Design and Construction of a 12 Volt Charge Controller

By

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A project submitted in partial fulfillment for the award of Bachelor of Engineering (B.Eng.) in Electrical and Computer Engineering Department, School of Engineering and Engineering Technology

Federal University of Technology, Minna

Niger State, Nigeria.

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DECLARATION

I hereby declare that apart from reference to other peoples work, which have been dully credited, this project was solely and wholly done by me Vajime, Carl Wanger of Electrical and Computer Engineering Department of Federal University of Technology Minna, under the supervision of Mr. Abraham Usman of Electrical and Computer Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, Minna, Niger State, during the 2003/2004 academic session.

Signature ____________

Date 9th DECEMBER, 2004

CERTIFICATION

This project entitled "Design and Construction of a 12 Volt Charge Controller" meets the requirement and also satisfies the regulation governing the award of Bachelor of Engineering (B. Eng.) Degree in Electrical and Computer Engineering Department of Federal University of Technology, Minna and is approved for its contribution to knowledge and literacy presentation.

Mr. Abraham Usman — 09/12/04

(Supervisor) — Date

External Examiner — 9/12/2004

Date

Head of Department — 9/12/2004

Date

DEDICATION

This project is first and foremost dedicated to Almighty God for his love, mercies and protection through out the course of my studies and up till now.

To my parents, Prof. and Dr (Mrs.) C.G Vajime, my loving sisters Avershima, Iyadoo and Adzahemen and also my Guardian Prof. and Mrs B. Oladimeji and Family for all the love, support and care you have shown me.

Also to my friends Attah, Iordondo, late Douglas (R.I.P), Nguseer, Sesugh, Justine, Albert, Afolabi, Amah, Mark, Obi, Seyi, Nosa, Ayo, Chima, Samuel, and Raphael, just to name a few, for all the lessons you have taught me.

I love you all!

ACKNOWLEDGEMENT

First and foremost to God Almighty, who in his infinite mercies saw me through to the completion of this piece of work.

My infinite appreciation also goes to my wonderful parents, Professor and Dr (Mrs) Vajime, for their moral and financial support. Many thanks also to my lovely sisters, Avershima, Iyadoo and Adza, for their great inspiration and support.

Also, to Mr And Mrs S.A Igbur for their love and support.

To my project supervisor, Mr. **Abraham Usman**, for his ever response which gave me the strength and encouragement to work diligently towards the successful completion of this project.

I am also grateful to my lecturers, who by their dedication and inspiration have made me achieve my dreams.

To my affectionate friends, Afolabi, Amah, Obiefuna, seyi, Ayo, Late Jibril (R.I.P), and many others, who in different means made my stay in School a memorable one.

ABSTRACT

Storing electrical energy for later use has been of great interest and this is possible by converting it to chemical energy in batteries. Battery charging can be done by direct current (dc) either converted from alternating current (ac) by rectifiers, or gotten from solar cells. Regulating the voltage from solar panels that flows into the rechargeable batteries and also protecting the solar panels from short circuit is also of great importance and has posed a great challenge to the application of photovoltaic generators.

Hence, the need for a charge controller which seeks through this project to address the highlighted problem. The charge controller is designed with the capacity to regulate the input voltage to the batteries at 12v, and to provide a cut-off when the batteries are fully charged, preventing them from overcharging.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

A cell is a converter that changes chemical energy into electrical energy. When the available chemical energy is gone, no more electrical power can be drawn from the cell. There are primary and secondary types of cells. Once a primary cell is discharged, it is no longer useable. The chemical action that discharged the primary cell cannot be reversed and it cannot be regenerated as a source of electrical power. The secondary type of cell is rechargeable. The chemical action is reversible; the electrodes and electrolyte can be restored to the same make up that existed before the discharge.

A secondary battery can be charged and discharged many times. However, the secondary cells which make up such a battery do deteriorate. The number of times a secondary cell can be charged and discharged depends upon its design, construction, usage and how well it is cared for.

1.2 BATTERY CHARGER

A battery charger is an electrical device that is used to put energy into a cell. A secondary battery is recharged by reversing the chemical activity within the cells, using electrical energy supplied by an external d.c source. Often, a secondary battery is recharged by a charge controller, a unit which changes a.c from the power line into d.c suitable for charging.

