

CASCADED MODULAR BATTERY SYSTEM IN ELECTRIC VEHICLE

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in
Electrical and Electronics Engineering

By

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

SCHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Nanthitha P (38140036)** and **Pavithra S (38140037)** who carried out the project entitled "**CASCADED MODULAR BATTERY SYSTEM IN ELECTRIC VEHICLE**" under my supervision from November 2021 to May 2022.

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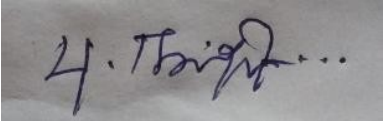
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DECLARATION

We **Nanthitha P** (Reg. No. 38140036) and **Pavithra S** (Reg. No. 38140037) hereby declare that the Project Report entitled “**CASCADED MODULAR BATTERY SYSTEM IN ELECTRIC VEHICLE**” done by us under the guidance of **Dr. S. JAYAPRAKASH** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

1.

A rectangular image showing a handwritten signature in black ink on a light-colored background. The signature appears to be 'N. Thirupathi...'.

2.

A rectangular image showing a handwritten signature in blue ink on a light-colored background. The signature appears to be 'S. Pavithra...'.

DATE : 20.04.2022

SIGNATURE OF THE CANDIDATES

PLACE: KRISHNAGIRI

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ABSTRACT

Building an Energy Storage System is now widely regarded as critical for maximum power demand reduction and stabilization, particularly in autonomous energy systems. This project's control strategy is based on a cascade of an external controller that controls active and reactive power to provide a reference signal and an internal current controller that generates gating signals for inverter semiconductor switches. The battery and charging station govern the duty cycle of the electric vehicle to charge it in a short period. The envisioned solution is a cascaded modular battery system for charging electric automobiles. Connect these in series to boost the energy voltage for motor feeding.

Because of the differences in electrochemical properties, a state of balance (SOC) and voltage level imbalance will occur between diverse cells. A single-phase power source is usually used to charge electric vehicles. A solar panel was installed. While driving, we can store energy. As a result, we'll save time and be able to cover more ground. The cost of charging will be less than that of electric fuelling.

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LIST OF SYMBOLS AND ABBREVIATIONS

V	- Voltage
A	- Ampere
C	- Capacitor
I	- Current
LCD	- Liquid Crystal Display
LED	- Light Emitting Diode
DC	- Direct Current
AC	- Alternating Current
IDE	- Integrated Development Environment
I/O	- Input/Output
USB	- Universal Serial Bus
CRT	- Cathode-Ray Tube
IR	- Infrared
CMBS	- Cascaded Modular Battery System
TCBS	- Traditional Cascaded Battery System
SOC	- State-of-charge
PWM	- Pulse Width Modulation
EV	- Electric Vehicles
LIB	- Lithium-Ion Batteries
ADC	- Analog-to-Digital Converter

IC	-	Integrated Circuit
VCC	-	Voltage Common Collector
GND	-	Ground
RC	-	Resistance-Capacitance
ASSR	-	Auditory Steady-State
RGB	-	ResponseRed RG Green Blue
TIA	-	Trans impedance Amplifier
CPU	-	Central Processing Unit
RAM	-	Random-Access Memory
PV	-	Photo voltaics
MPP	-	Maximum Power Point
VDC	-	Volts of Direct Current
SCR	-	Silicon Controlled Rectifier
BMS	-	Battery Management System

CHAPTER-1

INTRODUCTION

1.1 GENERAL INTRODUCTION

In the automobile business, electric vehicles play a vital role. Electric vehicles have several advantages, including being better for the environment, causing less pollution, requiring no gasoline, and emitting no pollutants. The charging duration, which takes 8 to 11 hours from empty to full using a charging port, is the main issue with electric vehicles. The dynamic wireless power transfer method has been used over the last decades to reduce charging time, battery capacity, and weight. Over the last few decades, the variable wireless power transfer method has been employed to cut charging time, battery capacity, and weight.

Efficiency and power factor are statistically significant in explaining power transmission capabilities and lowering operational costs. The cascaded modular battery has a wide range of applications in high and medium power applications, as it can manage high power and current. Cascaded modular batteries have a low switching frequency, which allows them to generate greater voltage in each unit. A hybrid approach of cascaded multilevel converter on three-level cells can be used in an existing system to generate additional voltage levels in each cell while keeping the energy in the battery cells. It can be obtained using a combination of Three-Level strategies effective clamping approach and an inverted H-bridge method. The series connection of the H-bridge connects all three levels together, with each level having its own dc source. With the less cascaded units, the output ac voltage can be obtained at each level and may be almost perfect sinusoidal. With the help of an inverter, the output voltage can be sent to the motor vehicle. For practical usage, the existing technology generates conversations on an energy storage system based on a multilevel cascade pulse width-modulated converter.

1.2 AIM OF THE PROJECT

At the end of its lifetime, battery electric (EV) lithium ion batteries (LIBs) are repurposed for stationary energy storage. Methods To tackle the concerns of key stakeholders corresponding to the both first (EV) and secondary life (mounted energy storage) battery applications, two systems were examined together. An equal lead-acid (PbA) battery was used to define the environmental feasibility criterion.

The distribution of environmental effects related to the manufacturing LIBs from across EV and stationary usage systems was a significant methodological difficulty addressed. The model also examined the impact of variables such as the percent of battery cells that may be reused, the service life of reconditioned cells, and the efficiency of PbA batteries. Under conservative estimates, cascade reuse of a LIB in permanent energy storage can lower net cumulative energy consumption and global warming capacity by 15%, and up to 70% under optimum refurbishing and reuse circumstances.

When post-EV LIB cells were directly compared to a new PbA scheme for stationary power Storage , the reusable cells had lower emissions, except in scenarios where only a small Percentage of the battery charge cells and modules could be reused and the secondary application's reliability was low(e.g., a life span of one year or less)

The findings show that EV LIB recycling in stationary applications has the potential to provide a twofold benefit—offsetting 4.1 – impacts by extending battery service life while also eliminating the fabrication and usage of a less-efficient PbA system. It is stated that life cycle-centric can be used to guide reuse decisions and the diversion of EV LIBs to suitable stationary applications. However, these systems' technological feasibility must be assessed, particularly in terms of the capacity to quickly investigate the dependability of EVLIB cells, modules, or packs for rehabilitation and reuse in secondary application.

1.3 MOTIVATION

- i. Compare the yearly operating expenses of pure battery electric vehicles to those of traditional diesel and gasoline
- ii. Automobiles. Affordable maintenance
- iii. Lighter, smaller batteries are preferable since they lower vehicle weight and hence increase performance. Most contemporary battery technologies have lower specific energy than liquid fuels, which influences the cars' potential all-electric range.

1.4 SCOPE OF THE PROJECT

Given the following facts, this endeavour is more relevant today and valuable to society:

- i. The CMBS has been offered as a clever solution to incorporate battery management functions and achieve maximum battery capacity utilisation without using cell balancing techniques like the TCBS.
- ii. Identify a design with an optimal number of cells per module to maximise the use of battery capacities as well as overall system efficiency and reliability while reducing size, cost, and complexity.

1.5 LITERATURE SURVEY

R.Monisha, (2021) Fast charging method for electric vehicles based on cascaded multilevel converter

In order to charge the electric vehicles within a small phase of time and the charging time of the electric vehicle depends on the battery and charging point. The proposed system is the cascaded multilevel converter for charging the electric vehicle using the five-level topology in an efficient manner.

The fast charging method for charging the vehicle from the single-phase supply, the voltage can be boosted in each level where all the five levels are cascaded. The voltage can be boosted by the cascaded multilevel converter to enhance the performance of the system and increases the life of the battery. The hardware setup and analysis are shown in this paper.

The proposed system is fast charging method for electric vehicles based on cascaded multilevel converter is able to reduce the charging time of the electric vehicles. To charge the electric vehicles within three to four hours and enhances the life of the battery. It is the fast charging method for the electric vehicles from the single-phase supply.

Ahmed, M. Fares^{1,2}, Christian Klumpner¹, Mark Sumner, (2019) Optimising the structure of a cascaded modular battery system for enhancing the performance of battery packs. This paper presents degradation of performance of battery packs in battery-based power systems as a result of mismatch of cell performance or aging can affect the overall system performance therefore battery management systems (BMS) have an important role to minimise these effects in order to improve the performance and energy utilisation of the battery pack and by reducing the stress on weaker cells, prolong its life time. The high-voltage bus required by the traction system of electric vehicles requires the use of a large number of series connected cells. Therefore, the capacity of battery packs with series connected cells may be limited by the weakest cell in the string, i.e. if one of the cells lost 10% of its capacity compared to the majority of cells, the overall capacity of the pack will lose 10% as a result as the weak cell will reach first the fully charged/discharged condition, and in order to prevent further degradation of this cell, the operation of the whole pack needs to be stopped.

Although the mismatching between pack's cells can be mitigated when the pack is manufactured by selecting cells with similar performance (matched capacity), after significant utilisation of the pack, the degree of capacity mismatch between pack's cells may increase and cannot be mitigated without a corrective action. TCBS are implementing one of the traditional cells balancing techniques in order to achieve charge balancing to maximise the utilisation of the pack capacity. The overall performance of battery packs may be affected by imbalances between the series connected cells which is more likely in packs with high number of cells needed to provide a high voltage as needed for example in electric vehicles. In this case, the overall capacity and power capability of the pack are limited by the weakest cell in the stack which results in incomplete utilisation of the pack's capabilities.

