Université d'Ottawa
Faculté de génie

École de science informatique
et de génie électrique

uOttawa
L'Université canadienne
Canada's university

University of Ottawa
Faculty of Engineering

School of Electrical Engineering
and Computer Science

ELG4912 - Electrical Engineering Project

Prepared for:

Professor Emil M. Petriu

2022-12-08

Prepared By:

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Contents

1.Project Charter

1.1 Document Change Control

As this project unfolds, the project team gains more information and understanding about the project and its implementation. Consequently, the project charter may have to be adjusted as the scope of the project becomes more precise and the deliverables are better understood.

This section is used to document any changes and serves to control the development and distribution of revisions to the project charter. It should be used together with a change management process and a document management system. Document management procedures of the sponsoring organization should be applied to determine when versions and subversions must be created. This practice keeps an accurate history of the original document that was first approved.

1.2 Executive Summary

This project is Initiated in support of UOttawa Electrical Engineering and Computer Science Department, in association with professor Emil M. Petriu and teaching assistant Haseeb Ur Rehman.

Our objective is to develop a solution to the electrical scooter battery inconvenience and inefficiency due to the climate characteristics of Canada; a group of 5 members will be assigned to this project.

Based on the analysis of project goals, project objectives, major milestones, key deliverables, primary risks, and estimated total costs, the project proposal has been approved by the Electrical Engineering and Computer Science Department.

1.3 Authorization

By signing below I agree to the assigned roles, the description of the project, and the project deliverables and outcomes presented in the project charter.

Client name: Eslin Ustun Karatop

Project Manager signature:

Key Stakeholders signature:

Lidan Huang

Josiah Bigras

张凯程

2 System Requirement Specification

2.1 Project Summary

As everything is going electric, e-scooter is getting popular around the campus, and many students choose to commute across the campus on an e-scooter; but it's not a choice during the winter due to the harsh climate characteristic here in Ottawa. Our group believe that this problem can be solved with an integrated add-on system that manipulates the battery status, so the main purpose of this project is to create a more efficient and convenient way for user's to ride their e-scooter during the winter. The integrated system will allow users to have direct monitor of the status of the battery and automatic control to maintain the battery status at optimal condition. The project will be built and tested with a lithium battery pack which can be installed on the e-scooter as an uninterrupted power supply.

2.2 System requirements

Our project requirements are divided into three parts: business, user, and design requirements. Based on these requirements, we designed our system for the battery pack. The system requirements show the lithium battery pack and add-on system via the block diagram. It contains the project's hardware components and other software resources. As our project progresses, we may fine-tune and add more features to our battery pack.

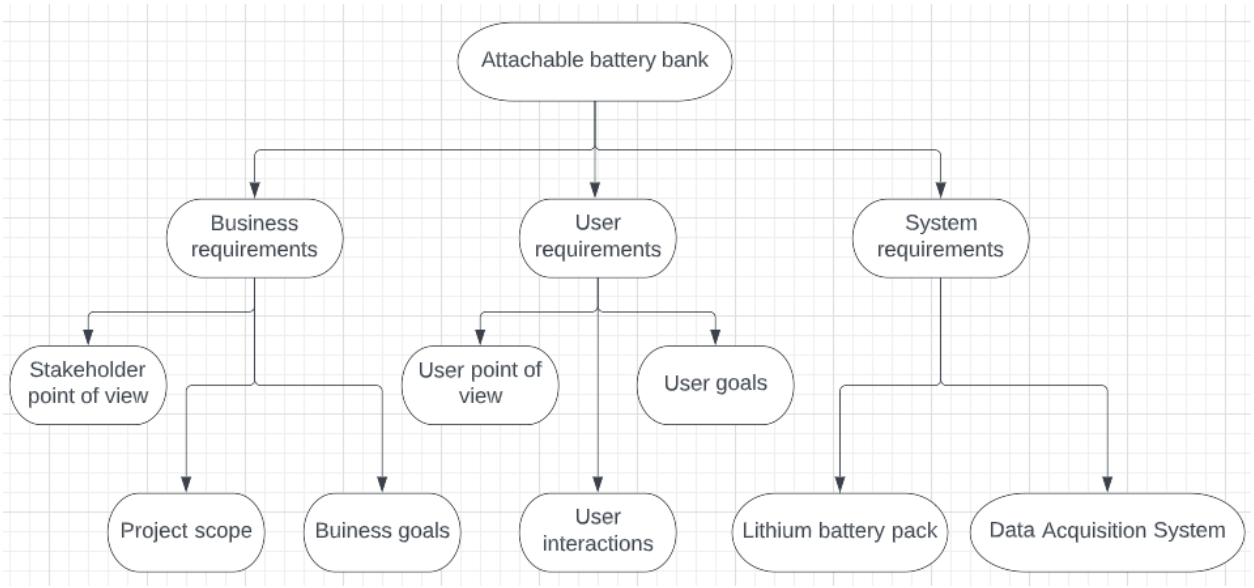

Figure 2.1 - Block diagram of the requirements of the project

2.2.1 Functional Requirements

Our products include but not limited to the following functions:

- Provide enough energy needed by the e-scooter
- Rechargeable
- Measure voltage, current, and temperature, speed of the scooter, energy consumption in the current route; control contactor, pre-charge
- Protection against: Over-charge, over-discharge, over-current, short circuits, and extreme temperatures
- Minimize current to keep the wire diameter small and reduce resistive
- State-of-charge (SOC) estimation, power-limit computation, balance/equalize cells
- Interface: Range estimation, communications, data recording, reporting.
- Thermal control in different environments
- Locate and track e-scooters

In order to achieve the above functions, we designed the hardware and software part of the battery pack

Hardware Requirements

18650 battery: Li-Ion batteries have an excellent energy density, the amount of energy stored per their physical weight. They also have excellent longevity meaning that they can be discharged and recharged or “cycled” many times and still maintain their storage capacity.

Battery insulators: Heat Shrink Wrap - Made of PVC with good insulation. It wraps and protects the battery to prevent dust from entering, it can better protect the battery and make it last longer.

DC-DC Converter: Used with Raspberry Pi for signal processing

Raspberry Pi, sensors, wires, etc...

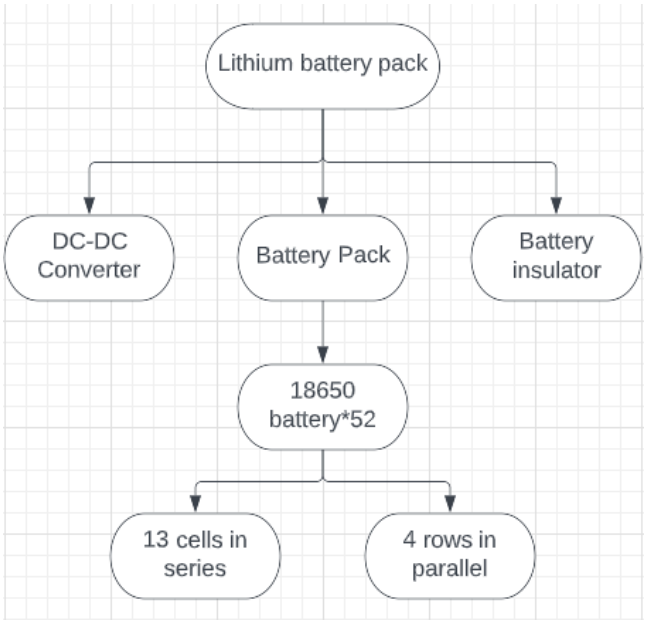

Figure 2.2 - Block diagram of the hardware installation of the project

Software Requirements

Its function is to collect data and control hardware. Also, it gives users insightful data about their battery consumption, as well as acts as a feedback loop to make sure all the parameters are within the desired range (such as voltage, etc.). The temperature control system and GPS include four different sensors and cooperate with raspberry pi for data collection and automatic control.

Temperature control system (Automatic detection and control):
The best working temperature for batteries is around 20℃. In a non-extreme environment, after working for dozens of minutes, the battery can rely on its heat to maintain a mild and comfortable "body temperature." However, lithium batteries cannot rely on their heat to resist the cold winter outside when it is extremely cold. At this time, the temperature control system can help the battery heat up if it detects that the battery temperature is too low. Here's the possible battery heating solution that we are considering:

- Passive insulation
- Resistance Heating System
- Liquid heating system
- External heat source heating
- Pulse self-heating

Currently, we tend to use Resistance Heating. Likewise, the temperature control system also prevents the battery from overheating. When the battery temperature exceeds the set value, the battery automatically disconnects.

GPS system:

Positioning systems are integral to military applications and emergency responders locating people in need. GPS technology often comes into play in many areas that we don't usually consider.

We decided to install a GPS system to achieve the following functions：

- Track the e-scooter and record the route
- Track the speed of the scooter
- Record how much battery is being consumed live and later during a specific path
- Find lost electric scooter
- In the event of an accident, help police investigate records

User interface/data storage system:
All data will be saved and uploaded to the cloud to help us follow up and upgrade the battery pack in the future, and some data, such as the remaining battery power, speed of the e-scooter, and battery consumption, will be displayed on the user interface to help users use it more conveniently
Here is the possible module that we might use for data uploading：

- DMS module
- Wi-Fi module (ESP8266)
- Bluetooth module

Currently, we tend to use DMS module because we can't let the user be in the range of Wi-Fi and Bluetooth at any time.

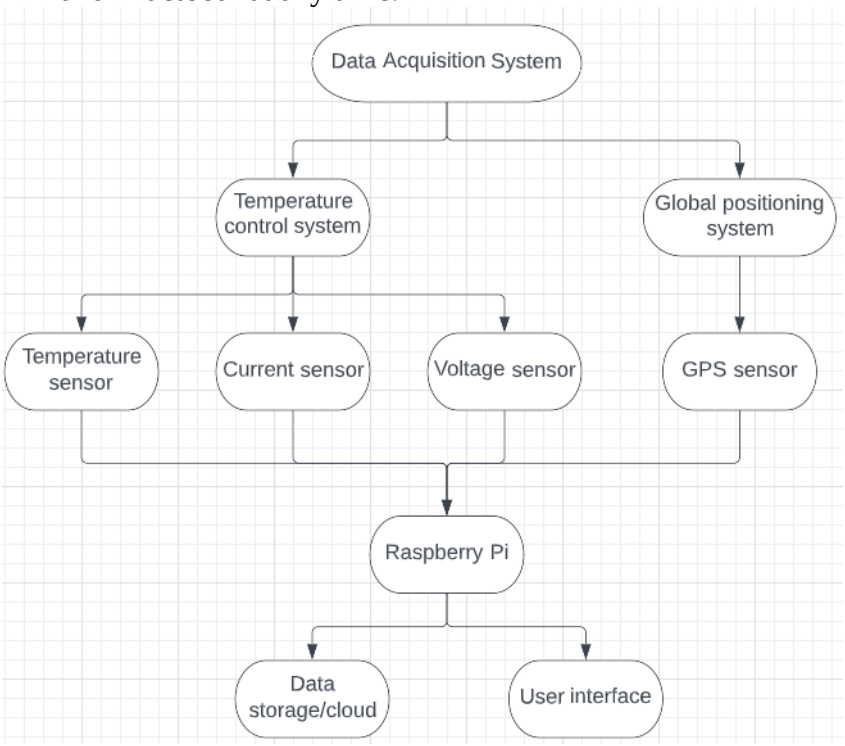

Figure 2.2 - Block diagram of the software add-on of the project

2.2.2 Non-functional requirements

Performance and scalability: The system returns results immediately. The performance is not significantly reduced with higher workloads.

Portability and compatibility: External battery pack, which can be easily fixed on the bottom plate of an e-scooter, is suitable for all types of e-scooters.

Reliability/Maintainability: The battery will have an average lifespan of 300-500 full charge cycles and usually takes 2-3 years for the average user.

