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Faculty of Engineering

Department of Electrical and Electronic Engineering

LIGHT ACTIVATED ALARM CIRCUIT

Graduation Project
EE – 400

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ABSTRACT

The purpose of any alarm system is to either protect life or property or to detect an intrusion. Many buildings and complexes being constructed today are equipped with some type of intrusion detection and fire alarm systems. Also in the homes, some alarm systems are used, for example burglar alams, light alarms etc. Numerous detection and fire alarm systems are in existence today.

An alarm gives an audible or visual warning of a problem or condition. These noisy reminders tell us when the things in our lives are not right. That is why we need information before choosing an alarm. Using this information we can make decisions about the alarm needed.

This project presents the design, construction and testing of a light-activated alarm. The principle of operation of this light-activated alarm is simple. When the intensity of light exceeds certain intensity, that is, when a light beam is shone into the sensor, the alarm is triggered and buzzer alarm begins to operate and sounds an alarm. Alarm sounds and the LED flashes. These actions thus alert the owner of the residence and/or security personnel of the presence of an intruder.

In all light-operated alarms, LDR is used as a light sensing element. The LDR is light-dependent resistor, and this light dependent resistor is a cadmium-sulphide photocell, and acts as a high resistance under dark conditions and as a low resistance when brightly illuminated.

In each circuit, l.d.r. is mounted in a normally dark area and the designs are such that the alarm sounds when a light shone into the protected area. The ldr and a potentiometer (variable resistor) form a potential divider that supplies the darligton pair. Under dark conditions the l.d.r. presents a high resistance, so zero drive applied to darlington pair transistors. When l.d.r. is illuminated, its resistance falls to a low value, and darlington pair is then applied to buzzer and activates the alarm. When the LDR resistance falls to less than 200kΩ in this circuit, alarm is activated.

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INTRODUCTION

The desing of an electronic circuit requires a priori information about the operation and connection procedures of electronic circuit elements. Using the breadboard, connection procedures of the breadboard and the elements, and why they are used in that circuit must be known before building a circuit. When these informations are not known completely, several mistakes might be done, elements may be burn and the circuit built may not operate.

An alarm circuit or an alarm system is one of the most important aspect of the security system. Alarms as the name implies are used to alert in the event of any situation that is a threat. The ability to sense the things and give an alarm sound for that which the alarm is sensitive, provide security in our homes or any building.

The purpose of any alarm system is to either protect life or property or to detect an intrusion. Many buildings and complexes being constructed today are equipped with some type of intrusion detection and alarm systems. Also in the homes, some alarm systems are used, for example burglar alams, fire alarms, light alarms etc. Numerous detection and fire alarm systems are in existence today.

This project is aimed to provide an light-activated alarm using in the homes and buildings which has to be in normally dark conditions. When a light is entering to that place, the alarm will give a sound. The construction is based on the sensitivity of the alarm.

The project consists of eleven chapters and conclusion. First 10 chapters introduces the circuit elements used in the light-activated alarm circuit, and gives information and test conditions about circuit components.

Last chapter, the circuit diagram and test results were introduced.

CHAPTER 1. USING BREADBOARDS

1.1 Overview

Breadboard is a thin plastic board full of holes used to hold electronic components (transistors, chips, etc.) that are wired together. It is used to develop electronic prototypes or one-of-a-kind systems circuit.

A breadboard is a reusable solderless device used to build a (generally temporary) prototype of an electronic circuit and for experimenting with circuit designs. A typical breadboard will have strips of interconnected electrical terminals, known as bus strips, down one or both sides either as part of the main unit or as separate blocks clipped on to carry the power rails.

A modern solderless breadboard consists of a perforated block of plastic with numerous tin plated phosphor bronze spring clips under the perforations. Interconnecting wires and the leads of discrete components (such as capacitors, resistors, inductors, etc.) can be inserted into the remaining free holes to complete the circuit topology. In this manner, a variety of electronic systems may be prototyped, from small circuits to complete central processing units (CPUs). However, due to large stray capacitance (from 2-25pF per contact point), solderless breadboards are limited to operating at relatively low frequencies, usually less than 10 MHz, depending on the nature of the circuit.

1.2 How it Works

The heart of the solder-less breadboard is a small metal clip. The clip is made of nickel silver material which is reasonably conductive, reasonably springy, and reasonably corrosion resistant. Because each of the pairs of fingers is independent we can insert the end of a wire between any pair without reducing the tension in any of the other fingers. Hence each pair can hold a wire with maximum tension.

To make a breadboard, an array of these clips is embedded in a plastic block which holds them in place and insulates them from each other, like this:

Figure 1.1 a breadboard array

Depending on the size and arrangement of the clips, we get either a socket strip or a bus strip. The socket strip is used for connecting components together. It has two rows of short (5 contact) clips arranged one above another, like this:

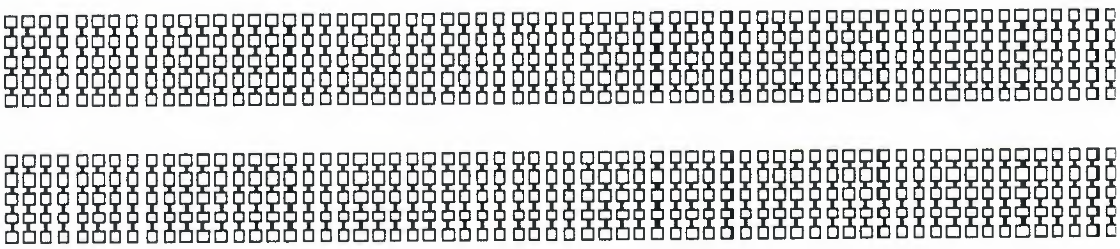


Figure 1.2 breadboard socket strip connections

The bus strip is used to distribute power and ground voltages through the circuit. It has four long clips arranged lengthwise, like this:

Figure 1.3 breadboard bus strip connections

Note that in their infinite wisdom, the manufacturer elected not to join the adjacent contact strips into a single full-length contact strip. If this is what you want, you will have to bridge the central gap yourself.

When we combine two socket strips, three bus strips, and three binding posts on a plastic base, we get the breadboard. The breadboard offers an easy way to build electrical circuits without soldering. The 2"x3" breadboard contains an array of holes where wires and components are to be inserted. The holes in the center portion of the breadboard are identifiable by row (vertical in the photos) and column (horizontal).

There are two sets of 30 rows numbered by 5's, and each set of rows has 5 columns labeled a-e and f-j. The 5 holes on each row are electrically connected to each other (but not across the center channel), so any components inserted into the same row would be connected just as if they had been soldered. However, the components can be removed and replaced with other components at any time, without the hassle of unsoldering and resoldering parts.

On either side of the breadboard are two columns marked by blue and red lines. The 25 holes in each column are electrically connected, but the columns aren't electrically connected to each other. The outermost column marked with the red line at the top will be used for all +9 V connections, while the outermost column marked with the blue line at the bottom will used for all ground (negative) connections.

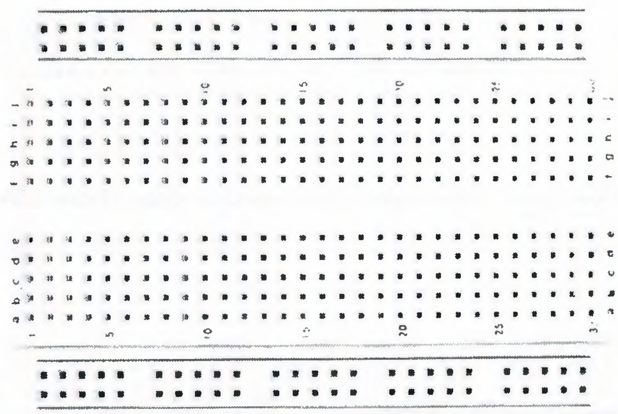


Figure 1.4 a breadboard

1.3 Naming History

The breadboard derives its name from an early form of point-to-point construction. In the early days of radio, amateurs would nail copper wire or terminal strips to a wooden board (often literally a board for cutting bread), and solder electronic components to them. Sometimes a paper schematic diagram was first glued to the board as a guide to placing terminals, components and wires.

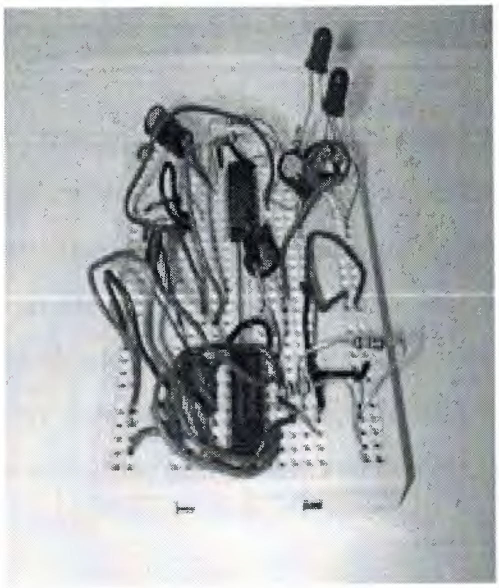


Figure 1.4 A breadboard with a completed circuit

1.4 Using the Breadboard

The bread board has many strips of metal (copper usually) which run underneath the board. The metal strips are laid out as shown below.

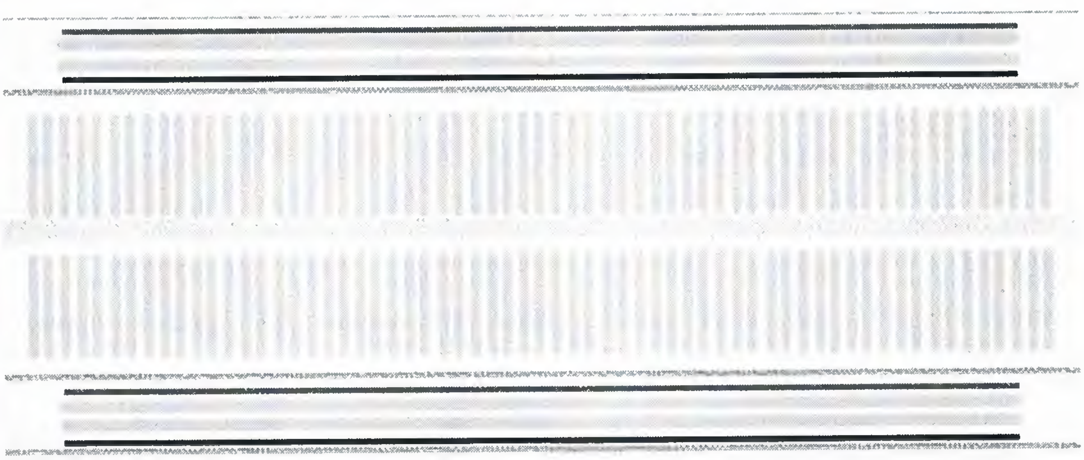


Figure 1.6 connections

These strips connect the holes on the top of the board. This makes it easy to connect components together to build circuits. To use the bread board, the legs of components are placed in the holes (the sockets). The holes are made so that they will hold the component in place. Each hole is connected to one of the metal strips running underneath the board.

Each wire forms a node. A node is a point in a circuit where two components are connected. Connections between different components are formed by putting their legs in a common node. On the bread board, a node is the row of holes that are connected by the strip of metal underneath.

The long top and bottom row of holes are usually used for power supply connections. The rest of the circuit is built by placing components and connecting them together with jumper wires. Then when a path is formed by wires and components from the positive supply node to the negative supply node, we can turn on the power and current flows through the path and the circuit comes alive.

For chips with many legs (ICs), place them in the middle of the board so that half of the legs are on one side of the middle line and half are on the other side.

1.4 Wiring Techniques

The basic idea of wiring on a solder-less breadboard is simple: just stick the ends of the component leads or wires into the holes. But like any seemingly simple process, there are a few subtleties that can make the difference between success and failure.First a note of caution, the material that the clips inside the breadboard are made of is a compromise between good conductivity, corrosion resistance, and springiness.The elastic limit is considerably less than of a good steel spring and if spread too far, can be permanently distorted. To avoid deforming the connector clips, never insert more than one wire in a hole.With the health of our breadboard assured, there are a few more things we can do to make sure that our connections are good ones.

Strip about 5 mm of insulation from each end of a piece of wire. Less than that raises the risk that insulation will be forced between the fingers of the clip. More leaves bare wire exposed that can short to adjacent components. One exception: strip about 15 mm from the end of a wire that will be clamped in the binding posts.

When inserting a small wire or component, use your needle nosed pliers rather than your fingers to hold it. If the end of a wire becomes kinked, cut it off or use your pliers to straighten it.

The solderless breadboard is a tool for rapid circuit development and assembly, in which design changes can easily be made. The breadboard is typical of most versions and skill in using it is essential for the practicing engineer.

The holes in the board reside over conducting metal spring clips into which component leads can be inserted. The conducting spring clips run lengthwise in the thin fields and vertically, in groups of five, in the fat fields.

There are NO connections between:

- adjacent thin field rows
- adjacent fat field columns
- thin fields and fat fields
- across the gutter

The thin fields are useful for connections that appear in many places in your circuit, such as power supply connections and ground. The holes on the breadboard are spaced at 0.10 inch, which is the same spacing as the pins of a dual-inline integrated-circuit package (DIP), variable resistor (potentiometers), and other standard components. The leads of discrete components such as resistors, capacitors, and transistors can be cut to size and bent at right angles, so that the components are easily inserted.

Good wiring practice requires that a breadboard circuit be compact, neat, and orderly, with all leads cut as short as possible. Component bodies should physically rest on or just above the board surface, and wires should be easy to trace and touch with a probe. The "bird's nest" approach, in which wires dangle and go haphazardly in every direction, should be avoided at all costs. Such a disorderly tangle of wires can cause component leads to short together causing wiring errors. Circuit testing also becomes extremely difficult when a circuit is messy as one become easily lost in a chaotic circuit. A sloppy circuit affects the attitude of the engineer, who is likely to take the design or analysis task less seriously if work on the circuit is difficult. The wise engineer produces circuits that are neat, compact, tidy, and easily accessible.

CHAPTER 2. BATTERY

2.1 Overview

An electrical device that converts chemical energy into electrical energy, consisting of a group of electric cells that are connected to act as a source of direct current. The term is also now commonly used for a single cell, such as the alkaline dry cell used in flashlights and portable tape players, but strictly speaking batteries are made up of connected cells encased in a container and fitted with terminals to provide a source of direct electric current at a given voltage. A cell consists of two dissimilar substances, a positive electrode and a negative electrode, that conduct electricity, and a third substance, an electrolyte, that acts chemically on the electrodes. The two electrodes are connected by an external circuit (e.g., a piece of copper wire); the electrolyte functions as an ionic conductor for the transfer of the electrons between the electrodes. The voltage, or electromotive force, depends on the chemical properties of the substances used, but is not affected by the size of the electrodes or the amount of electrolyte.

Batteries are classed as either dry cell or wet cell. In a dry cell the electrolyte is absorbed in a porous medium, or is otherwise restrained from flowing. In a wet cell the electrolyte is in liquid form and free to flow and move. Batteries also can be generally divided into two main types : rechargeable and nonrechargeable, or disposable. Disposable batteries, also called primary cells, can be used until the chemical changes that induce the electrical current supply are complete, at which point the battery is discarded. Disposible batteries are most commonly used in smaller, portable devices that are only used intermittently or at a large distance from an alternative power source or have a low current drain. Rechargeable batteries, also called secondary cells, can be reused after being drained. This is done by applying an external electrical current, which causes the chemical changes that occur in use to be reversed. The external devices that supply the appropriate current are called chargers or rechargers.

A battery called the storage battery is generally of the wet-cell type; i.e., it uses a liquid electrolyte and can be recharged many times. The storage battery consists of several cells connected in series. Each cell contains a number of alternately positive and negative plates separated by the liquid electrolyte. The positive plates of the cell are connected to form the positive electrode; similarly, the negative plates form the negative electrode. In the process of charging, the cell is made to operate in reverse of its discharging operation; i.e., current is forced through the cell in the opposite direction, causing the reverse of the chemical reaction that ordinarily takes place during discharge, so that electrical energy is converted into stored chemical energy. The storage battery's greatest use has been in the automobile where it was used to start the internal-combustion engine. Improvements in battery technology have resulted in vehicles in which the battery system supplies power to electric drive motors instead.

Batteries are made of a wide variety of electrodes and electrolytes to serve a wide variety of uses. Batteries consisting of carbon-zinc dry cells connected in various ways (as well as batteries consisting of other types of dry cells) are used to power such devices as flashlights, lanterns, and pocket-sized radios and CD players. Alkaline dry cells are an efficient battery type that is both economical and reliable. In alkaline batteries, the hydrous alkaline solution is used as an electrolyte; the dry cell lasts much longer as the zinc anode corrodes less rapidly under basic conditions than under acidic conditions. A more expensive type of lead-acid battery called a gel battery (or gel cell) contains a semisolid electrolyte to prevent spillage. More portable rechargeable batteries include several dry-cell types, which are sealed units and are therefore useful in appliances like mobile phones and laptops. Cells of this type (in order of increasing power density and cost) include nickel-cadmium (nicad or NiCd), nickel metal hydride (NiMH), and lithium-ion (Li-Ion) cells.

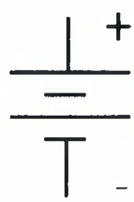


Figure 2.1 The schematic symbol of an electric battery

2.2 Classification of batteries

Batteries are usually divided into two broad classes:

Primary batteries irreversibly transform chemical energy to electrical energy. Once the capacity of the initial supply of reactants is exhausted, energy cannot be readily restored to the battery by electrical means.

Secondary batteries can have the chemical reactions reversed by supplying electrical energy to the cell, restoring their original composition.

2.3 How batteries work

Battery consists of one or more voltaic cells, each of which is composed of two half cells connected in series by the conductive electrolyte. Each cell has a positive terminal, and a negative terminal. These do not touch each other but are immersed in a solid or liquid electrolyte.

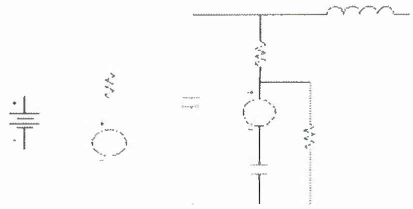


Figure 2.3 Circuit symbol for a battery; simplified electrical model; and more complex but still incomplete model (the series capacitor has an extremely large value and, as it charges, simulates the discharge of the battery).