In traditional centralised battery systems (TCBS), this is addressed by implementing cell active/passive balancing circuitry/techniques which restore some of the pack's energy capability. This paper proposes the use of cascaded modular battery systems (CMBS) to remove the need for extra balancing circuitry and maximises the performance and reliability of a battery system containing unequal matched/aged cells. The analysis is assessing the CMBS overall system efficiency, reliability and weight compared to the TCBS for a design of a 300 V/3.6 kW battery system as a case study.

Liezu, Wangkuj, (2019) A Hybrid Cascaded Multi-level Converter for Battery Energy Management Applied in Electric Vehicles. In electric vehicle (EV) energy storage systems, a large number of battery cells are usually connected in series to enhance the output voltage for motor driving. The difference in electrochemical characters will cause state-of-charge (SOC) and terminal voltage imbalance between different cells. In this paper, a hybrid cascaded multi-level converter which involves both battery energy management and motor drives is proposed for EV.

In the proposed topology, each battery cell can be controlled to be connected into the circuit or to be bypassed by a half-bridge converter. All half-bridges are cascaded to output a staircase shape DC voltage. Then an H-bridge converter is used to change the direction of the dc bus voltages to make up AC voltages. The outputs of the converter are multi-level voltages with less harmonics and lower dv/dt , which is helpful to improve the performance of the motor drives. By separate control according to the SOC of each cell, the energy utilization ratio of the batteries can be improved. The imbalance of terminal voltage and SOC can also be avoided, fault-tolerant can be easily realized by modular cascaded circuit, so the life of the battery stack will be extended. Simulation and experiments are implemented to verify the performance of the proposed converter.

N. Kalaiarasi, Ravi Varma, (2019) DC-AC Hybrid Cascaded Nine Level Converter for Battery Management Applied in Electric Vehicles

In this paper, each battery cell can be controlled to be connected into the circuit or to be bypassed by a half-bridge converter

All half- bridges are cascaded to output a staircase shape DC voltage. The outputs of the converter are multilevel voltages with less harmonics and lower dv/dt , which is helpful to improve the performance of the motor drives

By separate control according to the SOC (state-of-charge) of each cell, the energy utilization ratio of the batteries can be improved. The imbalance of terminal voltage and SOC can also be avoided, fault-tolerant can be easily realized by modular cascaded circuit, so the life of the battery stack will be extended.

The hybrid-cascaded nine level converter proposed in this paper can actualize the charging and discharging of the battery cells while the terminal voltage or SOC balance control can be realized at the same time. The proposed converter with modular structure can reach any number of cascaded levels and is suitable for the energy storage system control with low-voltage battery cells or battery modules. The fault module can be bypassed without affecting the running of the other ones, so the converter has a good fault-tolerant character which can significantly improve the system reliability. The PWM method with low switching loss for both discharging and charging control is proposed considering the balance control at the same time. The output of the circuit is multilevel AC voltages where the number of levels is proportional to the number of battery cells. The losses in the proposed system is lesser than the losses in the traditional system. The nine-level hybrid-cascaded multilevel converter improves output voltage, reduces output total harmonic distortion.

Sharon Sanjeev George, (2019) A modular multi-level converter for energy management of hybrid energy-storage systems in electric vehicles

This paper presents transportation plays a vital role in the advancement of human society. In fact, nations rely on various modes of transportation to stimulate social and economic development. However, the surging use of conventional transportation solutions, like automobiles, causes serious problems for the environment.

Electric motors convert electrical energy from the battery to mechanical energy to develop instant torque required for wheel rotation.

When the load-side electromotive force exceeds the source voltage, electric motors assume the role of generators and convert mechanical energy to electrical energy. In this way, EVs recover the kinetic energy while braking and use the resulting current to recharge the battery. This characteristic property of electric motor drives is featured as 'regenerative braking' and contributes to energy efficiency in EVs.

The proposed HESS adopted an MMC-based converter structure to manage the energy between battery and UC cells. The system has the ability to switch between high power, high energy and MTPA extension modes seamlessly. Additionally, the novel configuration eliminated the need for a system level drive inverter as the AC power signals were generated from the MMC modules. The control structure flexibility allowed easy implementation of energy management functions, some of which were presented in this study. The results indicate that the system can cater to various power demands while ensuring that the energy cells are efficiently utilized. The simplicity of the novel converter structure can aid in the development of high voltage energy packs without compromising power density.

Quraan, Tae-jung Yeo , (2015) Design and Control of Modular Multilevel Converters for Battery Electric Vehicles

This paper presents new advanced power conversion systems play an essential role in the extension of range and life of batteries. This paper proposes a new modular multilevel converter with embedded electrochemical cells that achieves very low cell unbalancing without traditional balancing circuits and an eligible harmonic content of the output currents. In this new topology, the cells are connected in series by means of half-bridge converters, allowing high flexibility for the discharge and recharge of the battery.

1.6 ADVANTAGES

- i. Extension of range and life of batteries.
- ii. It is the charging method for electric vehicles from the single-phase supply. Additionally, we connected the solar panel so we can charge the battery while driving. The time will be saved, we can drive a long way and the cost of the charging will be reduced compared to electric charging.
- iii. The cascaded modular battery system has been offered as a clever solution to accomplish critical battery management capabilities and maximize battery capacity without the requirement for typical cascaded battery system cell balancing procedures.

CHAPTER-2

PROJECT DESCRIPTION

2.1 BLOCK DIAGRAM

The below block diagram shows the basic working of an cascaded modular battery system in electric vehicle.

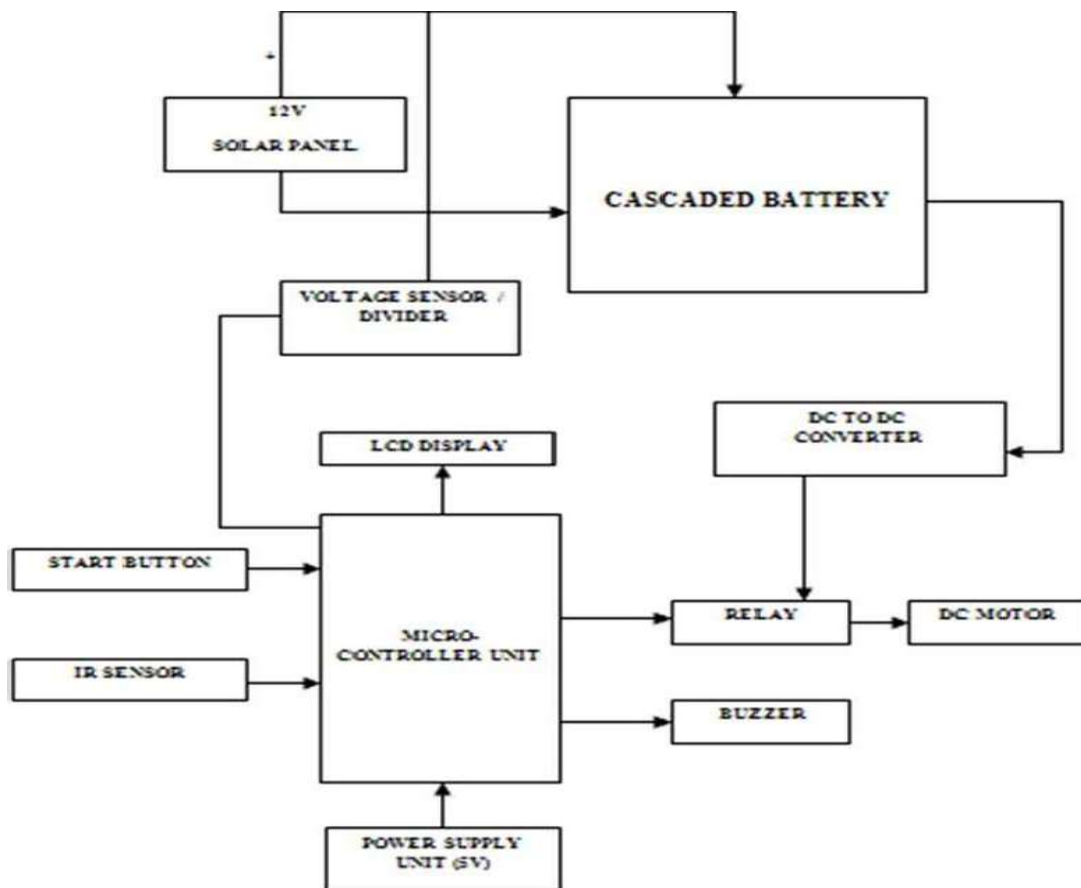


Fig.2.1 Block diagram

2.2 CONCEPT EXPLANATION

The electricity is generated by a 12-volt solar panel. For continuous power supply to the number of relays, the cascaded battery is coupled to a DC to DC boost converter. The dc motor is attached to the relay's opposite end. The DC motor is controlled by a microcontroller. If an impediment is detected by the IR sensor, the motor will halt and the buzzer will sound. The solar panel's current and voltage are displayed on the LCD. The quantity of voltage in an item is calculated and monitored using a voltage sensor.

The constituent blocks are described in depth in Chapter 4 HARDWARE DESCRIPTION.

