GUJARAT TECHNOLOGIAL UNIVERSITY

Chandkheda, Ahmadabad - 382424

Vishwakarma Government Engineering College, Chandkheda-382424
(Affiliated with Gujarat Technological University, Ahmedabad)

A
Project report
On

BATTERY MANAGEMENT SYSTEM

Prepared as a part of the requirement for the subject of
DESIGN ENGINEERING – II B (3160001)
B.E - Semester - VI
(Power Electronics Department)

Submitted by: 412477

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Academic Year
2022-23

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The record of work completed by them under our supervision and assistance toward a completion of **Design Engineering 2B (Power Electronics Engineering)** at Gujarat Technological University. The work presented has, in our judgement, met the standard necessary for evaluation. To the best of our knowledge, the results contained in this Project Work have not been submitted to any other polytechnic or university.

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Empathy Canvas	**Completed**
Ideation Canvas	**Completed**
Product Development Canvas	**Completed**
Prototype	**Completed**
Report	**Completed**

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ABSTRACT

Compared to traditional battery technology, lithium-ion batteries last longer and have a high-power density for more battery life in a lighter package. But in order to make the best use out of this battery, there is a huge requirement of such a charger that is specifically designed to observe the battery's charging status and provide a charge, when necessary, in order to maintain the battery, keeping it healthy and energized. In this project, we are working on a lithium-ion battery charger based on microcontroller. It will primarily work on constant current, constant voltage (CC/CV) type of charging algorithm. This charger will have specifications like battery level indication, voltage controls, auto power cut-off etc. This charger would be applicable in power backups/UPS, electric vehicles etc. It will completely eliminate the monitoring part for the users towards the battery and allow them to multitask or focus on different activities.

GIST OF TEAMWORK

Our team includes five members starting with me (Raju), the leader of the team. He handled the research work for the components used in the working model and also helped in preparation of working model. Next is (Anurag) he worked on the strategy to prepare canvas with utmost perfection. Next is (Ayushi), she was leading the observation strategy and also helped in preparing the canvases. Next is (Alpesh), he was in charge to prepare the strategicalframework of process to construct the working model. Our fifth member (Shreyash) also helped in construction of working model.

With all of our hard work and dedication we manage to complete this project together in the given time.

ACKNOWLEDGEMENT

We sincerely thank our guide Dr. A. M. Haque for guiding us through the technicalities and science behind the project. His support and encouragement helped us in dealing with core problems of the project.

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CHAPTER 1

INTRODUCTION: -

The major goal of this project is to use CC/CV charging algorithm to charge lithium-ion batteries to ensure their safety, longevity, and optimal performance. The constant current (CC) stage of the charging algorithm is used to provide a constant current to the battery until it reaches a certain voltage. Once the battery reaches the desired voltage, the constant voltage (CV) stage is activated, providing a constant voltage until the battery is fully charged.

The Arduino Mega 2560 microcontroller board is used to control the charging process, read battery parameters such as voltage and current, and adjust the charging current and voltage accordingly. The charger can be programmed to charge different types and capacities of lithium-ion batteries.

The charger circuit typically consists of an Arduino Mega 2560 board, a voltage regulator to supply a stable voltage to the microcontroller board, a charging circuit with a MOSFET switch to control the charging current, a voltage sensing circuit to measure the battery voltage, and a current sensing circuit to measure the charging current.

The charging algorithm can be programmed using the Arduino IDE (Integrated Development Environment), and the charger can be controlled and monitored using a computer or a smartphone application.

Overall, a CC/CV lithium-ion battery charger based on Arduino Mega 2560 provides a flexible, customizable, and cost-effective solution for charging lithium-ion batteries for a variety of applications such as portable electronics, electric vehicles, and renewable energy systems.

Keywords: - Arduino mega 2560, ACS712 current sensor, DC relay, Rectifier, LED display.

LITERATURE SURVEY: -

In the past, the researchers had gone through different types of technologies. A brief survey of various solutions to the tragic congestion problems are presented.

The literature survey shows that CC/CV lithium-ion battery chargers based on microcontroller are widely used in various applications, including portable electronic devices, electric vehicles, and renewable energy systems. These chargers are designed to operate in both CC and CV modes and are capable of charging a single cell or multiple cells in series or parallel. The microcontroller controls the charging process by monitoring the battery voltage and current and adjusting the charging current accordingly, which results in high efficiency and quick charging of the batteries.

So, we choose to do automatic microcontroller-based system which dons not required any monitoring part for the user towards the battery.

CANVAS

1.1 AEIOU SUMMARY

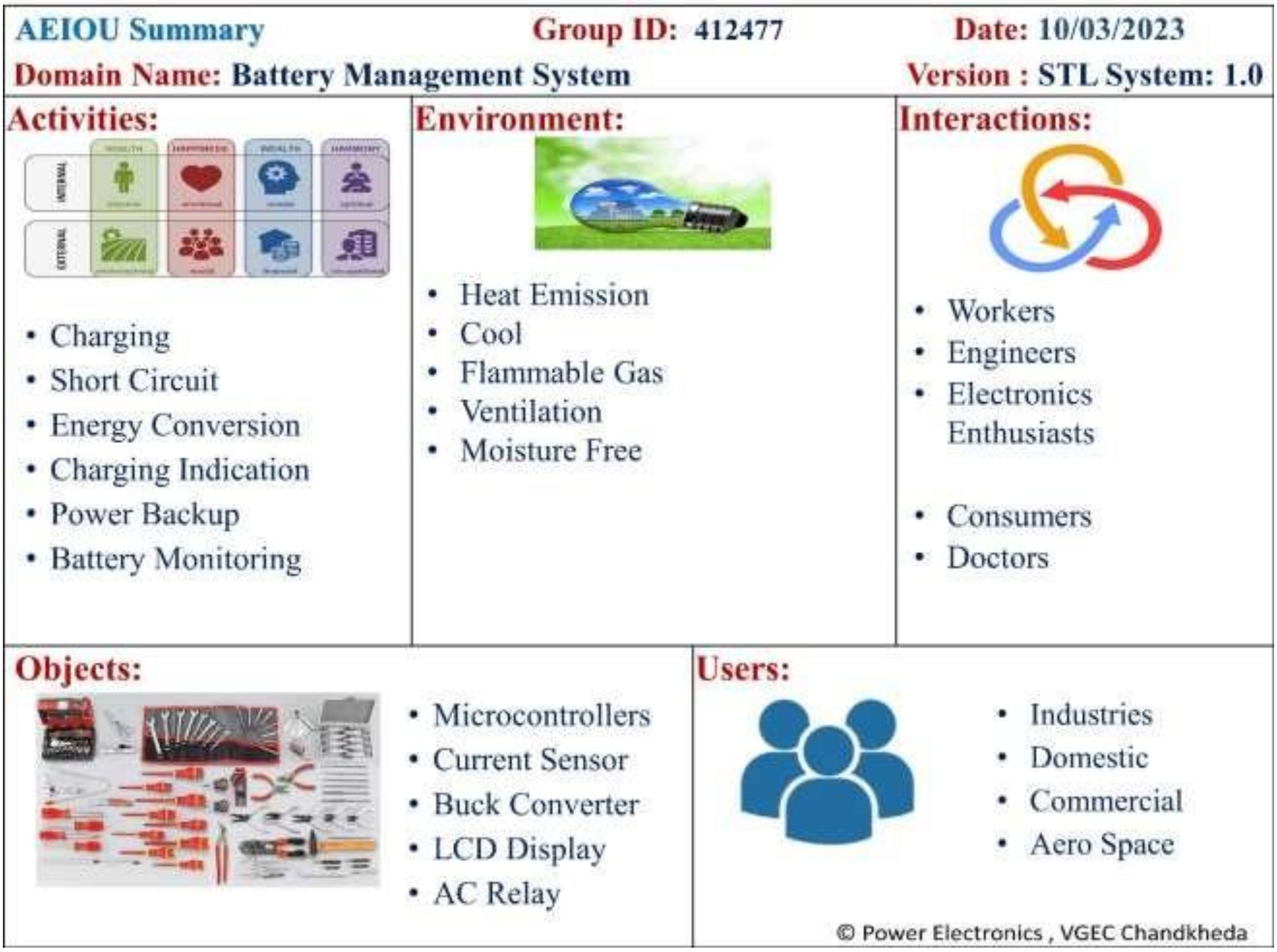

FIGURE 1: AEIOU SUMMARY

Users: - Our project users are as follows

- Medical devices
- Commercial
- EV owners
- Domestic
- Aero Space
- Industry

Activities: - This section will include the applications of the product such as following

