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# Design and Development of Battery Capacity Management(BCM) Gauge

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**ABSTRACT**
Environmental Issues Are Gaining More Importance Nowadays Due To Their Effect On Human Lives. The Major Percentage Of Environmental Pollution Is Due To Automobiles And Other Pollutant Industries. Hence There Is A Move To Change The Automobile Designs To Make Them Environmental Friendly. The Way Forward Is To Have Battery-Based Vehicles To Meet The Environmental Conditions As These Vehicles Do Not Contribute To Environmental Pollution. The Battery-Based Vehicles Performance Is Dependent On The Life Of The Battery. To Keep The Vigil On The Life Of The Battery It Is Necessary To Have A Battery Capacity Management System In Place. The Present Work On The Battery Capacity Management Gauge Provides The Information On The Battery Capacity And The Kilometers Covered/Can Be Covered By The Vehicle. The Battery Capacity Management Gauge (BCMG) Is Developed To Estimate The State Of Charge And State Of Health Based On The Coulomb Counting Method. The BCM Also Provides The Information On The Kilometers Covered And Can Be Covered Based On The Estimated State Of Charge/State Of Health By Assuming The Rated Kilometers/Charge Under Standard Test Conditions.

**Keywords –** Battery Capacity Management(BCM), Microcontroller, SOC, SOH, Voltage And Current Sensor.

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## I. INTRODUCTION

The Tangible Issue That The World Is Confronting Today Is The Natural Contamination, Expanding With Each Passing Year And Making Grave And Unsalvageable Harm The Earth. Major Percentage Of This Pollution Is Due To Air Pollution. Air Contamination Is Cause By The Damaging Smoke Radiated Via Autos, Transports, Trucks, Trains, And Manufacturing Plants, To Be Specific Sulfur Dioxide, Carbon Monoxide And Nitrogen Oxides.

Currently Evs/Hevs/Phevs Are Being Researched More To Provide A Safe And Healthy Transportation System. The Main Fuel Source Of These Vehicles Is Battery. The Life Of The Battery Determines The Performance Of These Vehicles. The Efficiency Of These Vehicles Can Be Improved By Extending The Life Of The Battery By Proper Management. Electric Vehicles Require Many Auxiliary Devices Or Subsystems To Enhance The Vehicle's Maneuverability And Driver's Comfortability. Some Of The Main EV Auxiliaries Are Battery Charger, Battery Management System (BMS) And Regenerative Braking System, Etc.

Assimilating All EV Auxiliaries Relating To Electrical Energy Control, Energy Management System (EMS) Plays A Valuable Role In Evs. The EMS Makes Use Of Sensory Inputs From Various Subsystems To Select Various Battery Operations Such As, The Battery Charging Scheme, To Indicate The Battery State Of Charge(SOC), To Indicate The State Of Health(SOH), To Predict The Driving Range, To Manage The Battery Operation, To Regulate Temperature Control In The EV Compartment, To Adjust Lighting Brightness And To Recover Regenerative Braking Energy To Charge The Battery.

A Significant Subset Of The EMS Is The Battery Management System(BMS). It Helves The Battery's Indication, Measurement, Prediction And The Overall Management. The BMS Consists Of Sensors (Voltage, Current And Temperature), Microprocessor-Based Control Unit And Some IO Interface Peripherals. The Basic Function Of The BMS Is To Monitor The Battery's Working Behaviors (Voltage, Current And Temperature), Therefore Predicting Its SOC, SOH And The Driving Range.

## II. PROPOSED SYSTEM

The Block Diagram of The Proposed System Is As Shown Below.