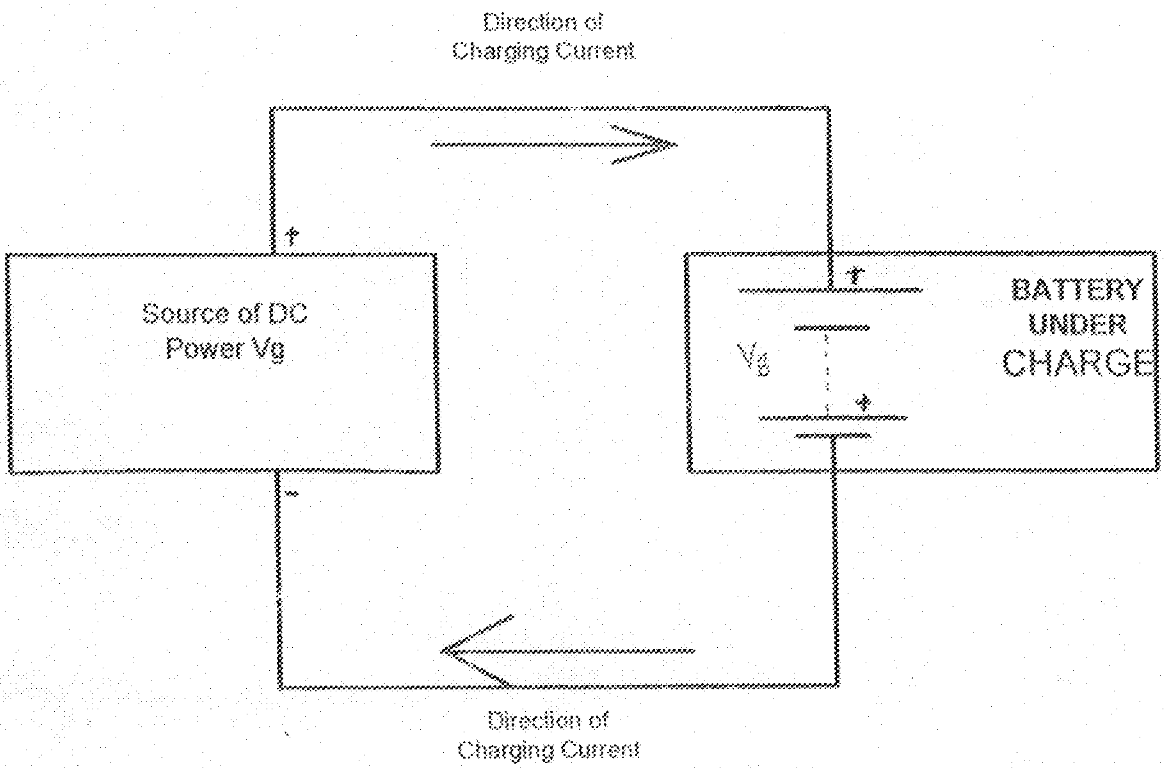


figure 1.2 Battery charging connections.

An external d.c voltage is necessary to produce a unidirectional current that does not change its direction. Also, the charging voltage must be more than the battery e.m.f. For lead-acid cells, approximately 2.5 volts per cell is enough to overcome the cell e.m.f so that the charging voltage can produce current opposite to the direction of discharge current. In addition to the source d.c current, several other things are needed to make a good battery charge controller system. Note that the reversal of current is obtained by connecting the battery V_B and the charging source V_G with (+) to (+) and (-) to (-) terminals. The charging current is reversed because the battery e.m.f effectively becomes the load resistance for V_G when it is higher than V_B. For instance, if $V_G = 15v$ and $V_B = 12v$, the net voltage available to produce the charging current is 3v (15 - 12 = 3). The charging current depends on the internal resistance of the source and that of the cell. In practice, the amount of charging current is regulated by introducing in series a resistance or some other current regulating device.

In case the charging voltage V_0 falls below V_B, the source will act as a load and the battery will start discharging through it. All charging systems therefore use some means to prevent such a thing from occurring. In most cases the rectifier diode used does this job. Also, in charge controller circuits (e.g in cars and other vehicles), a special cut-out relay disconnects the source from the battery as soon as the source voltage falls below the battery voltage.

1.3 FLOAT CHARGING:

This refers to a method in which the charge controller and the battery are always connected to each other for supplying current to the load.

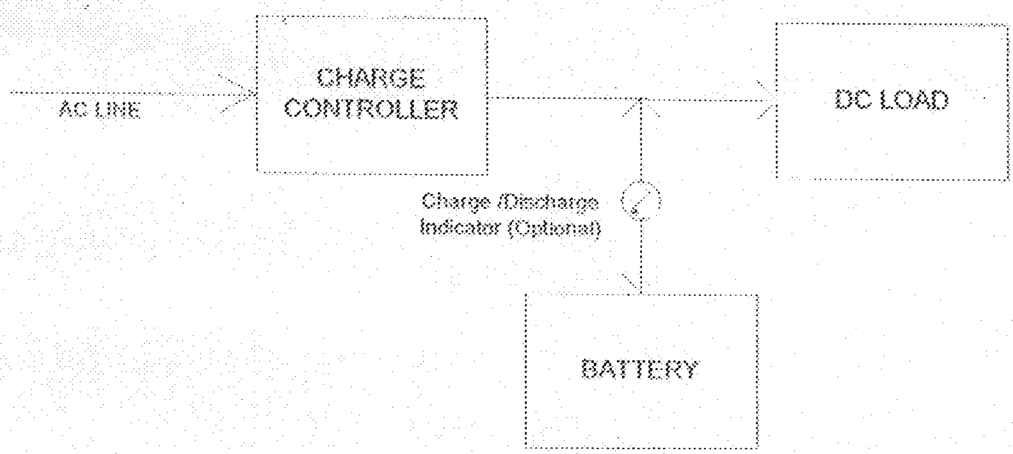


figure 1.3 Float charging.

The battery here is an auxiliary source of d.c power. When the source fails, the battery immediately takes over without any interruption.

1.4 MAINS OPERATED CHARGE CONTROLLER:

In this case, the charge controller draws its supply from the a.c mains and delivers d.c power to the battery at a voltage higher than that of the battery. Many charge controllers have additional items to monitor and control the charging process. In general, a mains operated charge controller contains the following elements:

1) A transformer to step down the high a.c mains voltage to a low voltage. It also provides electrical isolation to the charging circuitory.
2) A rectifier to convert a.c into unidirectional pulsating d.c.
3) A charge-current limiting circuit to prevent flow of excessive charging current into the battery under charge.
4) A device to prevent reversal of current, i.e discharging of the battery through the charging source voltage falls below the battery voltage.
5) Adjustable set points, i.e high voltage disconnect and low voltage disconnect.
6) Temperature compensation.
7) Low voltage warning.

