

EXPERIMENTAL ANALYSIS OF AN INDUSTRIAL BATTERY CHARGER AND CONTROLLER FOR LIP BATTERY SYSTEMS

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Abstract

In recent days, the global lithium iron phosphate battery was valued at 24,554,960,000,000.00 Nigerian naira in 2023 and projected to grow from 30,645,490,000,000.00 Nigerian naira in 2024 to 199,942,940,000,000.00 Nigerian naira by 2032. Lithium iron phosphate (LiFePO) battery or lithium Ferro Phosphate LFP battery is a type of lithium-ion battery that uses lithium iron phosphate (LiFePO) as the cathode material and carbon graphite with a metallic backing as the anode. LFP batteries are being used in a number of areas like in vehicle, utility-scale stationary applications, off-grid energy storage and backup power because of their lower cost, high safety, low toxicity, long cycle life and rechargeable technologies. For lithium iron phosphate batteries, an incomplete charge and discharge will cause the battery to produce a memory effect, a situation where batteries gradually lose their maximum energy capacity if they are repeatedly recharged after being only partially discharged. This effect can be erased after the battery is fully charged and discharged. One of the major causes of battery memory effect is poorly-designed chargers. This work centers on analysis of industrial charger and controller for lithium Iron Phosphate (LIP) battery systems. The system is designed to charge and control the current and voltage going into an industrial LIP battery. It makes use of robust hardware such as microcontroller with intelligence and smart software. The microcontroller computes and analyzes the monitored parameters such as temperature, current and voltage, compares them with the set points and uses the results to control the output of the system. The prototyping method used was simulation and the simulation software chosen was Proteus application software.

Keyword: Lithium Iron Phosphate (LiFePO), Lithium Ferro Phosphate LFP, Microcontroller

INTRODUCTION

Obviously, Lead has formed the core element for Lead Acid Batteries and not until recently that the lithium -ion technology have escalated. According to (Oswal, Paul, & Zhao, (2010), Lead is a very heavy metal and therefore the research was done from many years to make better battery that is lighter in weight as well has improved power density. Then Lithium became the logical choice to replace lead as it is the lightest metal available in the world. Lithium is not only light in weight but also highly reactive and for this reason pure lithium is never found in nature rather, they are found mainly as pegmatitic minerals, which were once the main source of lithium. Its solubility as an ion also made it available in ocean water and is commonly obtained from brines. Consequently, Lithium metal is extracted electrolytically from a mixture of lithium chloride and potassium. According to (Peng, Zhu, Chen, Ruoff & Yu, 2016), Lithium-ion batteries (LIBs) have dominated the portable electronics industry and solid-state electrochemical research and development for the past two decades. The significant progress of Lithium batteries is mainly due to the numerous innovations in materials, design and safety aspects of the batteries. This technology made waves in the 1970s and 1980s but its commercialization as a rechargeable battery was hindered for many years until 1990s when Sony came into the business. Lithium-ion batteries (LIBs) continue to draw vast attention as a promising energy storage technology due to their high energy density, low self-discharge property, nearly zero-memory effect, high open circuit voltage, and long lifespan (Kim, Song, Son, Ono & Qi, 2019).

In fact, Market Report Insights (2024) opined that the Lithium Iron Phosphate Battery Pack's market is expected to grow substantially between 2023 and 2031 and evidence to this is the prediction that the global lithium iron phosphate battery was valued at 24,554,960,000,000.00 Nigerian naira in 2023 and

is projected to grow from 30,645,490,000,000.00 Nigerian Naira in 2024 to 199,942,940,000,000.00 Nigerian naira by 2032.