The electrolyte is a conductor which connects the half-cells together. It also contains ions which can react with chemicals of the electrodes. Chemical energy is converted into electrical energy by chemical reactions that transfer charge between the electrode and the electrolyte at their interface. Such reactions are called faradaic, and are responsible for current flow through the cell. Ordinary, non-charge-transferring (non-faradaic) reactions also occur at the electrode-electrolyte interfaces. Non-faradaic reactions are one reason that voltaic cells (particularly the lead-acid cell of ordinary car batteries) "run down" when sitting unused.

Voltaic cells, and batteries of voltaic cells, are rated in volts, the SI unit of electromotive force. The voltage across the terminals of a battery is known as its terminal voltage. The terminal voltage of a battery that is neither charging nor discharging (the open-circuit voltage) equals its emf. The terminal voltage of a battery that is discharging is less than the emf, and that of a battery that is charging is greater than the emf.

Alkaline and carbon-zinc cells are rated at about 1.5 volts, because of the nature of the chemical reactions inside. Because of the high electrochemical potentials of lithium compounds, Li cells can provide as much as 3 or more volts. However, lithium compounds can also be hazardous.

The simplest characterization of a battery would give its emf (voltage), its internal resistance, and its capacity. In principle, the energy stored by a battery equals the product of its emf and its capacity.

2.4 Battery capacity and discharging

Since the voltage of a battery is relatively constant, the capacity of a battery to store energy is often expressed in terms of the total amount of charge able to pass through the device. This is expressed in ampere hours, where one A·h equals 3600 coulombs. If a battery can pump charges for one hour at a rate of one coulomb/sec or one ampere (1 A), it has a capacity of 1 A·h. If it can provide 1 A for 100 hours, its capacity is 100 A·h. The more electrolyte and electrode material in the cell, the greater the capacity of the cell. Thus a tiny cell has much less capacity than a much larger cell, even if both rely on the same chemical reactions (e.g. alkaline cells), which produce the same terminal voltage.

Because of the chemical reactions within the cells, the capacity of a battery depends on the discharge conditions such as the magnitude of the current, the duration of the current, the allowable terminal voltage of the battery, temperature, and other factors.

Battery manufacturers use a standard method to determine how to rate their batteries. The battery is discharged at a constant rate of current over a fixed period of time, such as 10 hours or 20 hours, down to a set terminal voltage per cell. So a 100 ampere-hour battery is rated to provide 5 A for 20 hours at room temperature.

The efficiency of a battery is different at different discharge rates. When discharging at low rate, the battery's energy is delivered more efficiently than at higher discharge rates. This is known as Peukert's Law. The relationship between current, discharge time, and capacity is expressed by Peukert's law.

The available capacity of a battery depends on the rate at which it is discharged. If a battery is discharged at a relatively high rate, the available capacity will be lower than expected. Therefore, a battery rated at 100 A·h (360000 coulombs) will deliver 20 A (20 coulombs per second) over a 5 hour period, but if it is instead discharged at 50 A (50 coulombs per second), it will run out of charge before the theoretically expected 2 hours. For this reason, a battery capacity rating is always related to an expected discharge time, which is typically 5 or 20 hours.

In general, the higher the ampere-hour rating, the longer the battery will last for a certain device. Installing batteries with different A·h ratings will not affect the operation of a device rated for a specific voltage.

Table 2.1 typical alkaline battery capacities

Typical alkaline battery capacities (mAh)	
D	20,500
C	8,350
AA	2,850
AAA	1,250
N	1,000
AAAA	625
AAAAAAAAA	39
9v	625

2.5 Battery life

The amount of time a battery will last can be calculated like this:

$$t = \frac{C}{I} \qquad (1)$$

t is the discharge time in hours, C is the battery's current capacity rating, and I is the current draw from the battery.This capacity varies depending on the end-point voltage allowed from the battery; more ampere-hours of capacity are available if a lower end voltage is permitted. If the batteries are connected in parallel, then multiply the capacity rating by the number of cells.

For example, a CD player draws a constant current of 200 mA from a 2300 mA·h rechargeable battery consisting of two AA cells connected in series for a total rated voltage of 3 V. So, 2.3 A·h/0.2 A = approximately 11.5 hours of battery life.

The actual time will be much less than calculated because this assumes that the battery voltage remains constant, which it does not, so it's only a rough approximate. Furthermore, battery capacity is dependent on discharge time and thus should be given with a stated discharge time.

2.6 Conversion to energy

The A·h rating of a battery is related to, but not the same as, the amount of energy it stores when fully charged. If two batteries have the same nominal voltage, then the one with the higher A·h rating stores more energy. It would also typically take longer to recharge.

The energy E available from a battery is approximately given by:

$$E = QV \qquad (2)$$

where, Q is the charge, and V is the nominal voltage.

This yields:

number of joules = number of ampere-hours × number of volts × 3600 seconds per hour, or number of watt-hours = number of ampere-hours × number of volts.

This is only an approximation though, due to the fact that the voltage during discharge is not actually constant.

2.7 Battery lifetime

Even if never taken out of the original package, disposable (or "primary") batteries can lose two to twenty-five percent of their original charge every year. This rate depends significantly on temperature, since typically chemical reactions proceed more rapidly as the temperature is raised. This is known as the "self discharge" rate and is due to non-current-producing chemical reactions, which occur within the cell even if no load is applied to it. Batteries should be stored at cool or low temperatures to reduce the rate of the side reactions. For instance, some people make a practice of storing unused batteries in their refrigerators to extend battery lifetime, although care should be taken to ensure the batteries do not freeze. Extremely high or low temperatures will reduce battery performance.

Rechargeable batteries self-discharge more rapidly than disposable alkaline batteries; up to three percent a day (depending on temperature). Due to their poor shelf life, they should not be stored and then relied upon to power flashlights or radios in an emergency. For this reason, it is a good idea to keep alkaline batteries on hand. Ni-Cd Batteries are almost always "dead" when purchased, and must be charged before first use.

Most NiMH and NiCd batteries can be charged several hundred times. Also, they both can be completely discharged and then recharged without their capacity being damaged or shortened.

Special "reserve" batteries intended for long storage in emergency equipment or munitions keep the electrolyte of the battery separate from the plates until the battery is activated, allowing the cells to be filled with the electrolyte. Shelf times for such batteries can be years or decades. However, their construction is more expensive than more common forms.

2.8 Battery explosion

A battery explosion is caused by the misuse or malfunction of a battery, such as attempting to recharge a primary battery, or short circuiting a battery. With car batteries, explosions are most likely to occur when a short circuit generates very large currents. In addition, car batteries liberate hydrogen when they are overcharged (because of electrolysis of the water in the electrolyte). Normally the amount of overcharging is very small, as is the amount of explosive gas developed, and the gas dissipates quickly.

When a battery is recharged at an excessive rate, an explosive gas mixture of hydrogen and oxygen may be produced faster than it can escape from within the walls of the battery, leading to pressure build-up and the possibility of the battery case bursting. In extreme cases, the battery acid may spray violently from the casing of the battery and cause injury. Additionally, disposing of a battery in fire may cause an explosion as steam builds up within the sealed case of the battery.

Overcharging, that is, attempting to charge a battery beyond its electrical capacity, can also lead to a battery explosion, leakage, or irreversible damage to battery. It may also cause damage to the charger or device in which the overcharged battery is later used.

2.9 Rechargeable and disposable batteries

From a user's viewpoint, at least, batteries can be generally divided into two main types: rechargeable and non-rechargeable (disposable). Each is in wide usage.

Disposable batteries, also called primary cells, are intended to be used once and discarded. These are most commonly used in portable devices with either low current drain, only used intermittently, or used well away from an alternative power source. Primary cells were also commonly used for alarm and communication circuits where other electric power was only intermittently available. Primary cells cannot be reliably recharged, since the chemical reactions are not easily reversible. Battery manufacturers recommend against attempting to recharge primary cells, although some electronics enthusiasts claim it is possible to do so using a special type of charger.

By contrast, rechargeable batteries or secondary cells can be re-charged after they have been drained. This is done by applying externally supplied electrical current, which reverses the chemical reactions that occur in use. Devices to supply the appropriate current are called chargers or rechargers.

Figure 2.4 Various batteries(clockwise from bottom left): two 9-volt, two "AA", one "D", a cordless phone battery, a camcorder battery, a 2-meter handheld ham radio battery, and a button battery, one "C" and two "AAA", plus a U.S. quarter, for scale.

Figure 2.5 From top to bottom:Two button cells, a 9 volt PP3 battery, a AAA battery, a AA battery, a C battery, a D battery, a large 3R12

2.10 Disposable (non-rechagreable) batteries

- Zinc-carbon battery - mid cost - used in light drain applications
- Zinc-chloride battery - similar to zinc carbon but slightly longer life
- Alkaline battery - alkaline/manganese "long life" batteries widely used in both light drain and heavy drain applications
- Silver-oxide battery - commonly used in hearing aids

- Lithium battery - commonly used in digital cameras. Sometimes used in watches and computer clocks. Very long life (up to ten years in wristwatches) and capable of delivering high currents but expensive
- Mercury battery - commonly used in digital watches
- Zinc-air battery - commonly used in hearing aids
- Thermal battery - high temperature reserve. Almost exclusively military applications.
- Water-activated battery - used for radiosondes and emergency applications

2.11 Rechargeable batteries

Also known as secondary batteries or accumulators.

- Lead-acid battery - commonly used in vehicles, alarm systems and uninterruptible power supplies. Used to be used as an "A" or "wet" battery in valve/vacuum tube radio sets. The major advantage of this chemistry is its low cost - a large battery (e.g. 70Ah) is relatively cheap when compared to other chemistries. However, this battery chemistry has lower energy density than other battery chemistries available today (see below)
- Absorbed glass mat
- Gel battery
- Lithium ion battery - a relatively modern battery chemistry that offers a very high charge density (i.e. a light battery will store a lot of energy) and which does not suffer from any "memory effect" whatsoever. Used in laptops (notebook PCs), modern camera phones, some rechargeable MP3 players and most other portable rechargeable digital equipment.
- Lithium ion polymer battery - similar characteristics to lithium-ion, but with slightly less charge density. This battery chemistry can be used for any battery to suit the manufacturer's needs, such as ultra-thin (1 mm thick) cells for the latest PDAs
- NaS battery
- Nickel-iron battery
- Nickel metal hydride battery
- Nickel-cadmium battery - used in many domestic applications but being superseded by Li-Ion and Ni-MH types. This chemistry gives the longest cycle life (over 1500 cycles), but has low energy density compared to some of the

other chemistries. Ni-Cd cells using older technology suffer from memory effect, but this has been reduced drastically in modern batteries.

- Nickel-zinc battery

PP3 (9V) Battery

A PP3 battery, commonly referred to simply as a nine-volt battery, is shaped as a rounded rectangular prism and has a nominal output of nine volts. Its nominal dimensions are 48 mm × 25 mm × 15 mm (ANSI standard 1604A). owever PP3 refers to the type of connection that is on top of the battery or snap. The PP3 connector (snap) consists of two connectors: one circular (male) and a hexagonal (female). The connectors on the battery are the same as on the connector itself -- the circular one connects to the hexagonal and vice versa.

The battery has both the positive and negative terminals on one end. The negative terminal is fashioned into a snap fitting which mechanically and electrically connects to a mating terminal on the power connector. The power connector has a similar snap fitting on its positive terminal which mates to the battery. This makes battery polarization obvious since mechanical connection is only possible in one configuration.

Inside a PP3 there are ordinarily six alkaline or carbon-zinc 1.5 volt (nominal) cells arranged in series. These are either AAAA cells, or special flat, rectangular cells. The exact size of the constituent cells varies from brand to brand -- some brands are slightly longer than others -- as does the manner in which they are joined together. Some brands use soldered tabs on the battery, others press foil strips against the ends of the cells. Very cheap versions may contain only five 1.5 volt cells. Rechargeable NiCd and NiMH batteries have various numbers of 1.2 volt cells. Lithium versions use three 3 V cells - there is a rechargeable lithium polymer version.

CHAPTER 3. RESISTORS

3.1 Overview

Resistors determine the flow of current in an electrical circuit. Where there is high resistance then the flow of current is small, where the resistance is low the flow of current is large. Resistance, voltage and current are connected in an electrical circuit by Ohm's Law. R=V/I

Resistors are used for regulating current and they resist the current flow and the extent to which they do this is measured in ohms (Ω). Resistors are found in almost every electronic circuit.

The most common type of resistor consists of a small ceramic (clay) tube covered partially by a conducting carbon film. The composition of the carbon determines how much current can pass through.

YELLOW 4	VIOLET 7	RED 00	RED +/- 2%	4K7 +/- 2%
GREEN 5	BLUE 6	BLACK NONE	GOLD +/- 5%	56R +/- 5%
BROWN 1	GREY 8	GREEN 00000	SILVER +/-10%	1M8 +/- 10%
ORANGE 3	ORANGE 3	ORANGE 000	NONE +/- 20%	33K +/- 20%

Figure 3.1 Resistor codes

Resistors are too small to have numbers printed on them and so they are marked with a number of coloured bands. Each colour stands for a number. Three colour bands shows the resistors value in ohms and the fourth shows tolerance. Resistors can never be made to a precise value and the tolerance band (the fourth band) tells us, using a percentage, how close the resistor is to its coded value.

The value of a resistor can be written in a variety of ways. Some examples are given below:

47R means 47 ohms

5R6 means 5.6 ohms

6k8 means 6800 ohms

1M2 means 1 200 000 ohms

A common value is 'K' which means one thousand ohms. So if a resistor has a value of 7000 ohms it can also be said to have a value of 7K.

3.2 Variable Resistors

Variable resistors have adjustable values. Adjustment is normally made by turning a spindle (e.g. the volume control on a radio) or moving a slider.

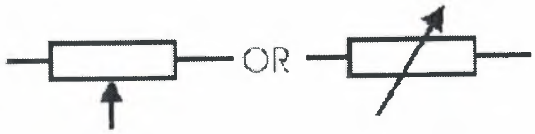


Figure 3.2 variable resistor circuit symbol

Variable resistors consist of a resistance track with connections at both ends and a wiper which moves along the track as you turn the spindle. The track may be made from carbon, cermet (ceramic and metal mixture) or a coil of wire (for low resistances). The track is usually rotary but straight track versions, usually called sliders, are also available.

Variable resistors may be used as a rheostat with two connections (the wiper and just one end of the track) or as a potentiometer with all three connections in use. Miniature versions called presets are made for setting up circuits which will not require further adjustment.

Variable resistors are often called potentiometers in books and catalogues. They are specified by their maximum resistance, linear or logarithmic track, and their physical size. The standard spindle diameter is 6mm.

The resistance and type of track are marked on the body:

4K7 LIN means 4.7 kΩ linear track.

1M LOG means 1 MΩ logarithmic track.

Some variable resistors are designed to be mounted directly on the circuit board, but most are for mounting through a hole drilled in the case containing the circuit with stranded wire connecting their terminals to the circuit board.

Figure 3.3 variable resistors

- **Linear (LIN) and Logarithmic (LOG) tracks**

Linear (LIN) track means that the resistance changes at a constant rate as you move the wiper. This is the standard arrangement and you should assume this type is required if a project does not specify the type of track. Presets always have linear tracks. A linear pot has a resistive element of constant cross-section, resulting in a device where the resistance between the wiper and one end terminal is proportional to the distance between them. Linear describes the electrical 'law' of the device, not the geometry of the resistive element.

- **Logarithmic (LOG) track**

Logarithmic (LOG) track means that the resistance changes slowly at one end of the track and rapidly at the other end, so halfway along the track is not half the total resistance! This arrangement is used for volume (loudness) controls because the human ear has a logarithmic response to loudness so fine control (slow change) is required at low volumes and coarser control (rapid change) at high volumes. It is important to connect the ends of the track the correct way round, if you find that turning the spindle increases the volume rapidly followed by little further change you should swap the connections to the ends of the track.

A log pot has a resistive element that either 'tapers' in from one end to the other, or is made from a material whose resistivity varies from one end to the other. This results in a device where output voltage is a logarithmic (or inverse logarithmic depending on type) function of the mechanical angle of the pot.

Most (cheaper) "log" pots are actually not logarithmic, but use two regions of different, but constant, resistivity to approximate a logarithmic law. A log pot can also be simulated with a linear pot and an external resistor. True log pots are significantly more expensive.

3.2.1 Potentiometer

Variable resistors used as potentiometers have all three terminals connected. A potentiometer is a variable resistor that functions as a voltage divider. Originally a potentiometer was an instrument to measure the potential (or voltage) in a circuit by tapping off a fraction of a known voltage from a resistive slide wire and comparing it with the unknown voltage by means of a galvanometer.

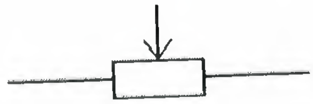


Figure 3.4 Potentiometer Symbol

The present popular usage of the term potentiometer (or 'pot' for short) describes an electrical device which has a user-adjustable resistance. Usually, this is a three-terminal resistor with a sliding contact in the center (the wiper). If all three terminals are used, it can act as a variable voltage divider. If only two terminals are used (one side and the wiper), it acts as a variable resistor. Its shortcoming is that of corrosion or wearing of the sliding contact, especially if it is kept in one position.

This arrangement is normally used to vary voltage, for example to set the switching point of a circuit with a sensor, or control the volume (loudness) in an amplifier circuit. If the terminals at the ends of the track are connected across the power supply then the wiper terminal will provide a voltage which can be varied from zero up to the maximum of the supply.

