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

2022-10-17

Prepared By:

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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 camps, 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 to 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

The system requirements show our first version of 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.

2.2.1 Functional Requirements

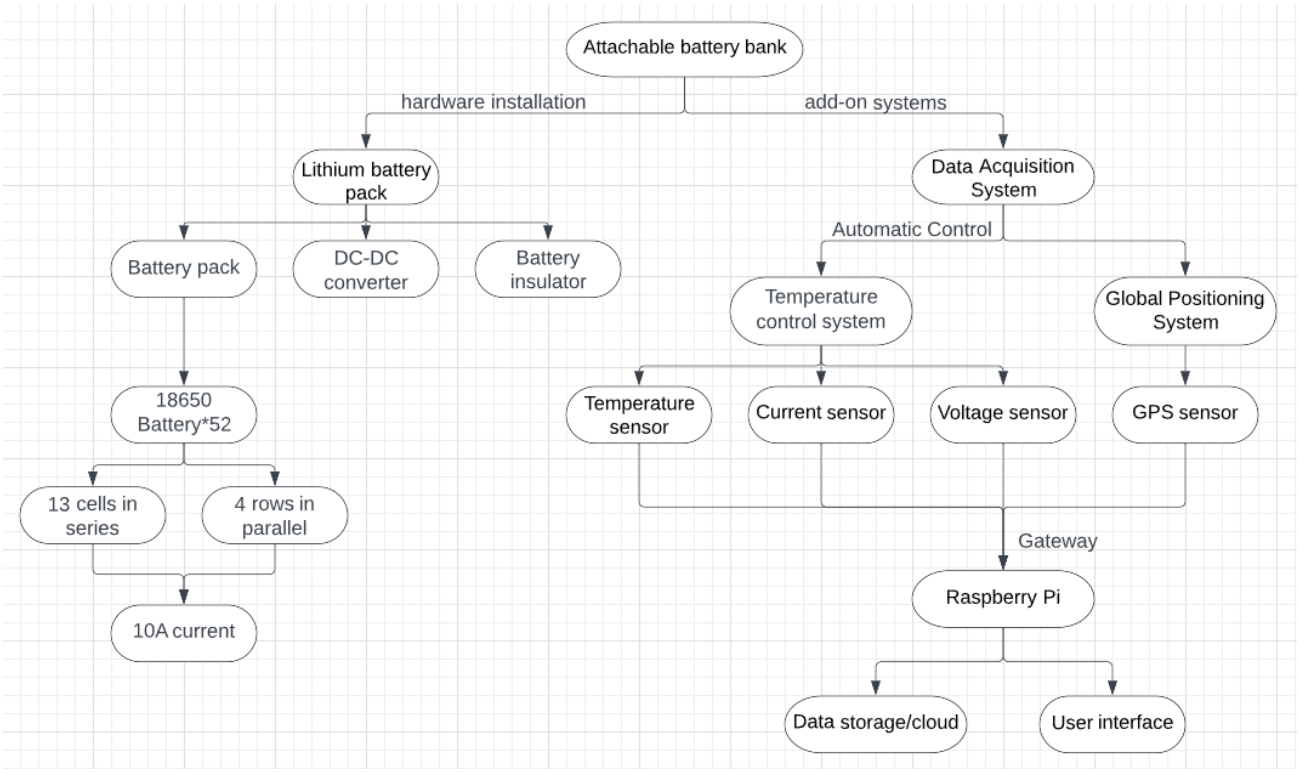

Figure 2.1 - Block diagram of the functional requirement of the project

Safety protection:
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.

Temperature control system (Automatic detection and control)
The best working temperature of lithium-ion batteries is around 20℃. In a non-extreme environment, after working for dozens of minutes, the battery can rely on its own heat to maintain a mild and comfortable "body temperature". However, lithium batteries cannot rely on their own heat to resist the cold winter outside when it is extremely cold. At this time, we need to detect and help the battery control the temperature. Likewise, this system also prevents the battery from overheating.
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

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：

- Find lost electric scooter
- Record itinerary

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, suitable for all types of e-scooter.

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

Usability: It's simple to use; take it from home and connect it to the e-scooter charger with the plug wire of the battery pack