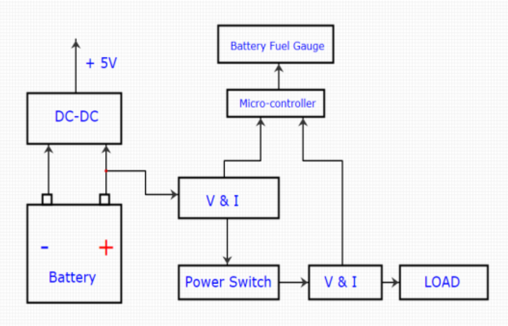


**Figure-1.0:** Block Diagram Of Proposed System

## III. LITERATURE SURVEY

This Section Puts Forth The Review Of Previous Work On The Battery Management System For Electric Vehicle Applications. The Incentive And The Problem Statement Are Derived From The Literature Survey.

The Transportation Technology Has Seen A Sea Of Changes Due To Electric Vehicles/Hybrid Electric Vehicles/Plug In Hybrid Vehicles. Electric Vehicles Have Become A New Paradigm Of Transportation. These Vehicles Are Environmental Friendly Because Of Low Emission And Sound Pollution. However, These Vehicles Have Bigger Challenges In Terms Of Battery Life, Energy Consumption.

Zhongyue Zou [4] Evaluated Four Model-Based State Of Charge (SOC) Estimation Methods For Lithium-Ion (Li-Ion) Batteries. As One Of The Key Parameters Of A Battery, The Condition Of Charge (SOC) Is One Of The Primary Investigation Points Of Battery Innovation. The SOC Is Characterized As The Proportion Of The Rest Of The Limit Over The Ostensible Limit Of A Battery [3,9].

Nothing Like The Voltage And The Current Of The Battery, The SOC Can't Be Estimated Straightforwardly. Accordingly, Appropriate Estimation Techniques Ought To Be Used To Acquire The SOC Of A Battery. Till Date Many Of SOC Estimation Methods Developed, Which Can Be Catalogued In Several Types: The Ampere-Hour Method (AHM), The Electrochemical Method, The Artificial Intelligence Methods, The Model-Based Method, Etc. According To The Definition Of The SOC, The AHM Is The Most Obvious Method [10–12].

Yukihiro Tanaka Et Al [13] Have Shown That Most Of The Electric Vehicles Are Inefficient Since Battery Supplies All Power Through DC-DC Converter All The Time. They Have Proposed A High Efficient Energy Conversion System (HEECS) Using Two Batteries: A Main Battery And A Sub Battery. The System Is Efficient Because The Battery Supplies All The Power Directly And Sub Battery Supplies Additional Power Through DC-DC Converter. Thus, The System Is Highly Efficient.

The Literature Survey Indicates That There Is A Need For Efficient Battery Management Mechanism For Electric Vehicle Applications. The Main Goal Is To Reduce Global Warming By Pollution Control. To Achieve The Desired Goal, The Electric Vehicle And Hybrid Electric Vehicles Are Necessary. Since These Vehicles Are Battery Operated, Efficient Energy Management And Efficient Electronic Battery Management Control Is Necessary To Deliver Optimum Performance.

## IV. HARDWARE DESIGN

In This Section The Design And Development Of The Project Is Presented. It Consists Of Hardware And Software Sections. Hardware Part Of The Project Involves The Circuit Design, Schematic Entry And Assembly Of The Designed PCB. Assembled PCB Will Have To Be Tested And To Be Integrated With The Firmware Developed. The Computer Aided Circuit Design Tool Namely "ORCAD" Has Been Used For Generating Circuit And The Printed Circuit Board.

## DC- DC CONVERTER

The DC-DC Converter Is Designed Using LM317 Device Which Acts As An Adjustable Voltage Regulator. It Operates As A Buck Converter That Converts The 12V, DC Supplied By The Battery To 5V, DC. It Makes Use Of A Voltage Divider Circuit To Set The Output Voltage. The Circuit Is Shown In The Figure-5.1.

