NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ALERT SYSTEM WITH PLC

Graduation Project
EE – 400

Student: Ercan Dursun (20001361)

Supervisor: Özgür Cemal Özerdem

Lefkoşa – 2004

TABLE OF CONSTENTS

ACKNOWLEDGEMENTS

It is my pleasure to take this opportunity to express my greatest gratitude to many individuals who have given me a lot of supports during my four-year Undergraduate program in the Near East University. Without them, my Graduation Project would not have been successfully completed on time.

First of all, I am indebted to my supervisor, Mr. Özgür Cemal Özerdem, for his valuable guidance and encouragement throughout the entire Graduation Project. Whenever I have problem in my project, he shows his enthusiasm to solve problems. He has given his best support for me to conduct and enjoy my Graduation Project work.

I thank Assist. Prof. Dr. Kadri Bürüncük for giving his time to me for doing my registirations, and I thank Prof.Dr. Şenol Bektaş for helping with our problems in school, I thank Prof. Dr Fakhreddin Mamedov for helping us with our problems in our department.

And also I thank all my friends for their charities and for their friendships, especially Birgül Kaya , Ali Kurttekin , Nedim Perihanoğlu and Mustafa Alıcı.

Finally, I want to thank my family, especially my parents without their endless support, I could never have prepared this thesis without the encouragement and support of my parents.

ABSTRACT

Home alarm system is an example of an application of a normally closed switch. Let's suppose that alarm system is intended for surveillance of the front door to the house. One of the ways to "wire" the house would be to install a normally open switch from each door to the alarm itself (precisely as with a bell switch). Then, if the door was opened, this would close the switch, and an alarm would be activated. This system could work, but there would be some problems with this, too. Let's suppose that switch is not working, that a wire is somehow disconnected, or a switch is broken, etc. (there are many ways in which this system could become dysfunctional). The real trouble is that a homeowner would not know that a system was out of order. A burglar could open the door, a switch would not work, and the alarm would not be activated. Obviously, this isn't a good way to set up this system. System should be set up in such a way so the alarm is activated by a burglar, but also by its own dysfunction, or if any of the components stopped working. (A homeowner would certainly want to know if a system was dysfunctional). Having these things in mind, it is far better to use a switch with normally closed contacts which will detect an unauthorized entrance (opened door interrupts the flow of electricity, and this signal is used to activate a sound signal), or a failure on the system such as a disconnected wire. These considerations are even more important in industrial environment where a failure could cause injury at work. One such example where outputs with normally closed contacts are used is a safety wall with trimming machines. If the wall doors open, switch affects the output with normally closed contacts and interrupts a supply circuit. This stops the machine and prevents an injury.

INTRODUCTION

A Programmable Logic Controller was defined by Capiel (1982) as: " A digitally operating electronic system designed for use in an industrial environment, which uses a programmable memory for the internal storage of instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic to control through analog or digital input/output modules, various types of machines or processes." Which explains the device perfectly.

In the late 1960's PLC's were first introduced. The first PLC can be traced back to 1968 when Bedford Associates, a company in Bedford, MA, developed a device called a Modular Digital Controller for General Motors (GM). The MODICON, as it was known, was developed to help GM eliminate traditional relay-based machine control systems.

The aim of this project is alert us for security against the thiefs.

The project consists of the eigth chapters, and conclusion.

Chapter-1 : Programmable logic controllers
Chapter-2 : Infrared sensor
Chapter-3 : Relay
Chapter-4 : Resistor
Chapter-5 : Capacitor
Chapter-6 : CD4001 BC of gate
Chapter-7 : Transistor
Chapter-8 : Alert system against thief

Chapter : 1 PROGRAMMABLE LOGIC CONTROLLERS

Topics:

- PLC History
- Ladder Logic and Relays
- PLC Programming
- PLC Operation
- An Example

Objectives:

- Know general PLC issues
- To be able to write simple ladder logic programs
- Understand the operation of a PLC

1.1 Introduction

Control engineering has evolved over time. In the past humans were the main method for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 970s, and has become the most common choice for manufacturing controls.

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come. Most of this is because of the advantages they offer.

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

1.1.1 Ladder Logic

Ladder logic is the main programming method used for PLCs. As mentioned before, ladder logic has been developed to mimic relay logic. The decision to use the relay logic diagrams was a strategic one. By selecting ladder logic as the main programming method, the amount of retraining needed for engineers and tradespeople was greatly reduced.

Modern control systems still include relays, but these are rarely used for logic. A relay is a simple device that uses a magnetic field to control a switch, as pictured in Figure 1. When a voltage is applied to the input coil, the resulting current creates a magnetic field. The magnetic field pulls a metal switch (or reed) towards it and the contacts touch, closing the switch. The contact that closes when the coil is energized is called normally open. The normally closed contacts touch when the input coil is not energized. Relays are normally drawn in schematic form using a circle to represent the input coil. The output contacts are shown with two parallel lines. Normally open contacts are shown as two lines, and will be open (non-conducting) when the input is not energized. Normally closed contacts are shown with two lines with a diagonal line through them. When the input coil is not energized the normally closed contacts will be closed (conducting).

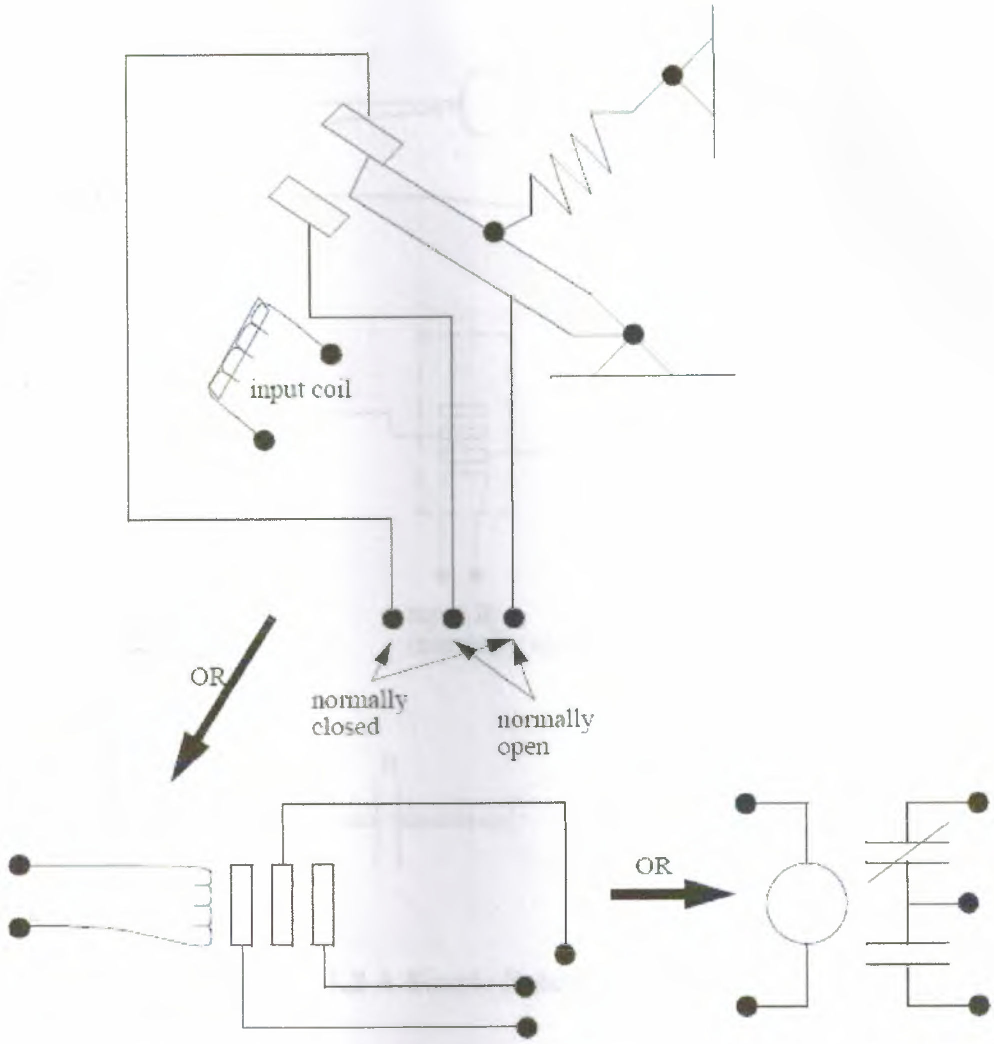


Figure : 1. 1 Simple Relay Layouts and Schematics

Relays are used to let one power source close a switch for another (often high current) power source, while keeping them isolated. An example of a relay in a simple control application is shown in Figure 1.2. In this system the first relay on the left is used as normally closed, and will allow current to flow until a voltage is applied to the input A. The second relay is normally open and will not allow current to flow until a voltage is applied to the input B. If current is flowing through the first two relays then current will flow through the coil in the third relay, and close the switch for output C. This circuit would normally be drawn in the ladder logic form. This can be read logically as C will be on if A is off and B is on.

