to calculate the voltages to account for lower precision resistors
        iii. Omar agreed with Jake
        iv. The group will try Jake's idea first and if that doesn't work, they will try Tyler's idea
    c. Scott wants the load current displayed on the LCD along with the results
        i. Omar suggested using the up and down arrows to scroll between the measured voltages and the load currents
        ii. The other group members agreed with this idea
    d. Scott wants all design tasks completed by the end of April
    e. Tyler will email Omar the rest of the meeting notes from the demo
3. Next Steps
    a. Tyler will continue working on sending results to the PC and then start testing with the full system
    b. Jake will work on implementing the two changes Scott wants to see by the next meeting
    c. Omar will continue working on the stepper motor code and then start working on the PCB layout design with Jake
    d. Omar can send any code he needs tested to Tyler and Jake who can test in the lab and report the results back

2CE1EE Meeting Notes
Team Meeting 19
Monday February 24th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake updated the software constants to calculate the voltage from the ADC
    b. Tyler is testing with the remote interface and had a meeting with the other group to discuss mechanical issues
    c. Omar started working on the PCB layout and is still working on the stepper code
2. ADC Voltage Reading
    a. Jake changed the constant of 5 for the voltage divider multiplication factor to 4.8 however the results are still not ideal
    b. Tyler suggested just using higher precision (1% tolerance instead of 5% tolerance) resistors and then modifying the voltage divider factor if needed
    c. Tyler has already emailed Scott regarding the higher precision resistors and he will deliver them later in the week
    d. For now, Jake will work on adding the current reading along with the results
3. Meeting with the Other Group
    a. Tyler had a brief discussion with the Scott's other senior design group
    b. They noted that the alligator clampers were starting to weld similar to their system
    c. They asked Scott for new clampers and recommended the group do the same
    d. Tyler has already emailed Scott and he will deliver them along with the resistors
    e. The other group also had a problem reading low currents
    f. Tyler noted that the current readings were not that precise
    g. However, Scott told the other group that he wants to be able to have precise measurements of currents besides 0 A and 500 A as well
    h. Jake also noted the max current goes significantly higher than 500 A
    i. Omar will work on improving the accuracy of the current measurements
4. Next Steps
    a. The group will have another meeting with Scott later in the week when the parts arrive
    b. Tyler will continue testing with the remote interface
    c. Jake will continue modifying the local interface with the features Scott wants and then install the new LCD
    d. Omar will work on improving the accuracy of the current measurement and then continue working on the stepper motor and PCB layout

2CE1EE Meeting Notes
Team Meeting 20
Wednesday March 5th, 2025
12:30pm-1:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake and Tyler have tried various methods to fix the ADC, but none have been successful
    b. Jake has modified the local interface with the features Scott asked for
    c. Omar is taking some time off for midterms, but will resume on the stepper motor later in the week
2. ADC Voltage Reading
    a. There is still a problem with the ADC receiving the correct input but producing an incorrect output
    b. Jake and Tyler have tried the following to fix the ADC but none were successful
        i. Switching to higher precision resistors
        ii. Using another one of Scott's chips
        iii. Using different ADC pins
        iv. Lowering the voltage reference
    c. The Curiosity Nano AVR128DB48 works, so the issue is with Scott's board
    d. The group can order an external ADC or voltage reference chip
    e. Tyler also suggested just using the Curiosity AVR128DB48, as Bryant had prior senior design groups solder the board to the design
    f. Tyler will contact Scott to discuss the group's options
3. PCB Layout and Design
    a. Jake and Omar agreed to work together on the PCB layout
    b. Jake will update the master schematic with updated hardware and send to Scott
    c. Tyler noted that the group still needs to design the circuitry for the LCD, EEPROM, remote interface, stepper motor, and temperature sensor
    d. The group agreed to expedite the PCB layout so that a board can be ordered as soon as possible
    e. Omar will try adding Scott to the Fusion360 Project
4. Next Steps
    a. Tyler will contact Scott regarding the ADC
    b. Tyler will continue testing with the remote interface
    c. Jake will make a master schematic of all of the new hardware to email to Scott and assist Omar with the PCB layout
    d. Omar will continue working on the stepper motor and PCB layout

