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Original Article

Multi-Zone Battery Charger Controller System

J Thilagavathy[1], K Rajasekar[2]
[1,2]Department of Electrical and Electronics Engineering, Grace College Of Engineering, Mullakkadu, Thoothukudi, Tamilnadu, India.

Abstract: *This project focuses on designing and implementing a battery charger controller for a multi-zone setup, where each zone (A, B, C, D) contains a multiple 12V battery. The system automatically manages the charging process based on the battery's voltage levels. An ATmega328 microcontroller is employed to monitor the battery voltages and control the charging mechanism through relays. When the voltage of any battery drops below a predefined threshold, the controller activates the corresponding relay to initiate the charging process. The system includes an LCD display to provide real-time information on the charging percentage and the estimated time remaining to fully charge the battery. As the battery voltage increases, the estimated charging time decreases accordingly. This project ensures efficient battery management and provides a user-friendly interface for monitoring and control*.

Keywords: *Multizone Charging, Load Balancing, Smart Charging, Dynamic Allocation, Power Management, Zoneisolation, Scalability, User Interface, Energy Efficiency, Safety Protocols.*

INTRODUCTION

1.1 INTRODUCTION TO MULTI-ZONE BATTERY CHARGER CONTROLLER SYSTEM

The evolution of battery technology and its applications in various fields has underscored the critical importance of efficient battery management systems. In contemporary settings where devices and systems rely heavily on battery power, maintaining the health and longevity of these batteries is paramount. This project aims to design and implement an advanced battery charger controller tailored for a multi-zone setup, where each zone (A, B, C, D) houses multiple 12V batteries. The core of this system is the ATmega328 microcontroller, which plays a pivotal role in monitoring battery voltages and controlling the charging mechanism through a series of relays.

1.2 THE GROWING NEED FOR EFFICIENT BATTERY MANAGEMENT

In today's technology-driven world, batteries power a wide range of devices and systems, from small consumer electronics to large-scale industrial applications. The efficiency and reliability of these batteries are crucial for the seamless operation of the devices they power. However, traditional manual charging methods are often inadequate, leading to issues such as overcharging or undercharging, which can significantly reduce battery lifespan and performance. This is where an automated battery charger controller becomes indispensable. By providing precise control over the charging process, the system ensures that each battery is maintained at its optimal charge level, thereby enhancing its performance and longevity. This is particularly important in multi-battery setups, where managing the charge levels of multiple batteries simultaneously can be challenging.

1.2.1. EV BATTERY CHARGING MANAGEMENT SYSTEM

As the price of petrol rises, electric vehicles (EVs) are growing in popularity. This situation has prompted numerous automakers to search for other sources of petrol energy. Because they generate less pollution, using electrical energy sources can benefit the environment. EVs offer significant advantages for protecting the environment and maximizing energy efficiency. Frequently, electric vehicles use rechargeable lithium-ion batteries. Compared to lead acid, it is smaller. In fact, it produces power consistently and has a 6–10 times longer energy life cycle than a lead–acid battery. The longevity of a lithium-ion battery can be decreased by some factors, including severe draining and overcharging. The size and shape of the battery and the body of the vehicle, on the other hand, frequently result in a limited operating range for electric vehicles (EVs). Currently, worries regarding the security of battery technology are severely restricting the adoption of EVs. For instance, overcharging a battery can lead to a significant drop in battery life as well as a severe safety risk like a fire. Therefore, in order to prevent the aforementioned issues, EVs must have a battery monitoring system that can inform the user of the battery state. The previous battery monitoring system did nothing more than track and detect the battery's condition while alternating the user via the vehicle's battery indicator.

SYSTEM AND IMPLEMENTATION

2.1 EXISTING SYSTEM

The existing battery charging systems, especially in multi-zone setups, primarily rely on manual or semi-automated processes for managing the charging of batteries. In such systems, the charging process is often managed by technicians who manually monitor the voltage levels of each battery and connect or disconnect chargers as needed. This manual approach is labour-intensive and prone to errors, such as overcharging or undercharging, which can significantly reduce the lifespan and performance of the batteries. Additionally, these systems lack advanced features like real-time data logging, remote monitoring, and predictive maintenance, which are crucial for ensuring optimal battery performance in modern applications. In some semi-automated systems, there might be some level of automation through the use of basic microcontrollers or timers, but these systems are usually limited in their capabilities. They often lack sophisticated algorithms to dynamically adjust the charging process based on real-time data. Moreover, the user interfaces in these systems are typically rudimentary, offering minimal information to the user and requiring manual interpretation of data, which can lead to incorrect decisions regarding battery management.

