Performance Effective Battery Management System(BMS) Design of Mini Electric Vehicles

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***Abstract*— Nowadays, the interest in electric vehicles is increasing and we observe that conventional vehicles and electric vehicles are gradually changing their places in some areas of life. However, at this point, a balanced control of electrical energy, which substitutes for "fuel" in conventional vehicles is very important. Rechargeable lithium batteries[1] are used in electric scooters, electric cars, electric logistics robots and many electric vehicles, which are used and widespread in our daily life. Health and safe charging of these batteries are of great importance[2]. It has been observed that the system designed for this article is more advantageous in terms of temperature than BMS cards, which are currently used frequently in the market, and are durable at high currents. (Temperature difference 5% under heavy load for 5 minutes) It has been observed that the system designed for this article is more advantageous in terms of temperature than BMS cards, which are currently used frequently in the market, and are durable at high currents. (Temperature difference 5% under heavy load for 5 minutes) Details of a designed BMS circuit are mentioned in this article. Details of a designed BMS circuit are mentioned in this article. It has been observed that this designed BMS circuit has a longer life and stable operation compared to other equivalents in long-term use and when the load ratio increases. As this method, two different cards are used for the system. The results of transmission large DC loads removed from the main board have been observed.**

Keywords*— *BMS, Battery Management System, mini electric vehicle, urban electric vehicle, performance effective system.

I. INTRODUCTION (*HEADING 1*)

Especially in 2010 and afterwards, thanks to the developments in lithium battery technology, a great increase has been observed in the use of mini electric vehicles in the city. In some cities, electric scooters have started to be used instead of motorcycles using internal combustion engines. In fact, the number of electric scooters was more in percentage terms than the number of motorcycles. By 2028, the use of electric scooters is expected to rise to 129 million worldwide. Especially, as some municipalities and private companies started to rent scooters, there was an increase in the use of these scooters in society.[3] In 2025, it is estimated that the electric scooter market will reach 13 billion dollars. An investment of 2.4 billion dollars has been made in China for the production of lithium-ion batteries in the last 2 years.[4]

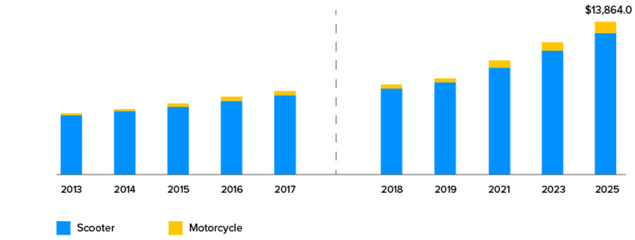

Fig. 1. e-Scooter Market Growth [4]

Considering these developments, lithium-ion battery prices have decreased significantly in the last 10 years due to the increasing demand and the development of production methods. We can see this graph in the chart below.

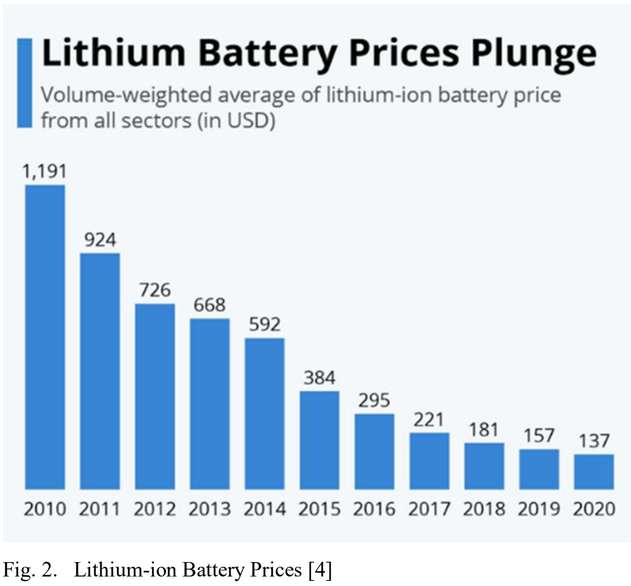

Fig. 2. Lithium-ion Battery Prices [4]

However, the increase in the use of these tools causes some problems. The most important of these is the accident rate.[5] The increase in the accident rate should not be considered only as a crash. Explosion of lithium batteries is one of these accidents. Therefore, these batteries must be protected seriously. In this study, a study was carried out by bringing a different perspective to BMS, Battery Management Systems, which plays an active role in the protection of batteries.[6] Battery Management Systems frequently used for mini electric vehicles are generally analog circuits. No return is expected for feedback from these circuits. They only charge, discharge and balance the circuits. They do not contain any IC (Integrated Circuit) [7] circuit elements. Only MOSFET control is performed. They are usually collected on a single

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board and have a heat-resistant thermal paste on the MOSFETs. However, an IC and MCU (Microcontroller Unit) were used in this study. Thus, voltage values, current values and temperature values for each cell of the batteries can be seen. These are elements that will assist the driver in controlled driving. In addition, since the power and control units are designed as two separate cards, the main board with the IC and MCU will be protected.