- **Potentiometer as electronic component**

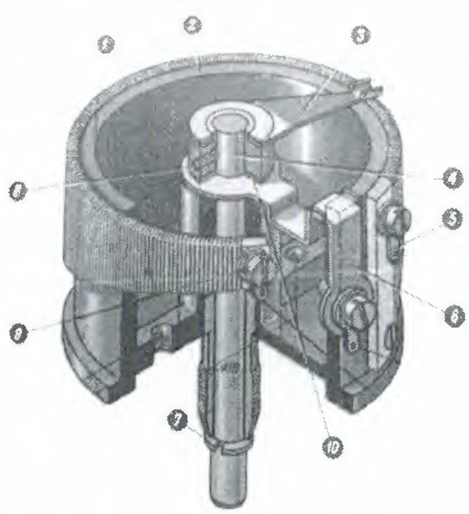


Figure 3.5 inside of a potentionmeter

Figure 3.5 is construction of a wire-wound circular potentiometer. The resistive element (1) of the shown device is trapezoidal, giving a non-linear relationship between resistance and turn angle. The wiper (3) rotates with the axis (4), providing the changeable resistance between the wiper contact (6) and the fixed contacts (5) and (9). The vertical position of the axis is fixed in the body (2) with the ring (7) (below) and the bolt (8) (above).

In modern usage, a potentiometer is a potential divider, a three terminal resistor where the position of the sliding connection is user adjustable via a knob or slider.

Potentiometers are sometimes provided with one or more switches mounted on the same shaft. For instance, when attached to a volume control, the knob can also function as an on/off switch at the lowest volume.

Ordinary potentiometers are rarely used to control anything of significant power (even lighting) directly due to resistive losses, but they are frequently used to adjust the level of analog signals (e.g. volume controls on audio equipment) and as control inputs for electronic circuits (e.g. a typical domestic light dimmer uses a potentiometer to set the point in the cycle at which the triac turns on). Potentiometers used to control high power are normally called rheostats.

- **Low-power types**

A potentiometer is constructed using a flat graphite annulus as the resistive element, with a sliding contact (wiper) sliding around this annulus. The wiper is connected to an axle and, via another rotating contact, is brought out as the third terminal. On panel pots, the wiper is usually the centre terminal. For single turn pots, this wiper typically travels just under one revolution around the contact. 'Multiturn' potentiometers also exist, where the resistor element may be helical and the wiper may move 10, 20, or more complete revolutions. In addition to graphite, other materials may be used for the resistive element. These may be resistance wire or carbon particles in plastic or a ceramic/metal mixture.

Figure 3.6 A typical single turn potentiometer

One popular form of rotary potentiometer is called a string pot. It is a multi-turn potentiometer with an attached reel of wire turning against a spring. It's very convenient for measuring movement and therefore acts as a position transducer. In a linear slider pot, a sliding control is provided instead of a dial control. The word linear also describes the geometry of the resistive element which is a rectangular strip, (not an annulus as in a rotary potentiometer). Because of their construction, this type of pot has a greater potential for getting contaminated. Potentiometers can be obtained with either linear or logarithmic laws (or "tapers").

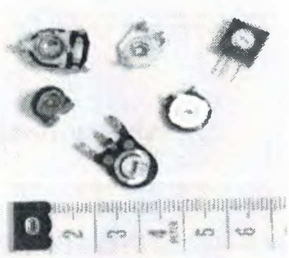


Figure 3.7 PCB mount trimmer potentiometers or "trimpots" intended for infrequent adjustment

- **High-power types**

A rheostat is essentially a potentiometer, but is usually much larger, designed to handle much higher voltage and current. Typically these are constructed as a resistive wire wrapped to form a toroid coil (or most of one) with the wiper moving over the upper surface of the toroid, sliding from one turn of the wire to the next.

Figure 3.8 A high power toroidal wirewound rheostat

Sometimes a rheostat is made from resistance wire wound on a heat resisting cylinder with the slider made from a number of metal fingers that grip lightly onto a small portion of the turns of resistance wire. The 'fingers' can be moved along the coil of resistance wire by a sliding knob thus changing the 'tapping' point. They are usually used as variable resistors rather than variable potential dividers.

3.2.2 Rheostat

Rheostats are often used to vary current, for example to control the brightness of a lamp or the rate at which a capacitor charges.

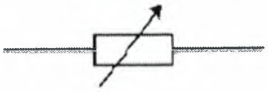


Figure 3.9 Rheostat Symbol

If the rheostat is mounted on a printed circuit board you may find that all three terminals are connected! However, one of them will be linked to the wiper terminal. This improves the mechanical strength of the mounting but it serves no function electrically.

3.2.3 Theory of operation of potentionmeter

The 'modern' potentiometer can be used as a potential divider (or voltage divider) to obtain a manually adjustable output voltage at the slider (wiper) from a fixed input voltage applied across the two ends of the pot.

This is the simplest way of using a variable resistor. Two terminals are used: one connected to an end of the track, the other to the moveable wiper. Turning the spindle changes the resistance between the two terminals from zero up to the maximum resistance.

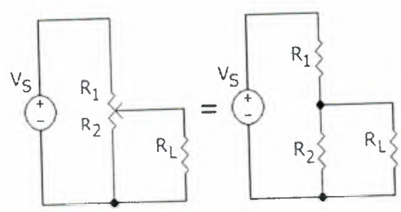


Figure 3.10 A potentiometer with a resistive load, showing equivalent fixed resistors for clarity.

This is the most common use of pots. The voltage across RL is determined by the formula:

$$V_L = \frac{R_2 \| R_L}{R_1 + R_2 \| R_L} \cdot V_s \qquad (3)$$

The parallel lines indicate components in parallel. Expanded fully, the equation becomes:

$$V_L = \frac{R_2 R_L}{R_1 R_L + R_2 R_L + R_1 R_2} \cdot V_s \qquad (4)$$

Although it is not always the case, if RL is large compared to the other resistances, the output voltage can be approximated by the simpler equation:

$$V_L = \frac{R_2}{R_1 + R_2} \cdot V_s \qquad (5)$$

As an example, assume;

$V_S = 10\ \mathrm{V}$, $R_1 = 1\ \mathrm{k}\Omega$, $R_2 = 2\ \mathrm{k}\Omega$, and $R_L = 100\ \mathrm{k}\Omega$

Since the load resistance is large compared to the other resistances, the output voltage VL will be approximately:

$$\frac{2\ \mathrm{k}\Omega}{1\ \mathrm{k}\Omega + 2\ \mathrm{k}\Omega} \cdot 10\ \mathrm{V} = \frac{2}{3} \cdot 10\ \mathrm{V} \approx 6.667\ \mathrm{V}$$

Due to the load resistance, however, it will actually be slightly lower: ≈ 6.623 V. One of the advantages of the potential divider compared to a variable resistor in series with the source is that, while variable resistors have a maximum resistance where some current will always flow, dividers are able to vary the output voltage from maximum (VS) to ground (zero volts) as the wiper moves from one end of the pot to the other. There is, however, always a small amount of contact resistance.

In addition, the load resistance is often not known and therefore simply placing a variable resistor in series with the load could have a negligible effect or an excessive effect, depending on the load.

3.2.4 Applications of potentiometers

Transducers

Potentiometers are also very widely used as a part of displacement transducers because of the simplicity of construction and because they can give a large output signal.

- **Audio control**

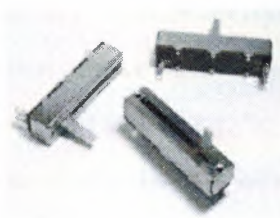


Figure 3.11 Sliding potentiometers ("faders")

One of the most common uses for modern low-power potentiometers is as audio control devices. Both sliding pots (also known as faders) and rotary potentiometers (commonly called knobs) are regularly used to adjust loudness, frequency attenuation and other characteristics of audio signals.

The 'log pot' is used as the volume control in audio amplifiers, where it is also called an "audio taper pot", because the amplitude response of the human ear is also logarithmic. It ensures that, on a volume control marked 0 to 10, for example, a setting of 5 sounds half as loud as a setting of 10. There is also an anti-log pot or reverse audio taper which is simply the reverse of a log pot. It is almost always used in a ganged configuration with a log pot, for instance, in an audio balance control. A potentiometer used in combination with an inductor or capacitor acts as a "tone" control.

CHAPTER 4. DIODES

4.1 Overview

Diode is two-terminal electronic device that permits current flow predominantly in only one direction. Most diodes are semiconductor devices; diode electron tubes are now used only for a few specialized applications. A diode has a low resistance to electric current in one direction and a high resistance to it in the reverse direction. This property makes a diode useful as a rectifier, which can convert alternating current (AC) into direct current (DC). An arrangement of four diodes, called a diode bridge, transforms AC into DC using both phases of the alternating current. When the voltage applied in the reverse direction exceeds a certain value, a semiconductor diode "breaks down" and conducts heavily in the direction of normally high resistance. When the reverse voltage at which breakdown occurs remains nearly constant for a wide range of currents, the phenomenon is called avalanching. A diode using this property, called a Zener diode, can be used to regulate the voltage in a circuit.

A circuit element diode is said to rectify if voltage increments of equal magnitude but opposite sign applied to the element produce unequal current increments. An ideal rectifier diode is one that conducts fully in one direction (forward) and not at all in the opposite direction (reverse). This property is approximated in junction and thermionic diodes. Processes that make use of rectifier diodes include power rectification, detection, modulation, and switching.

Negative-resistance diodes, which include tunnel and Gunn diodes, are used as the basis of pulse generators, bistable counting and storage circuits, and oscillators.

Breakdown-diode current increases very rapidly with voltage above the breakdown voltage; that is, the voltage is nearly independent of the current. In series with resistance to limit the current to a nondestructive value, breakdown diodes can therefore be used as a means of obtaining a nearly constant reference voltage or of maintaining a constant potential difference between two circuit points, such as the emitter and the base of a transistor. Breakdown diodes (or reverse-biased ordinary junction diodes) can be used between two circuit points in order to limit alternating-voltage amplitude or to clip voltage peaks.

Light-sensitive diodes, which include phototubes, photovoltaic cells, photodiodes, and photoconductive cells, are used in the measurement of illumination, in the control of lights or other electrical devices by incident light, and in the conversion of radiant energy into electrical energy. Light-emitting diodes (LEDs) are used in the display of letters, numbers, and other symbols in calculators, watches, clocks, and other electronic units.

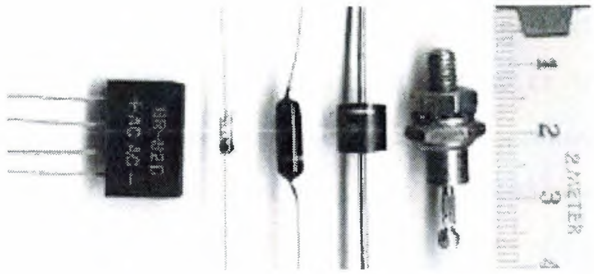


Figure 4.1 Diodes

4.2 Semiconductor diodes

Most modern diodes are based on semiconductor p-n junctions. In a p-n diode, conventional current can flow from the p-type side (the anode) to the n-type side (the cathode), but not in the opposite direction. Another type of semiconductor diode, the Schottky diode, is formed from the contact between a metal and a semiconductor rather than by a p-n junction.

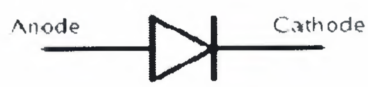


Figure 4.2 circuit symbol

Current can flow from the anode to the cathode, but not the other way around.

A semiconductor diode's current-voltage, or I-V, characteristic curve is ascribed to the behavior of the so-called depletion layer or depletion zone which exists at the p-n junction between the differing semiconductors. When a p-n junction is first created, conduction band (mobile) electrons from the N-doped region diffuse into the P-doped region where there is a large population of holes (places for electrons in which no electron is present) with which the electrons "recombine". When a mobile electron recombines with a hole, the hole vanishes and the electron is no longer mobile. Thus, two charge carriers have vanished. The region around the p-n junction becomes depleted of charge carriers and thus behaves as an insulator.

However, the depletion width cannot grow without limit. For each electron-hole pair that recombines, a positively-charged dopant ion is left behind in the N-doped region, and a negatively charged dopant ion is left behind in the P-doped region. As recombination proceeds and more ions are created, an increasing electric field develops through the depletion zone which acts to slow and then finally stop recombination. At this point, there is a 'built-in' potential across the depletion zone.

If an external voltage is placed across the diode with the same polarity as the built-in potential, the depletion zone continues to act as an insulator preventing a significant electric current. This is the reverse bias phenomenon. However, if the polarity of the external voltage opposes the built-in potential, recombination can once again proceed resulting in substantial electric current through the p-n junction. For silicon diodes, the built-in potential is approximately 0.6 V. Thus, if an external current is passed through the diode, about 0.6 V will be developed across the diode such that the P-doped region is positive with respect to the N-doped region and the diode is said to be 'turned on' as it has a forward bias.

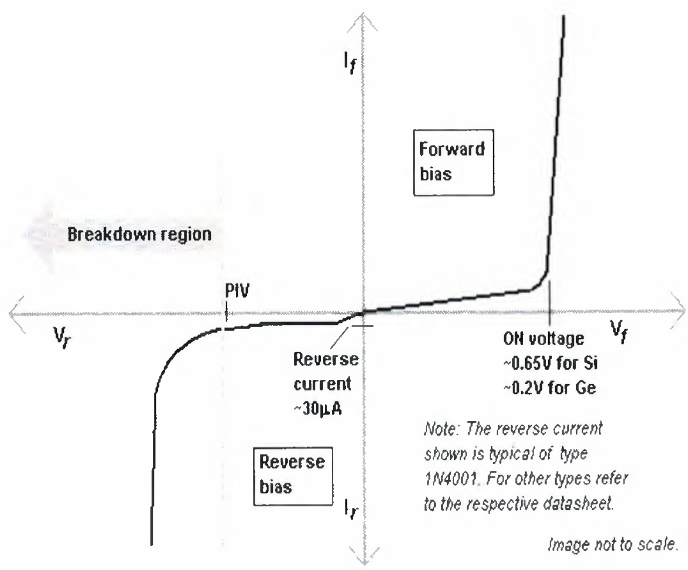


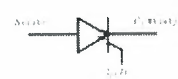
Figure 4.3 I-V characteristics of a P-N junction diode (not to scale).

A diode's I-V characteristic can be approximated by two regions of operation. Below a certain difference in potential between the two leads, the depletion layer has significant width, and the diode can be thought of as an open (non-conductive) circuit. As the potential difference is increased, at some stage the diode will become conductive and allow charges to flow, at which point it can be thought of as a connection with zero (or at least very low) resistance. More precisely, the transfer function is logarithmic, but so sharp that it looks like a corner on a zoomed-out graph (see also signal processing).

In a normal silicon diode at rated currents, the voltage drop across a conducting diode is approximately 0.6 to 0.7 volts. The value is different for other diode types - Schottky diodes can be as low as 0.2 V and light-emitting diodes (LEDs) can be 1.4 V or more (Blue LEDs can be up to 4.0 V).

Referring to the I-V characteristics image, in the reverse bias region for a normal P-N rectifier diode, the current through the device is very low (in the µA range) for all reverse voltages up to a point called the peak-inverse-voltage (PIV). Beyond this point a process called reverse breakdown occurs which causes the device to be damaged along with a large increase in current. For special purpose diodes like the avalanche or zener diodes, the concept of PIV is not applicable since they have a deliberate breakdown beyond a known reverse current such that the reverse voltage is "clamped" to a known value (called the zener voltage or breakdown voltage). These devices however have a maximum limit to the current and power in the zener or avalanche region.

Table 4.1 Some diode symbols

			
Diode	Zener Diode	Schottky Diode	Tunnel Diode
			
Light-emitting diode	Photodiode	Varicap	SCR

4.3 Applications of Diodes

Logic circuits: diode transistor loigc (DTL) and voltage clamps to avoid swings in voltage.

Rectifiers for waveshaping

varactor diodes for tuning circuits and mixers

- **Radio demodulation**

The first use for the diode was the demodulation of amplitude modulated (AM) radio broadcasts. In summary, an AM signal consists of alternating positive and negative peaks of voltage, whose amplitude or 'envelope' is proportional to the original audio signal, but whose average value is zero. The diode (originally a crystal diode) rectifies the AM signal, leaving a signal whose average amplitude is the desired audio signal. The average value is extracted using a simple filter and fed into an audio transducer, which generates sound.

- **Power conversion**

  Rectifiers are constructed from diodes, where they are used to convert alternating current (AC) electricity into direct current (DC). Similarly, diodes are also used in Cockcroft-Walton voltage multipliers to convert AC into very high DC voltages.

- **Over-voltage protection**

  Diodes are frequently used to conduct damaging high voltages away from sensitive electronic devices. They are usually reverse-biased (non-conducting) under normal circumstances, and become forward-biased (conducting) when the voltage rises above its normal value. For example, diodes are used in stepper motor and relay circuits to de-energize coils rapidly without the damaging voltage spikes that would otherwise occur. Many integrated circuits also incorporate diodes on the connection pins to prevent external voltages from damaging their sensitive transistors. Specialized diodes are used to protect from over-voltages at higher power.

- **Logic gates**

  Diodes can be combined with other components to construct AND and OR logic gates. This is referred to as diode logic.

- **Temperature measuring**

  A diode can be used as a temperature measuring device, since the forward voltage drop across the diode depends on temperature. This temperature dependence follows from the Shockley ideal diode equation given above and is typically around -2.2 mV per degree Celsius.

- **Charge coupled devices**

  Digital cameras and similar units use arrays of photo diodes, integrated with readout circuitry.

CHAPTER 5. LED

5.1. Overview

Led is a semiconductor diode that converts electric energy into electromagnetic radiation at a visible and near infrared frequencies when its pn junction is forward biased.

A light-emitting diode (LED) is a semiconductor device that emits incoherent narrow-spectrum light when electrically biased in the forward direction of the p-n junction. This effect is a form of electroluminescence. An LED is a small extended source with extra optics added to the chip that makes an LED to emit a complex radiation pattern. The color of the emitted light depends on the composition and condition of the semiconducting material used, and can be infrared, visible or near-ultraviolet.