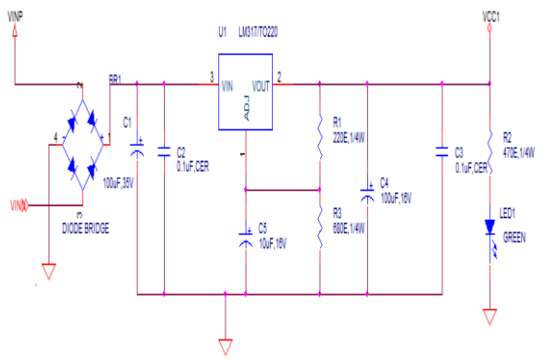


Figure-1.1: DC-DC Converter Using LM317

Design: Input Voltage: 12V

Output Voltage: 5V

Assume $R_1 = 220\Omega$ (1)

Output Voltage Is Given By:


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$$V_0 = 1.25\left(1 + \frac{R_3}{R_1}\right) \quad (2)$$

$$V_0 = 1.25\left(1 + \frac{R_3}{220}\right)$$

$$R_1 = 660\Omega \cong 680\Omega \quad (3)$$

C1= 1000uf Electrolytic Capacitor As Recommended In Data Sheet Of LM317.
C2=0.1uf Ceramic Non-Polarized As Recommended In Data Sheet Of LM317.
C3= 470uf/220uf Electrolytic As Smoothing Capacitor.
C4=10uf/16V Electrolytic To Remove Ripple.
R2= 470E, ¼ W, 5%
LED1 = Green LED To Indicate The Power Presence.

## V. MICROCONTROLLER CIRCUIT

The Microcontroller Circuit Is Shown In The Figure-5.2. The Microcontroller Used Is From Microchip With The Version Number PIC 16F877 Where PIC Stands For "Peripheral Interface Controller". It Is A 40-Pin Device Which Has 5 Ports, Each Of Which Can Be Used For Multiple Applications And I/O Peripherals. The Microcontroller Can Work In The Range Between 4mhz To 20 Mhz Clock. In This Application 20 Mhz Clock Is Used.

The Microcontroller Is Programmed Through In Circuit Serial Programming Method. In This Circuit Two I/O Pins Viz, AN0, AN1 Are Used As ADC Inputs To Acquire Battery Voltage And Current Sensor Data. The Port 'D' Is Used As A Data Bus To Exchange Data Between Liquid Crystal Display (LCD).

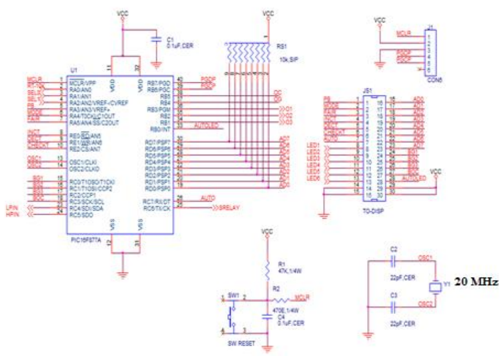



**Figure-1.2:** Microcontroller With Clock And Reset Circuitry

## SIGNAL CONDITIONING FOR BATTERY VOLTAGE SENSING

The Signal Conditioning Circuits Are Used To Make The Sensory Signals Compatible For Further Processing. The Battery Voltage That Is Sensed Using The ADC Of The Microcontroller Is Fed To The Signal Conditioning Circuit That Is Designed Using LM358. It Is Configured As A Buffer And A Low Pass Filter Using The RC Circuit. The Output Of This Buffer Is Limited To 5V By The 5.1V Zener Diode Thus, Providing Protection To The Microcontroller I/O Pin From Any Damage. The Voltage Sensing Circuit Is Depicted In Figure-5.4.