For some basic reasons, it will be undesirable to over charge the batteries. Overcharging can cause corrosion and breaking of lead plates, loss of electrolyte and build up of hydrogen gas. All these phenomena shorten battery life. Ordinarily, it will be better not to allow batteries to be charged at full current right up to the maximum level. Thus, as they approach full storage capacity, the charge controller reduces and then terminates the flow of incoming power from the transformer. This is called trickle charging.

Most contrrollers sense battery voltage and take action based on voltage level.

Some controllers have temperature compensation circuits to account for the effect of temperature on battery voltage and state of charge.

Charge controllers are not simple devices because voltage state of charge depends on many factors and it is difficult to measure. If for instance, a battery voltage changes from 95% to 20% state of charge, and the battery discharge is to be limited precisely to 40% it is difficult to select a single voltage value that represents this state of charge. Low voltage disconnect protection is recommended for all charge controllers to prevent excessive battery discharge. This is accomplished by temporarily turning off loads, activating lights or buzzers to alert user of low battery voltage. This low voltage load disconnect is a very useful feature because it accomplishes two things; first, it extends battery life by not allowing a battery to drop below its rated capacity. Second, it decreases the likelihood of damage to the load in cases where the load has a minimum input voltage requirement.

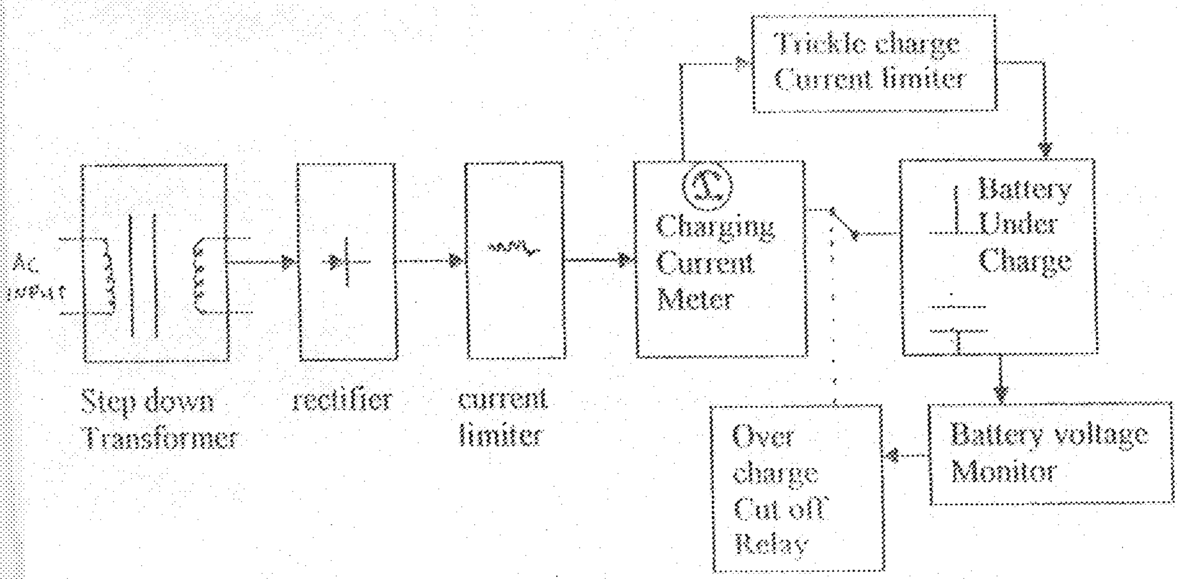


Figure 1.4 A battery charging system.

1.5 LITERATURE REVIEW

In various installations, batteries are kept floating on the line and are so connected that they are being charged when load demands are heavy or when the usual power supply fails or is disconnected. In some other installations, the battery is connected to the feeder circuit as and when desired, allowed to discharge to a certain point, then removed and re-charged for further requirements.

For batteries other than the 'floating' and 'system - governed' type, the following two general methods are employed (although there are some variations of these).

1) The constant - current system:

In this method, the charging current is kept constant by varying the supply voltage to overcome the back e.m.f of cells. If a charging booster (which is just a shunt dynamo directly driven by a motor) is used, the current supplied by it can be kept constant by adjusting its excitation. If charged on a d.c supply, the current is controlled by varying the rheostat connected in the circuit. The value of the charging current should be so chosen that there would be no excessive gassing during final stages of charging and, also, the cell temperature does not exceed 45 degrees Celsius. This method takes a comparatively longer time

2) Constant - Voltage System:

In this method, the voltage is kept constant but it results in very large charging current when the back e.m.f of the cell is low and a small current when their back e.m.f increases on being charged. With this method, time of charging is almost reduced to half. It increases the capacity by approximately 20% but reduces the efficiency by 10% or so.

1.6 OVERVIEW OF CONTROLLER COMPONENTS

Photovoltaic systems use charge controllers to manage the electrical power produced by the panels, to protect the batteries, and to act as a connection point for all the system components. To achieve these functions, the charge controller uses some components. The controller component include fuses, main switches, blocking diodes, LED indicators, low voltage disconnects and charge regulators.

1.6.1 FUSES OR MINIATURE CIRCUIT BREAKERS (MCB'S)

The charge controller, at the very least, should contain a properly installed junction box with fuses. Here the battery, source charge and load are fastened together by means of connector strips, and fuses that are incorporated to protect the equipment from damage by short circuits. Fuses protect the major circuits in the system from short circuits. MCB's are small switches that automatically break the circuit when there is a short circuit. They can be switched back ON when wiring problem is corrected.