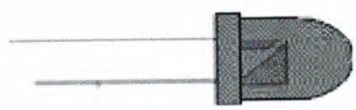


Figure 5.1 a diode

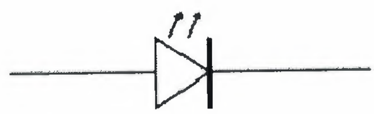


Figure 5.2 circuit symbol

Led is a semiconductor diode that produces visible or infrared light when subjected to an electric current, as a result of electroluminescence. Visible-light LEDs are used in many electronic devices as indicator lamps (e.g., an on/off indicator) and, when arranged in a matrix, to spell out letters or numbers on alphanumeric displays. Infrared LEDs are used in optoelectronics (e.g., in auto-focus cameras and television remote controls) and as light sources in some long-range fibre-optic communications systems. LEDs are formed by the so-called III-V compound semiconductors related to gallium arsenide. They consume little power and are long-lasting and inexpensive.

5.2 Physical function of led

An LED is a unique type of semiconductor diode. Like a normal diode, it consists of a chip of semiconducting material impregnated, or doped, with impurities to create a p-n junction. As in other diodes, current flows easily from the p-side, or anode, to the n-side, or cathode, but not in the reverse direction. Charge-carriers — electrons and electron holes — flow into the junction from electrodes with different voltages.

When an electron meets a hole, it falls into a lower energy level, and releases energy in the form of a photon.

The wavelength of the light emitted, and therefore its color, depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes, the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect bandgap materials. The materials used for an LED have a direct band gap with energies corresponding to near-infrared, visible or near-ultraviolet light.

LEDs are usually constantly illuminated when a current passes through them, but flashing LEDs are also available. Flashing LEDs resemble standard LEDs but they contain a small chip inside which causes the LED to flash with a typical period of one second. This type of LED comes most commonly as red, yellow, or green. Most flashing LEDs emit light of a single wavelength, but multicolored flashing LEDs are available too.

LED development began with infrared and red devices made with gallium arsenide. Advances in materials science have made possible the production of devices with ever-shorter wavelengths, producing light in a variety of colors.

LEDs are usually built on an n-type substrate, with electrode attached to the p-type layer deposited on its surface. P-type substrates, while less common, occur as well. Many commercial LEDs, especially GaN/InGaN, also use sapphire substrate. Substrates that are transparent to the emitted wavelength, and backed by a reflective layer, increase the LED efficiency. The refractive index of the package material should match the index of the semiconductor, otherwise the produced light gets partially reflected back into the semiconductor, where it gets absorbed and turns into additional heat.

The semiconducting chip is encased in a solid plastic lens, which is much tougher than the glass envelope of a traditional light bulb or tube. The plastic may be colored, but this is only for cosmetic reasons or to improve the contrast ratio; the color of the packaging does not substantially affect the color of the light emitted.

Conventional LEDs are made from a variety of inorganic semiconductor materials, producing the following colors:

- aluminum gallium arsenide (AlGaAs) - red and infrared
- aluminum gallium phosphide (AlGaP) - green
- aluminum gallium indium phosphide (AlGaInP) - high-brightness orange-red, orange, yellow, and green

- gallium arsenide phosphide (GaAsP) - red, orange-red, orange, and yellow
- gallium phosphide (GaP) - red, yellow and green
- gallium nitride (GaN) - green, pure green (or emerald green), and blue also white (if it has an AlGaN Quantum Barrier)
- indium gallium nitride (InGaN) - near ultraviolet, bluish-green and blue
- silicon carbide (SiC) as substrate — blue
- silicon (Si) as substrate — blue (under development)
- sapphire (Al2O3) as substrate — blue
- zinc selenide (ZnSe) - blue
- diamond (C) - ultraviolet
- aluminum nitride (AlN), aluminum gallium nitride (AlGaN) - near to far ultraviolet (down to 210 nm[4])

5.3 What is Inside an LED?

LED's are special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. A a clear (or often colored) epoxy case enclosed the heart of an LED, the semi-conductor chip.

LED leads

<-- -->

side lead on flat side of bulb = negative

Figure 5.3 diode leads

The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The negative side of an LED lead is indicated in two ways: 1) by the flat side of the bulb, and 2) by the shorter of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 milliamperes. Voltages and currents substantially above these values can melt a LED chip.

The most important part of a light emitting diode (LED) is the semi-conductor chip located in the center of the bulb as shown at the right. The chip has two regions separated by a junction. The p region is dominated by positive electric charges, and the n region is dominated by negative electric charges. The junction acts as a barrier to the flow of electrons between the p and the n regions. Only when sufficient voltage is applied to the semi-conductor chip, can the current flow, and the electrons cross the junction into the p region. In the absence of a large enough electric potential difference (voltage) across the LED leads, the junction presents an electric potential barrier to the flow of electrons.

5.4 What Causes the LED to Emit Light and What Determines the Color of the Light?

When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the junction between the p and n regions. In the p region there are many more positive than negative charges. In the n region the electrons are more numerous than the positive electric charges. When a voltage is applied and the current starts to flow, electrons in the n region have sufficient energy to move across the junction into the p region. Once in the p region the electrons are immediately attracted to the positive charges due to the mutual Coulomb forces of attraction between opposite electric charges. When an electron moves sufficiently close to a positive charge in the p region, the two charges "re-combine". Each time an electron recombines with a positive charge, electric potential energy is converted into electromagnetic energy. For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material (usually a combination of the chemical elements gallium, arsenic and phosphorus). Only photons in a very narrow frequency range can be emitted by any material. LED's that emit different colors are made of different semi-conductor materials, and require different energies to light them.

In the absence of a large enough electric potential difference (voltage) across the LED leads, the junction presents an electric potential barrier to the flow of electrons.

5.5 How Much Energy Does an LED Emit?

The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction. The different colored LED's emit predominantly light of a single color. The energy (E) of the light emitted by an LED is related to the electric charge (q) of an electron and the voltage (V) required to light the LED by the expression: $E = qV$ Joules. This expression simply says that the voltage is proportional to the electric energy, and is a general statement which applies to any circuit, as well as to LED's. The constant q is the electric charge of a single electron, -1.6 x 10-19 Coulomb.

5.6 LED applications

- Architectural lighting
- Status indicators on all sorts of equipment
- Traffic lights and signals
- Exit signs
- Motorcycle and Bicycle lights
- Toys and recreational sporting goods, such as the Flashflight
- Railroad crossing signals
- Continuity indicators
- Flashlights. Some models that do not even use batteries are of this type.
- Light bars on emergency vehicles.
- Elevator Push Button Lighting
- Thin, lightweight message displays at airports and railway stations and as destination displays for trains, buses, trams and ferries.
- Red or yellow LEDs are used in indicator and alphanumeric displays in environments where night vision must be retained: aircraft cockpits, submarine and ship bridges, astronomy observatories, and in the field, e.g. night time animal watching and military field use.
- Red, yellow, green, and blue LEDs can be used for model railroading applications
- Remote controls, such as for TVs and VCRs, often use infrared LEDs.
- In optical fiber and Free Space Optics communications.
- In dot matrix arrangements for displaying messages.
- Glowlights, as a more expensive but longer lasting and reusable alternative to Glowsticks.

- Movement sensors, for example in optical computer mice
- Because of their long life and fast switching times, LEDs have been used for automotive high-mounted brake lights and truck and bus brake lights and turn signals for some time, but many high-end vehicles are now starting to use LEDs for their entire rear light clusters. Besides the gain in reliability, this has styling advantages because LEDs are capable of forming much thinner lights than incandescent lamps with parabolic reflectors. The significant improvement in the time taken to light up (perhaps 0.5s faster than an incandescent bulb) improves safety by giving drivers more time to react.
- Backlighting for LCD televisions and displays. The availability of LEDs in specific colors (RGB) enables a full-spectrum light source which expands the color gamut by as much as 45%.
- New stage lighting equipment is being developed with LED sources in primary red-green-blue arrangements.
- Lumalive, a photonic textile
- As Voltage Reference in electronic circuits. The constant voltage drop (e.g. 1.7 V for a normal red LED) can be used instead of a Zener diode in low-voltage regulators. Zener diodes are not available below voltages of about 3 V.

5.7 Illumination applications of LED

LEDs used as a replacement for incandescent light bulbs and fluorescent lamps are known as solid-state lighting (SSL) - packaged as a cluster of white LEDs grouped together to form a light source (pictured). LEDs are moderately efficient; the average commercial SSL currently outputs 32 lumens per watt (lm/W), and new technologies promise to deliver up to 80 lm/W. The long lifetime of LEDs make SSL very attractive. They are also more mechanically robust than incandescent light bulbs and fluorescent tubes. Currently, solid state lighting is becoming more available for household use but is relatively expensive, although costs are decreasing. LED flashlights, however, already have become widely available. Recently a number of manufacturers have started marketing ultra-compact LCD video projectors that use high-powered white LEDS for the light source. Incandescent bulbs are much less expensive but also less efficient, generating from about 16 lm/W for a domestic tungsten bulb to 22 lm/W for a halogen bulb. Fluorescent tubes are more efficient, providing 50 to 100 lm/W for domestic tubes (average 60 lm/W), but are bulky and fragile and require starter or ballast circuits that sometimes buzz audibly. Compact fluorescent lamps, which include a quiet integrated ballast, are relatively robust and efficient and fit in standard light bulb sockets. They are currently the best choice for efficient household lighting. CFLs do still emit a quiet buzz, while LEDs are completely silent.

LEDs are now well established in applications such as traffic signals and indicator lamps for trucks and automobiles. High output LED fixtures suitable for general architectural lighting applications are beginning to appear on the market with system efficacies of up to 56 lumens per watt, which is comparable to fluorescent systems. Proponents of LEDs expect that technological advances will reduce costs such that SSL will replace incandescent and fluorescent lighting in most commercial and residential applications.

Due to their monochromatic nature, LED lights have great power advantages over white lights when a specific color is required. Unlike traditional white lights, the LED does not need a coating or diffuser that can absorb much of the emitted light

Considerations in use

Unlike incandescent light bulbs, which light up regardless of the electrical polarity, LEDs will only light with positive electrical polarity. When the voltage across the p-n junction is in the correct direction, a significant current flows and the device is said to be forward-biased. If the voltage is of the wrong polarity, the device is said to be reverse biased, very little current flows, and no light is emitted. LEDs can be operated on an alternating current voltage, but they will only light with positive voltage, causing the LED to turn on and off at the frequency of the AC supply.

Figure 5.4 Close-up of a typical LED in its case, showing the internal structure.

CHAPTER 6. TRANSISTORS

6.1 Overview

The word transistor comes from *transfer* of *resistance.*

Electronic systems, such as radios, televisions, and computers, were originally constructed usig vacuum tubes. Vacuum tubes were generally used to increase the strength of ac signals (amplify) and to convert ac energy to dc energy (rectify). Although they were able to perform these critical operations very well, vacuum tubes had several charateristc problems. They were large and fragile, and they wasted tremendeus amounts of power through heat loss.

In the 1940s, a team of scientistsworkng for Bell Labs developed the transistor, the first solid state device capable of amplifying ac signal. The term solid state was coined because the transistor was solid rather than hollow like the vacuum tube it was designed to replace. The transistor was also smaller, more rugged, and wasted much less power than did its vacuum tubes nearly every application.

Solid state components are made from elements that are calassified as semiconductors. A semiconductor element is one that is neither conductor nor an insulator, but rather lies halfway between the two. Under certain circumstances the resstive properties of a semiconductor can be varied between those of a conductor and those of an insulator. Three most commonly used semiconductor materials are silicon (Si) , germanium (Ge), and carbon (C). Silicon and germanium are used i th producto of solid-state components. Carbon is used mainly in the production of resistors and potentiometers. Characteristics of the most common semiconductor materials used to make transistors are given in the table below:

Semiconductor material characteristics

Semiconductor material	Junction forward voltage V @ 25 °C	Electron mobility m^2/Vs @ 25 °C	Hole mobility m^2/Vs @ 25 °C	Max. junction temp. °C
Ge	0.27	0.39	0.19	70 to 100
Si	0.71	0.14	0.05	150 to 200
GaAs	1.03	0.85	0.05	150 to 200
Al-Si junction	0.3	—	—	150 to 200

Table 6.1 semiconductor material charecteristic

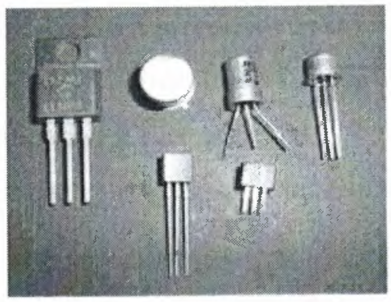


Figure 6.1 Assorted discrete transistors

A transistor is a semiconductor device, commonly used as an amplifier. The transistor is the fundamental building block of the circuitry that governs the operation of computers, cellular phones, and all other modern electronics. A transistor is an electronic component used in a circuit to control a large amount of current or voltage with a small amount of voltage or current. The transistor is a three-terminal device whose output current, voltage, and\or power are controlled by its input. In digital systems, the transistor is used as a high speed electronic switch capable of switching between two operating states (open and closed) at a rate of several bilions of times per second.

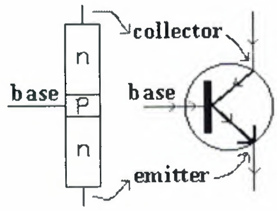
Because of its fast response and accuracy, the transistor may be used in a wide variety of digital and analog functions, including amplification, switching, voltage regulation, signal modulation, and oscillators. Transistors may be packaged individually or as part of an integrated circuit chip, which may hold thousands of transistors in a very small area.

The transistors consisted of a thin germanium wafer connected to two extremely thin wires. The wires are spaced only a few thousands of an inch part. A current introduced to one of the wires was amplified by the germanium wafer, and the larger output current was taken from the other wire.

How do transistors work?

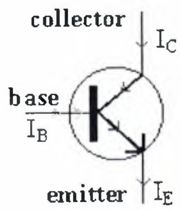
Transistors work on the principle that certain materials e.g. silicon, can after processing be made to perform as "solid state" devices. Any material is only conductive in proportion to the number of "free" electrons that are available. Silicon crystals for example have very few free electrons. However if "impurities" (different atomic structure - e.g. arsenic) are introduced in a controlled manner then the free electrons or conductivity is increased. By adding other impurities such as gallium, an electron deficiency or hole is created. As with free electrons, the holes also encourage conductivity and the material is called a semi-conductor. Semiconductor material which conducts by free electrons is called n-type material while material which conducts by virtue of electron deficiency is called p-type material.

The three layers in a transistor each have names, which indicate their function.



The "top" n-layer is the collector, the p-layer is the base, and the bottom n-layer is the emitter. The collector-base connection is forward-biased, while the emitter-base connection is reverse-biased. This means that in a transistor, current travels from the collector, through the base, to the emitter.

A transistor is similar to a faucet. When the base-emitter voltage, VBE, is above a certain level, the transistor, or symbolic faucet, is turned on. This then allows a current (or stream of water) to flow from the collector to the emitter. VBE, the voltage required to do this, is around 0.6 to 0.7 Volts. Without the 0.6 or 0.7 Volts, no current will flow, and the transistor is considered off.



There are three key parts to current involved in a transistor system: IB, the current flowing in at the base, IC, the current flowing in at the collector, and IE, the current flowing out the emitter. These three quantities are related in a very simple, yet useful, equation:

$$I_E = I_B + I_C$$

More than 99% of the emitter current is made up of the collector current, while less than one percent of it is made up of the base current.

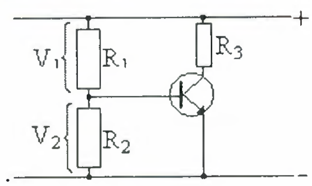
This leads us to an important transistor function: current amplification. Since the emitter current is a dependent amount, it varies with collector current and base current. In a transistor, the input always comes from the base, or the knob or valve on the faucet, which determines whether it is on or off. Because the collector current is about 100 times greater than the base current, the collector current is amplified by a large amount when the base current is only slightly increased. The ratio between the change in collector current and the change in base current is called the current gain of the transistor, and can be expressed thus:

$$h_{FE} = \frac{\Delta I_C}{\Delta I_B}$$

Note: hFE , the symbol for current gain in transistors, tells more than we might expect. The "F" stands for forward current, and "E" means the transistor is connected in the emitter mode (the only one we will be discussing). The fact that both the "F" and the "E" are capitalized indicates the current gain is in D.C..

For a common transistor - a silicon npn - hFE is usually between 100 and 200. It is important to remember that this amplifying action is controlled by current, not voltage, and also that it is a ratio, and therefore has no units.

The transistor also has another, perhaps more important function: that of a switch. We know that the transistor is controlled by the input of the base, but more importantly, it is the base-emitter voltage that determines whether the transistor is on or off. It is possible to control this using a simple system of resistors



In a series circuit, the ratio between the potential difference of different parts of the circuit is equal to the ratio between their respective resistances, or :

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

From this equation, we find:

$$\frac{R_1}{V_1} = \frac{R_2}{V_2}$$

The proportion of a resistance to its p.d. is the same throughout the circuit, which means that the greater the resistance for a certain part of the circuit, the greater the voltage for that part will be.

Let's say that we want to design a circuit that turns a streetlight on when it gets too dark. We would need to make sure that the base emitter voltage is at least 0.7 V when it is dark. One way of setting this up is to make sure that the resistance R2, is greater than the resistance R1 in darkness. This way, V2 (in this case VBE) would be greater than V1. Since only 0.7 Volts are required to turn on the transistor, it is therefore almost certain that whenever V2 > V1, the transistor will turn on.

However, in order not to waste electricity, we would want to make sure that the streetlight is not on during the day as well. This means that while it is light out, R1 needs to be greater than R2 in such a proportion that V2 coulds not possibly reach 0.7 V. A resistor that changes its resistance with light would be needed to detect the point at which the streetlight should go on. Since Light Dependent Resistors (LDR's) usually increase their resistance as it gets darker, we would want an LDR to be R2. But we definitely want to be able to decide at which point the streetlights should go on, which means deciding at which point R2 should become greater than R1. We can do this by using a variable resistor, which will allow us to set a specific resistance for R1. We should set the resistance of R1 just under the resistance of R2 when it is in darkness. When R2 allows V2 to be high enough, current can pass through R3 to activate whatever result is desired, in this case, the streetlights.

Similar switch functions can be set up using other forms of resistors, such as a water-detecting device for a sprinkler system. Devices like these, that convert a non-electrical signal into an electrical one are called transducers. Another example is a motion sensor that can send a signal (via a transistor) to start a burglar alarm.

How do holes and electrons conduct in transistors?