According to one of the leading influencers of Lithium-ion batteries (uk.Renogy.com 2023), Lithium-ion battery cells are made up of Cathode, Anode, Electrolyte, Separator and Container. Most lithium-ion battery cells have a Graphite anode (sometimes Silicon-Carbon) that extracts the Lithium ions released during charging. On the other hand, a Lithium metal or Lithium-enriched material such as Lithium Iron Phosphate (LFP or LiFePO₄) acts as the cathode. During the process of charging, the Lithium-based cathode releases positively charged Lithium ions (Li⁺) that travel through the electrolyte and separator to the anode. In the same way, during discharging, the cathode receives the previously discharged lithium ions and electrons back from the graphite anode. This reversible process that enables the charging and discharging of lithium-ion batteries is called intercalation and deintercalation. Intercalation occurs during charging while deintercalation occurs during discharging. The electrolyte acts as a medium to transport lithium ions between the two electrodes (cathode and anode), while the separator blocks electrons from traveling between electrodes through the electrolyte. The separator also helps prevent short circuits in the event the electrolyte evaporates. Lastly, the case or container holds all the other components securely. Not only that, the case also insulates and protects the battery's components from outside influences. When these batteries are discharged, there is a way of reversing this process through the help of a device called battery charger. A battery charger is a device that stores energy in a battery by running an electric current through it. The charging protocol which represents how much voltage or current, how long, and what to do when charging is complete largely depends on the size and type of the battery being charged. While some battery types have high tolerance for overcharging and must be disconnected manually, others do not and hence use a timer to cut off when charging is complete.

PROBLEM STATEMENT

Galuppini, Berliner, Lian, Zhuang, Bazant & Braatz, (2023) noted that Fast charging is a desirable feature for lithium-ion batteries. However, charging at high currents, however, can damage the battery and accelerate aging processes. It accelerates its aging due to higher temperatures, increased growth rate of the solid-electrolyte interface (SEI) layer, increased lithium plating, and higher mechanical stresses. This work will address the problem of how to experiment on an industrial charger capable of implementing constant current-constant voltage (CC--CV) charging strategy using microcontroller and how to monitor voltage and current as the input of the rechargeable battery as minimizing the charging time while fulfilling the requirements for safety of operations and reduced lifetime degradation.

LITERATURE REVIEW

Mobiles devices such as power banks, laptop computers, portable media players, wireless controllers for video game console, wireless pc

peripherals, electronic cigarettes, backup batteries etc., uses LiPO batteries. For that reason, they require a charger. What the charger does is to feed the correct voltage and current ratings into the battery and cut off power from it when it is fully charged through the help of the charge controller. As the name implies, a charge controller is an electronic module, which controls the amount of charge entering and exiting the battery. They are for optimum and most effective performance of the battery and to protect it from over and under charging.

OBJECTIVES OF THE STUDY

The aim of this study is to experiment on an industrial battery charger and controller for LIP battery.

To achieve the main objective, the specific objectives include:

- i. To experiment on an industrial charger capable of implementing constant current-constant voltage (CC--CV) charging strategy using microcontroller
- ii. To monitor voltage and current as the input of the rechargeable battery.

Concept of Overcharge Protection

Generally, an overcharge protection circuit is for protecting a secondary battery by controlling, by turning a charge control switch on and off, a charging current flowing through the secondary battery from the charger. In a 12V battery system, the voltage varies between 10.5 to 14.4volts, (depending on the actual state of charge of the battery, charge current, discharge current, type and age of the battery).

For a normal full loaded battery with no charging or discharging current, the battery voltage is about 12.4volts to 12.7volts. When charging current is flowing, the voltage jumps to a higher level e.g. 13.7V (depending on the current), and when loads are switched on, the voltage drops down to a lower level e.g. 12volts or 11.5 volts (also depending on the current).

Deep Discharge Protection

In deep discharge protection, there is need to identify the cut-off voltage of the battery such that when the battery reaches the cut-off voltage level, a switch disconnects the load from the battery. For cut-off voltage identification, a Zener diode is applied.

When a battery is deeply discharged, the reaction in the battery occurs close to the grids and weakens the bond between the active materials and the grids. When batteries are deeply discharge repeatedly, loss of capacity and lifespan eventually occurs. To protect the battery, from deep discharge, most charge controllers include an optional feature to disconnect the system loads once the battery

reaches a low voltage or low state of charge condition. If the voltage of the system falls below 11.5 volts for a minimum period of 20sec, then the charge controller will be switched off for a minimum 30 seconds. The delay of 30 seconds is integrated to protect the system against a swinging situation (Marufa, 2012).

Types of Charge Controllers

According to (Ishtiak, Abid, Navid, Irin & Saha, 2013) and (Lokesh Reddy, Kumar, Chandra, Babu, & Rajasekar, 2017), The most commonly used types controller especially the solar PV charge controllers are as follows

- i. Series
- ii. Shunt
- iii. PWM
- iv. MPPT

While all of these controllers are effectively used, each type may incorporate a number of variations that alter their basic performance and applicability.