- Energy conversion
- Charging indication
- Battery monitoring
- Power back-up
- Charging
- Short-circuit

Environment: - In this will include the effect of the objects placed in its surrounding such as following

- Heat emission
- Moisture free
- Ventilation
- Flammable gases
- Cool

Interaction: - This will include the stakeholders such as following here,

- Electronics enthusiasts
- Workers
- Consumers
- Engineers
- Doctors

Objects: - In this section of the canvas include the equipment used the production such as follow

- Microcontroller
- Current sensor
- DC relay
- Buck converter
- Rectifier
- LCD display

1.2 MIND MAPPING: -

Using pictures, lines, and linkages, mind mapping is a technique for connecting important ideas. The idea of "radiant thinking," in which ideas spread out from a single idea often depicted as an image is used in mind mapping.

From and to the main idea, branches extend in both directions. Mind maps arediagrams that are used to graphically organize information in a hierarchy. A single idea or picture is the focal point of a mind map, which is drawn around it.

Here, significant concepts directly branch offof the fundamental notion (Automation), with more specific concepts and details branching off from those levels.

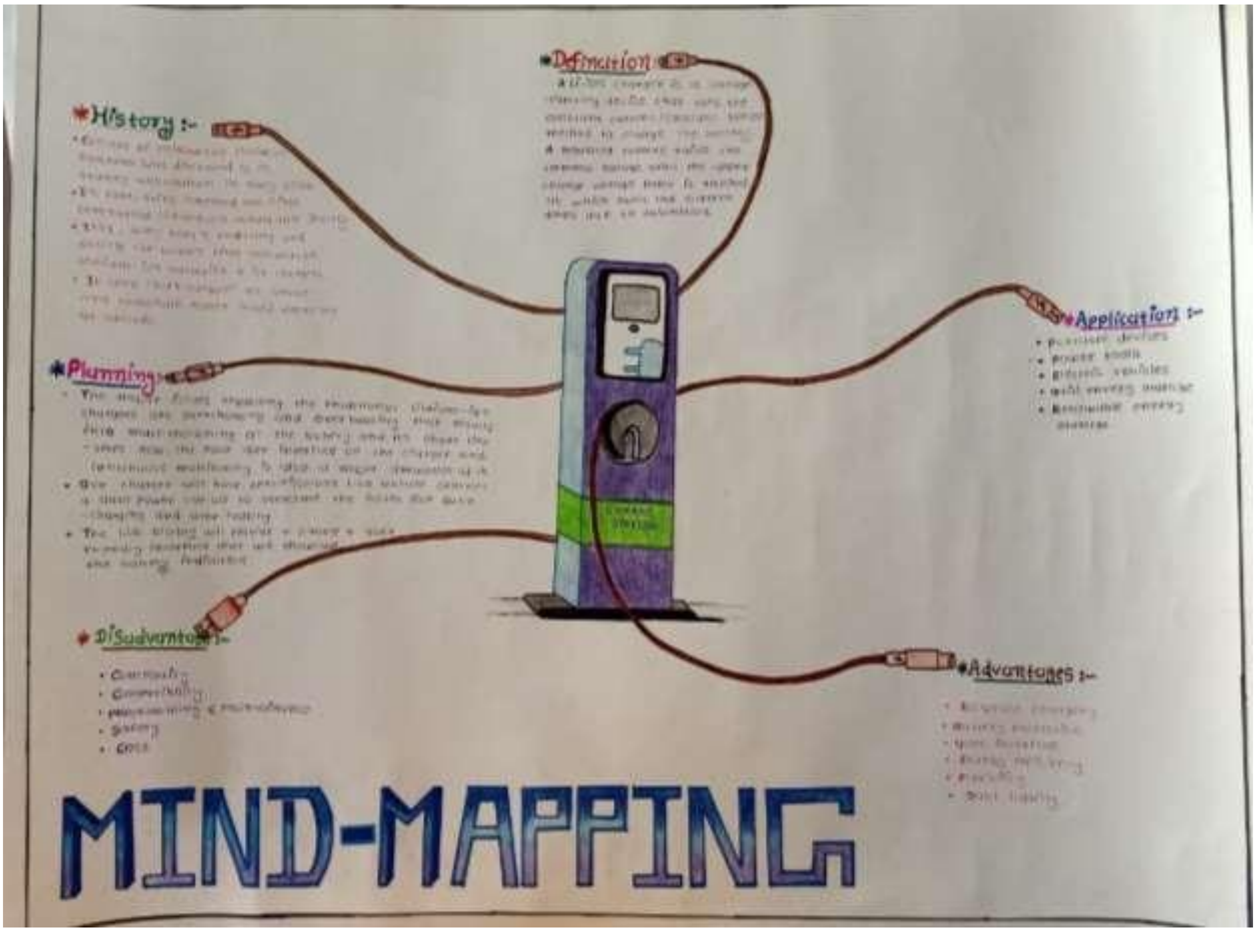

FIGURE 2: MIND MAPPING

1.3 EMPATHY CANVAS

This is the first step of the project or a problem. So, in this canvas, we will find out what is user? Who is a user? What is stakeholder? Who are they? And what are the broad stories of their activities?

The User: - In this stage, we find the various users which are directly or indirectly related to our project

- Medical devices
- Aero space
- EV owners
- Domestic
- Industry
- Commercial

Stakeholders: - In this stage, we find the user who will directly or indirectly related to users. Stakeholders mean a person or organization with an interest.

- Power distributing companies
- Cell manufactures
- Recycling plants
- Government

- Suppliers
- Consumers

Activities: - Are directly or indirectly related to stakeholders.
- Energy conversion
- Charging indication
- Power back-up
- Charging
- Short-circuit
- Charging Profile

