Design and Development of Control Module for Battery Charging and Monitoring

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Abstract : This paper presents the preliminary development of efficient control module for battery charging and monitoring. While designing a charging system for battery some parameters must be considered such as the state of charge, lifecycle of battery and charging time. These parameters are monitored and controlled with the help of Atmega microcontroller. This embedded module is interfaced with charging module for the battery. The battery used in this work is a lead acid battery. A two stage charging technique, includes combination of constant current and constant voltage source which is used to charge lead acid battery.

Index Terms **- Batteries, Constant Current Mode, Constant Voltage Mode, Lead Acid Battery, Microcontroller, Thermal Management**

I. Introduction

In a battery, multiple electrochemical cells are electrically connected together. These cells work on principle of reverse electrochemical reactions. During the charging process, the anode active material is oxidized to generate electrons, and the cathode active material is reduced, which consumes electrons flowing through the external circuit. The charge balance is provided by ion flow between electrodes through an ion-conducting electrolyte. During the discharge process, these processes occurs in reverse order (Grigorii L et al, 2011). Rechargeable batteries are widely used as an energy storage element in the renewable energy systems, back-up power supply systems and electric vehicles. Rechargeable batteries have grown significantly over the last few years due to reliability and steadily reduction in cost. As they are getting cheaper and efficient, the world is about to experience a sharp increase of their applications. As the demand for energy storage devices are increasing for different applications, there is a need for efficient and low cost charging device with monitoring system and faster charging time. Different methods are used to charge and monitor real time status of the batteries. A widely used microcontroller based charging system method suggests to use MOSFET based DC-DC converter and inductor to regulate the input voltage (W. Makni et al, 2016).

The present battery technologies have to be developed to unleash the full potential of energy storage devices. The recent development in high density battery technologies have greatly expanded the energy storage market for various applications like electric mobility, renewable energy storage. The current limitation that has to be overcome in the energy storage devices are rapid charging with better life cycle of the batteries. Thus initiated to develop the various adaptive rapid charging methods which can reduce charging time of the battery (Dong-Rak Kim et al, 2018).The charging control system must be capable enough to adapt itself according to the changes occurs while charging battery. To utilize the full potential of the battery, different parameters of batteries need to be monitored. For better life cycle of battery, they must be charged in multiple stages. Currently, Lead and lithium battery chargers are working in constant current(C-C) and constant voltage(C-V) mode. In C-C mode, charging current is kept constant. To maintain the constant current, the voltage across battery varies and when it reaches its assigned threshold voltage, the constant current mode changes into constant voltage mode. In this mode, the voltage is maintained constant and the current drops until the battery is charged completely. Temperature is one of the important factor that affects the battery life. The battery life changes according to different ambient temperature (Jiexun Liu et al, 2012). Temperature of battery rises, if it is damaged or charging at faster rate. To overcome this issue a reliable method to monitor such temperature changes is required.

This paper presents, the design and preliminary development of simple and low cost battery charger using Atmega microcontroller for various types of rechargeable batteries. Microcontroller has been implemented to monitor and protect the battery from over-charging and deep discharges. A 4.2 V lead acid battery has been used in this present work.

II. Proposed Methodology

The lead-acid batteries are made up of plates of lead and lead dioxide. This plates are immersed in an electrolyte solution of sulphuric acid and water. While discharging the electrodes turns into lead sulphate, whereas the sulphuric acid becomes water. A single cell of lead-acid battery is capable of generating 2.15 V (Hardik Keshan et al, 2016). In present prototype development, a two stage Constant Current-Constant Voltage technique is used to charge lead acid battery. The two stage charging technique is widely used traditional charging technique for lead acid batteries (Pamela G. Horkos et al, 2015). This technique is divided in two stage of charging. In the first stage, the charger provides constant charging current until the voltage of battery reaches a pre-set threshold voltage (Chih-Chiang Hua et al, 2002). In the second stage, the current decreases until the battery is fully charged (Pei-Hsuan Cheng et al, 2003).