If we take a piece of the p-type material and connect it to a piece of n-type material and apply voltage as in figure 6.2, then current will flow. Electrons will be attracted across the junction of the p and n materials. Current flows by means of electrons going one way and holes going in the other direction. If the battery polarity were reversed then current flow would cease.

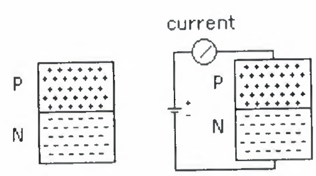


Figure 6.2 - electron flow in a p-n juction of a diode

Some very interesting points emerge here. As depicted in figure 1 above a junction of p and n types constitutes a rectifier diode. Indeed a transistor can be configured as a diode and often are in certain projects, especially to adjust for thermal variations. Another behaviour which is often a limitation and at other times an asset is the fact that with zero spacing between the p and n junctions we have a relatively high value capacitor.

This type of construction places an upper frequency limit at which the device will operate. This was a severe early limitation on transistors at radio frequencies. Modern techniques have of course overcome these limitations with some bipolar transistors having Ft's beyond 1 Ghz. The capacitance at the junction of a diode is often taken advantage of in the form of varactor diodes. See the tutorial on diodes for further details. The capacitance may be reduced by making the junction area of connection as small as possible. This is called a "point contact".

Now a transistor is merely a "sandwich" of these devices. A PNP transistor is depicted in figure 2 below.

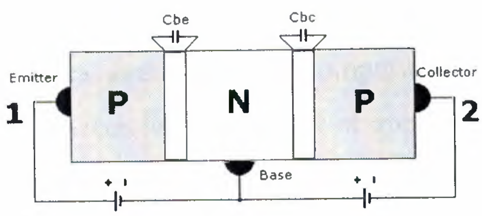


Figure 6.3 - sandwich construction of a PNP transistor

Actually it would be two p-layers with a "thin" n-layer in between. What we have here are two p-n diodes back to back. If a positive voltage (as depicted) is applied to the emitter, current will flow through the p-n junction with "holes" moving to the right and "electrons moving to the left. Some "holes" moving into the n-layer will be neutralised by combining with the electrons. See electron theory and atoms. Some "holes" will also travel toward the right hand region. The fact that there are two junctions leads to the term "bipolar transistor". If a negative voltage (as depicted) is applied to the collector of the transistor, then ordinarily no current flows BUT there are now additional holes at the junction to travel toward point 2 and elctrons can travel to point 1, so that a current can flow, even though this section is biased to prevent conduction.

It can be shown that most of the current flows between points 1 and 2. In fact the amplitude (magnitude) of the collector current in a transistor is determined mainly by the emitter current which in turn is determined by current flowing into the base of the transistor..

Transistor amplification

Because the collector current (where the voltage is relatively high) is pretty much the same as the emitter current and also controlled by the emitter current (where the voltage is usually much lower) it can be shown by ohms law $P = I 2 * R$ that amplification occurs.

Rules for Bias Connections

The Emitter - Base connection is always FORWARD biased. This means more Positive to P type & more Negative to N type. Also, for a Silicon transistor, there must be at least a 0.7 Volt DC bias across the emitter-base junction in order for the transistor to be active. Of course, the bias is 0.3 Volts DC for Germanium Transistors.

The Collector - Base connection is always REVERSE biased. This means more Positive goes to N type & more Negative goes to P type.

6.2 Importance

The transistor's low cost, flexibility and reliability have made it a universal device for non-mechanical tasks, such as digital computing. Transistorized circuits have replaced electromechanical devices for the control of appliances and machinery as well. It is often less expensive and more effective to use a standard microcontroller and write a computer program to carry out a control function than to design an equivalent mechanical control function.

6.3 Types of Transistors

Modern transistors are divided into two main categories: bipolar junction transistors (BJTs) and field effect transistors (FETs). The transistor characteristics depend on their type.

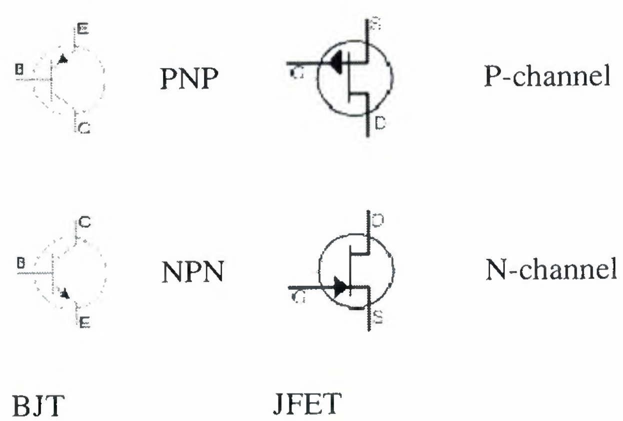


Table 6.2 BJT and JFET symbols

Transistors are categorized by:

- Semiconductor material: germanium, silicon, gallium arsenide, silicon carbide
- Structure: BJT, JFET, IGFET (MOSFET), IGBT, "other types"
- Polarity: NPN, PNP (BJTs); N-channel, P-channel (FETs)
- Maximum power rating: low, medium, high
- Maximum operating frequency: low, medium, high, radio frequency (RF), microwave (The maximum effective frequency of a transistor is denoted by the term fT, an abbreviation for "frequency of transition". The frequency of transition is the frequency at which the transistor yields unity gain).
- Application: switch, general purpose, audio, high voltage, super-beta, matched pair
- Physical packaging: through hole metal, through hole plastic, surface mount, ball grid array, power modules

PNP and NPN Transistors

The most common type of transistor is called bipolar and these are divided into NPN and PNP types. Today both are typically made by double-fission process that involves the deposition of two additional layers of doped silicon on a doped silicon wafer.

Their construction-material is most commonly silicon (their marking has the letter B) or germanium (their marking has the letter A). Original transistor were made from germanium, but they were very temperature-sensitive. Silicon transistors are much more temperature-tolerant and much cheaper to manufacture.

The only differences between PNP and NPN transistors are in manufacturing (i.e. location of the p-layers and n-layers) and of much importance in the biasing. The schematic symbols for PNP and NPN transistors, (the work horse is the NPN) are shown in figure 3 below. A silicon NPN transistor needs to be forward biased by about 0.65V for it to turn on.

The only functional difference between a PNP transistor and an NPN transistor is the proper biasing (polarity) of the junctions when operating. For any given state of operation, the current directions and voltage polarities for each type of transistor are exactly opposite each other.

- **Bipolar junction transistor**

The bipolar junction transistor (BJT) was the first type of transistor to be mass-produced. Bipolar transistors are so named because they conduct by using both majority and minority carriers. The three terminals of the BJT are named emitter, base and collector. Two p-n junctions exist inside a BJT: the base/emitter junction and base/collector junction. The BJT is commonly described as a current-operated device because the collector/emitter current is controlled by the current flowing between base and emitter terminals. Unlike the FET, the BJT is a low input-impedance device. As the base/emitter voltage (Vbe) is increased the base/emitter current and hence the collector/emitter current (Ice) increase exponentially. Because of this exponential relationship the BJT has a higher transconductance than the FET.

Bipolar transistors work as current-controlled current regulators. In other words, they restrict the amount of current that can go through them according to a smaller, controlling current. The main current that is controlled goes from collector to emitter, or from emitter to collector, depending on the type of transistor it is (PNP or NPN, respectively). The small current that controls the main current goes from base to emitter, or from emitter to base, once again depending on the type of transistor it is (PNP or NPN, respectively). According to the confusing standards of semiconductor symbology, the arrow always points against the direction of electron flow:

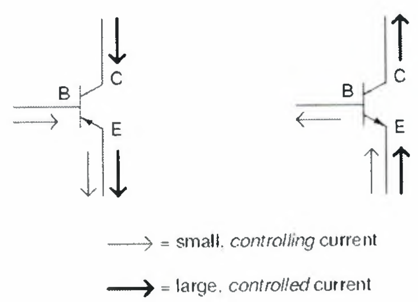


Figure 6.4 npn and pnp structure

Bipolar transistors are called *bi*polar because the main flow of electrons through them takes place in *two* types of semiconductor material: P and N, as the main current goes from emitter to collector (or visa-versa). In other words, two types of charge carriers -- electrons anIf there is no current through the base of the transistor, it shuts off like an open switch and prevents current through the collector. If there is a base current, then the transistor turns on like a closed switch and allows a proportional amount of current through the collector. Collector current is primarily limited by the base current, regardless of the amount of voltage available to push it.d holes -- comprise this main current through the transistor.

- **Field-effect transistor**

The bipolar jnction transistor is a current controlled device, that is the output transistor or FET is a voltage controlled device. The output characteristic of a FET are controlled by the input voltage, not by the input current.

The field-effect transistor (FET), sometimes called a unipolar transistor, uses either electrons (N-channel FET) or holes (P-channel FET) for conduction. The four terminals of the FET are named source, gate, drain, and body (substrate). On most FETs the body is connected to the source inside the package and this will be assumed for the following description.

A voltage applied between the gate and source (body) controls the current flowing between the drain and source. As the gate/source voltage (Vgs) is increased the drain/source current (Ids) increases roughly parabolically (Ids $\propto$ Vgs 2). In FETs the drain/source current flows through a conducting channel near the gate. This channel connects the drain region to the source region. The channel conductivity is varied by the electric field generated by the voltage applied between the gate/source terminals. In this way the current flowing between the drain and source is controlled.

6.4 Semiconductor material

The first BJTs were made from germanium (Ge) and some high power types still are. Silicon (Si) types currently predominate but certain advanced microwave and high performance versions now employ the compound semiconductor material gallium arsenide (GaAs) and the semiconductor alloy silicon germanium (SiGe). Single element semiconductor material (Ge and Si) is described as elemental.

The junction forward voltage is the voltage applied to the emitter-base junction of a BJT in order to make the base conduct a specified current. The current increases exponentially as the junction forward voltage is increased. The values given in the table are typical for a current of 1 mA (the same values apply to semiconductor diodes). The lower the junction forward voltage the better, as this means that less power is required to "drive" the transistor. The junction forward voltage for a given current decreases with temperature. For a typical silicon junction the change is approximately −2.1 mV/°C.

The electron mobility and hole mobility columns show the average speed that electrons and holes diffuse through the semiconductor material with an electric field of 1 volt per meter applied across the material. In general, the higher the electron mobility the faster the transistor. The table indicates that Ge is a better material than Si in this respect. However, Ge has four major shortcomings compared to silicon and gallium arsenide:

- its maximum temperature is limited
- it has relatively high leakage current
- it cannot withstand high voltages
- it is less suitable for fabricating integrated circuits

Because the electron mobility is higher than the hole mobility for all semiconductor materials, a given bipolar NPN transistor tends to be faster than an equivalent PNP transistor type. GaAs has the highest electron mobility of the three semiconductors. It is for this reason that GaAs is used in high frequency applications. A relatively recent FET development, the high electron mobility transistor (HEMT), has a heterostructure (junction between different semiconductor materials) of aluminium gallium arsenide (AlGaAs)-gallium arsenide (GaAs) which has double the electron mobility of a GaAs-metal barrier junction. Because of their high speed and low noise, HEMTs are used in satellite receivers working at frequencies around 12 GHz.

Max. junction temperature values represent a cross section taken from various manufacturers' data sheets. This temperature should not be exceeded or the transistor may be damaged.

Al-Si junction refers to the high-speed (aluminum-silicon) semiconductor-metal barrier diode, commonly known as a Schottky diode. This is included in the table because some silicon power IGFETs have a parasitic reverse Schottky diode formed between the source and drain as part of the fabrication process. This diode can be a nuisance, but sometimes it is used in the circuit.

6.5 Packaging

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.

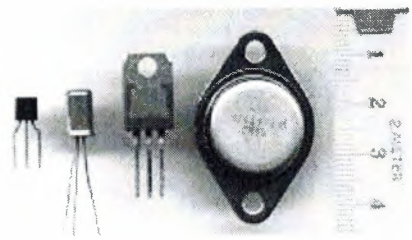


figure 6.5 Through-hole transistors (tape measure marked in centimetres)

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).

6.6 Usage of transistors

In analog circuits, transistors are used in amplifiers, (direct current amplifiers, audio amplifiers, radio frequency amplifiers), and linear regulated power supplies. Transistors are also used in digital circuits where they function as electronic switches, but rarely as discrete devices, almost always being incorporated in monolithic Integrated Circuits. Digital circuits include logic gates, random access memory (RAM), microprocessors, and digital signal processors (DSPs).

In the early days of transistor circuit design, the bipolar junction transistor, or BJT, was the most commonly used transistor. Even after MOSFETs became available, the BJT remained the transistor of choice for digital and analog circuits because of their ease of manufacture and speed. However, desirable properties of MOSFETs, such as their utility in low-power devices, have made them the ubiquitous choice for use in digital circuits and a very common choice for use in analog circuits.

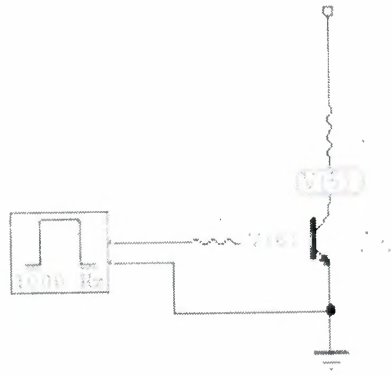


figure 6.6 BJT used as an electronic switch, in grounded-emitter configuration

The small base current controls the larger collector current. The transistor amplifies this small current to allow a larger current to flow through from its collector (C) to its emitter (E). A transistor amplifies current and can be used as a switch.

- **Switches**

Transistors are commonly used as electronic switches, for both high power applications including switched-mode power supplies and low power applications such as logic gates.

The transistor as a switch

Because a transistor's collector current is proportionally limited by its base current, it can be used as a sort of current-controlled switch. A relatively small flow of electrons sent through the base of the transistor has the ability to exert control over a much larger flow of electrons through the collector.

Suppose we had a lamp that we wanted to turn on and off by means of a switch. Such a circuit would be extremely simple:

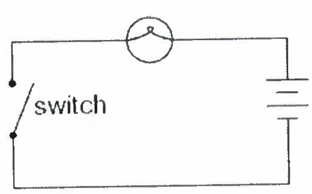


Figure 6.7

For the sake of illustration, let's insert a transistor in place of the switch to show how it can control the flow of electrons through the lamp. Remember that the controlled current through a transistor must go between collector and emitter. Since it's the current through the lamp that we want to control, we must position the collector and emitter of our transistor where the two contacts of the switch are now. We must also make sure that the lamp's current will move against the direction of the emitter arrow symbol to ensure that the transistor's junction bias will be correct:

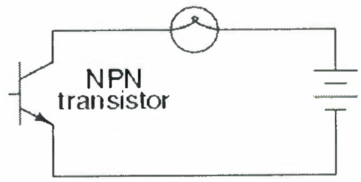


Figure 6.8

In this example was choosen an NPN transistor. A PNP transistor could also have been chosen for the job, and its application would look like this:

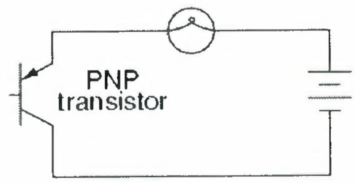


Figure 6.9

The choice between NPN and PNP is really arbitrary. All that matters is that the proper current directions are maintained for the sake of correct junction biasing (electron flow going against the transistor symbol's arrow).

Going back to the NPN transistor in our example circuit, we are faced with the need to add something more so that we can have base current. Without a connection to the base wire of the transistor, base current will be zero, and the transistor cannot turn on, resulting in a lamp that is always off. Remember that for an NPN transistor, base current must consist of electrons flowing from emitter to base (against the emitter arrow symbol, just like the lamp current). Perhaps the simplest thing to do would be to connect a switch between the base and collector wires of the transistor like this:

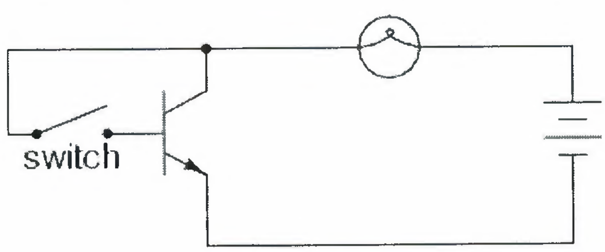


figure 6.10

If the switch is open, the base wire of the transistor will be left "floating" (not connected to anything) and there will be no current through it. In this state, the transistor is said to be cutoff. If the switch is closed, however, electrons will be able to flow from the emitter through to the base of the transistor, through the switch and up to the left side of the lamp, back to the positive side of the battery. This base current will enable a much larger flow of electrons from the emitter through to the collector, thus lighting up the lamp. In this state of maximum circuit current, the transistor is said to be saturated.

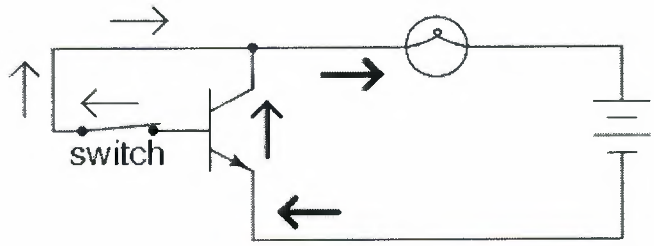


Figure 6.11

Of course, it may seem pointless to use a transistor in this capacity to control the lamp. After all, we're still using a switch in the circuit, aren't we? If we're still using a switch to control the lamp -- if only indirectly -- then what's the point of having a transistor to control the current? Why not just go back to our original circuit and use the switch directly to control the lamp current?

There are a couple of points to be made here, actually. First is the fact that when used in this manner, the switch contacts need only handle what little base current is necessary to turn the transistor on, while the transistor itself handles the majority of the lamp's current. This may be an important advantage if the switch has a low current rating: a small switch may be used to control a relatively high-current load. Perhaps more importantly, though, is the fact that the current-controlling behavior of the transistor enables us to use something completely different to turn the lamp on or off.

- **Amplifiers**

From mobile phones to televisions, vast numbers of products include amplifiers for sound reproduction, radio transmission, and signal processing. The first discrete transistor audio amplifiers barely supplied a few hundred milliwatts, but power and audio fidelity gradually increased as better transistors became available and amplifier architecture evolved.