Series

The series controller comes with a kind of control element mode of MOSFET which is connected in series between the PV array and the battery. This type of charge controller is widely used in small scale PV systems.

According to (Osaretin & Edeko, 2015), when the MOSFET switch is connected in series with the mains and the battery, the Controller is called Series Type. A series charge controller disables further current flow into batteries when they are full. This type of controller works in series with the array and the battery (Marufa, 2012). There are several variations to the series type controller, all of which use some type of control or regulation element in series. Relay or solid-state switch either opens the circuit between the array and the battery to discontinuing charging, or limits the current in a series-linear manner to hold the voltage of the battery at a high value.

Advantages of Series Type of Charge Controller

- i. Lesser switching noise: during charging.
- ii. Less susceptible to high voltage transient disturbances.
- iii. The voltage applied across the Series MOSFET switch is lesser and so experiences lesser stress and is, therefore, more reliable.
- iv. Because no Schottky diode is need to prevent short circuiting of the battery during the time the MOSFET switch connects to the Mains, Series type tends to have lower voltage drop, less heating and the reverse leakage through the Schottky is also eliminated (Samlexsolar, 2014).

Shunt

The shunt charge controller regulated the charging of a battery from the PV array by short-circuiting the array

internal to the controller. This type of charge controllers is mostly used to regulate the Voltage (or) Current to keep batteries from overcharging and deep discharging which causes damage to the battery. In other words, when the MOSFET switch is connected in parallel across the mains/ the Battery, it is called Shunt Type. In Series Type, the MOSFET Switch is kept open when the battery is fully charged. The Mains stops supplying current during this period. In the Shunt Type, when the battery is fully charged, the MOSFET switch is kept closed to shunt (divert) the full short circuit current of the Mains away from the battery (Samlexsolar, 2014)

A shunt charge controller diverts excess electricity to an auxiliary or "shunt" load, such as an electric water heater, when batteries are full.

The shunt controller regulates the charging of a battery from the Mains internal to the charge controller. All shunt controllers must have a blocking diode in series between the battery and the shunt element to prevent the battery from short-circuiting when the array is regulating (Marufa, 2012). The regulation element in shunt controllers is typically a power transistor or MOSFET, depending on the specific design.

The pulse width modulation (PWM) and maximum power point tracking (MPPT) adjusts charging rates depending on the battery's maximum capacity as well as monitors the battery temperature to prevent overheating (Noor and Ayuni, 2009).

Pulse Width Modulation (PWM) Charge Controller

Pulse width modulation (PWM) charge controller is the most effective means to achieve constant voltage battery charging by adjusting the duty ratio of the switches (MOSFET). In PWM charge controller, the current from the solar panel tapers according to the battery's condition and recharging needs. When a battery voltage reaches the regulation set point, the PWM algorithm slowly reduces the charging current to avoid heating and gassing of the battery; yet charging continues to return the maximum amount of energy to the battery in the shortest time. The voltage of the array will be pulled down to near that of the battery. PWM system has the following advantages;

- a. Higher charging efficiency
- b. Longer battery life
- c. Reduced battery over heating
- d. Minimizes stress on the battery
- e. Ability to de-sulphate a battery

A PWM controller is not a DC-to-DC transformer. The PWM controller is a switch which connects the solar panel to the battery. When the switch is closed, the panel and the battery will be at nearly the same voltage. Assuming a discharged battery, the initial charge voltage will be around 13V, and assuming a voltage loss of 0.5V over the cabling plus controller, the panel will be at=13.5V. The voltage will slowly increase with increasing state of charge of the battery. When absorption voltage is reached, the PWM controller will start to disconnect and reconnect the panel

to prevent overcharge and this gave it the name pulse width modulated charge controller (Vitronenergy, 2014).

Maximum Power Point Tracking (MPPT) Charge Controller

Nowadays, the most advanced solar charge controller available is the Maximum Power Point Tracking (MPPT). It is more sophisticated and more expensive. It has several advantages over the PWM charge controller. It is 30 to 40% more efficient at low temperature. The MPPT is based around a synchronous buck converter circuit. It steps the higher solar panel voltage down to the charging voltage of the battery. It will adjust its input voltage to harvest the maximum power from the solar panel and then transform this power to supply the varying voltage requirement of the battery plus load. It is generally accepted that MPPT will outperform PWM in a cold temperature climate, while both controllers will show approximately the same performance in a subtropical to tropical climate. The MPPT charge controller is a DC-to-DC transformer that can transform power from a higher voltage to power at a lower voltage (vitronenergy, 2014). The amount of power does not change, therefore, if the output voltage is lower than the input voltage, the output current will be higher than the input current, so that the product $P=VI$ remains constant. Hence, in order to get the maximum out of a solar panel, a charge controller should be able to choose the optimum current-voltage point on the current-voltage curve: *The Maximum Power Point*. An MPPT does exactly that. The input voltage of a PWM controller is, in principle, equal to the voltage of the battery connected to its output. The solar panel, therefore, is not used at its Maximum Power Point, in most cases.