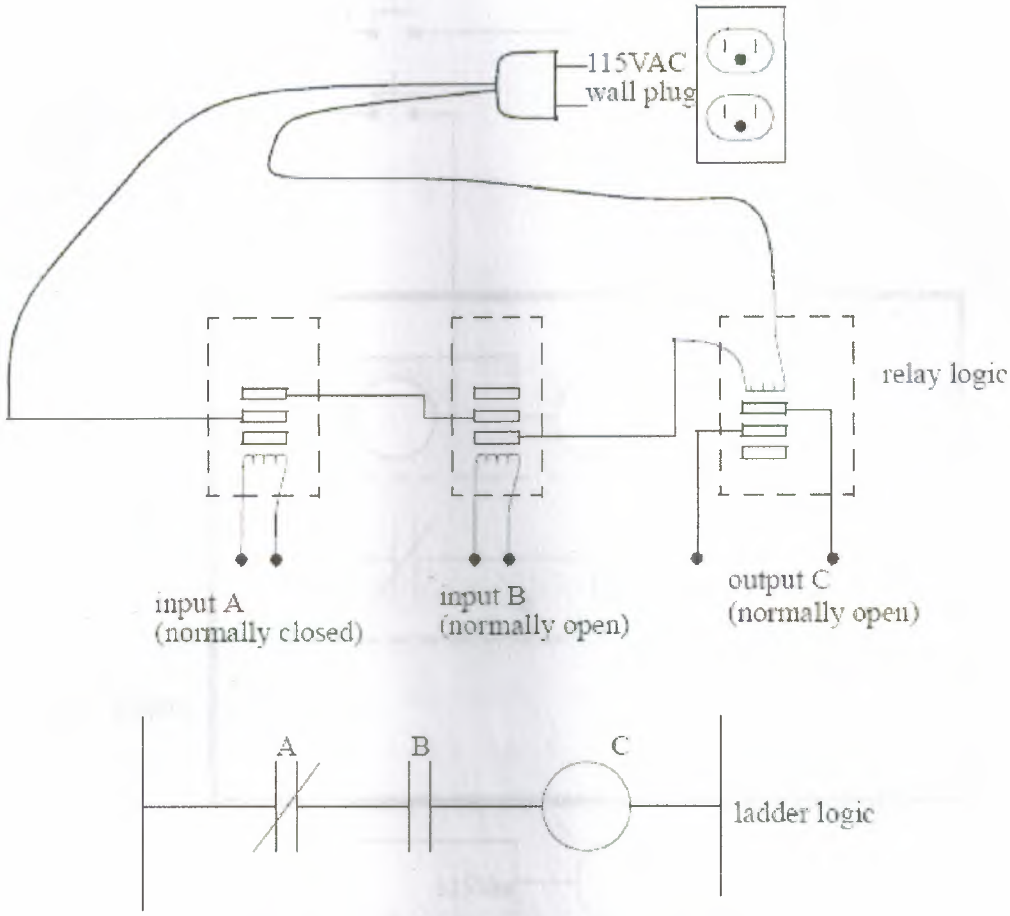


Figure : 1.2 A Simple Relay Controller

The example in Figure 1.2 does not show the entire control system, but only the logic. When we consider a PLC there are inputs, outputs, and the logic. Figure 1.3 shows a more complete representation of the PLC. Here there are two inputs from push buttons. We can imagine the inputs as activating 24V DC relay coils in the PLC. This in turn drives an output relay that switches 115V AC, that will turn on a light. Note, in actual PLCs inputs are never relays, but outputs are often relays. The ladder logic in the PLC is actually a computer program that the user can enter and change. Notice that both of the input push buttons are normally open, but the ladder logic inside the PLC has one normally open contact, and one normally closed contact. Do not think that the ladder logic in the PLC needs to match the inputs or outputs. Many beginners will get caught trying to make the ladder logic match the input types.

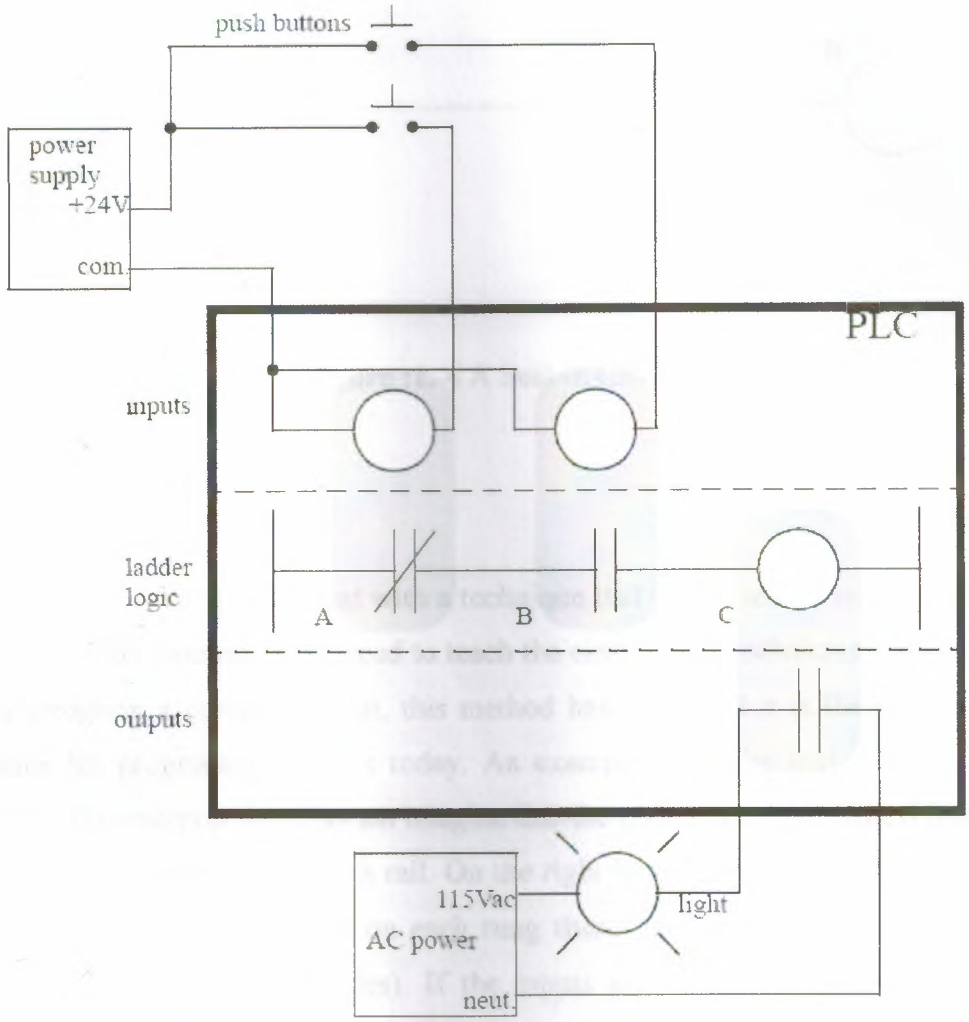


Figure :1. 3 A PLC Illustrated With Relays

Many relays also have multiple outputs (throws) and this allows an output relay to also be an input simultaneously. The circuit shown in Figure 1.4 is an example of this, it is called a seal in circuit. In this circuit the current can flow through either branch of the circuit, through the contacts labelled A or B. The input B will only be on when the output B is on. If B is off, and A is energized, then B will turn on. If B turns on then the input B will turn on, and keep output B on even if input A goes off. After B is turned on the output B will not turn off.

Figure :1. 4 A Seal-in Circuit

1.1.2 Programming

The first PLCs were programmed with a technique that was based on relay logic wiring schematics. This eliminated the need to teach the electricians, technicians and engineers how to *program* a computer - but, this method has stuck and it is the most common technique for programming PLCs today. An example of ladder logic can be seen in Figure 1.5. To interpret this diagram imagine that the power is on the vertical line on the left hand side, we call this the hot rail. On the right hand side is the neutral rail. In the figure there are two rungs, and on each rung there are combinations of inputs (two vertical lines) and outputs (circles). If the inputs are opened or closed in the right combination the power can flow from the hot rail, through the inputs, to power the outputs, and finally to the neutral rail. An input can come from a sensor, switch, or any other type of sensor. An output will be some device outside the PLC that is switched on or off, such as lights or motors. In the top rung the contacts are normally open and normally closed. Which means if input *A* is on and input *B* is off, then power will flow through the output and activate it. Any other combination of input values will result in the output *X* being off.

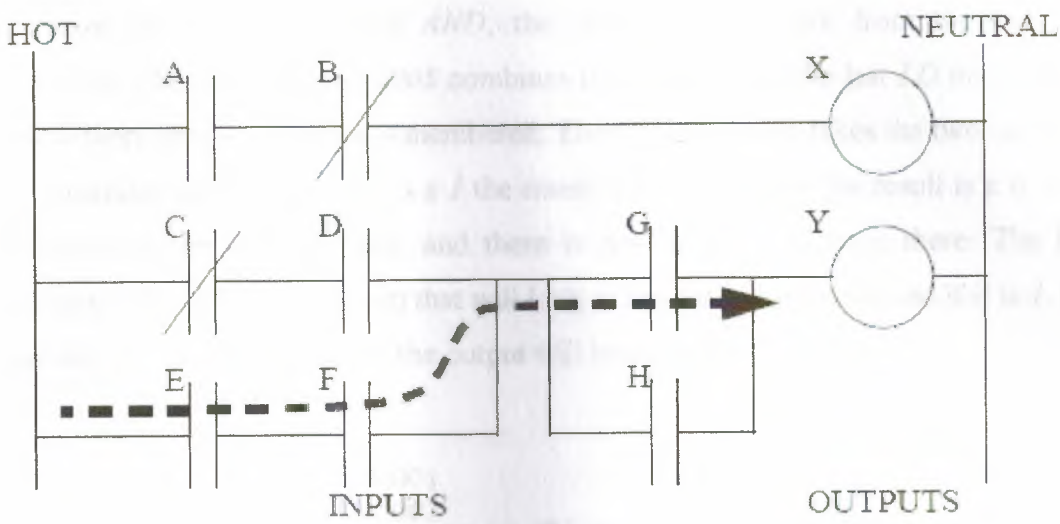


Figure : 1.5 A Simple Ladder Logic Diagram

The second rung of Figure 1.5 is more complex, there are actually multiple combinations of inputs that will result in the output *Y* turning on. On the left most part of the rung, power could flow through the top if *C* is off and *D* is on. Power could also (and simultaneously) flow through the bottom if both *E* and *F* are true. This would get power half way across the rung, and then if *G* or *H* is true the power will be delivered to output *Y*. In later chapters we will examine how to interpret and construct these diagrams.