The existing systems also struggle with scalability. Adding more batteries to the system often requires significant modifications and additional manual labor, making it difficult to adapt to growing needs. This lack of scalability can be a significant drawback in applications where the number of batteries may vary or increase over time, such as in renewable energy storage systems or electric vehicle fleets.

2.2 PROPOSED SYSTEM

The proposed multi-zone battery charger controller system represents a significant advancement over existing systems by incorporating a high level of automation, real-time monitoring, and user-friendly interface features. At the core of this system is the ATmega328 microcontroller, which continuously monitors the voltage levels of each battery in the multi-zone setup and automatically manages the charging process through relays. This automation ensures that each battery is charged efficiently and safely, preventing issues such as overcharging and undercharging that are common in manual systems. The proposed system includes advanced voltage sensors that provide accurate real-time data to the microcontroller. The microcontroller can activate or deactivate relays to connect or disconnect batteries from the charging circuit, thereby automating the entire charging process and eliminating the need for manual intervention.

One of the key features of the proposed system is the inclusion of an LCD display that provides real-time information on the charging status of each battery. The display shows the current voltage levels, charging percentage, and estimated time remaining to fully charge each battery. This user-friendly interface allows users to easily monitor the charging process and make informed decisions. The real-time feedback ensures transparency and helps in maintaining the health and longevity of the batteries. The proposed system also incorporates several safety features to protect the batteries and the charging equipment.The design allows for easy expansion by adding more voltage sensors and relays, making it adaptable to various applications and setups. Whether it is a small-scale consumer application or a large-scale industrial setup, the system can be scaled to meet the specific needs of the user. This flexibility makes the proposed system suitable for a wide range of applications, from renewable energy storage to electric vehicle fleets.

2.3 BLOCK DIAGRAM

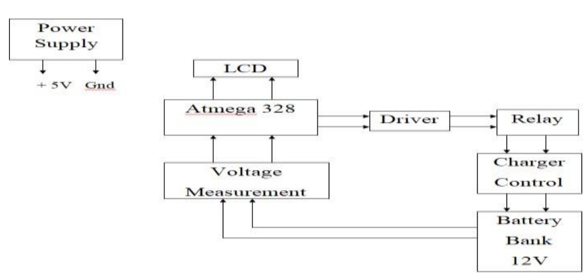

Figure 2.1: Proposed Hardware Block Diagram

2.3.1 BLOCK DIAGRAM DESCRIPTION

Power Supply:

Provides the necessary power to the entire system, ensuring that all components operate efficiently. Converts AC mains power to a suitable DC voltage required by the system.

ATmega328 Microcontroller:

The central processing unit of the system, responsible for controlling the entire battery management process. Executes the programmed logic to manage charging, monitors battery status, and controls other components.

Voltage Measurement:

Measures the voltage of the battery bank. Provides real-time voltage data to the microcontroller for monitoring and decision-making.

Driver:

Acts as an interface between the microcontroller and high-power components such as the relay. Amplifies the control signals from the microcontroller to drive the relay and other high-power components.

Relay:

An electrically operated switch used to control the connection between the power supply and the battery bank. Enables or disables the charging process based on the control signals from the microcontroller.

Charge Control:

Manages the charging process of the battery bank to ensure efficient and safe charging. Controls the charging current and voltage according to the battery's requirements and prevents overcharging.

Battery Bank (12V):

The energy storage unit of the system, consisting of one or more 12V batteries. Stores electrical energy for later use and provides power to connected loads when required.

LCD Display:

A user interface component that displays system status and information. Shows real-time data such as battery voltage, charging status, and other relevant parameters.