II. DESING CRITERIA AND METHODS

A. Desing Criteria

Battery management systems are systems that manage a rechargeable battery. Protecting the battery from the unsafe area, monitoring and balancing voltage and current values are among its main tasks. The main factor when choosing BMS is the cell number of the batteries. According to the number of serially connected batteries in the cells, BMSs are named by names such as 4S, 5S (4 Cells, 5 Cells). In the battery pack the greater the number of cells connected in series, the higher the voltage. For example, if 3 serially connected batteries are used in a battery pack using 18650 lithium batteries, this package is called 11.1 V and 3S. (18650 battery nominal voltage: 3.7 V) If the number of parallel connections in the battery pack increases, the capacity increases. [7]

$Q_{nominal} = 2800\ mA\ .\ hr$ *(Nominal Capacity for 18650 Battery)*

$V_{nominal} = 3.7\ V$ *(Nominal Voltage for 18650 Battery)*

$E_{nominal} = V_{nominal}\ x\ Q_{nominal} = 10{,}36\ .\ W\ .\ hr$ *(Energy in a single 18650 Battery)*

With BMSs, the voltages of the cells in the battery group can be seen. If one of the cells is not charged, or if the voltage value is lower than the others, it can be intervened.[8] With the help of a temperature sensor to be used, cell temperatures, cooler inlet and cooler outlet temperatures can be monitored. It can be seen how much current is drawn in charging or discharging situations.

Generally, BMS circuits are a structure with a BMS integration and MOSFET on a single card. If BMS IC is not integrated, balancing is done manually through a processor. In this study, 2 cards were used instead of a single card. Although it seems disadvantageous in terms of space, temperature and longevity were prioritized.[7]

The circuit we designed is for a mini electric vehicle operating with a supply voltage of 24-48 V. Batteries up to 9-15 cells can be balanced with this circuit. EEPROM programming is not required and communicates with the i2C master microcontroller. It also houses internally integrated cell balancing FETs. In this study, Texas Instruments BQ76940 chip was used. Cost and availability are sufficient for this type of work.[6]

BMSs can monitor energy management in electric vehicles. The state of charge of the batteries (SOC) [9] and the health of the batteries (SOH) can be observed with the BMS. With these, the driving range can also be viewed as an estimate. This feature is equivalent to the fuel gauge in internal combustion engines.

State of Charge (SoC): SOC is the term charged according to the capacity of a battery. We observe these capacities as% (percentage) on the user side. It can also be called a fuel gauge for the battery pack. [10] Usually this value cannot be measured directly. Previous data in the system is needed. We can do this using Coulomb Counter. (Charge and discharge at constant speed)

State of Health (SoH): We express the SoH value with % (Percentage). It means the health of the battery. SoH value of a battery will be 100% at the time of manufacture and will decrease over time. There is no specific value for SoH. BMS designers often make an estimate of SoH [9] using parameters such as internal resistance, capacity, voltage, self-discharge, total energy charged and discharged.

In this study, unlike the traditional, the BMS board is not made up of one piece, but two parts. One side is the main board, the other side is the power distribution side. The aim of this study is to ensure that the card works better and that the card is not damaged when exposed to high current temperatures for a long time and the life of the motherboard is extended

BQ76940 [7] is used as BMS chip and 32-bit STM32F072CB [11] is used as processor. It is designed for batteries of electric motors with 24-48 V supply voltage. It can also be used in solar panel.

The dimensions of the designed PCB are 80 mm x 80 mm. It is designed not to occupy much space in the battery group in electric vehicles. Red solder mask is used. It contains more than 120 components. In order not to be affected by high currents, it makes temperature swings with an extra punch card. Thermal paste can be used on FETs.