There are other methods for programming PLCs. One of the earliest techniques involved mnemonic instructions. These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a simple programming terminal. An example of mnemonics is shown in Figure 1.6. In this example the instructions are read one line at a time from top to bottom. The first line *00000* has the instruction *LDN* (input load and not) for input *00001*. This will examine the input to the PLC and if it is off it will remember a *1* (or true), if it is on it will remember a *0* (or false). The next line uses an *LD* (input load) statement to look at the input. If the input is off it remembers a *0*, if the input is on it remembers a *1* (note: this is the reverse of the *LD*). The *AND* statement recalls the last two numbers remembered and if the are both true the result is a *1*, otherwise the result is a *0*. This result now replaces the two numbers that were recalled, and there is only one number remembered. The process is repeated for lines *00003* and *00004*, but when these are done there are now three numbers remembered.

The oldest number is from the *AND*, the newer numbers are from the two *LD* instructions. The *AND* in line *00005* combines the results from the last *LD* instructions and now there are two numbers remembered. The *OR* instruction takes the two numbers now remaining and if either one is a *1* the result is a *1*, otherwise the result is a *0*. This result replaces the two numbers, and there is now a single number there. The last instruction is the *ST* (store output) that will look at the last value stored and if it is *1*, the output will be turned on, if it is *0* the output will be turned off.

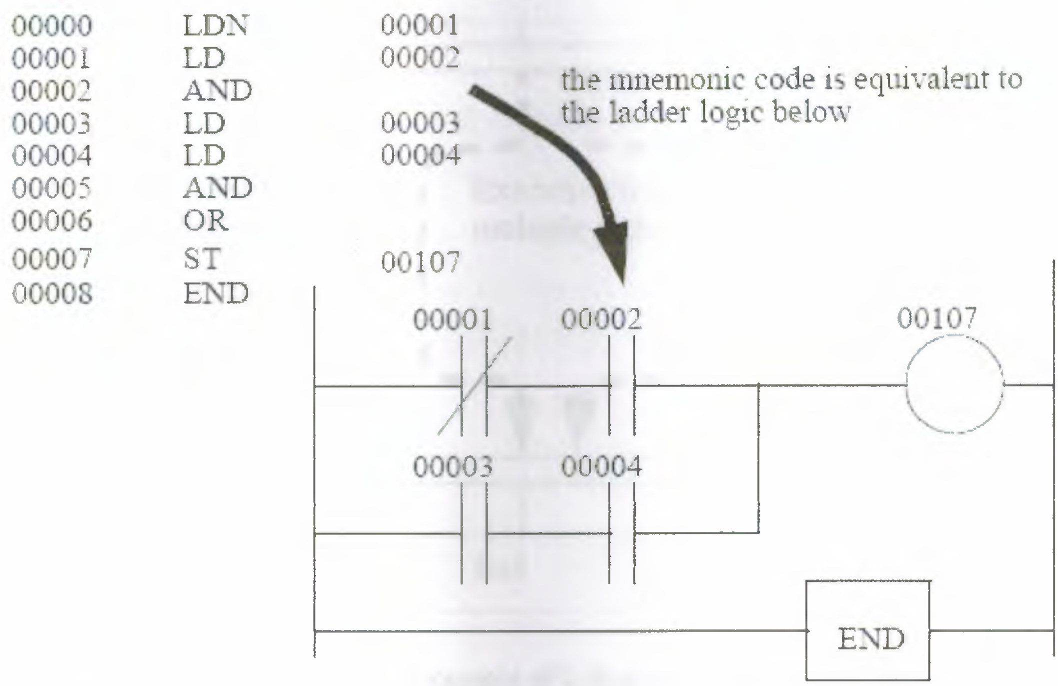


Figure : 1.6 An Example of a Mnemonic Program and Equivalent Ladder Logic

The ladder logic program in Figure1.6, is equivalent to the mnemonic program. Even if you have programmed a PLC with ladder logic, it will be converted to mnemonic form before being used by the PLC. In the past mnemonic programming was the most common, but now it is uncommon for users to even see mnemonic programs.

Sequential Function Charts (SFCs) have been developed to accommodate the programming of more advanced systems. These are similar to flowcharts, but much more powerful. The example seen in Figure 1.7 is doing two different things. To read the chart, start at the top where is says *start*. Below this there is the double horizontal line that says follow both paths. As a result the PLC will start to follow the branch on the left and right hand sides separately and simultaneously. On the left there are two functions the first one is the *power up* function. This function will run until it decides it is done, and the *power down* function will come after. On the right hand side is the *flash* function, this will run until it is done. These functions look unexplained, but each function, such as *power up* will be a small ladder logic program. This method is much different from flowcharts because it does not have to follow a single path through the flowchart.

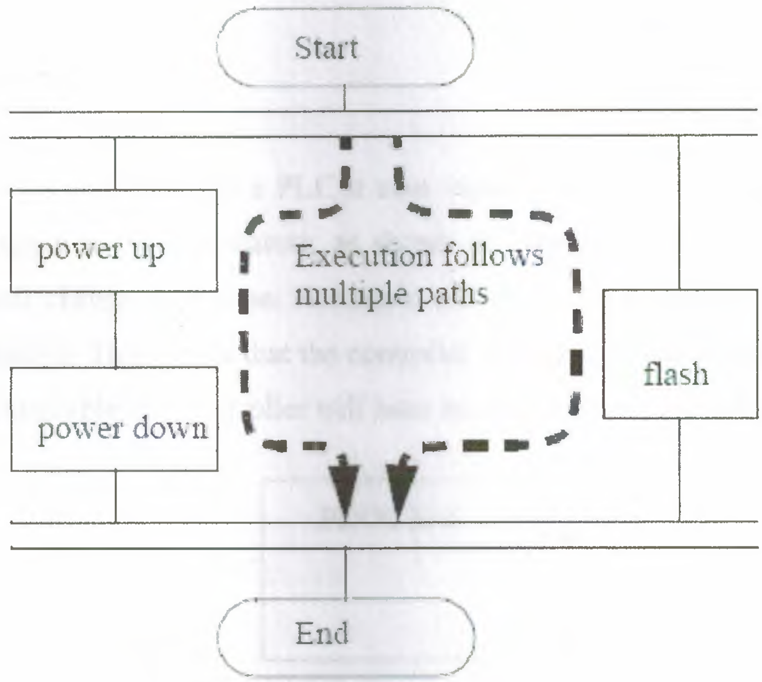


Figure : 1.7 An Example of a Sequential Function Chart

Structured Text programming has been developed as a more modern programming language. It is quite similar to languages such as BASIC. A simple example is shown in Figure 1.8. This example uses a PLC memory location N7:0. This memory location is for an integer, as will be explained later in the book. The first line of the program sets the value to 0. The next line begins a loop, and will be where the loop returns to. The next line recalls the value in location N7:0, adds 1 to it and returns it to the same location. The next line checks to see if the loop should quit. If N7:0 is greater than or equal to 10, then the loop will quit, otherwise the computer will go back up to the REPEAT statement continue from there. Each time the program goes through this loop N7:0 will increase by 1 until the value reaches 10.

```
N7:0 := 0;
REPEAT
N7:0 := N7:0 + 1;
UNTIL N7:0 >= 10
END_REPEAT;
```

Figure :1.8 An Example of a Structured Text Program

1.1.3 PLC Connections

When a process is controlled by a PLC it uses inputs from sensors to make decisions and update outputs to drive actuators, as shown in Figure 1.9. The process is a real process that will change over time. Actuators will drive the system to new states (or modes of operation). This means that the controller is limited by the sensors available, if an input is not available, the controller will have no way to detect a condition.

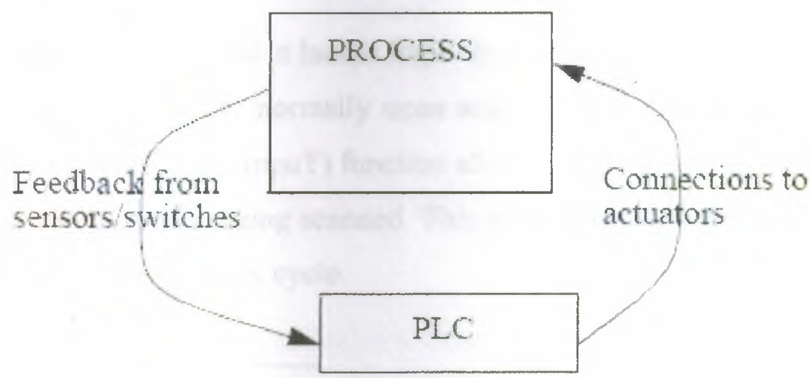


Figure :1.9 The Separation of Controller and Process

The control loop is a continuous cycle of the PLC reading inputs, solving the ladder logic, and then changing the outputs. Like any computer this does not happen instantly. Figure 1.10 shows the basic operation cycle of a PLC. When power is turned on initially the PLC does a quick *sanity check* to ensure that the hardware is working properly. If there is a problem the PLC will halt and indicate there is an error. For example, if the PLC backup battery is low and power was lost, the memory will be corrupt and this will result in a fault. If the PLC passes the sanity check it will then scan (read) all the inputs. After the inputs values are stored in memory the ladder logic will be scanned (solved) using the stored values - not the current values. This is done to prevent logic problems when inputs change during the ladder logic scan. When the ladder logic scan is complete the outputs will be scanned (the output values will be changed). After this the system goes back to do a sanity check, and the loop continues indefinitely. Unlike normal computers, the entire program will be *run* every scan. Typical times for each of the stages is in the order of milliseconds.

