NEAR EAST UVIVERSITY

Faculty of Engineering

Department of Electrical and Electronics Engineering

PHONE BATTERY CHARGER

Graduation Project
EE- 400

Student: Mohammad Al-Smadi (20034232)

Supervisor: Assoc. Prof. Dr. Murat Fahrioğlu

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ABSTRACT

The aim of this project is to design a circuit for phone battery charger, and this charger can be working with a difference inputs values.

The equipments, which I will use to connect the circuit, are resistors, capacitors, transistors, diodes, inductor, and a simple transformer. The function of these equipments taking the readings of value of these equipments and the value entering power. And on the other hand I will use these values and I will design them with a power circuit to obtain my result with as much as possible to give us a high efficiency.

1. BATTERIES AND ITS RECHARGEABLE

1.1. Battery and Battery Charging

It's a well known fact that rechargeable batteries have a tendency to "play possum", appearing to be dead, while merely napping instead. It is also a known fact that such batteries can be awakened from their siesta by giving them the proper "wake-up call". The Zap-Adapter described in this article is designed to arouse most of those batteries from their seemingly endless slumber.

Nickel - Cadmium batteries have a tendency to grow internal "whiskers" -- fine weblike shorting paths between the internal battery elements -- when not used for prolonged periods of time. Those whiskers eventually discharge the cell completely. when attempting to charge such a battery, the internal whiskers short out the relatively small charging current (which is usually only about 1/10th of the cell's ampere rating), preventing the battery from being recharged. Awakening a nickel - cadmium cell (assuming that it can be aroused) requires that a high

current be applied to the battery for a couple seconds to blase away the whiskers. Once the whiskers are gone, you can charge the battery in the normal manner. The Zap - Adapter that we'll describe is intended for use with AA rechargeable nickel - cadmium batteries, which seem to be the most popular size. The same design, with proper battery holders, can also be used for AAA, C, or D cells, all of which are single cell types.

About the Circuit: Figure 1 shows a schematic diagram of a simple circuit that can be used to dissolve the whisker formation that prevents nickel - cadmium batteries from receiving a charge.

The circuit consists of nothing more that two fully charged, series connected NiCad batteries (B1 and B2) and a switch (S1). Nickel cadmium batteries were used for the source because they can deliver lots of current. For example, AA - size cells can deliver a continuous current of 0.5 amperes. Switch S1 allows you to control the amount of time that rejuvenating power is applied to the sleeping battery. When S1 is closed, a jolt of current of sufficient magnitude is sent through the battery so as to cause the tiny whiskers (shorts) within to open. Also, if the dead battery has become reverse - polarized, the polarity is also corrected by the harsh treatment.

1.1.1. Construction of Battery

The Zap - Adapter was assembled on a small section of perfboard, just large enough to hold the circuit components. Three inexpensive AA battery holders (like those available at Radio Shack/Tandy or other electronic distributors) were mounted to the board; two battery holders, connected in series, for the source current and the third for the battery that is to be awakened. A push button switch was used for S1. The battery holders and switch can be mounted to the board using double - side tape. It is a good idea to put the single holder to one side of the board and the double holder (or two holder combinations) to the other side to separate the good cells from the bad. If you intend to include the meter and/or lamp circuit in your project, be sure to leave room for them. If you don't have a small DC mili - ammeter in your junkbox, look for one at swap meets, surplus outlets, or small order catalogs. The meter should have a full - scale current rating of from 50 μA to 1 mA. If you intend to include a meter in your circuit, it will be necessary to determine the appropriate value for R1. That can easily be done by placing a 50K potentiometer in series with the meter, and connecting that branch circuit in parallel with the main circuit, as shown in Fig. 1. Press S1, and adjust the potentiometer for a full - scale meter deflection. Once a full - scale reading is obtained, measure the resistance of the potentiometer, and replace the potentiometer with an equal - value fixed resistor. If the lamp circuit is included in the project, be aware that different lamps draw different currents, and some may not light with only 1.3 volts. The important thing though is not how bright the bulb glows (if at all), but how the meter reacts.

1.1.2. How to Use the Battery

Place two fully charged, nickel cadmium batteries in the source battery holders. The meter should give a 0 - volt reading since S1 (which is connected between the batteries and the meter) is open. When the switch is closed, the meter reading should jump to between 2.5 and 3.0 volts,

1.1.3. NiCad Battery

The NiCad battery is based on the Motorola Solid-State precision voltage reference device, TL431(ILP). The trip point (adjustable with P1 for both units) can be set to 4.4volt for the receiver pack and 8.8volt for the transmitter pack or whatever else you prefer as trip-point for your battery packs. Radio Shack can order this part in I was told. TL431ILP senses the preset voltage reference and trips the relay when that control voltage point is reached, adjusted with the 10-turn trimmer pots, which in turn activates the charger. The resistors used int this circuit provide an approximate discharge rate of 250mA. Since the remainder of the circuits power is also provided by the battery being discharged, an additional 50mA or so is discharged from the NiCad battery packs. The relay is configured as latch so that once the unit trips from discharge to charge, the unit cannot be recycled until the start switch is pressed. The component values, setting up the discharge values and trip points can be adjusted to handle any size or battery voltage up to the 30 volt maximum rating of the TL431. Remember, the relay coil voltage must also be taken into consideration when changing the operating voltage of the circuit. All components listed in the circuit can be easily obtained from your local electronics store or Tandy/Radio Shack, although the TL431 may have to be ordered in. If you find a significant drop in discharge time you have a clue that something is going bad with your pack and close examination or a new purchase may be needed.

When you have completed building the cycler, go back and make sure that all your connections are soldered solidly and that all connections are correct. If you're not sure, try to get help from someone with electronics experience. Although highly unlikely, it is possible to destroy the TL431 by reversing the positive/negative connections so try to make sure this particular device is hooked up correctly. Take your time checking your wiring and connections; the last thing you want is damage to your charger. To calibrate this unit you need 6 regular (1.5v) dry cells, it does not matter what size they are, AA, C or D cells are all good. Just make sure they are new . NiCads will not work for this step in the process. [I used an adjustable Power Supply instead since I can simulate depletion of a battery pack, by adjusting the voltage, to the point I prefer the relais to trip.] Your goal in calibrating the cycler is to adjust the trimmer pots in such a way that the unit will change from 'discharge' to 'charge' when the cells reach 1.1 volts per cell. On the receiver battery pack this will be 4.4 volts. On the transmitter pack this is 8.8 volt. Preset the trimmer controls all the way to one end. Connect 3 of the dry cells in series, giving you 4.5 volts total. This is just above the voltage you want the receiver pack to change over from 'cycle' to 'charge'. Connect the dry cell combination across the receiver battery leads of the cycler. Press and release the start button. If the LED lights and stays lit, turn the control all the way to the other end, and repeat the step above. Not turn the trimmer potentiometer back 1/8 turn, in the opposite direction you turned it to get the LED to go off. Press and release the start button one more time. IF the LED stays on, the receiver battery adjustment portion of the cycler is complete. If the LED still goes out, turn the trimmer an additional 1/8 turn back. Now the LED shoud stay lit when the start button is pressed and released. If it does not, or the relay seems to 'rattle' when you press the start button recheck your wiring; something is not connected right. For the transmitter section of the cycler use the same calibration method as described above but now use all 6 cells. At 1.5volts per cell this will add to 9 volts and again is just above the 8.8 volt trip level to change over from cycle to charge.

1.2. Battery Protection Circuits

A variety of circuit topologies exist for lithium ion cell and battery protection. For battery packs containing 2 or more cells these may consist of N or P-channel MOSFETs switching on the negative or positive rail of the battery output terminals respectively. For cell phones, where space is at a premium and typically only one Li-ion cell is used, N-channel switching topologies are more common.

The reason for this being that N-channel power MOSFET devices typically have a higher channel mobility and therefore lower Rdson per unit area for a given blocking voltage , see in figure 1.1.

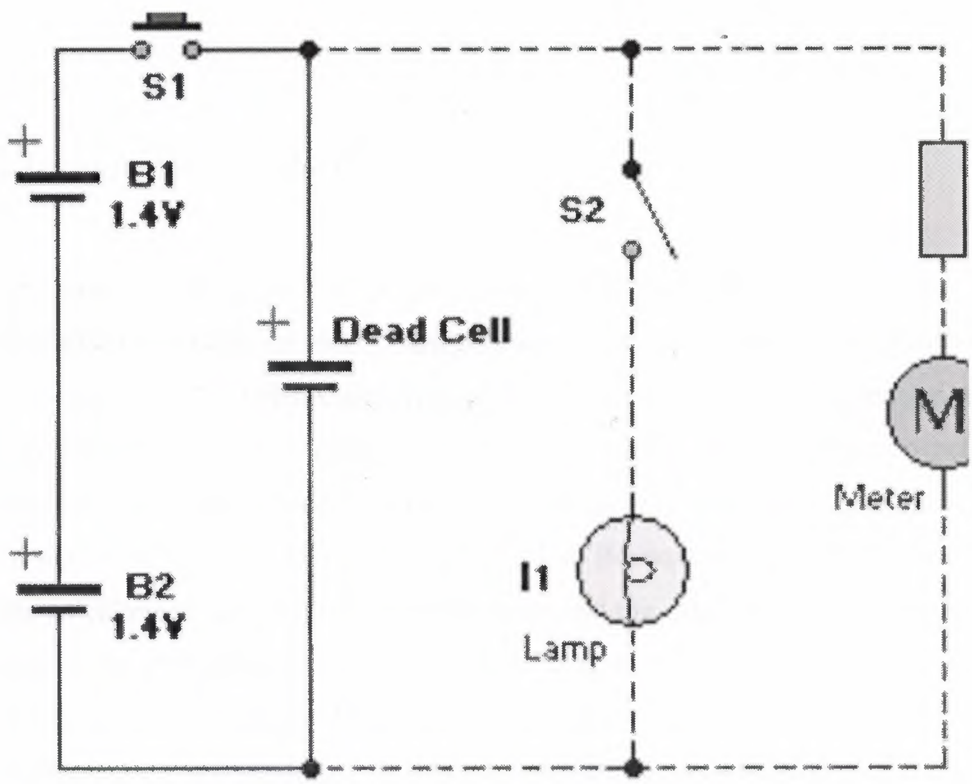


Figure 1.1. Protection circuit for the battery

The circuit consists as in figure 1.1 of a protection IC, gas gauge IC and N-channel power MOSFET devices. Depending upon IC used, additional components may also be present such as a current sense resistor, fuse, and temperature sensing elements.

1.3. Charging mode

Lithium ion cells are typically charged using a constant current constant voltage strategy. During charge mode the load is replaced or paralleled with a charger. Under normal charge conditions the charge FET is turned on (Vgs2 > Vgth).

The discharge FET's internal body diode will be conducting. In most cases the discharge FET will also be switched on to minimize the voltage drop between the charger and cell (Vgs1 > Vgth). As mentioned in the introduction, overcharge can also damage the cell. If the charge voltage increases past that of the IC's built in voltage reference, the charge FET and, if on, the discharge FET, will be turned off.

1.4. The Technical Bits of the Charger:

For those of my interested in how the value of essential components was calculated, read on. You may be able to design your own charger for use with a different current or voltage (like 6 - volt). Calculations origin from the voltage between points C and B of the LM350 regulator. When a resistor is connected between these two points, enough current starts to flow that the voltage over this resistor measures 1.25 volt. In our case, the resistor total is 2.2 + 100 + 150 =252.2 ohm. Because we deal with very small currents the calculations are performed in milliamps and the calculations of resistance in Kilo - Ohms. Thus, the current thru this resistor is 1.25 / 0.2522 = 4.9564 mA. The same current also flows thru the 1K & 2K series resistors. We want the output voltage to be 14.1 volt, meaning the voltage drop over these series resistors must be 14.1 - 1.25 = 12.85 Volt. The total resistance value thus must be 12.85 / 4.9564 = 2.5926 Ohms. To enable us to adjust it to this value, one of the resistors is chosen as a 10 - turn trimpot (trimmer potentiometer). Together with the 1K in series (making it a total of 3K)we can adjust it to this correct value. The Rx value is calculated this way; In this scenario we like to have a output voltage of 13.6 volt, in other words, the voltage on the connection point between the 1K/2Kpot should be 13.6 - 1.25 = 12.35 volt. This means that the current thru the 'voltage-divider' will be 12.35 / 2.5926 = 4.7635 mA and the leftover current should be 4.9564 - 4.7635 = 0.1929 mA thru Rx and also cause a voltage drop of 12.35 - 2.78 = 9.57 volt. Measuring this calculated value at the base of the BC558 transistor was 2.78 volt after the output of the LM1458 had become low. With the current of 0.1929 mA the result has become9.47 / 0.1929 = 49.611 Kilo-Ohm. A resistor of 47K would come close enough. Of course you could also use a 50K trimpot to adjust the value even more accurately. The 1K5 (1500 Ohm) resistor in series with the LED is to limit the current thru the LED below 20 mA. The only thing left is to calculate the value of the series resistor which determines the switch-over from charge to float condition. This occurs when the voltage drop over the 0.1 ohm (wire-wound) resistor at the positive leg smaller is than over the 2.2 ohm resistor. This value is 2.2 x 4.9564 = 10.9 mV. The resistance is 0.1 ohm, to get a voltage drop over this resistor of 10.9 mV is the current 10.9 x 0.1 = 109 mA. The second this charge current becomes lower then 109 mA, the LM1458 triggers over to the float condition. The adjustment with the 100-ohm trimpot determines the maximum charge current. The voltage on the walker of this trimpot varies between 10.9 mV - 506.54 mV. The current is this way made adjustable between 0.1A - 5A, but we should not go that far because the LM350K can not handle anything over 3Amp. If we chose a trimpot with a value of 50 ohm, then on the other hand the 3A can not be obtained. So, careful adjustment is the remedy. Take your time! With this information it is a simple task to calculate the dissipation values of the resistors. In other words, the product of the resistance multiplied with the current in square (I2xR). The only resistor which gets it difficult is the 0.1 ohm, but then again, not by much 3 x 3 x 0.1 = 0.9 Watt. Rest us to calculate the power. For that we have add a couple of voltages. We have the input voltage of 14.1, the voltage drop over the resistor, 0.1 x 3 = 0.33 volt, and 3 volt minimum over the LM1458 for proper function, total 17.43 volt. The transformer provides 18V (effective). With ideal rectifying this should total 18 x 1.41 = 25.38 volt. There are however losses via the diodes and bridge rectifier so there is about 23.88 volt remaining. Not much tolerance to play with, on the other hand, too much causes energy loss in the form of heat anyway. The voltage drop over the buffer capacitor may not be lower than 17.43 volt, meaning, the ripple voltage may reach about 23.88 - 17.43 = 6.45

volt. By double-fase rectifying is the ripple voltage equal to I/(2xfxC) whereby I is the discharge current, f is the supply frequencies and C is capacity of the buffer capacitor in Farad. Exchanging places this would give C = 3/(2x50x6.45) = 0.004651 Farad, or 4651 uF. A standard value of 4700 uF with a minimum voltage value of about 35-40 Volt. The other capacitor is not very critical and is only there to kill small voltage spikes which could influence the operation of this charger otherwise. The bridge rectifier gets a good workout also and it is therefore recommended to chose NOT a too light a unit. A 5A rectifier is often too small, better to take a 8 or 10A type. These are readily available everywhere. Last but not least, the transformer. The buffer capacitor has approximately 25 volt accros. The current is 3A. This calculates to a power of 25 x 3 = 75 watt. This transformer has its own problems with power loss (naturally occurring) and so a unit of about 80 watt is acceptable. Never attempt to charge a 6 volt battery with a 12 volt charger; you are asking for trouble.

