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Designing of IoT Enabled Smart EV Charging Station

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Abstract.

As more and more countries move towards pollution-free transportation, electric vehicles are becoming more and more popular all over the world and as the number of electric vehicles increases, electric vehicle charging infrastructure will also be a basic need. An IoT-enabled system would certainly streamline electric vehicle charging efficiency. This method is useful for transport systems and V2G systems. This proposed system will improve urban planning and facilitate city life. With IoT, we can easily manage the entire V2G system, which will save time and money. This work includes the realization of a smart application to connect to the network. Google Firebase was used, a real-time database used primarily for synchronizing data, its cloud-based monitoring and management of the smart charger station for electric vehicles (EVs) to improve the existing charging infrastructure. The data based on real-time information and the availability of reserves at charging stations could be uploaded to the users to help them locate the nearest charging station for an EV.

1 Introduction

The vehicle transport system is rapidly increasing toward a sustainable electric vehicle population and hence the penetration of EVs is deepening in the market creating the need for charging infrastructure. Electric vehicles (EVs) represent a growing opportunity for DISCOMs to capture new sources of demand flexibility while increasing revenue from a customer class that will grow significantly over the next decade. The Indian vehicle market is at the early stages of electrification and this is a great opportunity to make an entry into the Indian market. This project is based on the charging infrastructure of EVs, also we gave a software touch to this project for users' convenience. If managed correctly and planned, charging stations can be a huge help for us.

Index Terms: IoT (Internet of Things), EVs (Electric Vehicles), Charging station, PCB (Printed Circuit Board), Smart EV charging station

2 Literature Review

- Jose P. Martins et.al this paper is titled **“IoT and Blockchain Paradigms for EV Charging System”**. In this research work, the authors applied the Internet of Things technology with a decentralised blockchain approach to handle the EV charging process in shared spaces.{1}
- Tejal Hatim et.al. this paper is titled **“IoT Based Smart Charging of Electric Vehicle”**. The paper focuses on IoT and App development for mostly autonomous payment and charging of EVs. The methods used in this paper serve as the basis for the hardware architecture of this project. {2}
- Arunkumar P et.al. This paper is titled **“IOT Enabled smart charging stations for Electric vehicles”.**The paper describes a solution to the problem of imbalanced load on the Grid, and proposes a network architecture for the grid of interconnected charging stations. For this project, hardware implementation suggestions were taken from the literature.{3}
- Apoorv Prajapati et.al. This paper is titled **“IOT Enabled smart charging stations for Electric vehicles”**. This research work presents a product and system-based EV charging framework outlined and worked around the thoughts of smart charge planning, multiplexing (interfacing various vehicles to each circuit) and adaptability.{4}

3 Hardware

3.1 Hardware Topology:

With the Hardware, (or Electronics and Electrical Systems), a modular approach was chosen. This makes the system loosely coupled; the components can be easily swapped out for better/ new components(in the case of any failures or upgrades). This approach meant that the system would be easily serviceable, repairable and adaptable to any requirement if the need arose.

To implement this approach, the hardware was broken into 3 major categories:

1. Electrical Subsystem
2. Electronics Comtrol and Communication Subsystem
3. Electronics Measurement Subsystem

It was decided that the system must contain 3 major parts responsible for the categories described above.
A PCB (Printed Circuit Board) was designed for 2 of the significant custom subsystems and the Electrical Subsystem was made to accommodate off-the-shelf components. Figure 3.1 shows the hardware topology of the system.