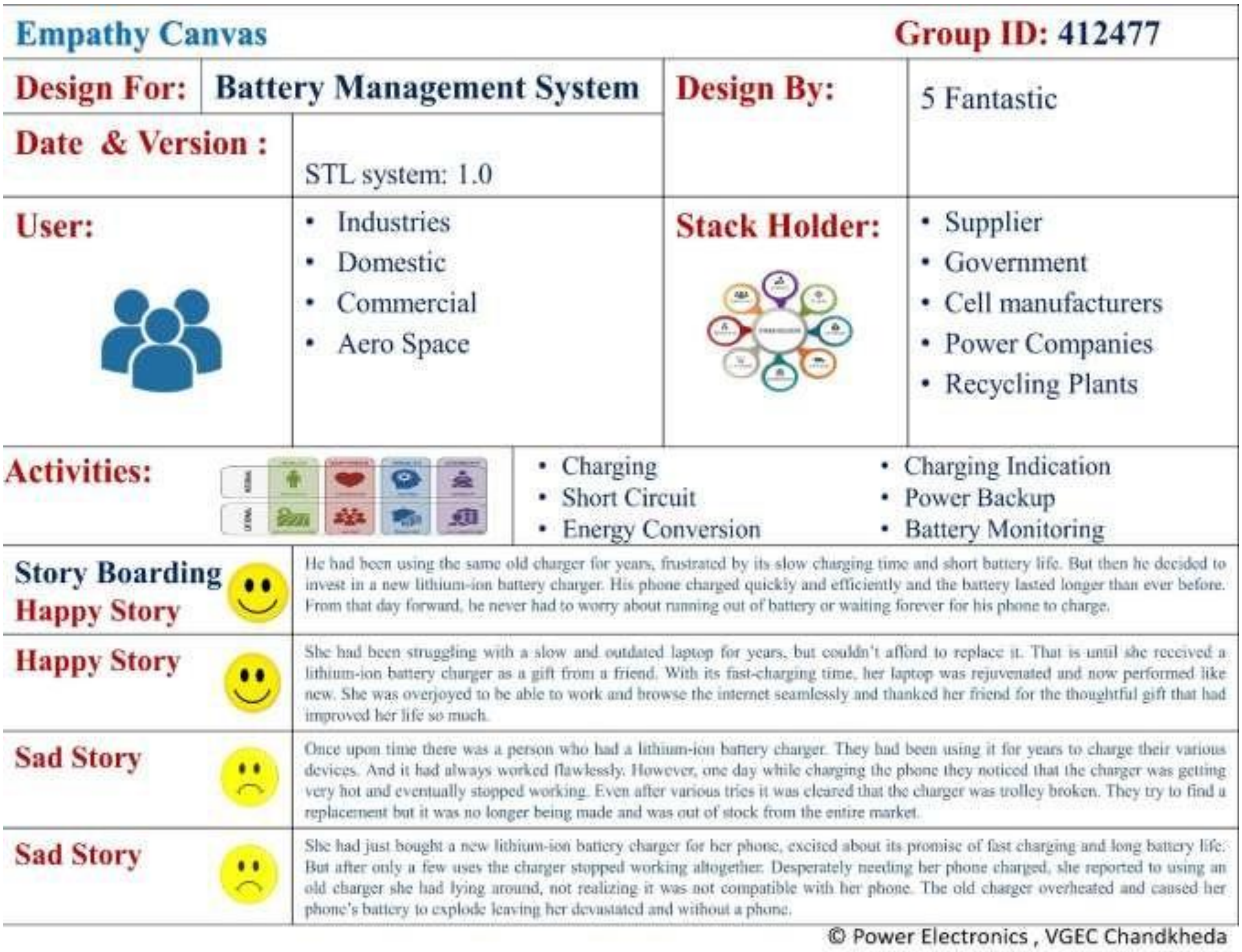

FIGURE 3: EMPATHY CANVAS

Story Boarding: -

⇒ **Happy: -** He had been using the same old charger for years, frustrated by its slow charging time and short battery life. But then he decided to invest in a new lithium-ion battery charger. His phone charged quickly and efficiently and the battery lasted longer than ever before. From that day forward, he never had to worry about running out of battery or waiting forever for his phone to charge.

⇒ **Happy: -** She had been struggling with a slow and outdated laptop for years, but couldn't afford to replace it. That is until she received a lithium-ion battery charger as a gift from a friend. With its fast-charging time, her laptop was rejuvenated and now performed like new. She was overjoyed to be able to work and browse the internet seamlessly and thanked her friend for the thoughtful gift that had improved her life so much.

⇒ **Sad: -** Once upon time there was a person who had a lithium-ion battery charger. They had been using it for years to charge their various devices. And it had always worked flawlessly. However, one day while charging the phone they noticed that the charger was getting very hot and eventually stopped working. Even after various tries it was cleared that the charger was trolley broken. They try to find a replacement but it was no longer being made and was out of stock from the entire market.

⇒ **Sad: -** She had just bought a new lithium-ion battery charger for her phone, excited about its promise of fast charging and long battery life. But after only a few uses the charger stopped working altogether. Desperately needing her phone charged, she reported to using an old charger she had lying around, not realizing it was not compatible with her phone. The old charger overheated and caused her phone's battery to explode leaving her devastated and without a phone.

1.4 IDEATION CANVAS

This canvas consists of the ideology behind the user, so in this canvas some brief ideas are expressed. People section consists of persons related to user technically and similar person may relate to user. Then we divided activities in social and technical and try to find out the importance of each activity and situations & location regarding are find out related to each.

People: -

- Industry
- EV owner
- Engineer
- Common man
- Doctors
- Student

Activities: -

- Energy conversion
- Charging indication
- Battery monitoring
- Power back-up
- Charging
- Short-circuit

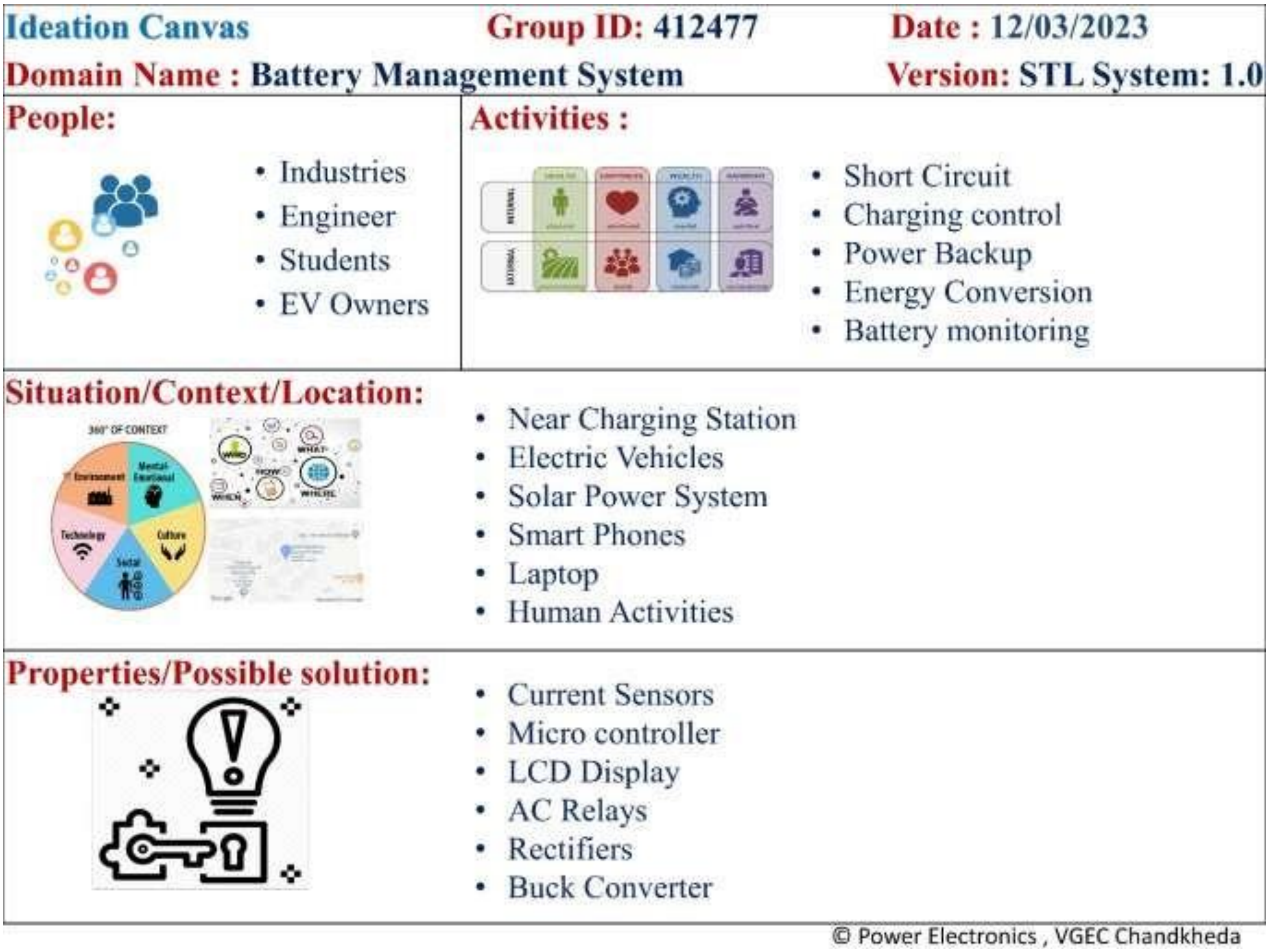

FIGURE 4: IDEATION CANVAS

Situation/Context/Location: -

- Electric vehicles
- Solar power system
- Human activity
- Smart phone
- Near charging station
- Emergency hospital work when power cur-off

Props/Possible Solution: -

- Microcontroller
- Current sensor
- DC relay
- Buck converter
- Rectifier
- LCD display

1.5 LEARNING NEED MATRIX

The LNM is containing a quadratic layout. The purpose of LNM is to identify the requirements of learning among the team members, while a new product/process is under development based on a unique idea. Each identified requirement of learning is connected depending upon interdependencies and paths are to be drawn. The team members can develop their own learning path to contribute to theefforts of the team for developing the concept underlying at the center of the LNM.