2. CIRCUIT DIAGRAM OF PHONE BATTERY CHARGER

2.1. Definition of Charger Circuit

Characterization of the behavior of an asynchronous system depending on the delay of components and wires is a major task facing designers. Some of these delays are outside the designer's control, and in practice may have to be assumed unbounded. The existing literature offers a number of analysis and specification models, but lacks a unified framework to verify directly if the circuit specification admits a correct implementation under these hypotheses.

Our aim is to fill exactly this gap, offering both low-level (analysis-oriented) and high-level (specification-oriented) models for asynchronous circuits and the environment where they operate, together with strong equivalence results between the properties at the two levels. One interesting side result is the precise characterization of classical static and dynamic hazards in terms of our model. Consequently the designer can check the specification and directly decide if the behavior of any implementation will depend, e.g., on the delays of the signals described by such specification.

We also outline a design methodology based on our models, pointing out how they can be used to select appropriate high and low-level models depending on the desired characteristics of the system.

There are several factors which affect the settling time of a signal. For example, ringing due to reflections from impedance mismatches within the bus system is a factor which affects the settling time of the signal. The voltage level of the launched signal relative to the overall signal swing is another factor which affects the settling time of the signal. The effectiveness of the termination of the bus is another factor which affects the settling time of the signal. Ringing, the relative voltage level and termination of the bus are controllable by controlling the output impedance of the driver. However, controlling the output impedance of an output driver can be challenging.

2.2. The Equipment of the Circuit

The circuit is contained a many type elements of electronics materials, for example in our circuit we can see resistors, capacitors, transistors, diodes . . ect. That as shown in figure 2.1.

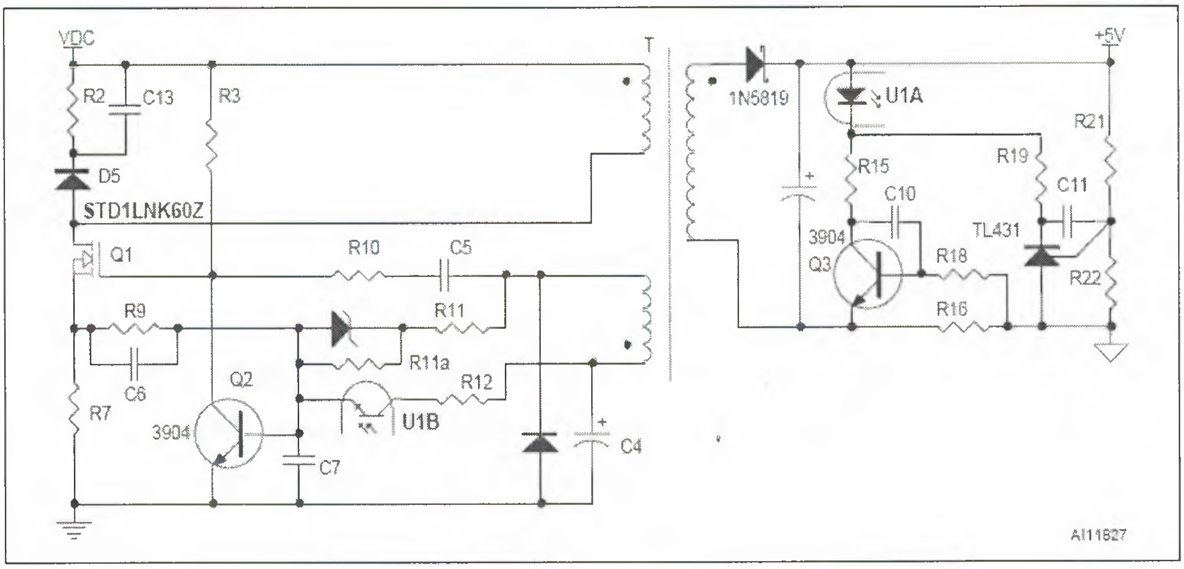
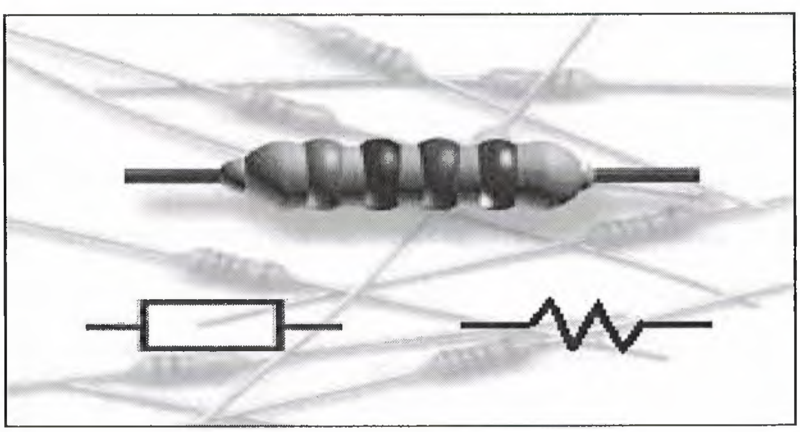


Figure 1.2. RCC Control Circuit Components Schematic.

2.2.1. The Resistors

In other word is Current Shunt Resistors , The Current sensors are required to measure an electric current in an output phase of an IGBT inverter. Depending on the IGBT inverter output power, several solutions are Well known today. Shunt resistors, placed on the printed circuit board (PCB) in an Inverter design, are popular due to the low system cost and exact current.



Measurement. Due to the losses in the current shunt resistors during operation this Solution is limed. Therefore other solutions have to be used for higher power. With a technology that allows placement of current shunt resistors on the base plate in an IGBT module these shunt resistors are as close as possible to the heat sink. In the range up to 35kW shunt resistors may be used for current measurement.

A different and in fact exciting solution is to use the advantage of current shunt Measurement in a higher power range were current transducers are utilised today.

2.2.1.1. To obtain a voltage from the current.

Fundamentally a current shunt resistor is a simple component. An electric current flows through a resistive material and an electric voltage drops across the resistance. This voltage is a perfect image of the current which is flowing through the resistor. Of cause only if the resistance is constant throughout the temperature range. This is unfortunately not the case. Not only an electric voltage is formed by the current through the resistance but also power losses are generated in this resistor. The power losses for a DC current are simply calculated as P=I2*R.

As simple as the DC losses may be to calculate as difficult is it dissipating the heat from a current shunt resistor with rising current. Also losses increase the temperature and with this the resistance. In a nutshell: Shunt resistors able to conduct higher currents have to be cooled.

Therefore the usefulness of current shunt resistors in power electronics applications was technically limited or simply not cost effective.

2.2.1.2. Current Shunt resistors in IGBT Modules.

In power electronics applications, especially in the wide field of frequency- and vector controlled inverters, current measurement is essential. Firstly to detect an over-current or short circuit current and secondly, this current information is necessary for the controller. While drive inverters below 5,5kW use shunt resistors on the PC-board mainly, inverters with higher power use mainly current transducers to get the current information. The concept to bring the shunt resistors onto the heat sink to dissipate the power losses is not new. But it is realized for the first time in the medium power range in a standard IGBT module package.

The value of the applied shunt resistors is between 1.2m□and 2.4m□. The resistance of the bond wires and copper traces inside the IGBT module is in the range of 2m□. Connections to IGBT module such as cables and the load like an electric motor have also a resistance which changes with the temperature.

The figure 2.2 shown the Paralleling four-wire shunt resistors by using ballast resistors .

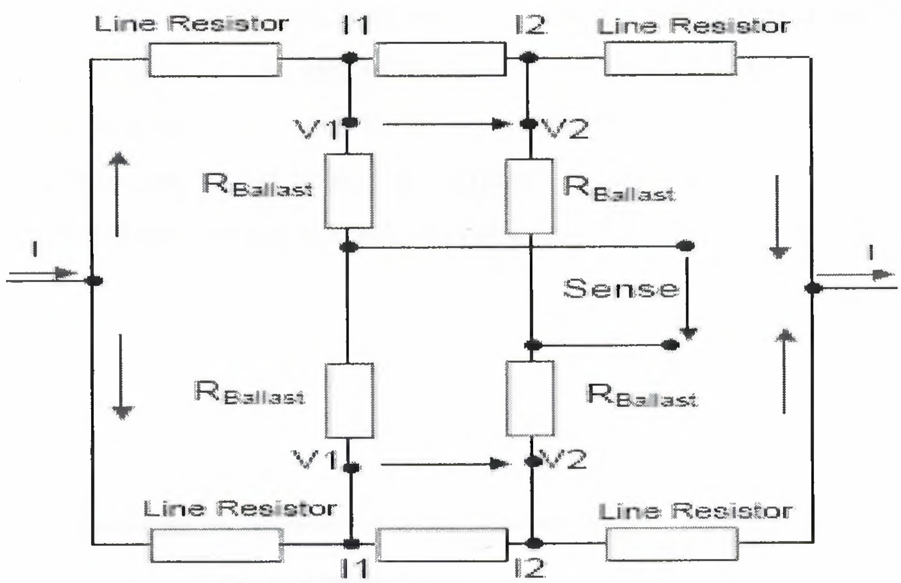


Figure 2.2. Shunt Resistor

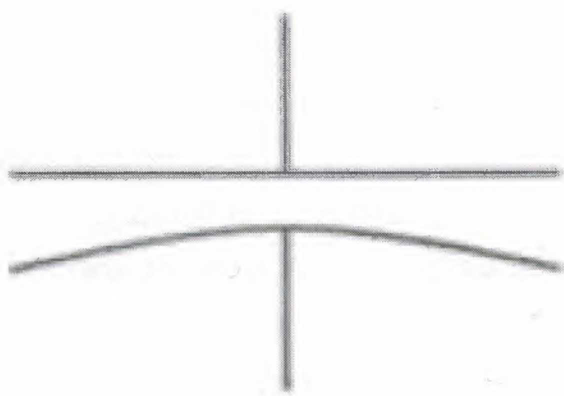
To avoid significantly higher currents in the sense lines than expected, ballast resistors must be used in the sense lines. Referring to the schematic of Figure 2.2, and remembering that the whole point of the Kelvin connections is to counteract the variability of the contact resistance, without the ballast resistors, unequal currents through the contact resistances could equalize in the sensing elements by flowing through the interconnected sense lines. These are typically not designed for high currents. The lower the Kelvin resistor value is, the higher will be the error introduced by mismatched connections.

2.2.2. The Capacitors.

For all practical purposes, consider only the parallel-plate capacitor: two conductors or electrodes separated by a dielectric material of uniform thickness. The conductors can be any material which will conduct electricity easily. The dielectric material must be a poor conductor – an insulator.

A favorite analogy compares the flow of electric current with the flow of water out of a tank. A capacitor stores energy when it is charged. The water tank would be the capacitor and it would be charged by a pump (a battery) which fills it up. The amount of charge in the capacitor would be analogous to the amount of water in the tank. The height of the water above some reference point would be the voltage to which the battery had pumped up the capacitor, and the area of the tank would be capacitance.

A tall, skinny tank might contain the same amount of water as a shallow, flat tank, but the tall, skinny tank would hold it at a higher pressure. There are also tall, skinny capacitors (high voltage, low capacitance) and shallow, flat capacitors (low voltage, high capacitance).



Capacitor Symbol

2.2.2.1. What happens inside a capacitor?

When charged by a battery, one electrode of the capacitor will become positively charged and the other one will be correspondingly negatively charged.

As shown in the figure 2.3.

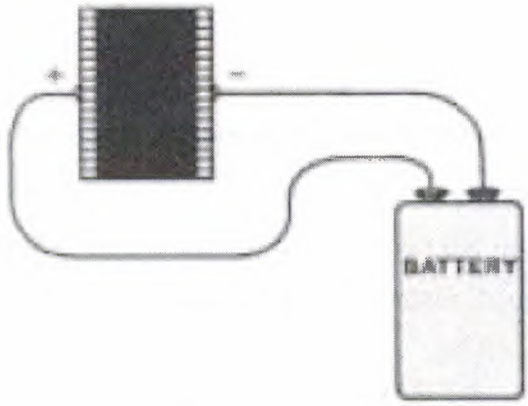


Figure 2.3. Charged Capacitor

When the diagram of the capacitor is magnified, it can be seen that the presence of electrical charges on the electrodes induces charges in the dielectric. These induced charges determine something called permittivity. Each different dielectric material has its own value of permittivity. A more practical and better known measurement tool is called "K," or dielectric constant. "K" is the *ratio* of the permittivity of the dielectric in use to the permittivity of free space – a vacuum. Therefore, all the capacitance values are related to the permittivity of vacuum.

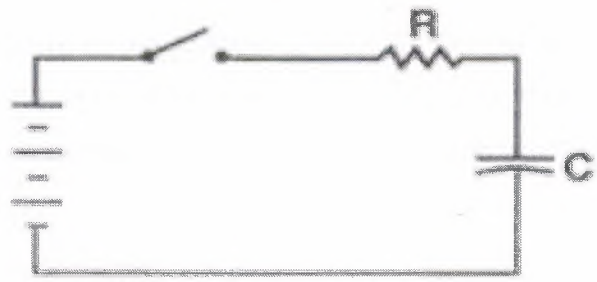
The only trick involved in using this equation is to keep the units consistent. Capacitance is in farads, the area "A" is in square meters and the distance between electrodes "D" is in meters. "K" is a ratio and a pure number without dimensions Sometimes different constants are used in the equation. This comes about when units other than farads and meters are used.

Microfarads and inches might be used, for example. To get an idea of what a farad is, calculate the area which would be necessary in a capacitor built to have one farad, to operate in a vacuum, and to have a spacing between electrodes of one millimeter. First, turn the equation around to solve for the area and then plug in the values known. This calculates to 113 million square meters, which would be a field about 6.5 miles on a side. It's not hard to see why one farad capacitors aren't made very often and when they are, they are never made with a vacuum dielectric and a one millimeter spacing. Vacuum capacitors are made, but the market is pretty well limited to laboratory standards.

All commercial capacitors use some different dielectric material with a higher value of K.

2.2.2.2. What is the behavior of capacitors when they are connected in circuits?

Probable the simplest is the RC timing circuit. It is called RC because the combination of resistance (R) and capacitance (C) determines its operation.



When the switch is closed, current from the battery flows through the circuit, charging the capacitor. When the capacitor is completely charged, it is like a closed tank which is completely filled up, and no further current flows. At that time, the voltage across the capacitor would be equal to the supply voltage of the battery.

Voltage across the capacitor advances from zero (fully discharge) to the supply voltage along some predetermined path with respect to time. If the resistor is small, current flows easily and the capacitor is charged more quickly.

