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# BATTERY TEST RIG AND BATTERY MANAGEMENT SYSTEM FOR RECYCLING LI-ION CELLS FOR AUTOMOBILE BATTERY PACK

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## ABSTRACT

The In the upcoming automobile market where the battery vehicle can dominate the industry is in need of resources. Scavenging the used battery cells for new battery packs is going to help to overcome the shortage of resources. Our project emphasizes on the idea of reusing the resources available and testing it for safety and avoid any catastrophic failure that may occur due to scavenging. The world moving fast towards the implementation of electric vehicles (EV's) in the next decade. The rise in portable devices and the implementation of technology anywhere and everywhere possible has caused rise in demand for the battery technology. Li-ion battery which are popularly used in every device available today has huge upside potential and very few downsides. Li-ion batteries are opted for every devices due to the least self-discharge capabilities, energy density and its capacity to maintain constant voltage throughout discharge cycle. Our project aims to check the parameters of the battery measure its life cycles, SOC (state of charge), SOH (state of health), discharge and charge cycles using battery test rig fabricated by the team and also create a battery management system and discuss the problems in battery safety and demands in auto sector come up with the solution for the problems. Batteries which are properly maintained can live up to decade with around 25% degraded capacity. The degradation of the battery is also conducted in the project using the HP elite book 2560p Battery pack and its in-built software to determine the battery parameters. The battery pack has 3S configuration with 11.8v and 5000mAh capacity.


**KEYWORDS:** Battery Test rig, BMS (battery management system), Audrino nano, Li-ion (18650) cell.

**INTRODUCTION:**

Batter management system is a Battery Monitoring system, keeping a check on the key operational parameters during charging and discharging such as voltage, current and the battery internal and ambient temperature. The monitoring circuits would normally provide inputs to protection devices which would generate alarms or disconnect the battery from the load or charger should any of the parameters become out of limits.

The project deals with the complete study and analysis of the li-ion battery and design of the battery protection and equalization circuit. First the battery testing is done checking its voltage, current usage and its capacity using a voltage divider and load application circuit with arduino microcontroller as its brain. The circuit is capable of checking battery voltage, current usage and battery capacity testing.

Second part of the project is to estimate the SOC (state of charge), SOH (state of health), charging and discharging cycles, voltage and current drop through the charging and discharging cycles. With the results obtained the charging, discharging and cell balancing circuit with overload and over discharging protection circuit will be designed.

Third part is to analyze the battery usage in automobile various demand from automobile and design a battery management system for the battery pack.

**Battery testing parameters:**

The tests followed in the experiments are:-

**Cycle Testing:**

This is perhaps the most important of the qualification tests. Cells are subjected to repeated charge - discharge cycles to verify that the cells meet or exceed the manufacturer's claimed cycle life. Cycle life is usually defined as the number of charge - discharge cycles a battery can perform before its nominal capacity falls below 80% of its initial rated capacity[1].

The 18650 cells which we have taken has undergone 702 cycles of charge and discharging Load Testing

**Load testing:**

Load testing is used to verify that the battery can deliver its specified power when needed.

The load is usually designed to be representative of the expected conditions in which the battery may be used. It may be a constant load at the C rate or pulsed loads at higher current rates or in the case of automotive batteries, the load may be designed to simulate a typical driving pattern. Low power testing is usually carried out with resistive loads.

We have used a 10 ohm 10 watt power resistor as a discharging resistor for constant load output.

**Calorimeter:**

Battery thermal management is critical for high-power battery packs. Obtaining accurate heat generation data from battery modules is essential for designing battery thermal management systems. A calorimeter is used to quantify the total amount of heat generated by the battery while it is cycled through its charge/discharge cycles[1].

As per the experiment conducted the battery operated at maximum efficiency at temperature between 25-45°c.

**Design and working of battery test rig:**

The design is based on Arduino Nano. An OLED display is used to display the battery parameters. Screw terminals are used for connecting battery and the load resistance. A buzzer is used for giving different alerts. Two voltage dividers circuit are used to monitor the voltages across the load resistance. The function of the MOSFET is to connect or disconnect the load resistance with the battery.