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

3.1 Work Breakdown Structure

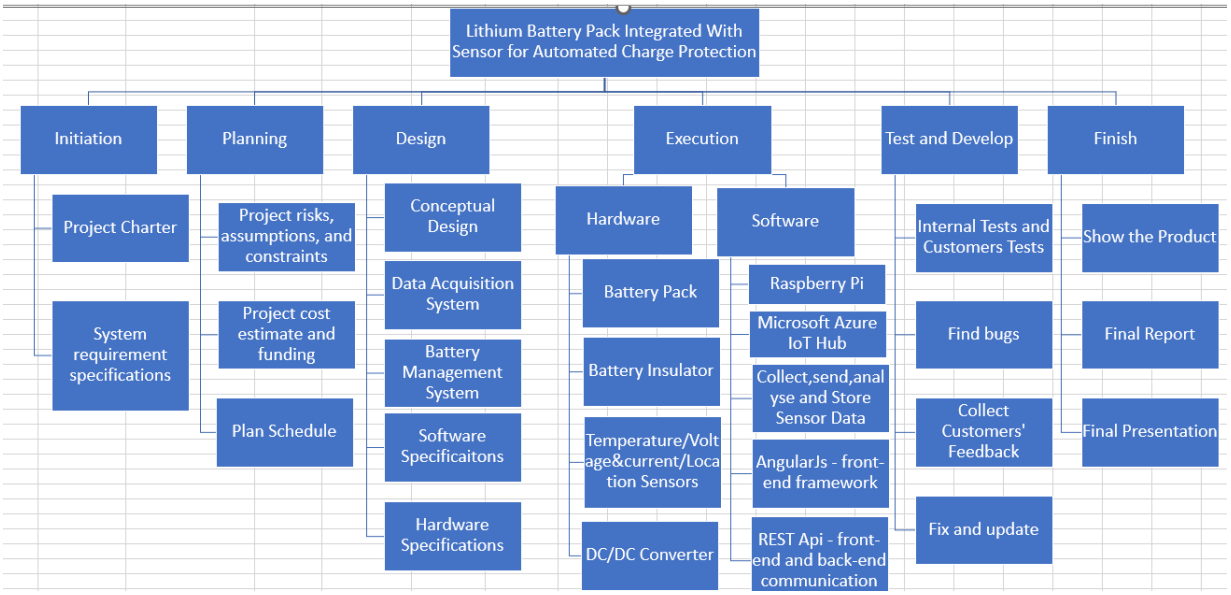

Figure 3.1 - Work Breakdown Structure

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 planning, such as estimated costs, risks, planning time.	2022/10/21
Phase 3: Testing and Debugging Software	Test plan.Staff test the software and debug.	2022/11/15
Phase 4:Post performance analysis	Evaluation of works. Contribution list.	20222/12/01

Phase5: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	5 days	Mon 10/17/22	Fri 10/21/22	100%	Kaicheng Zhang	
6	**Planning**	**5 days**	**Sun 10/16/22**	**Fri 10/21/22**	**100%**		
7	Project Risks, Assumptions, and Constraints	4 days	Sun 10/16/22	Wed 10/19/22	100%	Josiah Bigras	
8	Work Breakdown Structure	5 days	Mon 10/17/22	Fri 10/21/22	100%	Lidan Huang	
9	Gantt Chart & Milestone	6 days	Sun 10/16/22	Fri 10/21/22	100%	Lidan Huang	
10	Project Cost estimate and Funding	3 days	Mon 10/17/22	Wed 10/19/22	100%	Kaiyi Yuan	
11	Risk Mangement Plan	4 days	Tue 10/18/22	Fri 10/21/22	100%	Josiah Bigras	
12	**Conceptual Design**	**5 days**	**Sun 10/16/22**	**Fri 10/21/22**	**100%**		
13	Hardware Specifications	3 days	Wed 10/19/22	Fri 10/21/22	100%	Kaiyi Yuan	
14	Software Specifications	5 days	Mon 10/17/22	Fri 10/21/22	100%	Nima Mehrjoonezhad	
15	Data Acquisition	6 days	Sun 10/16/22	Fri 10/21/22	100%	Nima Mehrjoonezhad	
16	**Testing**	**9 days**	**Thu 11/3/22**	**Tue 11/15/22**	**0%**		
17	Software test	3 days	Thu 11/3/22	Mon 11/7/22	0%		
18	Debug	7 days	Mon 11/7/22	Tue 11/15/22	0%		#17
19	**Final**	**8 days**	**Tue 11/29/22**	**Thu 12/8/22**	**0%**		
20	Post performance analysis	3 days	Tue 11/29/22	Thu 12/1/22	0%		
21	Final Report	5 days	Fri 12/2/22	Thu 12/8/22	0%	Everyone	
22	Final Presentation	2 days	Wed 12/7/22	Thu 12/8/22	0%	Everyone	#21