Ifthere is a very large resistor, the charging process follows a different path and will take longer to complete.

The behavior of voltage versus time is also influenced by the size of the capacitor. If the capacitor's capacitance is very large, it will require more total energy to fill (the tank is large in diameter), and current flowing through the resistor will require a longer time to charge it.

Below are three charging curves, each approaching the same end point but along different paths. (By adjusting the value of resistance in R and the capacitance in C, curves 1, 2, 3, and many others can be formed.)

What good is it? To be able to leave the lights on in a car and have them go off automatically after a predetermined amount of time, the voltage across the capacitor would operate a switch when it reaches some predetermined value. If other considerations in this circuit required that the switch be operated on a decreasing voltage rather than an increasing voltage, the voltage which appears across the resistor could be used.

2.2.2.3. Alternating Current (AC)

With alternating current, the voltage goes from zero to some maximum value, back down to zero, and then in the negative direction before returning to zero once more. Alternating current frequently does look exactly like that shown, which is a sine wave. If it doesn't look like this, engineers find some way to transform their calculations so that they can then use all the mathematics which lie behind the sine wave.

2.2.2.4. What Happens When a Capacitor is Subjected to Alternating Current?

To the capacitor, it looks just like DC which is flowing in and flowing out again. The capacitor is alternately being charged, discharged, and then recharged in the opposite direction before being discharged again. One fact important to note is that the capacitor can never block the flow of AC but instead permits a steady flow of current. This throws the timing circuit out the window, but it opens up a lot of new possibilities.

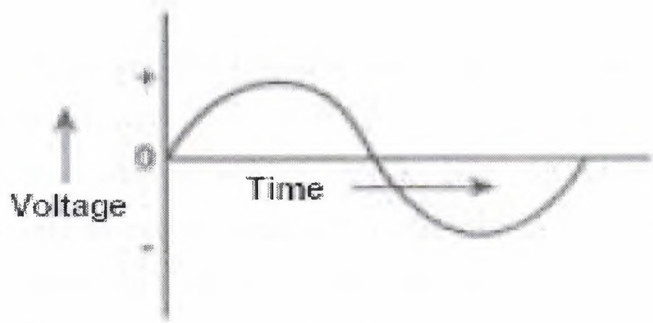


Figure 2.4. Alternating Current-The Sine Wave

The second factor affecting current flow is the frequency of the alternating current. If, instead of the previous wave form, there is one in which current reversal takes place in half the time (double the frequency), the amount of energy which flows into the capacitor before current reversal will be much less. In effect, the capacitor will stay closer to its discharged state than when the frequency of the wave form was lower.

Consequently, the hindrance to current flow that the capacitor offers will be less.

The capacitor, in an AC circuit, is acting something like a resistor in a DC circuit. The additional dimension of frequency has to be a consideration.

The two effects of frequency and capacitor size (capacitance) are combined in an expression known as capacitive reactance and symbolized as XC. Note that XC is expressed in ohms, which is the unit of resistance. Reactance acts something like resistance, and the same unit is used because the two will be combined later. The frequency is expressed as the number of alternations (complete sine waves) which occur in one second, and it used to be abbreviated "cps" for "cycles per second," but is now expressed in hertz. Note that capacitive reactance is inversely proportional to both frequency and capacitance. This fits exactly with the earlier explanation concerning the ease of charge and discharge of a capacitor when it was operating near its discharged state.

$$\mathbf{Xc = 1/(2\pi fc)}$$

Xc =capacitance, reactance, ohm

$\pi = 3.14$

f = frequency hertz

C = capacitance farad

There is a comparable expression for inductance which yields inductive reactance. The unit of inductance is the Henry.

The rest of the processing is needed only to gain electronic contact to the electrodes. It is easy to weld an external lead wire to the stub of the tantalum wire, but contacting the MnO2 is more difficult. To do this, the pellets are dipped into water containing a very finely divided carbon powder. After the water is evaporated, a layer of carbon (actually graphite) is left on all surfaces of the MnO2. Resistivity of the graphite is much lower than that of MnO2, and the fine particle size of the graphite enables this material to touch nearly all the very irregular MnO2 surface. On top of the graphite, a silver-pigmented paint is applied. The sliver is held by an organic resin and presents a solderable surface to facilitate attachment of the second lead wire. Putting all the layers together gives us a section which looks like this, with two wires being shown as indicative of external connection:

The encapsulation of a solid tantalum capacitor can follow several courses. The original design was soldered inside a metal can closed with a glass-to-metal hermetic seal. The next commercial design used potting with an epoxy resin inside of a premolded plastic shell. Later can transfer molding with epoxy,

and then dipping in liquid epoxy resin. The final step in evolution is the tantalum chip, which has been encapsulated in epoxy and has several innovations in terminal design to provide protection against the rigors of directly soldering onto ceramic or glass epoxy substrates.

Much work has gone into statistical treatment of failure rates of solid tantalum capacitors because these capacitors possess a unique "healing" mechanism which results in a failure rate apparently decreasing forever. The MnO2 provides the healing mechanism. If a fault, perhaps some impurity, produces an imperfection in the dielectric layer, a heavy current will flow through that minute area when a DC potential is applied to the capacitor. The current also flows through the MnO2 immediately adjacent to the fault. Resistance of the MnO2 to this current flow causes localized heating. As the temperature of MnO2 rises, this material is converted to a lower oxide of manganese, perhaps Mn2 O3, with much higher resistivity. The increase in resistance decreases the current flow. If this mechanism is successful, the current flow is reduced before localized heating goes too far, preventing a short circuit. Without this mechanism, the solid tantalum capacitor would never have gotten off the ground commercially.

2.2.3. The Transistors.

Transistors come in many different packages (chip carriers) (see images). The two main categories are through-hole (or *leaded*), and *surface-mount*, also known as surface mount device (SMD). The ball grid array (BGA) is the latest surface mount package (currently only for large transistor arrays). It has solder "balls" on the underside in place of leads. Because they are smaller and have shorter interconnections, SMDs have better high frequency characteristics but lower power rating.

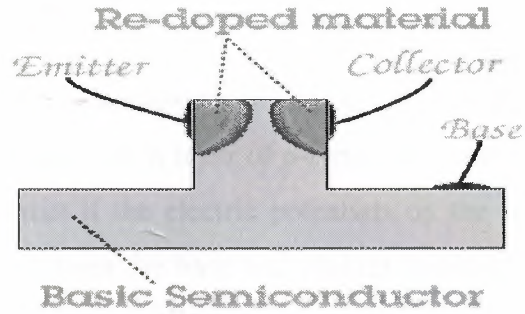


Figure 2.5. Basic Semiconductor

Transistor packages are made of glass, metal, ceramic or plastic. The package often dictates the power rating and frequency characteristics. Power transistors have large packages that can be clamped to heat sinks for enhanced cooling. Additionally, most power transistors have the collector or drain physically connected to the metal can/metal plate. At the other extreme, some surface-mount microwave transistors are as small as grains of sand.

Often a given transistor type is available in different packages. Transistor packages are mainly standardized, but the assignment of a transistor's functions to the terminals is not: different transistor types can assign different functions to the package's terminals. Even for the same transistor type the terminal assignment can vary (normally indicated by a suffix letter to the part number- i.e. BC212L and BC212K).

2.2.3.1. Types of Transistors

Three-terminal, solid-state electronic device used for amplification and switching. It is the solid-state analog to the triode electron tube; the transistor has replaced the electron tube for virtually all common applications.

The transistor is an arrangement of semiconductors materials that share common physical boundaries. Materials most commonly used are silicon, gallium-arsenide, and germanium, into which impurities have been introduced by a process called "doping. In n-type semiconductors the impurities or dopants result in an excess of electrons, or negative charges; in p-type semiconductors the do pants lead to a deficiency of electrons and therefore an excess of positive charge carriers or "holes.

a. The Junction Transistor

The *n-p-n* junction transistor consists of two *n*-type semiconductors (called the emitter and collector) separated by a thin layer of *p*-type semiconductor (called the base). The transistor action is such that if the electric potentials on the segments are properly determined, a small current between the base and emitter connections results in a large current between the emitter and collector connections, thus producing current amplification. Some circuits are designed to use the transistor as a switching device; current in the base-emitter junction creates a low-resistance path between the collector and emitter. The *p-n-p* junction transistor, consisting of a thin layer of *n*-type semiconductor lying between two *p*-type semiconductors, works in the same manner, except that all polarities are reversed.

b. The Field-Effect Transistor.

A very important type of transistor developed after the junction transistor is the field-effect transistor (FET). It draws virtually no power from an input signal, overcoming a major disadvantage of the junction transistor. An *n*-channel FET consists of a bar (channel) of *n*-type semiconductor material that passes between and makes contact with two small regions of *p*-type material near its center. The terminals attached to the ends of the channel are called the source and the drain; those attached to the two *p*-type regions are called gates. A voltage applied to the gates is directed so that no current exists across the junctions between the *p*- and *n*-type materials; for this reason it is called a reverse voltage. Variations of the magnitude of the reverse voltage cause variations in the resistance of the channel, enabling the reverse voltage to control the current in the channel. A *p*-channel device works the same way but with all polarities reversed.

c. The metal-oxide semiconductor field-effect transistor (MOSFET).

Is a variant in which a single gate is separated from the channel by a layer of metal oxide, which acts as an insulator, or dielectric. The electric field of the gate extends through the dielectric and controls the resistance of the channel. In this device the input signal, which is applied to the gate, can increase the current through the channel as well as decrease it.

2.2.4. Diodes and Rectifiers

A diode is an electronic component that, in general, will pass current in only one direction (there are a few exceptions like zener and current regulator diodes). They are used in virtually every piece of electronic equipment. In head units, they are virtually always used across the power input terminals to protect the head unit in case of reverse polarity (hooking the power wires up backwards). In amplifiers, they are used as rectifiers to convert AC to DC. In a large percentage of audio equipment, Zener diodes are used as voltage regulators. In alarm systems, rectifier diodes are commonly used to isolate 2 trigger sources.

For a general purpose rectifier diode... when the voltage on the anode is more positive than the voltage on the cathode, current will flow through the diode. If the voltage is reversed, making the cathode more positive, then current will not flow through a rectifier diode (unless the peak reverse voltage rating is exceeded).

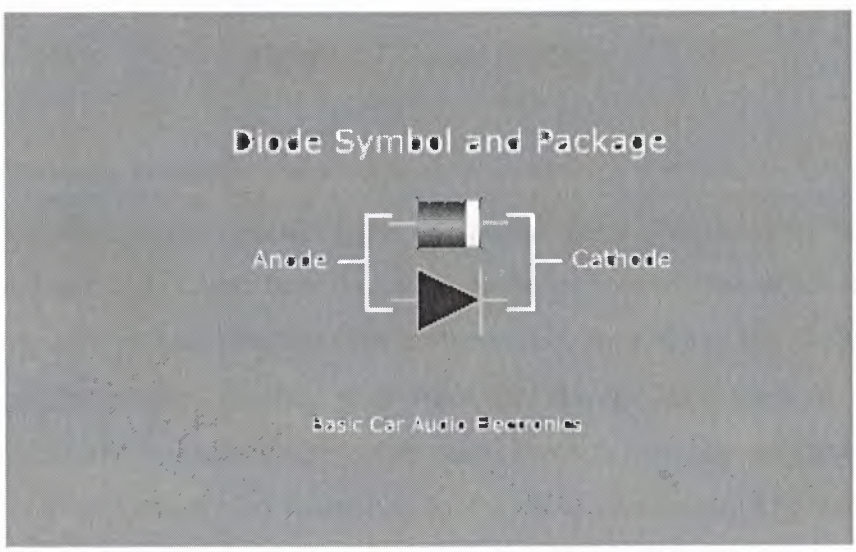


Figure 2.6. Diode Symbol

When voltage is applied to a diode and current is flowing through the diode, there will be approximately a .6 volt drop across the diode. In this first diagram, I've included the voltmeter so that you could see how the voltage indicators represent voltage. I'll use the indicators only in the rest of the diagrams. The green rectangular device is a current limiting resistor. It's needed to prevent excessive current flow through the diode when forward voltage is applied.

When the voltage on the cathode is greater than the voltage on the anode, current will not flow through the diode.

A picture of a couple of common diode packages.

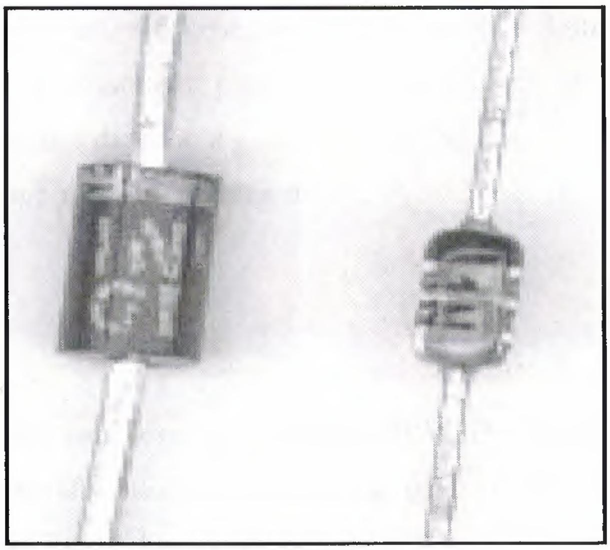


Figure 2.7. Diode Packages

2.2.4.1 Special Purpose Diodes

Before we discuss any specific types of special diodes, we need to show how voltage across a diode and current flow through a diode are related. The following graph shows voltage on the x-axis and current flow on the y-axis. As you can see, for a forward biased diode, as the voltage reaches ~0.6 volts the current flow starts to increase significantly. Before the voltage reaches ~0.6 volts, there is virtually no current flow. Above ~0.6v there is virtually no resistance to the flow of current. The same thing happens as the reverse voltage approaches the reverse breakdown voltage. If you push the 'sweep voltage' button, the voltage will sweep from the greatest negative value to the greatest positive voltage.

2.2.4.2 Peak Reverse Voltage (V_{RRM})

The peak reverse voltage for a diode is the maximum reverse voltage that won't force the diode to conduct. When V_{RRM} is exceeded, the depletion layer may breakdown and allows the diode to conduct in the reverse direction.

Typical values of V_{RRM} range from a few volts to thousands of volts. This value is specified in the spec. sheet for the diode. It must be considered when a replacement diode is required.

If the reverse voltage applied to a diode exceeds V_{RRM}, then the diode will conduct. This current, called the, can generate sufficient heat to destroy the diode. The peak reverse voltage is an important parameter (limit). When you are considering whether or not to use a specific diode in a given application, you must make sure that the diodes peak reverse voltage rating is greater than the maximum reverse voltage in the circuit.

Example:

A circuit has a maximum reverse voltage of 50 V. The replacement diode used here must have at We generally build in at least a 20 percent safety factor. Using this: What is the minimum V_{RRM} rating that should be used?

$$V = 1.2\ V = (1.2)(50V) = 60\ V\ \text{(minimum)}$$

As long as the diode used as the V_{RRM} rating that is equal to (or greater then) 60 V, it will be able to handle minor variations of voltage in the circuit without being driven beyond its reverse voltage limit.