Transistors are commonly used in modern musical instrument amplifiers, where circuits up to a few hundred watts are common and relatively cheap. Transistors have largely replaced valves in instrument amplifiers. Some musical instrument amplifier manufacturers mix transistors and vacuum tubes in the same circuit, to utilize the inherent benefits of both devices.

- **Computers**

The "first generation" of electronic computers used vacuum tubes, which generated large amounts of heat, were bulky, and were unreliable. The development of the transistor was key to computer miniaturization and reliability. The "second generation" of computers, through the late 1950s and 1960s featured boards filled with individual transistors and magnetic memory cores. Subsequently, transistors, other components, and their necessary wiring were integrated into a single, mass-manufactured component: the integrated circuit. Transistors incorporated into integrated circuits have replaced most discrete transistors in modern digital computers.

- **Using a transistor switch with sensors**

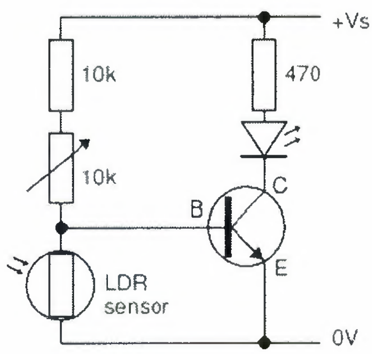


Figure 6.12 LED lights when the LDR is dark

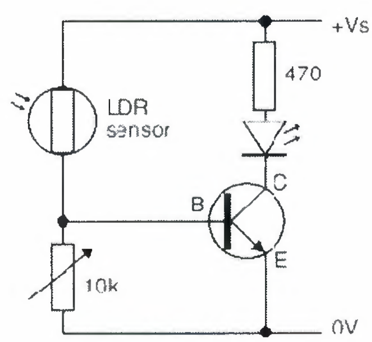


Figure 6.13 LED lights when the LDR is **bright**

The top circuit diagram shows an LDR (light sensor) connected so that the LED lights when the LDR is in darkness. The variable resistor adjusts the brightness at which the transistor switches on and off. Any general purpose low power transistor can be used in this circuit.

The 10kΩ fixed resistor protects the transistor from excessive base current (which will destroy it) when the variable resistor is reduced to zero. To make this circuit switch at a suitable brightness you may need to experiment with different values for the fixed resistor, but it must not be less than 1kΩ.

If the transistor is switching a load with a coil, such as a motor or relay, remember to add a protection diode across the load.

The switching action can be inverted, so the LED lights when the LDR is brightly lit, by swapping the LDR and variable resistor. In this case the fixed resistor can be omitted because the LDR resistance cannot be reduced to zero.

Note that the switching action of this circuit is not particularly good because there will be an intermediate brightness when the transistor will be partly on (not saturated). In this state the transistor is in danger of overheating unless it is switching a small current. There is no problem with the small LED current, but the larger current for a lamp, motor or relay is likely to cause overheating.

Other sensors, such as a thermistor, can be used with this circuit, but they may require a different variable resistor. You can calculate an approximate value for the variable resistor (Rv) by using a multimeter to find the minimum and maximum values of the sensor's resistance (Rmin and Rmax):

Variable resistor, Rv = square root of (Rmin × Rmax)

For example an LDR: Rmin = 100Ω, Rmax = 1MΩ, so Rv = square root of (100 × 1M) = 10kΩ.

You can make a much better switching circuit with sensors connected to a suitable IC (chip). The switching action will be much sharper with no partly on state.

6.7 Transistor codes

There are three main series of transistor codes used in the UK:

Codes beginning with B (or A), for example BC108, BC478. The first letter B is for silicon, A is for germanium (rarely used now). The second letter indicates the type; for example C means low power audio frequency; D means high power audio frequency; F means low power high frequency. The rest of the code identifies the particular transistor. There is no obvious logic to the numbering system. Sometimes a letter is added to the end (eg BC108C) to identify a special version of the main type, for example a higher current gain or a different case style. If a project specifies a higher gain version (BC108C) it must be used, but if the general code is given (BC108) any transistor with that code is suitable.

- **Codes beginning with TIP, for example TIP31A**

TIP refers to the manufacturer: Texas Instruments Power transistor. The letter at the end identifies versions with different voltage ratings.

- **Codes beginning with 2N, for example 2N3053**

  The initial '2N' identifies the part as a transistor and the rest of the code identifies the particular transistor. There is no obvious logic to the numbering system.

6.8 Choosing a transistor

Most projects will specify a particular transistor, but if necessary you can usually substitute an equivalent transistor from the wide range available. The most important properties to look for are the maximum collector current IC and the current gain hFE. To make selection easier most suppliers group their transistors in categories determined either by their typical use or maximum power rating.

To make a final choice you will need to consult the tables of technical data which are normally provided in catalogues. They contain a great deal of useful information but they can be difficult to understand if you are not familiar with the abbreviations used.

CHAPTER 7. DARLINGTON PAIR OF TRANSISTORS

7.1 Overview

In electronics, the Darlington transistor is a semiconductor device which combines two bipolar transistors in tandem (often called a "Darlington pair") in a single device so that the current amplified by the first is amplified further by the second transistor. This gives it high current gain (written β or hFE), and takes up less space than using two discrete transistors in the same configuration. The use of two separate transistors in an actual circuit is still very common, even though integrated packaged devices are available.

Transistors are an essential component in a sensor circuit. Usually transistors are arranged as a pair, known as a 'darlington pair'. It is very important that we can identify this arrangement of transistors and state clearly why they are used. A darlington pair is used to amplify weak signals so that they can be clearly detected by another circuit or a computer/microprocessor.

A Darlington pair behaves like a single transistor with a very high current gain. This is beneficial as many commonly-used transistors with high gains have a low current threshold. The total gain of the Darlington is the product of the gains of the individual transistors: βDarlington = $\beta 1 \times \beta 2$. The base-emitter voltage is also higher; it is the sum of both base-emitter voltages: VBE = VBE1 + VBE2

To turn on there must be ~0.6 V across both base-emitter junctions which are connected in series inside the Darlington pair. It therefore requires more than 1.2 V to turn on. When a Darlington pair is fully conducting, there is a residual saturation voltage of 0.6 V in this configuration, which can lead to substantial power dissipation. Another drawback is that the switching speed can be slow, due to the inability of the first transistor to actively inhibit the current into the base of the second device. This can make the pair slow to switch off. To alleviate this, a resistor of a few hundred ohms between the second device's base and emitter is often used. Integrated Darlington pairs often include this resistor.

The circuit below is a 'Darlington Pair' driver. The first transistor's emitter feeds into the second transistor's base and as a result the input signal is amplified by the time it reaches the output. The important point to remember is that the Darlington Pair is made up of two transistors and when they are arranged as shown in the circuit they are used to amplify weak signals.

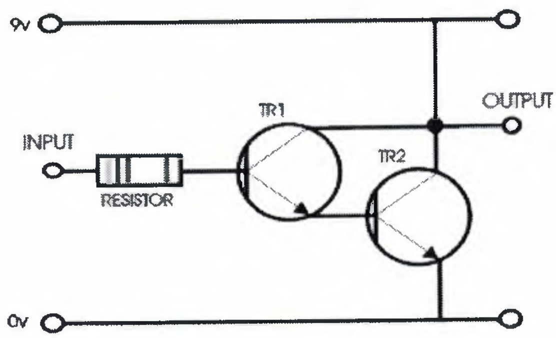


figure 7.1 Darlington pair driver

The circuit to the below shows a single transistor. When the switch is pressed current flows from the 9v to the 0v and also to the base of the transistor. This allows the transistor to switch and in turn, current / voltage flows through the bulb, which lights. However, there is a potential problem with this circuit. The signal / current at the base of the transistor may be too weak to switch the transistor and allow the bulb to light or it may flicker on and off.

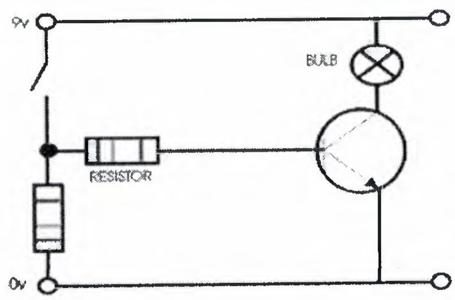


figure 7.2 single transistor circuit

A possible solution is seen below. A second transistor is added to the circuit, the circuit is now likely to work as the original signal / current is amplified. The amount by which the weak signal is amplified is called the 'GAIN'.

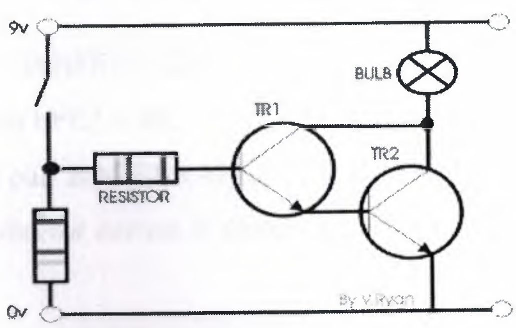


figure 7.3 darlington pair two transistors

This is two transistors connected together so that the current amplified by the first is amplified further by the second transistor. The overall current gain is equal to the two individual gains multiplied together:

Darlington pair current gain, $hFE = hFE1 \times hFE2$ (hFE1 and hFE2 are the gains of the individual transistors). This gives the Darlington pair a very high current gain, such as 10000, so that only a tiny base current is required to make the pair switch on.

A Darlington pair behaves like a single transistor with a very high current gain. It has three leads (B, C and E) which are equivalent to the leads of a standard individual transistor. To turn on there must be 0.7V across both the base-emitter junctions which are connected in series inside the Darlington pair, therefore it requires 1.4V to turn on. Darlington pairs are available as complete packages but you can make up your own from two transistors; TR1 can be a low power type, but normally TR2 will need to be high power. The maximum collector current Ic(max) for the pair is the same as Ic(max) for TR2.

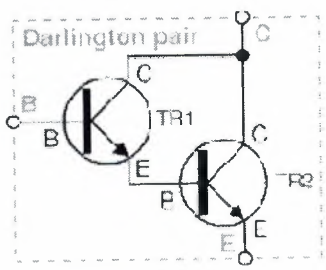


figure 7.4 darlington pair of two transistors

This is two transistors connected together so that the amplified current from the first is amplified further by the second transistor. This gives the Darlington pair a very high current gain such as 10000. Darlington pairs are sold as complete packages containing the two transistors. They have three leads (B, C and E) which are equivalent to the leads of a standard individual transistor.

You can make up your own Darlington pair from two transistors. For example:

For TR1 use BC548B with hFE1 = 220.

For TR2 use BC639 with hFE2 = 40.

The overall gain of this pair is $hFE1 \times hFE2 = 220 \times 40 = 8800$.

The pair's maximum collector current IC(max) is the same as TR2.

CHAPTER 8. THE LDR (The Light Dependent Resistor)

8.1 Overview

A light-dependent resistor, alternatively called an LDR, photoresistor, photoconductor, or photocell, is a variable resistor whose value decreases with increasing incident light intensity. The light dependent resistor is a cadmium-sulphide photocell, and acts as a high resistance under dark cınditions and as low resistance when brightly illuminated.

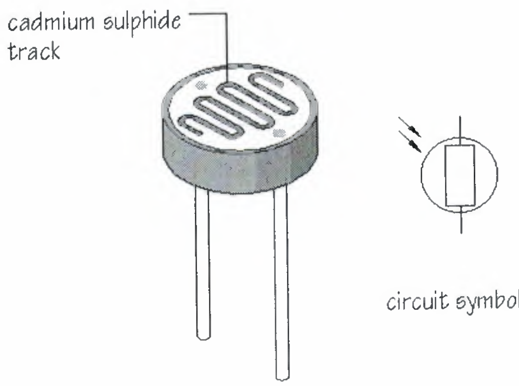


figure 8.1 light dependent resistor and its circuit symbol

The light-sensitive part of the LDR is a wavy track of cadmium sulphide. Light energy triggers the release of extra charge carriers in this material, so that its resistance falls as the level of illumination increases.

An LDR is made of a high-resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

A photoelectric device can be either intrinsic or extrinsic. In intrinsic devices, the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire bandgap. Extrinsic devices have impurities added, which have a ground state energy closer to the conduction band - since the electrons don't have as far to jump, lower energy photons (i.e. longer wavelengths and lower frequencies) are sufficient to trigger the device.

Two of its earliest applications were as part of smoke and fire detection systems and camera light meters. Because cadmium sulfide cells are inexpensive and widely available, LDRs are still used in electronic devices that need light detection capability, such as security alarms, street lamps, and clock radios. Other apllications are in camera, strobe (colour temperature reading) clocks, switch for lighting and optical switches.

8.2 Applications of LDR

The LDR or light Dependent Resistor are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1 MΩ, but when they are illuminated with light, resistance drops.

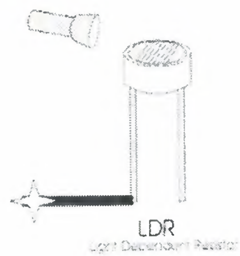


Figure 8.2 a LDR

When the light level is low the resistance of the LDR is high. This prevents current from flowing to the base of the transistors. Consequently the LED does not light. However, when light shines onto the LDR its resistance falls and current flows into the base of the first transistor and then the second transistor. The LED lights.

8.2.1 Light Sensors

A light sensor is a sensor that measures the amount of light that it sees. It reports the amount of light to the RCX as a number between 0 (total darkness) and 100 (very bright).

The light sensor detects light from a very wide angle. You can narrow its detection field by placing a 1x2 beam with a hole in front of the sensor. Now the light sensor will only detect light that is directly in front of it.

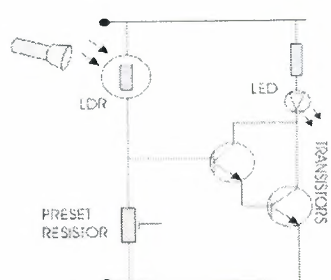


Figure 8.3 this is an example of a light sensor circuit. The preset resistor can be turned up or down to increase or decrease resistance, in this way it can make the circuit more or less sensitive.

Light sensors are devices that senses the light pulses in an optical fiber and converts them into electrical pulses. It uses the principle of photoconductivity, which is exhibited in certain materials that change their electrical conductivity when exposed to light.

Everything has an electrical resistance, some more than others. An LDR will have a resistance that varies according to the amount of visible light that falls on it. A close up of an LDR is shown below:

figure 8.4 ldr

The light falling on the brown zigzag lines on the sensor, causes the resistance of the device to fall. This is known as a negative co-efficient. There are some LDRs that work in the opposite way i.e. their resistance increases with light.

- **Photocells**

Photocells act as light sensors. Photocell is a solid-state device that converts light into electrical energy by producing a voltage, as in a photovoltaic cell, or uses light to regulate the flow of current, as in a photoconductive cell. It is used in automatic control systems for doors, lighting, etc. Photocells measure light levels, allowing artificial lighting to supplement natural daylight. Inlike infrared sensors that are good for line followers or detecting the presense of an object, photocells are good when you just want to detect light. For example, you might want a sensor that detects when a flashlight is on, or when the sun is out. Photocells are used in automatic night lights and in street lamps that turn themselves on at night.

figure 8.5 photocell

• Available in center tap dual cell configurations as well as specially selected resistance ranges for special applications

• Easy to use in DC or AC circuits - they are a light variable resistor and hence symmetrical with respect to AC waveforms

• Usable with almost any visible or near infrared light source such as LEDS; neon; fluorescent, incandescent bulbs, lasers; flame sources;
sunlight; etc

• Available in a wide range of resistance values

Applications

Photoconductive cells are used in many different types of circuits and applications.

Suitable for low voltage battery operation of many demanding applications such as, security lights, street lights, CCTVs, backlight controls for LCDs, PDAs, mobile phones, car navigation systems etc. dimmers for keypads, clocks and watches , Cam eras , automotive, rain, light and tunnel systems.

Analog Applications

• Camera Exposure Control
• Auto Slide Focus - dual cell
• Photocopy Machines - density of toner
• Colorimetric Test Equipment
• Densitometer
• Electronic Scales - dual cell
• Automatic Gain Control - modulated light source
• Automated Rear View Mirror

Digital Applications

• Automatic Headlight Dimmer
• Night Light Control
• Oil Burner Flame Out
• Street Light Control
• Position Sensor

Photocells With Lead Free Terminals

This small 'coated' CdS cell has lead free terminals that will withstand a soldering temperature of up to 260°C for 3 seconds at a distance of 5mm from its base. This cell is suitable for applications granted freedom to use CdS cells by an exclusion from RoHS.

Applications:

- Automatic Lighting
- Camera exposure control
- Automatic photoelectric control
- Opto-electronic coupling
- Automatic photoelectric inspection
- Photoelectric light-controlled toys

8.1.2 PHOTORESISTOR

A photoresistor is an electronic component whose resistance decreases with increasing incident light intensity. It can also be referred to as a light-dependent resistor (LDR), photoconductor, or photocell.

A photoresistor is made of a high-resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

Figure 8.7 The internal components of a photoelectric control for a typical streetlight.

The photoresistor is facing rightwards, and controls whether current flows through the heater which opens the main power contacts. At night, the heater cools, closing the power contacts, energizing the street light. The heater/bimetal mechanism provides a built-in time-delay.

A photoelectric device can be either intrinsic or extrinsic. An intrinsic semiconductor has its own charge carriers and is not an efficient semiconductor, eg. silicon. In intrinsic devices, the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire bandgap. Extrinsic devices have impurities added, which have a ground state energy closer to the conduction band — since the electrons don't have as far to jump, lower energy photons (i.e. longer wavelengths and lower frequencies) are sufficient to trigger the device. If a sample of silicon has some of its atoms replaced by phosphorus atoms(impurities), there will be extra electrons available for conduction. This is an example of an extrinsic semiconductor.