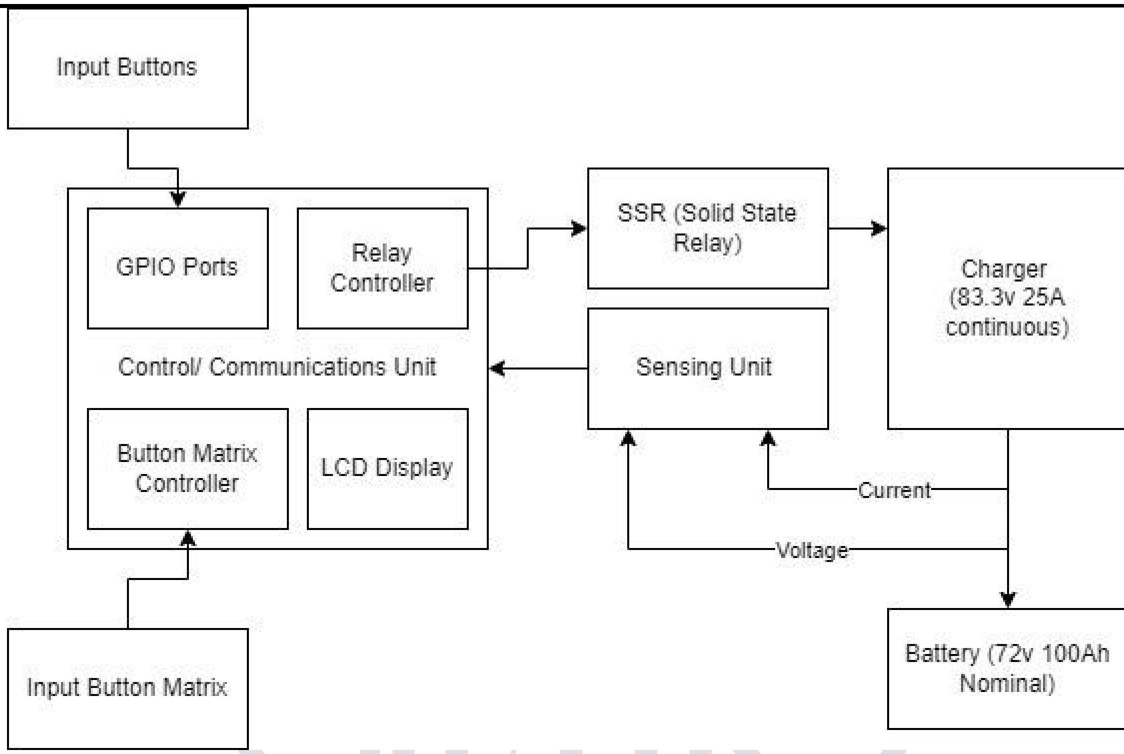

Figure 3.1: Hardware Topology

4 Calculations:

4.1 Temperature Rise Calculations:

The Safety Factor is considered to be 1.2, or 120% of nominal current flow. Therefore, I = 25 x 1.2, or 30A.

CASE 1:

For measuring a current of 30A, with an internal conductor resistance of 1.2 mΩ (as per datasheet of ACS712), from ohm's Law, we get the minimum power dissipation of IC (without the power dissipation of the sensing circuit) as

$P = I^2R$

Substituting values, considering safety factor of 1.2, we get:

P = 1.08W or ~1080 mW

Now, Temperature rise {1} based on this power loss is:

$T_J = T_A + (\theta_{JA} \text{ x } P)$ ….[1]

Where T_J is the junction temperature of IC in °C,

T_A is the Ambient temperature in °C,

θ_{JA} is the Junction-to-Ambient thermal resistance of IC in °C/W, and

P is the power dissipated by the IC in Watts.

From [1], we get:

TJ = 25 + (23 x 1.08)

TJ = 25 + 24.84

T_J = 49.84 °C

Rise in Temperature = 24.84°C

CASE 2:

For measuring a current of 30A with 2 ICs, with an internal conductor resistance of 1.2 mΩ,

$P = I^2R$

Substituting values based on case 2 (assuming equal current flow through both sensors, I/2), we get:

P =0.27W or ~270 mW

From [1], We get:

T_J = 25 + 6.21

T_J = 31.21 °C

Rise in Temperature = 6.21°C

CASE 3:

For measuring a current of 30A with 3 ICs, with an internal conductor resistance of 1.2 mΩ,

$P = I^2R$

Substituting values based on case 3 (assuming equal current flow through all sensors, I/3), we get:

P = 0.12W or ~120 mW

Now, Temperature rise based on this power loss is:

$T_J = T_A + (\theta_{JA} \times P)$

From [1], we get:

T_J = 25 + 2.76

T_J = 27.76 °C

Rise in Temperature = 2.76°C

Considering these calculations, the PCB design must feature 3 ACS712 sensors for current measurement, since variables such as temperature rise due to variation in the placement of thermal vias in the PCB, variation in the internal resistance of the conductor in IC etc have not been taken into account.

The Trace width calculations {2} for the pads is as follows:

First, the Area is calculated:

$$\text{Area}[\text{mil}^2] = \left(\frac{\text{Current}[A]}{(k * \text{Temperature Rise}[℃])^{b}}\right)^{\frac{1}{c}}$$

Then, the Width is calculated:

$$\text{Width}[\text{mils}] = \frac{\text{Area}[\text{mils}^2]}{\text{Thickness}[oz] * 1.378[\text{mils}/oz]}$$

As per IPC-2221, for external layers, k = 0.048, b = 0.44, and c = 0.725

where k, b, and c are constants obtained from curve fitting to the IPC-2221 curves

For this specific case, the trace width for a trace carrying 10A through a copper layer of 1 oz/ft^2 is 283 mil or 7.9mm. This trace width can be reduced by half by replicating the same trace on the back copper layer of the board with the same thickness, i.e, a trace width of 4mm on either side (connected through enough thermal vias) is sufficient to carry the required current of 30A through 1 IC. Additionally, the removal of the solder mask layer and the addition of a convex-shaped blob of solder on the top and bottom conductors shall further increase the current carrying capacity and improve the thermal performance of the traces.

Special care has been taken in the design of the Power measurement PCB to eliminate or minimise ground loops.

5 PCB design:- Software:- Autodesk Eagle

5.1 Measurement PCB:

Based on the calculations and guidelines in section 4, the measurement PCB was designed. It features:

- An ADS1115 16-bit 4-channel ADC for Voltage Measurement.
- 3 x ACS712 Hall-effect current sensor ICs for current Measurement.
- A linear voltage regulator for low noise (AC ripple) in supply, resulting in better performance for Analog measurements, and
- An optocoupler-based isolated digital voltage sensor to detect the state of connection with the vehicle battery.