The effect of V_{RRM} is shown in the diode characteristic curve shown Figure 2.8 the reverse current (I_R) a shown to be 0 until the value of V_{RRM} (-70V) is reached.

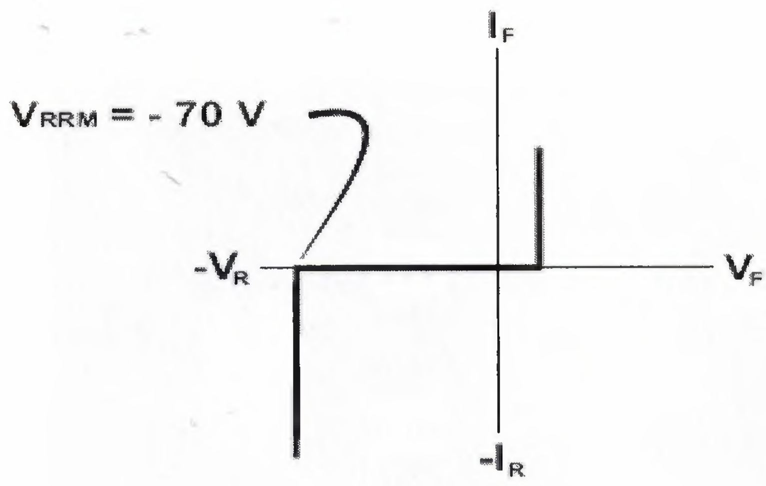


Figure 2.8. Peak Reverse Voltage (V_{RRM})

2.2.5. Zener Diodes

Zener diodes are generally used for voltage regulation. The diodes are used with reverse polarity when compared to their rectifier counterparts (you hook them up backwards to make them work properly). All diodes have a point at which they will conduct current when sufficient reverse voltage is applied. Most diodes are damaged when the reverse voltage reaches the breakdown (or avalanche) voltage. This is primarily due to the lack of any current limiting resistor. Zener diode circuits have a current limiting resistor in series with the diode as part of their design. In the diagram below, you can see how the positive terminal of the battery is connected to the resistor. The other end of the resistor is connected to the cathode of the zener. The other end of the zener, the anode, is connected to ground. If the zener diode is a 5.1 volt zener, the voltage on the cathode of the zener will be very close to 5.1 volts. The voltage is going to be close (but not usually exactly) the rated zener voltage. You can sometimes get the voltage very close to its rated zener voltage by varying the value of the resistor. This changes the current flow through the diode. If you look at the curve, you can see that a change in current (near the breakdown voltage) corresponds to a small change in the breakdown voltage. This type of circuit is good for use as a voltage reference but it is not very good to supply regulated voltage to circuits that draw a large amount of current.

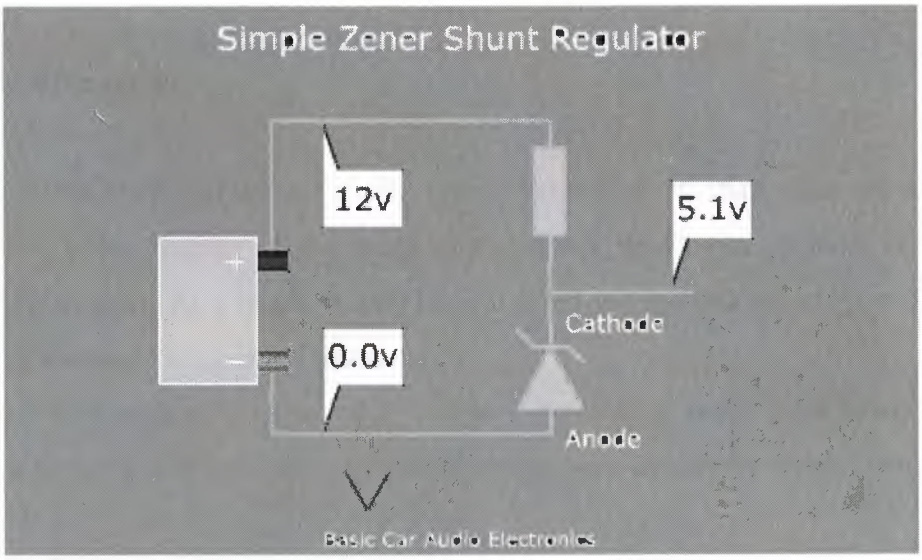


Figure 2.9. Simple zener shunt regulator.

The zener diode is used for its reverse operating characteristics and as shown in figure 2.10. For this device current flows when the cathode is more positive than the anode.

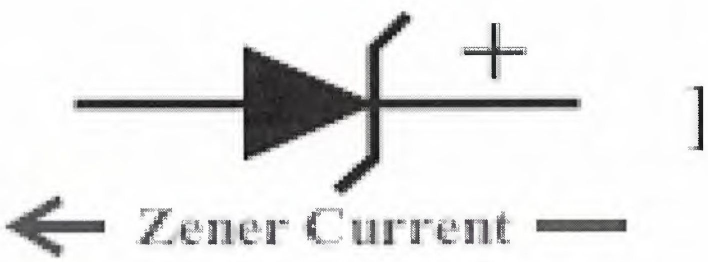


Figure 2.10. Zener current operation.

When the zener is operating in the reverse operating region, the voltage across the device will be nearly constant and equal to the zener voltage (V_z) rating of the device. Zener diodes have a range of V ratings from about 1.8V to several hundred volts. They also have power dissipation ratings of between 500 MW and 50W.

The zener rating always tells you the approximate voltage across the device when it is operating in the reverse breakdown region.

2.2.5.1. Zener Breakdown

Zener breakdown occurs at much lower values of V than does avalanche breakdown. The heavy doping of the zener diode causes the device to have at much narrower depletion layer. As a result, it only takes a small reverse voltage of typically 5V or less to cause the diode to go into breakdown.

Zener diodes with a V rating of 5V or less experience zener breakdown while those having a V rating of greater than 5V usually experience avalanche breakdown.

2.2.5.2. Zener Operating Characteristics

Figure 2.11 showed how a zener diode maintains the near constant reverse voltage for a range of reverse current values.

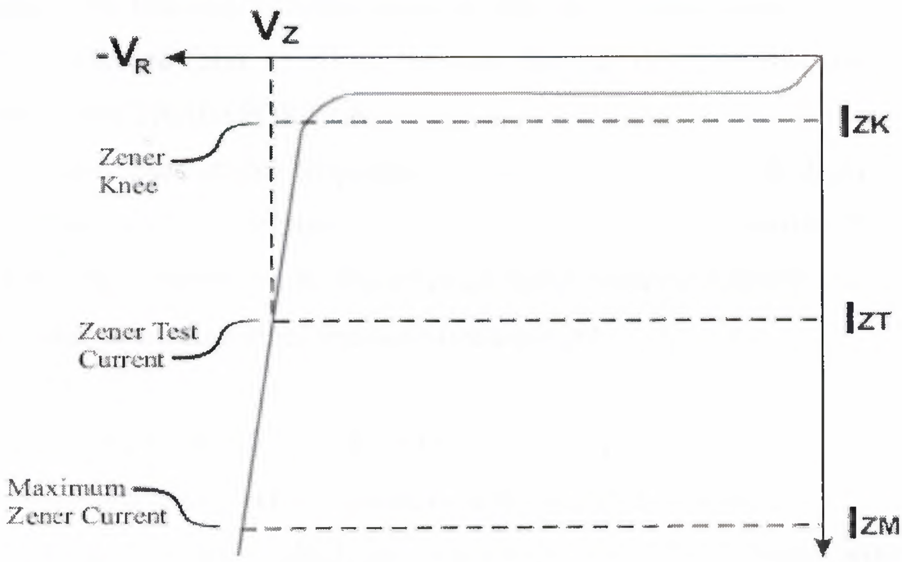


Figure 2.11. Zener Operation Characteristics

Note the three currents listed:

I_{ZK} : - This is the minimum value of I required to maintain voltage regulation. This is called the zener knee current. When a zener is used as a voltage regulator, the current through the diode must never be allowed to drop below I_{ZK}.

I_{ZT} : - This is the zener test current. It is the current level at which the V rating of the diode was taken. For example, if the diode has V = 9.1V and I = 20 mA, this means that the diode has a reverse voltage of 9.1V when the test current was 20 mA. At other currents the value of V will vary slightly above or below the rated value of 9.1V.

I_{ZM} : - This is the maximum allowable value of I. Currents above this value will damage or destroy the diode.

2.2.6. The Transformer

In the general transformer there is two coils of wire (called windings) are wound on some type of core material. In some cases the coils of wire are wound on a cylindrical or rectangular cardboard form. In effect, the core material is air and the transformer is called an AIR-CORE TRANSFORMER.

Transformers used at low frequencies, such as 60 hertz and 400 hertz, require a core of low-reluctance magnetic material, usually iron. This type of transformer is called an IRON-CORE TRANSFORMER. Most power transformers are of the iron-core type. The principle parts of a transformer and their functions are:

1- The Core: which provides a path for the magnetic lines of flux.
2- The Primary Winding: which receives energy from the ac source.
3- he Secondary winding: which receives energy from the primary winding and delivers it to the load.
4- The Enclosure: This protects the above components from dirt, moisture, and mechanical damage.

2.2.6.1. Core Characteristics

The composition of a transformer core depends on such factors as voltage, current, and frequency. Size limitations and construction costs are also factors to be considered. Commonly used core materials are air, soft iron, and steel. Each of these materials is suitable for particular applications and unsuitable for others. Generally, air-core transformers are used when the voltage source has a high frequency (above 20 kHz). Iron-core transformers are usually used when the source frequency is low (below 20 kHz). A soft-iron-core transformer is very useful where the transformer must be physically small, yet efficient. The iron-core transformer provides better power transfer than does the air-core transformer. A transformer whose core is constructed of laminated sheets of steel dissipates heat readily; thus it provides for the efficient transfer of power. The majority of transformers you will encounter in Navy equipment contain laminated-steel cores. These steel laminations (see figure 2.12) are insulated with a nonconducting material, such as varnish, and then formed into a core. It takes about 50 such laminations to make a core an inch thick. The purpose of the laminations is to reduce certain losses which will be discussed later in this chapter. An important point to remember is that the most efficient transformer core is one that offers the best path for the most lines of flux with the least loss in magnetic and electrical energy.

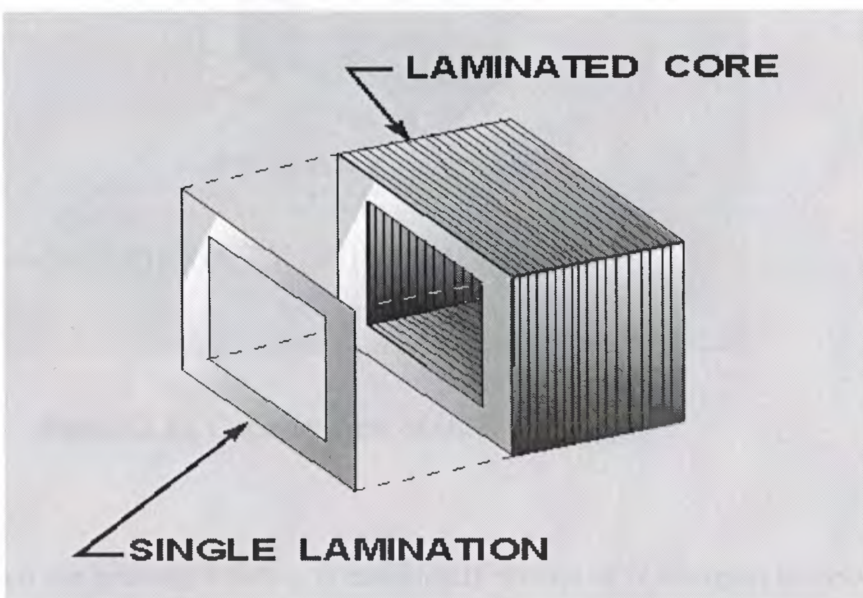


Figure 2.12. Hollow-core construction.

sections of the iron core are inserted into and around the windings as shown in figure 2.13

The leads from the windings are normally brought out through a hole in the enclosure of the transformer. Sometimes, terminals may be provided on the enclosure for connections to the windings. The figure 2.13 shows four leads, two from the primary and two from the secondary. These leads are to be connected to the source and load, respectively.

2.2.6.3. How a Transformer Works

Up to this point the chapter has presented the basics of the transformer including transformer action, the transformer's physical characteristics, and how the transformer is constructed. Now you have the necessary knowledge to proceed into the theory of operation of a transformer.

NO-LOAD CONDITION. You have learned that a transformer is capable of supplying voltages which are usually higher or lower than the source voltage. This is accomplished through mutual induction, which takes place when the changing magnetic field produced by the primary voltage cuts the secondary winding.

A no-load condition is said to exist when a voltage is applied to the primary, but no load is connected to the secondary, as illustrated by figure 5-8. Because of the open switch, there is no current flowing in the secondary winding. With the switch open and an ac voltage applied to the primary, there is, however, a very small amount of current called EXCITING CURRENT flowing in the primary. Essentially, what the exciting current does is "excite" the coil of the primary to create a magnetic field. The amount of exciting current is determined by three factors:

(1) The amount of voltage applied (E_a).

(2) The resistance (R) of the primary coil's wire and core losses.

(3) The X_L which is dependent on the frequency of the exciting current.

PRIMARY AND SECONDARY PHASE RELATIONSHIP. The secondary voltage of a simple transformer may be either in phase or out of phase with the primary voltage. This depends on the direction in which the windings are wound and the arrangement of the connections to the external circuit (load). Simply, this means that the two voltages may rise and fall together or one may rise while the other is falling.

Transformers in which the secondary voltage is in phase with the primary are referred to as LIKE-WOUND transformers, while those in which the voltages are 180 degrees out of phase are called UNLIKE-WOUND transformers.

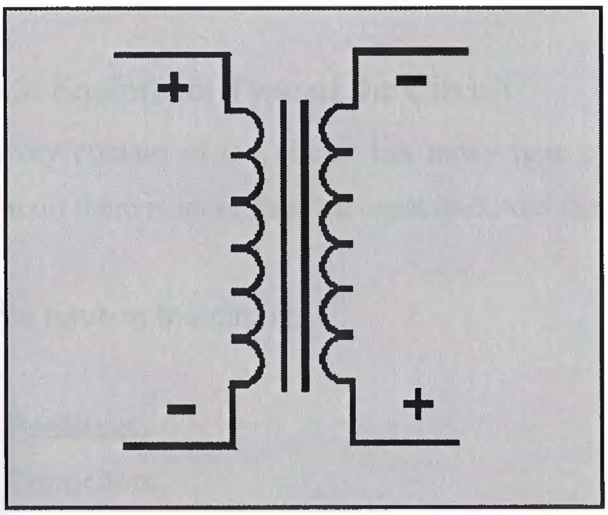


Figure 2.14. Transformer schematic symbol

Dots are used to indicate points on a transformer schematic symbol that have the same instantaneous polarity as figure 2.14 (points that are in phase).