Figure 3.2 - Gantt Chart

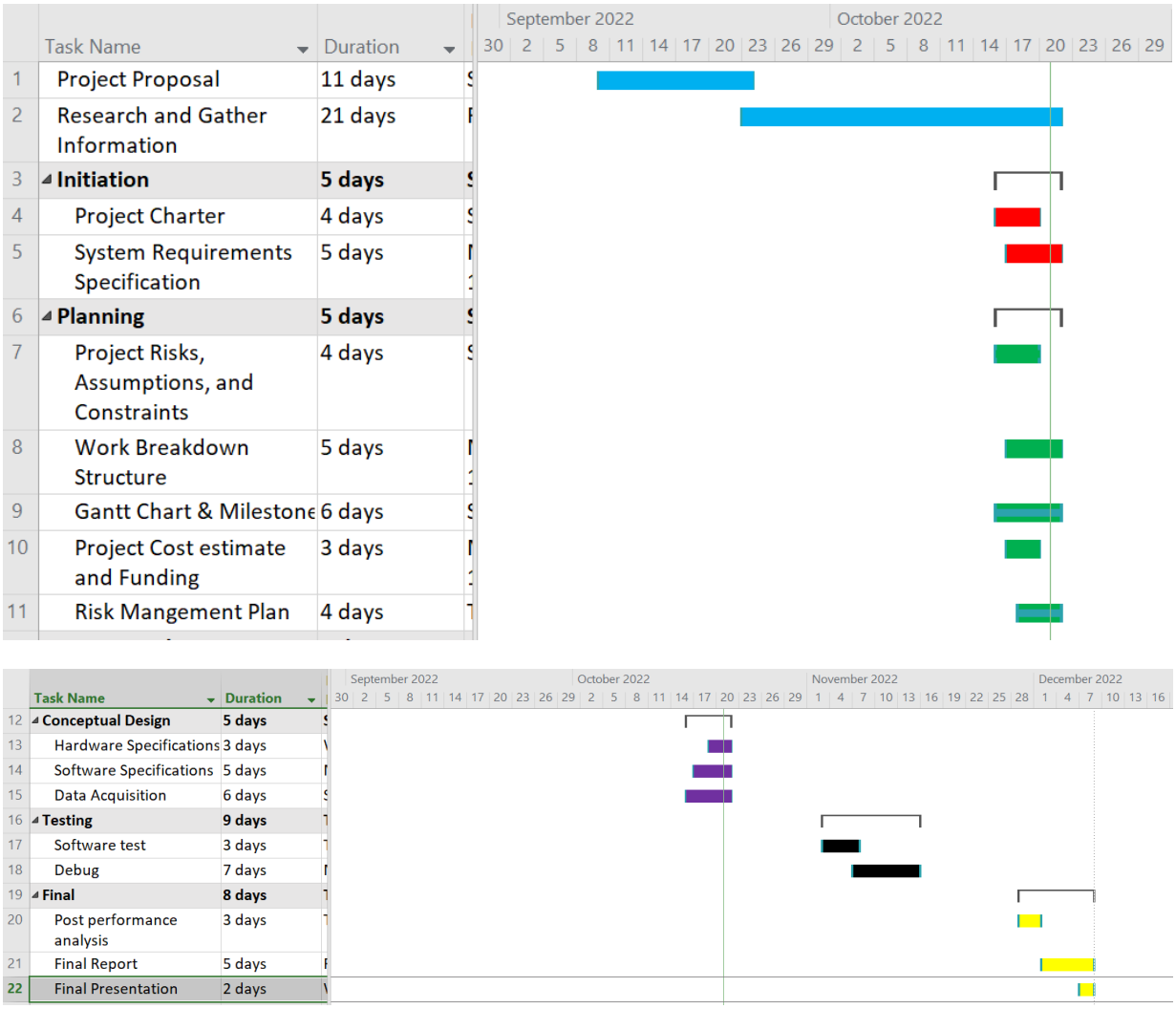

Figure 3.3 - Schedule and Detailed Gantt Chart

3.2 Deliverables

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

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 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
5	Final Presentation	Present the final report	2022-12-08

Table 3.2 - Deliverables

3.3 Project cost estimate and funding

3.3.1 Project cost estimate

Item Name	**Price**	**Link**
18650 Battery*52	$260	https://www.18650batterystore.com/en-ca/products/samsung-30q
Battery Management System	$12.99	https://www.amazon.ca/11-1V-Balance-Lithium-Battery-Protection/dp/B07JMY631D?th=1
Battery Insulator	$21.64	https://www.amazon.ca/CHGCRAFT-Meters-105mm-Shrink-Battery/dp/B0BDM95CFZ/ref=sr_1_10?crid=3BIM9RZPD0AV0&ke