1.6.2 MAIN CIRCUIT SWITCHES

It is often necessary to control certain load from the centrally located charge regulator using main circuit switches. For example in a school classroom lights maybe switched ON from the charge controller located in the office. This prevents misuse of lights by students in the classrooms. In a home, the lights can be turned OFF from the main circuit switch during the day to prevent draining of the battery by lights accidentally left ON.

1.6.3 LIGHT EMITTING DIODES (LED) INDICATORS

Part of the function of charge controllers is to inform the user whether the system is properly working. Usually, LEDs, beepers or alarms are used for such purposes. The following indicators are necessary:

a) The solar charge LED which indicates whether a current is flowing from the source. charge to the battery. It lights up when the source charge is charging the battery.

b) The low battery LED which notifies the user that the battery is in a low state of charge.

c) The battery full LED which tells the user that the battery is fully charged, with some controllers that the controller has reduced the battery charging current to a trickle charge.

1.6.4 LOW VOLTAGE DISCONNECT

The low voltage disconnect continuously measures the state of charge of the battery. If the battery voltage drops below a certain level, the charge controller automatically disconnects the load from the battery. Usually, a red LED lights up to notify the user that the battery has been disconnected. The controller will not re-connect the load until the battery voltage has been disconnected. The controller will not re-connect the load until the battery voltage has returned to a suitable level or in the case of some controllers, until the user manually resets it.

1.6.5 OVERCHARGE PROTECTION (CHARGE REGULATOR)

Charge regulators with this feature prevent the source charge from overcharging the battery. Like the low battery disconnect, the controller monitors the battery state of charge.

Depending on the type, the controller may either reduce the current from the source to a trickle charge and then stop charging altogether, or it may turn the charge off and on over a period of time. The cut-off voltage should be specified on the controller.

1.6.6 BLOCKING DIODES

These prevent current from flowing from the batteries to the source charge. A blocking diode is like a one-way gate that allows current to enter the battery from the source charge but does not allow it flow back.

1.6.7 CONTROLLER SIZING

The controller must be sized to handle incoming current from the source and the demand of the load. They are ordinarily rated to the current of the source charge Common charge controller sizes are 5, 10 and 20 amps inputs. Small home lighting systems can use a 5 amp unit, while a clinic or secondary school might use a 20 amp unit. Controllers also need to be sized to the system voltage. If the system is 12v, you need a 12v controller and if the system is 24v, you need a 24v controller. For this project, the charge controller size is for 12v input systems.

1.6.8 BATTERIES (ENERGY STORAGE)

The rechargeable batteries chemically store electric charges. Stated simply, a battery is like a tank for electric energy. Note that it is impossible to remove more energy from the battery than is put in by charging.

Batteries are groups of electrochemical cells-devices that convert chemical energy into electrical energy-connected in series. As a battery is charged electrical energy is stored as chemical energy within the cells. When the battery is being discharged, (i e when it is connected in circuit with a load) stored chemical energy is being removed from the battery and converted to electrical energy. The two most common types of secondary batteries used in the world today are lead-acid and nickel cadmium batteries.

1.6.9 RATED STORAGE CAPACITY

The amount of energy that a battery can store is called its capacity. Similarly, a battery can only store a fixed amount of electrical energy, typically marked on the side of the battery by the manufacturer. The capacity of a battery is measured in amp hours (Ah). This indicates the amount of energy that can be drawn from the battery before it is completely discharged. A battery of 100 Ah should ideally give a current of 2 amps for 50 hours. The rated storage capacity however, is a general guideline and not an exact measurement of the battery's age or condition, the temperature, and the rate at which power is drawn from it. If current is drawn from the battery at a high rate, its capacity is reduced. It should be noted that amp hours are not a measure of energy, but to convert amp hours to watt hours, multiply by battery voltage.

1.6.10. STATE OF CHARGE AND ITS MEASUREMENT

The state of charge is a measure of the energy remaining in the battery. It tells whether a battery is fully charged, half charged or completely discharged. With lead-acid batteries (but not with nicads) it is possible to accurately measure state of charge using a voltmeter (which measures the voltage of the battery and cells) or hydrometer (which measures the thickness of sulphuric acid in each cell). The state of charge is checked to determine the condition of the individual cells.