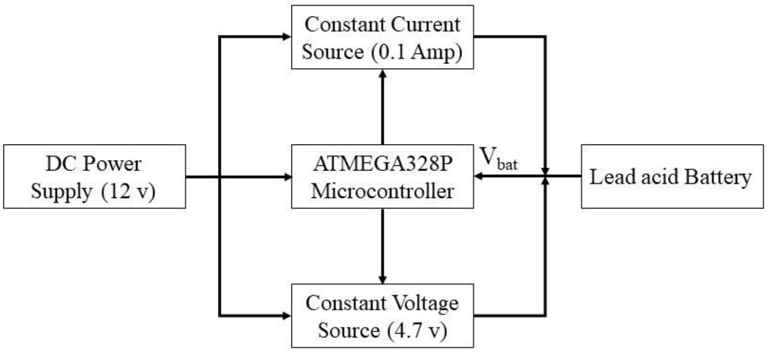

Fig.1 Block Diagram

Figure 1 shows the block diagram of proposed charging methodology. Two separate circuits are designed for constant voltage and constant current source. In constant voltage the voltage is maintained constant by using LM317T voltage regulator. A 12 V power supply is given as an input to this circuits. An Atmega microcontroller(µC) is interfaced with the C-C and C-V circuits for switching between the circuits. The output of both circuits are connected to the lead acid battery.

The 4.2 V lead acid battery with full charge voltage (V_{full}) is 4.2 V and full discharge voltage is 3.9 V. Thus, the 75% above discharge voltage is selected as threshold voltage (V_{th}) for switching between C-C and C-V circuits. The capacity of battery used in present work is 1.0 Ah. The constant charging current is set to low value of 0.1 C of the battery and the battery is charged with constant current of 100 mA. The 4.2 V lead acid battery consist of 2 cell each of 2.1 V. In constant voltage mode, each cell of lead acid battery is charged with a voltage of 2.4 V. So the constant voltage source is maintained at the voltage of 4.8 V.

The voltage is monitored by µC. If the battery voltage (V_{batt}) is less than the threshold voltage (V_{th}) then controller will switch on the C-C source until the voltage of battery reaches Vth. Then the µC will switch off the C-C source and will switch on the C-V source. As the battery voltage reaches near the V_{full} the controller checks the V_{batt} at faster rate. When this battery voltage reaches V_{full} then the microcontroller will switch off the C-V source.

After switching into any mode, the µC initially checks the battery fault for 5 times with interval of 1 minutes. In battery fault checking the uC switch off all the sources and measure the voltage. This measured voltage is compared with the previous measured voltage. If the voltage does not increase, then the controller shows "Battery fault" and both C-C, C-V source is switched off, else it will continue in preset charging mode.

III. IMPLEMENTATION

3.1 Hardware Implementation

The schematic diagram of the designed battery charging system is shown in Fig.2. In the circuit, the optocoupler is used to isolate the µC output pins from the external charging circuits. This eliminates the possibility of damage of the µC due to external circuits. LM317 is used to regulate the output at constant voltage of 4.8 V. The adjust pin of the LM317 is used for regulating the output voltage. The µC reads the voltage of battery at assigned interval of time from V_{batt} pin. This measured voltage is compared to the pre-set threshold voltage and accordingly gives the output to control mode which is connected at input pin 1 and input pin 2 as shown in Fig.2. Input pin 1 is for constant current and input pin 2 is for constant voltage source. Both the sources are supplied with 12 V DC power supply. The battery, need to be charged is connected at the output of the circuit.