2CE1EE Meeting Notes
Team Meeting 21
Wednesday March 12th, 2025
2:30pm-3:00pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake and Tyler have figured out the issue with the ADC was due to too short power supply wires.
        i. They replaced the wires and now the ADC is working properly
    b. Jake has started working on the PCB layout design
    c. Omar is taking some time off for midterms, but will assist with the PCB layout next week during spring break
    d. Scott reduced the scope of the project to not include the stepper motor or the EEPROM
    e. Scott wants a feature so that the loaded test can be performed at different currents for both the local and remote interfaces
2. PCB Layout and Design
    a. Jake has started the PCB layout and Omar will assist once his midterms are over
    b. Jake will update the master schematic with updated hardware and send to Scott
    c. Jake has already shared the Fusion Project with Scott and he has received it
    d. Jake is currently working on the Bill of Materials
    e. Tyler has received schematic feedback from Scott
    f. Scott wants a SSR input series resistor to limit the current of the fan's internal LED diode.
        i. Omar will make sure to add this in the PCB design
    g. Tyler asked if the PCB layout could be finished by the end of Spring Break so a board can be ordered ASAP
        i. Jake and Omar will try to meet this deadline
3. Progress Report 2
    a. Progress Report 2 is due March 27th
    b. Jake will work on the Discussion of Completed Tasks with Supporting Data
    c. Omar will work on the Abstract
    d. Tyler will work on the Description of Remaining Tasks, Gantt Chart, and formatting and submission
4. Next Steps
    a. Tyler will continue testing with the remote interface and add the functionality to change the loaded test current for the remote interface

b. Jake will add the functionality to change the loaded test current for the local interface
c. Jake will finalize the Bill of Materials and order the parts
d. Jake and Omar will continue working on PCB layout
e. Everyone will work on their respective parts of Progress Report 2
f. No meeting next week due to Spring Break

2CE1EE Meeting Notes
Team Meeting 22
Monday March 24th, 2025
10:30am-11:00am (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Omar has implemented additional features to the local interface and still wants to implement the stepper motor
    b. Omar has ordered additional op-amps to increase accuracy at low currents
        i. Jake noted that he was able to reconfigure the op-amp to increase the accuracy at low currents
        ii. Omar does not need to test the new op-amps since Jake fixed the op-amp
    c. Jake is working on the PCB layout
    d. Tyler was able to configure the remote interface to run a test
2. PCB Layout and Design
    a. The stepper motor will be included in the PCB layout
    b. Jake asked if an external EEPROM, temperature sensor, or real time clock will be included in the final design
        i. Omar wants to implement these features but he is using the internal EEPROM instead of an external EEPROM
        ii. Tyler noted that Scott wants the project to start wrapping up
        iii. The group agreed to implement the internal EEPROM, but not the temperature sensor or real time clock
    c. Jake and Omar will work on the PCB design after the stepper motor is tested
3. Case Design
    a. Jake plans to make a cutout in the case for the LCD and push buttons
    b. The PCB will lay flat against the case with the LCD and push buttons on one side and the other components on the other side
    c. Jake noted the case would be quite small
        i. Tyler asked about the stepper motor
        ii. Omar plans to plug the stepper motor into the carbon pile knob
        iii. Tyler asked if it was possible to do manual and automated tests
        iv. Omar implemented that functionality but the manual knob would need to be replaced with the stepper motor and vice versa to switch between tests
4. Progress Report 2
    a. Progress Report 2 is due on Thursday
    b. Jake will work on the Discussion of Completed Tasks with Supporting Data
    c. Omar will work on the Abstract

    d. Tyler will work on the Description of Remaining Tasks, Gantt Chart, and formatting and submission
5. Oral Presentation
    a. The group has a presentation in 2 weeks on April 8
    b. The group will start preparing next week
6. Next Steps
    a. Tyler will integrate Omar's code with Tyler and Jake's remote interface code then start implementing remote interface code to store results from the microcontroller's EEPROM. He will also test the local interface features Omar added
    b. Omar will finish the stepper motor and then work on the PCB design
    c. Jake will work on the PCB design and case
    d. Everyone will work on their respective portions of Progress Report 2