Localization: All features of the battery are designed based on the Ottawa environment; it works fine in the extreme cold of Ottawa's winter.

Usability: It's simple to use; take it from home and connect it to the e-scooter charger with the plug the wire of the battery pack. There are no additional operations required.

3.WBS, Schedule with Milestones, Gantt Chart, and budget estimate

3.1 Work Breakdown Structure

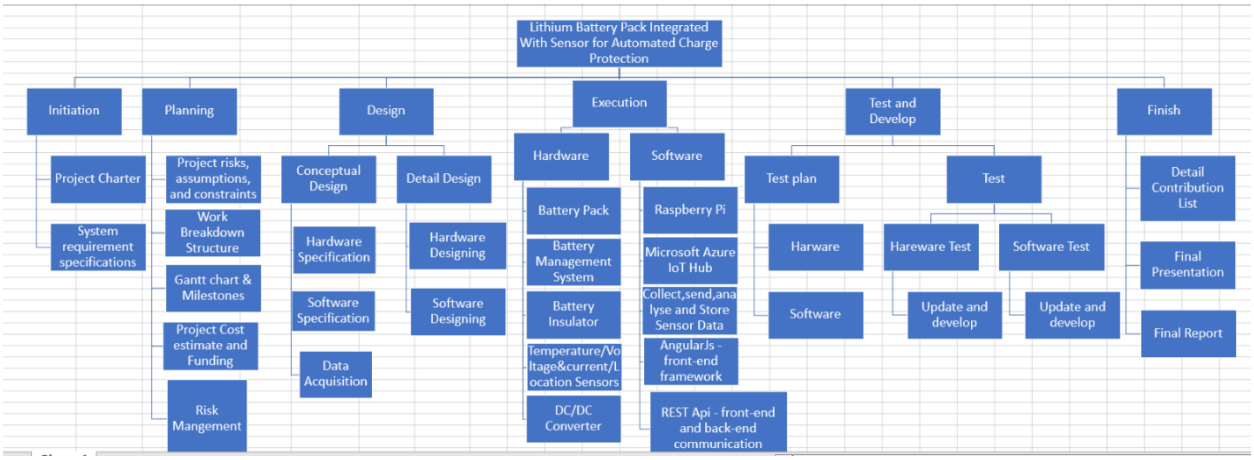

Figure 3.1 - Work Breakdown Structure

Project Milestone	Description	Date
Phase 1: Completed the Project Proposal	Determine the project topic. Gather information.	2022/09/23
Phase 2: Plan and Design	Battery pack hardware and software conceptual design. System requirement specifications. Project	2022/10/21

	planning, such as estimated costs, risks, planning time.	
Phase 3: Detail Design	Hardware and software detailed design.	2022/11/12
Phase 4: Testing and Debugging	Test plan. Staff test the software and debug.	2022/11/20
Phase 5: Updated Project Report	Updated and detailed SRS, Gantt chart, WBS, schedule with milestones, estimated budget, risk management plan, contribution list	2022/11/30
Phase 6: Final Report and Presentation	Detailed plan, conceptual design, schedule, estimated budget and post performance analysis. Analyze test results and developments. Present about the final report.	2022/12/08

Table 3.1 – Milestones

	Task Name	Duration	Estimated Date	Estimated Finish	% Complete	Task Owner	Task Depend on
1	Project Proposal	11 days	Sat 9/10/22	Fri 9/23/22	100%	Everyone	
2	Research and Gather Information	21 days	Fri 9/23/22	Fri 10/21/22	100%	Everyone	#1
3	**Initiation**	**5 days**	**Sat 10/15/22**	**Fri 10/21/22**	**100%**		
4	Project Charter	4 days	Sun 10/16/22	Wed 10/19/22	100%	Kaiyi Yuan	
5	**System Requirements Specification**	**39 days**	**Mon 10/17/22**	**Thu 12/8/22**	**100%**		
6	Midterm SRS	5 days	Mon 10/17/22	Fri 10/21/22	100%	Kaicheng Zhang	
7	Final and Detailed SRS	6 days	Thu 12/1/22	Thu 12/8/22	100%	Kaicheng Zhang	#6
8	**Planning**	**39 days**	**Sun 10/16/22**	**Thu 12/8/22**	**100%**		
9	Project Risks, Assumptions, and Constraints	4 days	Sun 10/16/22	Wed 10/19/22	100%	Josiah Bigras	
10	**Work Breakdown Structure**	**35 days**	**Mon 10/17/22**	**Fri 12/2/22**	**100%**		
11	Midterm Work Breakdown Structure	5 days	Mon 10/17/22	Fri 10/21/22	100%	Lidan Huang	
12	Trello board	2 days	Thu 12/1/22	Fri 12/2/22	100%	Lidan Huang	
13	Final Work Breakdown Structure	3 days	Wed 11/30/22	Fri 12/2/22	100%	Lidan Huang	#11
14	**Gantt Chart & Milestones**	**14 days**	**Sun 10/16/22**	**Thu 11/3/22**	**100%**		
15	Midterm Gantt Chart & Milestones	6 days	Sun 10/16/22	Fri 10/21/22	100%	Lidan Huang	
16	Final Gantt Chart & Milestones	1 day	Thu 11/3/22	Thu 11/3/22	100%	Lidan Huang	#15
17	**Project Cost estimate and Funding**	**35 days**	**Mon 10/17/22**	**Sun 12/4/22**	**100%**		
18	Midterm Project Cost estimate and Funding	3 days	Mon 10/17/22	Wed 10/19/22	100%	Kaiyi Yuan	
19	Final Project Cost estimate and Funding	4 days	Wed 11/30/22	Sun 12/4/22	100%	Lidan Huang	#18
20	**Risk Mangement Plan**	**34 days**	**Tue 10/18/22**	**Fri 12/2/22**	**100%**		
21	Midterm Risk Mangement Plan	4 days	Tue 10/18/22	Fri 10/21/22	100%	Josiah Bigras	
22	Final Risk Mangement Plan	6 days	Sun 11/27/22	Fri 12/2/22	100%	Josiah Bigras	#21
23	Controbution List	3 days	Tue 12/6/22	Thu 12/8/22	100%	Lidan Huang	
24	Conceptual Design	5 days	Sun 10/16/22	Fri 10/21/22	100%		
25	Hardware Specifications	3 days	Wed 10/19/22	Fri 10/21/22	100%	Kaiyi Yuan	
26	Software Specifications	5 days	Mon 10/17/22	Fri 10/21/22	100%	Nima Mehrjoonezhad	
27	Data Acquisition	6 days	Sun 10/16/22	Fri 10/21/22	100%	Nima Mehrjoonezhad	
28	**Detail Design**	**10 days**	**Mon 10/31/22**	**Sat 11/12/22**	**100%**		
29	Hardware Designing	11 days	Mon 10/31/22	Sat 11/12/22	100%	Kaiyi Yuan	#25
30	Software Designing	11 days	Mon 10/31/22	Sat 11/12/22	100%	Nima Mehrjoonezhad	#26
31	**Testing and Debug**	**19 days**	**Mon 11/14/22**	**Thu 12/8/22**	**100%**		
32	**Test Plan**	**5 days**	**Mon 11/14/22**	**Sat 11/19/22**	**100%**		
33	Hardware	6 days	Mon 11/14/22	Sat 11/19/22	100%	Kaiyi Yuan	#29
34	Software	6 days	Mon 11/14/22	Sat 11/19/22	100%	Nima Mehrjoonezhad	#30
35	Hardware Test	7 days	Sun 11/20/22	Sat 11/26/22	100%	Kaiyi Yuan	#33
36	Software test	7 days	Sun 11/20/22	Sun 11/27/22	100%	Nima Mehrjoonezhad	#34
37	Debug	9 days	Mon 11/28/22	Thu 12/8/22	100%	Nima Mehrjoonezhad	#36
38	**Final**	**8 days**	**Tue 11/29/22**	**Thu 12/8/22**	**100%**		
39	Post performance analysis	3 days	Tue 11/29/22	Thu 12/1/22	100%	Everyone	
40	Final Report	6 days	Thu 12/1/22	Thu 12/8/22	100%	Everyone	
41	Final Presentation	1 day	Tue 12/6/22	Tue 12/6/22	100%	Everyone	

Figure 3.2 - Gantt Chart

	Task Name	Duration
1	Project Proposal	11 days
2	Research and Gather Information	21 days
3	**Initiation**	**5 days**
4	Project Charter	4 days
5	**System Requirements Specification**	**39 days**
6	Midterm SRS	5 days
7	Final and Detailed SRS	6 days
8	**Planning**	**39 days**
9	Project Risks, Assumptions, and Constraints	4 days
10	**Work Breakdown Structure**	**35 days**
11	Midterm Work Breakdown Structure	5 days
12	Trello board	2 days
13	Final Work Breakdown Structure	3 days
14	**Gantt Chart & Milestones**	**14 days**
15	Midterm Gantt Chart & Milestones	6 days
16	Final Gantt Chart & Milestones	1 day
17	**Project Cost estimate and Funding**	**35 days**
18	Midterm Project Cost estimate and Funding	3 days
19	Final Project Cost estimate and Funding	4 days
20	**Risk Mangement Plan**	**34 days**
21	Midterm Risk Mangement Plan	4 days
22	Final Risk Mangement Plan	6 days
23	Controbution List	3 days
24	Conceptual Design	5 days
25	Hardware Specifications	3 days
26	Software Specifications	5 days
27	Data Acquisition	6 days
28	**Detail Design**	**10 days**
29	Hardware Designing	11 days
30	Software Designing	11 days
31	**Testing and Debug**	**19 days**
32	**Test Plan**	**5 days**
33	Hardware	6 days
34	Software	6 days
35	Hardware Test	7 days
36	Software test	7 days
37	Debug	9 days
38	**Final**	**8 days**
39	Post performance analysis	3 days
40	Final Report	6 days
41	Final Presentation	1 day

Figure 3.3 - Schedule and Detailed Gantt Chart

Project Deliverables	Description	Acceptance Criteria	Due date
1	Project Proposal	Project Description, Project Rationale, Project Research,	2022-09-23

		Procedure, References	
2	Midterm Report	Project charter, System requirements specification, Conceptual design, WBS, Schedule with milestones, estimated budget, Risk management plan, contribution list	2022-10-21
3	Midterm Presentation	Present the midterm report	2022-11-03
4	Final Presentation	Present the final report	2022/12/06
5	Final Report	Project charter, SRS, Detailed Design, Updated Gantt chart, WBS, Schedule with milestones, estimated budget, updated risk management plan, Test plan, Proof of Concept, Contribution list, PPA, References, URL/Links Access	2022-12-08

Table 3.2 -Deliverables

3.3 Project cost estimate and funding

3.3.1 Project cost estimate

Item Name	Price
18650 Battery * 52	$260

Battery Management System	$12.99
Battery Insulator	$21.64
Raspberry Pi	$119.86
Heat Sensor	$22.99
Current Sensor	$12.99
Voltage Sensor	$10.20
Geekstory BN-220	$29.99
Capacitor	$16.99
Wires	$0
Total Cost	506.71

Table 3.3 - Project Cost Estimates

3.3.2 Funding

Most of the basic materials will be provided by the faculty laboratory, if the required material is not available at the lab, the group will purchase it at our own expense. This is not the final version of our budget list. All costs will be equally split among 5 members.

4 Risk Management Plan

The risks of developing an attachable battery extension for e-scooters (electric scooters) around Ottawa can greatly change the usability of our device. These risks must be realized and mitigated to decrease potential hazards that may arise during the use and construction of our battery. Lithium batteries are known for their great energy density and weightlessness. But along with these great features, there are some undesired risks and uncertainties. We must address all these concerns to obtain the desired outcome for our battery.