The COEFFICIENT OF COUPLING of a transformer is dependent on the portion of the total flux lines that cuts both primary and secondary windings. Ideally, all the flux lines generated by the primary should cut the secondary, and all the lines of the flux generated by the secondary should cut the primary. The coefficient of coupling would then be one (unity), and maximum energy would be transferred from the primary to the secondary. Practical power transformers use high-permeability silicon steel cores and close spacing between the windings to provide a high coefficient of coupling.

Lines of flux generated by one winding which do not link with the other winding are called LEAKAGE FLUX. Since leakage flux generated by the primary does not cut the secondary, it cannot induce a voltage into the secondary.

The voltage induced into the secondary is therefore less than it would be if the leakage flux did not exist. Since the effect of leakage flux is to lower the voltage induced into the secondary, the effect can be duplicated by assuming an inductor to be connected in series with the primary. This series

2.3. Equipment Type of the Circuit

Every contain of the circuit has many type or a difference value, for example in our circuit there is more than ten capacitors, and these capacitors have a difference values

We have in the circuit:-

- Resistors.
- Capacitors.
- Transistors.
- Diodes.
- Inductor.
- Zener.
- Simple transformer.
- Copper wire.

In this table shown us the type and the code of all Components of the circuit.

Designator	Part Type	Foot Print	Description	Accurate
L1	1mH		Inductor	
C1	4.7uF/400V		Electric Capacitor	85°C
C2	4.7uF/400V		Electric Capacitor	85°C
C3	222/1KV		Ceramic Capacitor	
C4	100u/16V		Electric Capacitor	105°C
C5	682/60V	0805A	SMD Capacitor	
C6	222/60V	0805A	SMD Capacitor	
C7	472/60V	0805A	SMD Capacitor	
C8	330u/16V		Electric Capacitor	105°C
C9	47u/16V		Electric Capacitor	105°C
C10	102/60V	0805A	SMD Capacitor	
C11	0.1u/60V	0805A	SMD Capacitor	
CY	102/Y2		Y2 Capacitor	
R1	10Ω/1W	1W	Resistor	10%
R2	150K/1W	1/2W	Resistor	10%
R3	1.8M	0805A	SMD Resistor	5%
R4	1.2M	0805A	SMD Resistor	5%
R5	1.2M	0805A	SMD Resistor	5%
R6	5.1Ω	0805A	SMD Resistor	5%
R7	6.8Ω	0805A	SMD Resistor	1%
R8	6.8Ω	0805A	SMD Resistor	1%
R9	360Ω	0805A	SMD Resistor	5%
R10	1.5K	0805A	SMD Resistor	5%
R11	36K	0805A	SMD Resistor	5%
R12	1K	0805A	SMD Resistor	5%
R13	5.1Ω	0805A	SMD Resistor	5%
R14	10K	0805A	SMD Resistor	5%
R15	75Ω	0805A	SMD Resistor	5%
R16	3Ω	1206R	SMD Resistor	1%
R17	2.2Ω	1206R	SMD Resistor	1%
R18	910Ω	0805	SMD Resistor	5%

Designator	Part Type	Foot Print	Description	Accurate
R19	150Ω	0805	SMD Resistor	5%
R20	2.7Ω	0805	SMD Resistor	5%
R21	910Ω	0805	SMD Resistor	1%
R22	1K	0805	SMD Resistor	1%
D1	1N4007	DO-41	Diode	
D2	1N4007	DO-41	Diode	
D3	1N4007	DO-41	Diode	
D4	1N4007	DO-41	Diode	
D5	STTH108	DO-41	Diode	ST
D6	1N4148		Diode	
D7	1N5819	DO-41	Diode	ST
Z1	Jumper		Jumper	
Q1	STD1LNK60	IPAK	MOSFET	ST
Q2	MMBT3904	SOT23L	Bipolar	ST
Q3	MMBT3904	SOT23L	Bipolar	ST
U1	P817	DIP4	Optocoupler	Sharp
U2	TL431	TO92L		ST

3. POWER CIRCUIT DISGN CALCULATION

3.1. Introduction of Calculations.

This application note is a Ringing Choke Converter (RCC)-based, step-by-step cell phone battery charger design procedure.

The RCC is essential to the self-oscillating fly-back converter, and operates within the Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM) boundaries without noticeable reverse recovery of the output rectifying diodes. RCC control is achieved by using discrete components to control the peak current mode, so the overall RCC cost is relatively low compared to the conventional Pulse Width Modulation (PWM) IC fly-back converter. As a result, RCC is widely used for low power applications in industry and home appliances as a simple and cost-effective solution.

That we see the result and the efficiency calculation of the phone battery charger circuit.

3.2. Power Transformer Design Calculations.

- The specifications:
  - V_{ac} = 85~265V
- Line frequency: 50~65Hz
  - V_O = 5V
  - I_O = 0.4A

Taking transient load into account, the maximum output current is set as

I_O (max) = 1.2 I_O = 0.48A

3.2.1. Switching Frequency.

The system is a variable switching frequency system (the RCC switching frequency varies with the input voltage and output load), so there is some degree of freedom in switching frequency selection. However, the frequency must be at least 25kHz to minimize audible noise.

Higher switching frequencies will decrease the transformer noise, but will also increase the level of switching power dissipated by the power devices. The minimum switching frequency and maximum duty cycle at full load is expressed as where the minimum input voltage is 50kHz and 0.5, respectively.

I_O (max) =1.2 I_O = 0.48A

fs (min) = 50 kHz

D_{max} = 0.5

3.2.2. Primary Current.

- Primary Peak Current is expressed as:

$$I_{ppk} = (2V_O I_{O(max)}) / (\eta D_{(max)} V_{DC(min)})$$

$$= (2 * 5 * 0.48) / (0.7 * 0.5 * 90) = 0.152 \text{ A}$$

- Primary Root Mean Square (RMS) Current is expressed as

$$I_{prms} = I_{ppk} \sqrt{(D_{(max)}/3)} = (0.152) \sqrt{(0.5/3)} = 0.062 \text{ A}$$

where,

I_{ppk} = Primary peak current

V_O = Voltage output

$I_{O\,(max)}$ = Maximum current output

η = Efficiency, equal to 0.7

D_{max} = Maximum duty cycle

$V_{DC\,(min)}$ = Minimum input bus voltage

I_{prms} = Primary RMS current

3.2.3. Primary Inductance.

Primary Inductance is expressed as

$L_p = (V_{DC(min)}\, D_{max}) / (f_{s(min)}\, I_{ppk}) = (90 * 0.5) / (0.152 * 50) = 5.92$ mH

where,

$V_{DC\,(min)}$ = Minimum Input DC voltage

$f_{s\,(min)}$ = Minimum switching frequency

D_{max} = Maximum duty cycle

$f_{s(min)}$ = Minimum switching frequency

I_{ppk} = Primary peak current

For example, if Primary Inductance is set to 5.2mH, the minimum switching frequency is:

$f_{s(min)} = (V_{IN\ DC(min)}\, D_{max}) / (L_p\, I_{ppk}) = (90 * 0.5) / (0.152 * 5.2) = 75$ KHz

3.2.4. Primary Winding.

-Winding Turns: The effective area of an EE16 core is 20.1mm2 (in the core's datasheet). The number of turns of primary winding is calculated as

$N_p = (V_{DC(min)}\, Dmax) / (f_{s(min)}\, \Delta B A_e)$

$= (90 * 0.5) / (0.22 * (20.1*10\text{^}(-6)) * (57*10\text{^}3)) = 179$

Where,

N_p = Primary Winding Turns

$V_{DC\,(min)}$ = Minimum Input DC voltage

D_{max} = Maximum duty cycle

$f_{s(min)}$ = Minimum switching frequency

ΔB = Flux density swing

Ae = Effective area of the core

-Wire Diameter: The current density (AJ) allowed to flow through the chosen wire is 4A/mm2. The Copper diameter of primary wire is expressed as

$$d_p = \sqrt{\ ((4I_{prms}) / (A_J\pi))} = (4 * 0.062) / (4 * \pi) = 0.142 \text{ mm}$$

Where,

d_p = Diameter of primary winding wire

I_{prms} = Primary RMS current

A_J = Current density

-Practical Flux Swing: Using the N_p = 168 value, the practical flux swing is expressed as

$$\Delta B = (V_{DC(min)} D_{max}) / (f_{s(min)} A_e N_p)$$
$$= (90*0.5) / (168 *(20.1\ 10^{\wedge}-6)\ 57 * 10^{\wedge}3) = 0.234 \text{ T}$$

where,

ΔB = Flux density swing

$V_{DC(min)}$ = Minimum input bus voltage

D_{max} = Maximum duty cycle

$f_{s(min)}$ = Minimum switching frequency

A_e = Effective area of the core

N_p = Primary Winding Turns

3.2.5. Secondary Winding

Using triple insulation wire with a 0.21mm Copper diameter, the number of turns of secondary winding is expressed as

$$N_s = N_p / N = 168 / 14 = 12$$

Where,

N_s = Secondary Winding Turns

N_p = 168 (total turns for all 4 primary winding layers)

N_p = Primary Winding Turns

N = Number of turns per primary winding layer

3.2.6. Winding Turns

The MOSFET gate voltage at minimum input voltage should be 10V to conduct the MOSFET completely. For this application, the optocoupler is powered by the fly-back method, so the number of auxiliary winding turns of auxiliary winding is calculated as

$$V_g = [((V_{DC(min)}N_a) / N_p) + (((V_o + V_F)N_a) / N_s)] > 10$$

Where,

V_g = Gate voltage

$V_{DC(min)}$ = Minimum input bus voltage

N_a = Auxiliary Winding Turns

N_p = Primary Winding Turns

V_o = Optocoupler voltage

V_F = Fly-back voltage

3.2.7. Gap Length

The gap length setting is based on the number of primary winding turns and primary inductance during the manufacturing process.

Note: In practice, the saturation current value must be ensured. If it is not, then the design activity should be restarted.

3.3. Based RCC Control Circuit Components

The base RCC circuit components has built-in, back-to-back Zener diodes specifically designed to enhance not only the Electrostatic Discharge (ESD) protection capability, but also to allow for possible voltage transients (that may occasionally be applied from gate to source) to be safely absorbed.
That sees in figure 3.1.

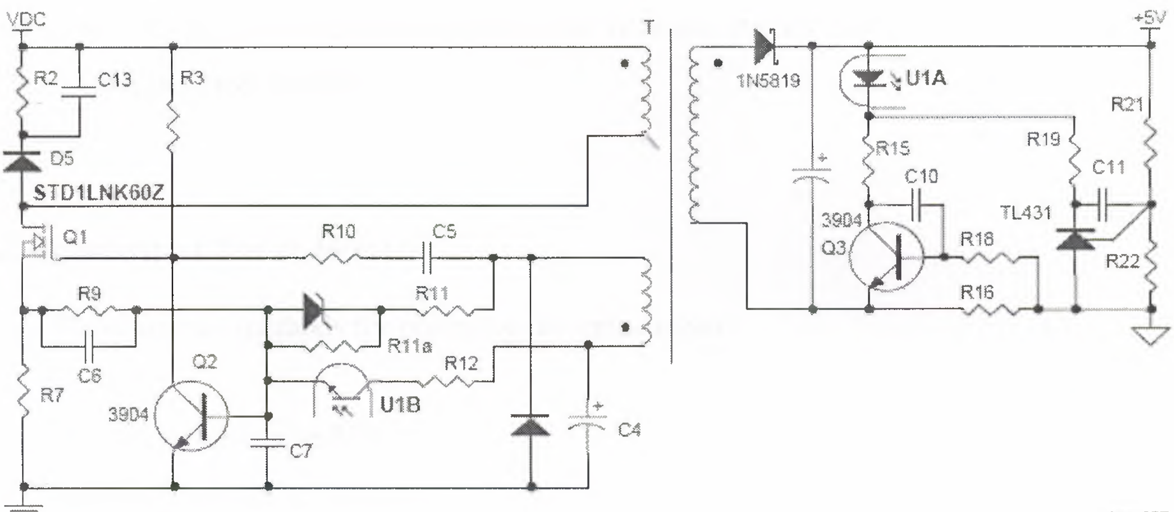


Figure 3.1. RCC Control Circuit Components Schematic

3.3.1. R3 Startup Resistor

<u>-Minimum Power Dissipation:</u> The startup resistor R3 is limited by its power dissipation because of the high input bus voltage that moves across it at all times. However, the lower the R3 value is, the faster the startup speed is. Its power dissipation should be less than 1% of the converter's maximum output power. The minimum power dissipation value is expressed as

$((V_{DC(max)}\text{^}2) / R_3) < 1\text{percent} * (V_{olo(max)} / \eta)$

$R3 > (\eta V_{DC (max)} \text{^}2) / (0.01 * V_{olo (max)})$

$= (0.7 * 375\text{^}2) / (0.01 * 5 * 0.48) = 4.1\ M\Omega$

-Maximum Power Dissipation: If R3 is set to 4.2MΩ, its max power dissipation is expressed as

$P_{R3 (max)} = V_{DC (max)} / R_3 = (0.7 * 375\text{^}2) / (4.2 * 10\text{^}6) = 0.0335W$

-Startup Resistors and the Power Margin: The power rating for an SMD resistor with a footprint of 0805 is 0.125W. Three resistors (1.2MΩ, 1.2MΩ, and 1.8MΩ, respectively) are placed in series to produce the required startup resistor value and still have enough power margins.

3.3.2. Optocoupler Power Methods

There are two methods for powering the optocoupler:

-Fly-back (see figure 3.2).
-forward (see figure 3.3).