All measurements have been made on the DC output of the charger in section 6.

Advantages of using hall-effect-based current sensing:

1. Total Isolation
2. Repeatable Measurements
3. Low-Cost

Disadvantages:

1. Sensor Drift
2. Initial Calibration Required

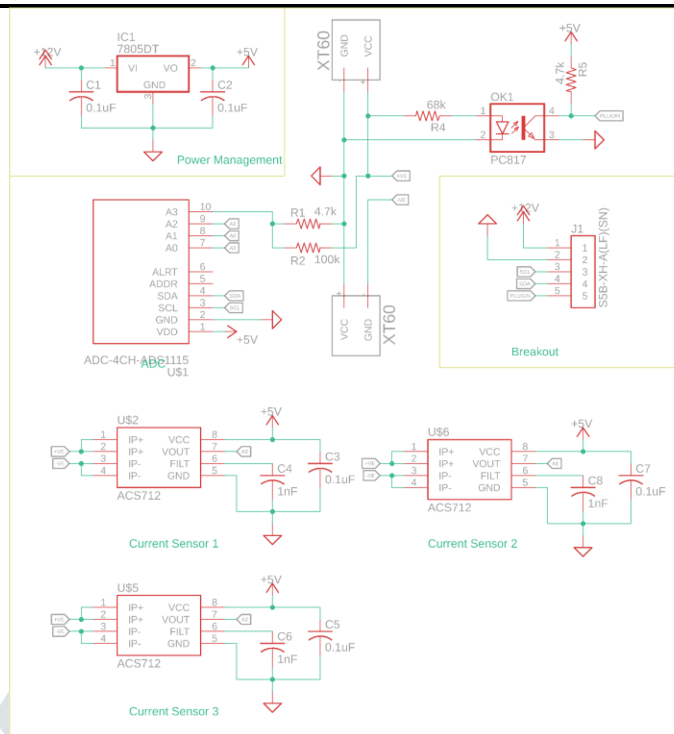

Figure 5.1.1: Measurement PCB Schematic

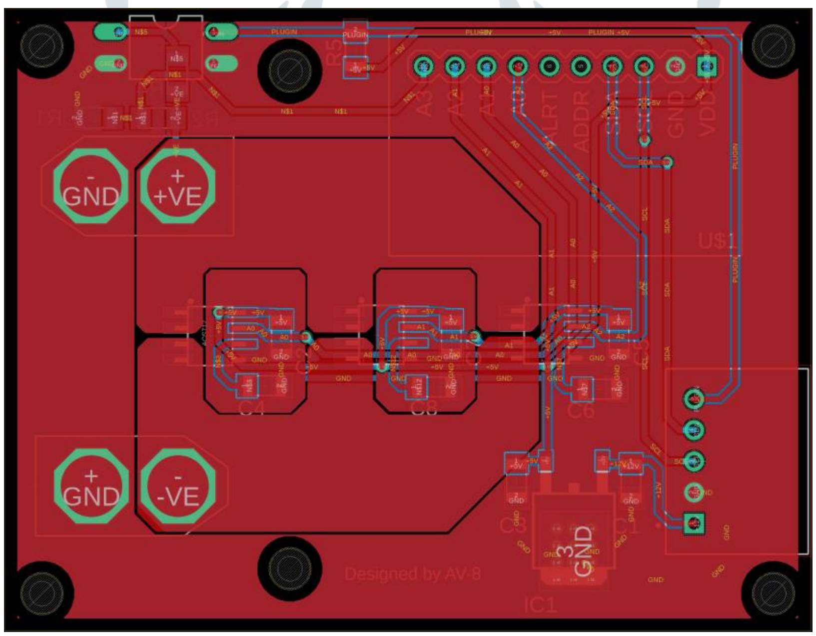

Figure 5.1.2: Measurement PCB Layout

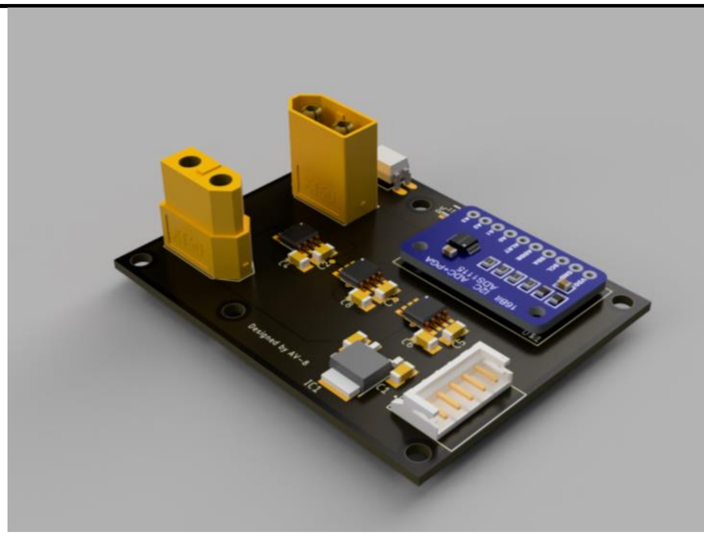

Figure 5.1.3: Measurement PCB render

5.2 Control PCB

- Keeping the modular design in mind, the control PCB was fabricated. It features:: An ESP32 (Microcontroller from Espressif Systems) based development board with WiFi and BLE capabilities for communication with the cloud and the user respectively.