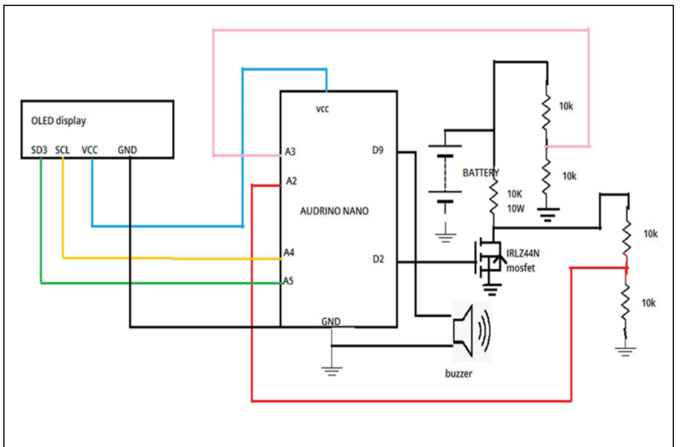


**Fig 1.1 Circuit diagram of test rig**

Materials used for construction of circuit:

1. MOSFET - IRLZ44
2. 0.96" OLED Display
3. Resistors (10k – 4 no's, 10W 10 ohm)
4. Screw Terminals ( 3 Nos)
5. Arduino Nano

6. Buzzer
7. 18650 Battery Holder
8. 18650 Battery
9. Bread board
10. Jumper cables
11. Prototype board

Tools required:
1. Soldering Iron
2. Wire Cutter / Stripper
3. Glue Gun

**Selecting the MOSFET**
Here MOSFET is act like a switch. The digital output from the Arduino pin D2 controls the switch. When 5V (HIGH) signal is fed to the gate of the MOSFET, it allows current to pass from the positive terminal of the battery, through the resistor, and the MOSFET then completes the path back to the negative terminal. This discharges the battery over a period of time.

We have used an n-channel logic level power MOSFET IRLZ44. The L shows that is a logic level MOSFET. A logic level MOSFET means that it is designed to turn on fully from the logic level of a microcontroller.

**Display**
To display the Battery Voltage, discharge current and capacity, we used a 0.96" OLED display. It has 128x64 resolution and uses I2C bus to communicate with the Arduino.

5V ----->Vcc

GND -->GND

A4 -----> SDA

A5 -----> SCL

**Buzzer**
To provide different warning or alert, a buzzer is used. The different alerts are

1. Battery Low Voltage
2. Battery High Voltage
3. No Battery

D9 ----> Positive terminal

GND--> Negative terminal

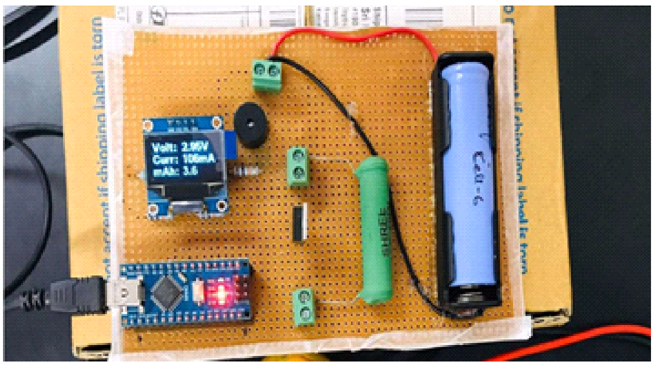

**Fig 1.2 constructed test rig**

**Working**
Arduino check the battery condition, if the battery is good, gives command to switched ON the MOSFET. It allows current to pass from the positive terminal of the battery, through the resistor, and the MOSFET then completes the path back to the negative terminal. This discharges the battery over a period of time. Arduino measures voltage across the load resistor and then divided by the resistance to find out the discharge current. Multiplied this by the time to obtain the mili amp-hour (capacity) value.