		ywords=battery+insulation&qid=1666325438&qu=eyJxc2MiOiIyLjgyIiwicXNhIjoiMS45OCIsInFzcCI6IjAuODEifQ%3D%3D&s=electronics&sprefix=battery+insulation%2Celectronics%2C109&sr=1-10
Raspberry Pi	$119.86	https://www.amazon.ca/Raspberry-Pi-Zero-W/dp/B06XFZC3BX/ref=sr_1_5?crid=1HALWGDGEXVAK&keywords=raspberry+pi&qid=1666325484&qu=eyJxc2MiOiI2Ljg3IiwicXNhIjoiNi4xNyIsInFzcCI6IjUuNTEifQ%3D%3D&s=electronics&sprefix=raspberry+pi%2Celectronics%2C101&sr=1-5
Heat Sensor	$22.05	https://www.amazon.ca/Ultra-Durable-12001656-Sensor-Replacement/dp/B074DSGJXS/ref=sr_1_9?keywords=heat+sensor&qid=1666325523&qu=eyJxc2MiOiI0LjM2IiwicXNhIjoiMy4wNCIsInFzcCI6IjIuMTYifQ%3D%3D&sr=8-9
Current Sensor	$12.99	https://www.amazon.ca/COVVY-Current-Arduino-ACS712ELC-20A-Indicator/dp/B07TQ5M9MP/ref=sr_1_8?crid=AVI93H3SW4QD&keywords=current+sensor&qid=1666325596&qu=eyJxc2MiOiI1LjA5IiwicXNhIjoiNC42NyIsInFzcCI6IjMuOTEifQ%3D%3D&sprefix=current+senso%2Caps%2C100&sr=8-8
Voltage Sensor	$10.20	https://www.amazon.ca/Robojax-Voltage-Sensor-Module-Arduino/dp/B07C6893X3/ref=sr_1_5?crid=3UA700CESDMF7&keywords=Voltage+sensor&qid=1666325639&qu=eyJxc2MiOiIzLjMwIiwicXNhIjoiMi45NiIsInFzcCI6IjIuNTkifQ%3D%3D&sprefix=voltage+sensor%2Caps%2C111&sr=8-5
Total Cost	$443.73	

Table 3.3 - Project Cost Estimates

3.3.2 Funding

Most of the required material will be provided by the faculty lab, if the required material is not available at the lab, the group will purchase it at our own expense. Initially we are planning a $150 budget which will be evenly split among 5 of the members.

4 Risk Management Plan

4.1 Risks

The goal of this project is to develop an attachable battery bank that acts as an extension to the current battery of a wide range of e-scooters (electric scooters). However, this poses many risks and uncertainties, it is very difficult to create such a device with such a wide variety of electric scooters. Assuming the current form factor of a scooter, we must take in consideration the bulkiness of adding an additional component to the scooter and placement of such device so

that it doesn't interfere with the user. This consideration touches many different factors, such as, but is not limited to, the weight of the device, the placement of the device on the scooter, the attachment mechanism on the device, the voltage on the device and usability with various environmental conditions, the intractability with the device and the user, the cost, and safety precautions of the device itself. We also have safety risks when constructing this battery, batteries are very flammable, and we are putting ourselves at risk when we construct this battery bank. We must be careful when we decide to weld (solder) the contacts of every battery in place, and be cautious of the voltage and power of the batteries, it is a shock hazard.

A major concern with this project, is the usability of our device in the climate of Ottawa, specifically throughout the winter, where the battery and system of existing E-scooters are compromised. We risk the possibility that the existing E-scooters aren't as usable in the winter, due to large amounts of snow, or how the current system is designed. However, that isn't the scope of our project, we are strictly focusing on the extension of the battery of E-scooters so that that may be used in any condition, with the addition of extra functionality and usability.

Here is a table ranking the importance of these risks (rating from 1-10, where 1 is low and 10 is high).

	Device Weight	Device Placement	Device Attachment	Voltage/Power Specifications	Construction Hazards	Cost	Safety Precautions
Risk Rating	5	3	4	7	9	4	8

Figure 3.4 - Risk Rating Table

Another risk we must consider is the hazards of dealing with flammable lithium batteries. It's important to understand all the possible consequences if a battery is damaged or shorted and the possible control measures needed to decrease the risk of hazard. Some control measures that can be used to help reduce this risk is to perform deal with the batteries in a well ventilated areas (in case a battery combusts), wear appropriate personal protection equipment (such as gloves, glasses, and protective clothing), perform the welding and soldering of components in a isolated area, and to have an emergency plan in the case a hazard does occur.

Upon spot welding batteries, an emergency plan is required to insure 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, they will be placed in the bucket of sand, brought outside, and they 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.

A hazard assessment has been attached, as well as an explanation of further precautions and hazards regarding this project.

4.2 Assumptions

For our project to work, we first have to assume that E-scooters can be used as it is in the winter and other climates in Ottawa. This is a very important assumption, because if E-scooters aren't usable in these climates, applying our solution to the existing battery and system won't work as expected. It's important to know that the physical conditions of the scooter must be able to be used in various climates.

4.3 Constraints

For this project, we are limited to using the existing available supply of E-scooters. This means that we must adapt our design to work with these E-scooters. This constraint may cause complications when it comes to physically mounting our desire, or connecting our device to the existing E-scooter system.

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 decide to use 18650 battery cells to form a battery pack.

Figure 5.1 - 18650 Battery cell

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.