2.3 CIRCUIT DIAGRAM

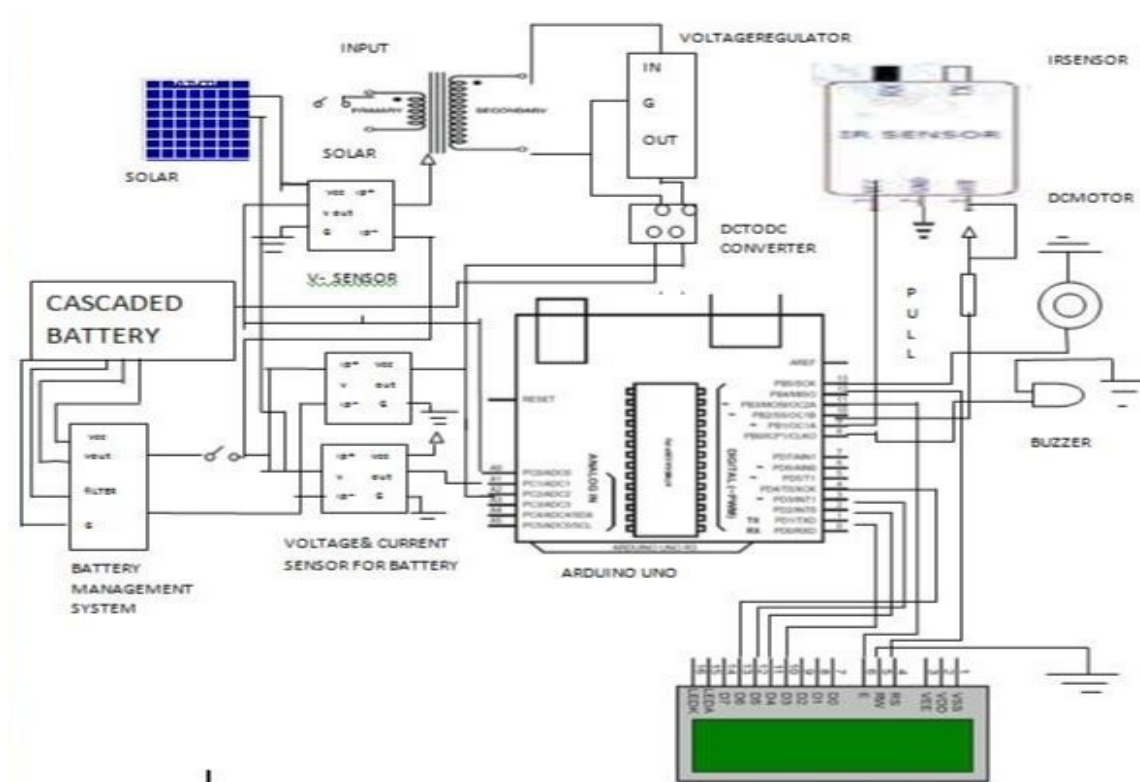


Fig.2.2 Circuit diagram

2.3.1 CIRCUIT DIAGRAM EXPLANATION

This whole operation is managed by an Arduino mega 328p microcontroller, which manages the connection between the various system components, such as sensors, motors, and LCD displays. The IR Sensor, LCD Display, and Motor are all attached to the board. We've used a 16x2 LCD and a 12v ac transformer. It'll be linked to the power supply, and we've used a 7805 regulator. The Arduino Board, which is shorter in length and features a microcontroller, receives the power supply. When a cascaded modulator battery is linked to a BMS, it charges all of the cells at the same time. As a result, we may recharge the cells in a short amount of time. We also fitted a solar cell to the vehicle so that we could charge it all while traveling. We're using two voltage sensors here: one for current and one for solar panels. Using the push button, we can verify the voltage of the solar panel. We'll utilize a dc gear motor to make an electric car out of this. The motor will stop automatically when the IR sensor detects obstructions, and the buzzer will sound.

2.4 PRESENT WORK EXPLANATION

The lithium-ion battery is used in the traditional form since it is compact and delivers good power efficiency. For example, if 10 cells are connected and the battery is charged, the first cell is charged first, followed by the next cell. The procedure will be repeated until the last cell is reached. As a result, the charging duration will lengthen, and the batteries will weaken day by day, lowering the power efficiency.

To solve this disadvantage, we employ a cascaded modular battery technology, which has a compact battery size and great power efficiency. We use a battery management system to charge the battery evenly. We can charge the battery in three to four hours using the cascaded modular battery technology. We also include a solar panel to charge the battery. The benefit of using a solar panel is that we may charge the battery while driving, saving time. We have the ability to go a vast distance. When compared to electric charging, the cost of charging will be lower.

CHAPTER – 3

PROPOSED SYSTEM

3.1 COMPARSION BETWEEN EXISTING AND PROPOSED SYSTEM

EXISTING SYSTEM

- i) In an existing system, a hybrid approach of cascaded cells may be used to produce extra voltage levels in each cell while keeping the energy in the Lithium-ion battery cells stable.
- ii) It's possible to get it by combining the effective clamped approach of three-level strategies with the inverting H-bridge method. The series circuit of a H-bridge connects all three levels together, with each level having its own dc source.
- iii) With the fewer cascaded units, the output ac voltage may be acquired at each level and may be almost perfect sinusoidal.
- iv) The charging period of the battery 8 to 9 hours

PROPOSED SYSTEM

- i) Lithium-ion battery packs recycled from end-of-life electric vehicles (EVs) provide prospective options for enhancing energy systems and resource efficiency on a technological, economic, and environmental level.
- ii) In energy storage systems designed under commercial settings, EV battery reuse has proved technological feasibility and exhibited energy efficiency gains.
- iii) With the aid of an inverter, the output voltage may be sent to the motor electric vehicle.

3.2 SOFTWARE TOOL

The software used in this project is given below

- PROTEUS
- IDE

3.2.1 PROTEUS

Circuit simulation has always been a non-interactive process. Netlists were created by hand inside the start, and the result constituted mainly sheets of numbers. The currents and voltages are shown in a pseudo-graphical output with asterisks.

Although schematic capture and on-screen plotting have grown more common in recent years, the simulation method remains non-interactive: you create the circuit, hit go, and then examine the results in some sort of post-processing.

This is great if the circuit you're evaluating has a somewhat static behavior, such as an oscillator that sits and vibrates at 1MHz. However, if you're creating a burglar alarm system and would like to know what will happen if a would-be thief enters the erroneous PIN, the needed setup becomes impracticable, and a physical model must be used instead.

Only in academic contexts does have an effort been made to show circuit simulation as real life electronics, where the circuit may be interacted with while being simulated.

The issue is that the dynamic component models are hard-coded into the software. Furthermore, the accuracy of circuit design has frequently fallen short of expectations. One important product of this sort, for example, contains no temporal information in its virtual objects.

It is unexpectedly possible to Proteus Vsm combines the greatest features of both worlds. It combines a fantastic multi pathing circuit simulator with animated component models, all based on industry-standard SPICE3F5. It also provides an architecture that allows anybody, including end-users, to develop additional animated models. Many forms of animated models may be created without the need for code. As a result, PROTEUS VSM enables expert engineers to execute interactive simulations of real-world designs and realize the benefits of this circuit modeling technique. As if that weren't enough, we've also produced a collection of animated models for relevant peripheral devices including LEDs and Liquid crystal display monitors, keypads, an RS232 terminal, and more. It is unexpectedly possible to build software for whole microcontroller systems without having access to the physical prototype, it is possible to mimic complete microcontroller systems.

3.2.2 IDE

IDE, meaning Integrated Development Environment, allows programmers to combine the many parts of building a software program into one convenient location.

IDEs boost programmer productivity by merging typical software development tasks such as editing source code, creating executables, and troubleshooting into a single interface.