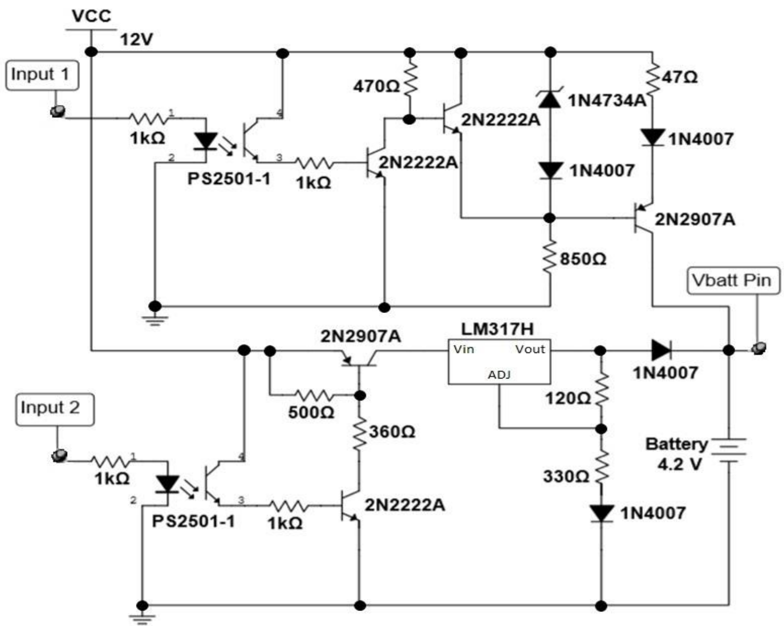

Fig.2 Circuit Diagram

3.2 Software Implementation

The Figure 3 Shows the flowchart of software implementation. The pre-set threshold voltage of 4.1 V and fully charged battery voltage (V_{full}) of 4.2 V is initialized. The battery voltage is measured by µC. This measured V_{batt} is compared with V_{full}. If the battery is fully charged, then the charging will be stopped and if it is below V_{full} then it will further compare with the Vth voltage of 4.1 V. If the measured voltage is above 4.1 V then µC will switch to the C-V source. Initially µC checks for the battery fault. If battery fault occurs then all the sources are switched off, else the CV mode continues. As the V_{batt} approaches near to V_{full} µC monitors the V_{batt} at fast interval of 1 minutes. If the V_{batt} crosses the V_{full}, all the sources are switched off and then the charging will be terminated.

If the measured voltage is below V_{th} then µC will switch on the constant current circuit. After getting into C-C mode the microcontroller will initially check the battery for fault. If battery is not faulty then it will again continue in C-C charging mode. After interval of 10 minutes it will regularly monitor battery voltage. As soon as battery voltage starts approaching near to the Vth, then again µC will measure V_{batt} with fast interval of one minute. As soon as the V_{batt} goes above Vth then µC will switch off the C-C source and switch to the C-V source. In C-V mode, battery will be again monitored at an interval of one minute. When the V_{batt} starts approaching near to V_{full} i.e. 4.2 V the µC will start checking V_{batt} at an interval of one minute. As the voltage crosses the V_{full} voltage then µC will switch off all the sources and stop charging.