4.1 Assumptions

Aside from the potential risks of our design, we must first go through all the assumptions to help us focus on the expectation of the project. It is important to remember that we are not redesigning the scooter. Instead, our battery extension will directly assist the existing system in increasing efficiency. This is one of the most important realizations for our project, as the

scooters that we'll be applying our solution to, should still be capable of running on their own, without our battery attached. With the variety of scooters available, there are possibilities that Ottawa may use different models of scooters. These different scooters may use different charging protocols for their systems, so we must ensure and assume that the scooters used with our system can communicate with a generic charger, that is, a charger that just uses positive and negative charging terminals. Since we will be using these charging terminals to connect our extension battery, the scooter must be functional while it's charging. Some e-scooters models may lock the functionality of their scooter while they are docked or charging, which may pose some difficulties for our design.

4.2 Risks

Risks can vary between potential risks towards our project design, or personal health risks, either to us while constructing the device, or to the user of the device. Our safety and the safety of the user come first. When dealing with lithium-ion batteries like this, there is always a risk of a fire hazard, which usually only occurs when the battery is mistreated or damaged physically. There is also a shock risk or a burn risk, which usually only occurs when we aren't cautious with the battery terminals. While constructing the battery, upon soldering and spot-welding battery terminals of solder joints, lots of fumes are emitted, and these fumes can irritate and possibly damage the lungs if we aren't careful. Lithium batteries can be unforgiving if mistreated.

When building a battery storage device, there are a lot of technicalities to consider, some of which involve a lot of monitoring of the battery conditions. In our battery system, we must monitor the Over and Under voltage of the batteries, as well as dead shorts of the battery terminals, and monitor the temperatures of the batteries while in use and while being charged. Some considerations need to be made toward the physical safety of the batteries. Lithium batteries can be very fragile to physical abuse and punctures; therefore, we must ensure that the battery is protected in some way.

All these risks can cause a lot of long-term damage to lithium batteries and overall shorten their lifespan. Along with this long-term damage, the batteries could become unstable and cause potential hazards. To mitigate these risks, the battery must be equipped with voltage, current, and temperature sensors. When the voltage or current draw becomes too high, the battery management system of the device will automatically isolate the battery, thus protecting the batteries themselves and any external device connected to the system. This isolation will protect against the accidental dead shortening of the positive and negative leads. The voltage sensor will monitor the voltage levels of the batteries so that they aren't discharging past their minimum limit and charging past their maximum limit. Along with the voltage sensor, we will be using a designated charging controller. The temperature sensors will monitor if the batteries are overheating or need to be heated in colder temperatures. While charging the battery is too cold or

warm temperatures, can negatively impact the battery or potentially damage it. To prevent this, the battery will again isolate itself.

As for potential personal risks from the device, it's important that our safety, and the safety of the consumer, comes first. All hazards should be mitigated, and all risks should be labeled and made clear. When it comes to the actual construction of our device, we must follow our process plan and follow the step-by-step plan that will mitigate human errors and protect us when working with equipment. If we must deviate from our process plan, we will keep note of it in case we need to retrace our steps. It's also important to have an emergency plan in case the battery does become unstable. In all cases, a fire extinguisher should be present. But in the case that the batteries dead short, or experience physical damage and begin expanding or smoking, they should be placed in a bucket of sand, brought outdoors, and left until the batteries stop showing signs of being unstable. The fire extinguisher can also be used in extreme situations. Our team is in close contact with the University of Ottawa's engineering health, safety, and risk manager, Pierre Laflamme to ensure that our plan of action, and procedures, are performed appropriately and safely. We will be continuously communicating with Laflamme and will be transparent about our development throughout the design of our battery.

4.3 Safety

Along with safety while constructing the device, it's good practice to also be safe in the working environment. PPE or personal protective equipment is necessary when working in an electrical lab. Some personal protection that will be used in our project are gloves, which can prevent shocking hazards and cuts, glasses, which will help protect against sparks when spot welding, and a mask, which can be very important to protect against solder fumes or other dangerous fumes when constructing the battery. When in the lab, the person responsible for the space must be notified, as well as the teaching assistant. No equipment will be operated alone, and no team member will be working in the lab environment alone. In our case, we will always be working in groups. While following the process plan, since we will be working in groups of two people or larger, the supervising group member will assure that all steps are performed correctly and that no corners are cut when the following procedure. Our developments in the lab will be continuously communicated to the teaching assistant.

Since we will be performing lots of work with lithium batteries, heavy metals, and electronic components, it's important to remember the carbon footprint of all these components and to recycle them when possible. Components such as these shouldn't be disposed of in normal waste bins, and instead should be disposed of at appropriate recycling plants. This is good practice since devices like lithium-ion batteries can be very harmful to the environment and may be hazardous to workers when disposed of in the landfill.

4.4 Hazard Assessment

With the potential risks and the potential hazards of our project, we must assign the project a risk rating of ‘HIGH’. The likelihood of exposure to the hazard is rated at a level of three out of five (‘POSSIBLE), while the consequence of exposure to the hazard is at a level of three out of five (‘MODERATE’). A hazard assessment has been attached, as well as an explanation of further precautions and hazards regarding this project.

5.Concept Design

5.1 Hardware Concept Design

5.1.1 Battery Pack

To build the battery pack that’s capable of supplying the e-scooter, we decided to use 18650 battery cells to form a battery pack.

Figure 5.1 - 18650 Battery cell

The 18650 battery is a lithium-ion cell classified by its 18mm x 65mm size, which is slightly larger than a AA battery. They're often used in flashlights, laptops, and high-drain devices due to their superior capacity and discharge rates.

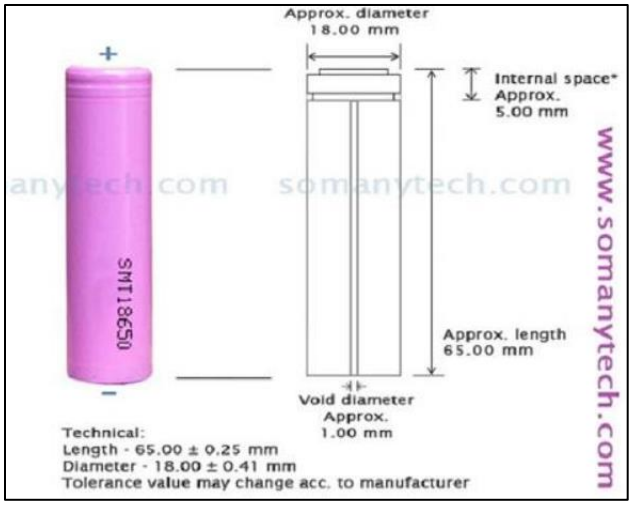

Figure 5.2: 18650 battery size

Each cell has 3.7 voltage and 2.5A. To achieve sufficient power supply for the e-scooter, 13 cells will be connected in series through spot welding in order to achieve 48V, and 4 rows of 13 cells will be connected in parallel to supply 10A current.

Of course, there are different connections to reach desired voltage and current output, considering the power consumption of the e-scooter and the durability of our product, the chose design is the most favorable.

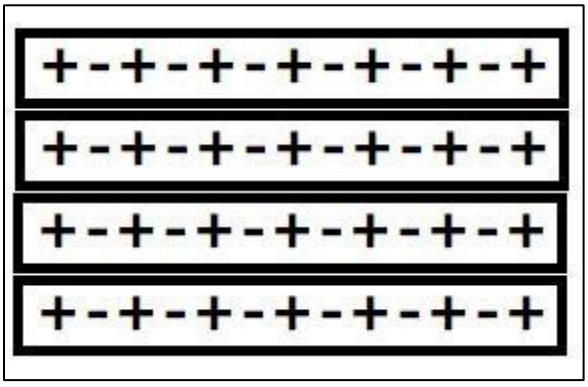

Figure 5.2 - Battery cells arrangement

5.1.2 Battery Management System

In order to further protect the battery pack and extend its life, a battery management system will be soldered alongside the battery pack. It will add features like over discharge and over voltage protection, but most importantly it makes sure that the battery cells are balanced while charging.

Over voltage range: 4.25-4.35v ± 0.05v;

Over discharge voltage range: 2.3-3.0v ± 0.05v

Maximum operating current: 0-25A; Maximum transient current: 34-40A

Attention: do not mix the good battery and poor battery to use.

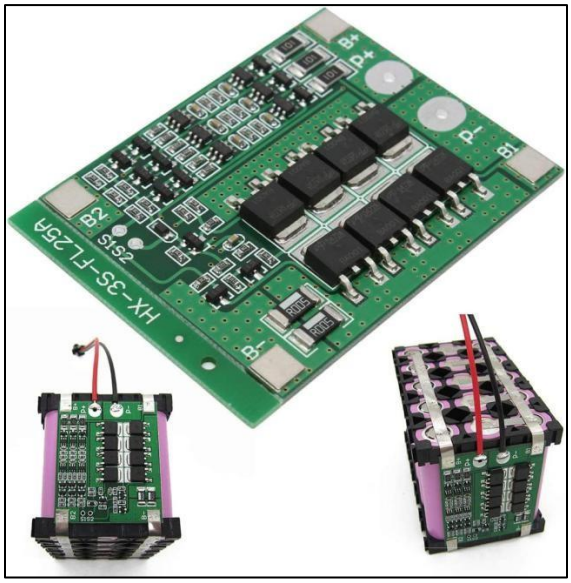

Figure 5.4 - Battery Management System

5.1.3 Insulation

Batteries are very susceptible to heat and vibration that could cause premature failure and hazardous leaks. We are planning to wrap the insulator around the finished battery pack to reduce the physical impact it may receive while using. The battery insulation is capable of damping vibration and will absorb and neutralize any damaging leaky battery acids.

Figure 5.5 - Battery Insulator

5.2 Software Concept Design

5.2.1 Data Acquisition:

Our smart battery offers data to users to make their ride smoother. We will collect information about our battery through various sensors implemented in the battery pack.

1. Temperature sensor - it is important that our battery pack does not overheat, we will ensure this through reading the temperature of the pack using a temperature sensor.
2. Voltage sensor - to make sure voltage is within the desired range.
3. Current sensor - to give us feedback on the current levels so our system can make sure overheating does not occur.
4. GPS sensor - this sensor allows us to collect and analyze the data on the speed of the scooter. Through backend calculations we will give users insight on how their battery is being used.

5.2.2 Sensor Specifications

Temperature sensor:

Temperature sensors measure temperature readings via electrical signals. They contain two metals that generate an electrical voltage or resistance when a temperature change occurs. Temperature sensors work by measuring the voltage across the diode terminals. When the voltage increases, the temperature also increases, which is then followed by a voltage drop between the transistor terminals and the emitter (in a diode).

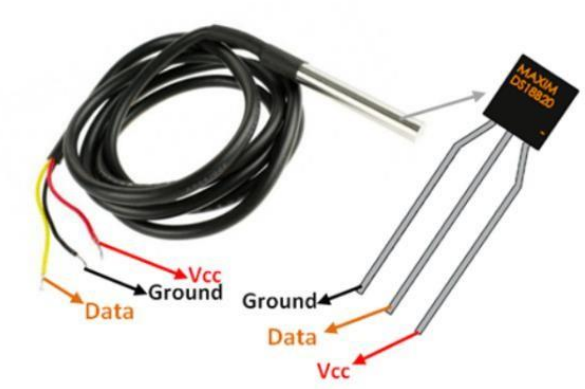

Figure 5.6 - DS18b20 temperature Probe

Parameters	Specifications
Voltage Supply	3.3V or 5V
Temperature Range	−55°C to 120°C −55°C to 120°C

Accuracy	$\pm 5°C$
Ground Pin	Connect to the ground of the circuit
Vcc	Powers the Sensor (5.0 V)
Data	This pin gives output the temperature value which can be read using 1-wire method

Table 5.1 - DS18b20 temperature sensor specs

Voltage Sensor:

A voltage sensor is a sensor used to calculate and monitor the amount of voltage in an object. Voltage sensors can determine the AC voltage or DC voltage level. We will be using the WayinTop brands DC0-25V Voltage Tester Terminal Sensor.