Top-right quadrant identified the learning requirement regarding applicable standards, design specification, exploration and understanding of scientific principles and identification of different typesof experiment to be performed over a period of time.

Top-left quadrant suggests making identification of learning the use of various tools, processes, methods of application, theories to apply tools involved. The lower-left quadrant contains identified needs for learning of software, simulation techniques, skills, mathematical learning requirements and so on.

Lastly, the lower-right quadrant shall have the needs identified pertaining to an understanding of various alternative materials, its strength and other properties, standards, as well as its testing requirements, depending upon envisaged quality.

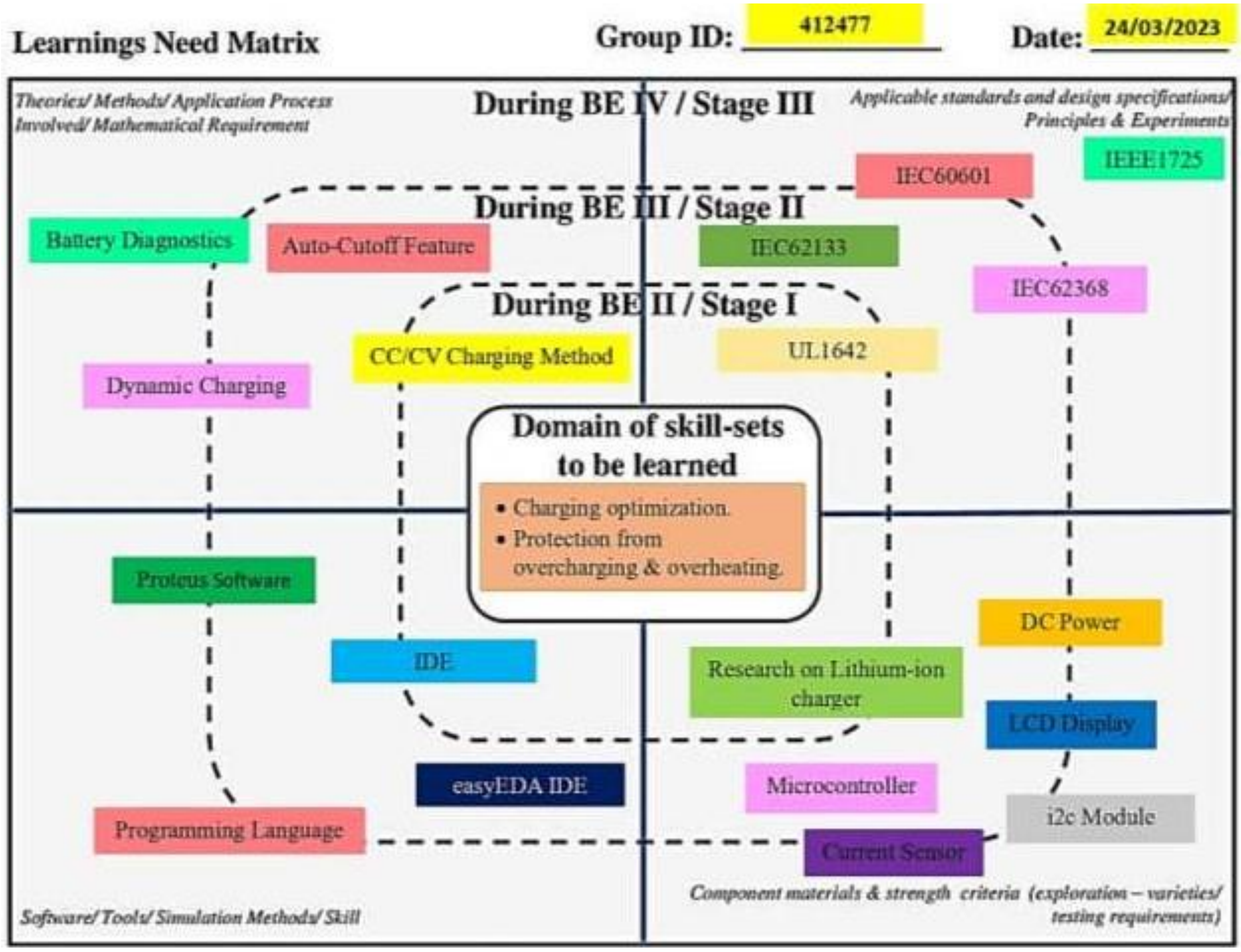

FIGURE 5: LEARNING NEED MATRIX

1.6 PRODUCT DEVELOPMENT CANVAS

Product development canvas comprises of a process that streamlines thought, systematically. Once, an idea is generated, next step is to identify a product/process (in a comprehensive manner) to resolve the specific difficulty for a user group. Product development canvas had given us insights to the problems which we had faced while creating an ideation of our product, factors such as Purpose, people, product experience, product functions, product features, and components.

FIGURE 6: PRODUCT DEVELOPMENT CANVAS

Purpose: -

- Minimize the lifespan of battery
- Accurately charge the battery
- Protection from overcharging & overheating
- Charging optimization
- Replenish the energy stored in the battery

People: -

- Student
- Industry
- Common man
- EV owners
- Doctors

- Military

Components: -

- Microcontroller
- Rectifier
- LCD display
- Buck converter
- Current sensor
- Relay

Product Features: -

- Voltage regulation
- Users interface
- Charging status indications
- Battery protection
- Customization
- Auto cut-off

Product Functions: -

- Voltage monitoring
- Charging cycle management
- Charging current control
- Safety features
- Battery diagnostics

Product Experience: -

- User friendly
- Fast charging
- Multiple charging
- Allow multitasking

Customer Revalidation: -

- Auto cur-off
- Overheating issues
- Charging time

Reject/Redesign/Retain (3-R): -

- Relay for auto cut-off
- CC/CV method for overheating issues
- Adde high performance ICs for fast charging

CHAPTER 2

2.1 Reverse Engineering: -

2.1.1 Introduction: - "Reverse engineering is a path of exploration from an end to start point (reverse journey of change) for developing an insightful understanding on each underlying applications of scientific and engineering principle of a product/process".

The process of performing reverse engineering as an exercise by learners can be inclusive of a simulation, experimental disassembling of a product, imagination and interview-based exploration of a finished good/product. Information that is of secondary in nature shall be used for understanding theprocess of development while reaching to level 0 to 1.

The reverse engineering is a concept to understand a product or process in a reverse order, i.e., to reachto its conceptualization stage beginning analysis from the final product as available. It helps in performing analysis in a back-step mode so as underlying insights are unveiled.

2.1.2 Process: - We started the process of reverse engineering by capturing the data from the existingpart & identifying the assembly components and their interrelationships. Then we build the circuit in proteus software for a proper outlook of the electrical circuit of the model. We tried differentcombinations of circuit preparations to get the satisfactory result. At last, we manufactured the circuitin real and tried different combination in breadboard to make it compact.

2.1.3 Conclusion: - The concept of reverse engineering helped us to find the faults in the completed project. It helped us in getting the in-depth understanding of the completed project. We were able to run analyses & tolerance simulations of the completed project. We explored the existing designs and manoeuvres by reconstructing the product circuit multiple times in proteus. We were able to discover various vulnerabilities of the product along with this we also explored the most efficient way to designthe product.