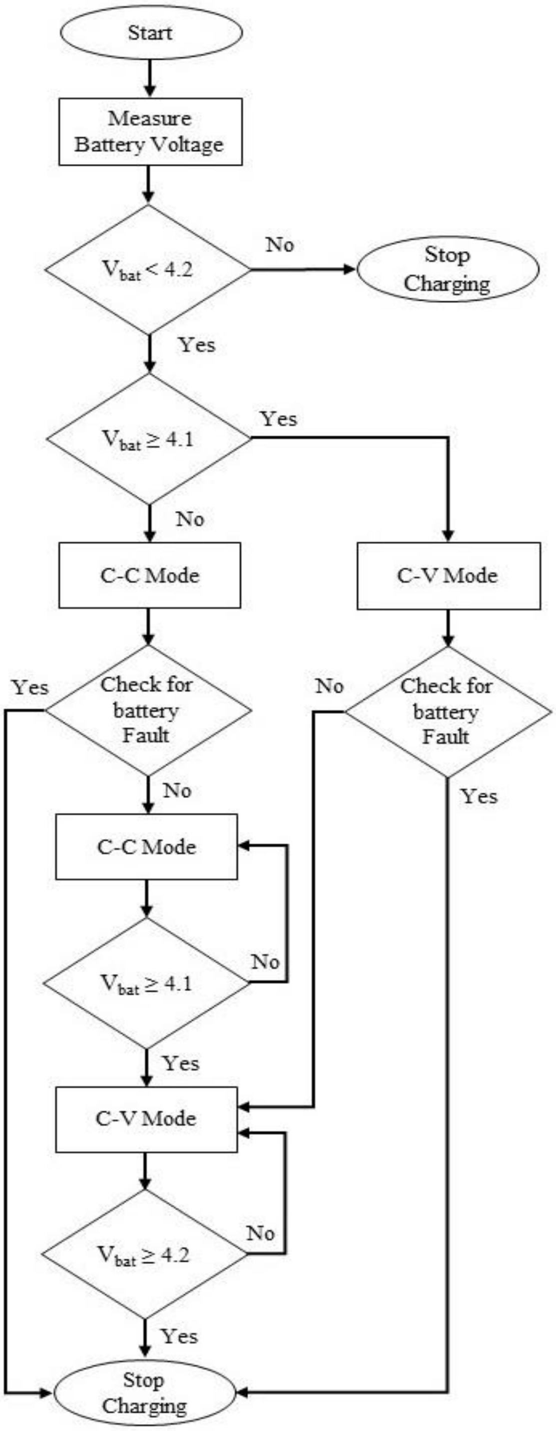

Fig.3 Flow Chart

IV. Results and Discussions

A 12 V DC power supply was connected to the circuit. To control the charger, the microcontroller pins was connected to the charging mode control pins. The microcontroller reads the battery voltage and accordingly switch the charging mode.

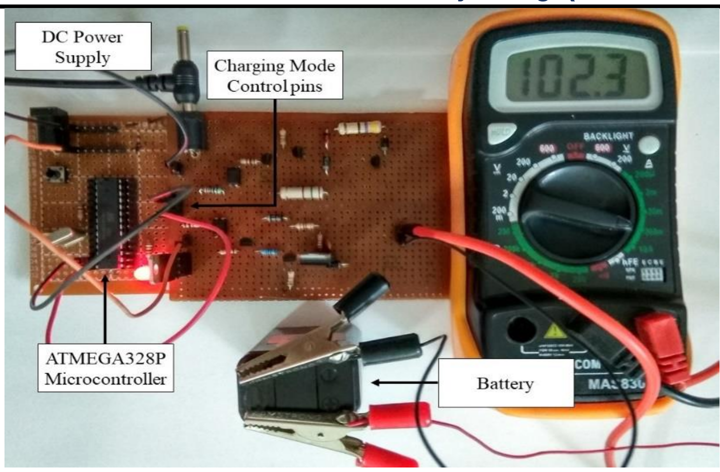

Fig.4 Constant Current Mode

The Fig.4 shows the charge controller in constant current mode. The constant current of 102 mA flows through the battery. The voltage of battery was below V_{th}, thus the charger was in constant current mode until the battery voltage crosses threshold voltage.

As soon as the voltage of battery rises above the Vth, the Charging mode changed to constant voltage mode. The battery was charged with a constant voltage of 4.85 V. The voltage of battery was regularly monitored until the voltage rises above the V_{full} voltage. Then the controller switched off all the circuits. The below Fig.5 shows the charger in constant voltage mode.

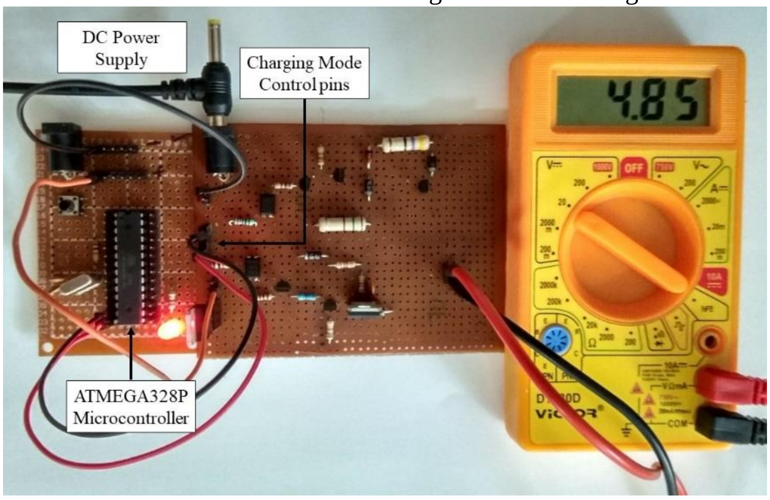

Fig.5 Constant Voltage Mode

V. CONCLUSION

The present work is a development and testing of preliminary prototype module of the charging system. The use of microcontroller in the system allows to develop more flexible and smart system. Such modules can be programmed for charging different types of rechargeable batteries. This module will be further developed to integrate multiple modules of temperature sensing, thermal management, current sensing and MPPT charging module for charging and monitoring energy storage devices. To minimize cell degradation and increase charging rate an innovative adaptive rapid charging method will be implemented. Such systems will help to increase life cycle and efficiency of the rechargeable batteries.

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