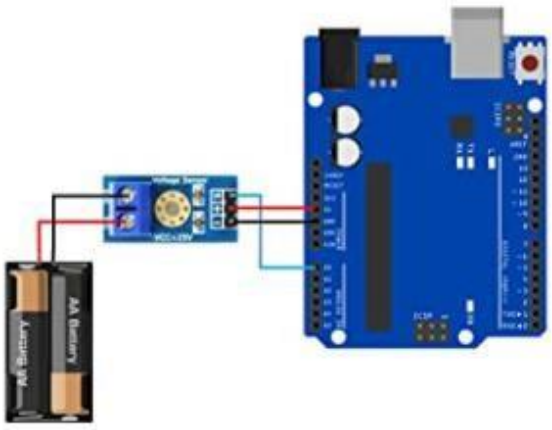

Figure 5.7 - Voltage Sensor connection

Parameters	Specifications
Voltage detection range	0.02445 - 25V DC
Voltage Analog Resolution	0.00489V
Product Dimensions	16 x 10 x 2 cm; 20 Grams

Table 5.2 - WayinTop DC0-25V specs

Current Sensor:

DC current sensors are used to measure DC electrical current in industrial settings. Engineered for accuracy and durability, they are suited to deliver precision current measurements in DC

applications. We will be using WayinTops ACS712 Hall Effect Current Sensor Module for this project.

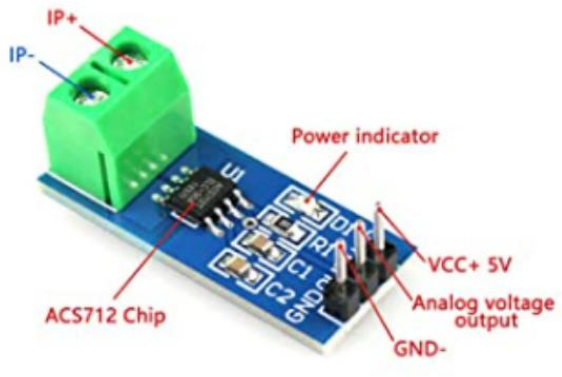

Figure 5.8 - Current sensor physical layout

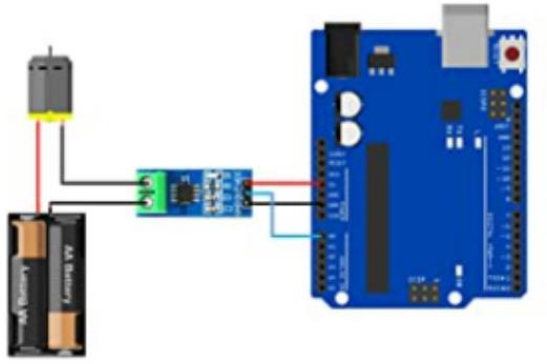

Figure 5.9 - Connection of current sensor

Parameters	Specifications
Chip	ACS712ELC-30A
Range of current detection	-30A to 30A DC
Analog Output	66mV/A
Product Dimensions	16 x 10 x 2 cm; 20 Grams

Table 5.3 - WayinTop ACS712 sensor specs

Location sensor (GPS):

GPS sensors are receivers with antennas that use a satellite-based navigation system with a network of satellites in orbit all around the earth. These satellites send signals to the GPS sensors (receivers) to provide position. The Location sensor will be used to keep track of the user's location. The Location sensor we chose to use is the Geekstory BN-220. The specifications for this sensor are listed below.

Figure 5.10 - GPS sensor module

Parameters	Specifications
Supply Voltage	3V - 5.5 V (typically 5V)
Current Output	50 mA
Operating Temperature	-40 to + 85 **℃**
Max Altitude	50,000 m
Max Velocity	515 m/s

Table 5.4 - Geekstory BN-220 sensor properties

Once this data is collected it will be sent to the raspberry pi through its input/output pins. Raspberry pi will process this signal which will be converted to digital signal and sent to the cloud. The block diagram below shows the overall architecture of our data acquisition system.

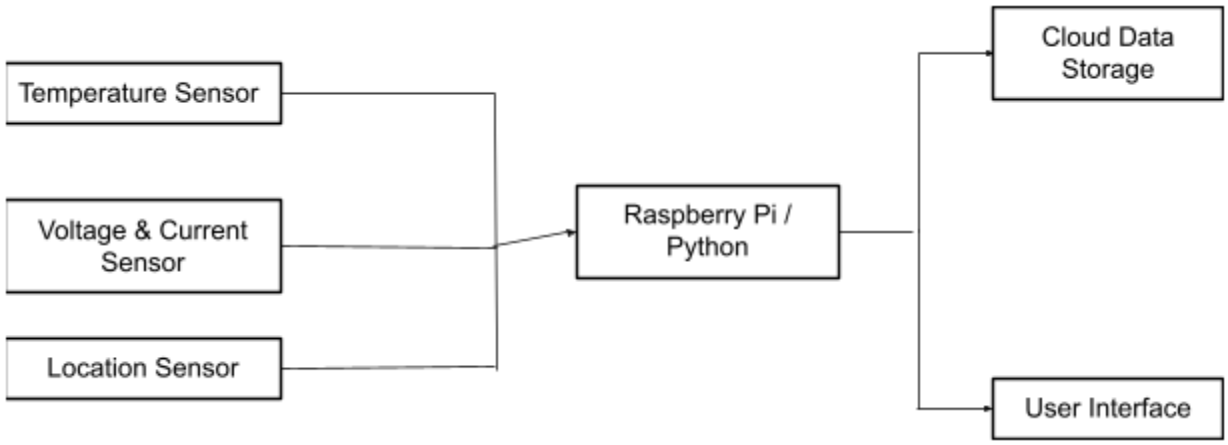

Figure 5.11 - Block diagram of the overall Data Acquisition system

In the next section we will go into more detail as to what happens to the signals collected by the sensor and how it is processed to digital signal for the computer to understand. We will go into more details about the Cloud platform and the User Interface part of the system later in this section.

5.2.3Raspberry Pi:

Once the sensors have collected the data, it is sent to the cloud through the Raspberry Pi. Raspberry Pi acts as a gateway and sends the collected data to Event Hub. Azure Event Hub is the big data streaming service of Azure. It is designed for high throughput data streaming scenarios where customers may send billions of requests per day.

Once the data has entered the Event Hub, the Event Grid is then triggered which will perform a function to let us know that there is new data available. Azure Stream analytics is used to read

the data live and potentially store it in Blob Storage. We then use Power Bi to display the data to users on a webpage.

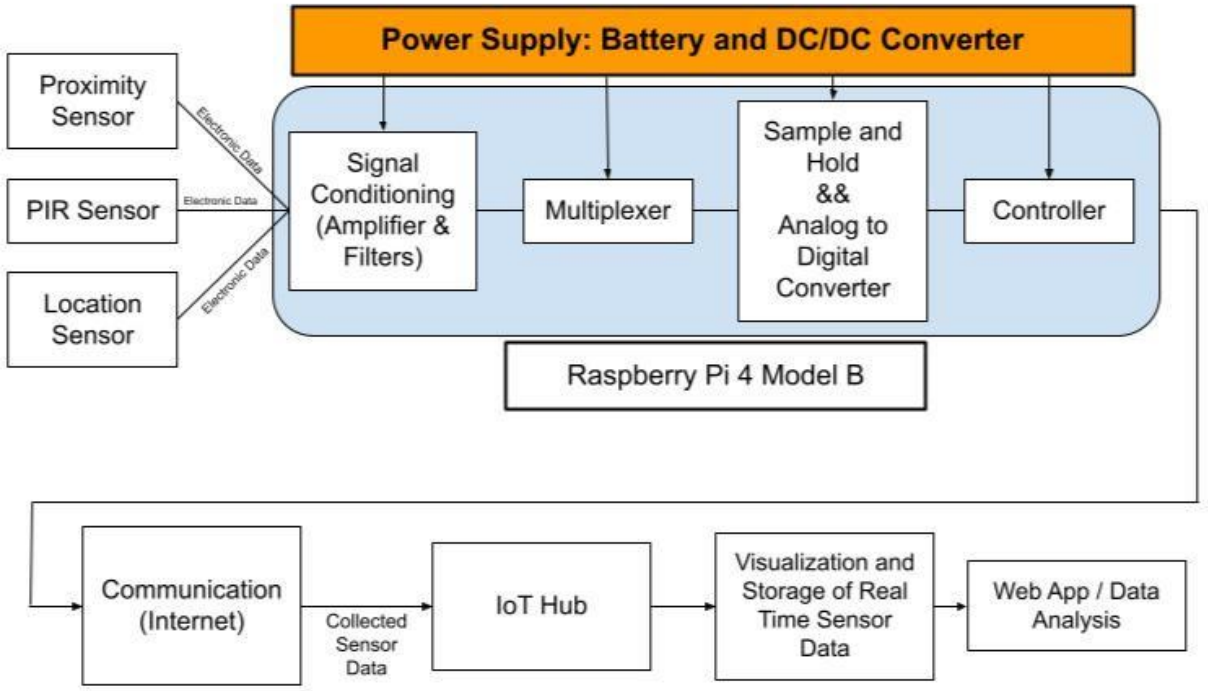

Figure 5.12 - More Detailed Block Diagram of the Data Acquisition System

Once this data is collected, we will use raspberry pi 4 b+ to send this data to the cloud. We will be using the Microsoft Azure Cloud platform for our product. The data that is uploaded to the cloud is stored and can be accessed remotely at any time. There will be data processing done in the raspberry pi.

The signal that is sent to the raspberry pi first gets filtered and amplified. It then goes through a multiplexer which is mostly used for the GPIO Pins. It decides which inputs are sending in a signal and allows those pins to pass through. Next the signal will go through a sample and hold which is used in combination with Analog to Digital converter to convert the signal into binary values that can be read by the computer. This digital signal is then sent to the cloud through Wi-Fi communication between the raspberry pi and Microsoft Azure IoT Hub.

5.2.4 Cloud

The data collected from the sensors will be sent to Microsoft Azure IoT hub through wifi connection. IoT Hub is a Platform-as-a-Services (PaaS) managed service, hosted in the cloud, that acts as a central message hub for bi-directional communication between our data

visualization software and raspberry pi. Device-to-cloud telemetry data tells the user about the state of their battery.

Azure IoT Hub provisions, authenticates and manages the batteries at scale and in a highly secure manner. It processes messages, triggers actions, and collects information about the battery's system health. Then it catalogs and analyzes the data and dispatches it to the appropriate software for displaying it. Besides this, Azure IoT Hub offers device management which allows us to add more battery systems in the future. We can register the new device to Azure IoT Hub and manage it from there. Also, Microsoft's IoT connector generates a unique access key for every single device. This ensures that devices can only do what they are supposed to and allows us to disable single devices when they get corrupted.