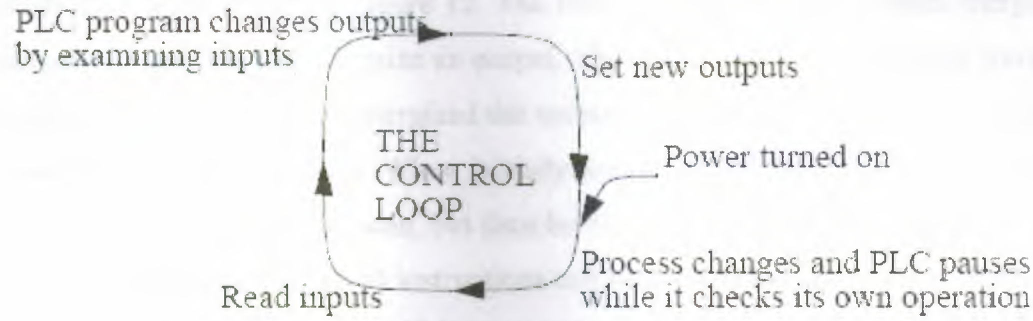


Figure : 1.10 The Scan Cycle of a PLC

1.1.4 Ladder Logic Inputs

PLC inputs are easily represented in ladder logic. In Figure 1.11 there are three types of inputs shown. The first two are normally open and normally closed inputs, discussed previously. The *IIT* (Immediate InpuT) function allows inputs to be read after the input scan, while the ladder logic is being scanned. This allows ladder logic to examine input values more often than once every cycle.

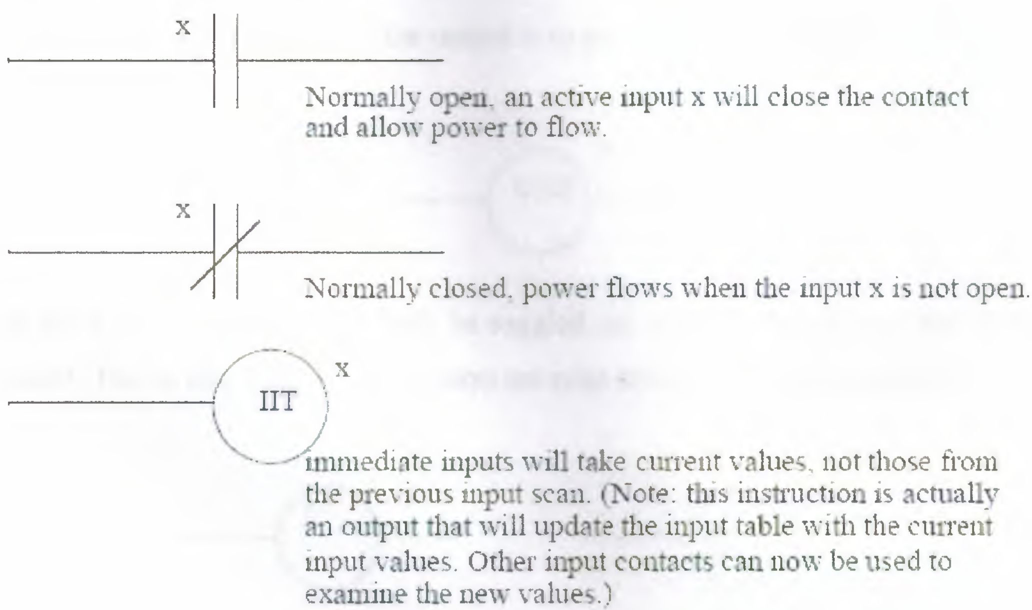


Figure :1.11 Ladder Logic Inputs

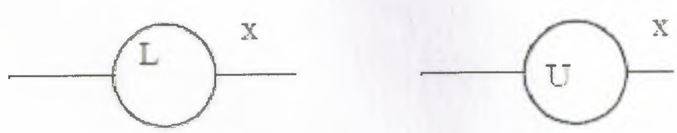
1.1.5 Ladder Logic Outputs

In ladder logic there are multiple types of outputs, but these are not consistently available on all PLCs. Some of the outputs will be externally connected to devices outside the PLC, but it is also possible to use internal memory locations in the PLC. Six types of outputs are shown in Figure 12. The first is a normal output, when energized the output will turn on, and energize an output. The circle with a diagonal line through is a normally on output. When energized the output will turn off. This type of output is not available on all PLC types. When initially energized the OSR (One Shot Relay) instruction will turn on for one scan, but then be off for all scans after, until it is turned off. The L (latch) and U (unlatch) instructions can be used to lock outputs on. When an L output is energized the output will turn on indefinitely, even when the output coil is deenergized. The output can only be turned off using a U output. The last instruction is the IOT (Immediate Output) that will allow outputs to be updated without having to wait for the ladder logic scan to be completed.

When power is applied (on) the output x is activated for the left output, but turned off for the output on the right.

An input transition on will cause the output x to go on for one scan (this is also known as a one shot relay)

When the L coil is energized, x will be toggled on, it will stay on until the U coil is energized. This is like a flip-flop and stays set even when the PLC is turned off.



Some PLCs will allow immediate outputs that do not wait for the program scan to end before setting an output. (Note: This instruction will only update the outputs using the output table, other instruction must change the individual outputs.)

Figure : 1.12 Ladder Logic Outputs

1.2 Summary

- Normally open and closed contacts.
- Relays and their relationship to ladder logic.
- PLC outputs can be inputs, as shown by the seal in circuit.
- Programming can be done with ladder logic, mnemonics, SFCs, and structured text.
- There are multiple ways to write a PLC program.

Chapter :2 INFRARED SENSOR

2.1 Infrared Sensor Instruction

2.1.1 General

The product is a energy-saving automatic switch adopted integrated circuit and precise detecting components. It can be on when body detect it and will be off automatically after body leave. Its performance is stable. It can identify day and night. The light can turn on when body enter detection field and move, it can turn off automatically when body leave detection field .

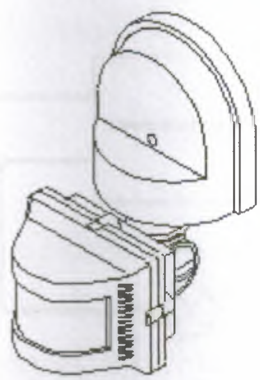


Figure : 2.1 Infrared sensor

2.1.2 Function

Can identify day and night automatically, the ambient-light can be selected, so it works at night automatically and stop in daytime.

Detection distance can be adjusted according to the local place.

Time-delay can be adjusted vary to the place.

2.1.3 Specifications

- Detection range: 120°
- Detection distance: >12m (22m)
- Power source: 110V/AC~130V/AC 180 ~240V/AC

- Rated load: 1000W(180 ~240V/AC)
- Working temperature:-10C~+40C
- Working humidity: <93%RH
- Time-delay: min
- 5sec Max 11min±3min
- Ambient-light: <10Lux~2000Lux
- Installation height: 2m~4.5m

2.1.4 Installation

Avoid installing it near heating or air conditioning outlet, air stream according to connection-line.(figure 2.2)

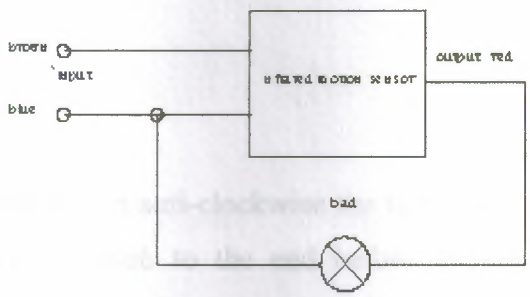


Figure : 2.2 Connection of infrared

N _ blue
L _ brown
Earthing yellow and green
Red (be from infrared sensor)
connect blue and brown with power
connect blue and red with load

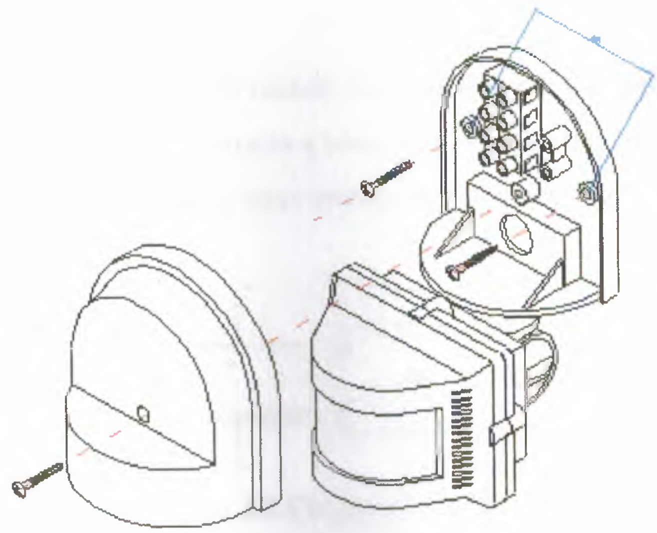


Figure : 2.3 Instalation of infrared sensor

2.1.5 Test

1. After installation, please turn anti-clockwise the time knob to the end and turn anti-clockwise the light-control knob to the end before you switch on the power. the sensitivity knob turn clockwise to the maximum value.