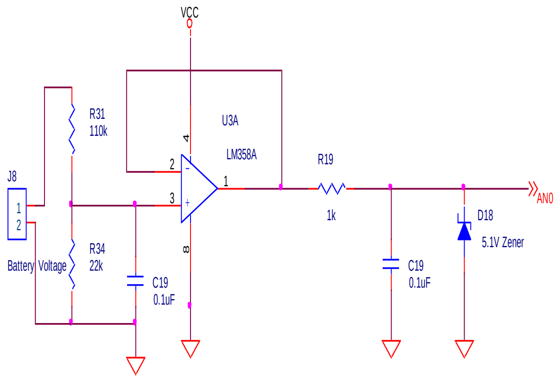



**Figure-1.3:** Signal Conditioning Circuit For Voltage Sensing

## VI. SIGNAL CONDITIONING FOR BATTERY CURRENT SENSING

The Signal Conditioning Circuit Is Designed Using LM358. The Battery Current Is Sensed By The Microcontroller And Fed To This Circuit. It Is Configured As A Buffer And A Low Pass Filter Using The RC Circuit. The Output Of This Buffer Is Limited To 5V By The 5.1V Zener Diode Thus, Providing Protection To The Microcontroller I/O Pin From Any Damage That Can Happen When High Voltage Appears At The Output Of The Buffer. The Current Sensing Circuit Is Depicted In The Figure-5.5.

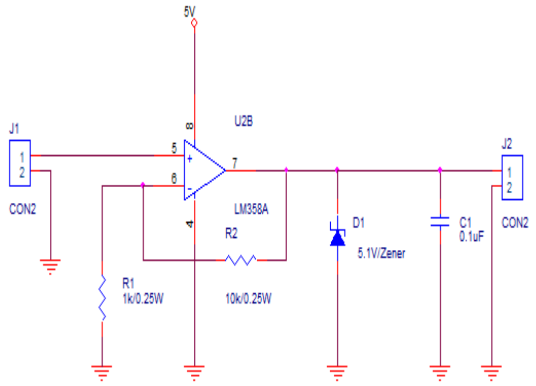



**Figure-1.4:** Signal Conditioning Circuit For Current Sensing

## VII. METHODOLOGY

A Conclusion Section Must Be Included And Should Indicate Clearly The Advantages, Limitations, And Possible Applications Of The Paper

The System Is Operated By The Battery. System Is Designed With Microcontroller And LCD Display. The Microcontroller Tabulates The Battery Voltage And Current In Conjunction With The Time Of Battery Usage. The Product Of Current Consumed And Time Elapsed Is Calculated To Find The Battery Capacity In Ah.

To Estimate The State Of Charge(SOC), "Coulombs Counting Method" Is Used And The Values Are Tabulated For Each Time Interval. The Corresponding State Of Health(SOH) Of The Battery Is Also Calculated For Every Half An Hour Interval. The Equations Used To Calculate The SOC And SOH Are As Follows,

$$SOC = \left[1 - \frac{\int_0^t i_t dt}{Q_r}\right] * 100$$

$$SOH = \frac{Q_m}{Q_r} * 100$$

Where, $Q_m$= Maximum Energy Released In Ah

$Q_r$=Rated Capacity In Ah

The Maximum Kilometers That Can Be Covered By The Battery Of 12V, 7Ah Capacity Is Assumed To Be 60km. And Considering The Usable Energy To Be 90% Of Charge, The Distance Already Covered, And The Distance Expected To Be Covered Are Calculated And Tabulated.

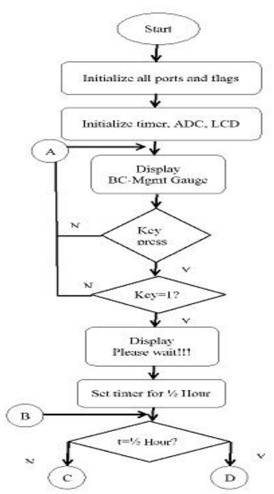
The Kilometers Covered Is Given By,

$$KMC = SOH * {}^{60}/_{90}$$

Expected Kilometers Is Given By,

$$KME = SOC * 0.67$$

Thus, The System Helps In Estimation Of Battery Parameters And Improve The Battery Capacity Management.