3.3 SIMULATION

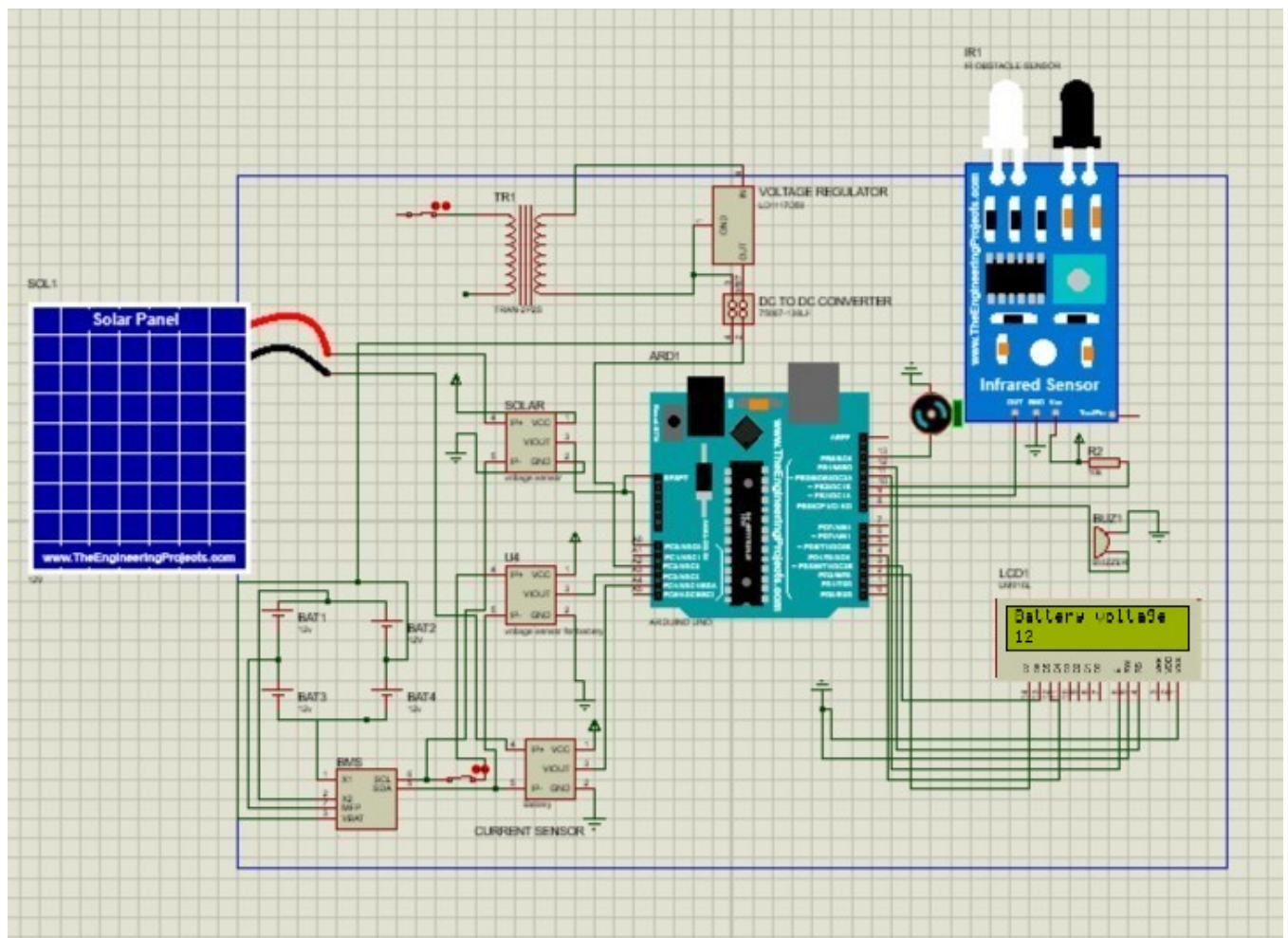


Fig 3.1 Simulation diagram

3.4 SIMULATION OUTPUT



Fig .3.2 Simulation output

We're using four batteries, each of which is charged evenly. As a result, we're testing using 12v batteries. The intended result is obtained. As a result, we may use this technology for high- voltage batteries.

The charging time of an electric vehicle is now 8 to 11 hours, but we can charge it in 3 to 4 hours employing our cascaded modular battery method.

3.5 MODES OF OPERATION

3.5.1 MODE 1 : ARDUINO UNO INSTALLATION AND SETUP

We don't have an Arduino board in the proteus library, thus we'll have to obtain the file and upload it.

1. To begin, install the Arduino Library.
2. Save the file to your computer's hard drive.
3. Download the.zip file to your desktop and unzip it.
4. Cut the Nano TEP.IDX and Nano TEP files.
LIB the two files you got from computer's desktop.
5. Navigate to C:Program Files(x86) Lab center Electronics Proteus 8.9
6. By default, the file Library is sometimes hidden.

7. Choose C Drive/Organize/Folder and Search Options/view/Tick from the drop-down menus. Files, folders, and drives that have been hidden will be visible.
8. Go to C:/ProgramData/Labcentre Electronics/Proteus 8 Professional/Library/Paste in Library.
9. Copy and paste the files into this box.
10. Using this arduino uno we interface the ir sensor, solar panel, voltage sensors, current sensor, Batteries etc...

3.5.2 MODE 2: IR SENSOR INSTALLATION AND SETUP

For Proteus, download the IR Proximity Infrared Sensor Library. After you've downloaded this

1. item, unzip it to find three Library.zip files.
2. Place all.zip file files in Proteus software's Library folder.
3. Locate LaCenter devices in both the programme file folders on C drive.
4. Here's the whole Proteus 8 Libraries folder link: Labcenter Electronics Proteus 8 Professional LIBRARY is located in C:Program Files (x86)
5. Open your Proteus ISIS software after you've added these library files.
6. If you installed the Library correctly, get comparable results
7. In the Program File section, navigate to the InfraredSensorTEP.HEX file you previously downloaded and saved to Proteus' Library folder.
8. After setup the IR sensor we move to interfacing
9. IR sensor we have 3 pins : GND,VCC,VOUT,TESTPIN

3.5.3 MODE 3: SOLAR PANEL INSTALLATION AND SETUP

We don't have an solar panel in the proteus library, thus we'll have to obtain the file and upload it.

1. To begin, install the Solar Panel Library for Proteus.
2. You will receive a zip file containing the following two library files: Solar Panel TEP.IDX SolarPanelTEP.LIB
3. Now drag and drop these two files into Proteus software's library folder.
4. Because Proteus isn't very clever, we'll need to restart it for it to add new Library Components to itsdatabase.
5. Select the components option in the Proteus program and search for Solar Panel.
6. Now, drag and drop this component into Proteus program.

7. Now double-click this solar panel to bring up the Properties panel
8. If you've dealt with solar panels before, probably aware that the output of a solar panel is determined by the intensity of sunlight.
9. The output voltage is set to 12V by default.
10. Solar panel is connected into voltage sensor to monitor the voltage , other end is connected toCurrent sensor.

3.5.4 MODE 4: OPERATION

- 1 As shown in the circuit diagram, connections are made. We used the Arduino IDE to write the code in C, check it, and compile it.
- 2 A .hex file is produced on the system during the program's saving. Then, in proteus, go to the Arduino board and paste the .hex file.
- 3 The motor will operate and the battery voltages will be shown on the LCD board after clicking the run button and closing all the switches.
- 4 When the switch is closed, the batteries are charged evenly, and the output is shown the LCD board.

CHAPTER - 4

HARDWARE DESCRIPTION

4.1 HARDWARE REQUIREMENTS

- i. Start button
- ii. Push button
- iii. Voltage sensor
- iv. Buzzer
- v. LCD
- vi. IR sensor
- vii. Solar panel
- viii. DC motor
- ix. Battery
- x. Microcontroller

4.2 WORKING PRINCIPLE

The switch is used for on and off purposes. The switch is connected 12 V ac converter, it will convert 230v . A supply is given to the power supply. Here we use a 7805 voltage regulator. The microcontroller is supplied with power. In microcontrollers, we interface solar panels, voltage sensors, IR sensors, LCD display, etc. Four lithium-ion batteries are connected in parallel and this battery is connected to BMS. In BMS MOSFET act as a switch, the main working of BMS is it will charge the cells equally. additionally, the 12 volts 10 Watt solar panel is connected so we can charge the vehicle while driving. Here 60 rpm gear motor act as a vehicle.

We're using two voltage sensors here, one for monitoring solar voltage and the other for checking battery voltage. For obstacle detection, an infrared sensor is utilised. If it identifies an obstruction, the motor will immediately stop and the buzzer will sound. While pressing the push button, we can observe the solar voltage on the LCD display.

4.3 HARDWARE SETUP

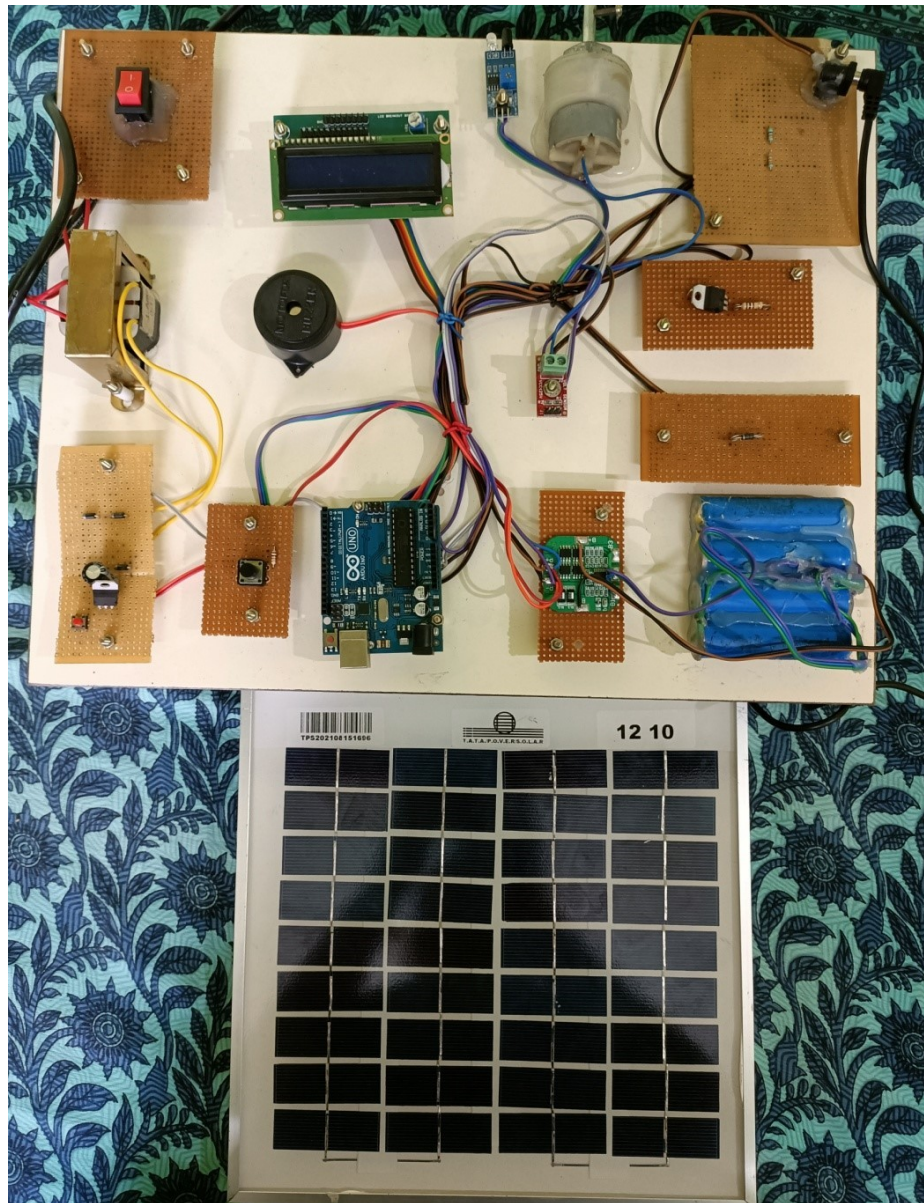


Fig.4.1 Hardware setup

4.4 PROJECT RESULT



i. while ON the switch



ii. it will continuously increase upto 16V



iii. While clicking the push button solar voltage will be display



iv. When the solar panel placed under sunlight
it will charge continuously

v. If IR sensor detect any obstacle ,
within a minute it will display in LCD

4.5 EXPERIMENTAL INPUT AND OUTPUT RESULTS

S.NO	PARAMETERS	VALUE
1	Input voltage	12V
2	Battery voltage output	14.53V (Upto 16V)
3	Solar voltage output	3.78 V (Depends on weather)
4	Charging period of the battery	3 to 4 Hours

Table 4.1 Experimental input and output results

4.6 ARDUINO UNO

In this project we use microcontroller Arduino .This whole process is managed by an Arduino mega 328p microcontroller, which manages the connection between the various system components, such as sensors, motors, and LCD displays. The IR Sensor, LCD Display. The Arduino Uno microcontroller device runs on the ATmega328 microprocessor (datasheet).