CHAPTER 3

3.1 Prior Art Search:

PAPER 1

1. https://www.researchgate.net/publication/357224952_Monitoring_of_lithiumion_cells_using_a_microcontroller

   Summary: - In this paper monitoring of lithium-ion cells is essential to ensure safe & optimal operation of the battery system. The microcontroller collects data from multiple sensors, including voltage & temperature. Sensor & perform calculations to determine the state of charge & state of health. They have many applications in different sector due to their high charge holding capacity, high charging discharging efficiency & ability to withstand huge currents. The module makes a detailed analysis of above-mentioned parameter & suggests a microcontrollers-based prototype that is very much useful of monitoring the lithium-ion battery.

PAPER 2

2. Jadhav B. Madhuri, and T. Ketan, "intelligent traffic light control system (ITLCS).", proceeding of the 4th IRF international conference, Pune, 16 march 2014. (https://www.researchgate.net/publication/332113197_Smart_Traffic_Control_System_with_Path_Cleara nce_Ability_and_Theft_Vehicle_Detection)

   Summary: - In this paper Ladder logic, function block diagrams, sequential function charts, instruction lists, and structured text are five PLC programming languages that are illustrated in this paper. The methodology used in this study entails counting the number of vehicles using inductive loop sensors and using radio frequency identification technology to identify the authorized priority cases. An illustration of how these sensors will be used can be found in the methodology section. The junction is used to count the number of vehicles in this data collection, and RFID (radio frequency identification) is used to identify priority cases. the system created to manage a four-way intersection.

PAPER 3

3. Sateen Javaid, Ali Sofian, S.P.M.T (2018). Smart traffic management system using internet ifthings. 20th international conference communication technology (ICACT). (Sabeen-Javaid/publication/324464391_Smart_traffic_management_system_using_Internet_of_Things/links/5d99 cc68299bf1c363fbb8f7/Smart-traffic-management-system-using-Internet-of-Things.pdf)

   Summary: - This paper offers a practical response to the daily increase in traffic, especially in large cities, which standard traffic management methods are unable to handle. A smart traffic management system is suggested to more efficiently and effectively handle traffic problems on roads while also taking into account the most recent developments in traffic management systems. More effectively than before, it regulates traffic flow by intelligently adjusting the signal time in accordance with the volume of traffic on the specific roadside. The decentralized approach makes it more efficient and effective because the system continues to function even when a local server or centralized server crashes.

PAPER 4

4. M. S. Arifin, M. R. palash, M. I. Khalil, M. M. S. khan, and M. H. Haque, “a microcontrollerbased smart traffic system” GUBJ. Sci. Eng., vol. 2, no. 1, PP. 40-44, 2015. (https://www.sciencepublishinggroup.com/journal/paperinfo?journalid=236&doi=10.11648/j.ajesa.201 90701.13)

Summary: - This paper proposes a novel intelligent traffic control system based on microcontrollers. This technique permits passing the cars while taking into account the volume of traffic on the roadways,as opposed to changing traffic lights automatically for a predetermined interval. The traffic control system is implemented using an ATMEGA 32 microcontroller and IR sensors. For this, an algorithm is also created. The technology is also implemented and emulated by building a test rig. The outcomes ofthe modelling and experimental test rig validate its suitability for use on various city roads. This intelligent traffic control system doesn't require any additional processing techniques.

PAPER 5

5. A. Patnaik, v. Natarajan, B. Karthikeyan, and P. Surendra, “automatic traffic control system forsignal lane tunnels” 2014 int. conf. adv. Elec. Eng. IC AEE 2014, PP. 1-4, 2014. (https://www.semanticscholar.org/paper/Automatic-traffic-control-system-for-single-lane-Patnaik-Natarajan/426eeebe8503f656d00ac098ea20013742d4a8b9)

Summary: - - This proposed traffic controls signal can significantly avoid accidents in single Len tunnels. It uses and automatic traffic control system for all possible traffic condition. It detects the traffic with IR sensor on either side of tunnel. This automatic traffic control system comprises of novation board logic circuit and ARM context- m0 microcontroller. This traffic control signal logic isa time efficient and human independent system.

PAPER 6

6. Jian-hui li, Shenzhen (CN) “traffic management system includes a data processing unit whichcommunicates with a road leading unit and a vehicle management unit.” US 2012/0169515 A1. PP. 5-7-2012. (https://patents.google.com/patent/US8803705B2/en)

Summary: - This disclosure relates to the traffic management system based on the near field Communications. It comprises a data Processing Unit with the road loading unit that comprise groovesand isolation railing. The Processing Unit receive vehicle identification information and driving direction in formation from vehicle management unit. The isolation Railing can extend or get Retract on the demand of total traffic index. The data analysis module in the data Processing Unit is operate to estimate root condition information and count total traffic demand index for each Road.

CHAPTER 3

3.1 Schematic: -

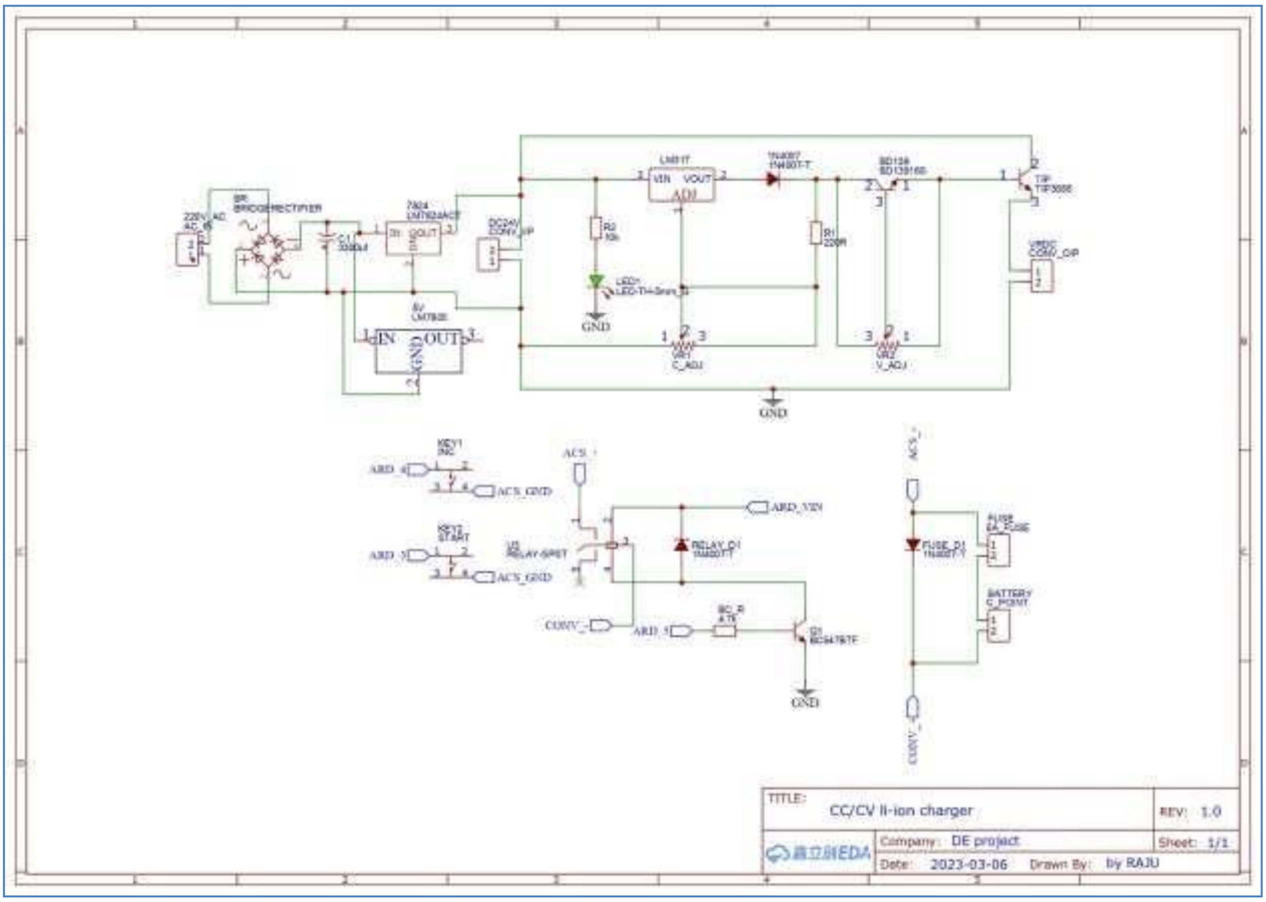

FIGURE 7: SCHEMATIC OF CC/CV LITHIUM – ION BATTERY CHARGER

Here,

We use a ACS712 current sensor to measure the current circulating in the circuit.
Used rectifier circuit to obtain the 24V DC.