Comparison between MPPT and PWM Charge Controller

Though people may have shown more preference to MPPT controller, but the two technologies come with its specific advantages which depend on the site conditions, system components, size of array, load and cost of a particular solar panel system. Apart from these parameters, the two technologies could also be compared under the following parameters.

Temperature conditions

An MPPT controller is better suited for colder conditions. The MPPT controller is able to capture the excess module voltage to charge the batteries. It produces up to 20-25% more charging than a PWM controller. The PWM type is unable to capture excess voltage because the pulse width modulation technology charges at the same voltage as the battery. But when solar panels are deployed in warm or hot climates, there is no excess voltage to be transferred making the MPPT unnecessary and negating its advantage over a PWM.

Array Voltages

Mains and battery voltages should match for PWM but Mains voltage can be higher than battery voltage for MPPT.

Battery Voltage

PWM operates at battery voltage, so it performs well in warm temperature and when battery is almost full while MPPT operates above the battery voltage, so it can provide "boost" in cold temperatures and when the battery is low.

System Size

PWM is typically recommended for use in smaller systems where MPPT benefits are minimal, while MPPT is recommended for a 150W-200W or higher sized systems to take advantage of its benefits.

Cost

MPPT controllers are typically more expensive than PWM controllers but are more efficient under certain condition, so they can produce more power with the same number of solar modules than a PWM control.

Charge Cycle of a Charge Controller

Most quality charge controller units have what is known as a 3-stage charge cycle as follows:

Bulk: In this stage, the battery will accept all the current provided by the solar array. The value of this current will be equal to the Short Circuit Current I_{sc} of the solar array (Samlexsolar, 2014). During the bulk phase of the charge cycle, the voltage gradually rises to the bulk level (usually 14.4 to 14.6volts) while the batteries draw maximum current. When bulk voltage level is reached, the absorption stage begins.

Absorption: During this phase, the voltage is held constant (maintained at bulk voltage level) for a specified time (usually an hour) while the current gradually tapers off as the batteries charge up. This is to avoid over-heating and over-gassing the battery. The current will taper off to safe levels as the battery becomes more fully charged. (Samlexsolar, 2014)

Float: When a battery becomes fully charged, dropping down to the float stage will provide a very low rate of maintenance charging while reducing the heating and gassing of a fully charged battery. When the battery is fully recharged, there can be no more chemical reactions and all the charging current is turned into heat and gassing. The purpose of float is to protect the battery from long-term overcharge (Samlexsolar, 2014). After the absorption time phase, the voltage is lowered to float level. This is typically (usually 13.4 to 13.7volts) for a 12V battery and the batteries draw a small maintenance current until the next cycle.

METHODOLOGY

Method

The system comprises of a microcontroller, relays, switches, voltage measurement, current measurement, LCD, OP-AMP, diodes, transformer etc. The relays are used to start and stop the charging voltage getting to the battery, the OP-AMP configured as a differential amplifier is used to monitor the charging current, the battery voltage is

displayed on the LCD, the switches are used to manually start and stop the charging, the microcontroller manages the entire process. The different functions include, battery voltage monitoring, current monitoring, display function, start and stop function, etc. these are depicted in the system block diagram shown below.