Fig.4.2 Arduino uno

4.6.1 ARDUINO UNO INTERFACE WITH SENSOR & BUZZER

Simply attach it to a computer with a USB wire or power it with an AC-to-DC converter to get started with the microcontroller. For connecting with a computer, another Arduino board, or other microcontrollers, the Arduino Uno includes a variety of features.

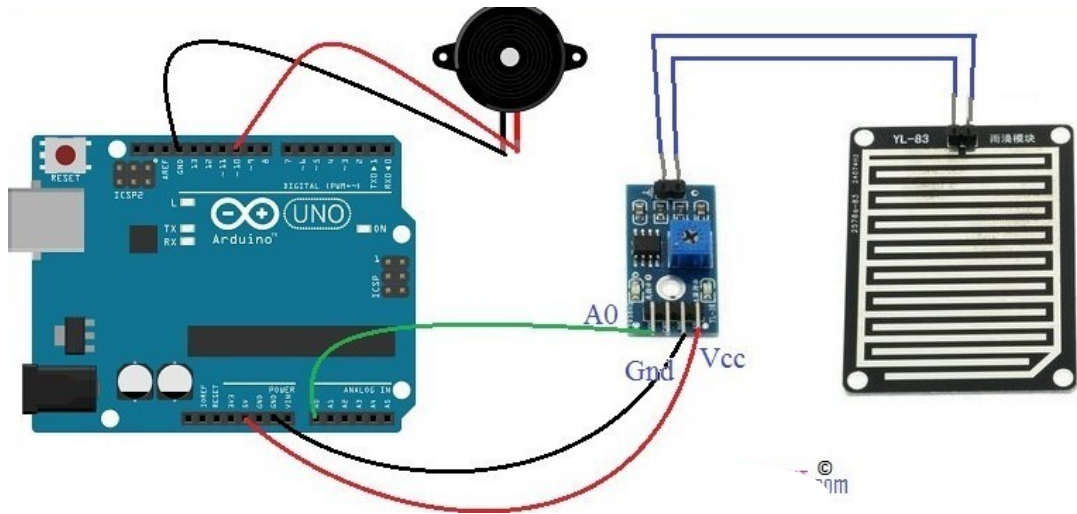


Fig.4.3 Arduino uno interface with sensor and buzzer

4.7 ATMEGA328IC

Here we use ATMEGA328IC because it provides high performance in limited voltage and gadgets works with an operating voltage of 1.8 through 5.5 volts. The device's through put is close to 1 MIPS for every MHz.

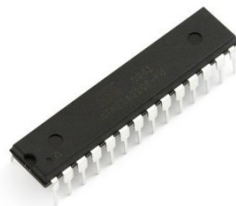


Fig.4.4 Atmega328p

4.7.1 ATMEGA328P PIN DIAGRAM

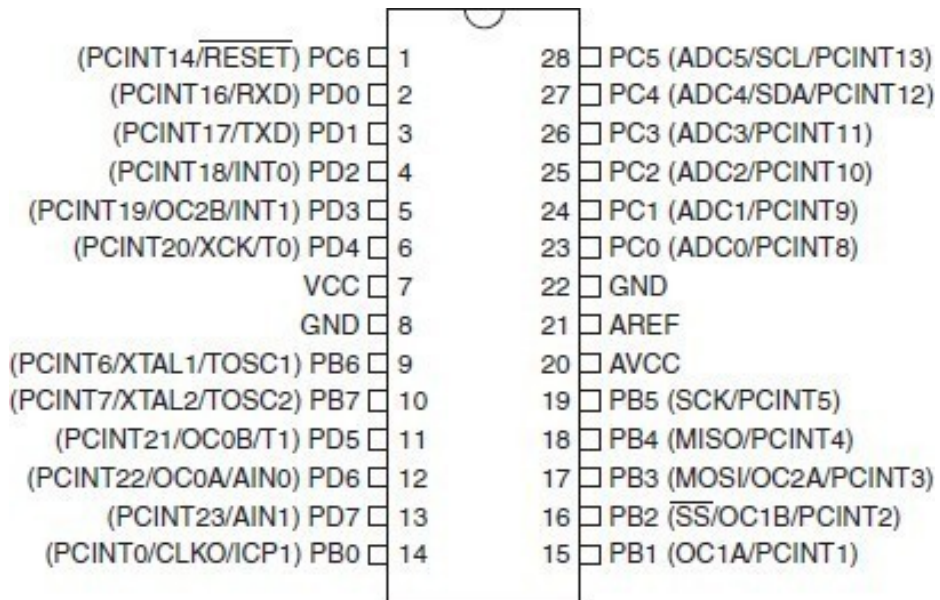


Fig.4.5 Atmega328pIC pin diagram

Atmel®AVR® 8-Bit Microcontroller Series is a high-performance, low-power microcontroller family.

- i) 131 Powerful Instructions in Advanced RISC Architecture
- ii) The number of times a single clock cycle is executed is the highest.
- iii) General Working Register 32 x 8
- iv) Fully Static Module features

At 20MHz, you can have approximately 20 MIPS throughput

4.7.2 ARCHITECTURE DIAGRAM

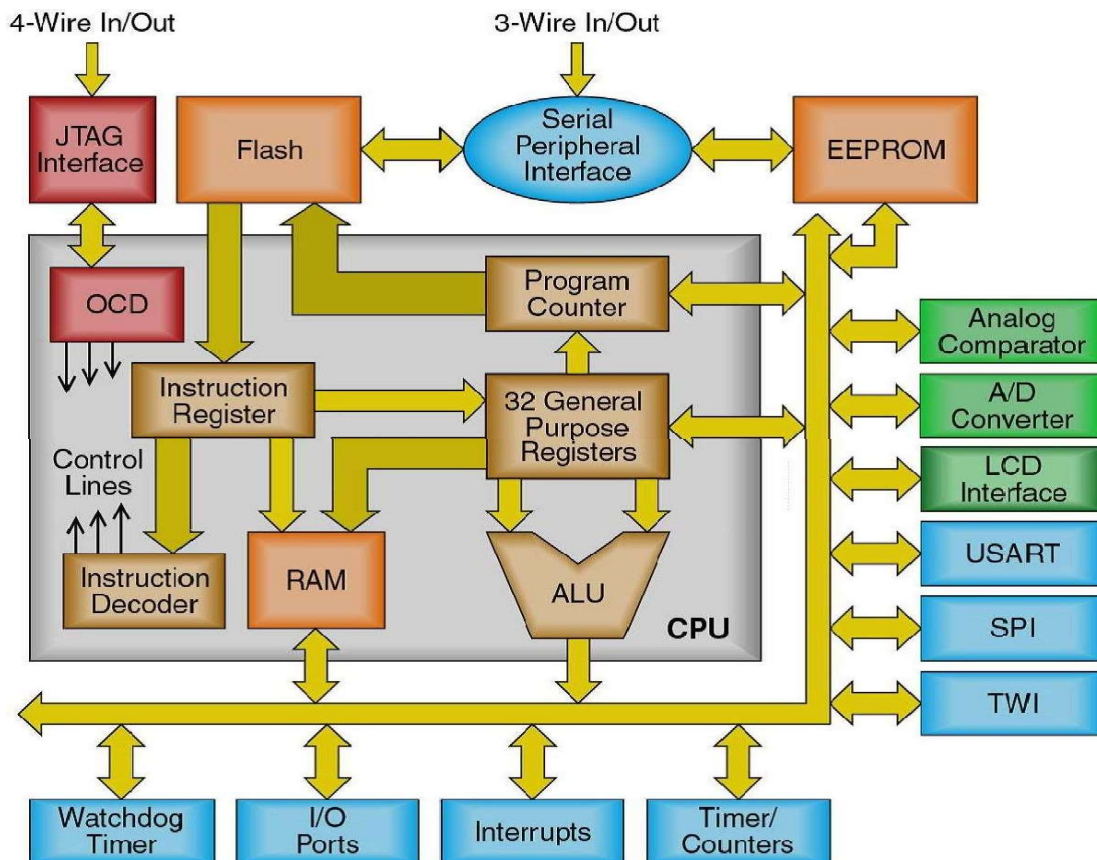


Fig.4.6 Atmega architecture diagram

PortB(PB7:0)XTAL1/XTAL2/TOSC1/TOSC2

Interface B has internal pull-up resistors which is an 8-bit bi-directional I/O port. The products as much as possible on Port B offer symmetrical drive characteristics and high sink and source capabilities. If the Port B pins are externally pulled low, they will source current as inputs.