Also, we used two push buttons to start and control the overall system and for auto cut-off we used a 12V relay circuit.

We used a buck converter to step-down the 24V DC into required variables and we used one 5A fuse and diode for reverse charging polarity protection.

With converter we used two potentiometers to vary the voltage and current as per required.
We used Arduino mega 2560 to controlling allover system.

3.2 Block Diagram: -

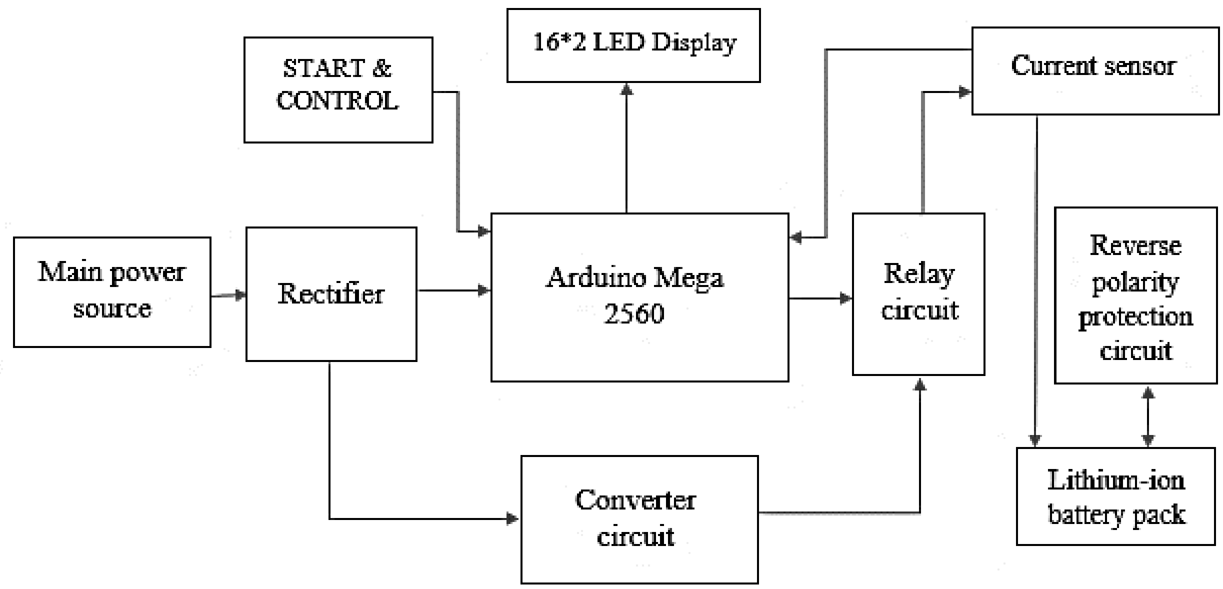

FIGURE 8: BLOCK DIAGRAM OF BMS

3.3 Working: -

Once the charger is turned on, you will be prompted for the battery capacity of the connected device. To increase the battery capacity displayed on the screen, press the INC button.

It will increase by 100mAh on the display for each press. With this charger, batteries with capacities between 1000mAh and 5000mAh can be charged. Any additional increment will reset to 1000mAh once you reach 5000mAh.

When you press the start button, the screen will show the 0.5C charging current that was previously set to the CC/CV buck converter. The current sensor is then calibrated, and the stray magnetic field is then taken into account by Arduino. This may take five to fifteen seconds.

The charger begins examining the CC and CV modes. If the charging current is decreased by 20% from the initial current, CV mode will be displayed. The charging procedure itself is about to begin. Charging stops when the current reaches 0.1C, and you can remove the battery from the charger at that point.

If you set charging current more than 0.7C on buck converter, the charger will detect as over-current and halts charging. You need to bring it below 0.7C (ideally 0.5C).

If the charging process is not finished within the allotted time, the timeout process will start and the charging will be stopped. If you'd like, you can alter the timeout setting in the code.

3.4 Flow Chart: -

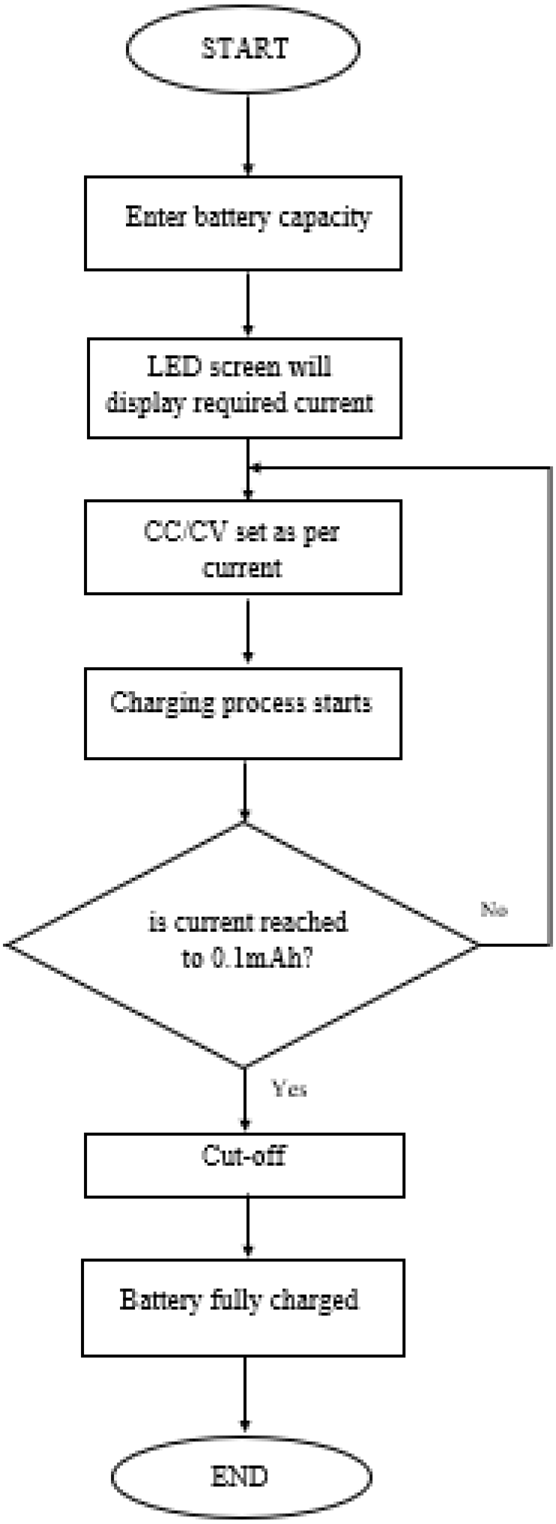

FIGURE 9: FLOW CHART

CHAPTER 4

4.1 Component List: -

- Arduino Mega 2560
- CC/CV converter
- ACS712 current sensor
- 16*2 LCD display
- DC 9V relay
- Fuse and protection diode
- 2 - Push buttons
- Input power supply
- Connecting wires
- Breadboard

4.1.1 Arduino Mega 2560: -

FIGURE 10: ARDUINO MEGA 2560

The Mega 2560 microcontroller board is entirely based on the ATmega2560. It has sixteen analogue inputs, four hardware serial ports (UARTs), a sixteen MHz crystal oscillator, 54 digital input/output pins, of which 15 can be used as PWM outputs, a USB port, an ICSP header, and a reset button. You can use a USB cable to connect it to a laptop or an AC-to-DC adapter to power it initially. It includes everything needed to support the microcontroller. The majority of shields created for the Uno and previous boards, Demilune or Decimal, are compatible with the Mega 2560 board.