B. Methods

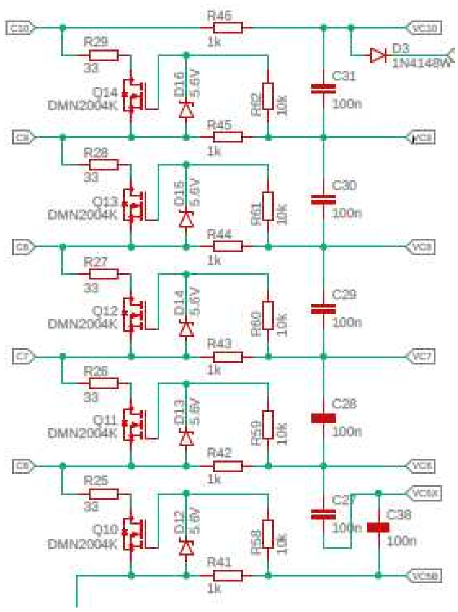

Fig. 3. First 5 Cells on the Balance Side

Switching is done using DMN2004K [12] N channel MOSFETs where the batteries are connected. 15 cells can be connected here. The first 5 are shown here.

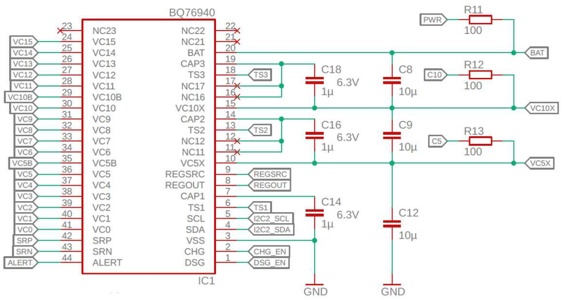

Fig. 4. BQ76940 Connection and Pins

The VC pins of the BMS represent the cells. CHG and DSG at the bottom right represent charge and discharge. Pins 4 and 5 are used in i2C communication with the microprocessor (STM32F0). Some pins are left open, not used.

TABLE I. BQ76940 PIN DESCRIPTION

Pin	Name	Type	Description
1	DSG	O	Discharge FET driver
2	CHG	O	Charge FET driver
3	VSS	-	Chip VSS
4	SDA	I/O	I2C communication to the host controller
5	SCL	I	I2C communication to the host controller
6	TS1	I	Thermistor #1 positive terminal
7	CAP1	O	Capacitor to VSS

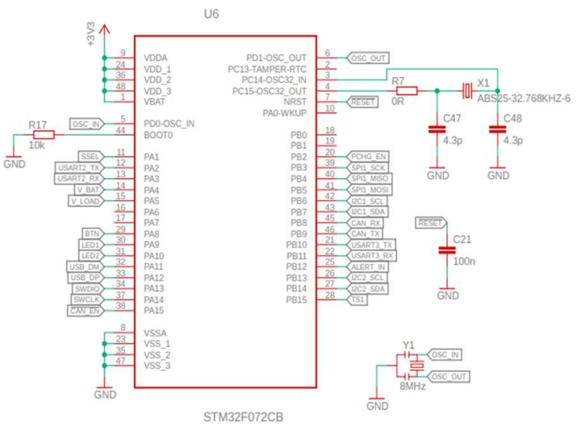

Fig. 5. MCU Side of the Board

The board view of the external power adapter card, which is one of the two cards that make up the system, is given above. It has a perforated structure to carry high current. The 24-48 V voltage coming from the battery pack comes directly to this card first. The bms power distribution board and main board are shown in picture 4 above. The distribution board is designed to be resistant to high currents. There are holes for high current on the board. This technique can be used in many temperature releasing applications. For example, it can be used in mini electric vehicles as in the topic of this article. or it can be used in solar panels. 24-48V voltage is exposed to this board first. then the other card is fed.

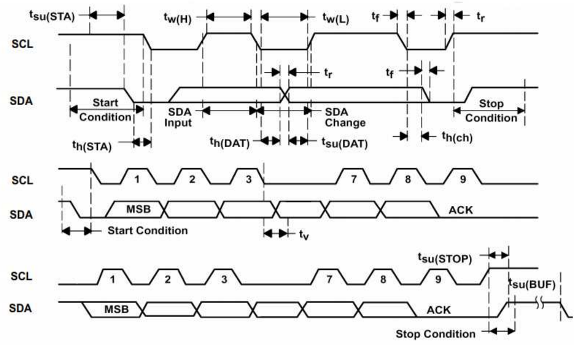

Fig. 6. i^{2}c Diagram

I^{2}C serial bus was used for communication [13] with the microcontroller of BQ76940, which is the BMS integrated we use. This is a master-slave communication. This communication was provided through the I^{2}C pins of the microcontroller and the BMS IC. The BMS integrated circuit used here was used as the slave and the microcontroller as the master. In this way, the microcontroller and the BMS integration became able to talk. With this communication, we will be able to see values such as temperature, voltage and current. In addition, a CANBUS interface [14] has been left open on the board in order to use it when needed and to use the CANBUS feature of the microcontroller.