The pull-up resistors are turned on. Even if the clocks is not running, the Port B pins remain tri-stated whenever a reset condition is current.

PB6 can be employed as an input to the inverted Oscillator amplifier and as an input to the internal clock operational circuit, dependent on the clock selecting fuse settings. PB7 can be utilized as an output from the inverted Oscillator amplifier dependent on the clock selecting fuse settings.

PortC(PC5:0)

Interface C has integrated pull-up resistors as well as being a 7-bit bi-directional I/O port. The PC5 0 products as much as possible include symmetrical driving characteristics, as well as strong sink and citation capability. If the pull-up resistors were engaged, Port C pins that remotely pulled down will source current as inputs.

Even though the clock also isn't running, the Port C pins remain tri-stated whenever areset condition is active.

PortD (PD7:0)

Port D is indeed an 8-bit bi-directional I/O port having pull-up resistors built-in (selected for each bit). The output buffers for Port D have balanced drive characteristics and strong sink and source capabilities. If the pull-up resistors are engaged, Port D pins that are dynamically pulled low will originate current as inputs.

Even though the clock is not running, the Port D pins remain tri-stated when a definitely changed is active.

PC6/RESET

PC6 is utilized as an I/O pin if the RSTDISBL Toggle is configured. It's worth noting that the electrical properties of PC6 vary from that of the other Port C pins. PC6 is employed as a Rollback input if the RSTDISBL Toggle is not configured. Even if the clock also isn't running, a low rate on this pin for more than the threshold pulse length will cause a Reset. Table 28-3 on page 308 lists the minimum pulse length

AVCC

AVCC is the A/D Converter, PC3:0, and ADC7:6 supply voltage pin. Even if the ADC isn't used, it should be directly connected to VCC.

AREF

The A/D Converter's analog reference pin is AREF.

ADC7:6(TQFP and QFN/MLF Package Only)

ADC7:6 are analog inputs to a converter in the TQFP as well as QFN/MLF packages. The analog longer supply these pins, which function as 10-bit ADC channels.

ANALOG PORTS

The analog-to-digital converter (ADC, A/D, A–D, or A-to-D) in electronics is a device that converts an analog signal into a digital signal, such as sound scooped up by a microphone or light entering a digital camera. An ADC can also offer an isolated measurement, such as an electronics device that converts a digital number proportionate to the magnitude of an input analog voltage or current.

Because embedded systems work with digital values, A/D conversion is critical. Their surroundings frequently consist of a variety of analog signals.

Before being processed by the microcontroller, analog signals must be converted to digital. At this time, we can see how to use a PIC microcontroller to read an external analog signal and display its digital o/p convert on an Lcd screen. The i/p signal could be a voltage ranging from 0 to 5 volts.

If an ADC is employed, a low-pass filter should be used to link it to VCC. PC6.4 uses VCC, which is a digital supply voltage.

4.8 PWMPIN'S

PWM refers to Pulse Width Modulation, that's not particularly useful if you're unfamiliar with modulation. Modulation is the process of superimposing knowledge on a high-speed signal or carrier in electronics.

wattage average Because most lipo packages as well as all 18650 style battery packs produce 3.7 volts at a theoretical charge level, a lot of APVs use PWM signals to regulate power below the battery's provided voltage. The DC-DC signal is indeed a flat signal.

PWM (pulse width modulation) is a technical name for a sort of digital signal. Pulse width modulation was employed in a wide range of applications, including complex control circuitry. We use them all the time at SparkFun to regulate the dimming of RGB LEDs or the movement of a servo motor

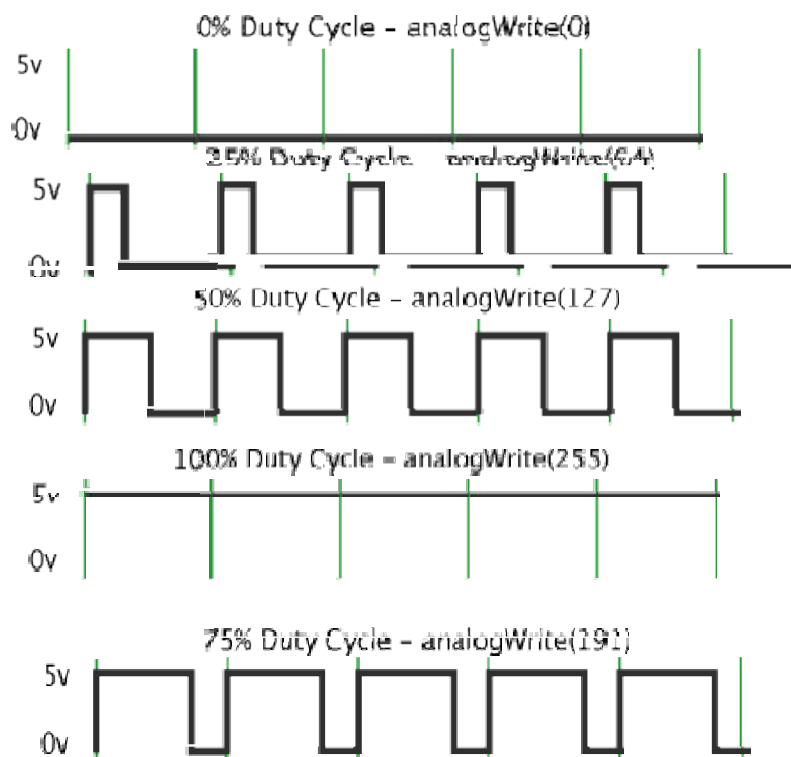


Fig.4.7 Pulse Width Module

4.8.1 PWM PIN'S ARDUINO

PWM is a method for digitally extracting analog outcomes. Digital control is utilized to create an output waveform, which is an on/off signal.

PWM is a method for digitally extracting analog outcomes. Digital control is utilized to create an output waveform, which is an on/off signal. Newer and faster trends can mimic voltage levels both in loaded on (5v) then off states by altering the duration of the signal is on versus off (0 Volts). The time spent "on" is measured by the pulse width. Users change and tweak the signal width in order to get different analogue values. When you repeat this on-off sequence with an LED quickly enough, the signal is represented to be a continuous voltage between 0 and 5 volts, adjusting the LED's brightness.



Fig.4.8 PWM Pin's Arduino

4.9 REGULATOR

we are using 7805 regulator, it maintains a steady voltage level automatically. A voltage regulator can be simple "feed-forward" or have negative - feedback loops. An electrical components could be used.

The three-terminal positive regulators of the LM78XX series are accessible as in the TO220 package and with a variety of preset voltage levels, making them suitable for a wide range of applications. Internal current limiting, temperature shut down, and safe operating zone protection are all used in each kind, making it almost indestructible



Fig.4.9 Regulator

PIN DIAGRAM

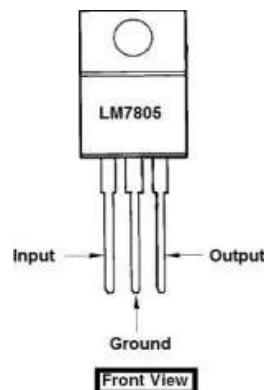


Fig.4.10 Regulator pin diagram

4.9.1 REGULATOR CIRCUIT DIAGRAM

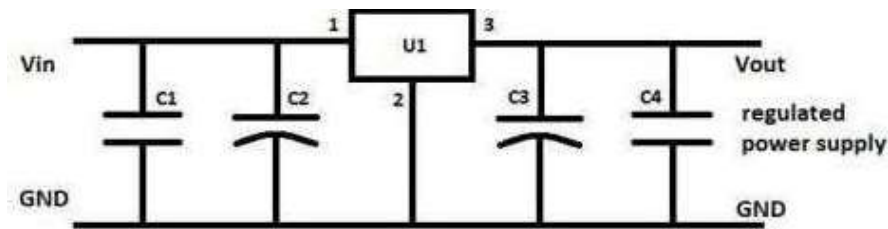


Fig.4.11 Regulator circuit diagram

They can produce over 1A output current .if appropriate heat sinking is given. Although these devices are generally designed as fixed voltage regulators, they may be used in conjunction with external components to achieve variable voltages and currents.

4.10 RESET BUTTON

The first circuit disables the device by pulling the RESET pin low. The second circuit is the same as the first, except it includes a reset button. The chip will be reset if you press that. When the 5V power is turned on, the capacitor shorts to 5V, and the RC circuit is progressively empty,bringing the reset pin to zero.

CIRCUIT DIAGRAM FOR RESET BUTTON CONNECT WITH CONTROLLER

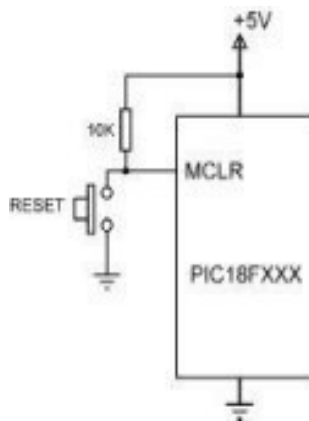


Fig.4.12 Reset button circuit diagram

4.11 IR SENSOR

An infrared sensor seems to be an device that emits infrared light in order to detect certain obstacles. In this project infrared sensor detects obstacles as well as measures the heat of an item. A passive infrared sensor is one that measures infrared radiation instead of emitting it.