**Formula used for measuring parameters:**
**Voltage measurement**
The Arduino board has an inbuilt analog values (upto1024) that can measure voltages up to 5v.

**Current measurement**
Current (I) = Voltage (V) - Voltage drop across the MOSFET (0) / Resistance (R).[2]

**Capacity measurement**
Stored Charge (Q) = Current (I) x Time (T).[2]

The millis() function in Arduino can be used to measure the elapsed time.

**Selecting Load**
Resistance (R) = Max Battery Voltage / Discharge Current.[2]
= 4.2 /0.5 = 8.4 Ohm.

Heat dissipated = I^2 x R = 0.5^2 x 8.4 =2.1 Watt.

**Audrino code Explanation:**
*Initial Values assigned for variables used*[3]

```
float Capacity = 0.0     Capacity in mAh
float Res_Value = 5.0    Resistor Value in Ohm
float Vcc =  4.9         Voltage of Arduino 5V pin
float Current = 0.0      Current in Amp
float mA=0               Current in mA
float Bat_Volt = 0.0     Battery Voltage
float Res_Volt = 0.0     Voltage at lower end of the Resistor
float Bat_High = 4.3     Battery High Voltage
float Bat_Low = 2.9      Discharge Cut Off Voltage
```

*Display settings and position*[3]

```
u8g.drawStr (0, 20, "Volt:  “)
u8g.drawStr (0, 40, "Curr: ")
u8g.drawStr (0, 60, "mAh: ")
u8g.setPrintPos (58, 20)
u8g.print (Bat_Volt, 2)
u8g.println ("V")
u8g.setPrintPos (58, 40)
u8g.print (mA,0)
u8g.println ("mA")
u8g.setPrintPos (58, 60)
u8g.print (Capacity, 1)
```

*Buzzer function* [3]

```
analogWrite(9, 20);
delay(delay_time);
analogWrite(Buzzer_Pin, 0);
delay(delay_time);
```

*main function*
Check if the battery voltage is within the safe limit. If the condition is satisfied then the MOSFET is switched on to start discharging. Time is calculated using the millis function. Current is calculated by the formula that I=V/R. Current value is then converted to mA and displayed on the screen. Capacity is calculated using the formula 'mA*time elapsed'. Serial print function is used to get the data on the excel sheet using PLX-DAQ add on.

*Below is the main function code*

```
if(Bat_Volt > Bat_Low && Bat_Volt < Bat_High  )
{
digitalWrite(MOSFET_Pin, HIGH);
millisPassed = millis() - previousMillis;
Current = (Bat_Volt ) / Res_Value;
mA = Current * 1000.0 ;
Capacity = Capacity + mA * (millisPassed / 3600000.0); // 1 Hour = 3600000ms
```

```
previousMillis=millis();
Serial.print("DATA,TIME,");
Serial.print(Bat_Volt);
Serial.print(",");
Serial.println(Capacity);
row++;
x++;
delay(4000);
}
```

**RESULTS:**
The data from the Audrino is loaded on to the excel sheet and graph is obtained using PLX-DAQ add-on.

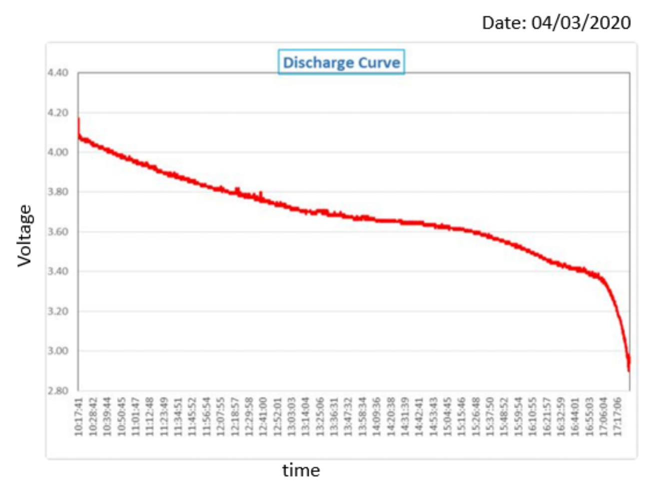


**Fig 2.1 voltage vs time graph**

In the result graph imported from audrino and put onto Excel we can see the voltage drop from 4.1-2.9v over the period of 7 hours under constant discharge current of 200ma.