III. APPLICATION AND RESULTS

A. Application

The circuit designed in this section has been tested. The test was conducted with a BLDC Hub Servo Motor generating between 100-350 watts of power. [15] The motor was powered from a 36V battery at different times. Different BMS circuits have been installed on the battery in different time periods. The graphs below show the test results. Circuits have been tested for 45 minutes. Just 10 Cell Battery used in this test.

Fig. 7. Used BLDC Hub Servo Motor 100-350W

While conducting the application tests, motor, motor driver, designed cards, battery and USB-TTL [16] converter were used. The connection diagram is shown below.

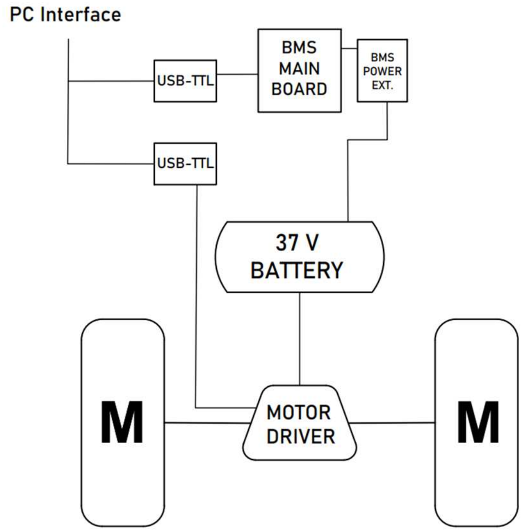

Fig. 8. Test Setup Diagram

Here, they are 350 watt BLDC Servo Motors indicated with the letter "M". A driver is required to drive these servo motors. The phases of the motors and hall-efect cables are connected to the motor driver shown in the diagram. It is then powered by a 37V battery. After that, the battery-bms connection is made. Then, control is made with the user interface created on the computer.

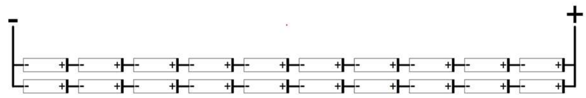

Fig. 9. Battery Connections (10 Series, 2 Parallel)

In practice, 2 parallel 10 series batteries are used. Ten of the BMS cells were used. (10S) Thus, a total voltage of 37 V is reached. With the parallel connection, the capacity is increased and becomes 5600 mAh in total. (2800 * 2)

B. Results

As a result of the tests, better results were obtained than the BMS used before. In terms of temperature, there is a later warming. The graphs below show the change in temperature depending on the current and motor speed.

In the chart, "Temperature 1" indicates the old, stock BMS board. The expression "Temperature 2" represents the newly designed BMS board.