Fig.4.13 IR sensor

CIRCUIT DIAGRAM

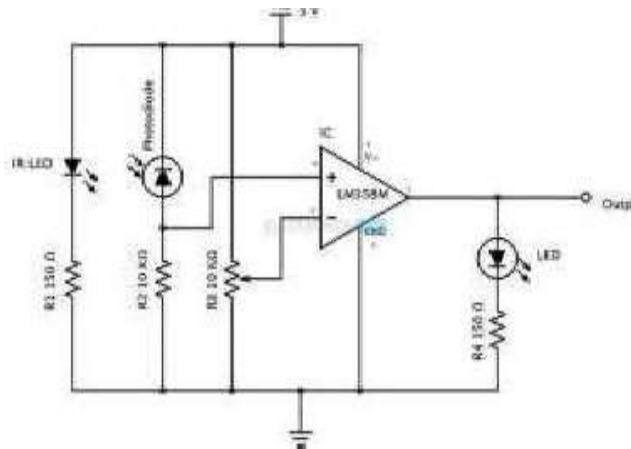


Fig.4.14 IR sensor circuit diagram

4.12 VOLTAGE SENSOR

A voltage sensor will be able to determine the voltage source, as well as monitor and measure the solar voltage and battery voltage.

It may then take those measurements and convert them into a signal that can be read. The signal is usually routed to a specialized electronic device for recording, although an observer may be present to manually examine the sensor output.



Fig.4.15 voltage sensor

4.13 SOLAR PANEL (10 WATTS)

The solar charger controller, also known as a battery regulator, is a device that regulates the charger process, which is powered by the electric current generated by the PV module and adjusts the discharge process to a load attached to a solar charger with a voltage of 12V.

Although a solar panel can be operated without a solar charger or battery charger circuit, this is not recommended since it may overwhelm the panel's performance owing to high load, resulting in catastrophic damage to the solar panel.



Fig.4.16 Solar panel

4.13.1 SOLAR PANEL INTERFACING WITH MICRO CONTROLLER

Cascaded batteries must also be safeguarded from mechanical and moisture damage. The majority of photovoltaic panels are rigid , however semi-flexible ones based on thin-film cells are available.



4.17 Solar panel interfacing with microcontroller

4.14 BUZZER

A buzzer is an electrical signaling device that is commonly seen in vehicles. In this project Buzzer is used for alarm purpose.



Fig.4.18 Buzzer

CIRCUIT DIAGRAM

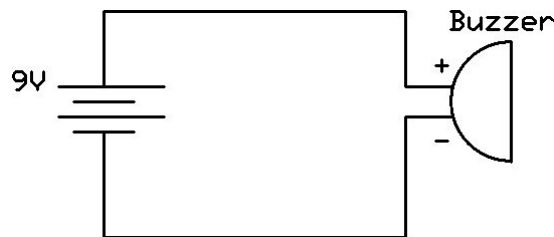


Fig.4.19 Buzzer circuit diagram

By adding D.C voltage, it creates a steady single tone sound. This kind can be employed where enormous sound levels are required by using a well-built resonant system. We sell several of the most common sorts at Future Electronics, which are organized by Form, Sound Quality, Frequency, Rated Voltage, Dimension, and Packaging Type.

4.15 CASCADED BATTERY (12V)

Cascaded batteries consist up of one or more cells, each of which uses chemical processes to produce an electron flux between atoms. In this case, a cascade battery is proposed, which integrates two electrochemical processes in a single battery.

In this case, four 12v batteries are linked in series. This battery was connected to a BMS. cascaded battery is unable to produce power whenever the substance in the cathode or anode is destroyed or is no longer usable in the reaction. Battery packs are consumable batteries that must be disposed of after usage. Rechargeable batteries are classified as secondary batteries.

The 12-volt battery was first used in transistor radios in the most common configuration. It's structured like such a rectangular prism with rounded corners and a polarised snap connector on top to keep time.

4.16 DC GEAR MOTOR (60RPM)

In this project the purpose of using gear motor is gears are being used to reduce the motor's velocity while boosting the output torque.



Fig.4.20 DC gear motor

4.16.1 DC GEAR MOTOR INTERFACE WITH CONTROLLER



Fig.4.21 DC gear motor interface with controller

In this project fundamental efficiency point of a motor is somewhat lower than the maximum efficiency point. When the motor is connected to a machine with a known load value, the current drawn may be measured to derive load torque

4.17 LCDDISPLAY

The liquid crystal display (LCD) technology is used for display the battery voltage and solar voltage. LCDs, like LED and gas plasma technologies, allow displays to be far smaller than cathode ray tube (CRT) technologies.



Fig.4.22 16X2 LCDdisplay

4.17.1 LCD INTERFACE WITH MICROCONTROLLER

This is an E-blocks-specific LCD display. It has a single 9-way D-type connection and a 16 character, 2-line alphanumeric LCD display. This enables the device to connect to the majority of E-Block I/O ports.

The LCD display requires serial data, which is described in full in the user guide below. A 24V power supply is also required for the display. Please ensure that the voltage does not exceed 5V, since this will harm the gadget.

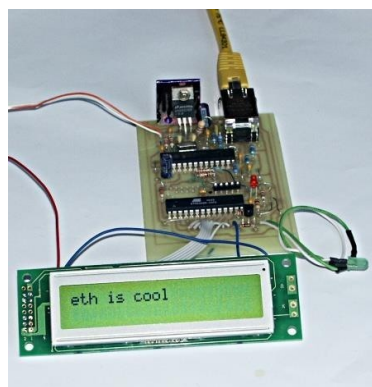


Fig.4.23LCD interface with microcontroller

4.17.2 LCD INTERFACE BOARD

The LCD board was created specifically for use with Arduino. The data and control components of this board are divided into two sections. A potentiometer is included on this board for adjusting the LCD.

The board's supply voltage comes from either the controller or a separate source. A set of communication methods and pin outs, as well as an external power connector, are included on the communication extension board



Fig.4.24 LCD interface board

4.18 PUSH BUTTON SWITCH

In this project pushbutton is used for getting solar voltage. The SCR is also triggered by the gate terminal via a push button. These are the most frequent buttons seen on electronic gadgets in our daily lives. The article concludes with a list of some of the Push button's uses.

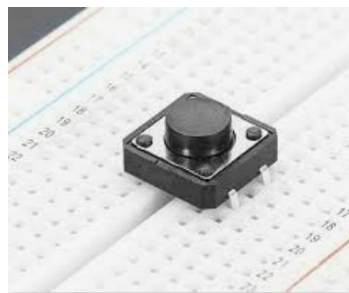


Fig.4.25 Push button switch

4.19 TRANSFORMER

In this project we use 12V AC transformer and the power is given to supply. The transformer's primary windings are 240V, and the secondary winding is tapped in the middle. The electrical device acts as step down converter, changing 240V AC to 12V AC. Power provides for a good variety of comes gate boards.



Fig.4.26 Transformer

CIRCUITDIAGRAM

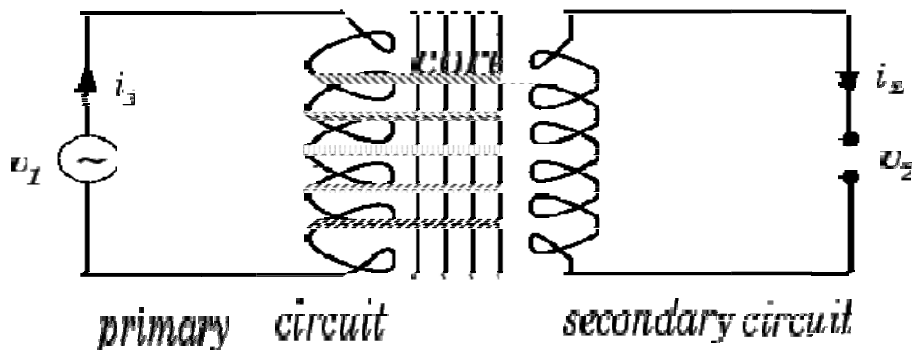


Fig.4.27 Transformer circuit diagram

An electrical device could be a device that uses magnetic attraction induction to transmit electrical power across 2 or a lot of circuits. magnetic attraction induction generates Associate in Nursing electromotive among a conductor that's subjected to unsteady magnetic fields over time. Transformers area units employed in electrical power operations to reinforce or scale back alternating voltages

4.20 BATTERY MANAGEMENT SYSTEM (BMS)

There are only three types of BMS depending on their architecture in terms of hardware structure: centralized BMS, distributed BMS, and modular BMS.