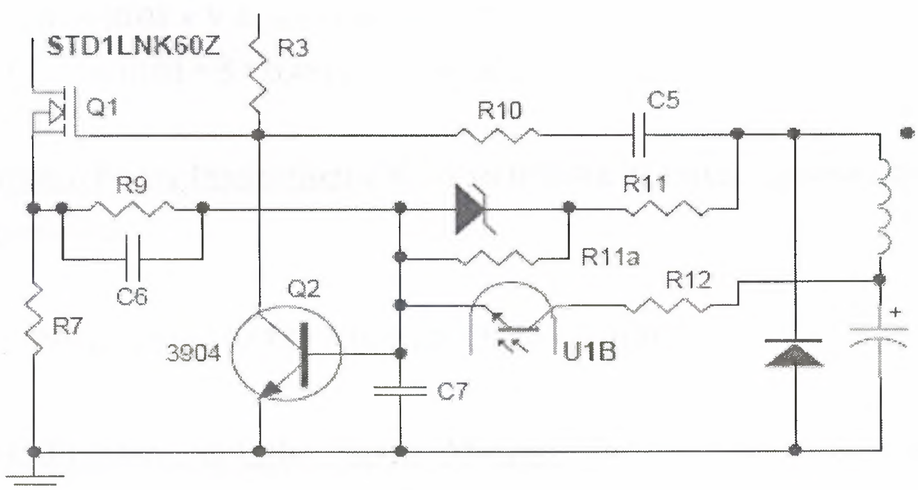


Figure 3.2. Optocoupler Fly-back Power

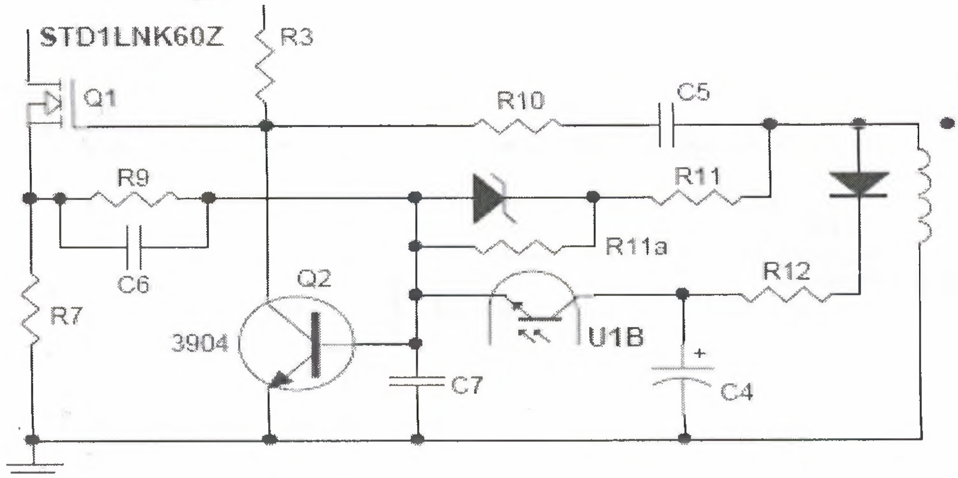


Figure 3.3. Optocoupler Forward Power

The fly-back method was chosen for the RCC application because it provides more stable power for the optocoupler.

3.3.3. R7 Sense Resistor

-Minimum Power Dissipation: Sense resistor R7 is used to detect primary peak current. It is limited by its maximum power dissipation, which is set to 0.1% of the maximum power. The minimum power dissipation is expressed as

$$R_7 < (0.01 \times V_o I_{o\,(max)}) / (\eta\, I_{(prms)}\,\text{^}2)$$
$$= (0.01 * 5 * 0.48) / (0.7 * 0.0622\text{^}2) = 8.9\ \Omega$$

-Maximum Power Dissipation: If R7 is set to 3.4Ω, its maximum power dissipation is expressed as

$$P_{R7\,(max)} = I_{prms}\text{^}2 * R_7 = 0.0622\text{^}2 * 3.4 = 0.013W$$

-Sense Resistors and the Power Margin: Two resistors (6.8Ω, and 6.8Ω, respectively) are placed in parallel to produce the required sense resistor value and still have enough power margins. Ramp-up voltage (via R_7 x I_{ppk}), when added to the

DC voltage [(I_1+I_e) (R_7+R_9)] achieves good output voltage and current regulation (see figure 3.4).

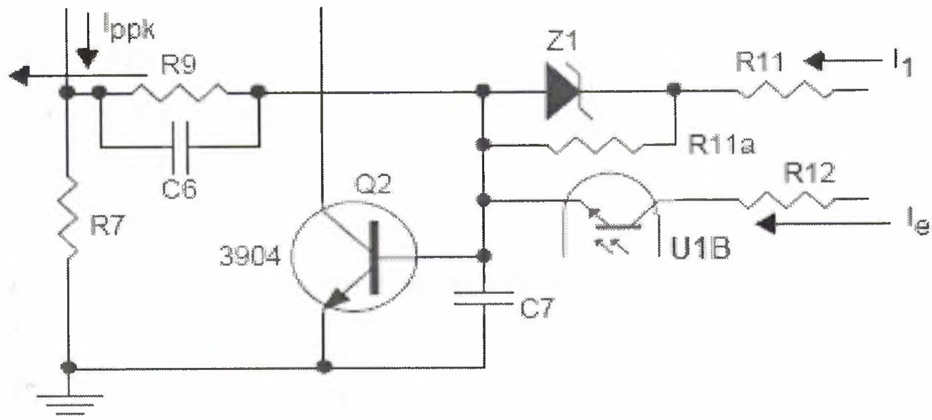


Figure 3.4. Current Sense Circuit

Note: The R_9 value should be much greater than the R_7 value. The minimum primary current, I_{ppk}, and the maximum current, I_2, are in a stead state at the minimum load, while the maximum I_{ppk} and the minimum I2 are in a stead state at the maximum load.

The cathode current, I_k, of TL431 is limited to 1mA< I_k <100mA, and the maximum diode current of optocoupler PC817 is 50mA. In order to decrease quiescent power dissipation, the maximum operation diode current, I_F, of PC817 can be set to 10mA.

3.4. Constant Power Control

The pole of capacitor C7 can filter the leading edge current spike and avoid a Q2 switch malfunction. However, it will also lead to delays in primary peak transfer as well as the turning on of Q2. As a result, different power inputs are produced at different input voltages.

Z1, R11, and R11a provide constant current, which is proportional to the input voltage. This way, power inputs are basically the same at different input voltages.

Note: They must be carefully selected and adjusted to achieve basically constant power input at different input voltages. The basic selection process is expressed as

$\Delta I = (V_{DC} / L_P) * T_d$

Where,

ΔI = Current change

V_{DC} = Input bus voltage

L_P = Primary Inductance

T_d = Transfer delay

Note: R11>> R9 >> R7, so in this case, only R11 is used:

Note: Constant control accuracy is not as good if Z1 is not used, and applying it is very simple. For the purposes of this application design:

C7 = 4.7nF, and

R11 = 36KΩ.

3.5. Constant Voltage and Constant Current

The Constant Voltage (CV) configuration is comprised of the error amplifier TL431, R21, R22, and C11. TL431 provides the reference voltage. R21 and R22 divide the output voltage and compare it with the reference. C11 compensates the error amplifier TL431. R19 limits the optocoupler diode current (see figure 3.5 and figure 3.6 for operation characteristics at difference values of input voltage).

For the purposes of this application, the devices selected are:

R21=1kΩ;

R22=1kΩ;

C11=100nF; and

R19=150Ω.

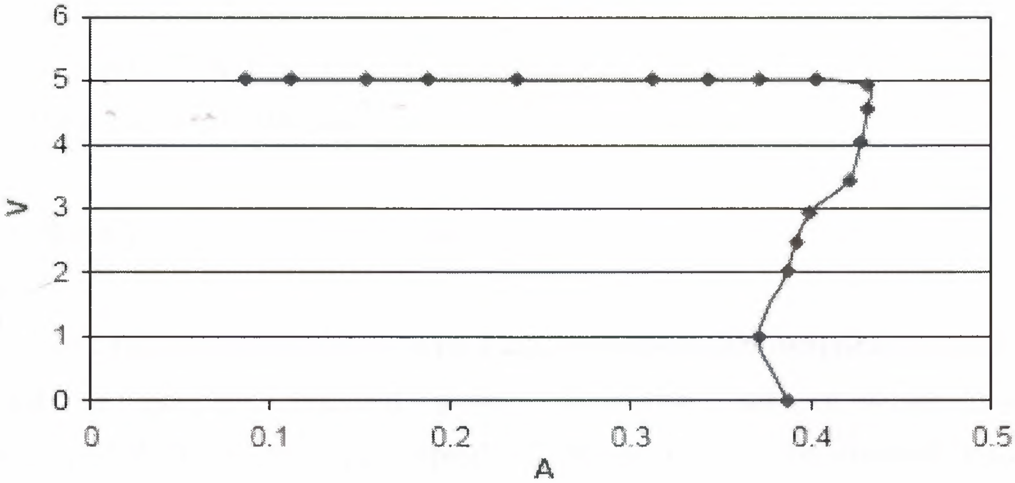


Figure 3.5. CV and CC Curve at 110VAC

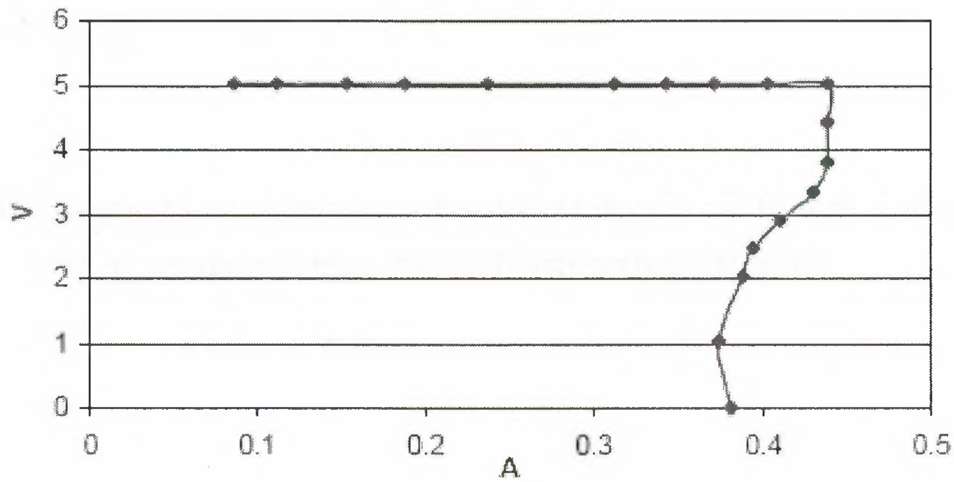


Figure 3.6. CV and CC Curve at 220VAC

The Constant Current (CC) can be established simply with a transistor, Q3, and the resistors, R16, R18, R15, and capacitor, C10. Output current flows through the sense resistor R16. Transistor Q3 is turned on when the voltage drop of resistor R16 reaches the same value as the base turn-on voltage of transistor Q3. This increases the current through the optocoupler and the converter goes into constant current regulation.

Resistor R16 senses the output current, and R18 limits the base current of Q3. The rating power of R16 must then be considered.

If $I_o = 0.4A$ and $V_b = 0.5V$, then

$$R_{16} = V_b / I_o = 0.5 / 0.4 = 1.25\ \Omega$$

Two resistors, one 3.0Ω and one 2.2Ω, with SMD1206 footprint are placed in parallel to get the required power dissipation and resistance value. Similarly, R15 limits the optocoupler's IF diode current for constant current regulation. C10 compensates the constant current control.

For the purposes of this application, the devices are:

$R_{15} = 75\Omega$,

$R_{18} = 360\Omega$, and

$C_{10} = 1nF$.

<u>Note:</u> The parameters of the remaining transformer devices can be seen in the table 2.1 that shown us the type and the code of all Components of the circuit

3.6. Test Results

As we see in the table 3.1, that is the test result of the No-load and Full-load voltage and load regulation.

Table 3.1. Line and Load Regulation

Supply Voltage	No Load	Full Load	Load Regulation
$85V_{AC}$	4.749V	4.743V	±0.06%
$110V_{AC}$	4.750V	4.743V	±0.06%
$220V_{AC}$	4.750V	4.743V	±0.06%
$265V_{AC}$	4.750V	4.743V	±0.06%
Line Regulation	±0.01%	±0.0%	

In the table 3.2 that we see the efficiency ratings for some difference input voltage.

Table 3.2. Efficiency Ratings

Description	$85V_{AC}$	$110V_{AC}$	$220V_{AC}$	$265V_{AC}$	Units
Input power	2.754	2.706	2.918	3.006	W
Output voltage	4.743	4.743	4.743	4.743	V
Output current	0.4	0.4	0.4	0.4	A
Output power	1.9	1.9	1.9	1.9	W
Efficiency	69.0	70.2	65.1	63.2	%

In the table 3.3 we see the result of stand-by power for some difference input voltage.

Table 3.3. Stand-by power

Input voltage	$100V_{DC}$	$160V_{DC}$	$300V_{DC}$	$375V_{DC}$
Input current	0.512A	0.224A	0.222A	0.242A
Input power	51mW	36mW	67mW	91mW

4. BATTERY CHARGER SYSTEMS DESIGNING

4.1. Introduction of the Systems

While most modern electrical appliances receive their power directly from the utility grid, a growing number of everyday devices require electrical power from batteries in order to achieve greater mobility and convenience. Rechargeable batteries store electricity from the grid for later use and can be conveniently recharged when their energy has been drained. Appliances that use rechargeable batteries include everything from low-power cell phones to high-power industrial fork lifts. The sales volume of such products has increased dramatically in the past decade. Hundreds of millions of these products are sold annually to businesses and consumers, with close to a billion in use in the U.S. alone.

The system used to draw energy from the grid, store it in a battery, and release it to power a device is called a *battery charger system.* While designers of battery charger systems often maximize the energy efficiency of their devices to ensure long operation times between charging, they often ignore how much energy is consumed in the process of converting ac electricity from the utility grid into dc electricity stored in the battery.

Significant energy savings are possible by reducing the conversion losses associated with charging batteries in battery-powered products. We can achieve these savings using technology that is readily available today and employed in existing products.

4.2. Functions and Efficiency of the systems

4.2.1. Construction and Basic Functions of a Battery Charger

Batteries cannot be charged simply by connecting them to a standard wall outlet. A series of power conversion steps must be performed to shape the high-voltage ac electricity from the utility into low-voltage dc electricity that can be accepted by the battery, and the charging process must be controlled so that the battery receives the appropriate amount of current. Battery chargers accomplish all this through three functions:

(1) Reducing voltage from the utility level to the lower voltage at which batteries operate,

(2) Rectifying ac electricity into dc electricity,

(3) Controlling the low-voltage dc current into the battery.

The first two stages are functions typically incorporated into ac-dc power supplies. The addition of the third stage – controlling the rate of charge of the battery with charge control circuitry – is typically what distinguishes a battery charger from an ac-dc power supply. These power supply and charge control circuitry subsystems are illustrated in Figure 4.1.

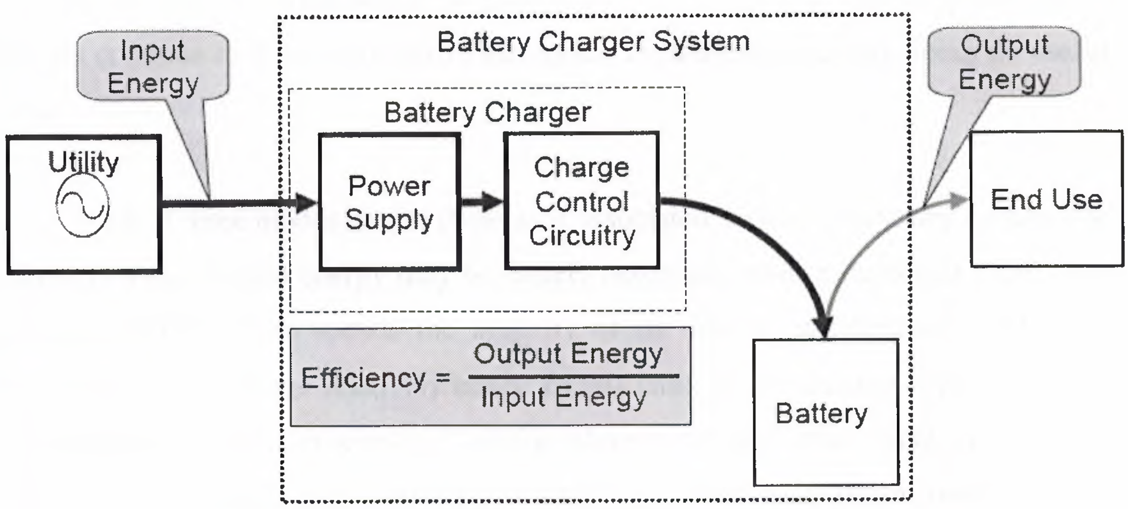


Figure 4.1. Block diagram of battery charger system

Some battery chargers, which we call *multi-piece chargers*, are simply conventional power supplies with additional control circuitry added to the output. Multi-piece chargers are cheap to design and build, being specified from pre-designed, off-the-shelf components, but tend to be relatively inefficient. They are commonly used in smaller, less expensive products. The power supply, often an *external power supply*, may be an ac-dc power supply with a regulated output voltage, or an ac-ac power supply with an ac output. The output from this kind of power supply is changed to regulated dc current through the charge control circuitry.