2. Restore the main power, the light can be on after 30sec. After it turns off, take 5sec to sense.

3. If all are under good condition, with time adjustment knob the light period can be adjusted according to your desire, with light-control knob ambient-light can be adjusted ,with sensitivity adjustment knob the detection distance can be adjusted.

Chapter : 3 RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches.

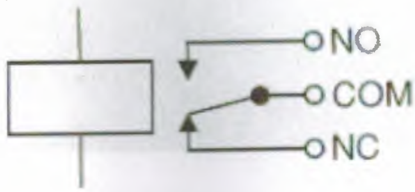


Figure : 3.1 Circuit symbol for a relay

Figure : 3.2 Relays

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.

The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

Relays are usuallly SPDT or DPDT but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available. For further information about switch contacts and the terms used to describe them please see the page on switches.

Figure : 3.3 Relay showing coil and switch contacts

Most relays are designed for PCB mounting but you can solder wires directly to the pins providing you take care to avoid melting the plastic case of the relay.

The supplier's catalogue should show you the relay's connections. The coil will be obvious and it may be connected either way round. Relay coils produce brief high voltage 'spikes' when they are switched off and this can destroy transistors and ICs in the circuit. To prevent damage you must connect a protection diode across the relay coil.

The animated picture shows a working relay with its coil and switch contacts. You can see a lever on the left being attracted by magnetism when the coil is switched on. This lever moves the switch contacts. There is one set of contacts (SPDT) in the foreground and another behind them, making the relay DPDT.

The relay's switch connections are usually labelled COM, NC and NO:
COM = Common, always connect to this, it is the moving part of the switch.
NC = Normally Closed, COM is connected to this when the relay coil is off.
NO = Normally Open, COM is connected to this when the relay coil is on.
Connect to COM and NO if you want the switched circuit to be on when the relay coil is on.
Connect to COM and NC if you want the switched circuit to be on when the relay coil is off

3.1 Choosing a Relay

You need to consider several features when choosing a relay:

3.1.1 Physical Size and Pin Arrangement

If you are choosing a relay for an existing PCB you will need to ensure that its dimensions and pin arrangement are suitable. You should find this information in the supplier's catalogue.

3.1.2 Coil Voltage

The relay's coil voltage rating and resistance must suit the circuit powering the relay coil. Many relays have a coil rated for a 12V supply but 5V and 24V relays are also readily available. Some relays operate perfectly well with a supply voltage which is a little lower than their rated value.

3.1.3 Coil Resistance

The circuit must be able to supply the current required by the relay coil. You can use Ohm's law to calculate the current:

$$\text{Relay coil current} = \frac{\text{supply voltage}}{\text{coil resistance}}$$

3.1.4 Switch Ratings (Voltage and Current)

The relay's switch contacts must be suitable for the circuit they are to control. You will need to check the voltage and current ratings. Note that the voltage rating is usually higher for AC, for example: "5A at 24V DC or 125V AC".

3.1.5 Switch Contact Arrangement (SPDT, DPDT etc)

Most relays are SPDT or DPDT which are often described as "single pole changeover" (SPCO) or "double pole changeover" (DPCO). For further information please see the page on switches.

3.1.6 Protection Diodes for Relays

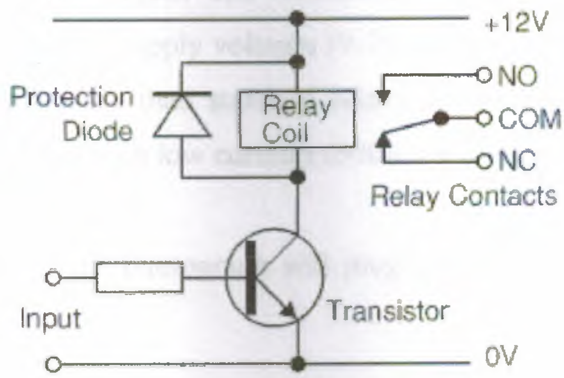


Figure : 3.4 Protection diodes for relays

Transistors and ICs (chips) must be protected from the brief high voltage 'spike' produced when the relay coil is switched off. The diagram shows how a signal diode (eg 1N4148) is connected across the relay coil to provide this protection. Note that the diode is connected 'backwards' so that it will normally not conduct. Conduction only occurs when the relay coil is switched off, at this moment current tries to continue flowing through the coil and it is harmlessly diverted through the diode. Without the diode no current could flow and the coil would produce a damaging high voltage 'spike' in its attempt to keep the current flowing.

3.2 Reed Relays

Reed relays consist of a coil surrounding a reed switch. Reed switches are normally operated with a magnet, but in a reed relay current flows through the coil to create a magnetic field and close the reed switch.

Figure : 3.5 Reed Relay

Reed relays generally have higher coil resistances than standard relays (1000Ω for example) and a wide range of supply voltages (9-20V for example). They are capable of switching much more rapidly than standard relays, up to several hundred times per second; but they can only switch low currents (500mA maximum for example).

The reed relay shown in the photograph will plug into a standard 14-pin DIL socket ('chip holder').

3.3 Relays and Transistors Compared

Like relays, transistors can be used as an electrically operated switch. For switching small DC currents (< 1A) at low voltage they are usually a better choice than a relay. However transistors cannot switch AC or high voltages (such as mains electricity) and they are not usually a good choice for switching large currents (> 5A). In these cases a relay will be needed, but note that a low power transistor may still be needed to switch the current for the relay's coil! The main advantages and disadvantages of relays are listed below:

3.4 Advantages of Relays

- Relays can switch AC and DC, transistors can only switch DC.
- Relays can switch high voltages, transistors cannot.
- Relays are a better choice for switching large currents (> 5A).
- Relays can switch many contacts at once.

3.5 Disadvantages of Relays

- Relays are bulkier than transistors for switching small currents.
- Relays cannot switch rapidly (except reed relays), transistors can switch many times per second.
- Relays use more power due to the current flowing through their coil.
- Relays require more current than many chips can provide, so a low power transistor may be needed to switch the current for the relay's coil.

Chapter : 4 RESISTOR

Resistors are the most commonly used component in electronics and their purpose is to create specified values of current and voltage in a circuit. A number of different resistors are shown in the photos. (The resistors are on millimeter paper, with 1cm spacing to give some idea of the dimensions). Figure 4.1 a shows some low-power resistors, while Figure 4.1 b shows some higher-power resistors. Resistors with power dissipation below 5 watt (most commonly used types) are cylindrical in shape, with a wire protruding from each end for connecting to a circuit (Figure 4.1 a). Resistors with power dissipation above 5 watt are shown below (Figure 4.1 b).

Figure : 4.1 a Some low-power resistors

Figure : 4.1 b High-power resistor and rheostats

The symbol for a resistor is shown in the following diagram (upper: American symbol, lower: European symbol.)

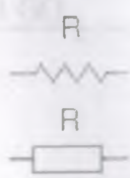


Figure : 4.2 Resistor symbols

The unit for measuring resistance is the OHM. (the Greek letter Ω). Higher resistance values are represented by "k" (kilo-ohms) and M (meg ohms). For example, 120 000 Ω is represented as 120k, while 1 200 000 Ω is represented as 1M2. The dot is generally omitted as it can easily be lost in the printing process. In some circuit diagrams, a value such as 8 or 120 represents a resistance in ohms. Another common practice is to use the letter E for resistance. For example, 120E (120R) stands for 120 Ω, 1E2 stands for 1R2 etc.

4.1 Resistor Markings

Resistance value is marked on the resistor body. The first three bands provide the value of the resistor in ohms and the fourth band indicates the tolerance. Tolerance values of 5%, 2%, and 1% are most commonly available.

The following table shows the colors used to identify resistor values:

Table : 4.1 Colors used to identify resistor values

COLOR	DIGIT	MULTIPLIER	TOLERANCE	TC
Silver		x 0.01 Ω	±10%	
Gold		x 0.1 Ω	±5%	
Black	0	x 1 Ω		
Brown	1	x 10 Ω	±1%	$\pm 100*10^{-6}/K$
Red	2	x 100 Ω	±2%	$\pm 50*10^{-6}/K$
Orange	3	x 1 kΩ		$\pm 15*10^{-6}/K$
Yellow	4	x 10 kΩ		$\pm 25*10^{-6}/K$
Green	5	x 100 kΩ	±0.5%	
Blue	6	x 1 MΩ	±0.25%	$\pm 10*10^{-6}/K$
Violet	7	x 10 MΩ	±0.1%	$\pm 5*10^{-6}/K$
Grey	8	x 100 MΩ		
White	9	x 1 GΩ		$\pm 1*10^{-6}/K$