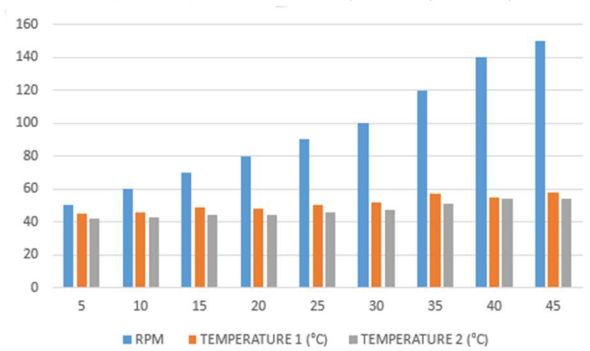

Fig. 10. Time-Motor RPM-Temperature Graph for BMSs

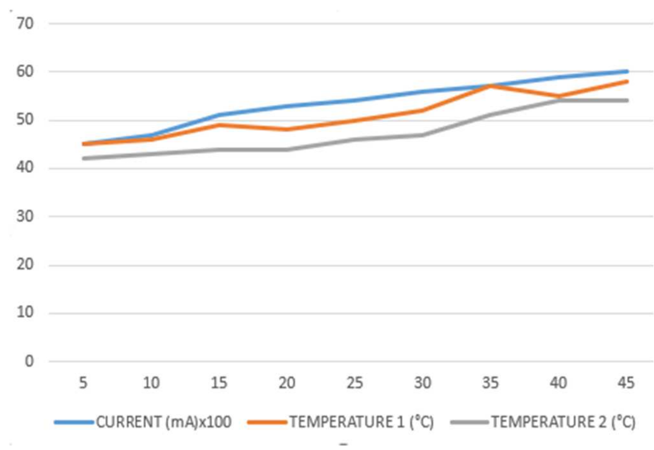

Fig. 11. Time-Current-Temperature Graph for BMSs

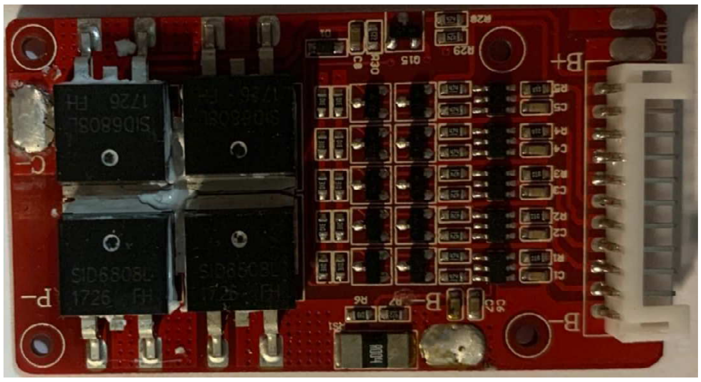

Fig. 12. Stock BMS Circuit 10S

During the test, the temperatures on the board were tried to be observed by an external thermistor sensor. The data were recorded at 5-minute intervals to ensure stability in frequency. The board designed according to the chart above emits 5% less temperature than the other Stock Board, as can be read from the chart.

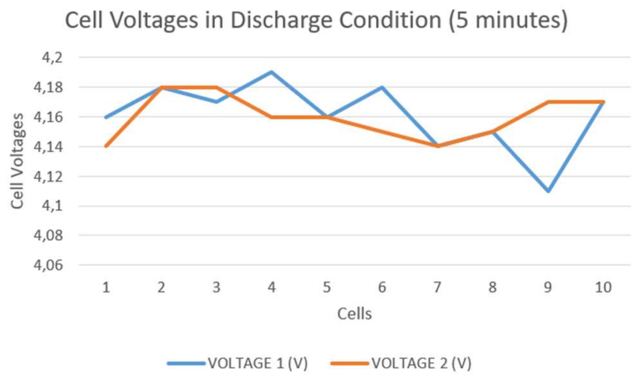

Fig. 13. Cell Voltages in Discharge Condition (5 minutes)

The graph above shows the voltage conditions in the battery cells 5 minutes after the engine is started. Here, "Voltage 1" indicates the stock, old BMS board. With the word "Voltage 2", the newly designed BMS board is shown.

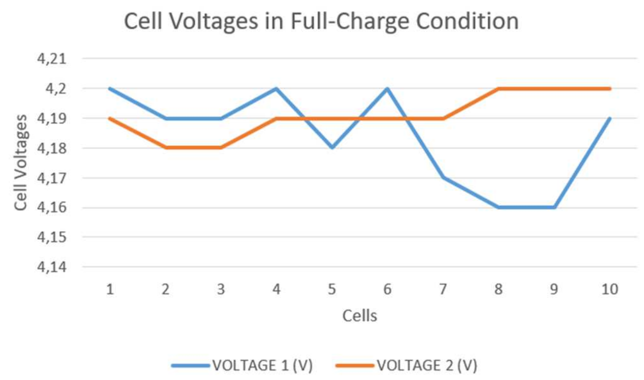

Fig. 14. Cell Voltages in Full-Charge Condition (15 minutes)

In the graph above, the voltage status of the battery cells is observed in 15 minutes of charging. We can see the balance here. The newly designed BMS is denoted "Voltage 2". The old one is shown as "Voltage 1".

IV. Conclusion

In this study, a different interpretation has been made to the BMS design. With this work, a more sustainable and interactive BMS design for mini electric vehicles has been achieved. A BMS has been designed with better charge, discharge and temperature performance than a BMS selected for comparison and currently used.

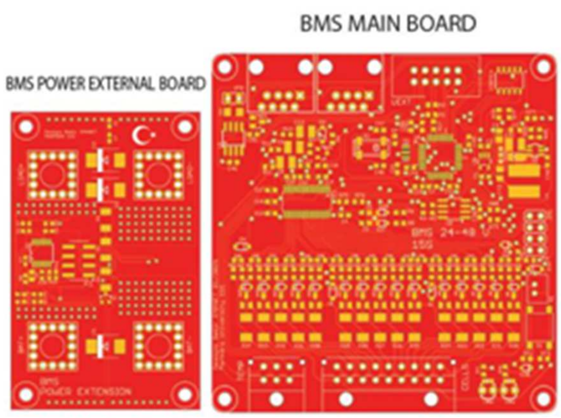

Fig. 15. BMS Power Distribution Board & BMS Main Board

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ATTACHMENTS

BMS Main Board Schematics Page 1 & Page 2