Cadmium sulphide or cadmium sulphide (CdS) cells rely on the material's ability to vary its resistance according to the amount of light striking the cell. The more light that strikes the cell, the lower the resistance. Although not accurate, even a simple CdS cell can have a wide range of resistance from less than 100 Ω in bright light to in excess of 10 MΩ in darkness. Many commercially available CdS cells have a peak sensitivity in the region of 500nm - 600nm. The cells are also capable of reacting to a broad range of frequencies, including infrared (IR), visible light, and ultraviolet (UV). They are often found on street lights as automatic on/off switches. They were once even used in heat-seeking missiles to sense for targets.

Applications

Photoresistors come in many different types. Inexpensive cadmium sulphide cells can be found in many consumer items such as camera light meters, clock radios, security alarms, street lights and outdoor clocks. They are also used in some dynamic compressors to control gain reduction. At the other end of the scale, Ge:Cu photoconductors are among the best far-infrared detectors available, and are used for infrared astronomy and infrared spectroscopy.

CHAPTER 9. BUZZER

9.1 Overview

Buzzer is a transducer which converts electrical energy to sound. A transducer is a device, usually electrical, electronic, or electro-mechanical, that converts one type of energy to another for various purposes including measurement or information transfer. In a broader sense, a transducer is sometimes defined as any device that converts a signal from one form to another.

For example, an LDR is an input transducer (sensor) which converts brightness (light) to resistance. It is made from cadmium sulphide (CdS) and the resistance decreases as the brightness of light falling on the LDR increases.

Transducers are electric or electronic devices that transform energy from one manifestation into another. Anything that converts energy can be considered a transducer. Transducers that detect or transmit information include common items such as microphones, Geiger meters, potentiometers, pressure sensors, thermometers, and antennae. A microphone, for example, converts sound waves that strike its diaphragm into an analogous electrical signal that can be transmitted over wires. A pressure sensor turns the physical force being exerted on the sensing apparatus into an analog reading that can be easily represented

Most transducers have an inverse that allows for the energy to be returned to its original form. Audio cassettes, for example, are created by using a transducer to turn the electrical signal from the microphone pick-up – which in turn went through a transducer to convert the sound waves into electrical signal – into magnetic fluctuations on the tape head. These magnetic fluctuations are then read and converted by another transducer – in this case a stereo system – to be turned back into an electrical signal, which is then fed by wire to speakers, which act as yet another transducer to turn the electrical signal back into audio waves.

Other transducers turn one type of energy into another form, not for the purpose of measuring something in the external environment or to communicate information, but rather to make use of that energy in a more productive manner. A light bulb, for example, one of the many transducers around us in our day-to-day lives, converts electrical energy into visible light. Electric motors are another common form of electromechanical transducer, converting electrical energy into kinetic energy to perform a mechanical task. The inverse of an electric motor – a generator – is also a transducer, turning kinetic energy into electrical energy that can then be used by other devices.

As in all energy conversions, some energy is lost when transducers operate. The efficiency of a transducer is found by comparing the total energy put into it to the total energy coming out of the system. Some transducers are very efficient, while others are extraordinarily inefficient. A radio antenna, for example, acts as a transducer to turn radio frequency power into an electromagnetic field; when operating well, this process is upwards of 80% efficient. Most electrical motors, by contrast, are well under 50% efficient, and a common light bulb, because of the amount of energy lost as heat, is less than 10% efficient.

An electronic buzzer comprises an acoustic vibrator comprised of a circular metal plate having its entire periphery rigidly secured to a support, and a piezoelectric element adhered to one face of the metal plate. A driving circuit applies electric driving signals to the vibrator to vibrationally drive it at a 1/N multiple of its natural frequency, where N is an integer, so that the vibrator emits an audible buzzing sound. The metal plate is preferably mounted to undergo vibration in a natural vibration mode having only one nodal circle. The drive circuit includes an inductor connected in a closed loop with the vibrator, which functions as a capacitor, and the circuit applies signals at a selectively variable frequency to the closed loop to accordingly vary the inductance of the inductor to thereby vary the period of oscillation of the acoustic vibrator and the resultant frequency of the buzzing sound.

Buzzer is an electric signaling device, such as a doorbell, that makes a buzzing sound. A buzzer or beeper is a signalling device, usually electronic, typically used in automobiles, household appliances such as a microwave oven, or game shows.

It most commonly consists of a number of switches or sensors connected to a control unit that determines if and which button was pushed or a preset time has lapsed, and usually illuminates a light on the appropriate button or control panel, and sounds a warning in the form of a continuous or intermittent buzzing or beeping sound. Initially this device was based on an electromechanical system which was identical to an electric bell without the metal gong (which makes the ringing noise). Often these units were anchored to a wall or ceiling and used the ceiling or wall as a sounding board. Another implementation with some AC-connected devices was to implement a circuit to make the AC current into a noise loud enough to drive a loudspeaker and hook this circuit up to a cheap 8-ohm speaker. Nowadays, it is more popular to use a ceramic-based piezoelectric sounder like a Sonalert which makes a high-pitched tone. Usually these were hooked up to "driver" circuits which varied the pitch of the sound or pulsed the sound on and off.

The word "buzzer" comes from the rasping noise that buzzers made when they were electromechanical devices, operated from stepped-down AC line voltage at 50 or 60 cycles. Other sounds commonly used to indicate that a button has been pressed are a ring or a beep. Some systems, such as the one used on Jeopardy!, make no noise at all, instead using light.

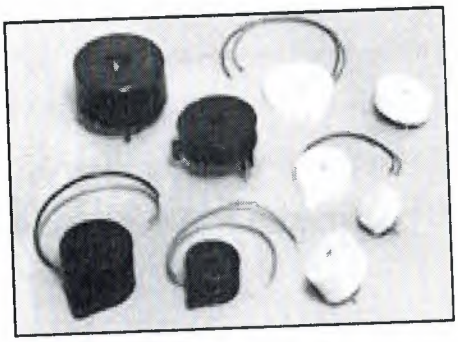


Figure 9.1 electric buzzers

Buzzer and Bleeper

These devices are output transducers converting electrical energy to sound. They contain an internal oscillator to produce the sound which is set at about 400Hz for buzzers and about 3kHz for bleepers.

Buzzers have a voltage rating but it is only approximate, for example 6V and 12V buzzers can be used with a 9V supply. Their typical current is about 25mA. Bleepers have wide voltage ranges, such as 3-30V, and they pass a low current of about 10mA. Buzzers and bleepers must be connected the right way round, their red lead is positive (+).

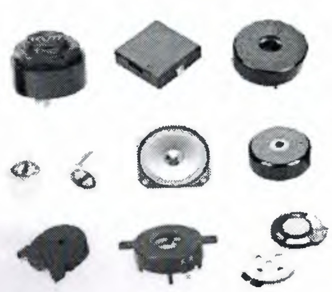


Figure 9.2 buzzers

CHAPTER 10. TESTING OF THE ELECTRONIC DEVICES

10.1 Testing battery

Battery Testing can be done in more than one way. The most popular is measurement of specific gravity and battery voltage. To measure specific gravity buy a temperature compensating hydrometer and measure voltage, use a digital D.C. Voltmeter. A good digital load tester may be a good purchase if you need to test batteries sealed batteries.

You must first have the battery fully charged. The surface charge must be removed before testing. If the battery has been sitting at least several hours (I prefer at least 12 hours) you may begin testing. To remove surface charge the battery must experience a load of 20 amps for 3 plus minutes. Turning on the headlights (high beam) will do the trick. After turning off the lights you are ready to test the battery.

Table 10.1

State of Charge	Specific Gravity	Voltage	
		12V	6V
100%	1.265	12.7	6.3
*75%	1.225	12.4	6.2
50%	1.190	12.2	6.1
25%	1.155	12.0	6.0
Discharged	1.120	11.9	6.0

*Sulfation of Batteries starts when specific gravity falls below 1.225 or voltage measures less than 12.4 (12v Battery) or 6.2 (6 volt battery). Sulfation hardens the battery plates reducing and eventually destroying the ability of the battery to generate Volts and Amps..

10.2 Transistor Testing Methodology

You can think of a transistor as two back-to-back diodes in one package as shown in *figure.*

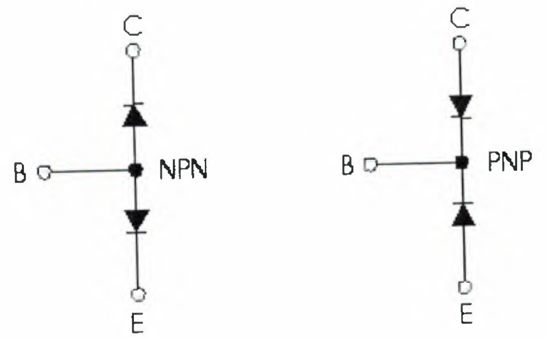


Figure 5

Transistors come in many different case styles, three of which are shown in Figure 10.1. It is important to know where C, B, E are for any given case. Assuming it is known that if the transistor is NPN or PNP, and assuming it is known where B, C, and E are, then just test the B-C junction and the B-E junction as if they were standard diodes. if one of those junctions is a "bad diode", then the transistor is bad.

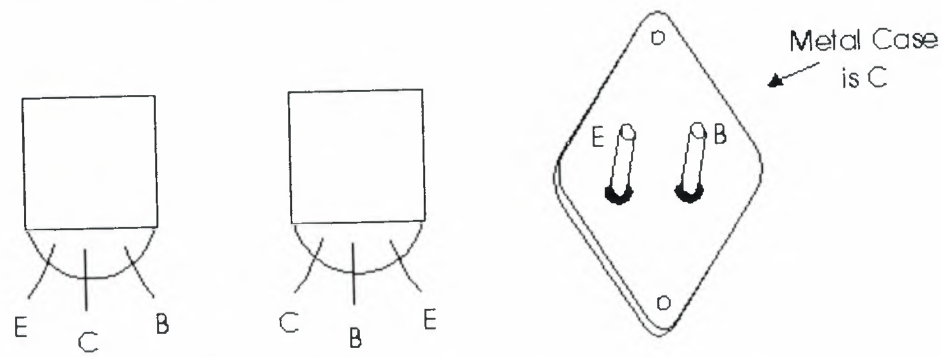


Figure 10.1 different case styles of transistors

The best way to test transistors with a DMM is to make use of the "diode test" function. For this method, if we read a short circuit (0 Ohms or voltage drop of 0), or the transistor fails any of the readings, it is bad and must be replaced. Connect the meter leads with the polarity as shown and verify that the base-to-emitter and base-tocollector junctions read as a forward biased diode: 0.5 to 0.8 VDC. Reverse the meter connections to the transistor and verify that both PN junctions do not conduct. Meter should indicate an open circuit. (Display = OUCH or OL.)

Finally read the resistance from emitter to collector and verify an open circuit reading in both directions. (Note: A short can exist from emitter to collector even if the individual PN junctions test properly.) Assuming it is known that if the transistor is NPN or PNP, and assuming it is known where B, C, and E are, then B-C junction and the B-E junction can be tested as if they were standard diodes. If one of those junctions is a "bad diode", then the transistor is bad.

Also, check the resistance from C to E using a higher Ohms scale (say, the 2 Meg scale). Be sure your fingers don't touch the metal test points or you will just measure your skin resistance.

If the transistor is good, you should get an open-circuit reading from collector to emitter.A transistor can be tested for shorts, opens, or leakage, as though it is just a pair of connected diodes.

Usıng Meter To Separate Npn From Pnp

If it does not known if the transistor is NPN or PNP, then it can be found out which it is using Ohm-meter if it is known which lead of your meter is positive. Assuming it's known where C, B, and E are on the transistor, the following must be done:

Connect the positive lead of the Ohm-meter to the base. Touch the other lead of your meter to the collector. If there is a reading, the transistor is NPN. To verify, move the lead from the collector to the emitter and you should still get a reading.

If the meter reads open-circuit, then connect the negative lead to the base and touch the positive lead to the collector. If there is a reading, then the transistor is PNP. Verify by measuring from base to emitter.

Testing with a (Digital) DMM

Set your meter to the diode test. Connect the red meter lead to the base of the transistor. Connect the black meter lead to the emitter. A good NPN transistor will read a junctıon drop voltage of between .45v and .9v. A good PNP transistor will read OPEN. Leave the red meter lead on the base and move the black lead to the collector. The reading should be the same as the previous test. Reverse the meter leads in your hands and repeat the test. This time, connect the black meter lead to the base of the transistor. Connect the red meter lead to the emitter. A good PNP transistor will read a JUNCTION DROP voltage of between .45v and .9v. A good NPN transistor will read OPEN. Leave the black meter lead on the base and move the red lead to the collector. The reading should be the same as the previous test. Place one meter lead on the collector, the other on the emitter. The meter should read OPEN. Reverse your meter leads. The meter should read OPEN. This is the same for both NPN and PNP transistors.

10.3 Testing Darlington Transistors

A Darlington is a special type of configuration usually consisting of 2 transistors fabricated on the same chip or at least mounted in the same package. Discrete implementations as well as Darlingtons with more than 2 transistors are also possible.
In many ways, a Darlington configuration behaves like a single transistor where:
the current gains (Hfe) of the individual transistors it is composed of are multiplied together and, the B-E voltage drops of the individual transistors it is composed of are added together. Darlingtons are used where drive is limited and the high gain - typically over 1,000 - is needed. Frequency response is not usually that great, however.

Testing with a VOM or DMM is basically similar to that of normal bipolar transistors except that in the forward direction, B-E will measure higher than a normal transistor on a VOM (but not open and 1.2 to 1.4 V on a DMM's diode test range due to the pair of junctions in series. Note, 1.2 V may be too high for some DMMs and thus a good Darlington may test open - confirm that the open circuit reading on your DMM is higher than 1.4 V or check with a known good Darlington.

10.4 Testing LEDs

Electrically, LEDs behave like ordinary diodes except that their forward voltage drop is higher.
Typical values are:
An LED can be weak and still pass the electrical tests so checking for output is still necessary.

Color	Potential Difference
Infrared	1.6 V
Red	1.8 V to 2.1 V
Orange	2.2 V
Yellow	2.4 V
Green	2.6 V
Blue	3.0 V to 3.5 V

These voltages are at reasonable forward current. Depending on the actual technology (i.e., compounds like GaAsP, GaP, GaAsP/GaP, GaAlAs, etc.), actual voltages can vary quite a bit. For example, the forward voltage drop of red LEDs may range at least from 1.50 V to 2.10 V. Therefore, LED voltage drop is not a reliable test of color though multiple samples of similar LEDs should be very close. Obviously, if the device is good, it will also be emitting light when driven in this way if the current is high enough.

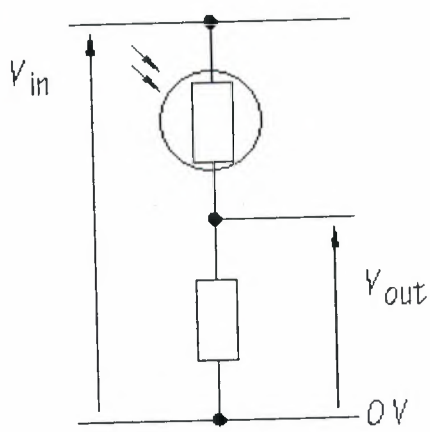
So, test for short and open with a multimeter (but it must be able to supply more than the forward voltage drop to show a non-open condition).

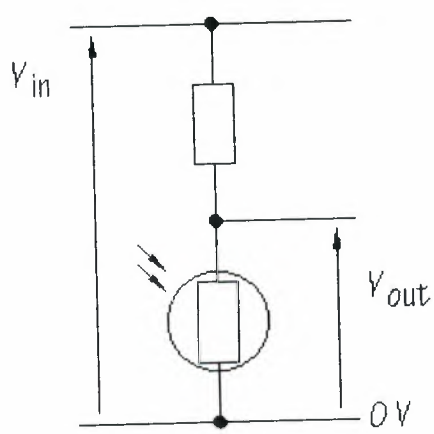
10.5 LDR TESTING

Possible circuits :

This practical circuits about using a light dependent resistor (LDR) as a sensor. The LDR must be part of a voltage divider circuit in order to give an output voltage Vout which changes with illumination.

There are just two ways of constructing the voltage divider, with the LDR at the top, or with the LDR at the bottom:





The formula for calculating Vout :

$$V_{\text{out}} = \frac{R_{\text{bottom}}}{R_{\text{bottom}} + R_{\text{top}}} \times V_{\text{in}} \qquad (6)$$

For example, R= 10 kΩ , LDR has a resistance of 5 kΩ room light, and 200 kΩ in the dark conditions. Then, according to the formula, Vout = 6V in light, and 0.43V in dark conditions. In other words, this circuit gives a LOW voltage when the LDR is in the shade, and a HIGH voltage when the LDR is in the light. The voltage divider circuit gives an output voltage which changes with illumination.

We can measure the LDR'S resistance by using multimeter as an ohmmeter to see if our LDR is ok or not. First we measure it under light conditions, then in the dark conditions and compare the results.

It doesn't need to shine light directly onto the LDR. If the reading on the meter changes as shadows fall onto the surface of the LDR, LDR is ok. Now cover the LDR with your hand so that it is in the shade. The resistance of the LDR will increase.

The voltage divider is most sensitive when the resistance of the fixed resistor is equal to the resistance of the LDR. Voltage dividers are most sensitive when Rbottom and Rtop have equal values

Perhaps first circuit should be called a dark sensor, since it gives a HIGH Vout when the LDR is covered.

The action of the voltage divider is reversed when the LDR is used as Rbottom instead of as Rtop.

Conclusions

It matters what value of fixed resistor used in a voltage divider.

The optimum value of fixed resistor gives the biggest changes in Vout . This happens when Rbottom = Rtop .

It can be decided that how a voltage divider circuit is going to work by thinking about whether to use the sensor component as R_{bottom} or as R_{top} .

CHAPTER 11. CIRCUIT DIAGRAM AND RESULTS

The light activated alarm circuit was constructed in accordance with the circuit designed as illustrated Figure 11.1.