- An I2C-enabled I/O expander for reading user inputs
- Breakouts for pushbuttons, displays and user I/O, and
- A buck converter for stepping down the Voltage from 12v DC to 3.3v DC for the Microcontroller.

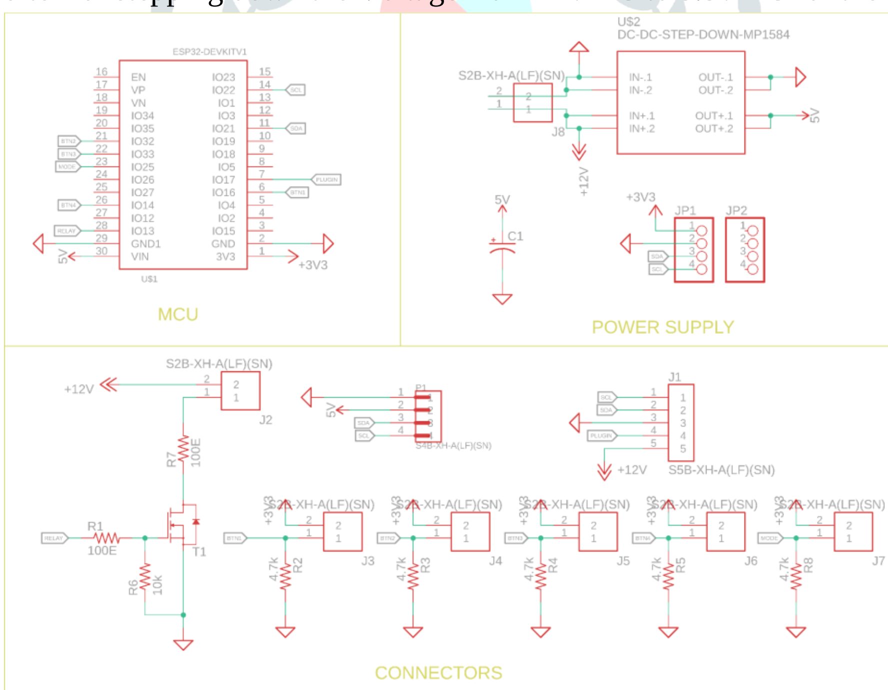

Figure 1.4: Control PCB Schematic

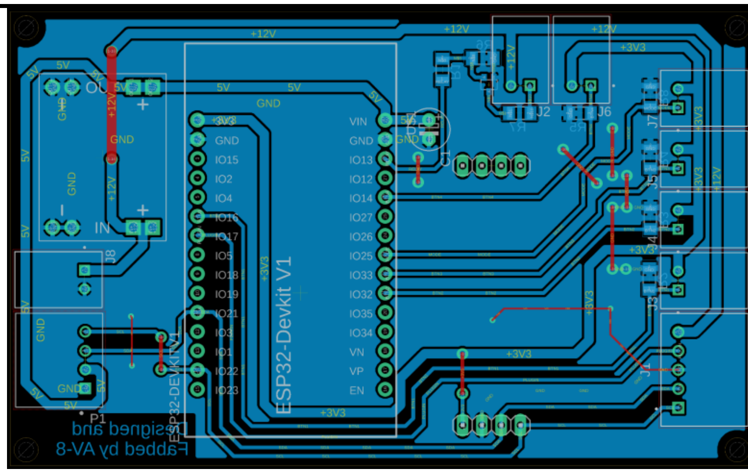

Figure 1.5: Control PCB Layout

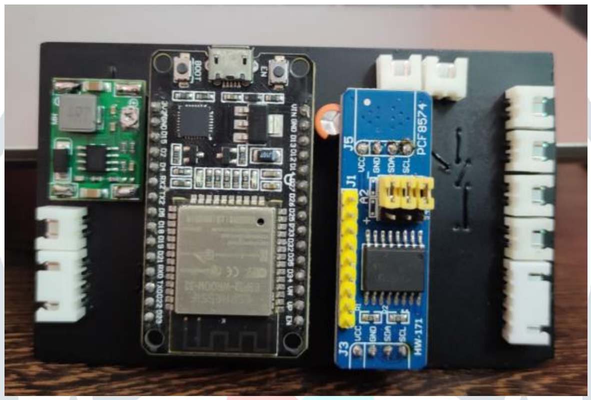

Figure 1.6: Control PCB Image

6 Charger

6.1 Charger Specifications:

The determining factor for the selection of charger was the battery and its specifications. Factors affecting the charger specifications are:

- Recommended charging voltage
- Charging method, and
- Recommended charging current.