2.4 CIRCUIT DIAGRAM

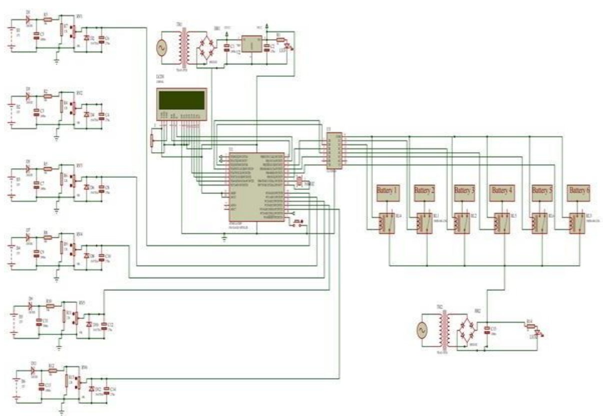

Figure 2: Proposed Hardware Circuit Diagram

2.4.1 CIRCUIT DIAGRAM DESCRIPTION

DC power supply or AC-DC adapter. Connected to the Vcc and GND rails of the circuit to provide power to all components. Provides a stable DC voltage (e.g., 12V) to power the entire system. ATmega328 Microcontroller ATmega328 microcontroller. Vcc and GND pins connected to the power supply. Analog input pin (e.g., A0) connected to the voltage measurement circuit. Digital output pins connected to the driver circuit and LCD display. Central controller that manages the battery charging process, monitors voltage, and displays information. Voltage Measurement Voltage divider circuit (resistors). Connected across the battery bank terminals. Output connected to an analog input pin of the ATmega328 Relay Coil connected between the driver circuit and the power supply. Common (COM) and Normally Open (NO) terminals connected in series with the power supply and the battery bank through the charge control circuit. Charge Control Input connected to the relay output (NO terminal). Output connected to the positive terminal of the battery bank. GND connected to the negative terminal of the battery bank. Battery Bank (12V) Positive terminal connected to the charge control output. Negative terminal connected to GND. Stores electrical energy for later use. LCD Display Displays real-time information such as battery voltage, charging status, and system messages.

HARDWARE DETAILS

3.1 ATMEGA 328

Figure 3: Atmega 328 IC Model DIP Type

ATMEGA 328 microcontroller, which acts as a processor for the arduino board. Nearly it consists of 28 pins. From these 28 pins, the inputs can be controlled by transmitting and receiving the inputs to the external device. It also consists of pulse width modulation (PWM). These PWM are used to transmit the entire signal in a pulse modulation. Input power supply such as Vcc and Gnd are used. These IC mainly consists of analog and digital inputs. These analog and digital inputs are used for the process of certain applications.

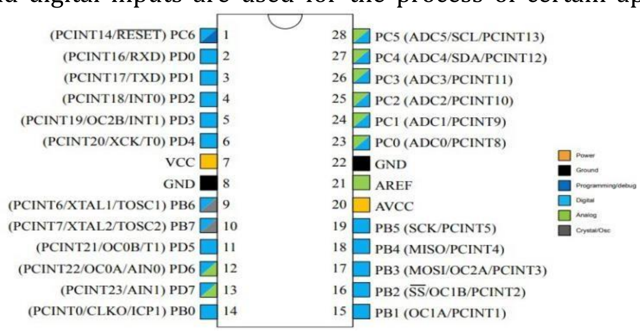

Figure 4: Atmega328 Pin Diagram

VOLTAGE MEASURING CIRCUIT

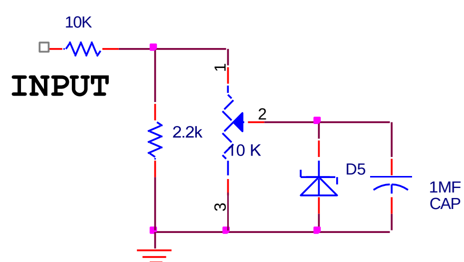

Figure 5: Voltage Measuring Circuit

The attenuator circuit reduces the voltage to a required level. The attenuator circuit usually passive devices made from simple voltage divider networks. Switching between different resistances forms adjustable stepped attenuators and continuously adjustable ones using potentiometers. A capacitor is connected across the rectifier to filter out the ripples. Then the filtered output is given to the micro controller.

3.3 LCD DISPLAY

Figure 6: LCD Module

Liquid Crystal Displays (LCDs) have materials, which combine the properties of both liquid and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. One each polarizer are pasted outside the two glass panels. This polarizer would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarizer and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent. When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction.