CHAPTER TWO

DESIGN AND ANALYSIS

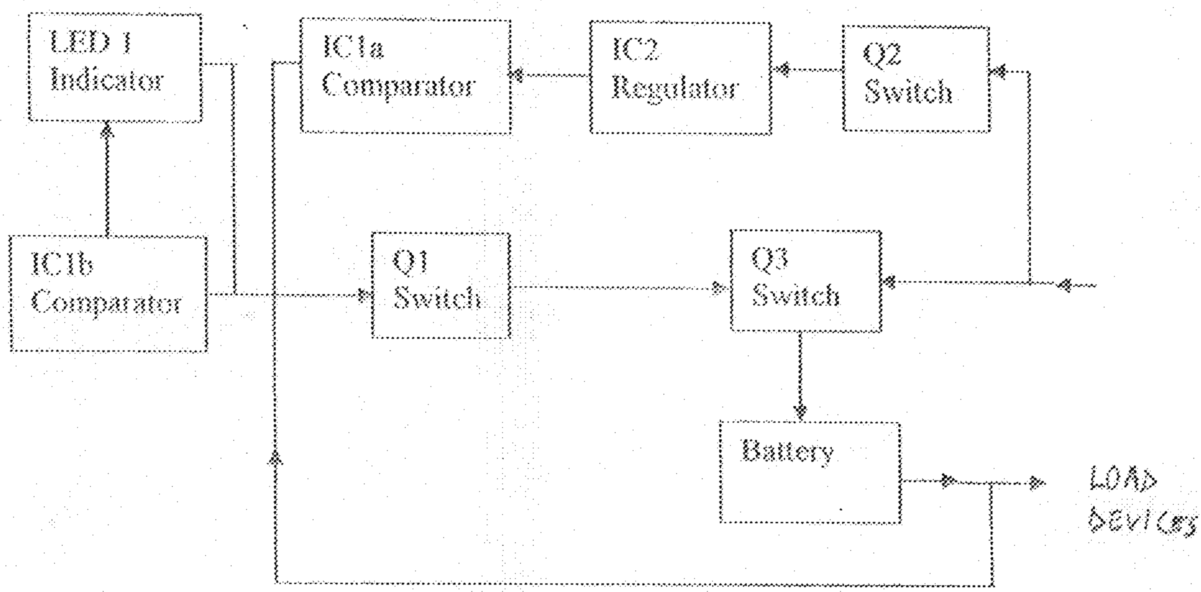


figure 2.1 Block diagram of a 12V Charge Controller

2.1 BLOCK DIAGRAM COMPONENTS

The block diagram is made up of a number of components which include switches, a regulator, comparators, an indicator and a battery. Two of the switches are transistors (Q1 and Q2) and the other is a mosfet (Q3). The regulator is an integrated circuit. The indicators consists of two light emitting diodes.

2.2 WORKING PRINCIPLE OF THE CIRCUIT (THEORY)

The charge controller (circuit) acts as a medium power DC current switch between the positive terminals of the source charge and battery. Diode D1 prevents backward flow of current from the battery back to the source charge.

When the battery voltage is below the desired full voltage, comparator IC1a turns on and activates Q1 and Q3, this allows the source's charging current to flow into the battery

When the battery reaches the full charge point, IC1a operates as a comparator based Schmidt trigger oscillator, it switches the charging current ON and OFF. The switching causes the battery voltage to oscillate a few tens of millivolts above and below the desired set point. A rail-to rail op-amp is required for proper operation. Transistor Q1 switches power on to the rest of the circuit when the voltage of the source charge is higher than that of the battery. IC2 provides a 5 volt regulated voltage to power the comparator circuit and to act as a reference voltage.

The red/green charging/full LED is driven between the output of IC1a and IC1b, which has an inverted signal. This indicates either a charging condition or a full charge point condition. Pin 5 of IC1b only needs an approximate center point to work as an on-off comparator, it is only connected to the varying IC1a pin 2 to avoid needing it's own reference circuit.

The resistors and thermistor on the input side of IC1a form a resistive bridge circuit that is used to compare the battery voltage to a reference voltage coming from IC2/R8/R9. The potentiometer adjusts the voltage point around which the circuit will oscillate on full charge. Resistor R7 adds positive feedback to IC1a for a Schmidt trigger characteristic. The thermistor provides thermal compensation, as the temperature goes down, full voltage goes up

2.2 TRANSISTOR SWITCH

A transistor switch is an application in which a small control current enables a much larger current flow in another circuit. Transistor switches make very rapid switching possible, typically in a small fraction of a micro-second

2.4 METAL-OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR (MOSFET)

MOSFET is one of the different field-effect transistors (FETS) which are different from the ordinary transitors. A MOSFET is a 3-terminal device in which the conduction between two electrodes depends on the availability of charge carriers, which is controlled by a voltage applied to a third control electrode. There are two kinds of MOSFET. They are depletion MOSFET and enhancement MOSFET. The enhancement MOSFET is also of two types, the n-channel type and the p-channel type.

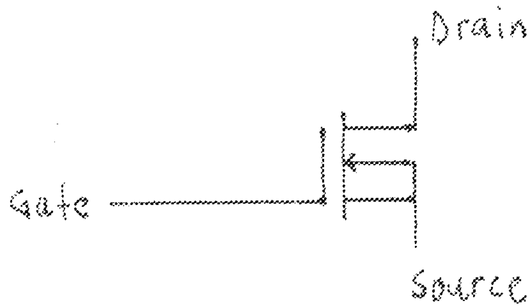


Figure 2.4 Symbol of an n-channel MOSFET.

Conduction in an n-channel MOSFET is by electrons, while it is by holes in a p-channel One.

2.5 REGULATOR (VOLTAGE REGULATOR)

Variations in the DC voltage may be present due to changes in the mains input voltage, change in temperature and change in load resistance. The regulator is used to stabilize the output voltage of the switch Q2 by keeping it at 5V.

2.6 COMPARATOR

It is quite common to want to know which of two signals exceeds a predetermined value. A comparator is used to compare two (input) signals and to give the differential output..

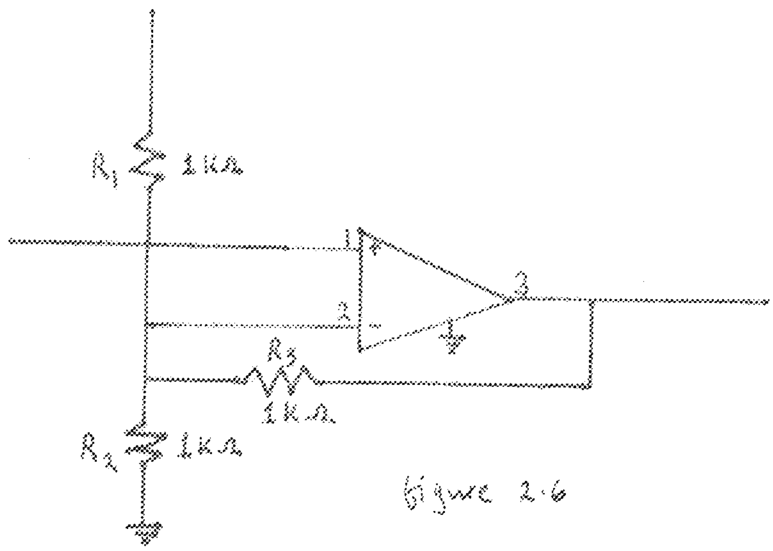


figure 2.6

Figure 2.6 shows a comparator circuit with positive feedback which has advantages over the simpler type. One of the advantages is that for a very slowly varying input the output swing cannot be slow, that is, Schmidt trigger characteristic. There are also special integrated circuits intended for use as comparators.