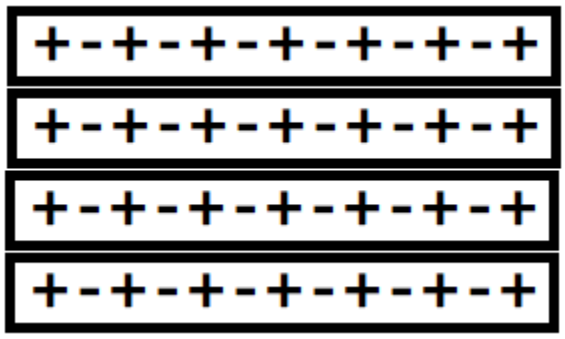

Figure 5.2 - Battery cells arrangement

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.

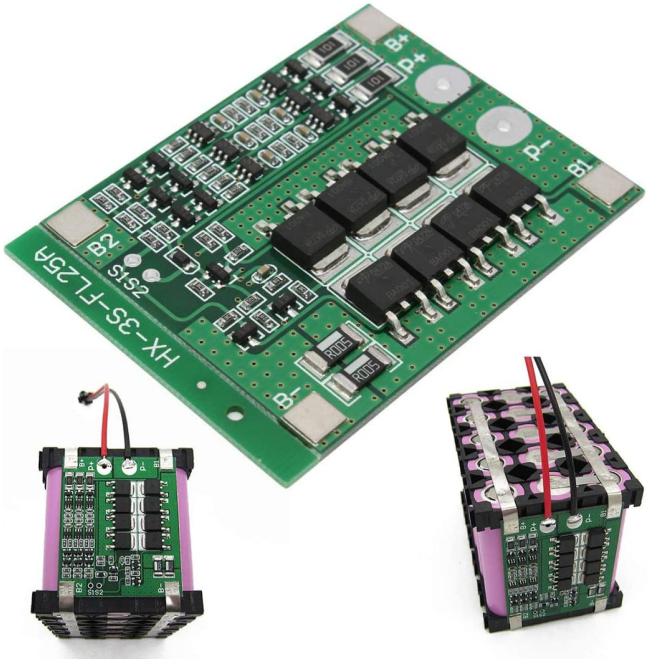

Figure 5.3 - Battery Management System

5.1.3 Insulation

Batteries are very susceptible to heat and vibration that could cause premature failure and hazardous leaks. Battery insulate is capable of damping vibration and will absorb and neutralize any damaging leaky battery acids.

Figure 5.4 - 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).

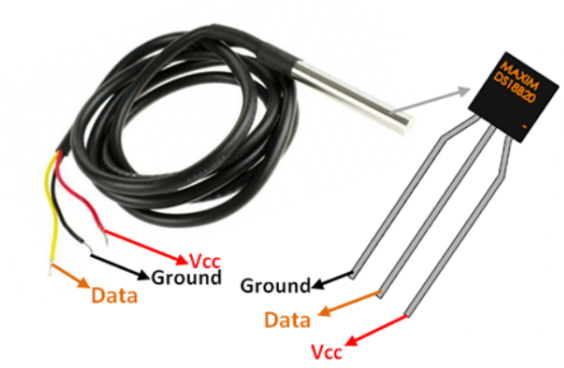

Figure 5.5 - DS18b20 temperature Probe

Parameters	Specifications
Supply Voltage	3.3 V or 5.0 V
Temperature Range	$-\ 55^{\circ}C$ to $+\ 125^{\circ}C$
Accuracy	$\pm\ 0.5^{\circ}C$
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.

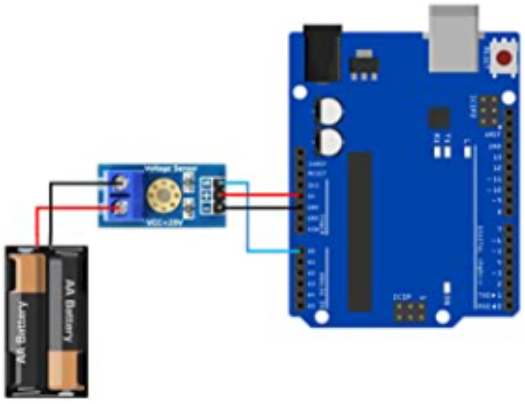

Figure 5.6 - Voltage Sensor connection

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.