5.2.5 Data Visualization

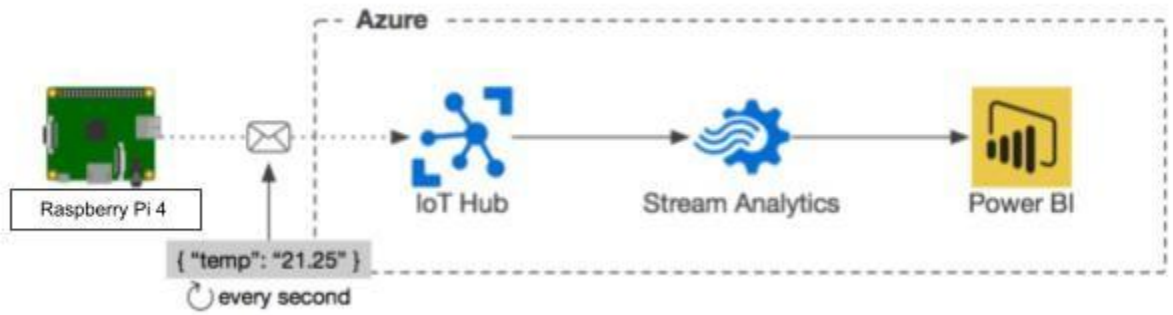

Figure 5.13 Data Visualization block diagram

With the help of Microsoft Power BI, you can execute self-service and corporate business intelligence (BI) across massive data sets. Azure Stream Analytics is a fully managed, real-time analytics service created to assist you in analyzing rapidly changing data streams that can be used to gain insights, create reports, or set off alarms and actions.

6.Proof of Concept

Hardware: Power Supply Calculation

To determine how durable our battery pack is, we conducted a simple calculation, based on the assumption that the series voltage is 48.1V and the total current is 10A; connected to an e-scooter motor that consumes 250Wh.

Durability Calculation

Voltage	**48.1V**
Current	10A

E-scooter motor consumption	250Wh
Durability when fully charged	48.1V*10A/250W=1.924Hr

To further validate the value we obtain, a simulation is performed through Multisim.

To validate our voltage assumption, we connected 13 voltage sources in series and 4 series in parallel, and the multimeter read 48.1 V as we expected.

The current assumption is also validated by the current simulation as the multimeter reads 100A when connected to 4 current sources in parallel.

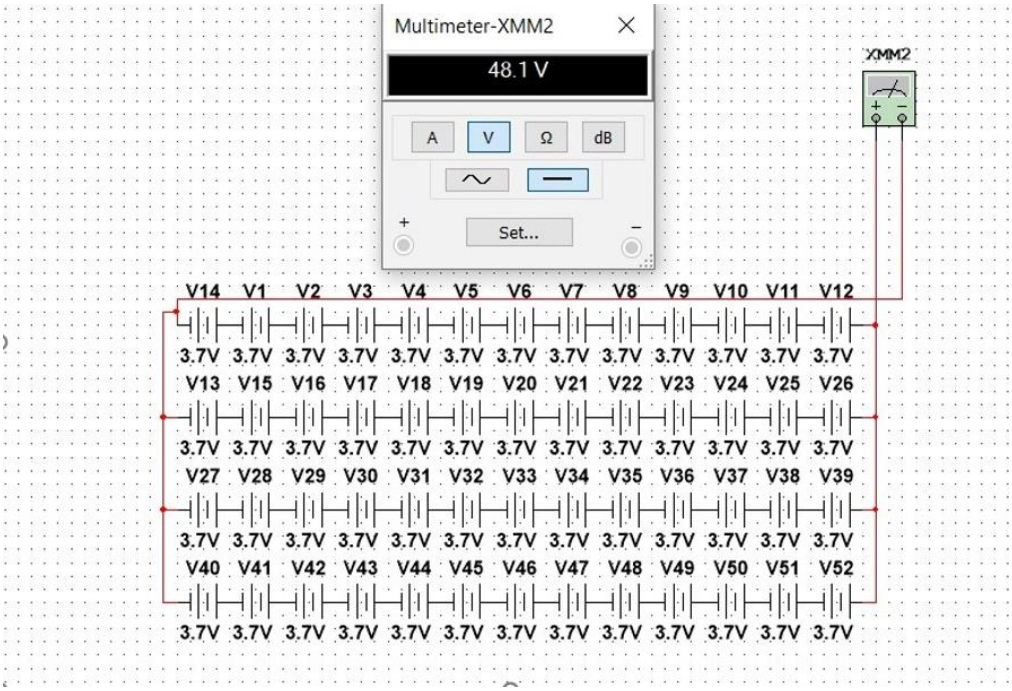

Figure 6.1: Voltage Simulation

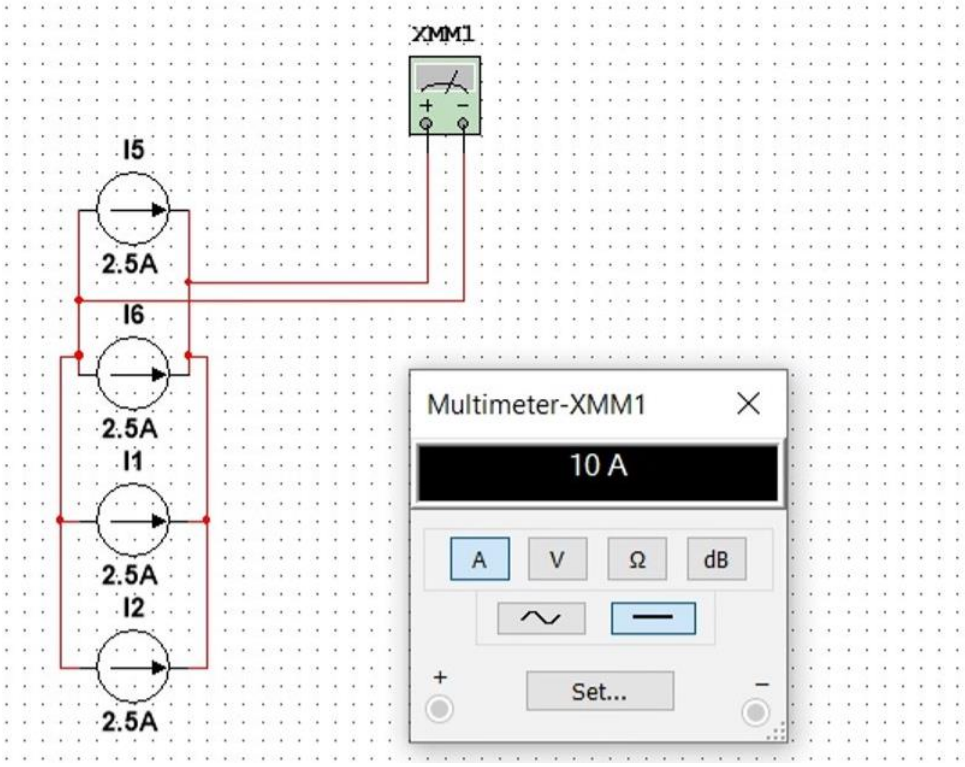

Figure 6.2: Current Simulation

Software:

We decided to run two simulations to test our software from data collected by the sensors to display data to users. First, we used Simulink to simulate our sensor signal and how those signals get processed and converted to a digital signal by the Raspberry Pi. This simulation allows us to visualize what happens to the signal inside Raspberry Pi. Figure 5.12 shows the detailed version of the signal processing steps inside the Raspberry Pi. We can see that once the sensor outputs a signal based on the physical change in the environment around it, it sends the signal to Raspberry Pi. More specifically, the signal is directed to the Raspberry Pi processor, the electronic circuit that executes instructions given to it. Inside the processor, the signal goes through various circuits that eventually translate it into binary bits for the computer to understand. These steps can be seen in the figure; some primary circuits include amplifiers, filters, multiplexers, sample and hold, and finally, analog to digital converters.

Simulation 1:

For our first simulation we focused on the signal processing of the raspberry pi. We decided to simulate all the circuits that play a role in converting the signal from analog (original form) to digital (final form).

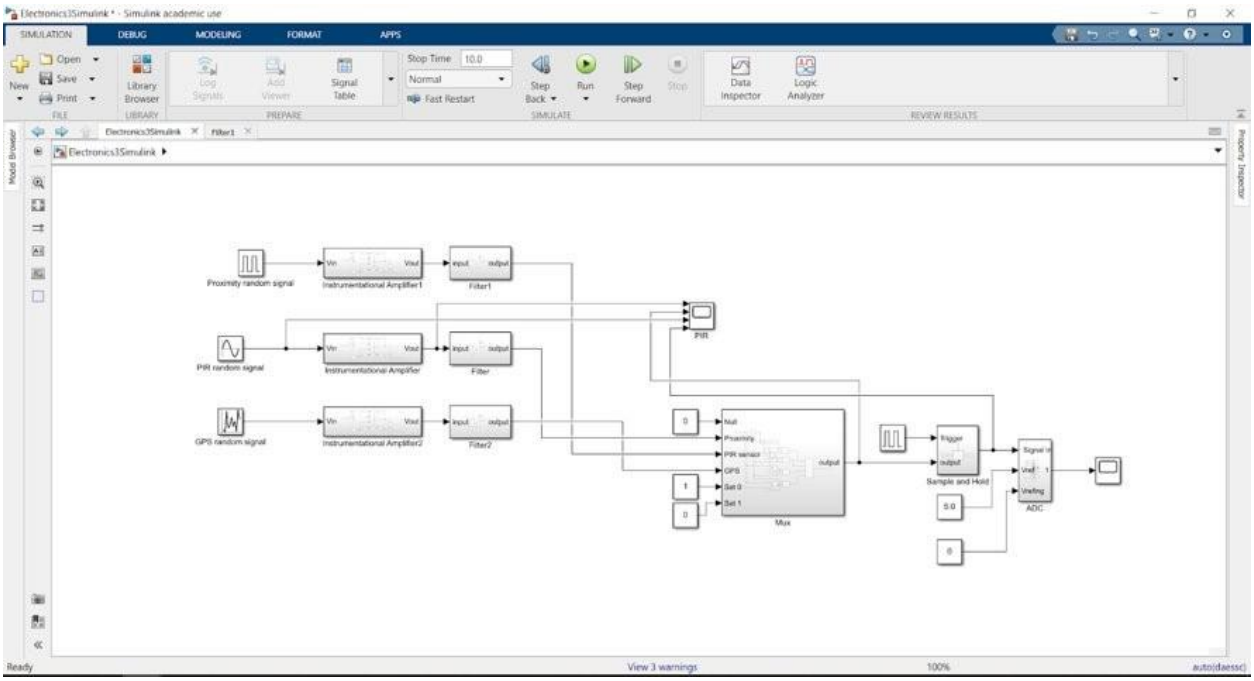

Figure 6.3 – Simulink circuit of the entire system

The above circuit is the blue area in figure 5.12. For our sensor signal, we used a random signal generator for the GPS sensor and other forms of signals such as square pulse and sinusoidal wave. These signals represent the analog signal output by the sensors. As mentioned before, the first step of signal processing is an amplifier. After the desired signal has been amplified, it goes to a filter that removes any undesired noise that might have been added to the signal along the way. Once the signal is clean and amplified, the multiplexer decides which signals are let through to the next step. We only need certain signals at specific times; this decision-making is determined by the code we wrote in python. Once the signal has permission to pass through the multiplexer, it enters the sample and holds. The sample and hold work in combination with analog to digital converter to convert the analog signal into binary form for the computer to understand.

Let’s look at what is inside of those blocks.