3.4 DRIVER:

Driver is used for drive the relay. ULN2003A IC is used as driver. This IC has some special features

- Seven Darlington's per package
- output current 500ma per driver (600ma peak)
- output voltage 50v
- integrated suppression diodes for inductive loads
- outputs can be paralleled for higher current
- ttl/cmos/pmos/dtl compatible inputs

DESCRIPTION

The ULN2001A, ULN2002A, ULN2003 and ULN2004Aare high voltage, high current Darlington arrays each containing seven open collector dar-lington pairs with common emitters. Each channel rated at 500mAand can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout. The four versions interface to all common logic families

These versatile devices are useful for driving a wide range of loads including solenoids, relays DC motors; LED displays filament lamps, thermal print-head sand high power buffers ULN2001A/2002A/2003Aand 2004A is sup-plied in 16 pin plastic DIP packages with a copper lead frame to reduce thermal resistance. They are available also in small outline package (SO-16) as ULN2001D/2002D/2003D/2004D.

Pin Diagram - ULN 2003

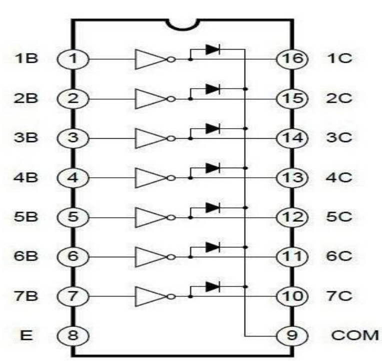

Figure 7: Driver IC ULN2003 Pin Diagram

The ULN2003A is a high voltage, high current, Darlington Arrays each containing seven open collection Darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite to outputs to simplify layout. It is a 5V TTL, CMOS. This versatile device is useful for driving a wide range of loads including solenoids, relays, DC motors, LED displays, and high power buffers. Outputs can be paralleled for higher current.

The output of MC is applied to the input of relay driver transistor at its phase terminals. When the input base voltage is reduced so that the relay is de-energized, the collector current falls to zero abruptly. This sudden switching off the relay current induces a very high back emf in the relay coils, which may be high enough to puncture the collector-emitter junction at the transistor and damage it. A large capacitor connected in parallel with the relay coil absorbs this transient and protects the transistor. However large capacitor connected in parallel with the relay coil absorbs this transient, protects the transistor and sluggish the relay operations.

3.5 RELAY

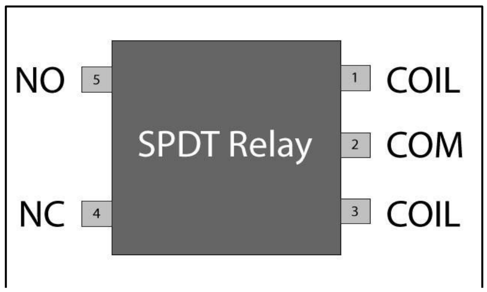

Figure 8: Relay Pin Diagram

Relays are switching devices. Switching devices are the heart of industrial electronic systems. When a relay is energized or activated, contacts are made or broken. They are used to control ac or dc power. They are used to control the sequence of events in the operation of a system such as an electronic heater, counter, welding circuits, and X-ray equipment, measuring systems, alarm systems and telephony. Electromagnetic relays are forms of electromagnets in which the coil current produces a magnetic effect. It pulls or pushes flat soft iron armatures or strips carrying relay contacts. Several relay contact can be operated to get several possible ON/OFF combinations.

3.6 SINGLE POWER SUPPLY:

Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC.12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resister.LED voltage is 1.75V.if voltage is above level beyond the limit, and then it will be dropped on resister.

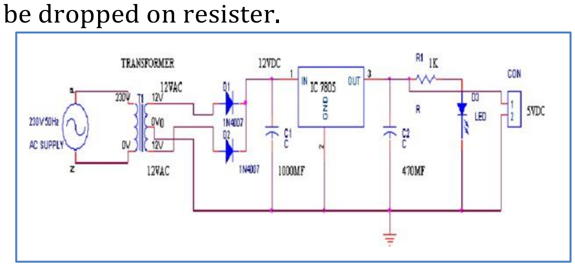

Figure 9: Power Supply Circuit

4.7 BATTERY

Figure 10: Battery 4V

In this project, the focus is on creating a multi-zone battery charger controller for 4V batteries connected in series to form 12V connections. The system employs advanced automation and real-time monitoring to ensure efficient and safe charging processes. Here’s an explanation of how the battery connection works:

RESULT AND DISCUSSION

4.1 WORKING PRINCIPLE OF MULTI-ZONE BATTERY CHARGING MONITORING

The operation of the multi-zone battery charger controller is based on the continuous monitoring and control of the battery voltages. The system is designed to automatically manage the charging process, ensuring that each battery is charged efficiently and safely. The following sections describe the key operational principles of the system:

Monitoring:

The voltage sensors continuously measure the voltage levels of each battery in the multi-zone setup. This data is fed to the ATmega328 microcontroller, which processes the information in real-time. The microcontroller compares the voltage levels against predefined thresholds to determine the charging status of each battery.

Control:

The Control Based on the monitored data, the microcontroller activates or deactivates the relays to control the connection between the batteries and the charging circuit. If the voltage of any battery drops below the threshold, the microcontroller activates the corresponding relay to connect the battery to the charging circuit. This initiates the charging process. Once the battery voltage reaches the desired level, the microcontroller deactivates the relay to terminate the charging process.

User Interface:

The LCD display provides real-time feedback to the user. It shows the current voltage levels of each battery, the charging percentage, and the estimated time remaining to fully charge the battery. This information is updated continuously, allowing users to monitor the charging process and make informed decisions. The user-friendly interface ensures that users can easily manage the charging process and ensure the optimal performance of the batteries.

4.2 RESULT

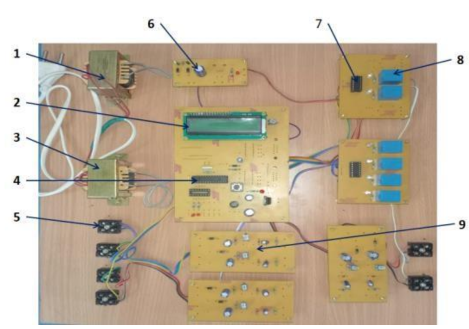

Figure 11: Hardware Prototype model for “Multi-Zone Battery Charging Control”

The Above figure 5.1 show know following the components for:

1. **Charging Transformer-12V/1Amps**
2. **Liquid Crystal Display -16*2**
3. **Power supply transformer -12V/Amps for using hardware components**
4. **Embedded Controller- Atmega 328**
5. **Battery Connector- 12V for 6-Zone connector**
6. **Battery Charger- AC-DC converter for voltage 13.5V-14V**
7. **Driver IC- ULN 2003 to drive the relay module.**
8. **Relay- 12VDC Coil type to control the charger**
9. **Voltage Measurement- The Voltage measurement circuit to measure the Battery Voltage for input for the controller.**

Figure 12: Hardware side Zone 1 Battery voltage

The figure 5.2 is monitor the zone 1 battery voltage monitoring the real time monitor for 84.56% of the battery voltage the charger will be turn off.

Figure 13: Display the Zone 2 Battery voltage

The figure 5.3 is shown in the battery voltage for Zone 2 is 0% of voltage and the charging time for 378 min for the full charging for the battery the charger will be ON. The same process for every zone the battery charging percentage below 80% the battery charger will be turn ON for every zone to display the expected the charging time will be display to help of LCD monitoring

CONCLUSION

The multi-zone battery charger controller project represents a significant advancement in the field of battery management systems. By leveraging the capabilities of the ATmega328 microcontroller, the system ensures efficient and reliable charging of multiple 12V batteries across different zones. The continuous monitoring and real-time control provided by the system enhance the performance and longevity of the batteries, making it an ideal solution for applications ranging from renewable energy storage to electric vehicles. The user-friendly interface provided by the LCD display ensures that users have access to critical information, allowing for informed decision-making and greater control over the charging process. The project's emphasis on automation, real-time monitoring, and user-friendly design highlights the importance of integrating advanced technologies in battery management systems. As technological advancements continue to evolve, future iterations of this system could incorporate features such as wireless communication, remote monitoring, and advanced predictive algorithms to further enhance efficiency and reliability. The multi-zone battery charger controller not only addresses the current needs of battery management but also sets the stage for future innovations in the field, paving the way for more sustainable and energy-efficient solutions.

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