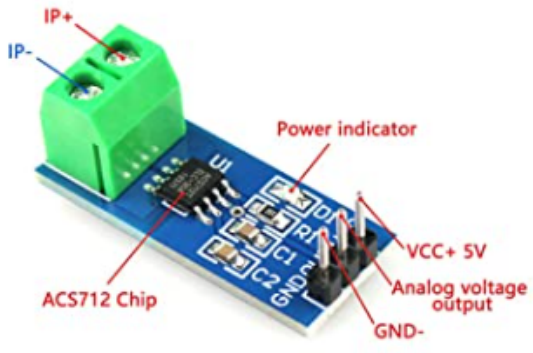

Figure 5.3 - Current sensor physical layout

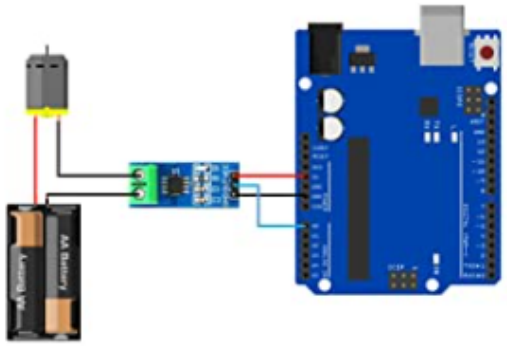

Figure 5.4 - Connection of current sensor

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.

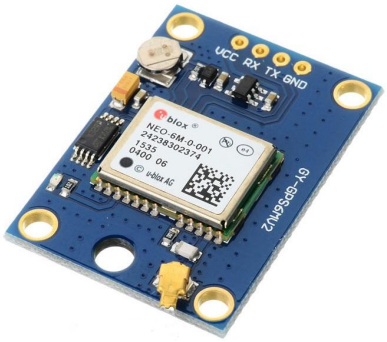

Figure 5.5 - GPS sensor module

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.

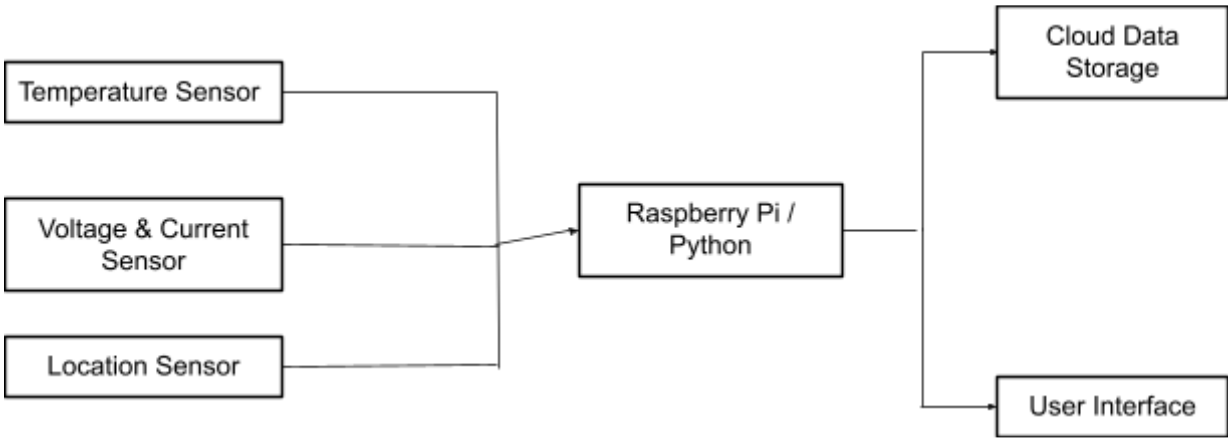

Figure 5.6 - Block diagram of the overall Data Acquisition system

In the next section we will go into more details 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 a Blob Storage. We then use Power Bi to display the data to users in a webpage.

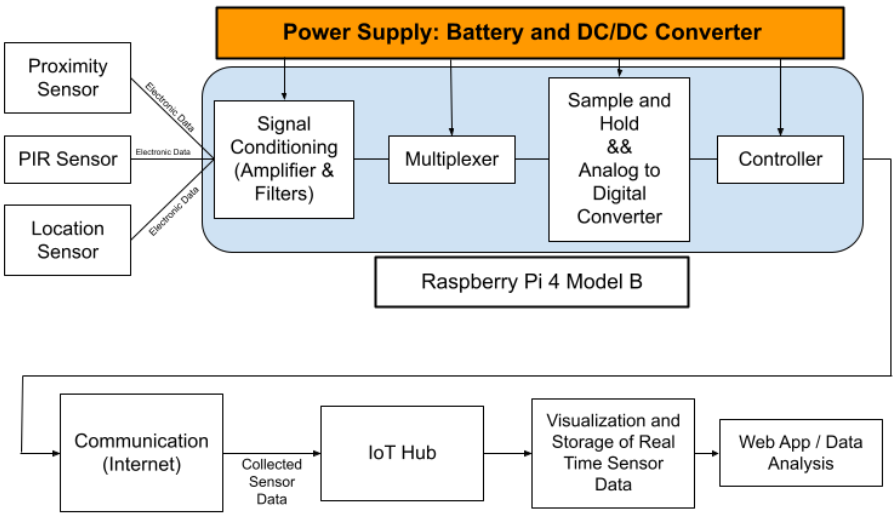

Figure 5.7 - More Detailed Block Diagram of the Data Acquisition System

Once this data is collected we will use raspberry pi 4 b+ to send this data to the cloud. We will be using 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.