2CE1EE Meeting Notes
Team Meeting 23
Monday March 31st, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Omar has completed the PCB layout
    b. Jake has verified the PCB layout and everything appears to be good
    c. Tyler was able to store results from the EEPROM, but there are still some minor issues that need to be sorted out
2. PCB Layout and Design
    a. Jake wants the PCB to be more evenly distributed as opposed to everything on the right side
    b. Omar thought the board would be smaller but had to expand it later to accommodate the LCD
    c. Jake asked which buttons were used
    d. Omar used the Fusion push buttons
    e. Jake asked which terminal block was used
    f. Omar used the default Fusion terminal block
    g. Jake suggested moving the terminal blocks to the other side of the board
    h. Omar agreed but wants to order an initial PCB first
    i. Tyler agreed as the group is already behind with PCB layout
    j. Jake noted that the group would need to order extra parts
    k. Omar suggested ordering extra parts anyways
    l. Jake will make edits to the board by the end of the day
    m. Omar will order the board and parts at the end of the day using Tyler's address so they get mailed to campus
3. Remote Interface Demo with Scott
    a. Scott would like to have a remote interface demo meeting
    b. Jake and Tyler are available most of the week
    c. Omar is available
    d. The group will propose meeting tomorrow or next Monday or Tuesday
4. Oral Presentation
    a. The group has a presentation on next Tuesday
    b. The group will start preparing this week
5. Documentation
    a. The hardware description document, software description document, and user manual are due in 2 weeks, on April 14th

b. Omar has started the software description document
c. The user guide needs to be modified with updated images and the new procedure with the automated tests
d. Everyone should comment their code

6. Next Steps
    a. Tyler will fix the issues with storing results from the EEPROM and then fix the local interface menus displayed on the LCD so they have a consistent format
    b. Jake will fix the PCB and send it to Omar, then work on adding the remote interface software to run automated tests and then create a case for the design
    c. Omar will review the PCB then order the parts
    d. Tyler will contact Scott regarding the remote interface demo date
    e. Everyone will work on the presentation for next week
    f. Everyone will work on documentation for Scott

2CE1EE Meeting Notes
Team Meeting 24
Monday April 7th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Jake and Omar have modified, verified, and ordered the PCB and it will be arriving by Wednesday at the latest
        i. Jake was not able to order the real time clock as part of the design because of its high cost so it will not be implemented in the final design
        ii. He left the clock circuitry on the board though
    b. Tyler has modified the remote interface to run automated tests and it appears to be working at low currents, but he is unable to test at higher currents because the stepper motor assembly has not been completed yet
    c. Tyler has ordered the parts and they will arrive later today
2. Remaining Tasks
    a. The project is due at the end of the month
    b. The remaining crucial tasks are the case and assembling everything together
    c. Tyler wants to add additional features to the remote interface to improve the user experience
3. Remote Interface Demo with Scott
    a. The meeting was rescheduled for Wednesday at noon
4. Oral Presentation
    a. The group has a presentation tomorrow
    b. Two demo videos will be recorded, one for the local interface and one for the remote interface
    c. Tyler will be talking about the remote interface, conclusions, and upcoming tasks and walk through the demo videos
    d. Omar will be talking about the stepper motor, test procedure, health rating system, and local interface
    e. Jake will be talking about the project background, schematics, prototype setup and assembly and PCB board
    f. Either Jake or Omar will discussing the current sensing circuitry depending on who has more slides
    g. The group will finish all presentation slides tonight and rehearse before class tomorrow
5. Documentation

    a. The hardware description document, software description document, and user manual are due next Monday
    b. Omar has started the software description document
    c. The user guide needs to be modified with updated images and the new procedure with the automated tests
    d. Everyone should comment their code
6. Next Steps
    a. Tyler will continue adding enhancements to the remote interface to improve the user experience
    b. Jake and Omar will start soldering components onto the board when the PCB arrives
    c. Jake will design the case
    d. Everyone will prepare for the presentation
    e. Everyone will work on documentation for Scott