According to the formula

Charge stored= discharge current* time

Which results in,

Capacity= 100ma*7 = 700mah

Company specified capacity is 850mah as mentioned on the battery.

The degraded capacity of the battery is 17.64% over 7 years which results in 2.52% degradation/ year.

**DISCUSSION OF DESIGN OF BMS:**
The battery pack is a series connection of individual battery cells. These cells even though made with the same process has slight different chemistry. The charging and discharging cycles may vary with prolonged use of these batteries. In order to maintain a healthy battery chemistry it should be maintained properly without overcharging, over discharging, or overheating. To control all these parameters properly in a battery back a circuit is designed which acts as a switch and balancer for battery pack is known as battery management system.

**Requirements discussed:**

1. Provide huge surge or supply of current for sudden pickup of the vehicle.
2. Provide high voltage for higher vehicle speed.
3. Provide a consistent energy supply through the battery discharge cycle.
4. Super-fast recharging the battery pack.
5. Higher life extraction from the battery pack.
6. Avoid catastrophic accidents that may occur during overloading or overcharging.

**Solutions discussed:**
**Requirement 1:** Li-ion battery cells are excellent for all applications but doesn't provide a huge surge current as that of lead acid batteries hence the solution is to use a small lead acid battery for the surge current and boost the vehicle pickup. The BMS must be able to switch between the two different batteries for energy extraction

**Requirement 2:** High voltage output is obtained from the battery pack arrangement and adding up a step up and step down transformer to compensate the drop in voltage. The increase in voltage also means decrease in current so the BMS must sense the vehicle demand (more torque=more current required, more speed=more voltage required).

**Requirement 3:** maintain a constant discharge from all the cells uniformly.

**Requirement 4:** Li-ion batteries have higher charge capacity so if each individual cell is recharged separately the recharging of batteries can be accomplished with least time with maximum safety but with increased energy loses during charging.

**Requirement 5 and 6:** design a circuit with overcharge and overload protection with smart temperature control unit and cut-off unit.

**Block diagram of the solution discussed**

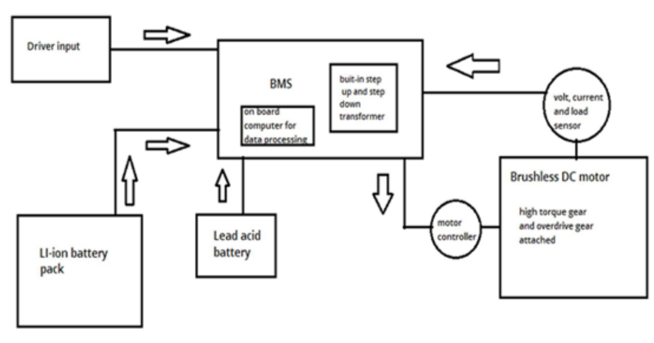


**Fig 3.1 block diagram of BMS function**

**CONCLUSION:**
In the upcoming market where the battery vehicle can dominate the industry is in need of resources. Scavenging the better cells for new battery pack is going to help us overcome the shortage of resources. Our project emphasizes on the idea of reusing the resources available and testing it for safety and avoid any catastrophic failure that may occur due to scavenging.

The project is about to implement using a good characteristics from two different batteries with different cell chemistries. This also comes with the challenge to carefully handle the functioning of two different battery sources.

In the project various tests such as state of charge, state of health, charging and discharging cycles, voltage drop across the cycles on the 18650 cells which are used in HP Elite book 2560p notebook for a period of over 7.67 years and has undergone 702+ cycles.

**REFERENCES:**


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II. Electronics text book for II PUC (revised edition 2015-2016)

III. www.audrino.cc