2.7 INDICATOR:

The indicator consists of two light emitting diodes. One of the diodes emits red light indicating that charging process is on. The other diode emits green light indicating that float voltage (or battery full voltage) is reached.

2.8 BATTERY

A battery is a device which chemically stores electric charge. A battery can be a primary cell (i.e dry cell) which can only be used once or a collection of recharegeable secondary cells connected together in single. A 12V lead acid battery is used in this work.

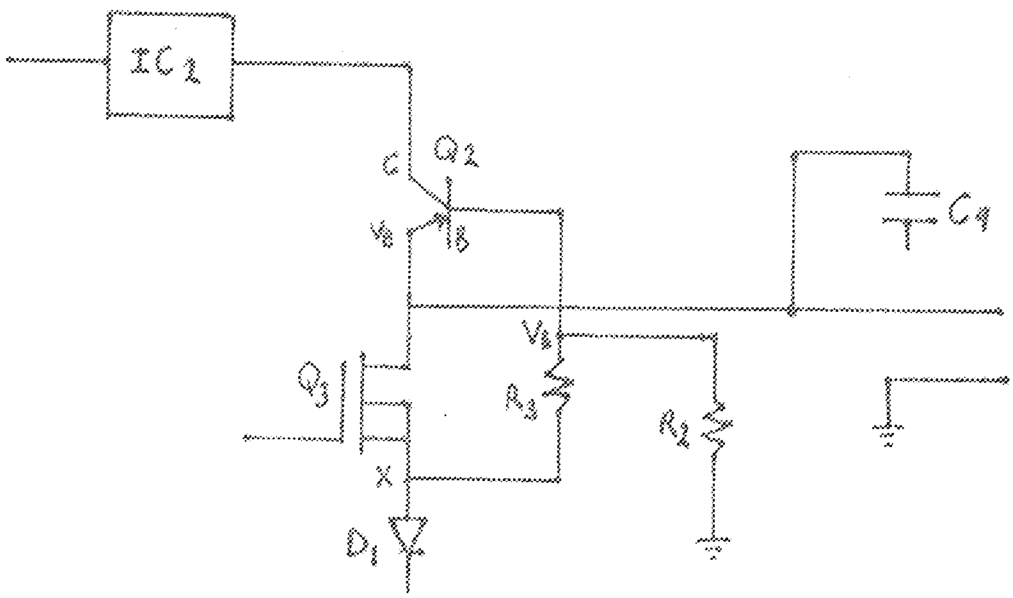
2.9 ANALYSIS

Design specification:

Voltage from source = 12V

Current from source = 1A

Battery full voltage = 12V



At full charge, point X is at 12V (battery full voltage). Now choosing a transistor with VB = 11V, we have:

12V*R2/(R2+R3)= 11V (by voltage divider principle)

11(R2+R3) = 12R2

11R3+11R2 = 12R2

11R3 = 12R2-11R2 = R2

R3 = R2/11

Now choosing R2 = 100KOhms,

R3 = 100,000/11 = 9090.9ohm = 10KOhms

VE = 12V (source voltage)