2CE1EE Meeting Notes
Team Meeting 25
Monday April 14th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Tyler met with Scott last Friday and the remote interface demo went well
    b. Scott would like to be able to name the different battery cells by their identifiers (A, B, C, D, A1, etc) instead of B1, B2, B3, B4
    c. There will be one last meeting with Scott in May to hand over the prototype and return parts
    d. Jake soldered the components to the microcontroller, but is having an issue with a short circuit
    e. Jake and Omar met with the other group who noticed that the ammeter is measuring current incorrectly
2. Carbon Pile and Shunt
    a. Jake and Omar met with the other group who noticed that the ammeter is measuring current incorrectly
    b. The max current being drawn is around 350-450 A
    c. The carbon pile discs cannot support drawing a current as high as 500 A
    d. It is unlikely that either group will be able to fix the electromechanical hardware before the end of the project, so it will most likely be left as is
3. PCB
    a. Jake is having issues with the PCB having short circuits
    b. Omar noted that on Fusion, some of the components are not connected to ground
    c. Jake does not think that is a problem with the board
    d. Omar checked the other PCB components and noticed that the issue is only on the board with soldered components, therefore the issue has to do with one of the components soldered on
    e. Jake thinks the microcontroller is the one causing the problem
    f. Omar and Jake will start desoldering each of the components to see which is causing the problem
    g. A new board might need to be ordered if there are problems with the parts
4. Senior Design Reimbursement
    a. Professor Dhadwal is not signing reimbursement forms, so Scott needs to be the one to sign off on the forms
    b. Everyone should send Tyler their forms and receipts by Thursday so he can get Scott’s signature for them and submit them to the department on Friday

5. Documentation
    a. The hardware description document, software description document, and user manual are due tonight
    b. Omar will work on the setup and connecting the battery section of the user manual, ADC, local interface, and stepper motor portions of the software document, and stepper motor and ADC portions of the hardware document
    c. Jake will work on the local interface portion of the user manual, remote interface C code of the software document, and electromechanical, pushbuttons, buzzer, microcontroller, and power supply board portions of the hardware document
    d. Tyler will work on the remote interface portion of the user manual, remote interface Python code, main program and initialization, and LCD code portions of the software document, and UART bridge and JTAG programmer portions of the hardware document.
6. Next Steps
    a. Tyler will continue adding enhancements to the remote interface to improve the user experience
    b. Jake and Omar will fix the issues with the PCB and order a new one if necessary
    c. Everyone will finish their parts of the documentation to be handed in to Scott tonight
    d. Everyone should send their receipts and reimbursement forms to Tyler on Thursday

2CE1EE Meeting Notes
Team Meeting 26
Monday April 21st, 2025
2:00pm-2:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Tyler added the functionality to name the battery cells in the remote interface
    b. Jake determined the problem with the PCB was due to the temperature sensor
    c. Jake and Omar have noticed the PCB is not accurately measuring the voltages and currents
    d. Omar tested a new op-amp that improves the current reading accuracy at low voltages
2. Op-Amps
    a. Omar noticed that the op-amp installed on the PCB is not measuring current correctly at low voltages
    b. He bought higher precision op-amps which are working better
    c. Any new PCB will use the new op-amp
3. PCB
    a. Jake fixed the problem with the PCB, but the voltage reading and current reading is not correct
    b. Omar fixed the current reading as mentioned above
    c. Jake thought the voltage reading issue had to do with the microcontroller, but when he replaced it with another one, he had the same problem
    d. Jake will try switching the PCB and see if that fixes the problem
    e. If not, a new PCB will need to be ordered
    f. Omar noted that Scott wants some changes to be made to a new PCB
    g. The power supply board should be combined with the main PCB
    h. The push buttons should be moved under the LCD
4. Poster
    a. The poster is due Friday May 2nd
    b. Tyler will upload the poster template to the shared Google Drive
5. Next Steps
    a. Tyler will continue adding enhancements to the remote interface to improve the user experience
    b. Jake and Omar will fix the issues with the PCB and order a new one if necessary