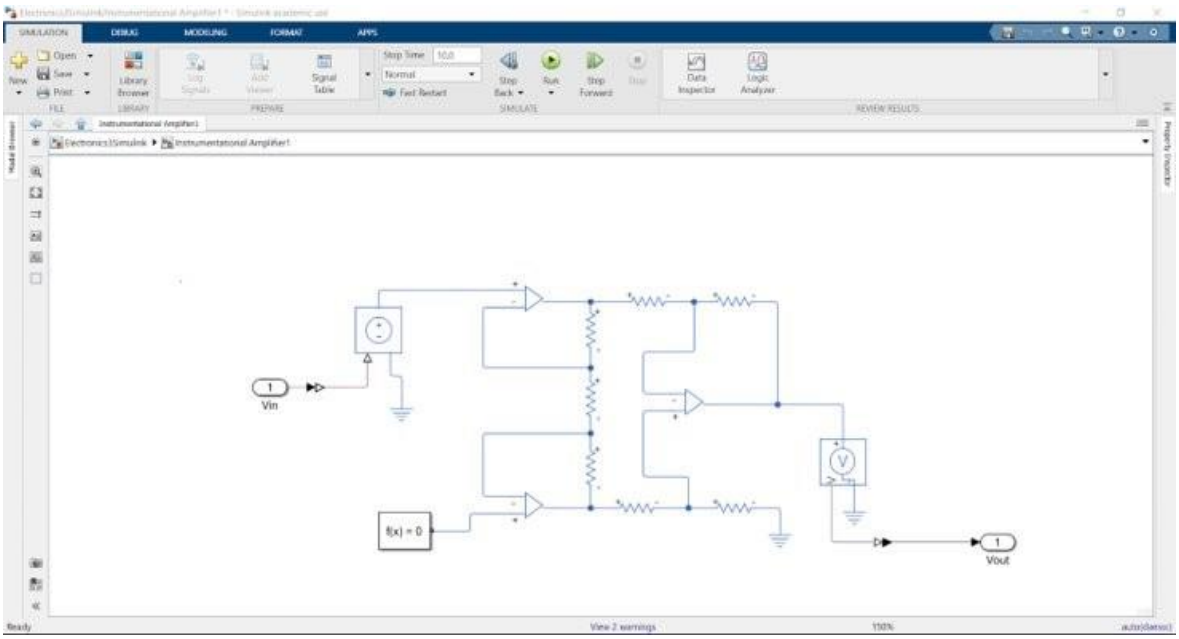

Figure 6.4 – Amplifier circuit

We picked an instrumental amplifier to simulate our amplifier block; this is due to the high input impedance characteristic of the circuit. An instrumental amplifier consists of two non-inverting amplifiers connected to a voltage follower, also called a buffer. Since we are feeding the bottom amplifier with f(x) = 0, this will amplify the difference between our input voltage and zero, which is just our input voltage. So, this circuit amplifies the desired sensor signal. After the signal has been amplified, it gets passed to a filter.

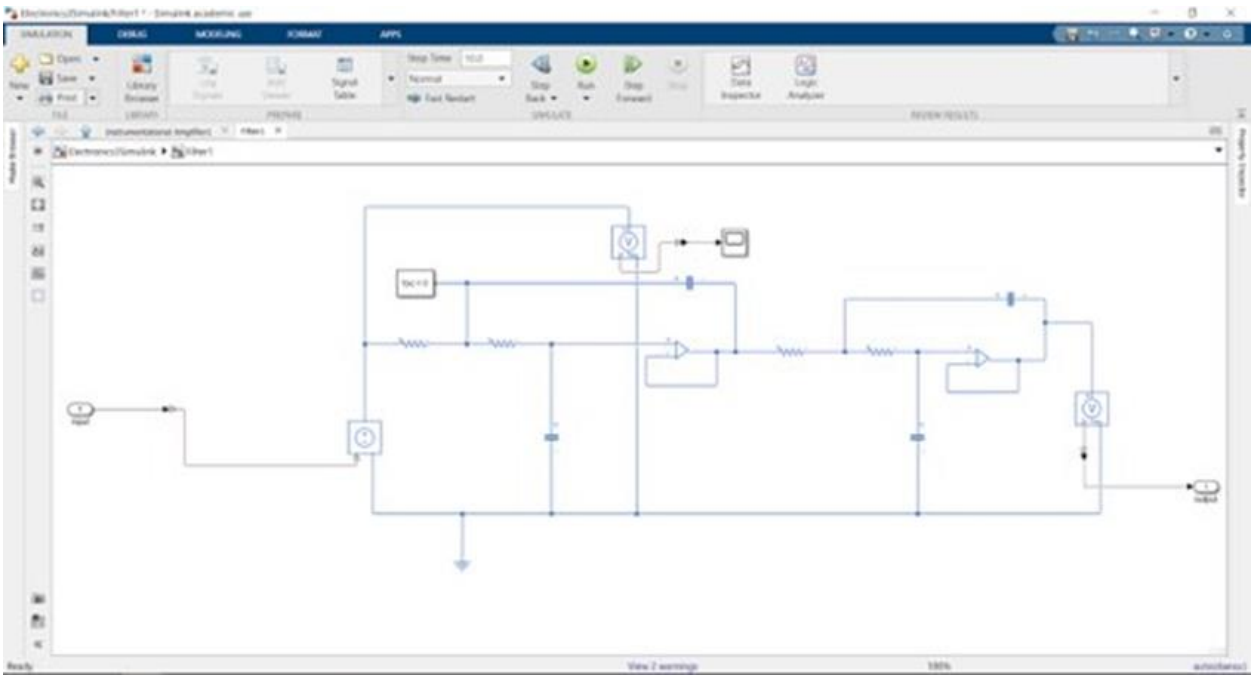
Figure 6.5 – Filter circuit

We used a bandpass filter in our filter block. A bandpass filter's characteristic function is designed to block undesired high-frequency noise and pass the desired sensor signal. This filter makes the signal a lot cleaner and more accurate. In addition, this process decreases the chance of error when encoding the signal into bits in the analog-to-digital converter. Next block is multiplexer.

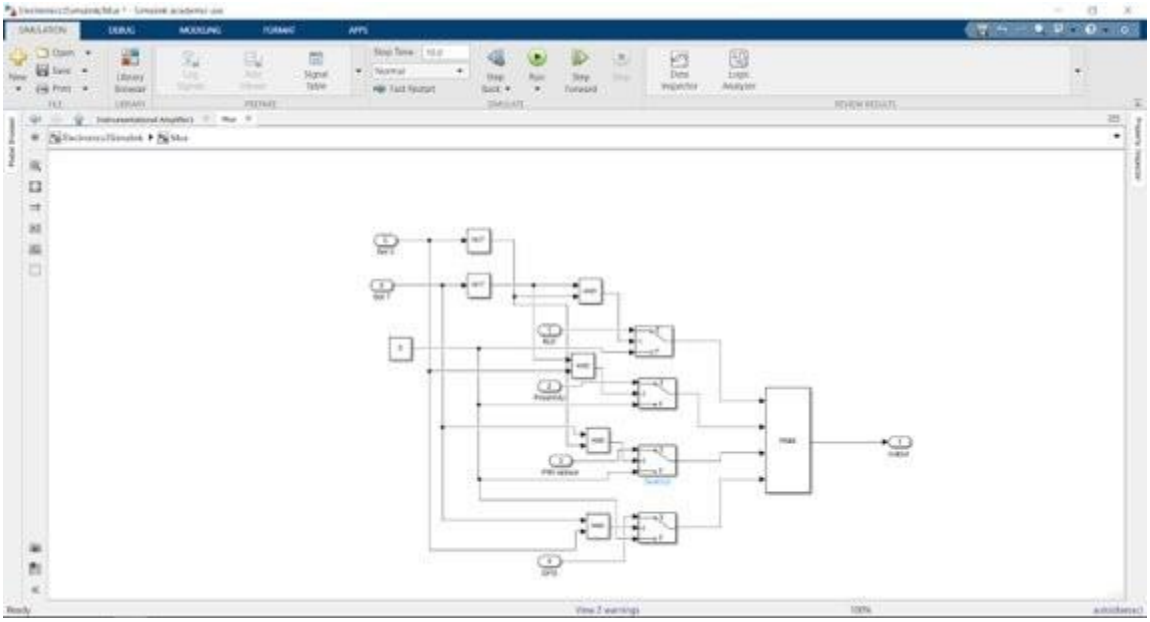

Figure 6.6 – Multiplexer circuit

Next, we look at the multiplexer circuit block. A multiplexer is a combinational logic circuit with multiple inputs and one output signal. It allows a signal to pass through based on the selected inputs. Like the other circuits, the multiplexer is in the processor and is controlled by the CPU. This means the code we write on, for example, python three, will eventually tell the multiplexer what to do and which signals to pass at what time.

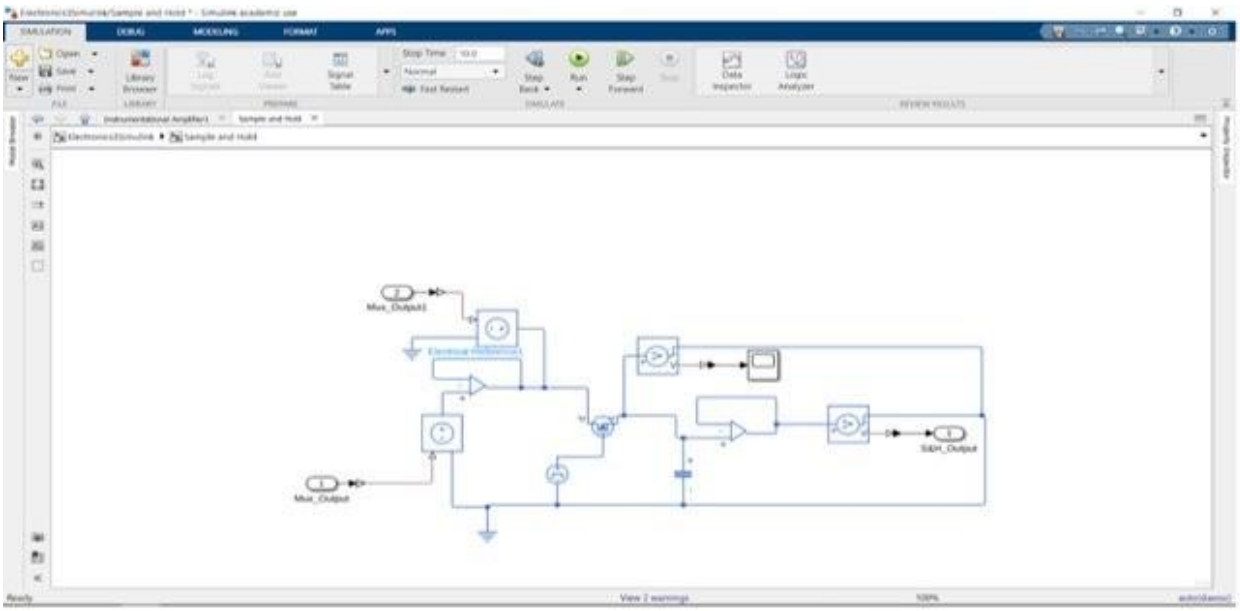

Figure 6.7 – Sample and Hold circuit

The next block is a sample and hold. The sample and hold circuit's job is to sample the signal at a given time and hold that sampled value. This circuit is combined with analog to digital converter to convert the signal to digital form.