A light-activated alarm circuit diagram is:

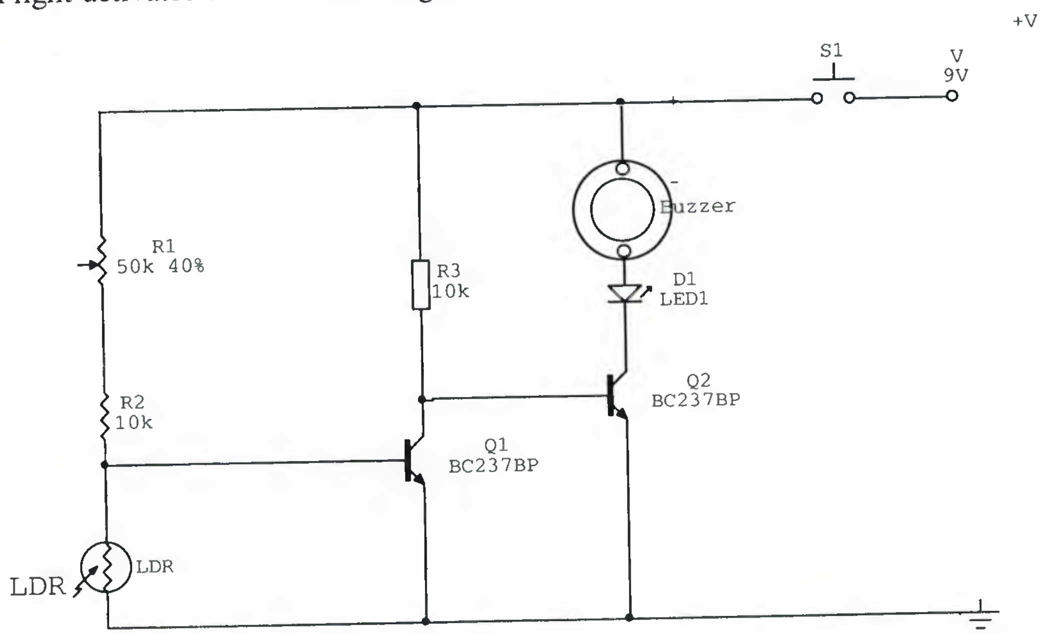


Figure 11.1 light-activated alarm circuit diagram

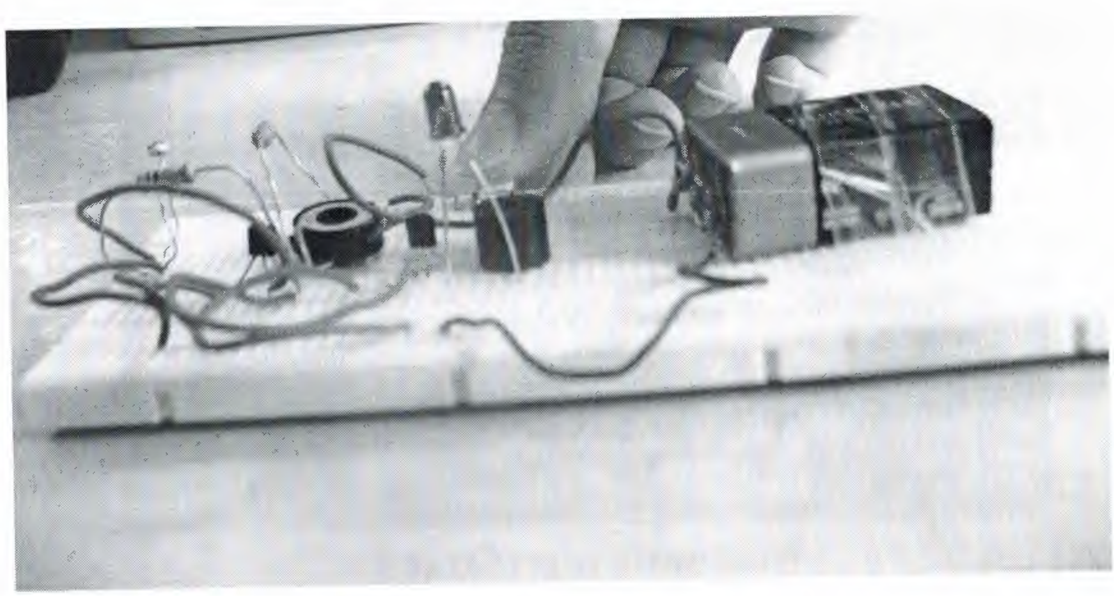


Foto 11.1 complete circuit on the breadboard

The design was simulated on breadboard. In the circuit, alarm sounds when a light is shone to the LDR, and when pressing the reset button under lighting conditions.

This light activated alarm uses a light detecting resistor (LDR) to monitor the absence or presence of light. The alarm is triggered when light is detected. A LED turns on when the alarm is activated. A potentiometer adjusts the sensistivy of the light activated alarm.

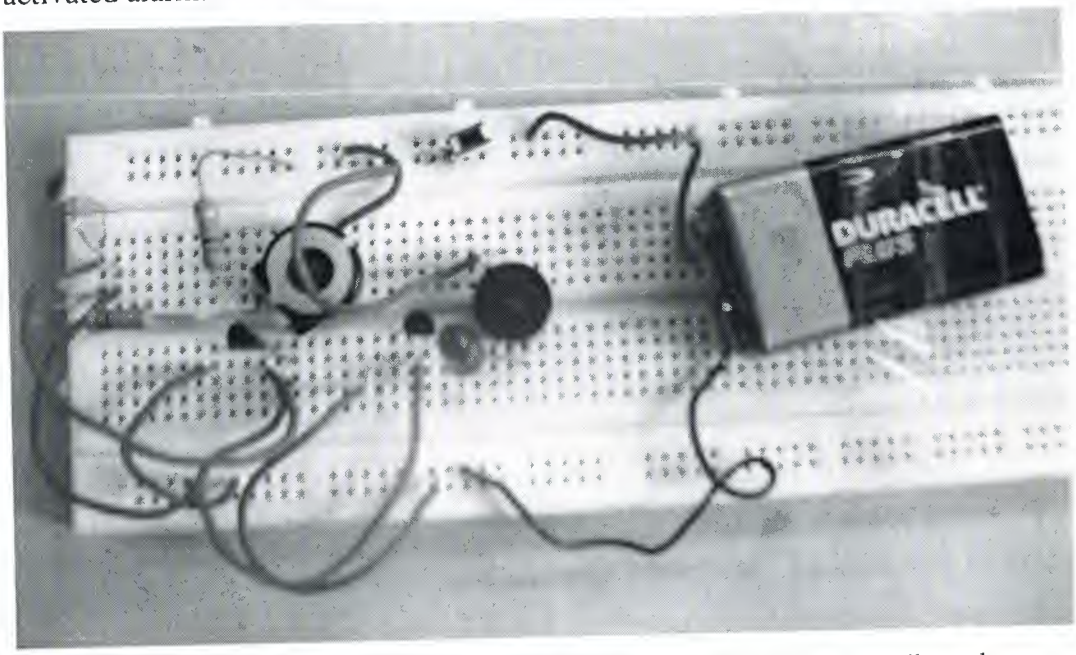


Foto 11.2 light-activated alarm circuit built on the breadboard

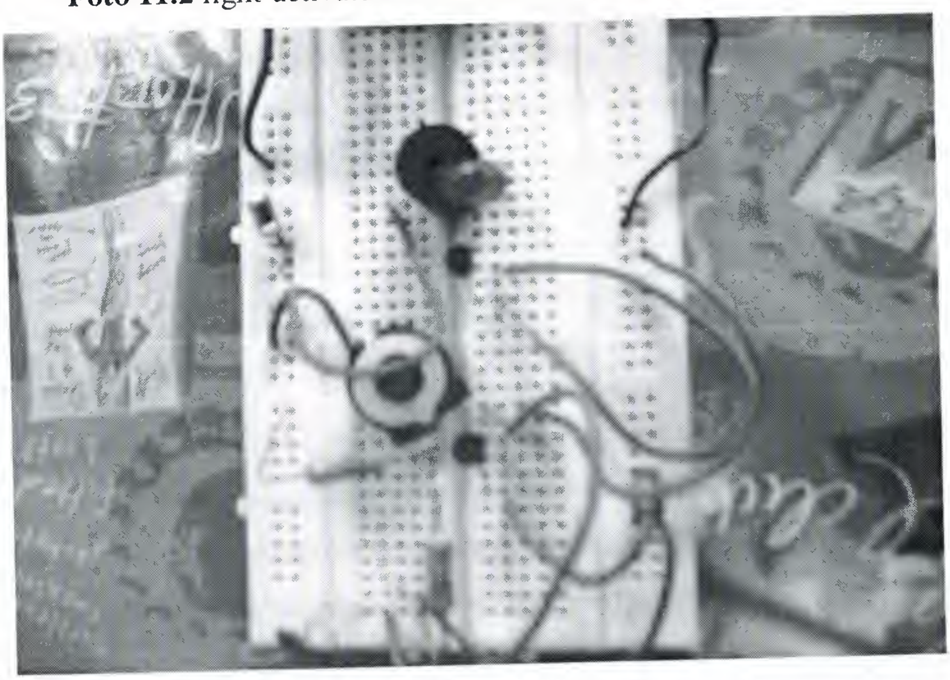


Foto 11.3 Circuit without battery

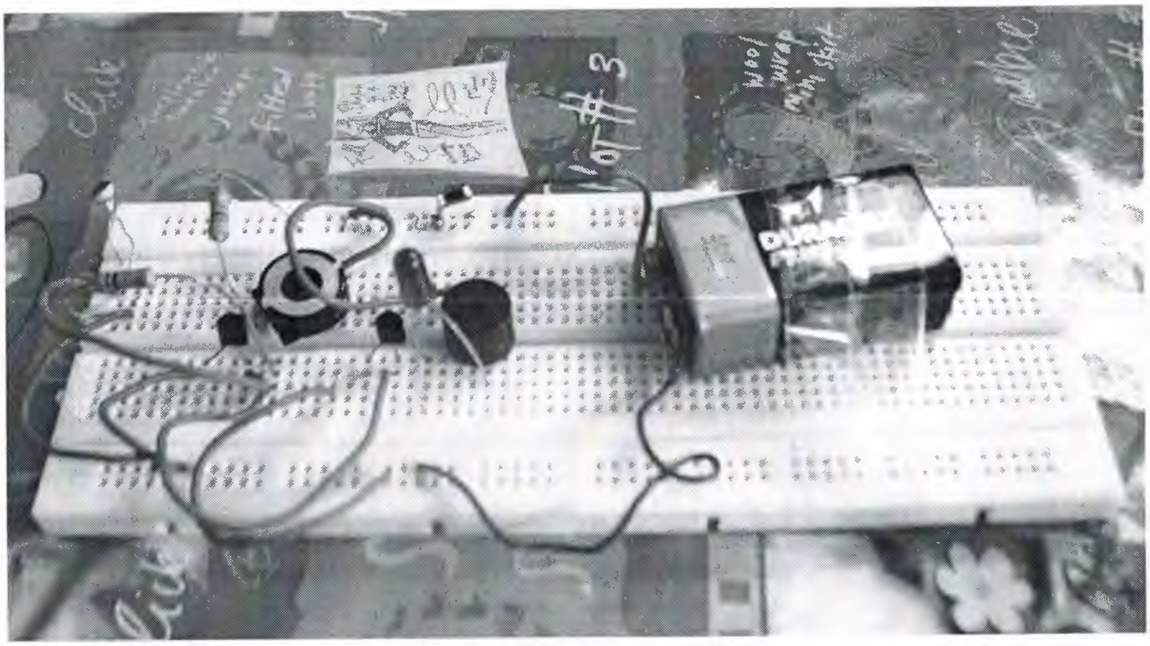


Foto 11.4 light activated alarm circuit simulated on the breadboard

The LDR in this circuit, is set up with a transistor in such a way so that in light condition, it's resistance is low, allowing current to trigger the transistor Q1. When the light is low, the resistance of the LDR is too much and the transistor is not triggered. The amount of light needed (sensitivity) to switch the transistor can be adjusted by R1, which sets the bypass level of the transistor. Once the Q1 is triggered, it acts with Q2 as a Darlington pair. The warning sound is transmitted throughout the speaker and the as LED is lighted.

The LDR and 10k resistor and 50k potentiometer form a potential divider that supplies the transistor 1. When the LDR is in the dark, its resistance is high, there is a large voltage across the LDR. There is a voltage drop across the base of the transistor so that the base is at 0.7V. The resistor R3 limits the current to the base. The transistor is turned on. It can allow a big enough current to flow to turn the alarm on.

Transistors with darlington pair is used for higher current gain for turn on the buzzer. After darlington paired transistors are triggered, alarm is turned on and activated and it sounds and at the same time LED emits light for viewable warning.

Under dark conditions, the LDR presents a high resistance, so transistors are not triggered and so alarm doesn't sound.

Whne the LDR is illuminated, its resistance falls to a low value, and transistors are triggered and so alarm is turned on and it sounds.

The sensitivity of this alarm circuit can be adjusted by adjusting the 50k potentiometer. When the potentiometer resistance is increased, from the voltage divider, voltage on the LDR is decreasing, and so less light can activate the circuit.

11.1 Results of testing the circuit elements

Transistor BC237 testing results:

Under diode test:

VBC = 1572 mV and VBE = 1570 mV. These values are normal on forward biased junction, and when the polarities reversed there is no conduction. So this transistors passed this test.

Transistor resistances are:

RBC = 5.2 MΩ, RBE = 5 MΩ, and REC = open circuit, so this transistors passed this test too.

Under operation, BC237 voltgaes are: VCE =0.73V VEB = 1.2V under light conditions.

Under shade, VCE = 0.09 and VEB = 1.5V.

Transistor H237 test results:

VBC = 655.5 mV and VBE = 654mV. These are normal values for this transistor.

Resistances are: RBC = 5.77 MΩ, RBE = 5.8 MΩ, REC = open circuit. So it passed the test.

Under operation, under light conditions: VCE = 2.78V , VEB =0.7V

Under shade conditions: VCE = 10V and VEB =0V.

Buzzer:

When the buzzer resistance is measured, it is seen that it is 0.53 MΩ. The resistance of the buzzer is a little big, so voltage drop on the buzzer is is high.

On the diode test function on the multimeter, voltage drop of the buzzer is 1745mV. During the operation of the circuit under the light conditions, the voltage on the buzzer is 7V. Under dark conditions, that voltage is 0.23 volt, so buzzer does not operate, so it does not give sound.

LDR test results:

Under daylight conditions, LDR resistance is measured 6.5 kΩ, when it is shaded its resistance becomes changing between 40 – 50 kΩ, and under dark conditions whne it is closed by a box, its resistance becomes nearly 20 MΩ.

LED test result:

When the LED used in the circuit connected to multimeter for diode test, its forward voltgae $V_F = 1.86V$. Its a normal value for red light-emitting diode.

CONCLUSIONS

A light-activated alarm system has been designed, constructed and tested in this project. This light-activated alarm is suitable for indoor security especially in small rooms, artifacts in museums, jewelry stores, art galleries and any safe room. This light-activated alarm is thus very good for safe guarding valuables.

Like every other work, this work is not without its limitations and can be improved upon. On this basis recommendations have been made for improvement.

To improve the operation, a programmed microchip can be used to control the operation of the alarm. For example, a microchip can be programmed for continious alarm in the circuit. Under light conditions of this circuit, alarm operation stops when the light removed, and start to operate again when the light comes again to LDR. But if a microchip is used with suitable program, then even a short period light shone into the circuit, the alarm continues sounding even the light is removed.

To improve the portability of the alarm sensor, it is recommended that the sensor be separated from the rest of the circuit by incorporating a radio based transmitter and receiver circuit connected to the microphone and the rest of the alarm circuit respectively. The sensor can be connected at the area that needs to be protected while the rest of the alarm circuit can be connected to a security room to alert security personnel.

All external wires and cables used within the circuit should be concealed within the building.

For wider coverage in more practical situations, it is recommended that a multi channel amplifier or an exclusive OR gate be used in conjunction with several sensors (LDRs) placed at strategic locations within the building. It is also recommended for this purpose that an omni directional LDR with higher sensitivity should be used.

A multi channel amplifier with several connections to several speakers or buzzers can be used to confuse the burglar as to where the sound is coming from.

Finally, it is recommended that provision for a security alarm system should be included in the electrical services design of for every safe rooms..

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APPENDICES

1. Datasheet of the buzzer

Magnetic Transducer in 25 x 12.5mm Size

Model Number:MT23 Series

Key Specifications/Special Features:

- Magnetic transducer
- Size (mm): 25 x 12.5
- MT23A
  - Operating voltage (V): 3 - 7
  - Rated voltage (V): 5
  - Max. rated current (mA): 80
  - Coil resistance (ohm): 27 +/- 4
  - Min. S.P.L. at 10cm (dB): 85 at 1000Hz
  - Resonant frequency (Hz): 1000-1500 (min 80dBA)
  - Operating temperature (deg. C): -20 to +70
- MT23B
  - Operating voltage (V): 3 - 8
  - Rated voltage (V): 6
  - Max. rated current (mA): 70
  - Coil resistance (ohm): 36 +/- 5
  - Min. S.P.L. at 10cm (dB): 85 at 1000Hz
  - Resonant frequency (Hz): 1000 - 1500 (min 80dBA)

- Operating temperature (deg. C): -20 to +70

- MTB12
    - Operating voltage (V): 9 - 15
    - Rated voltage (V): 12
    - Max. rated current (mA): 40
    - Coil resistance (ohm): 115 +/- 12
    - Coil impedance (ohm): 200
    - Min. S.P.L. at 10cm (dB): 85 at 1000Hz
    - Resonant frequency (Hz): 1000-1500 (min 80dBA)

Operating temperature (deg. C): -20 to +70

2. NPN general purpose transistors BC237; BC237B data

Pin discription:

1. emiter   2.base   3.collector

Features

· Low current (max. 100 mA)

· Low voltage (max. 45 V).

Applications

General purpose switching and amplification.

Description

NPN transistor in a TO-92; SOT54 plastic package.

PNP complements: BC307; BC307B

Quick Reference Data

VCBO collector-base voltage open emitter 50 V max

VCEO collector-emitter voltage open base 45 V max

ICM peak collector current 200 mA max

Ptot total power dissipation Tamb £ 25 °C 500 mW max

hFe : DC current gain IC = 2 mA ; VCE = 5 V

BC237B 200mA min, 460mA max

fT transition frequency IC = 10 mA; VCE = 5 V; f = 100 MHz : 100 MHz min