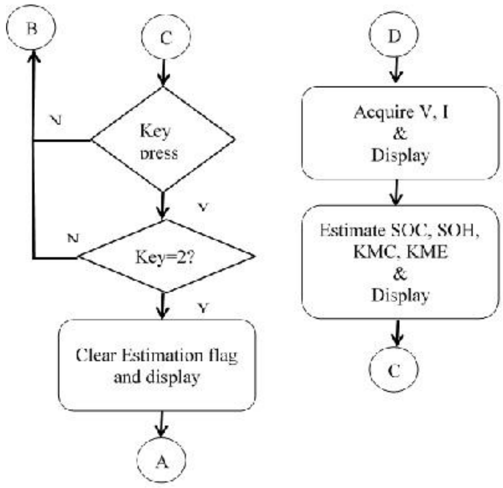




**Figure-1.5:** Flowchart Of The System

## VIII. RESULTS AND ANALYSIS

The Experimental Results And Analysis Of The Proposed Prototype Is Presented In This Section. The State Of Charge(SOC) Is Defined As The Percentage Representation Of The Available Capacity. The Antonym For SOC Is Depth Of Discharge(DOD). SOC Represents The Short-Term Value Of The Available Competence Of The Battery. To Estimate The SOC Of The Battery Coulomb's Counting Method Is Commonly Used.

The State Of Health(SOH) Is Defined As The Measurement That Reflects The Condition Of The Battery And Its Performance Compared To An Unused Battery. The SOH Represents The Long-Term Capability Of The Battery. To Estimate The SOH Of A Battery Its Cell Impedance Is Monitored.

Calculation Of SOC And SOH

$$SOC = \left[1 - \frac{\int_0^t i_t dt}{Q_r}\right] * 100$$

$$SOH = \frac{Q_m}{Q_r} * 100$$

Where, $Q_m$= Maximum Energy Released In Ah

$Q_r$=Rated Capacity In Ah

$$Q_m = 604 * 10^{-3} A * 0.5hr$$

$$Q_m = 302 * 10^{-3} Ah$$

$$SOH = \frac{302 * 10^{-3}}{7}$$

$$SOH = 43.14 * 10^{-3} * 100_{\simeq 4\%}$$

$$SOC = 100 - 4 \simeq 96\%$$

Assume That The Kilometres/ Charge Be 60 Km, Considering The Usable Energy To Be 90% Of Charge

Then Kilometres Covered Is Given By,

$$KMC = SOH * {}^{60}/_{90}$$

$$KMC = 4 * 0.67 \simeq 3km$$

Expected Kilometres Is Given By,

$$KME = SOC * 0.67$$

$$KME = (96 - 10) * 0.67$$

$$KME = 57km$$

## IX. FIGURES And Tabulation

Experimental Setup: This Section Depicts The Experimental Setup Of The Proposed System.

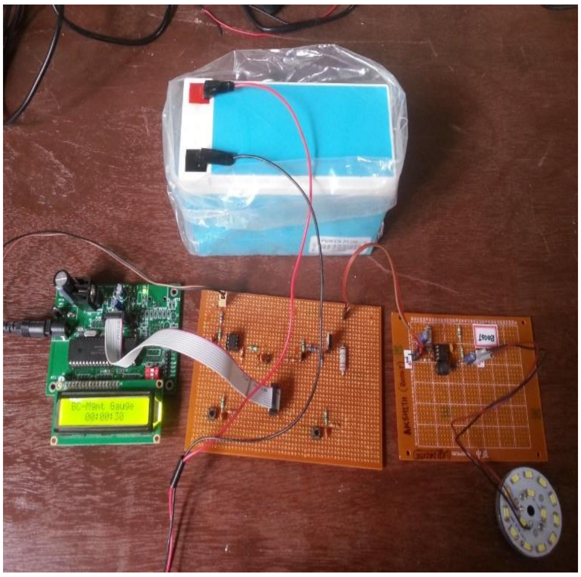


**Figure-1.6:** Experimental Setup

The Figure-1.6 Represents The Experimental Setup Before The Operation I.E., Before The Start Button Is Pressed. And The Setup During The Operation Of The System Is Depicted In The Figure-1.7.