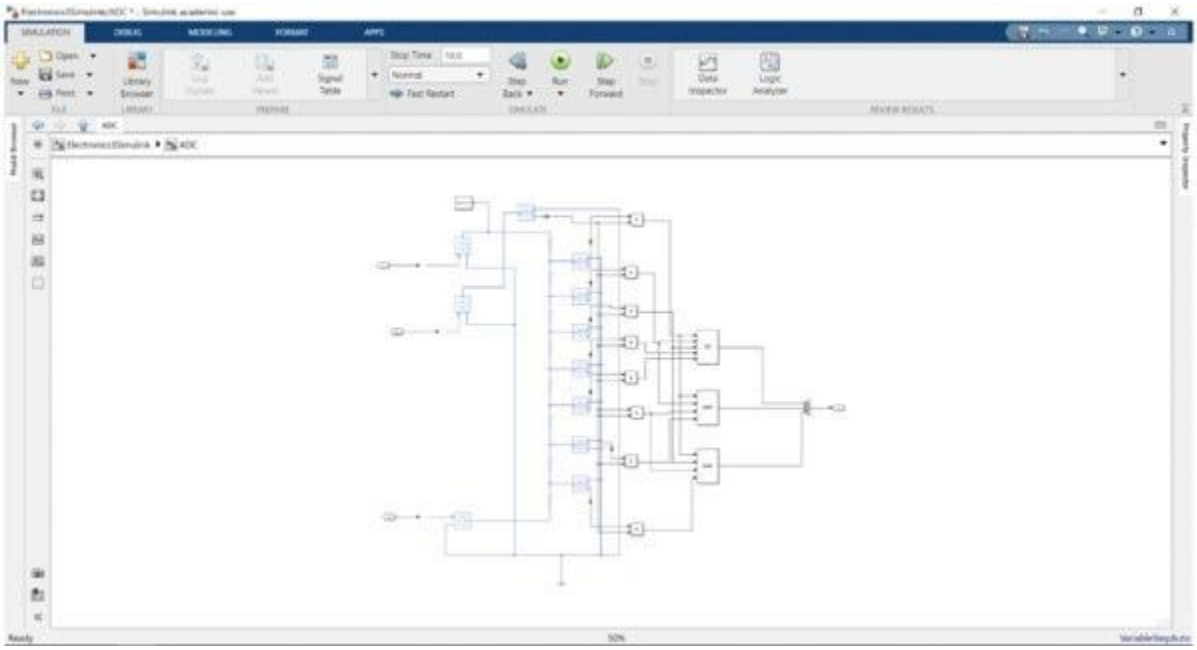

Figure 6.8 – Analog to Digital Converter circuit

The analog-to-digital converter is the last signal processing stage on the Raspberry Pi. It has three steps: the sample and hold, followed by a quantizer and a decoder. The quantizer and

decoder use the sampled values to determine the combination of 0s and 1s to represent the analog signal. After that, the digital signal is to be interpreted and sent to the cloud.

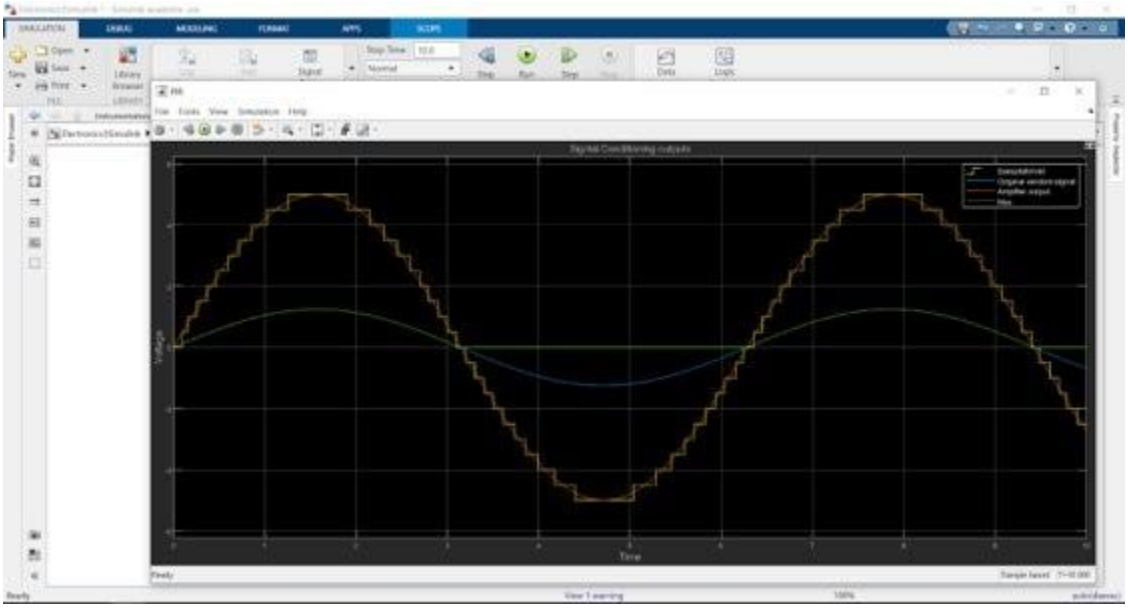

Figure 6.9 – Signal at every step of signal processing stages

Above signal is the output of the signal in each step of the simulation. The blue line is the original signal which we can see operates at $\pm 1.5V$ $\pm 1.5V$, and yellow is the output of the quantizer. This simulation allowed us to better understand the role of each circuit in the signal processing phase and to see what happens to the signal after it is collected by the sensors.

Simulation 2: For our second simulation, we used the online Raspberry Pi Azure IoT Simulator to set up our configuration and test the Raspberry Pi python code.

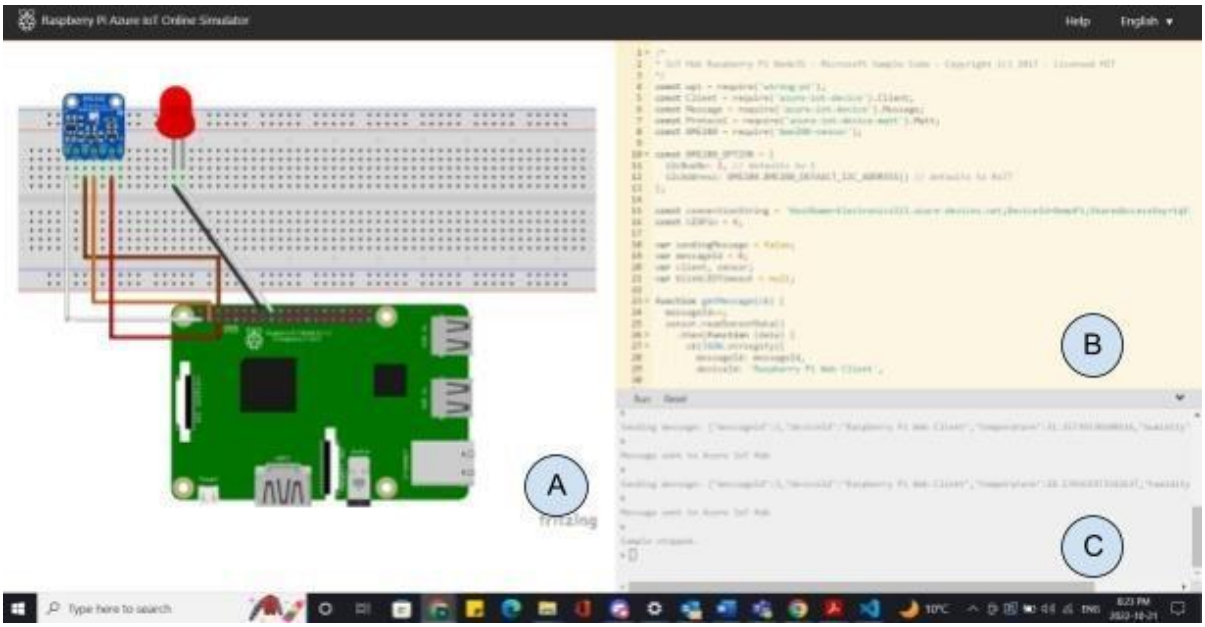

Figure 6.10 - Raspberry pi Azure IoT Online Simulator Window

There are three areas in the web simulator.

A. Assembly area - A BME280 sensor and an LED are connected to a Pi by default. Since the section is locked in the preview version, personalization is not presently possible.
B. Coding area - An online code editor for the code for Raspberry Pi. The default sample application helps to collect sensor data from BME280 sensor and sends it to your Azure IoT Hub. The application is fully compatible with real Pi devices.
C. Integrated console window - It shows the output of your code, i.e. the messages that are being sent to the IoT hub.

We then linked the Raspberry pi to IoT Hub to receive its message. Next step was to create a device identity in the identity registry in our IoT hub. A device can't connect to a hub unless it has an entry in the identity registry.

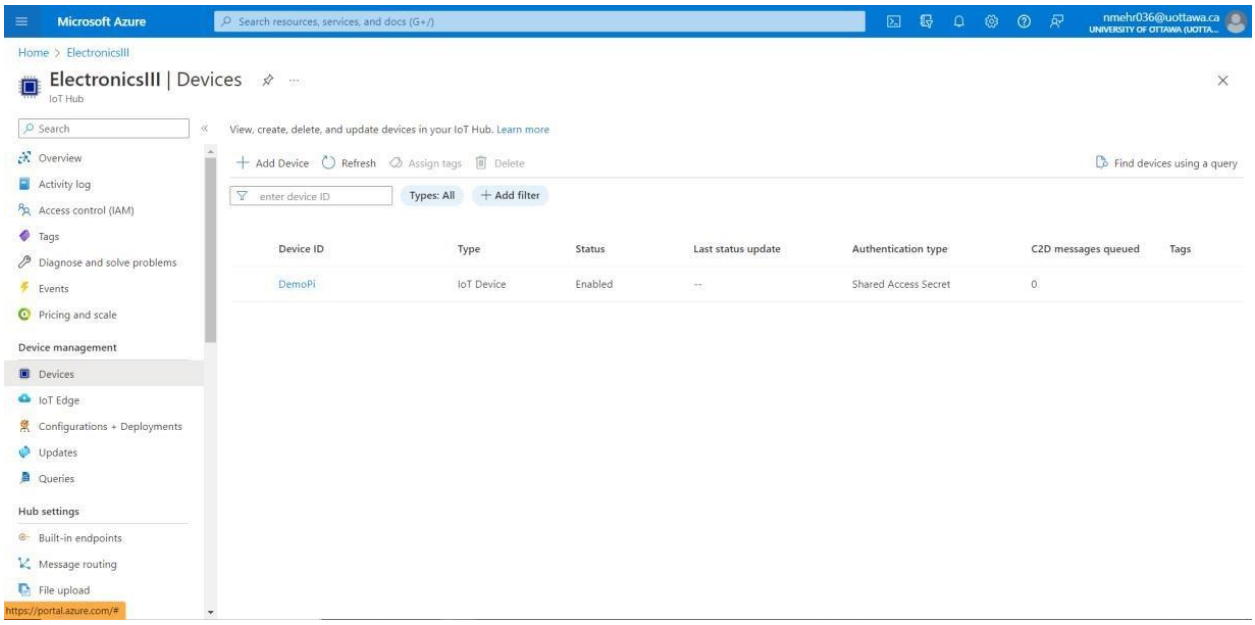

Figure 6.11 - IoT Hub Devices Window

We then display the message received by the IoT hub in Visual Studio Code Terminal. This is done through the Azure IoT Hub Extension available in VS Code.

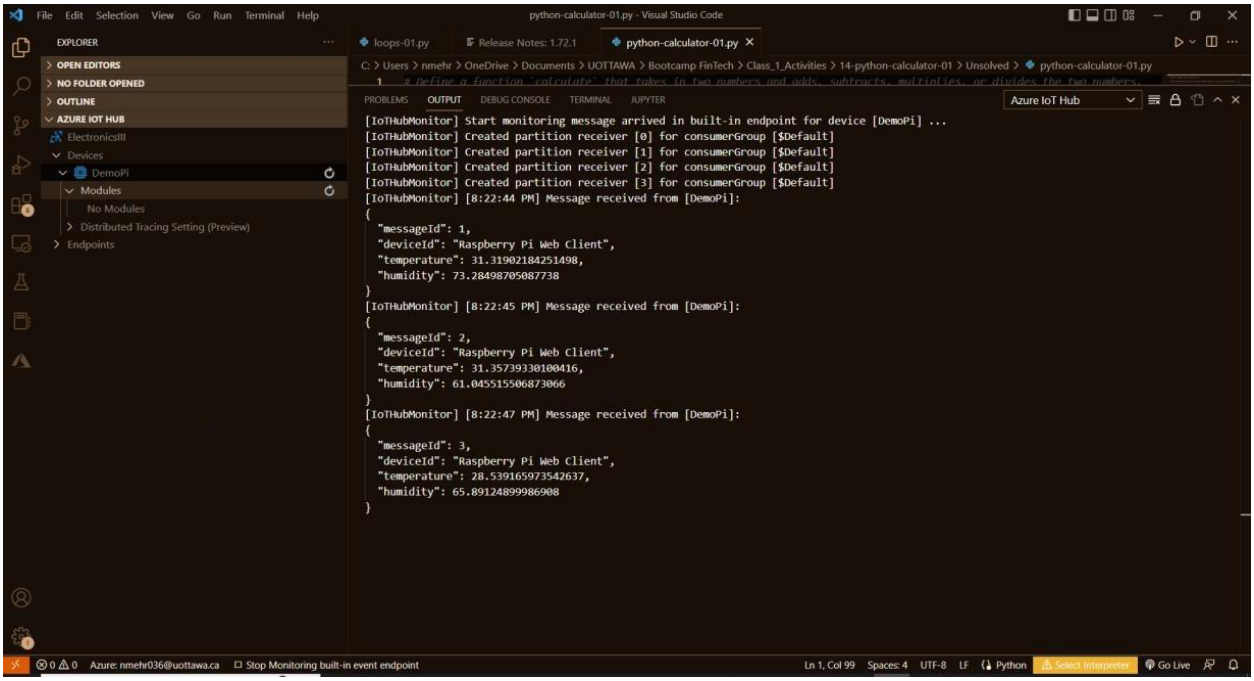

Figure 6.12 - VS Code Terminal

Once we register the device using its *Secondary Key Connection String* which is provided by IoT Hub, we can receive and display the live data being sent by the Raspberry Pi. Figure 5.11 shows VS Code Terminal displaying the messages sent by the Raspberry Pi simulation in figure 5.9 displayed in its integrated console window.