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 wifi 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

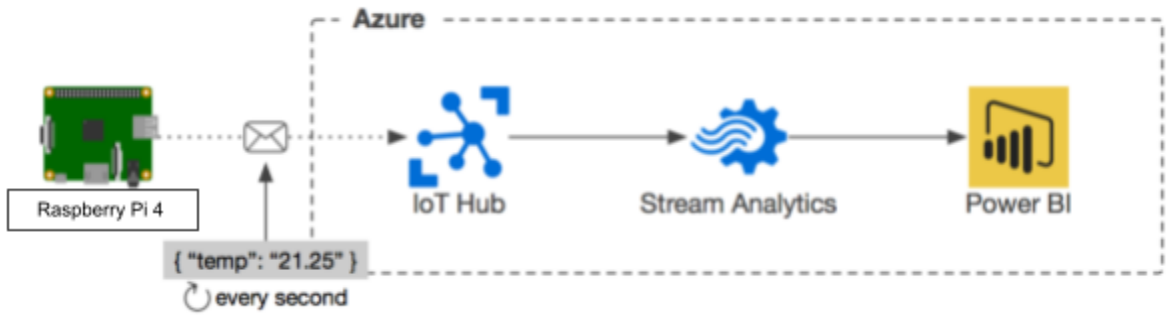

Figure 5.8 Data Visualization block diagram

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.

5.2.6 Simulation

We used the online raspberry pi Azure IoT Simulator to set up our configuration and test the raspberry pi python code.

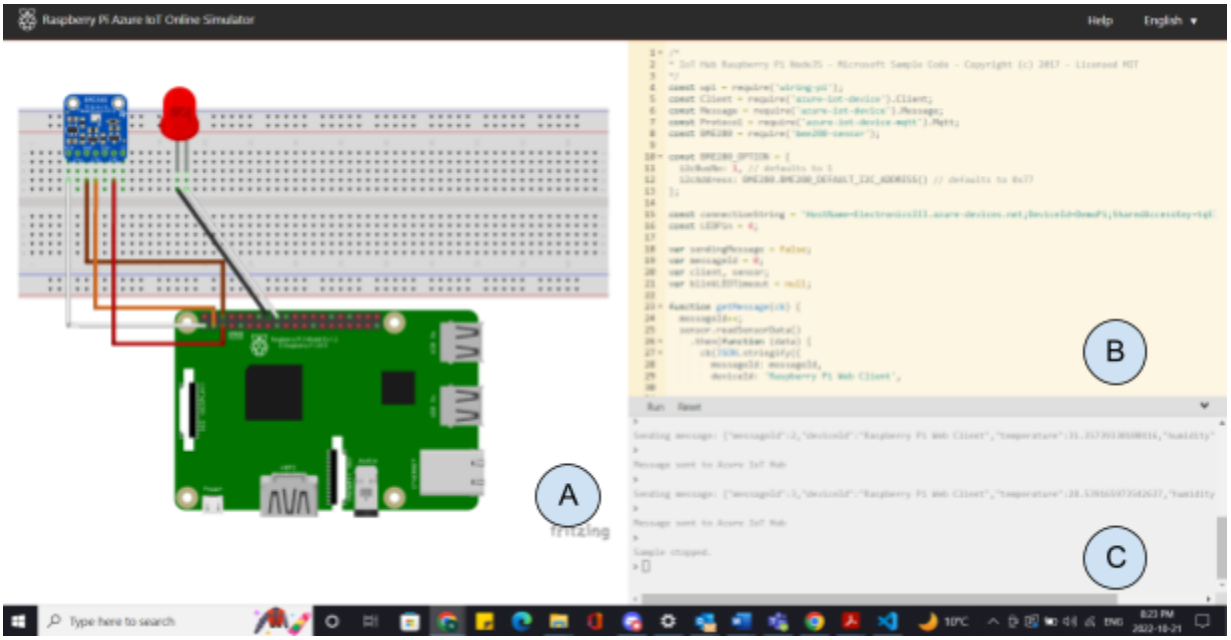

Figure 5.9 - Raspberry pi Azure IoT Online Simulator Window

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, ie 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.