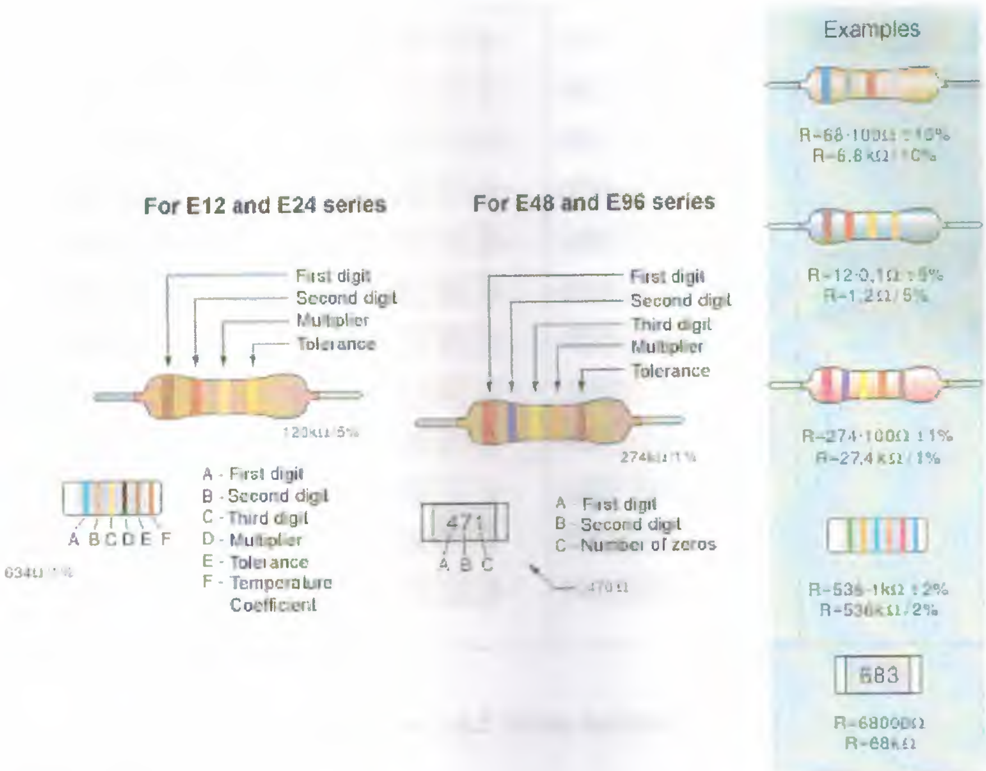


Figure : 4.3 Four-band resistor, c. Five-band resistor, d. Cylindrical SMD resistor, e. Flat SMD resistor

The following shows all resistors from 1R to 22M

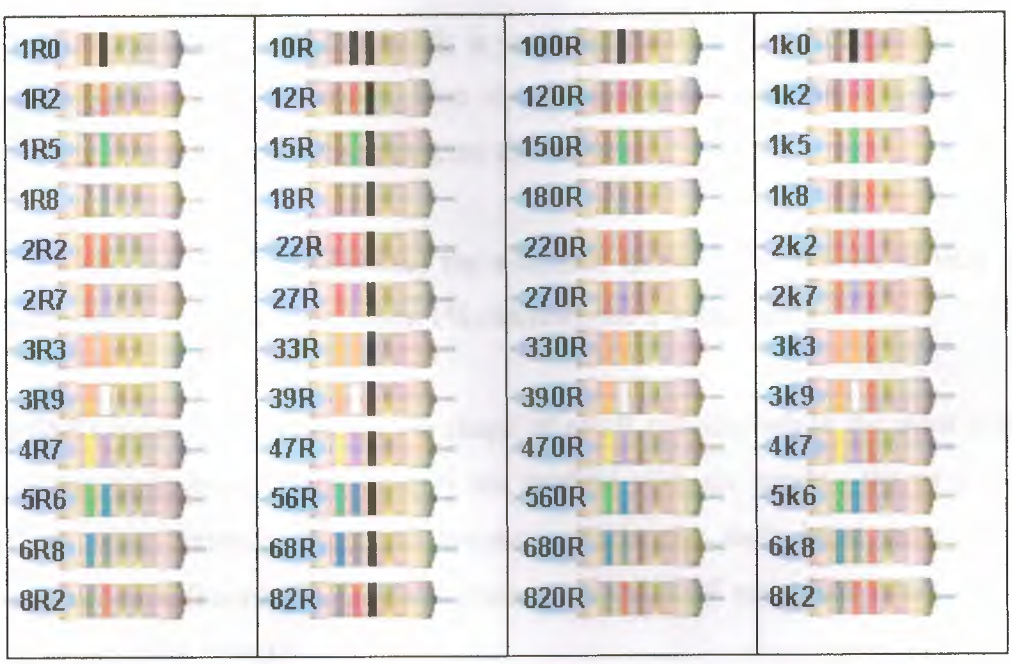


Figure : 4.4 Some resistor values

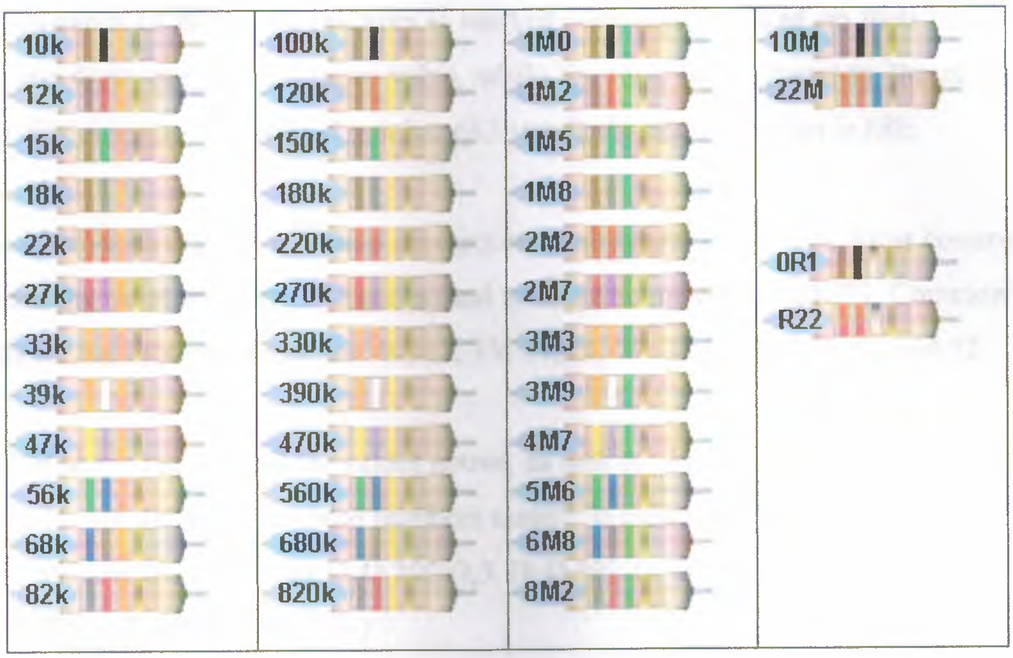


Figure : 4.5 Some resistor values

Common resistors have 4 bands. These are shown above. First two bands indicate the first two digits of the resistance, third band is the multiplier (number of zeros that are to be added to the number derived from first two bands) and fourth represents the tolerance.

Marking the resistance with five bands is used for resistors with tolerance of 2%, 1% and other high-accuracy resistors. First three bands determine the first three digits, fourth is the multiplier and fifth represents the tolerance.

For SMD (Surface Mounted Device) the available space on the resistor is very small. 5% resistors use a 3 digit code, while 1% resistors use a 4 digit code.

Some SMD resistors are made in the shape of small cylinder while the most common type is flat. Cylindrical SMD resistors are marked with six bands - the first five are "read" as with common five-band resistors, while the sixth band determines the Temperature Coefficient (TC), which gives us a value of resistance change upon 1-degree temperature change.

The resistance of flat SMD resistors is marked with digits printed on their upper side. First two digits are the resistance value, while the third digit represents the number of zeros. For example, the printed number 683 stands for 68000 Ω , that is 68k.

It is self-obvious that there is mass production of all types of resistors. Most commonly used are the resistors of the E12 series, and have a tolerance value of 5%. Common values for the first two digits are: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68 and 82.

The E24 series includes all the values above, as well as: 11, 13, 16, 20, 24, 30, 36, 43, 51, 62, 75 and 91. What do these numbers mean? It means that resistors with values for digits "39" are: 0.39 Ω,3.9 Ω,39 Ω,390 Ω,3.9k Ω,39k Ω, etc are manufactured. (0R39,3R9,39R,390R, 3.9k, 39k)

For some electrical circuits, the resistor tolerance is not important and it is not specified. In that case, resistors with 5% tolerance can be used. However, devices which require resistors to have a certain amount of accuracy, need a specified tolerance.

4.2 Resistor Dissipation

If the flow of current through a resistor increases, it heats up, and if the temperature exceeds a certain critical value, it can be damaged. The wattage rating of a resistor is the power it can dissipate over a long period of time.

Wattage rating is not identified on small resistors. The following diagrams show the size and wattage rating:

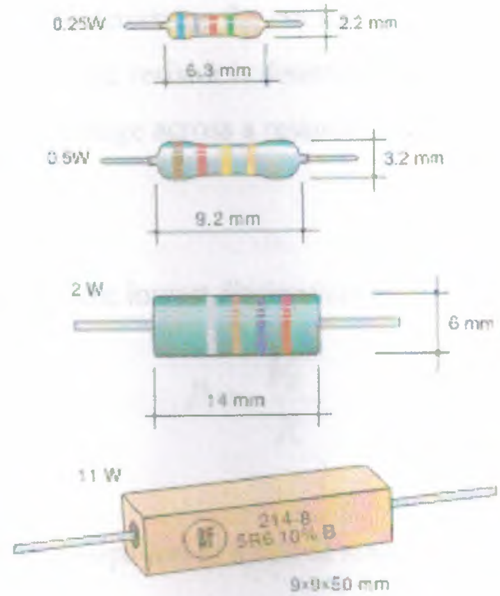


Figure : 4.6 Resistor dimensions

Most commonly used resistors in electronic circuits have a wattage rating of 1/2W or 1/4W. There are smaller resistors (1/8W and 1/16W) and higher (1W, 2W, 5W, etc). In place of a single resistor with specified dissipation, another one with the same resistance and higher rating may be used, but its larger dimensions increase the space taken on a printed circuit board as well as the added cost.