Other Specifications are listed in table 6.1.1.

Battery Pack EV (73.6V 100Ah)		
General Characteristics	Cell Type	**LFP Prismatic**
	Battery Capacity (Ah)	**100Ah**
	Number of cells in series	**23**
	Number of cells in parallel	**1**
	Total number of cells	**23**
Electrical characteristics	Battery Nominal voltage (V)	**73.6**
	Battery Rated Energy (kWh)	**7.36**

and Protection Specifications	Battery Operating voltage range (V)	**57.5V ~ 83.95V**
	Recommended Charging mode	**CC-CV**
	Recommended Charging voltage (V)	**83.95V**
	Recommended Charging current (A)	**25**
	Cell low cut off voltage (V)	**2.5**
	Cell high cut cutoff voltage (V)	**3.65**
	Cell Nominal Voltage (V)	**3.2**
	Operating temperature (charging)	0°C to 45°C
	Operating temperature (Discharging)	-20°C to 60°C
	Communication Protocol	CAN 2.0, Bluetooth
	Module dimension (LXWXH) in mm	**404×410×285**
	Life cycles	**5000**

Table 6.1.1: Battery Specifications

Specification	Value	Unit
Maximum Charging Voltage	83.95	V
Maximum Charging Current	25.5	A
Nominal Charging Voltage	73.5	V
Nominal Charging Current	25	A
Weight	7	kg
Operating Temperature Range	-40 / +80	°C
Ingress Protection rating	IP44	----
Nominal Output Power	2500	W

Table 6.1.2: Charger Specifications

7 Firmware

In this project, firmware plays a major role as the entire functioning of the machine is dependent on it. The firmware is responsible for taking in user inputs, processing them, sending and receiving data from the servers and controlling the machine based on all the variables.

The firmware schema defines how the firmware reacts to user inputs, errors, unexpected conditions and failure situations. Figure 7.1 describes the firmware schema for the same.