2CE1EE Meeting Notes
Team Meeting 27
Monday April 28th, 2025
12:00pm-12:30pm (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Tyler started working on the final report and poster
    b. Jake was able to fix the issues with the voltage reading but was not able to fix the current reading
    c. Jake and Omar made a new PCB and ordered it
2. PCB
    a. Jake fixed the issues with the voltage reading by switching to another copy of the same PCB
    b. The current is still not right even on the new PCB
    c. Jake and Omar made a new PCB with the higher performance OPAMP and ordered it
    d. The next PCB will arrive later in the week
    e. Jake and Omar will solder and test the new PCB when it arrives
3. Stepper Motor
    a. Omar still wants to implement the automated tests
    b. He brought the stepper motor coupler and will work on adding that to the carbon pile knob this week
    c. Tyler noted that the automated portion does not need to be completed and the manual version is fine if it takes too long to implement
    d. Omar will still try to implement it
4. Poster
    a. The poster is due this Friday May 2nd
    b. Tyler uploaded the poster template to the shared Google Drive
    c. Tyler has already completed the sections on background, objective, and software
    d. Jake and Omar should work on the hardware sections
    e. Poster day is Thursday May 8th at 12pm and everyone must attend
5. Final Report
    a. The final report is due Friday May 9th
    b. Most sections can be reused
    c. Scott gave feedback on the interim report
    d. Everyone will work to address the feedback Scott gave on the sections they wrote on previous reports

    e. There are 3 new sections: Innovation: Uniqueness of Proposed Solutions, Method and Materials, and Results and Discussion
    f. Tyler will work on Innovation: Uniqueness of Proposed Solutions
    g. Omar will work on Methods and Materials
    h. Jake will work on Results and Discussion
6. Documentation
    a. Scott sent out documentation feedback and generally the documentation was pretty good with only minor changes that need to be made
    b. Tyler scheduled a meeting on Wednesday April 30th at 12pm with Scott to discuss further
    c. Everyone will work to address the feedback Scott gave on the sections they wrote on the draft version of documentation
7. Final Demo Meeting with Scott
    a. Scott wants a final demo meeting to demo and hand over the project by Monday May 19th latest
    b. The documentation, source code, and all other project files will be handed over on this date
    c. Jake and Tyler want to do the demo meeting on May 19th
    d. Omar is not sure about his availability and will inform the group later on about a demo meeting
8. Next Steps
    a. Everyone will work on their parts of the poster, final report, and documentation
    b. Jake and Omar will solder and test the new PCB when it arrives
    c. Omar will work on implementing the stepper motor assembly

2CE1EE Meeting Notes
Team Meeting 28
Monday May 5th, 2025
10:30am-11:00am (30 mins)

Individuals Present: Tyler Shaw (team leader), Jake Lin, Omar Mohamed

1. Updates
    a. Omar got the stepper motor working
    b. Jake soldered most of the components onto the PCB and the initial test went well
    c. Tyler added text boxes to the remote interface to name the batteries and enter the desired current, as well as the code to run automated tests from the remote interface
    d. Tyler reminded everyone not to test batteries with an unloaded voltage of less than 3 V in the loaded state
2. PCB
    a. Jake soldered most of the components onto the PCB and the initial unloaded test went well
    b. He did not solder the stepper motor onto the PCB yet or test the remote interface or loaded test
    c. Omar will help Jake with testing the stepper motor and other components more thoroughly
3. Stepper Motor
    a. Omar connected the stepper motor to the carbon pile load and successfully ran an automated test
    b. The next phase is to connect the stepper motor to the PCB
4. Software
    a. Tyler is working on enhancements to the remote interface including the running automated tests, cancelling a test in the middle of a run, and providing text boxes to enter the current and battery names
    b. He has written the Python code, but now needs to write the C code and test these features
    c. The next step will be to implement the safety feature Scott requested over the last weekend, which is to prevent batteries with unloaded voltages less than 3 V from having a loaded test done on them
    d. Omar is working on similar software for the local interface
    e. Tyler will go through all of the Python and C code once everything is completed and comment and consistently format the code
    f. Tyler reminded everyone to include all software changes in the User Manual and Software Description Document.

5. Poster Day
    a. Poster Day is Thursday May 8th from 12-2pm in the SAC
6. Final Report
    a. The final report is due this Friday May 9th
    b. Most sections can be reused
    c. Scott gave feedback on the interim report
    d. Everyone will work to address the feedback Scott gave on the sections they wrote on previous reports
    e. There are 3 new sections: Innovation: Uniqueness of Proposed Solutions, Method and Materials, and Results and Discussion
    f. Tyler will work on Innovation: Uniqueness of Proposed Solutions
    g. Omar will work on Methods and Materials and update the Design Selection part of the report
    h. Jake will work on Results and Discussion
7. Final Demo Meeting with Scott
    a. Scott wants a final demo meeting to demo and hand over the project by Monday May 19th latest
    b. The documentation, source code, and all other project files will be handed over on this date
    c. The group agreed to meet on May 19th at 11am
8. Next Steps
    a. Everyone will work on their parts of the final report and documentation
    b. Tyler will look through the embedded C code files to ensure everything is consistently commented and formatted
    c. Tyler will work on software enhancements to the remote interface
    d. Omar will work on software enhancements to the local interface
    e. Jake and Omar will work to test the PCB and integrate the stepper motor with the PCB