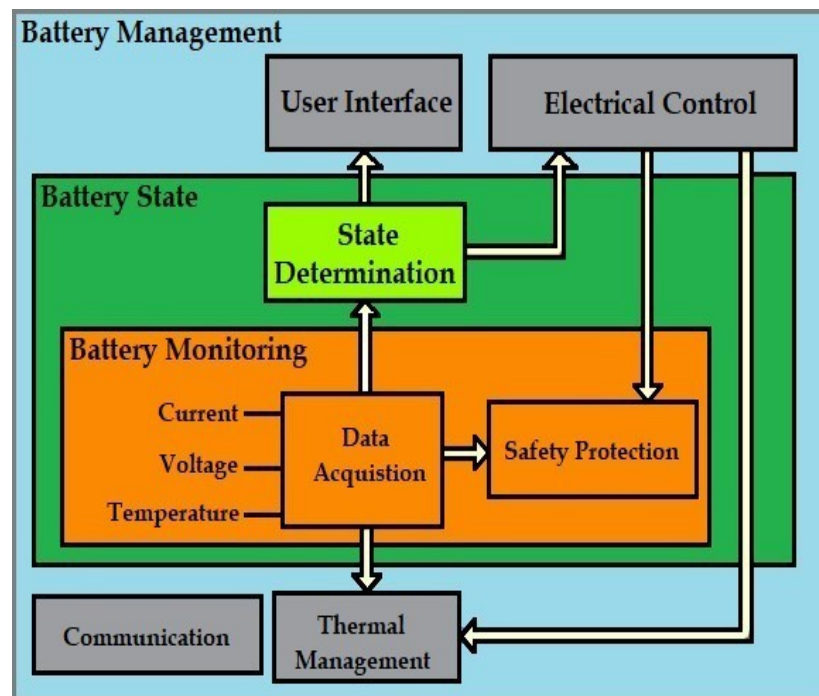


Fig.4.28 Battery management system block diagram

4.20.1 BMS DATA ACQUISITION

Here BMS' principal job is to monitor the battery, which necessitates the collection of three important metrics from each cell in the battery pack: voltage, current, and temperatures.

We know that battery packs are made up of several cells connected in series or parallel, such as Tesla's 8,256 cells, of which 96 are connected in series and 86 in parallel to make a pack.

If a group of cells is linked in series, we must measure the voltage across each cell, but the current for the entire set will be the same since the current in a series circuit is stable. When a group of cells is connected in parallel, we get the same result.

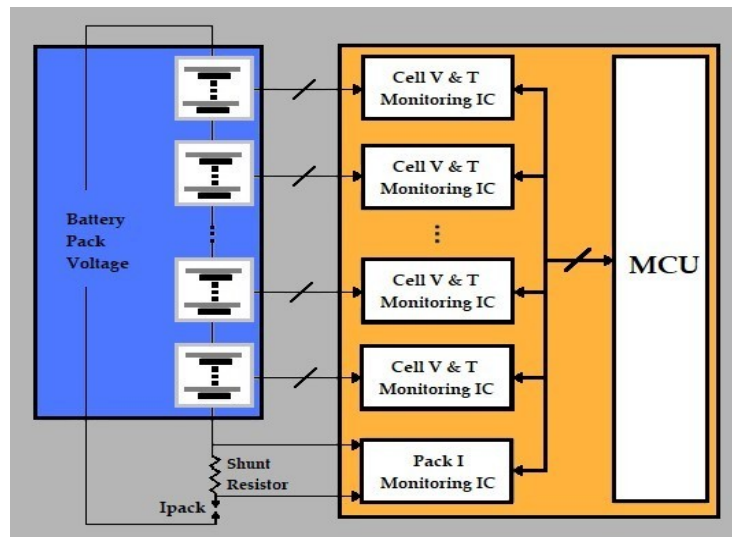


Fig.4.29 BMS data acquisition

CHAPTER- 5

CONCULSION

The cascaded modular battery system has indeed been provided in the proposed system as a smart solution to achieve significant battery management functionality and maximum usage of battery capacity without the requirement for typical cascaded battery system cell balancing procedures.

Normally, electric cars are charged using a single-phase power source. We also attached the solar panel. While driving, we may charge the battery. As a result, we will save time and be able to drive a longer distance. In comparison to electric charging, the cost of charging will be lower. Its modular form makes it appropriate for a large number of cascaded levels, as well as energy storage systems that use lower voltage battery modules or cells.

If a defect occurs in the battery module, it may be bypassed without impacting the other modules in the system. As a result, this converter has strong fault- control capabilities and can increase system dependability.

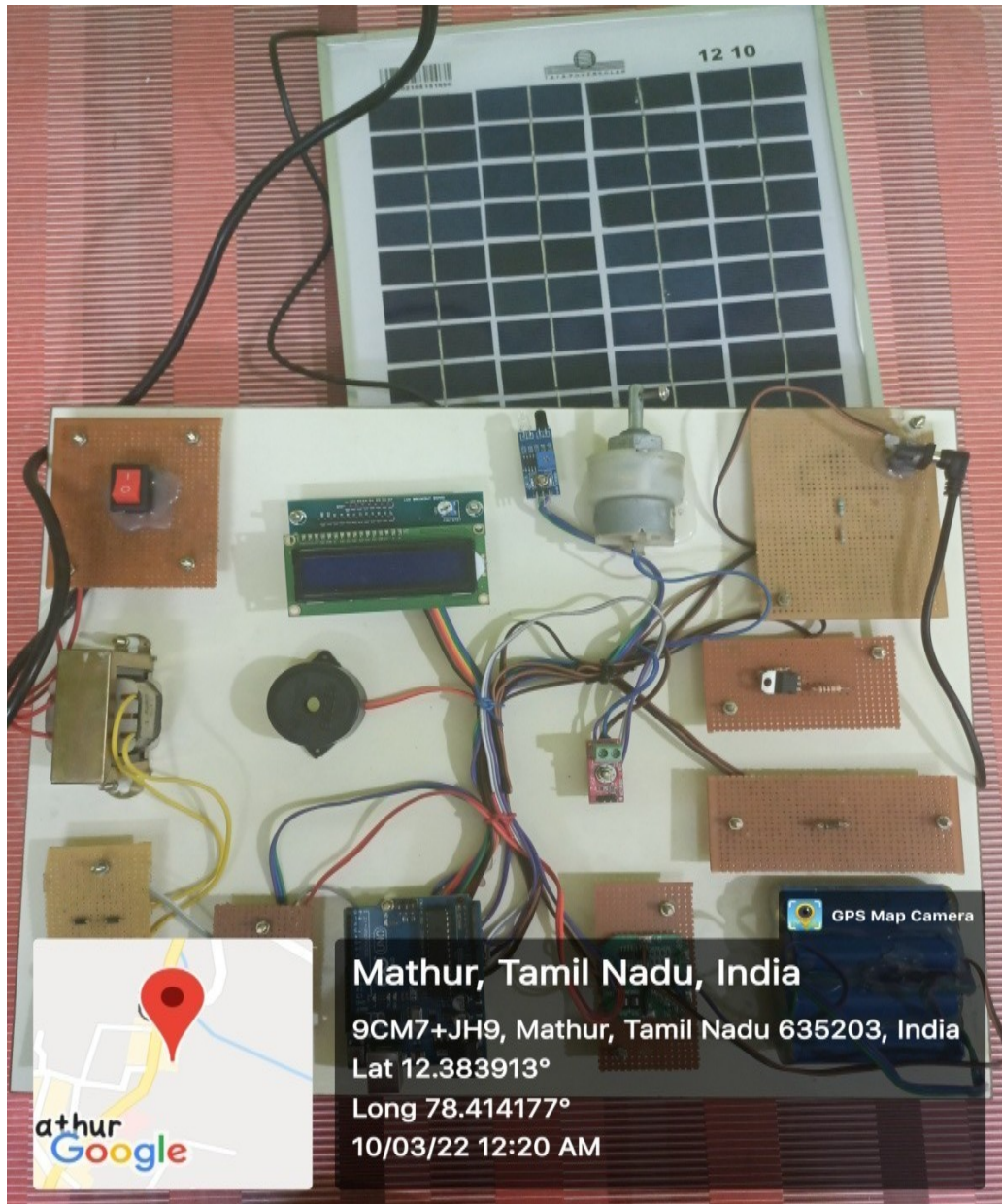
We can build super charging methods for EVs in the future utilising this technology, allowing us to charge the vehicle in one hour.

REFERENCES

1. Chol-Ho.k, Young-Do. k , and Gun-Woo.M, "Individual cell voltage equalizer usings Elective two current paths for series connected Lion battery strings." In Proc. Energy Convers . Congr. Expo.2009. pp.1812-1817.
2. Emadi A, Lee.Y.J and Rajashekara .K.R, "power electronics and motor drives in electric, hybrid electric and plug-in hybrid electric vehicles" IEEE Trans. Ind. Electron. ,vol.55,no.6 June2008.
3. Joghoon.K , Jhongwon.S, Changyoon.C, and Cho.B.H, "Stable configuration of a Lion series battery pack based on a screening process for improved voltage / SOC balance I EEETrans.PowerElectron.,vol.27,no.1,pp.411- 424,Jan2012.
4. Luick.S.M, Cao.J, Bnasal.R.C ,Rodriguez.F and Emadi.A, "energy storage system for automotive applications"IEEETrans.Ind.Electron.vol.55no.6 pp,Jul 2008.
5. Shen.H, .Zhu.W, and Chen.W , "Charge equalization using magnetic winding model for Lithium-ion battery string."InProc.Asia-pacific power Energy Eng. Conf .2010,pp.1
6. Sang-Hyun.P,Ki-BUM,P,Hyoung-suk. K ,Gun-woo. M ,and Myung.Y magnetic cell-to-charge equalization coverter with reduced number of transformer windings." IEEE Trans Power Electron., vol.27 no.6,pp,2900-2911,Jun2012.
7. Yarlagadda.S ,Hartley.T.T , and Hussain. T,"A battery management system using an active charge equalization technique based on DC/DC converter topology," in Proc. Energy Convers.Congr.Expo.,2011,pp.1188-1195.
8. Zhang.H.M and Ding.S.P "Application of synergic electric power supply in HEV" 8th World Congr .Intelligent controlaction,2010.
9. Zedong zheng, member, IEEE, kui wag, member, 1EEE, lie xu, member IEEE and yongdong li, member "A hybrid cascaded multilevel converter for battery energy management applied in electric vehicle"IEEE2014.

GEOTAGGED PHOTOS

HARDWARE SETUP



RESULT OF THE PROJECT