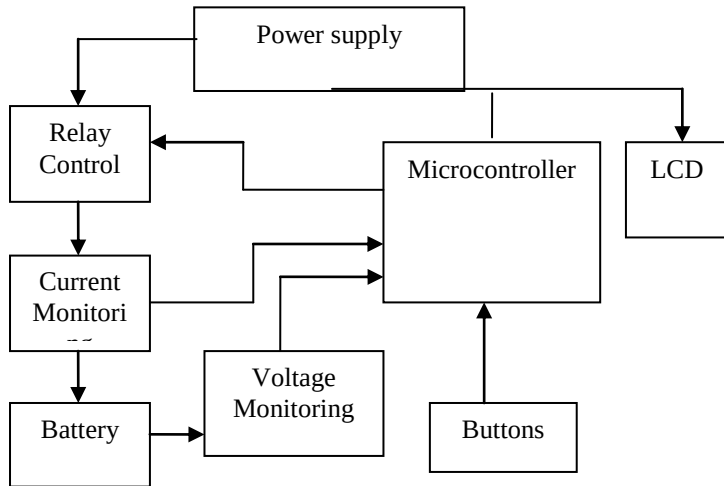


Figure 1: System block diagram

Microcontroller Unit (MCU)

The ADC in the Microcontroller is a 10-bit ADC, using successive approximation method. The converted Analogue voltage is stored as a 10-bit integer value for further processing and use. A reference voltage (V_{RHF}) has to be provided and it's normally chosen as the power supply voltage of the microcontroller in other to cancel out any power supply variation induced error. The microcontroller power supply voltage is 5v. The resolution of the ADC here is 10-bit which is $2^{10} - 1$. Hence, the smallest voltage (stepsize) that can be measured is given by $\text{Step size} = V_{RE}F/2^{\text{RESOLUTION}} - 1$ Which is $5/2^{10} - 1 = 0.004888V - 4.88mV$.

This voltage is far smaller than the ACS758 current sensor and voltage monitoring unit hence the microcontroller will effectively measure any voltage from the sesensors. The ADC stores the result of the conversion in a memory location referred to as AD RESULT. The analogue voltage from the sensor is given by $\text{Analogue Voltage} = V_{RE}F/2^{\text{RESOLUTION}} - 1 \times \text{AD RESULT}$

The voltage (as measured) has to be further processed by including the scaling factor of the sensor.

Datasheet of the ACS758 current sensor specifies a 20.3 mV/A sensitivity factor. Hence the measured voltage is multiplied by this scaling factor to get the actual current measured.

The Relay Control

The relay is used by the microcontroller to extend charging power to the battery. It in effect switches the battery charging on/off under the control of the microcontroller. The relay has a diode connected across its power supply terminals to prevent the interface

transistor from damage due to back emf. The transistor is used to complete the connection between the microcontroller and the relay hence providing the necessary 12volts required to drive the relay power. The base of the transistor is then connected to the microcontroller using an appropriate resistor whose value is determined by the datasheet of the transistor BC547.

The relay circuit consists of a relay connected through an NPN transistor. When the microcontroller wants to start charging the battery, the output voltage from the microcontroller to the transistor is a logic one. i.e 5v. When an over current situation is detected, the microcontroller outputs a low to the base of the transistor. This causes current not to flow into the transistor hence switching the relay off. When this happens, the charging power to the battery is cut off.

From transistor load line equation

$$VCE = VCC - IcRL$$

Where VCC is power supply voltage, VCE is voltage between the collector and the emitter, Ic is the collector current which passes through the relay, RL is the (load resistance) relay coil resistance. Current through the relay when the transistor is active is

$$Ic = (VCC - VCe)/RL$$

$$Ic = (12-0)/400$$

$$Ic = 12/400 = 0.03 \text{ Amps}$$

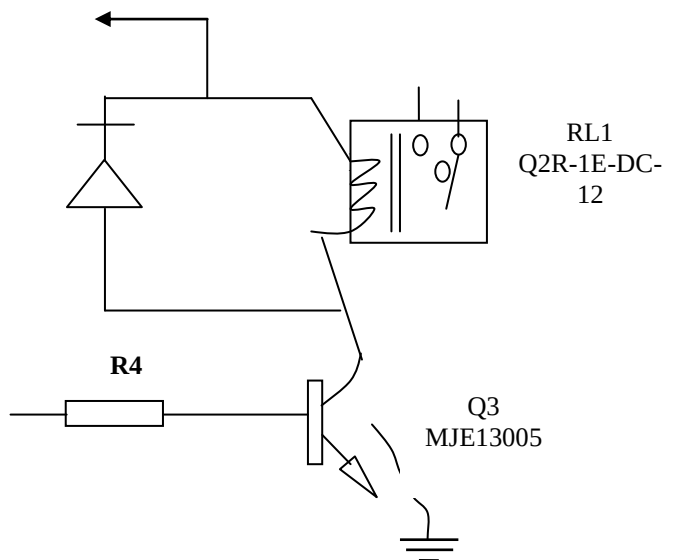


Figure 2: The Relay Circuit

Current Monitoring

This is achieved using the ACS758 current sensor module. The Allegro™ ACS758 family of current sensor ICs provides economical and precise solutions for AC or DC current sensing. Typical applications include motor control, load detection and management, power supply and DC-to-DC converter control, inverter control, and over current fault detection. The device consists of a precision, low-offset linear Hall circuit with a copper conduction path located near the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through