Appendix C - Team Discussions and Team Member Resumes

The project can be logically divided into three parts: electromechanical components, local interface, and remote interface. Since the team has three people, each person is responsible for one part of the project. Omar is working on the local interface, Jake is working on the electromechanical components, and Tyler is working on the remote interface. This is working well for the design team because each part is independent of the others, allowing each person to work at their own pace (TS).

Although each member is working on a separate part of the project, the team has weekly meetings to discuss individual progress and next steps. The team leader, Tyler, makes sure that in these meetings, everyone is heard. He often proposes a division of tasks and asks the other members for their feedback before finalizing the plan. Additionally, he performs administrative work for the team including organizing the shared drive, writing up meeting notes, keeping track of upcoming deadlines, submitting assignments, and communicating with the faculty advisor and course professor. The team has also set up a text message chat for communication outside of the weekly meetings (TS).

Due to limited laboratory hours, not all group members are able to fully test their programs on the microcontroller. This has led to an unofficial system where one person writes a software program and another tests the program in the lab with the hardware. This system encourages collaboration by requiring that each group member understands each other's parts. During the weekly meetings, group members often ask questions about how each person's part works as well as how their part relates to the project as a whole. Based on the results of the hardware test, group members can give feedback on what needs to be changed in the future (TS).

Jake Lin

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EDUCATION:

Stony Brook University, Stony Brook, NY — **GPA: 3.78**

Bachelors in Computer Engineering — **Expected May 2025**

Masters in Electrical Engineering — **Expected May 2026**

EXPERIENCE:

- **Test Engineer** — **May 2024-August 2024**
  RCE Manufacturing — **Commack, NY**
  - Responsible for testing and calibrating all manufactured hardware including the power supply and main boards used in digital ultrasonic applications for leak, vibration, and bearing wear detections.
  - Applied Lean Six Sigma methodologies to achieve incremental improvements in the manufacturing process of electronic parts, resulting in an increased passing rate for these products.
- **Undergraduate Teaching Assistant for Data Structures (C++)** — **August 2023-December 2023**
  Stony Brook University — **Stony Brook, NY**
  - Debugged and guided students through programming issues during lab sessions (3 hrs/week).
  - Designed bi-weekly lab assignments to strengthen students' understanding of data structures.

PROJECTS:

- ***DC-DC Converter* | Fusion360, PCB Design**
  - Designed and fabricated a DC-DC power supply on a PCB board using the LM2596 switching buck converter.
  - Designed a custom enclosure for the device, with access points to the input (AC adapter), and output (screw terminal), as well as a potentiometer for adjustable output voltage.
- ***Automated Load Battery Analyzer* | AVR128DB48 Microcontroller, Embedded C, Electromechanical Assembly, PCB Design**
  - Designing a real-world EV battery analyzer capable of automatically measuring the voltage of a quad-pack lithium-ion battery in both loaded (500A) and unloaded states, assessing the health of each battery in the pack.
  - Contributing to the carbon pile load and mechanical assembly, installation of fan and buzzer, UART for remote interface, and power supply PCB for functionality.
- ***Shipping Data Logger using MS8607 (Pressure Humidity Temperature Sensor) | C, Saleae Logic, Microchip Studio, OrCAD***
  - Configured MS8607, DS3231 (real-time clock), and LCD using the AVR128DB48's SPI and I2C modules to read the temperature, pressure, and humidity every minute/second and display on an LCD.
  - Learned to carefully examine the MS8607 datasheet to correctly perform communication protocol and process large data.
- ***Household Plant Caretaker using Arduino (Personal Project) | C, Arduino IDE***
  - Developed a system utilizing Arduino to automate plant care tasks, including watering and light adjustment.
  - Integrated real-time clock, servo, DIY water dispenser, photoresistor, and thermistor for automated plant maintenance.