Power (in watts) can be calculated according to one of the following formulae:

$$P = V \cdot I$$

$$P = R \cdot I^2$$

$$P = \frac{V^2}{R}$$

where V represents resistor voltage in Volts, I is the current flowing through the resistor in Amps and R is the resistance of resistor in Ohms. For example, if the voltage across an 820 Ω resistor is 12V, the wattage dissipated by the resistors is:

$$P = \frac{V^2}{R} = \frac{12^2}{820} = 0.176\ \text{W} = 176\,\text{mW}$$

A 1/4W resistor can be used.

In many cases, it is not easy to determine the current or voltage across a resistor. In this case the wattage dissipated by the resistor is determined for the "worst" case. We should assume the highest possible voltage across a resistor, i.e. the full voltage of the power supply (battery, etc).

If we mark this voltage as V_B, the lowest dissipation is:

$$P = \frac{V_B^2}{R}$$

For example, if V_B=9V, the dissipation of a 220 Ω resistor is:

$$P = \frac{9^2}{220} = 368\,\text{mW}$$

A 0.5W or higher wattage resistor should be used

4.3 Nonlinear Resistors

Resistance values detailed above are a constant and do not change if the voltage or current-flow alters. But there are circuits that require resistors to change value with a change in temperate or light. This function may not be linear, hence the name NONLINEAR RESISTORS.

There are several types of nonlinear resistors, but the most commonly used include :
NTC resistors (Figure 6 a) (Negative Temperature Co-efficient) - their resistance lowers with temperature rise. PTC resistors (Figure 6 b) (Positive Temperature Co-efficient) - their resistance increases with the temperature rise. LDR resistors (Figure 6 c) (Light Dependent Resistors) - their resistance lowers with the increase in light. VDR resistors (Voltage dependent Resistors) - their resistance critically lowers as the voltage exceeds a certain value. Symbols representing these resistors are shown below.

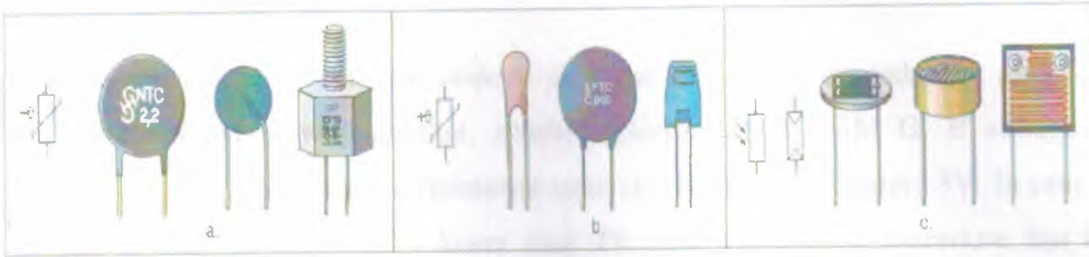


Figure : 4.7 Nonlinear resistors - a. NTC, b. PTC, c. LDR

4.4 Practical Examples With Resistors

Figure 4.8 shows two practical examples with nonlinear and regular resistors as trimmer potentiometers, elements which will be covered in the following chapter.

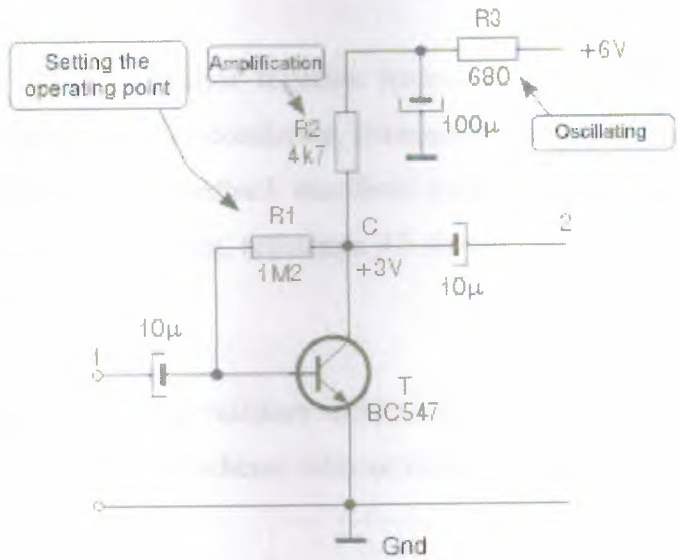


Figure : 4.8 a: RC amplifier

Figure 4.8 a represents the so called RC voltage amplifier, that can be used for amplifying low-frequency, low-amplitude audio signals, such as microphone signal. Signal to be amplified is brought between node 1 and gnd (amplifier input), while the resulting amplified signal appears between node 2 and gnd (amplifier output). To get the optimal performance (high amplification, low distortion, low noise, etc) , it is necessary to "set" the transistor's operating point. Details on operating point will be provided in chapter 4; for now, let's just say that DC voltage between node C and gnd should be approximately one half of battery (power supply) voltage. Since battery voltage equals 6V, voltage in node C should be set to 3V. Adjustments are made via resistor R1.

Connect the voltmeter between node C and gnd. If voltage exceeds 3V, replace the resistor R1=1.2M Ω with another, smaller resistor, say R1=1M Ω. If voltage still exceeds 3V, keep lowering the resistance until reaching approximately 3V. In case that voltage in node C is originally lower than 3V, follow the same procedure, but keep increasing the resistance of R1.

Amplified signal is gained on resistor R2 from figure 4.8 a. Degree of amplification depends on R2 resistance: *higher resistance - higher amplification, lower resistance - lower amplification*. Upon changing the resistance R2, voltage in node C should be checked and adjusted if necessary (via R1).

Resistor R3 and 100μF capacitor together form a filter to prevent feedback from occurring across positive supply conductor, between the amplifier from figure 4.8 a and the next amplifier level. This feedback manifests itself as a high-pitched noise from the speakers. In case of this occurring, resistance R3 should be increased (to 820 Ω, then to 1k Ω, etc) until the noise stops.

Practical examples with regular resistors will be plenty in the following chapters, since there is practically no electrical scheme without resistors.

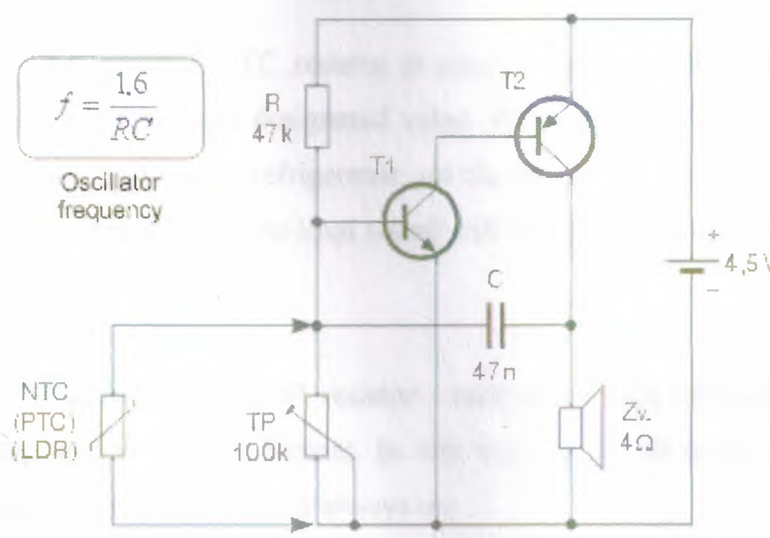


Figure : 4.8 b Sound indicator of changes in temperature or the amount of light it is an audio oscillator. Frequency of the sound it generates can be calculated according to the following formula:

$$f = \frac{1.6}{RC}$$

In our case, R=47k Ω and C=47nF, and the frequency equals:

$$f = \frac{1.6}{47 \cdot 10^3 \cdot 47 \cdot 10^{-9}} \approx 724\ Hz$$

When, according to the figure, trimmer pot and NTC resistor are added, oscillator frequency increases but it keeps "playing". If trimmer pot slider is set to the uppermost position, oscillator stops working. At the desired temperature, slider should be lowered very carefully until the oscillator starts working again. For example, if these settings were made at 2°C, oscillator remains still at higher temperatures than that, as NTC resistor's resistance is lower than nominal. If temperature falls the resistance increases and at 2°C oscillator is activated.

If NTC resistor is installed on the car, close to the road surface, oscillator can warn driver if the road is covered with ice. Naturally, resistor and two copper wires connecting it to the circuit should be protected from dirt and water.

If, instead of NTC resistor, PTC resistor is used, oscillator will be activated when temperature rises above certain designated value. For example, PTC resistor could be used for indicating the state of refrigerator: set the oscillator to work at temperatures above 6°C via trimmer TP, and the loud sound will signal if anything's wrong with the fridge.

Instead of NTC, we could use LDR resistor - oscillator would be blocked as long as there is certain amount of light present. In this way, we could make a simple alarm system for rooms where light must be always on.