taking a quiescent current of 1mA

RE = VE(V)/1MA = 12*10^{3}ohm = 12000 Ohms = 12KOhms

RE for Q2 is 12KOhms

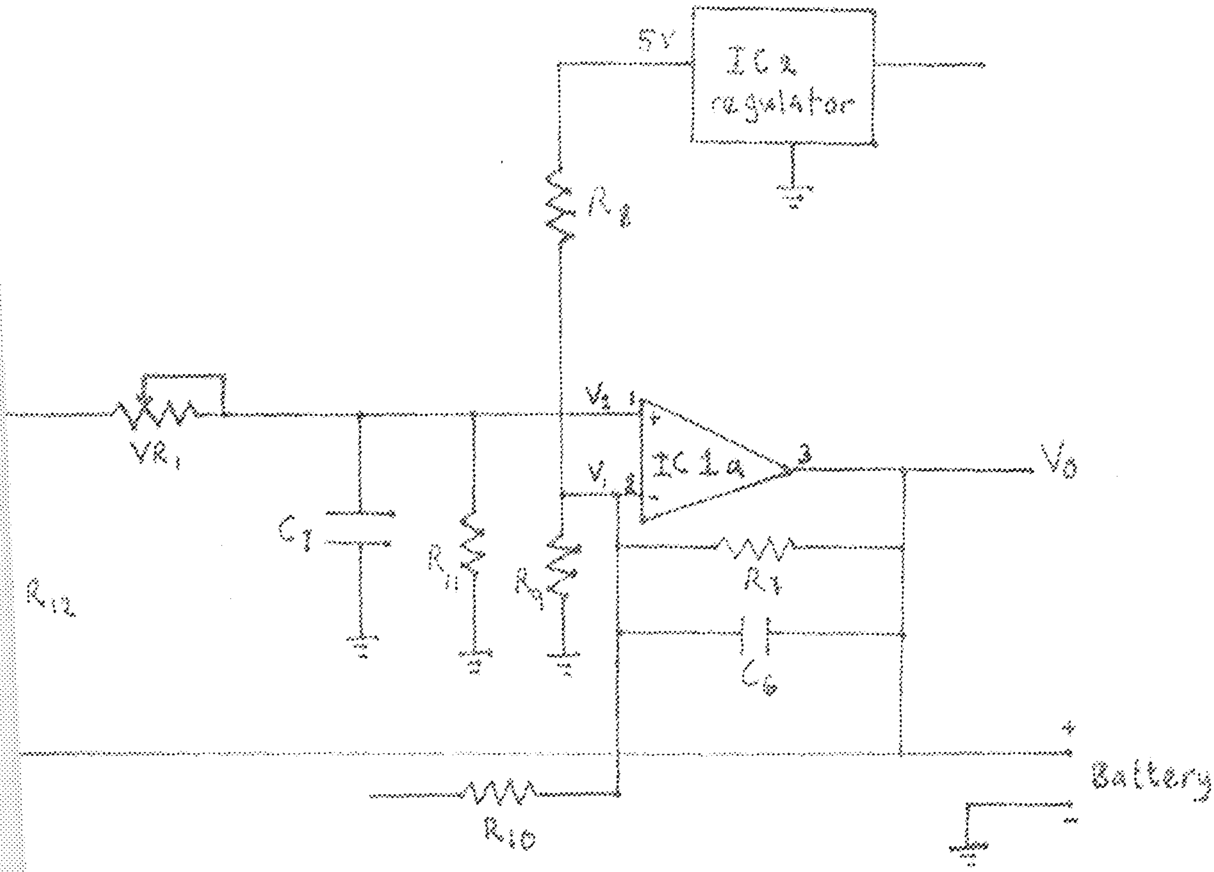
The voltage of the collector terminal of Q2 can be called Vcc.

Now, VE = 0.5Vcc

12 = 0.5Vcc

Vcc = 12/0.5 = 24V.

This is the voltage supplied to the regulator. The regulator gives out a regulated or fixed voltage of 5V.



By voltage divider principle: V1 = (5*R9)/(R8+R9) volts

Choosing R8 = 100Kohm and R9 = 200KOhms, we have,

V1 = (5*200,000)/300,000 = 3.33V

At full charge battery voltage = 12V

Voltage from source = 12V and the current = 1A

Also by voltage divider principle,

V2 = (R11*12)/(R11+R12+VR1)

At full voltage, it is required that V2 = V1

Then; 3.33 = R11*12/(R11+R12+VR1)

3.33(R11+R12+VR1) = 12R11

3.33R11+3.33R12+3.33VR1 = 12R11

12R11-3.33R11 = 3.33(R12+VR1)

8.67R11 = 3.33(R12+VR1)

R11 = 3.33(R12+VR1)/8.67

= 0.384(R12+VR1)

Choosing R12 = 300Kohm and VR1 = 100KOhms,

R11 = 0.384(300+100)*1000

= 0.384*400*1000

= 153*1000 Ohms

= 153KOhms

Now, for IC1a, taking a loop as indicated in the diagram above, we have;

V1 = R10*Vo/(R10+R7)

V1(R10+R7) = VoR10

i.e VoR10 = V1(R10+R7)

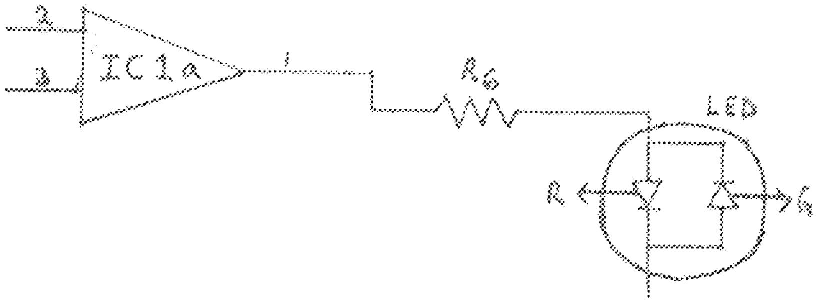
Vo/V1 = (R10 + R7)/R10

Vo = V1(R10 + R7)/R10

Now, V1 could be taken as Vi (input voltage)

then, Vo/Vi = (R10 + R7)/R10 = A

A is the gain of the differential amplifier, i.e IC1a. This is also the gain of IC1b.



For the LED1 to indicate a red (charging/colour), diode R must be forward biased,

meaning that Vo from IC1a is greater than zero; then, V1-IR5-0.6 = 0.