the close proximity of the magnetic signal to the Hall transducer. A precise, proportional output voltage is provided by the low-offset, chopper stabilized BiCMOS Hall IC, which is programmed for accuracy at the factory. High level immunity to current conductor dV/dt and stray electric fields, offered by Allegro proprietary integrated shield technology, provides low output voltage ripple and low offset drift in high-side, high voltage applications. The output of the device has a positive slope ($>V_{CC} / 2$) when an increasing current flow through the primary copper conduction path (from terminal 4 to terminal 5), which is the path used for current sampling. The internal resistance of this conductive path is 100 μH typical, providing low power loss. The thickness of the copper conductor allows survival of the device at high over current conditions. The terminals of the conductive path are electrically isolated from the signal leads (pins 1 through 3). This allows the ACS758 family of sensor ICs to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

Voltage Monitoring

This is used to measure the voltage across the battery being charged. This unit is very important. The battery voltage monitoring unit comprises of a voltage divider and the battery whose voltage is being to measure. The voltage is designed to have a range of 0v to 25v. It is because the system requires +5volts, hence the 25volt range must be scaled down to 5v. This is achieved by using the voltage divider network shown below. The voltage from the battery goes through the voltage divider then to the microcontroller. The microcontroller converts this analogue voltage to digital form, processes it and then displays it on the LCD.

The LCD

This has the function of displaying information to the user. It displays the welcome message when the system is powered on, the status of the battery charger, the battery voltage level etc.

Batteries (LiFePO4)

Lithium iron phosphate (LiFePO₄ or LFP) is a rechargeable battery technology that has become popular due to its safety, long lifespan, and efficiency. LiFePO₄ batteries appear in this experiment as off-grid energy storage and backup power systems.

Power Source

The high efficiency multi-crystal, Kyocera KD135GX-LPU photovoltaic module will be used. It is 59.06" by 26.30" by 1.8". It has cell irradiance of 1000/ m^2 at 25°C, an open circuit voltage of 22.1 V, and a short circuit current of 8.67 A. it will serve as the input power source for the experiment

Materials

The lithium iron phosphate battery

The lithium iron phosphate battery or LFP battery is a type of lithium-ion battery using lithium iron phosphate as the cathode material, and a graphitic carbon electrode with a metallic backing as the anode.



Figure 3: Lithium Iron Phosphate Battery

Solar Panel

A solar panel is a device that converts sunlight into electricity by using photovoltaic (PV) cells. When light shines on a photovoltaic (PV) cell, such light may be reflected, absorbed, or pass right through the cell. The PV cell is composed of semiconductor material, when the semiconductor is exposed to light, it absorbs the light's energy and transfers it to negatively charged particles in the material called electrons. This extra energy allows the electrons to flow through the material as an electrical current. This current is extracted through conductive metal contacts – the grid-like lines on a solar cell. The efficiency of a PV cell is simply the amount of electrical power coming out of the cell compared to the energy from the light shining on it, which indicates how effective the cell is at converting energy from one form to the other. The amount of electricity produced from PV cells depends on the characteristics (such as intensity and wavelengths) of the light available and multiple performance attributes of the cell. An important property of PV semiconductors is the bandgap, which indicates what wavelengths of light the material can absorb and convert to electrical energy. If the semiconductor's bandgap matches the wavelengths of light shining on the PV cell, then that cell can efficiently make use of all the available energy.