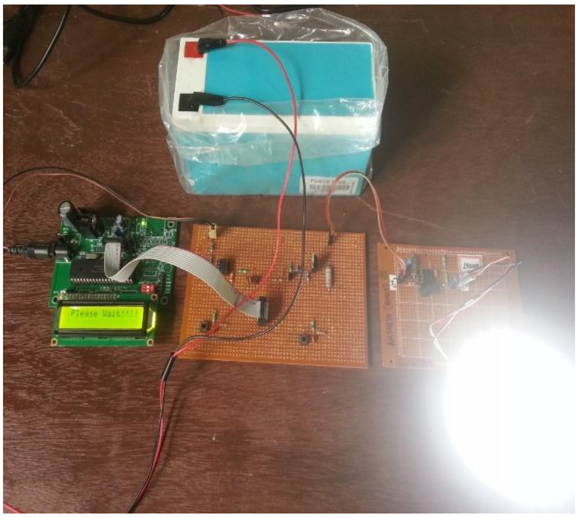


**Figure-1.7:** Experimental Setup With The Boost Converter And LED Load

**TABLE 1** System Parameters With Respect To Time Elapsed

| Sl No. | $V_L$(V) | $I_L$(Ma) | Time Elapsed(Hr) | SOC (%) | KMC (Km) | KME (Km) |
|---|---|---|---|---|---|---|
| 1 | 12.79 | 604 | 0.5 | 96 | 3 | 57 |
| 2 | 12.69 | 601 | 1 | 92 | 5 | 54 |
| 3 | 12.16 | 498 | 1.5 | 88 | 8 | 52 |
| 4 | 12.04 | 494 | 2 | 84 | 11 | 49 |
| 5 | 12.48 | 536 | 2.5 | 80 | 13 | 46 |
| 6 | 11.95 | 520 | 3 | 76 | 16 | 44 |

**TABLE 2** Soc And SOH Recorded Against The Time Elapsed

| Time Elapsed (Hours) | SOC (%) | SOH (%) |
|---|---|---|
| 0.5 | 96 | 4 |
| 1 | 92 | 8 |
| 1.5 | 88 | 12 |
| 2 | 84 | 16 |
| 2.5 | 80 | 20 |
| 3 | 76 | 24 |

The Figure Represents The Graphical Representation Of The Battery's SOC And SOH Characteristics With Respect To Time Elapsed.

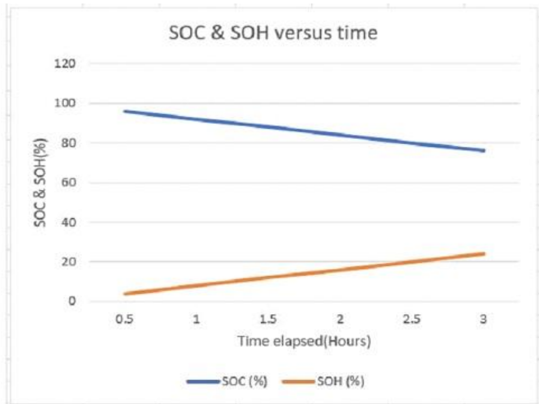



**Figure-1.8:** SOC And SOH Characteristics Of The 12Ah Battery

## X. CONCLUSION

The Battery Capacity Management Gauge (BCMG) Has Been Developed Using Microcontroller. The Estimation Of State Of Charge And State Of Health Has Been Carried Out By

Discharging The Battery With A Load Of 7W LED. The Coulomb Counting Method Was Used In The Experiments. The Developed System Was Able To Estimate The SOC, SOH And Display The Estimated Values On Display. Gauge Was Also Used To Display The Kilometres Covered, And The Expected Kilometres To Be Covered Based On The State Of Health And State Of Health Respectively. It Was Assumed That The 60 Kilometres Could Be Covered With Fully Charged Battery, I.E., With 100% SOC.

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