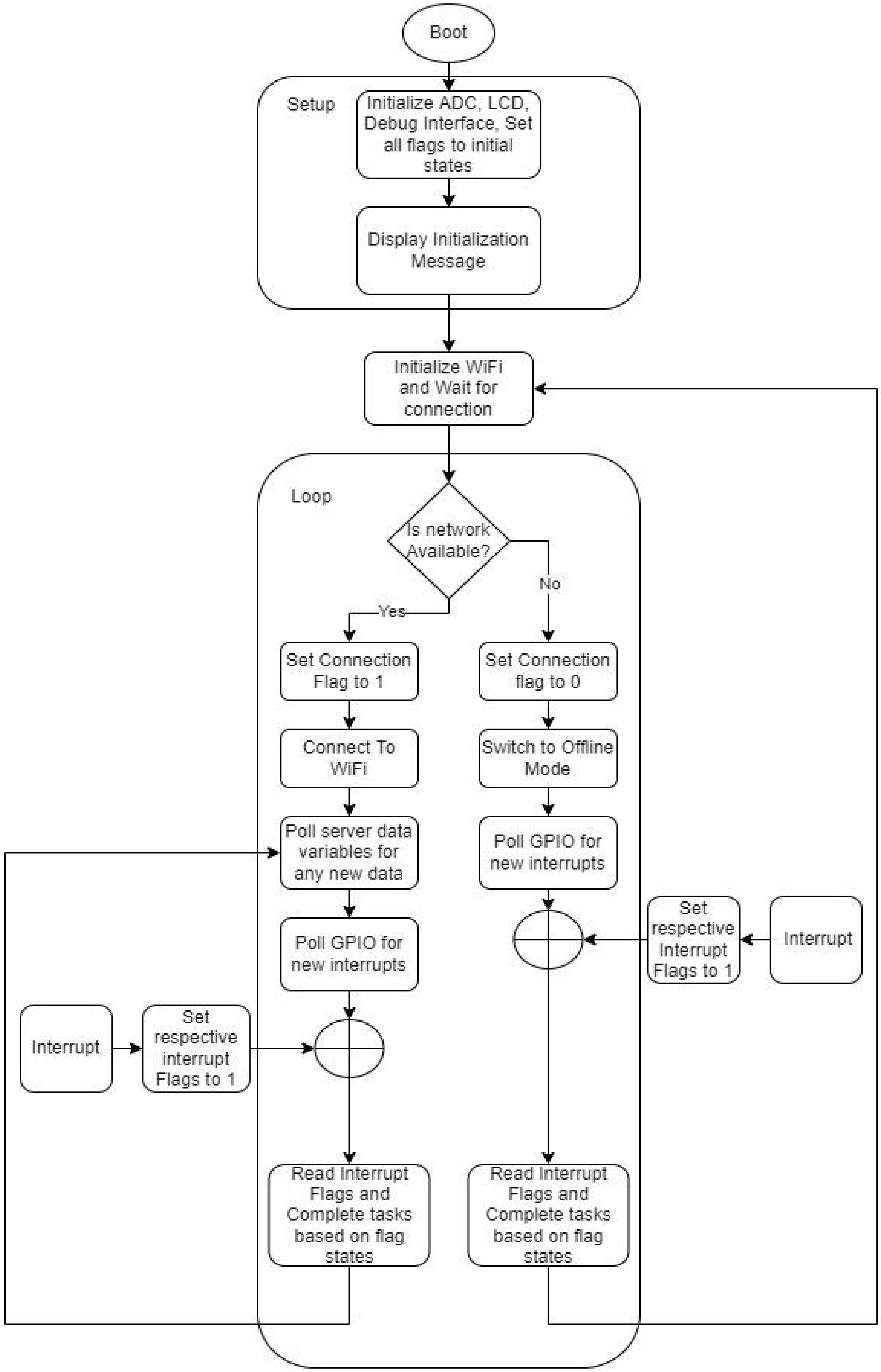

Figure 7.1: Firmware Schema

8 Software:

The software provides the major part of the User Experience and User Interface. Data is sent to Google Firebase's RealTime DataBase and displayed on the website, developed using HTML, CSS and Javascript. The user also has the option to book the nearby charging stations with the help of a slot booking service. As the user is registered for the first time, the vehicle type and other details are stored. This data is then used to match the plug type of the vehicle of the user and display compatible charging stations the next time the service is used.

8.1 User Flow

User flow describes the steps followed by the user during the use of the service.

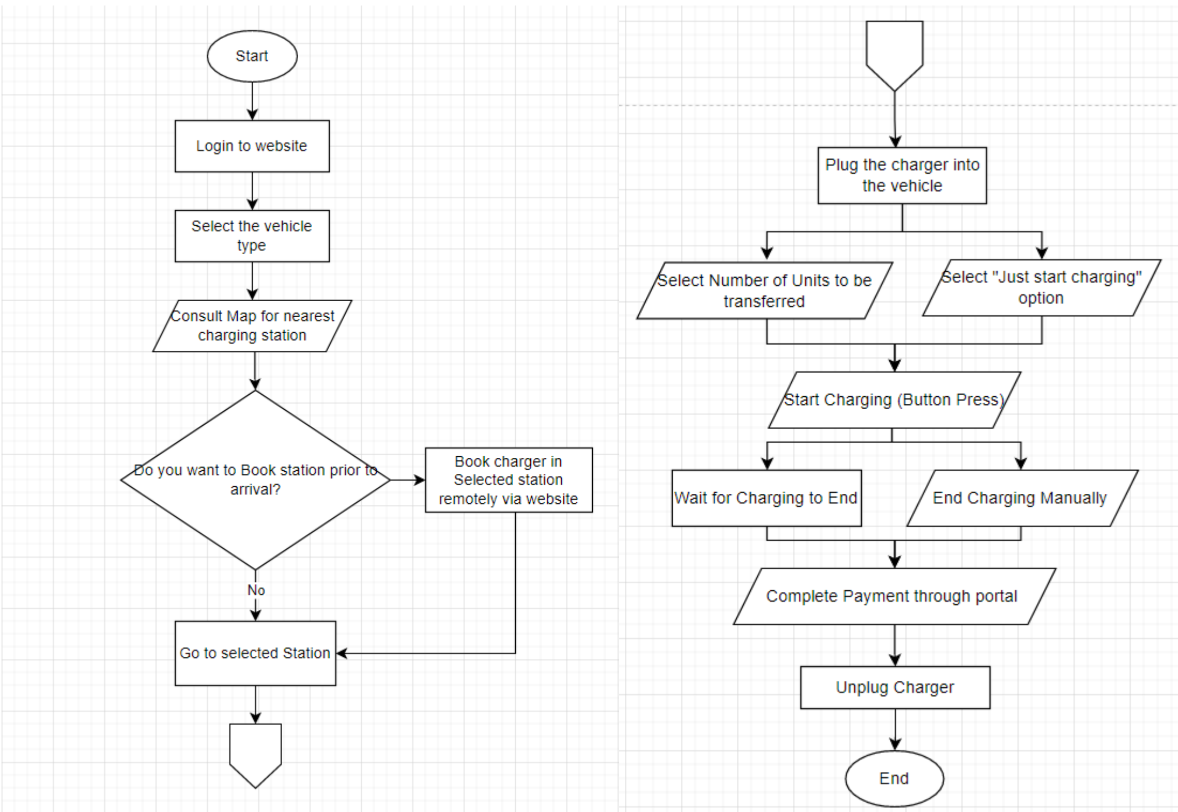

Figure 8.1.1: User Flow Diagram

8.2 Webpages

Responsive webpages were created to serve as the web interface of the project. Figures 8.2.1 - 8.2.4