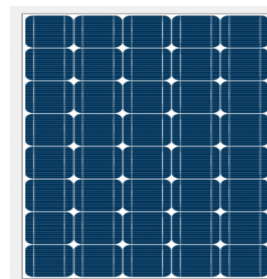


Figure 4: Image of a solar panel for charger power source

Charge Relay

A charge relay is an electrical control device that can give a specified amount of input and hold it for a long enough time to cause a predetermined step change in the controlled quantity in the electrical output circuit. When the input drops to a certain level and remains for a sufficient period of time, it returns to the initial state. Relays are usually used in control circuits. It usually has no primary contact because the overload capacity is relatively small. Relays comes as current relays: for undercurrent or overcurrent protection and control of the battery and voltage relays: mainly used as overvoltage, undervoltage and zero voltage

protection of the battery. The safety of high voltage is an important factor to ensure the safety of the lifepo4 battery, and the relay must be disconnected in an emergency to ensure that the power battery will not output power.



Figure 5: Charge Relays

Current Sensor ACS758

ACS758 current sensor provides an economical and precise solution for AC or DC for current sensors. Typical applications include motor control, load detection, power supply and DC-to-DC converter control, inverter control, and overcurrent fault detection.



Figure 6: The Packaging of the ACS758 Current Sensor Voltage Sensor Circuit

The voltage sensor functions to read the voltage value of a circuit. Arduino can read the voltage value by using an analog pin. If the read voltage distance is between 0 -5 V, you can directly use the analog pin, whereas if the read voltage range is > 5 V you must use an additional circuit, namely the voltage divider because Arduino pins work at max 5 V DC.



Figure 7: Voltage Sensor LCD Module

The LCD has 16 pins on its body. It's a 2 line 16-character.

Pin Configuration

Pins 1 & 2 are for power supply to the LCD. The datasheet specifies a voltage of +5V. Pin3 is used to modify the brightness of the characters on displays on the LCD. This is done by connecting a 10kΩ variable resistor between pin3 and pin 1. Pin 4 is used to specify whether you are sending data or a command to the LCD. Pin5 specifies whether you are writing to or reading from the LCD, Pin6 is used to

provide clocking/enable to the LCD. Pin8 to pin14 are the data pins. Pin15 & 16 is used to power the LED backlight. These pins are connected to pins on the microcontroller except the power supply pins and the LED backlight pins.



Figure 8: The LCD The Buttons

There are two buttons used to manually start and stop the battery charging. They are single pole single throw switches provides some form of interaction between the user and the system which are connected to the microcontroller such that there is only one of two possible positions: pressed or not pressed. When not pressed, the microcontroller gets logic high, but when pressed, the microcontroller gets logic low. Connection of the button to the microcontroller is shown thus: -

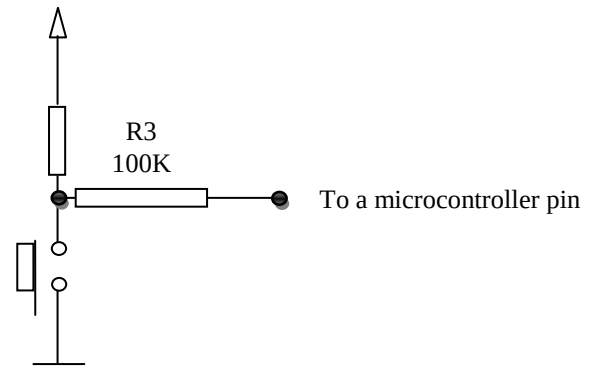


Figure 9: Connection of the button to the microcontroller

A resistor of high value 100 kΩ is connected in series between the vcc and the button so as to limit the dissipated current when the button is pressed. This is because when it's pressed, the microcontroller pin gets connected to the ground when current flows from vcc to the ground and dissipated as heat on the body of the resistor. The current is given by

$$I = \frac{(5 - 0)}{100000} = 0.00005A = 500\mu A.$$

The Microcontroller

Microcontroller ATMEGA 328 (Arduino UNO) has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. This microcontroller is the heart of the industrial battery charger. It makes the charger an embedded system and coordinates between all the other components. It responds to the button when pressed, puts alphabet on the LCD for display, switches relays on/off as well as monitor the signal from the battery voltage and current sensors.

CONCLUSIONS

Through the software simulation, this work was able to demonstrate how to experiment on an industrial charger capable of implementing constant current-constant voltage (CC--CV) charging strategy using microcontroller and how to monitor voltage and current as the input of the rechargeable battery as minimizing the charging time while fulfilling the requirements for safety of operations and reduced lifetime degradation. It achieved the CC-CV charging strategy through the differential amplifier and the computing power of the microcontroller which analyzes the monitored parameters such as temperature, current and voltage, compares them with the set points and uses the results to control the output of the system. The differential amplifier is used to monitor the charging current.

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