4.2.2. Battery chargers

Battery chargers operate in three modes:

1- Active charge mode, during which the battery is being charged from a discharged state. Most battery chargers draw the most power from the outlet during thismode.

2- Maintenance charge mode, during which the battery charge state is being maintained at a fully-charged state. A battery charger typically draws less power in this mode than in active charge mode.

3- No battery mode, during which no battery is connected to the charger at all. Many chargers continue to draw a current in this mode, even though they are doing no useful work.

Each of three modes has inefficiencies associated with it. Depending on how the product is used, wasted energy may be largely associated with a particular mode. For instance, a UPS system spends the majority of its time in maintenance mode, and experiences active charge relatively rarely. In this case, wasted energy depends largely on maintenance mode efficiency. Cellular phones, on the other hand, are usually drained and fully recharged every day, so that they spend a significant time in active charge mode. In many cases, the chargers for cellular phones are left plugged in even if the phone is not present, so that no-battery mode may also be important. The 24-hour charging and maintenance period used in testing is intended to capture inefficiencies in both active charge and maintenance modes; separate no-battery mode testing is required to measure inefficiencies when a battery is not attached.

4.3. Battery Charger Systems: Current Practice

Most battery chargers can be divided into four basic design types, or topologies:

- Linear chargers
- Switch mode chargers
- Ferroresonant chargers
- SCR (silicon controlled rectifier) chargers

Linear and switch mode chargers are analogous to linear and switch mode power supplies with the exception that the charger topologies also incorporate charge control circuitry on their outputs. Most multi- or single-piece chargers are either linear or switch mode chargers. These two categories are the ones most commonly found in consumer applications, particularly in the residential sector. Ferroresonant and SCR battery chargers form a large percentage of the chargers used in industrial applications.

The following sections describe the four types of chargers, where they are used, and their major advantages and disadvantages.

4.3.1. Linear Chargers

Linear chargers consist of a power supply, which converts ac power to lower voltage dc power, and a linear regulating element, which limits the current that flows into the battery. The power supply typically consists of a transformer that steps down ac power from 115 Vac to a lower ac voltage closer to that of the battery and a rectifier that smoothes out the existing sinusoidal ac signal into a constant-voltage dc signal. The linear regulating element may be a passive component such as a resistor or an active component such as a transistor that is controlled by a reference signal.

The principal difference between a linear power supply and a linear battery charger is that the battery charger incorporates a battery charge control element to regulate current output. Figure 4.2 shows a simplified schematic of a linear charger with a linear power supply and a resistor as the current regulating element.

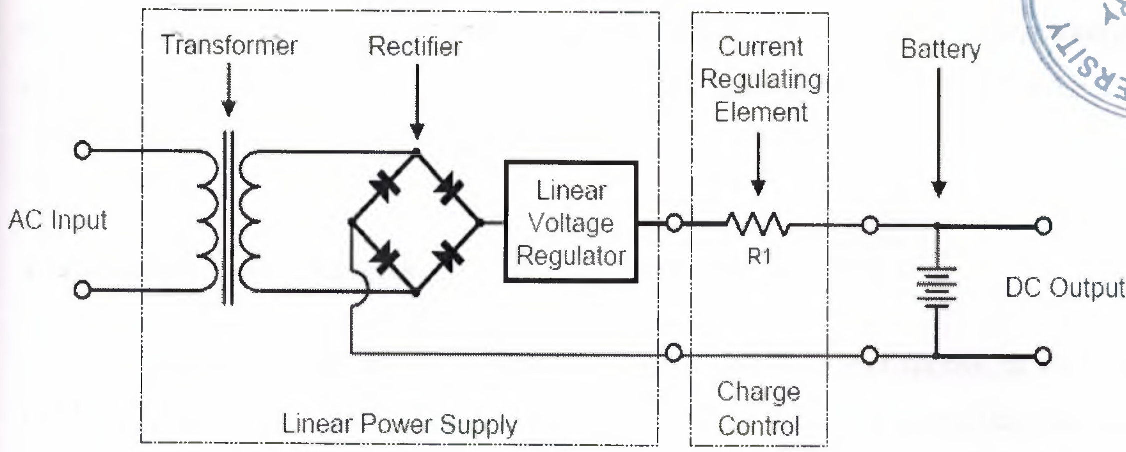


Figure 4.2. Multi-piece linear charger using an external power supply

Some linear battery chargers are composed of two pieces, with an external power supply and battery charge control circuitry in separate housings. The power supply may contain only the transformer (for ac-ac power supplies), or both the transformer and the rectifier (for ac-dc power supplies). Other components may be located in a separate base station or with the battery.

Note that the power supply might be either a linear or a switch mode power supply, but the presence of a linear current regulating element (the resistor) makes the charger a linear charger.

When a linear power supply is used, there is a substantial reduction in efficiency, since there are two linear dissipative elements in series: one in the power supply to regulate voltage and one in the charge control circuitry to regulate current. This approach is common for less expensive equipment, because linear external power supplies are inexpensive and readily available off-the-shelf.

How efficient are linear chargers? Linear chargers control output current by dissipating excess energy from the regulator as heat, allowing only the desired current to reach the battery. As a result, a linear charger will always be somewhat inefficient due to the losses in the current regulating element. In active charge mode, energy losses occur mainly in the current regulating element, because of the voltage drop across the current regulating element. The battery voltage rises as it is charged, reducing this voltage drop and the corresponding loss. In maintenance mode and no-battery mode, energy losses occur primarily in the power supply section. These losses are independent of the losses in the battery during charge and discharge. Overall, linear battery charger systems may have total cycle efficiencies (as defined in Figure 4.1) ranging from 2 to 35%, including losses in the battery.

4.3.2. Switch Mode Chargers

The switch mode charger is similar to a switch mode power supply, in which ac power from a wall outlet is converted to high-voltage dc power by a rectifier, and then converted to low-voltage dc power through a dc-dc converter. (Figure 4.3) illustrates the parts of a switch mode power supply for a cell phone. In this case the current control is performed by a dc-dc converter within the cell phone, making this product a two-stage multi-piece charger.

In principle, the only difference between switch mode chargers and switch mode power supplies is that switch mode chargers contain additional charge control circuitry to regulate current flow into the battery. The charge control regulates the way in which the power switch turns on and off, and may be accomplished through a circuit, a specialized integrated chip, or some type of software control.

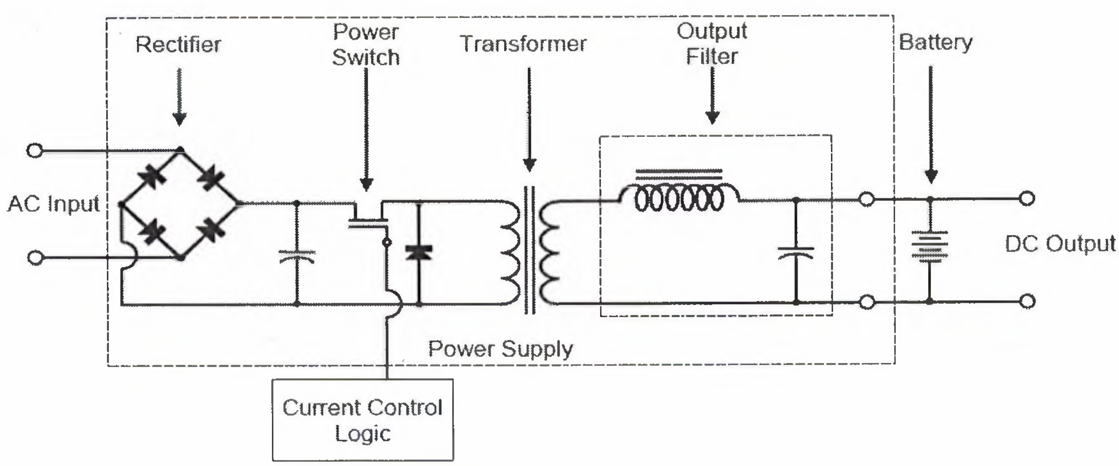


Figure 4.3. Two-stage switch mode charger.

Switch mode chargers are widely used in small portable applications, especially in high-tech equipment such as laptop computers, cellular phones, and personal digital assistants (PDAs). While the cost of switch mode chargers makes them relatively rare in larger applications, they are gaining ground in specialized applications such as fast chargers for lead-acid forklift batteries and other materials handling equipment. The topology of the charger may change somewhat in larger applications, but the principle is the same.

Switch mode chargers are generally more efficient than linear chargers in all modes, during active charge, most losses occur in the switch and the output rectifier diode, since a great deal of power is passing through these components. During maintenance mode and no-battery mode, on the other hand, most losses result from the power drawn by the control circuitry. Overall, full-cycle efficiencies for switch mode battery charger systems range from 40% to 60%, including losses within the battery. We will address improvements to switch-mode chargers in the later section, "Improving the Efficiency of Switch-mode Chargers."

4.3.3. Ferroresonant Chargers

Ferroresonant chargers (sometimes called ferro chargers), operate by way of a special component called a ferroresonant transformer. The ferroresonant transformer reduces the voltage from the wall outlet to a lower regulated voltage level while simultaneously controlling the charge current. A rectifier then converts the ac power to dc power suitable for the battery. (Figure 4.4) shows a block diagram of a ferroresonant charger.

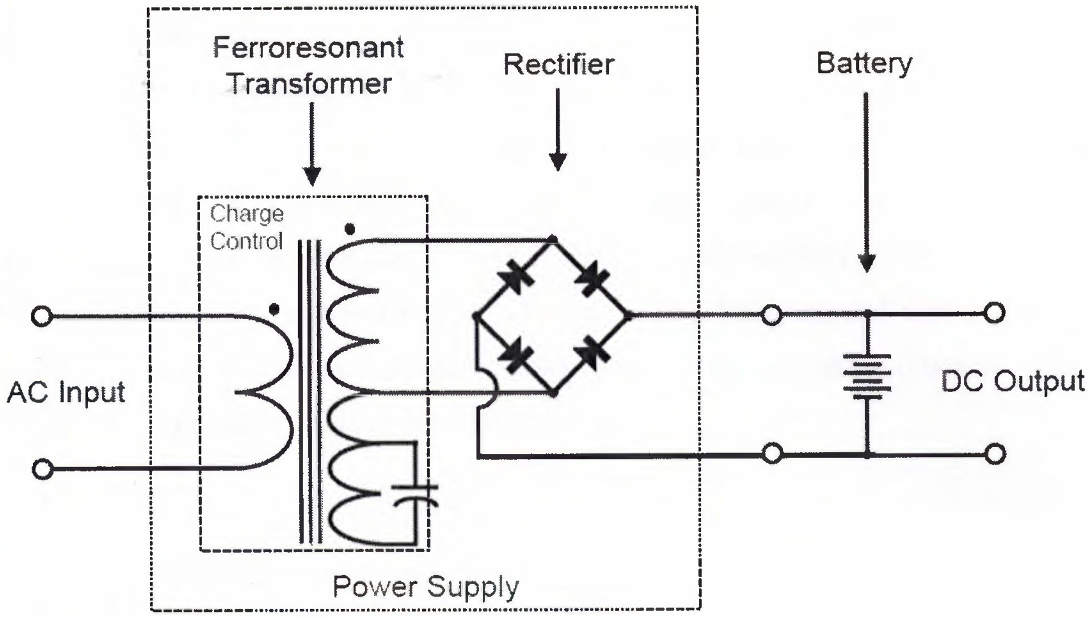


Figure 4.4. Simplified schematic of a ferroresonant charger.

Ferroresonant chargers have been used for decades to charge flooded lead-acid batteries, including those used in electric vehicles such as golf carts and material handling applications such as forklifts and electric pallet jacks. These chargers are highly cost-effective for larger applications (particularly those for which average ac power input exceeds 500 watts), especially if the charger targets one application with a single battery voltage. They are extremely durable because of the absence of sensitive electronic components. Unfortunately, they are also heavy and bulky and are not capable of highly sophisticated current control. These disadvantages make ferroresonant chargers unattractive for smaller batteries in portable applications and unsuitable for more sensitive batteries, including those based on NiMH and Li Ion technologies.

Ferroresonant chargers tend to be less efficient than switch mode chargers, with a full-cycle efficiency range of 25 to 50% (including the battery). In all modes of operation, the largest source of energy loss is the ferroresonant transformer, which draws and consumes a fixed amount of magnetizing current regardless of the charging current. The magnetizing current is dissipated as heat within the transformer. During active charge, the losses compose a small percentage of the overall power consumption, and ferroresonant chargers are nearly as efficient as switch mode chargers, during maintenance mode, however, the losses due to magnetizing current can constitute a large percentage of the input.

Some ferroresonant chargers use an active circuit to reduce this current, resulting in higher efficiencies during maintenance charge. Active circuits are commonly used in applications in which the charger spends a large portion of its operating time in maintenance mode, such as in standby batteries used in uninterruptible power supplies (UPS), telecom reserve batteries, and utility substation batteries. Figure 4.5 shows charge profiles for two ferroresonant chargers, similar except for the presence of an active cutoff circuit.

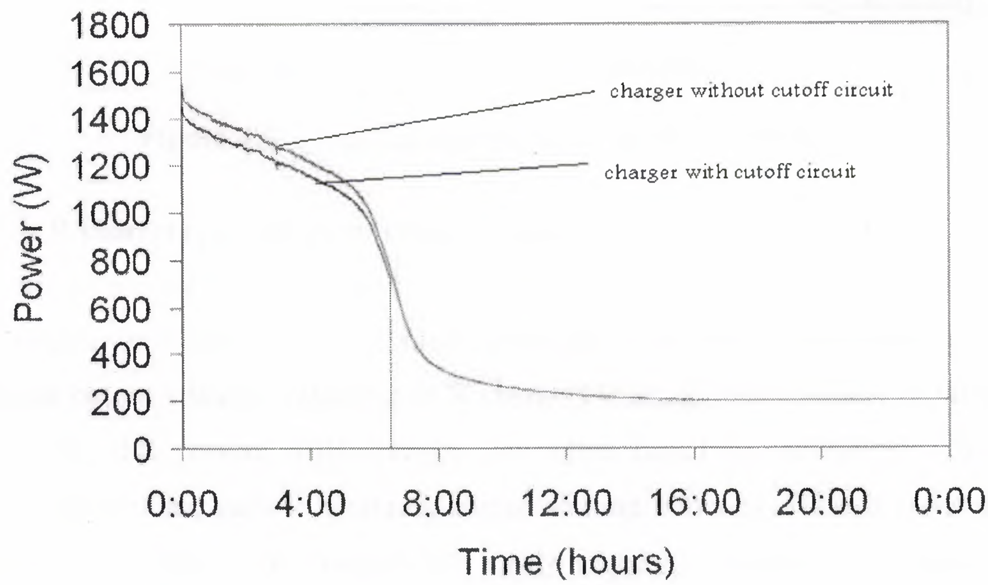


Figure 4.5. Charge Profiles for ferroresonant chargers

If connected to the grid, the ferroresonant transformer will draw magnetizing current even if no battery is connected to the output of the charger. For this reason, most ferroresonant designs already incorporate an automatic switch to disconnect the ferroresonant transformer from the grid if there is no battery attached to the output.