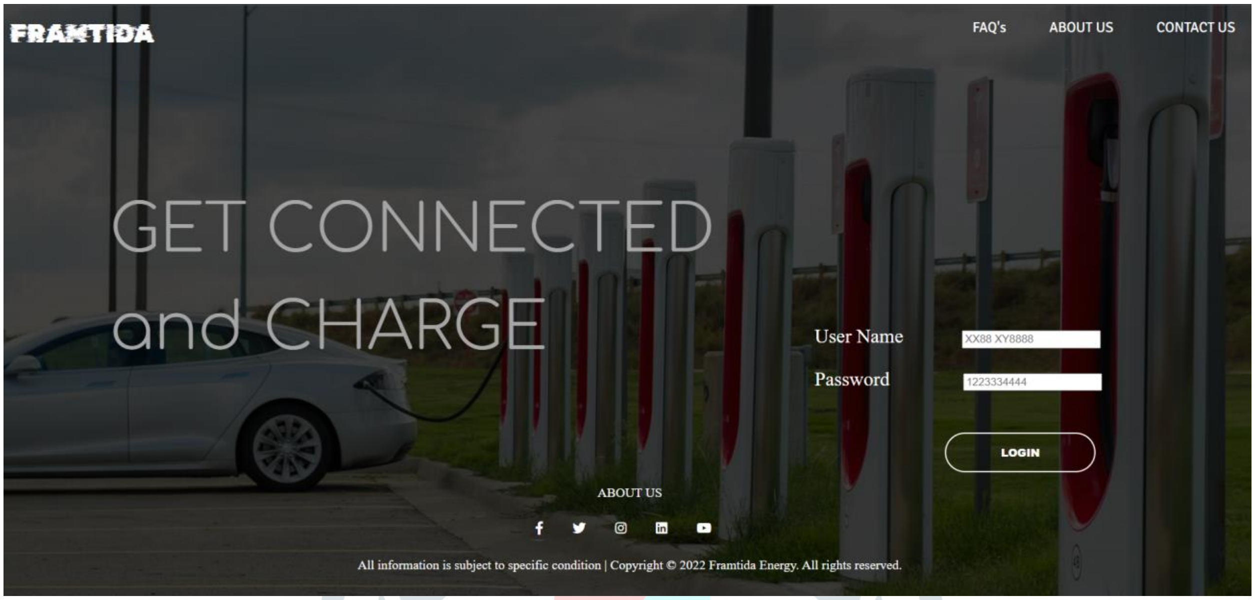

Figure 8.2.1: Landing Page

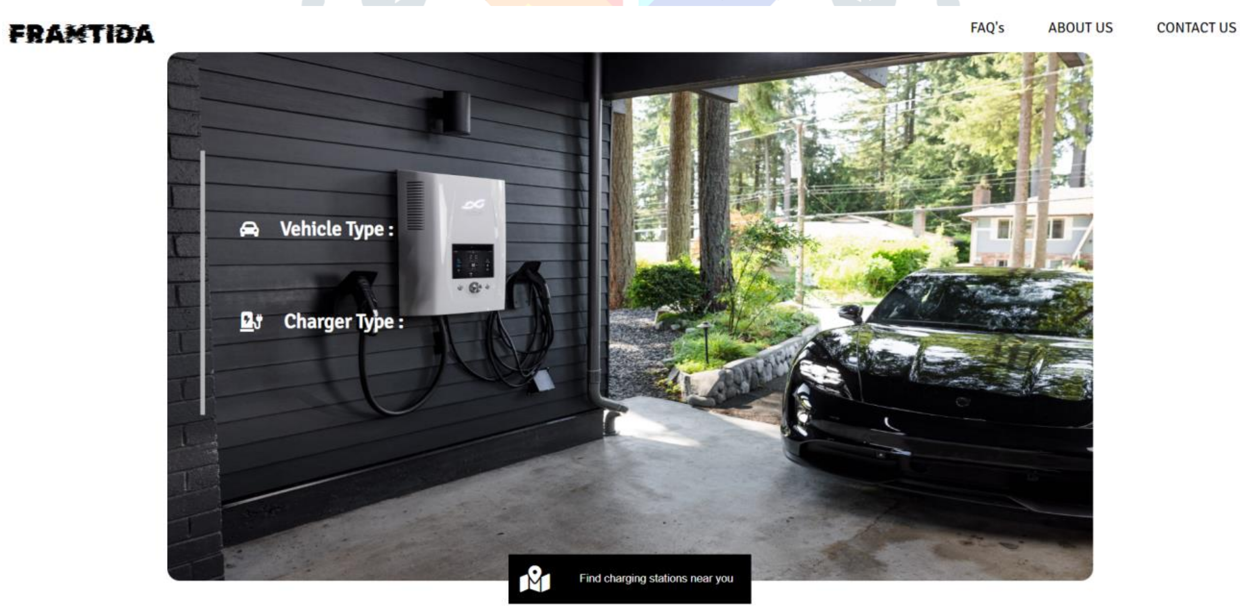

Figure 8.2.2: Charge Page

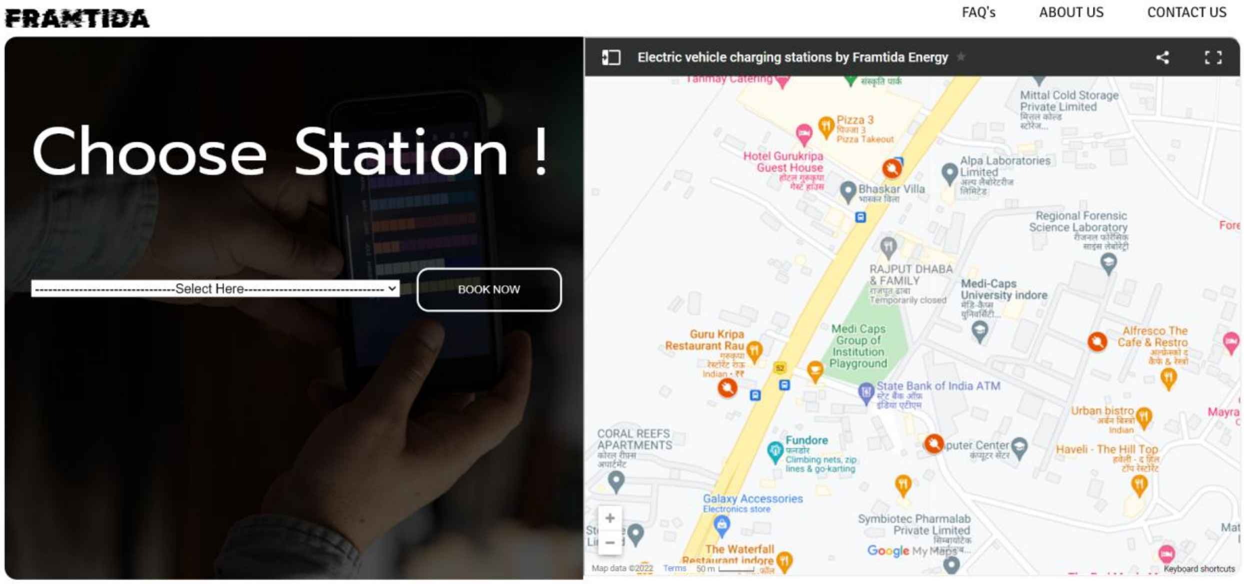

Figure 8.2.3: Maps and Location page

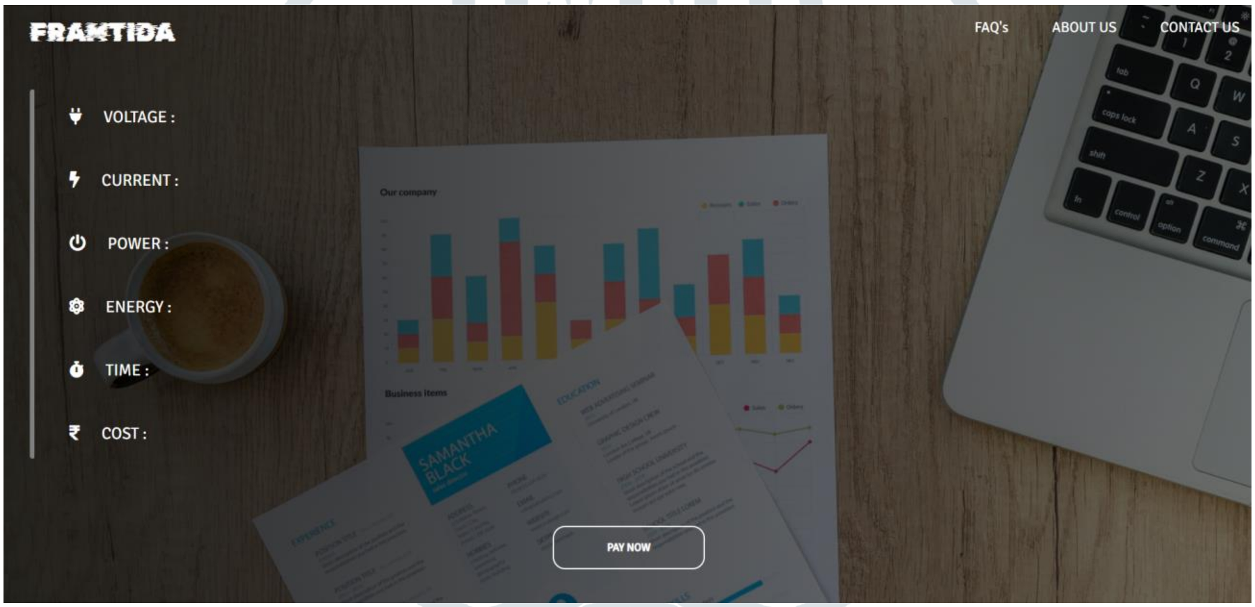

Figure 8.2.4: Charging Data Page

9 Conclusion.

This paper contains detailed description of the design process and ideologies used in the construction of a 2.5kW EVSE, to be used with an E-rickshaw(3W) with LFP Battery pack. With the advent of Electric vehicles in India and the world, EVSEs similar to one described here shall prove to be the major stepping stones in the growth of this sector.

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