4.1.1.2 Technical Specification: -

TABLE: SPECIFICATION OF ATMEGA2560

Microcontroller	**ATmega2560**
Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (Limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
Dc Current Per I/O Pin	20 mA
Dc Current For 3.3v Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

4.1.1.3 Power Source: -

Using an external power source or the USB connection, the Mega 2560 can be powered. Automatic selection of the power source occurs.

Both batteries and AC-to-DC adapters (wall warts) can provide external (non-USB) power. A 2.1mm center-positive plug that fits into the board's energy jack can be used to connect the adapter. In the GND and Vin pin headers of the POWER connector, battery leads can be inserted.
On an external supply ranging from 6 to 20 volts, the board can function. However, the 5V pin might also supply much less than five volts if it is supplied with less than seven volts, and the board might also start to wobble. The voltage regulator can also overheat and harm the circuit board if more than 12V is used. Seven to twelve volts is the recommended range.

4.1.1.4 Controller Memory: -

The ATmega2560 has 4 KB of EEPROM (which can be read and written with the EEPROM library), 8 KB of SRAM, and 256 KB of flash memory for storing code, of which 8 KB is used for the bootloader.

4.1.2 CC/CV Converter: -

The CC/CV power supply, which is really a converter, is in charge of controlling the voltage and current going to the lithium-ion battery. Similar to other voltage buck converters, this constant current/constant voltage converter also has the ability to limit current. Two control potentiometers, one for voltage and the other for current, are present in this circuit. The short circuit current won't go over 1A once the current limit is set to, say, 1A.

The output voltage and output current can both be changed using the two multiturn trim pots. The output voltage can be raised gradually by turning the voltage adjustment (V-ADJ) trim pot clockwise, and it can be lowered gradually by doing the opposite. Similar to this, turning the current adjustment (I-ADJ) trim pot clockwise raises the current limit while doing so anticlockwise lowers it. It is recommended to first adjust the voltage level before adjusting the current level.

4.1.2.1 Set Current Limit: - To set current limit on this type of converter we need a multimeter.

- Set the multimeter at 10A mode.
- Power the buck converter with 9V supply.
- Touch the multimeter leads at buck converter output’s which will short circuit. Note that the output is current limited so it won’t fry the buck converter.
- Using a Phillips screw driver rotate the current potentiometer anti-clockwise to reduce the current and vice-versa to the desired current limit.
- Set current to 0.5C of the battery capacity. (0.5 x Ah)

4.1.2.2 Set Voltage: -

- Set the multimeter to 20VDC range.
- Connect the leads at the output and rotate the voltage potentiometer clockwise to increase voltage and vice-versa.
- Set voltage to 4.20V precisely.

4.1.3 ACS712 Current Sensor: -

To measure the circuit's charging current, we are using an ACS712 (ACS712-05B) 5A (AC/DC) current sensor module. The magnetic effect principle, which states that a conductor carrying current will create a magnetic field around it and that the strength of the magnetic field is directly inversely proportional to the current flow, underlies the operation of this current sensor.

The IC on the breakout board senses the magnetic field and produces a proportional analogue voltage between 0 and 5V. Since it is capable of measuring both AC and DC, the output voltage will be 2.5V in the absence of input current and will change to 5V or 0V if current is applied. The output of this sensor, however, rarely centers at 2.5V and strongly deviates from the actual current value because it is noisy and picks up stray magnetic fields from its surroundings.

As demonstrated, we can add a 0.47uF capacitor of any kind in parallel with the current SMD component to further improve accuracy.

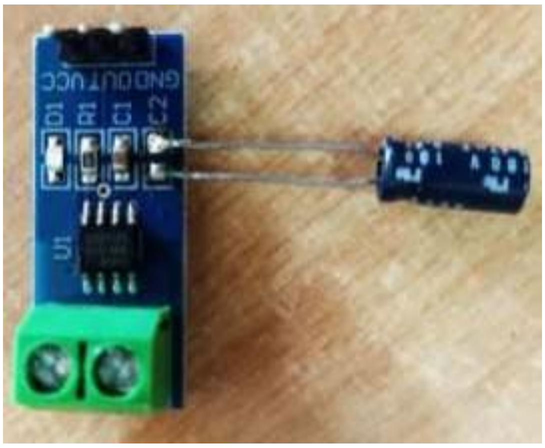

FIGURE 11: ACS712 CURRENT SENSOR

4.1.4 LCD Display & i2c Module: -

We use a "16*2" LCD display to show the battery's current state of charge as well as other crucial charging-related information. In order to simplify the project's wiring, we are employing an I2C LCD adaptor module.

FIGURE 12: LCD & I2C

4.1.5 DC Relay: -

We are using a 12V relay which is activated by a low power NPN transistor. A diode will arrest high voltage back EMF while switching the relay ON and OFF.

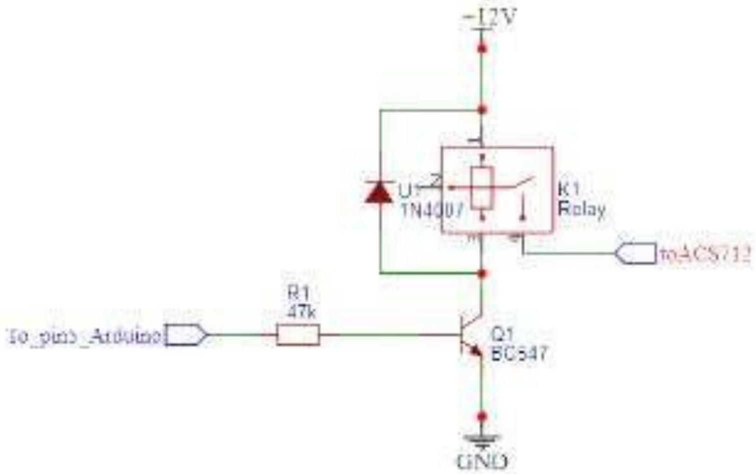

FIGURE 13: RELAY DIAGRAM

4.1.6 Fuse & Diode: -

Simple protection from reverse polarity is provided by the fuse and diode. The diode is reverse biased and does not short circuit the battery to blow the fuse when the battery is attached in the proper polarity. In the case that the polarity is reversed, the diode conducts, creating a short circuit that immediately blows the fuse and stops any additional battery or circuit damage.

FIGURE 14: 5A FUSE

4.1.7 Push Button: -

Two push buttons are given in this circuit: one to begin the charging process and the other to enter the battery capacity that you are going to connect (INC - increment button) (START button).

FIGURE 15: PUSH BUTTON

4.1.8 Input Power Supply: -

In our test setup, a 2000mAh battery was charged with a 1A current limit using 24V 2A rectified DC (at converter).