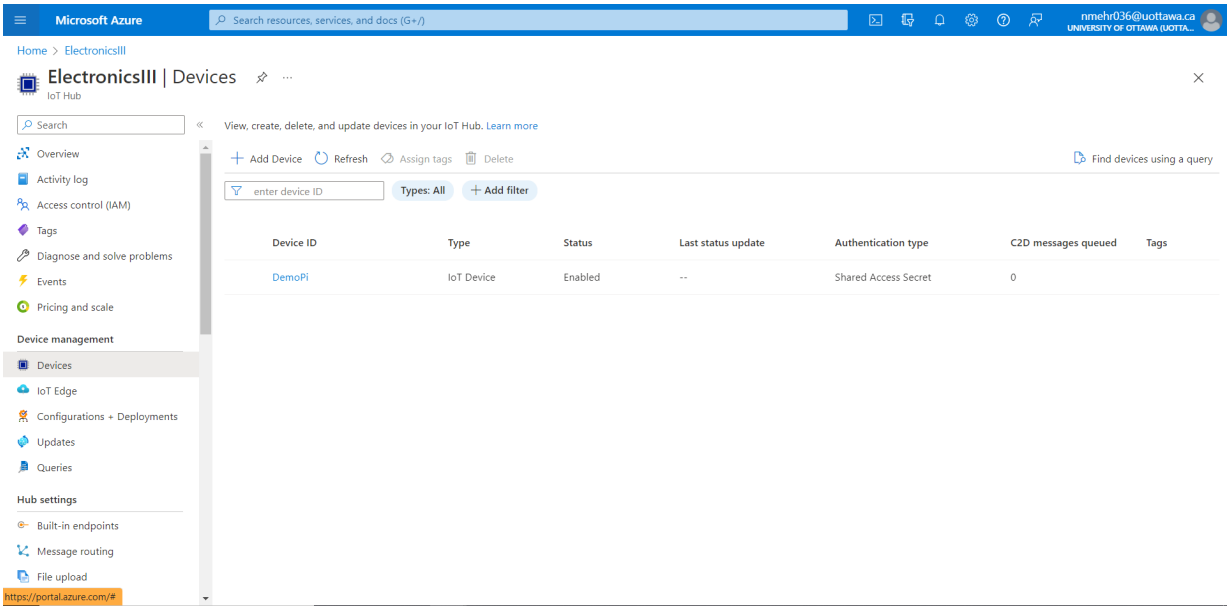

Figure 5.10 - IoT Hub Devices Window

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.

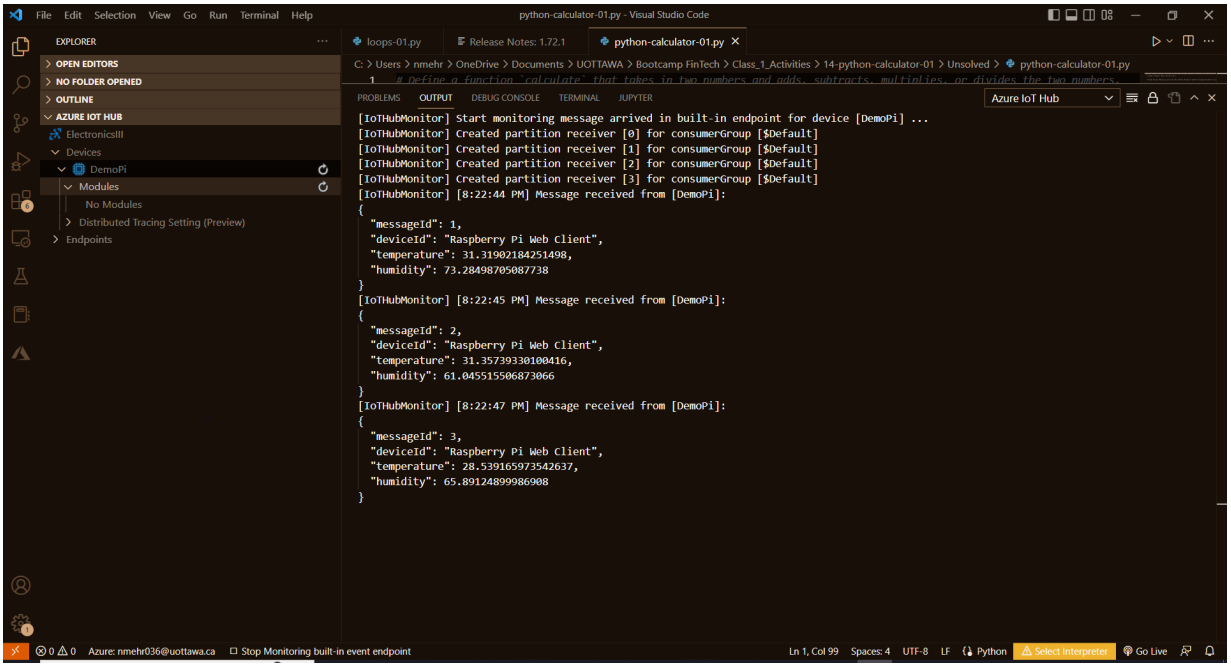

Figure 5.11 - VS Code Terminal

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.

6.Project Organization

6.1 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

Nima

Software Conceptual design

Lidan

Milestones

Work Breakdown Structure (WBS)

Gantt Chart

Kaiyi

Project charter

Hardware Conceptual design

estimated budget

6.2 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.

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