7.Test Plan

In order to further improve our safety index for the product and mitigate the potential hazards that the circuit may induce, we have developed a detailed test plan regarding different components of our product, mostly hardware.

Test	Objective	Expected Value	Result
Battery Management System test	To ensure each battery cell can be equally charged to full capacity	2.5A+-0.2A	
Insulation Megger test	Determine the maximum current insulation can resist	N/A	
Insulation Temperature test	Determine the maximum temperature the insulation can resist	N/A	

Circuit Connection test	To make sure the circuit is properly connected by the weld and solder	N/A	
Sensor I/O Function test	To make sure the sensors react properly to the change of input	N/A	
Integrated System test	Ensure different components interacts with each other properly	N/A	

Battery management System test: Since we are planning to solder the battery management system onto the battery pack, we have to run a charging test regarding the proper function of the system; by measuring the current of the battery cell separately, we can make sure that the connection between the system and the battery cells are reliable.

Insulation Megger test: This test is to determine the maximum current that insulator can resist; it's a bit redundant.

Insulation Temperature test: This test is to determine the maximum temperature the insulator can resist before melting, by conducting this test we will have a better understanding of the reaction between insulator and battery pack, and we'll prevent insulator melting from overheated batteries.

Circuit Connection test: Our battery pack will be connected by weld and solder, and none of the team members are familiar with either of these tools; so, the circuit connection test is crucial for the safety reason because small errors in connection can lead to severe damage of the battery and users.

Sensor Input/Output test: Our design involves a lot of sensors for monitoring purposes, as the basic element of the control system. Conducting this test will ensure stable performance of the sensor during operation.

Integrated System test: This test is scheduled to be conducted after the first prototype is done, it's an overall test of our product. The purpose is to make sure different components interact with others properly.

Post-Performance Analysis

The primary purpose of our group this semester is to set up our project plans and software design. This also includes the background of the work conducted, the design methodology, the design diagrams, the analysis of the results obtained, and the conclusion and recommendation for further development. Based on the cooperation of this semester, we can summarize our PPA.

Mistakes were made: In the process of uploading and saving the design information, we took it for granted that using the Wi-Fi module is the most common and convenient choice, so we researched and designed some codes and tested them. When we thought the result was perfect, TA suggested we use the BMS module instead of the Wi-Fi module. Because when users use the e-scooters outdoors, we cannot guarantee that they will be covered by Wi-Fi at any time.

Things worked well:

After our team members searched and investigated the basic information, we successfully decided on the direction of the project through brainstorming. After listing the specific plan, the division of labor is clear, and the team members get along well and help each other at any time. The software is designed successfully and runs smoothly.

We could have done differently: If we start over this semester, we will think more about the real-world functions of our product. When designing a battery pack, not only consider its function and price, etc. But also pay more attention to its assembly method and the shape and size of the finished product to make it as convenient as possible for customers to use. Currently, our product size may be bigger than the average battery pack size.

Improvements would suggest if our project was extended: The biggest challenges for battery design are energy density, power density, charging time, life, cost, and sustainability. If we have more time for this semester, we hope to find ways to improve these performances and add them to our battery pack. Each feature improvement requires a lot of research and design. In the hardware production of the next semester, we will adjust as much as possible to improve the performance of the battery pack.

8.Contribution List

Task		Owner
Initiation		
Project Charter		Kaiyi Yuan
System Requirement Specification		Kaicheng Zhang
Planning		
Project risks, Assumptions, and Constraints		Josiah Bigras
Work Breakdown Structure		Lidan Huang
Gantt Chart & Milestones		Lidan Huang
Project cost estimate and Funding		Kaiyi Yuan, Lidan Huang
Risk Management Plan		Josiah Bigras
Design		
Conceptual Design	Hardware Specifications	Kaiyi Yuan
	Software Specifications	Nima Mehrjoonezhad
	Data Acquisition	Nima Mehrjoonezhad
Detail Design		
Hardware Designing		Kaiyi Yuan
Software Designing		Nima Mehrjoonezhad
Test Plan	Hardware	Kaiyi Yuan
	Software	Nima Mehrjoonezhad
Hardware Plan		Kaiyi Yuan
Software Plan		Nima Mehrjoonezhad
Debug		Nima Mehrjoonezhad
Post-Performance Analysis		Kaicheng Zhang
Final		
Detail Contribution List		Lidan Huang
Final Presentation		Nima Mehrjoonezhad, Kaiyi Yuan, Josiah Bigras, Lidan Huang, Kaicheng Zhang
Final Report		Nima Mehrjoonezhad, Kaiyi Yuan, Josiah Bigras, Lidan Huang, Kaicheng Zhang

9.Project Organization

9.1 Roles and Responsibilities

This section defines the roles and responsibilities assigned to the project team members. All team members should have their roles and responsibilities identified.

Josiah

Risk management plan

Project hazard assessment

Kaicheng

System requirements specification

Functional/Non-functional requirements

Post-Performance Analysis

Nima

Software Conceptual design

Lidan

Milestones

Work Breakdown Structure (WBS)

Gantt Chart

Kaiyi

Project charter

Hardware Conceptual design

estimated budget

9.2 Project Facilities and Resources

We will mainly use the resources provided by the university lab for testing and simulation during the development of this project, any other components that can't be provided by the school will be purchased at the group's expense.

Reference

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Project Risk Assessment – University of Ottawa

uOttawa

Project details

The supervisor must review this document with the student(s). After doing so, the supervisor and student(s) must sign where indicated. If there are any subsequent changes to the project, a new project risk assessment must be done.

Project title: Electrical Engineering Project – Scooter Battery Extension
Start date: September 7th , 2022
Expected end date :April 10th, 2023
Faculty: Electrical Engineering
Department: Applied Science (Engineering)
Main work location: STEM/SITE
Name of student(s): Kaiy Yuan, Josiah Bigras, Lidan Huang, Nima Mehrjoonezhad, Kaicheng Zhang
Name of supervisor: Emil Petriu,

Student signature(s):

Josiah Bigras 张凯程 Lidan Huang

Supervisor signature: _____

Risk rating (see matrix below)

-

Note: If rated as **High** or **Extreme**, a dedicated standard operating procedure must be in place.

Hazard type

☐ Biological	☐ Biomechanical	☒ Chemical
☒ Physical	☐ Radiological	☐ Other (specify) _____

Training required

☐ Advanced TDG	☐ Aerial work platform	☐ Biosafety
☐ Fall prevention	☒ Fire safety	☐ First aid
☒ Lab safety	☐ Laser safety	☐ Radiation safety
☐ Spills response	☐ Dry lab risk management	☐ Other (specify) _____

Engineered (built in) control

☐ Biological safety cabinet	☐ Fumehood	☐ Glovebox
☒ Local exhaust device	☐ Other (specify) _____	

Personal protective equipment (PPE)

☒ Eye/face protection	☒ Gloves	☐ Harness
☐ Head protection	☐ Hearing protection	☒ Protective clothing
☐ Protective footwear	☒ Respiratory protection	☐ Other (specify) _____

Other considerations

Shared laboratory	☒ Yes	☐ No
Impact on other areas	☐ Yes	☒ No
Use of controlled goods	☒ Yes	☐ No
Emergency plan required	☒ Yes	☐ No

Summary

Sequence of events (tasks)	Potential hazard	Work location	Likelihood of exposure to hazard Rare =1 Unlikely = 2 Possible = 3 Likely = 4 Almost certain = 5	Consequence of exposure to hazard Insignificant = 1 Minor = 2 Moderate = 3 Major = 4 Catastrophic = 5	Risk rating Low Medium High Extreme	Control measure(s)
Soldering Spot Welding	Fire Hazard, Smoke Hazard, Potential Electric shock	STEM / SITE	3	3	HIGH	Increased Ventilation, Appropriate PPE, Tasks performed in isolated areas.

Additional notes

Upon spot welding batteries, an emergency plan is required to ensure that in the case of an unstable battery (due to shorts or damage), the hazard is contained and there will be no unwanted injuries or damage to the building. The emergency plan is to have a fire extinguisher on hand and a bucket of sand. If in the case, a battery becomes unstable, it will be placed in the bucket of sand, brought outside, and it will be left outside for a long period until we are certain there are no more hazards. The fire extinguisher will be used if needed.

Upon welding and soldering of the components, they must be done in a space with good ventilation with an exhaust to remove dangerous fumes. If ventilation isn't possible, it's recommended that the individual soldering the components wears a mask.

The likelihood of the hazard is very dependent on the skill and experience of the individual performing the work. If the individual is cautious, there should not be a hazard. However, there are many ways a hazard can take place (shorting the batteries, overheating, sparking the batteries, etc.) Therefore, this work has been given a hazard of 3. The consequences of this hazard vary a lot, depending on the emergency plan taken into place, if it is not performed properly, it can be very dangerous and cause a lot of damage, such as the spreading of a fire, or injuring someone. However, if all the emergency steps are well considered, and all individuals are very precautionary, then there shouldn't be an issue. For this reason, we have given the consequence of the hazard a 4.

Overall, the risk of this project is High, which is expected since we will be dealing with flammable batteries and electric devices with high currents and high voltage. It's very important to be aware of the possible dangers and be cautious.

Risk Rating Matrix
– Low Risk, Medium Risk, High Risk, Extreme Risk –

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Likelihood	**Almost Certain**	High	High	Extreme	Extreme	Extreme
	Likely	Medium	High	High	Extreme	Extreme
	Possible	Low	Medium	High	Extreme	Extreme
	Unlikely	Low	Low	Medium	High	Extreme
	Rare	Low	Low	Medium	Medium	High

Scales

Likelihood

- **Almost certain:** Anticipated to occur *often* during entire project
- **Likely:** Anticipated to occur *several times* during entire project
- **Possible:** Reasonably anticipated to occur *at some time* during entire project
- **Unlikely:** Not anticipated to occur during entire project but *possible*
- **Rare:** *Not anticipated* during entire project

Consequence

- **Catastrophic:** Results in death, total loss or shutdown of system, significant release into the environment affecting the public or regulatory intervention
- **Major:** Results in permanent impairment, serious lost-time injury, loss or shutdown of part of system, large on-site release into environment
- **Moderate:** Short-term lost-time injury, short-term interruption in use of system, recoverable release into environment
- **Minor:** Minor injury, minor damage to system, minor confined release into the environment
- **Insignificant:** Very minor injury, with consequence less serious than **Minor**