CHAPTER 5

5.1 Program Code: -

```
#include "ACS712.h"
#include <EEPROM.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);
#define sensorInput A0
ACS712 sensor(ACS712_05B, sensorInput);

//------ Time out Setting -------- //
int h_lt = 4; // in hrs
int m_lt = 20; // in min
//_____________________________________//

const int relay = 5;
const int inc = 4;
const int ok = 3;
int address = 0;
int batt_cap;
int current_lt = 0;
float peak_I_lt = 0;
float cut_off = 0;
boolean set_batt = true;
boolean var = true;
int i = 0;
int hrs = 0;
int Min = 0;
int sec = 0;
float  currentReading;
float CV_current = 0;
void setup()
{
  pinMode(relay, OUTPUT);
  digitalWrite(relay, LOW);
  pinMode(inc, INPUT_PULLUP);
  pinMode(ok, INPUT_PULLUP);
  lcd.init();
  lcd.backlight();
  EEPROM.get(address, batt_cap);
  if (batt_cap < 1000)
  {
    EEPROM.put(address, 1000);
  }
  lcd.clear();
  while (set_batt)
  {
    lcd.setCursor(0, 0);
    lcd.print("Enter capacity:");
    lcd.setCursor(0, 1);
    EEPROM.get(address, batt_cap);
    lcd.print(batt_cap);
    lcd.print(" mAh");
    if (digitalRead(inc) == LOW)
    {
      while (var)
      {
        if (digitalRead(ok) == LOW) var = false;
```

```
        if (digitalRead(inc) == LOW)
        {
          lcd.setCursor(0, 1);
          batt_cap = batt_cap + 100;
          if (batt_cap > 5000) batt_cap = 1000;
          lcd.print(batt_cap);
          lcd.print(" mAh");
          delay(250);
        }
      }
    }
    if (digitalRead(ok) == LOW)
    {
      EEPROM.put(address, batt_cap);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Your battery");
      lcd.setCursor(0, 1);
      lcd.print("is ");
      lcd.print(batt_cap);
      lcd.print(" mAh.");
      delay(2000);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Set current");
      lcd.setCursor(0, 1);
      lcd.print("limit = ");
      current_lt = batt_cap * 0.5;
      peak_I_lt = batt_cap * 0.7 * 0.001;
      cut_off = batt_cap * 0.1 * 0.001;
      lcd.print(current_lt);
      lcd.print(" mA");
      delay(3000);
      set_batt = false;
    }
  }
  current_calib();
  CCCV();
}

void loop()
{
  for (i = 0; i < 10; i++)
  {
    currentReading = sensor.getCurrentDC();
    delay(100);
  }
  timer();
  lcd.clear();
  lcd.setCursor(0, 0);
  if (currentReading <= CV_current)
  {
    lcd.print("MODE:CV");
  }
  if (currentReading > CV_current)
  {
    lcd.print("MODE:CC");
  }
  lcd.setCursor(0, 1);
  lcd.print("CURRENT: ");
```

```
  lcd.print(currentReading);
  lcd.print(" A");
  if (currentReading <= cut_off)
  {
    for (i = 0; i < 10; i++)
    {
      currentReading = sensor.getCurrentDC();
      delay(100);
    }
    if (currentReading <= cut_off)
    {
      digitalWrite(relay, LOW);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("BATTERY FULLY");
      lcd.setCursor(0, 1);
      lcd.print("CHARGED.");
      while (true) {}
    }
  }
  currentReading = sensor.getCurrentDC();
  if (currentReading >= peak_I_lt)
  {
    digitalWrite(relay, LOW);
    current_calib();
    digitalWrite(relay, HIGH);
    delay(3000);
    currentReading = sensor.getCurrentDC();
    if (currentReading >= peak_I_lt)
    {
      while (true)
      {
        digitalWrite(relay, LOW);
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Overcharging");
        lcd.setCursor(0, 1);
        lcd.print("current detected");
        delay(2000);
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Charging halted.");
        lcd.setCursor(0, 1);
        lcd.print("Press reset.");
        delay(2000);
      }
    }
  }
}

void current_calib()
{
  lcd.clear();
  lcd.print("Auto Calibrating");
  lcd.setCursor(0, 1);
  lcd.print("Current Sensor.");
  sensor.calibrate();
  delay(1000);
  currentReading = sensor.getCurrentDC();
  if (currentReading >= 0.02 || currentReading <= -0.02 )
```

```
  {
    sensor.calibrate();
    delay(5000);
    currentReading = sensor.getCurrentDC();
    if (currentReading >= 0.02)
    {
      current_calib();
    }
  }
}

void timer()
{
  sec = sec + 1;
  if (sec == 60)
  {
    sec = 0;
    Min = Min + 1;
    re_calib();
  }
  if (Min == 60)
  {
    Min = 0;
    hrs = hrs + 1;
  }
  if (hrs == h_lt && Min == m_lt)
  {
    digitalWrite(relay, LOW);
    while (true)
    {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Time out !!!");
      lcd.setCursor(0, 1);
      lcd.print("Charge Completed");
      delay(2000);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print(" Press reset");
      lcd.setCursor(0, 1);
      lcd.print("****************");
      delay(2000);
    }
  }
}

void re_calib()
{
  if (Min == 10 || Min == 20 || Min == 30 || Min == 40 ||
      Min == 50 || Min == 60 && sec == 0)
  {
    digitalWrite(relay, LOW);
    current_calib();
    digitalWrite(relay, HIGH);
  }
}

void CCCV()
{
  lcd.clear();
```

```
  lcd.setCursor(0, 0);
  lcd.print("Analyzing CC/CV");
  lcd.setCursor(0, 1);
  lcd.print("Modes...");
  digitalWrite(relay, HIGH);
  for (i = 0; i < 20; i++)
  {
    currentReading = sensor.getCurrentDC();
    delay(100);
  }
  if (currentReading <= -0.1)
  {
    while (true)
    {
      digitalWrite(relay, LOW);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Reverse current");
      lcd.setCursor(0, 1);
      lcd.print("detected.");
      delay(2000);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Flip current");
      lcd.setCursor(0, 1);
      lcd.print("sensor polarity.");
      delay(2000);
    }
  }
  CV_current = currentReading * 0.8;
}
```

5.2 Working Model: -

FIGURE 16: WORKING MODEL

5.3 Guidelines on Standards: -

IEC 62133: This is an international standard that outlines safety requirements for rechargeable lithium- ion batteries. It includes requirements for chargers and charging circuits, as well as requirements for the batteries themselves.

UL 1642: This is a safety standard for lithium-ion batteries. It includes requirements for the materials used in the batteries, as well as requirements for testing the batteries under various conditions.

IEC 60601: This is a standard that applies to medical electrical equipment, including battery-powered devices. It includes requirements for the safety and performance of the equipment, as well as requirements for electromagnetic compatibility.

IEC 62368: This is a standard that applies to audio/video, information and communication technology equipment. It specifies safety requirements for equipment that uses mains voltage or has the potential to generate hazardous energy, such as a lithium-ion charger.

IEEE 1725: This is a standard that outlines safety requirements for lithium-ion batteries used in portable devices, including requirements for charging circuits and charging algorithms.

Website: - https://www.intertek.com/energy-storage/battery-safety/iec-62133/

Conclusion: -

Lithium-ion battery have found their application in various industries because of their high energy density and 99% efficiency. But if they are not orated within an optimal operating range that is determined by parameters such as temperature, charging and discharging current and voltage, they are bound to fail and age quickly and this may even lead thermal breakdown.

Therefore, it is important to monitor these parameters and whenever the battery exceeds the prescribed limits and warning should be generated. This problem is solved using the prototype that monitors current using an ACS712 current sensor and voltage using the inbuilt ADC of the microcontroller. All of the indication are shown on LED screen as well as the real time readings.

Microcontroller basic and Arduino mega is capable of monitoring lithium-ion battery with a few enhancements and can provide a real time solution that is required for expecting energy from lithium-ion battery efficiency and safety.

Future work: -

Although the presented lithium-ion battery charger based on microcontroller is itself a complete package and its capable for multitasking such as charging the battery, monitoring the battery and implementing the safety protocols, some further improvisations and innovations can also be experimented with it such as replacing the AC power supply with solar power, introducing wireless/magnet-based charging, energy management etc in order to increase the speed and efficiency of the charger.

FIGURE 17: PICTURE WITH OUR MENTOR

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