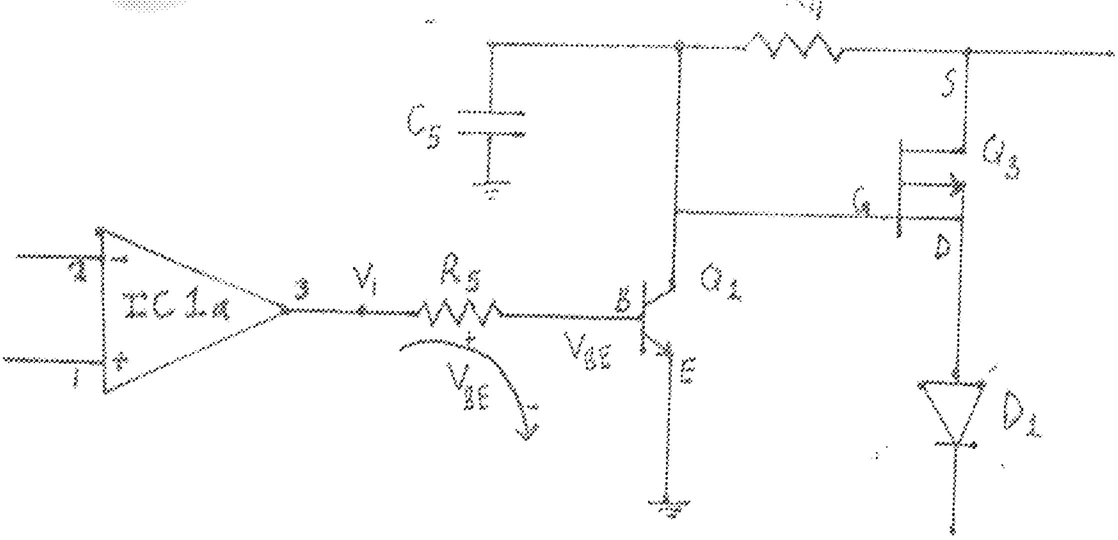
Where I is the current rating of the diode, and 0.6 is the voltage rating (Vd across diode) of the diode.

R6 = (V1-0.6)/I

When battery is almost complete by discharged, V2 will be very close to zero. This implies that Vo will be approximately V1.

Now, taking I = 10mA (the rating of diode)

We have, R6 = $(5-0.6)*10^3/10 = 4.4*10^2 = 440$ Ohms



Choosing a transistor with V_{BE} of about 4V, and taking the loop as indicated, we have,

$Vo-IR5-V_{BE} = 0.$

When the battery is almost discharged, Vo=V1=5

Then, 5-IR5-4 = 0,

Taking I=0.01mA, (transistor input base current) we have:

$5-4 = 0.01*10^{-3}R5$

$R5 = 10^3/0.01 = 100KOhms.$

R4 is chosen to be 10KOhms

Q3 is chosen such that its impedance (R_{Q3}) when combined in parallel with R4 will be equal to RE.

RE is the input resistance to Q2.

RE = 12KOhms.

Choosing C2 for 3dB of 100Hz, we have, 1/(2*3.142*100Hz*R3//R2)

Now, R3//R2 = (10*1000*100*1000)/110000 = 9090 Ohms

$C2 = 1/(2*3.142*100*9090) = 0.17*10^{-6}F = 0.17\mu F$

C5 = 1/(2*3.142*100Hz*RE)

RE = 120KOhms (input resistance to Q2)

$= 1/(2*3.142*100*120{,}000) = 0.13*10^{-6}F = 0.13\mu F$

$C6 = 1/(2*3.142*100*R5)$

$= 1/(2*3.142*100*100{,}000) = 0.015*10^{-6}F = 0.003\mu F$

voltage from source = 12V and current = 1A

Thus, resistance = V/I = 12/1A = 12 Ohms

Then C9 for 3dB of 100Hz,

$C9 = 1/(2*3.142*100*3) = 0.053\mu F$

2.10 COMPONENT SELECTION

The list of components is given below:

COMPONENT	DESIGNED VALUE
C1	47µF, 50v
C2	0.1µF
C3	0.1µF
C4	0.1MF
C5	0.01µF
C6	0.01µF
C7	0.1µF
C8	0.1µF
C9	0.1µF
R2	100Kohm
R3	10Kohm
R4	10Kohm
R5	100Kohm
R6	1Kohm

R7	4.7Mohm
R8	100Kohm
R9	200Kohm
R10	180Kohm
R11	153Kohm
R12	300Kohm
VR1	100Kohm

Other parts of the circuit are:

IC1	TLC2272CP
IC2	78L05
D1	19TQ015
Q1	2N 3904
Q2	2N 3904
Q3	IRF 9540
LED1	red/green bicolour
F1	4amp fuse

CHAPTER THREE

CONSTRUCTION AND TESTING

3.1 CONSTRUCTION:

From the design, it could be noted that not all the values from calculations are standard values. Due to this fact, the nearest values are used for the construction of the circuit. The complete 12 Volt Charge Controller design was assembled on a breadboard one unit after the other, and tested before soldering on a vero board. The results of the test was satisfactory after minor adjustments in the circuit design. The device on the breadboard was later transferred component by component for final soldering on a vero board. The device on the vero board was later transferred to a housing of a well treated wooden casing with the following dimensions: Height = 8cm, length = 15cm and width = 9cm.

3.2 TESTING:

The circuit was tested before and after casing. The circuit was connected to the 12V power supply from the mains and a rechargeable battery whose voltage read 9V was connected to the battery side. Then, the red light emitting diode came on while the green light was off. The red light indicated that the battery was being charged. Then, the battery was disconnected and the variable DC source connected to this side. When the voltage was increased to 12V the green light indicated that the charging current was switched off and the battery full voltage of 12V is reached.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION AND REFERENCES

4.1 CONCLUSION:

To construct a 12V Charge Controller has been the aim of this project. This posed a lot of challenge but finally it was achieved.

The charge controller was constructed with cheap components. It was tested and found working. It switched on the charging current from the power supply unit when the battery voltage is less than 12V and swiched the current off when the voltage reached 12V.

4.2 RECOMMENDATION

I recommend the voltage and current levels of operation of the circuit as areas of improvement.

I would also want to recommend for the school and department that students should be more exposed to practical projects to ensure that their final year project would not seem new.

Having been exposed to practical projects, the students will be able to identify components, diagnose faults and build projects of interest to themselves and even the nation.

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CHARGE CONTROLLER CIRCUIT DIAGRAM.....fig 2.4