SKILLS:

- ***Embedded:*** UART, SPI, I2C, Saleae Logic Analyzer, OrCAD, Microchip Studio
- ***FPGA:*** VHDL, SystemVerilog, Active-HDL, Synplify, ispLever, Synopsys Design Compiler, QuestaSim, AXI-Stream
- ***Electrical:*** Oscilloscope, Function Generator, Multimeter, Power Supply, Test Fixtures, Soldering, Fusion 360, MOSFET design
- ***Mechanical:*** High-Volume Manufacturing, Manual Lever Press, Silicon Gluing, Electrical Wiring
- ***Programming Languages & Tools:*** C++, C, Java, MATLAB, Dev C++, Visual Studio, Linux

RELEVANT COURSES:

Electronics, Modern Circuit Board Design and Prototyping, Advanced Digital System Design and Generation, Digital Design Using VHDL and PLDs, Computer Architecture, Embedded Microprocessor Design I and II, Fundamental Algorithms for Machine Learning, Real Time Operating Systems, Advanced Programming and Data Structures

Omar Mohamed

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EDUCATION

Stony Brook University — **Stony Brook, NY**

Bachelor of Engineering, Electrical Engineering — *Expected Graduation May 2025*

Honors/Awards: Dean's List (All semesters) — GPA: 3.8

SKILLS

- **Programming**: C, Embedded C, C++, Python, Assembly Language, MATLAB, VHDL, Verilog
- **Software**: Fusion360, OrCAD, LTspice, Pspice, KiCad, Altium, Multisim, Vivado, Aldec, Cadence, Visual Studio
- **Hardware**: STM32, Ateml, ESP, FPGA, Schematic Capture, PCB Layout
- **Lab:** Oscilloscope, Signal Generator, Logic Analyzer, Spectrum Analyzer, Vector Network Analyzer, Multimeter
- **Standards**: UART, I2C, SPI, RS232, PCIe, Ethernet, JESD204B, VGA, AXI4

EXPERIENCE

SRC — Syracuse, NY

Digital Hardware Engineering Intern — May 2024 – August 2024

- Configured **JESD204B** clock generators to **synchronize** multiple **PLL** synthesizers deterministically
- Utilized evaluation boards to generate binary configuration files for **PCIe-to-Ethernet bridge**
- Performed extensive **power supply** load testing, **power tree sequencing**, and simulations with **LTpowerCAD**
- Developed **firmware** for **fan PWM** control and tested accelerometer, oscillator, and warning lights.

PROJECTS

50-ohm 100MHz Bandwidth Mixed Signal Oscilloscope

- Designed a 50-ohm, 100MHz bandwidth **analog front end** with, single-ended to **differential signal** conversion, programmable **signal conditioning**, and an **anti-aliasing filter** to interface with multiple **interleaved ADCs**.
- Created custom **RTL modules** and instantiated **IP cores** in **Vivado** to implement **FFT, IIR & FIR Filters, DDS, Fixed-point Arithmetic, amplitude modulation, JESD204B, FIFO, SPI,** and **I2C** on a **Xilinx FPGA**..
- Used **MATLAB** to generate filter coefficients and verify **DSP** algorithms.

60 Watt Programmable Benchtop Power Supply

- Created a topology of **synchronous buck converter**, **preregulator**, and **parallel linear regulators**.
- Implemented **short-circuit protection** and **closed feedback loop** between **buck converter** and **LDO** output.
- Programmed an **STM32 MCU** to display measured current and voltage parameters on an LCD display.

50-ohm 1MHz Bandwidth Function Generator

- Implemented a custom **RTL** design with **generics** for a **Direct-Digital-Synthesis (DDS) synthesizer** in **VHDL**.
- Created and simulated **testbenches** for each component in design to verify functionality.
- Interfaced FPGA output with a **DAC** and **low pass filter** to interpolate in between samples.

ESP32 Weather and Time Monitor

- ESP32 uses Wi-Fi to periodically fetch live weather, time, and date information after **timer interrupts**.
- Information and GUI is displayed on the SSD1306 OLED display using **I2C** interface.
- Microcontroller interfaces with external DHT11 temperature and humidity sensor, keypad, and buzzer.