4.3.4. SCR Chargers

SCR chargers use a special component known as a silicon controlled rectifier (SCR) to control the current to the battery. The SCR is a controllable switch that can be turned on and off many times a second. After a transformer reduces utility voltage to a value near that of the battery, the diodes rectify the current while the SCR enables the flow of charge current according to a control signal. A block diagram of an SCR charger is shown in figure 4.6.

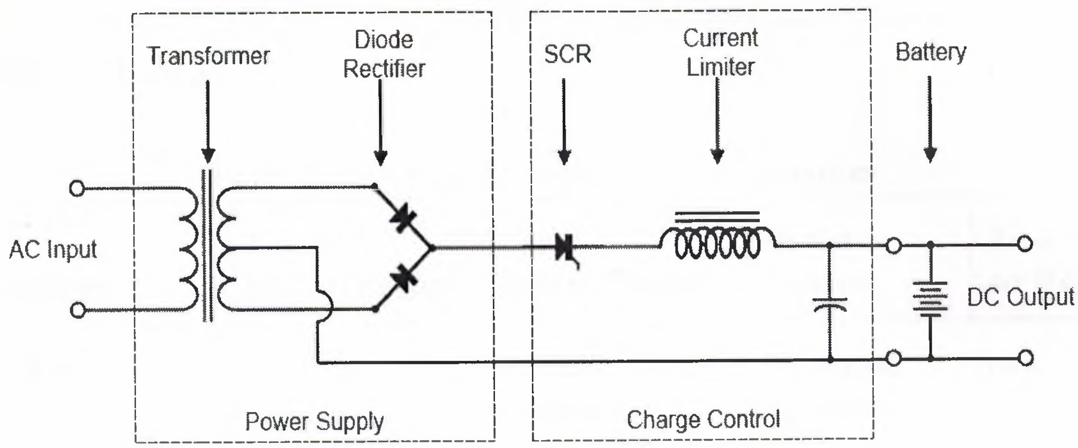


Figure 4.6. Simplified schematic of an SCR charger.

SCR chargers provide more charge current control than ferroresonant chargers, but are not as precise as switch mode chargers. Also, these chargers are too large for use in portable applications. Their greatest advantage is the ability to produce a number of different output voltages, allowing SCR chargers to work with a variety of different batteries. For this reason, SCR chargers are often found in multipurpose battery charging applications, such as charging engine-starting batteries. Though common in industrial applications, SCR chargers are rarely found in residential or commercial applications except where large banks of lead-acid batteries are used, such as in mid-range UPS systems.

From an efficiency standpoint, SCR chargers fall between ferroresonant chargers and switch mode chargers with a full-cycle efficiency range of 30% to 55% percent (including the battery). During active mode, the largest sources of inefficiency in SCR chargers are the voltage drops across the SCR and the rectifying diodes. In maintenance mode and no-battery mode, the magnetizing current drawn by the transformer is the largest power draw.

An SCR charger configured for use with a range of battery voltages is often less efficient than an SCR charger specially designed for a specific battery voltage. In fact, an SCR charger designed for use with a number of different batteries will charge a battery less efficiently than a ferroresonant charger designed specifically for that battery.

-The various charger topologies and their typical characteristics are summarized in the (table 4.1):

Table 4.1. Summary of Battery Charger Topologies

Topology	*Typical Efficiency Range*	*Example Products*	*Market Segment*	*Relative Cost per Watt*
Linear	2 % - 35%	Cordless phones, power tools	Residential, Commercial	Low
Switch Mode	40% - 60%	Laptop computers, cell phones	Residential, Commercial	High
Ferroresonant	25% - 50%	Golf carts, forklifts	Commercial, Industrial	Low
SCR	30% – 55%	Recreational vehicle battery chargers, forklifts	Commercial, Industrial	Medium

4.4. Battery Charger System Efficiency

As shown in Figure 4.1, the "battery charger system" comprises both the battery charger (providing energy conversion) and the battery (providing energy storage). The boundary of the system occurs where energy enters from the utility grid and where energy is released to an end use appliance such as a cordless phone. The efficiency of the system is defined as the total energy released by the battery to the powered appliance divided by the total energy required to charge and maintain the battery over 24 hours.

4.4.1. Improving Efficiency in Linear Battery Chargers

As shown above, in figure 4.7 and figure 4.8 two-piece linear chargers that are composed of external power supplies with regulating elements tend to be among the most inefficient designs, since losses occur in both the power supply and the regulating element. A simple way to save energy is to ensure that both parts of this design are as efficient as they can be. Replacing linear power supplies with switch mode power supplies can improve efficiency substantially.

Switch mode power supplies are now readily available from a variety of vendors, and their prices have fallen significantly, making them a competitive alternative to linear power supplies. Despite the use of a switch mode power supply, the charger is still considered a linear charger because of the presence of a linear charge current regulating element.

The gains that can be achieved through these approaches are illustrated in figure 4.7 and figure 4.8.

Figure 4.7 shows a linear power supply with a resistor used as a linear regulator. We measured the energy passing through each point in the system (in mWh) over a 24-hour period to understand where losses were occurring. We then discharged the battery under standard conditions to measure the energy that was extracted (in this case 10 mWh) The resulting full-cycle charging efficiency (with the battery) is only about 10%, meaning that 90% of the energy supplied from the grid is dissipated as heat without performing useful work.

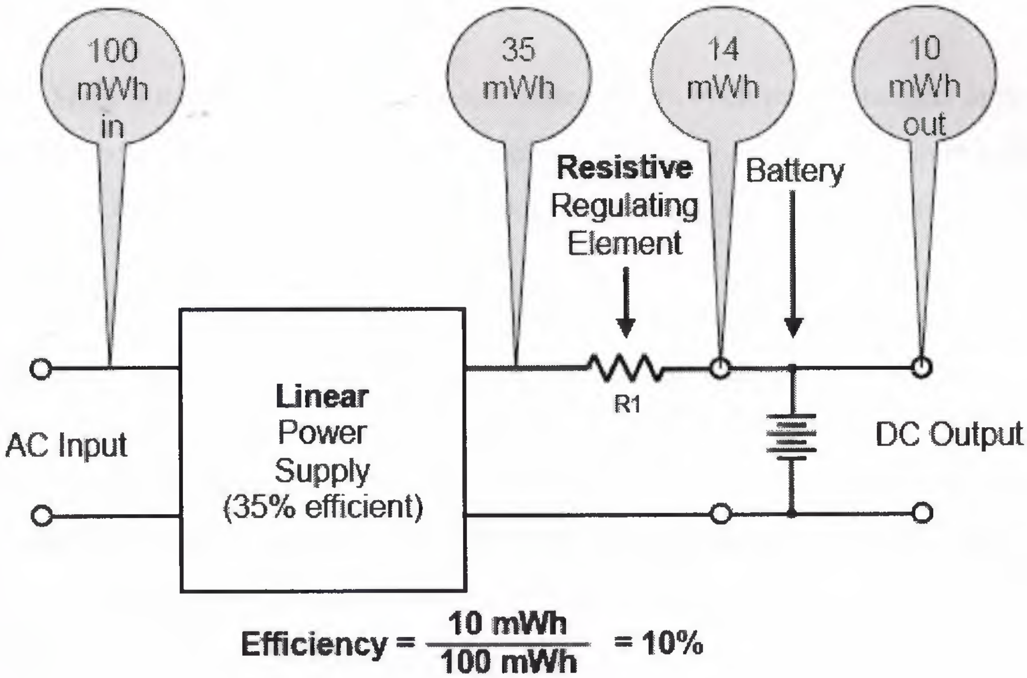


Figure 4.7. Two-piece charger composed of a linear power

Figure 4.8. Shows a more efficient approach. Here, a switch mode power supply replaces the linear power supply, causing the overall battery charger system efficiency to increase more than two-fold to 24%.

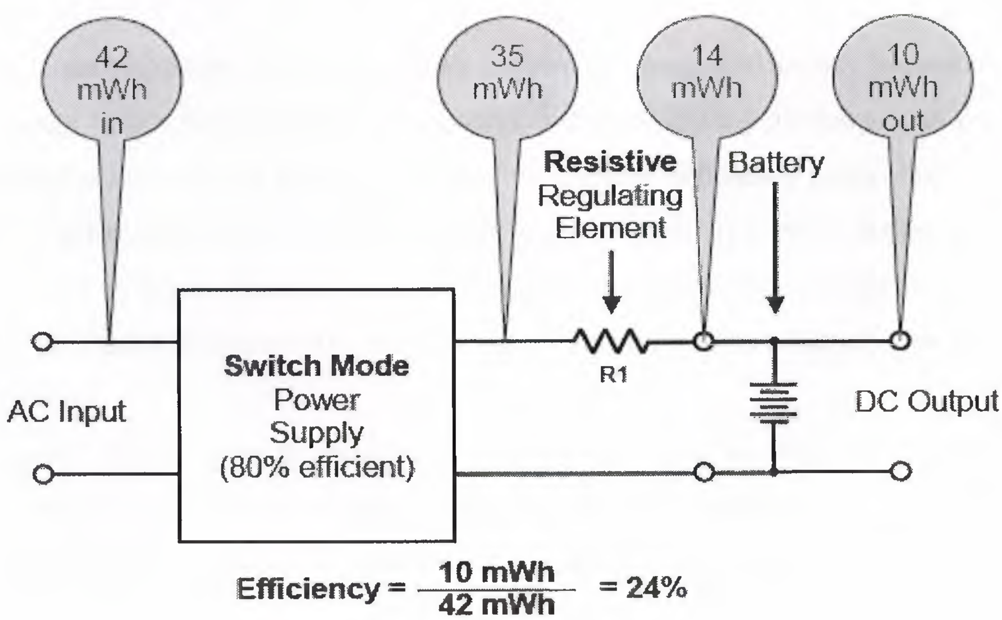


Figure 4.8. More efficient two-piece charger with the linear power supply

4.4.2. More Efficient Switches

Since a large part of the losses associated with switch mode chargers appear in the semiconductor switch, any effort to improve efficiency must look at more efficient switches. Constant advances in switching technology have made such switches possible.

However, these switches are not always used in manufactured products because of the costs to redesign the electronics and retool existing manufacturing. For manufacturers to act on these innovative technologies there must be a clear market pull towards products using these switches, whether for efficiency purposes or superior performance in some other way. The efficiency improvement in using new switches is difficult to quantify as it depends on both the type of switch as well as the design of the charger.

Future technologies may allow great improvement in efficiency. An estimated efficiency improvement of 10 percentage points may be achievable with existing technology.

4.4.3. More Efficient Batteries

Batteries are important to consider when improving charger efficiency because they suffer energy losses twice: once during charge and once during discharge. As a result, employing a high-quality battery can yield measurable efficiency gains. Some gains in battery efficiency may be made through improvements in battery design or manufacturing. For example, batteries may be designed to have lower voltage drops through improved inter-cell connections. Such changes generally have relatively minor effects on efficiency.

The most effective way to improve battery efficiency is to switch to more efficient battery chemistries. For example, lithium ion batteries have properties that make them more energy efficient in practice than nickel-cadmium and nickel-metal hydride batteries.

The lithium ion cell has an inherently higher coulombic efficiency than NiCd and NiMH cells. Lithium ion batteries also operate at a higher voltage per cell than nickel-cadmium and nickel-metal hydride batteries. This means that one-third the number of cells is required in a lithium ion battery operating at the same voltage, reducing losses from contacts and interconnects between cells. Finally, lithium ion batteries also have a lower self-discharge rate than nickel-cadmium and nickel-metal hydride batteries. This means lithium ion batteries require less in the way of energy during maintenance charge.

The main disadvantage of lithium ion batteries in these markets is their relatively high cost. This cost has been falling rapidly, however, and many analysts expect the cost of lithium ion to fall to the same level or even below the costs for nickel-cadmium and nickel-metal hydride equivalents by 2010.

Until recently, lithium ion batteries were best-suited for relatively low-power applications such as electronics; they could not deliver the high currents necessary for power tools and similar motor-driven equipment. Since 2004, new high-power lithium ion batteries have been released in several new markets, including the power tool and hybrid electric vehicle markets.

Despite these advancements, lithium ion faces an up-hill struggle in markets such as UPS, electric vehicles, and motive power, in which lead-acid batteries are dominant. Lead-acid batteries also have relatively low self-discharge and relatively high-voltage cells, such that the advantages of lithium ion batteries are less attractive in these markets.

The extremely low cost of lead-acid batteries, along with their relative ruggedness and simplicity, makes them very difficult to replace in these applications.

4.4.4. Best-in-Class Efficiency: A Design Example

In order to demonstrate how these techniques come together in a design, (Table 4.2) summarizes the degree to which efficiency can be improved for today's various charger topologies.

Table 4.2. Potential for Efficiency Improvements in Charger Topologies

Topology	*Typical Efficiency Range (%)*	*Estimated Improved Efficiency Range*
Linear	2% - 30%	20% - 40%
Switch Mode	40% - 60%	50% - 70%
Ferroresonant	25% - 50%	45% - 55%
SCR	30% - 55%	45% - 60%

At a time when many common battery charger systems have measured efficiencies of less than 15%, comparable systems with overall efficiencies of 65% or greater are technically feasible.

The technical path to higher efficiency is clear. It is now necessary to develop the policies that will encourage and accelerate the market adoption of the technologies and practices that can reduce battery charger energy consumption cost-effectively, while preserving the essential convenience of these products that has made them popular.

CONCLUSION

The most important thing I have to write about it is that charger was originally designed to work with small batteries like those used in mobile phone. In principle it can be used to charge car batteries also but will take a lot longer. The charger below charges a battery with a constant current to 5 volt and 0.4 ampere. When this level is reached, the current charge drops automatically to a safer level (4.75) volt and keeps charging at this slower rate until the LED lights up indicating a fully charged battery.

The efficiency of this charger is rating for the input voltage, for example this charger can working at 110 ac input voltage and 220 ac input voltage. So that the efficiency is ranged "between" (60 – 70) %, look to the table 3.2 to know more about these efficiency, and table 2.1 shown the result that related with no-load and full-load of voltage regulation.

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