Adaptive IIR and FIR Filters with Programmable Bandwidth

- Created **VHDL** design description for **fixed-point IIR** and **FIR** filters with **reloadable coefficients**
- Used **DDS** and **fixed-point arithmetic** to generate **windowed sinc filter kernel** for **FIR** convolution.
- IIR and FIR filters are cascaded with **downsampler** for **antialiasing** and **decimation.**

Assembly Language Temperature and Humidity Display System

- Used **serial communication** to read temperature and humidity data from DHT11 sensor with an **AVR128 MCU**
- Performed **floating point multiplication** and **BCD** conversion to display data on 7-segment display.
- Written entirely in assembly language, uses subroutines, timer counters, and interrupts.

Library Management System

- Created a **C++** based library management system using **object oriented programming** and **file operations**.

Tyler Shaw

Queens, NY 11364 ● 347.884.4885 ● tylershaw312@gmail.com

EDUCATION

Stony Brook University, Stony Brook, NY **Expected May 2025**
Bachelor of Engineering in Computer Engineering GPA: 3.91
University Scholars Honors Program

RELEVANT COURSEWORK

Advanced Programming and Data Structures, Embedded Microcontroller Systems Design I and II, Electronics, Computer Architecture, Operating Systems, Advanced Digital System Design and Generation, Design of Secure IoT Embedded Systems

SKILLS

Programming Languages: Java, Python, C, C++, AVR Assembly, MIPS Assembly, MATLAB, VHDL, SystemVerilog
Software: Microsoft Office, G-Suite, OrCAD, LTSpice, Aldec Active HDL, Microchip Studio, Vivado
Tools: Oscilloscope, Function Generator, Saleae Logic Analyzer
Communication Protocols: USART (RS-232), I2C, SPI, AXI, AXI-Stream

PROJECTS

Hichhiker-Shipping Data Logger **Apr 2024-May 2024**

- Implemented a fully functional system that displays the pressure, temperature, humidity, date, and time on an LCD in real time
- Interfaced a MS8607 PHT Sensor, DS3231 real-time clock, and DOGM163W-A LCD to the AVR128DB48 microcontroller
- Developed unique driver functions to allow each of the external devices to communicate with the microcontroller.

Pipelined SIMD Multimedia Unit Design **Oct 2023-Dec 2023**

- Designed a pipelined SIMD processer with 32 128-bit registers in VHDL
- Implemented arithmetic and logical operations for 16-, 32-, and 64-bit operands
- Wrote a C++ program to generate machine code from pseudocode and place it in a text file that could be read by the processor

Digital Sine Wave Generator **Apr 2023-May 2023**

- Designed a system in VHDL to display a sine wave over a range of different frequencies
- Created a lookup table with every possible value of sine to model one quarter of a sine wave
- Utilized finite state machines (FSMs) to determine which part of the sine wave is being displayed and if the sine lookup table should be counting up or down

Library Management System (LMS) **Oct 2022-Dec 2022**

- Utilized C++ to develop a fully functional library management system where users can search, borrow, and return books
- Adapted the quicksort sorting algorithm to sort books by title, then author, then ISBN, then copy ID
- Developed methods to insert and remove users from a sorted binary tree that contains each of the users in the LMS

WORK EXPERIENCE

Artemis Inc., Hauppauge, NY **Jan 2024-Jul 2024**
FPGA Engineer Intern

- Designed SystemVerilog testbenches for VHDL IP cores using Vivado
- Modified IP cores in VHDL to ensure they meet system needs
- Reviewed block diagram of radar design in order to understand system level testing

Stony Brook University, Stony Brook, NY **Aug 2023-Dec 2023**
Teaching Assistant for Embedded Systems Design I

- Verified students' designs during weekly three hour lab sections
- Tutored students on course content during weekly office hours
- Independently completed course labs using an AVR128DB48 microcontroller and common breadboard components

Project STEM **May 2022-Oct 2023**
Teaching Assistant

- Debugged code and answered curriculum related questions from students and teachers on online forums
- Reviewed and updated lesson plans, code files, and coding examples as part of Project STEM's yearly curriculum revision
- Screen recorded Java and Python coding videos to be used as part of Project STEM's computer science classes