LDR can be coupled with resistor R. In that case, oscillator works when the light is present, otherwise it is blocked. This could be an interesting alarm clock for huntsmen and fishermen who would like to get up in the crack of dawn, but only if the weather is

LDR can be coupled with resistor R. In that case, oscillator works when the light is present, otherwise it is blocked. This could be an interesting alarm clock for huntsmen and fishermen who would like to get up in the crack of dawn, but only if the weather is clear. In the desired moment in the early morning, pot slider should be set to the uppermost position. Then, it should be carefully lowered, until the oscillator is started - this the desired position of the slider. During the night, oscillator will be blocked, since there is no light and LDR resistance is very high. As amount of light increases in the morning, LDR resistance drops and the oscillator is activated when LDR is illuminated with the accurate amount of light matching the previous settings.

Trimmer pot from the figure 4.8 b is used for fine adjustments. Aside from that, it can be used for modifying the circuit, if needed. Thus, TP from figure 4.8 b can be used for setting the oscillator to activate under different conditions (higher or lower temperature or amount of light).

4.5 Potentiometers

Potentiometers (also called *pots*) are variable resistors, used as voltage or current regulators in electronic circuits. By means of construction, they can be divided into 2 groups: coated and coiled.

With coated potentiometers, (figure 4.9 a), insulator body is coated with a resistive material. There is an elastic, conductive slider moving across the resistive layer, increasing the resistance between slider and one end of pot, while decreasing the resistance between slider and the other end of pot.

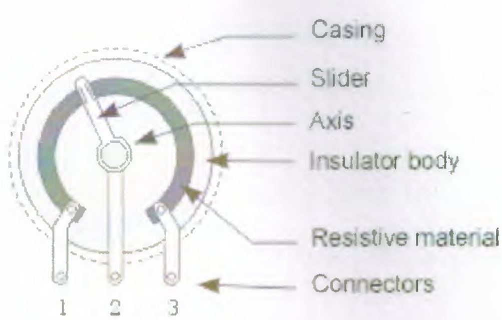


Figure : 4.9 a Coated potentiometer

Coiled potentiometers are made of conductor wire coiled around insulator body. There is an elastic, conductive slider moving across the wire, increasing the resistance between slider and one end of pot, while decreasing the resistance between slider and the other end of pot.

Coated pots are much more common variant. With these, resistance can be linear, logarithmic, inverse-logarithmic or other function depending upon the angle or position of the slider. Most common are linear and logarithmic potentiometers, and the most common applications are radio-receivers, audio amplifiers, and similar devices where pots are used for adjusting the volume, tone, balance, etc.

Coiled potentiometers are used in devices which require increased accuracy and constancy of attributes. They feature higher dissipation than coated pots, and are therefore a necessity in high current circuits.

Potentiometer resistance is commonly of E6 series, most frequently used multipliers including 1, 2.2 and 4.7. Standard tolerance values include 30%, 20%, 10% (and 5% for coiled pots).

Potentiometers come in many different shapes and sizes, with wattage ranging from 1/4W (coated pots for volume control in amps, etc) to tens of Watts (for regulating high currents). Several different pots are shown in the figure 4.9 b, along with the symbol for a potentiometer.

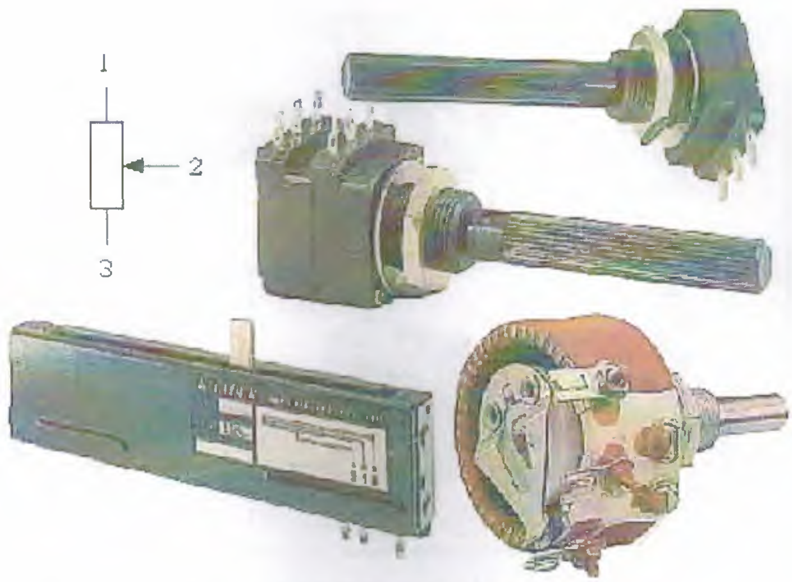


Figure : 4.9 b Potentiometers

Uppermost models represent the so called stereo potentiometer. These are actually two pots in one casing, with sliders mounted on shared axis, so they move simultaneously. These are used in stereophonic amps for simultaneous regulation of both LF channels, etc.

Lower left is the so called ruler potentiometer, with a slider moving across straight line, not in circle as with other pots.

Lower right is coiled pot with wattage of 20W, commonly used as rheostat (for regulating current while charging accumulator and similar).

For circuits that demand very accurate voltage and current value, *trimmer potentiometers* (or just *trimmers*) are used. These are small potentiometers with slider that is adjusted via screw (unlike other pots where adjustments are made via push-button mounted upon the axis which slider is connected to).

Trimmer potentiometers also come in many different shapes and sizes, with wattage ranging from 0.1W to 0.5W. Image Figure 4.10 shows several different trimmers, along with the symbol for this element.

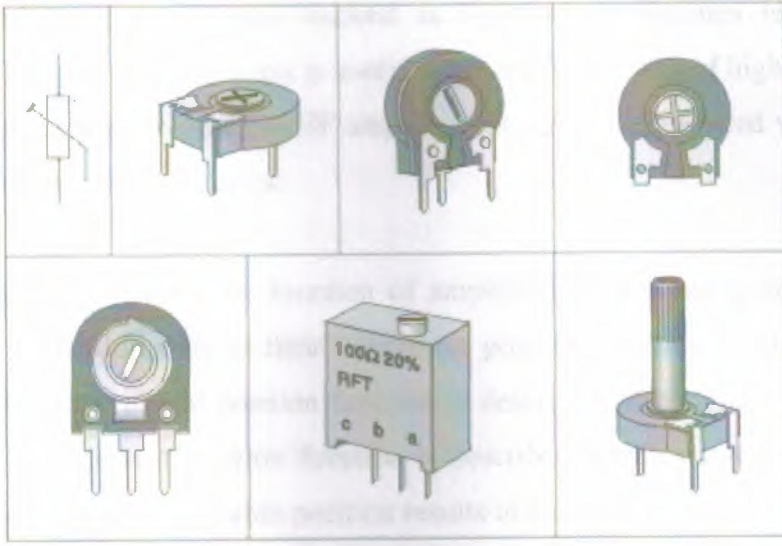


Figure : 4.10 Trimmer potentiometers

Resistance adjustments are made via screw. Exception is the trimmer from the lower right corner, which can be also adjusted via plastic axis. Particularly fine adjusting can be achieved with the trimmer in plastic rectangular casing (lower middle). Its slider is moved via special transmission system, so that several full turns of the wheel are required to move slider from one end to the other.

4.6 Practical Examples With Potentiometers

As previously stated, potentiometers are most commonly used in amps, radio and TV receivers, cassette players and similar devices. They are used for adjusting volume, tone, balance, etc.

As an example, we will analyze the common circuit for tone regulation in audio amps. It contains two pots and is shown in the figure 10 a.

In similar fashion, potentiometer marked as SOPRANO regulates high frequency amplification. High frequency boost is useful when music consists of high-pitched tones such as chimes, while for example HF amplification should be reduced when listening to an old record to reduce the noise.

Diagram figure 10 b shows the function of amplification depending upon the signal frequency. If both sliders are in their uppermost position function is described with a curve 1-2, if both are in mid position function is described with a line 3-4, and if both sliders are in their lowest position function is described with a curve 5-6. Setting the pair of sliders to any other possible position results in a curve between curves 1-2 and 5-6.

Potentiometers BASS and SOPRANO are coated by construction and linear by resistance function.

Third pot from the image serves as volume regulator. It is also coated by construction, but is logarithmic by resistance function (hence the mark *log* underneath it)

Chapter : 5 CAPACITOR

A capacitor is a device that stores an electrical *charge* or energy on it's plates. These plates, a positive and a negative plate, are placed very close together with an insulator in between to prevent the plates from touching each other. A capacitor can carry a voltage eaqual to the battery or input voltage. Usually a capacitor has more than two plates depending on the capacitance or dielectric type.

The 'Charge' is called the amount of stored electriciy on the plates, or actually the electric field between theses plates, and is proportional to the applied voltage and capacitor's 'capacitance'.

The Formula to calculate the amount of capacitance is $Q = C * V$ where:

- Q = Charge in Coulombs
- C = Capacitance in Farads
- V = Voltage in Volts

There is also something else involved when there is 'charge', something stored called 'Energy'.

The formula to calculate the amount of energy is: $W = V^2 * C / 2$ where:

- W = Energy in Joules
- V = Voltage in Volts
- C = Capacitance in Farads

Is it difficult or complicated to 'charge' a capacitor? Not at all. Put proper voltage on the legs of the capacitor and wait till current stops flowing. It goes very fast. Do NOT exceed the capacitor's working breakdown voltage or, in case of an electrolytic capacitor, it will explode. The break down voltage is the voltage that when exceeded will cause the dielectric (insulator) inside the capacitor to break down and conduct. If that happens the results can be catastrophic. And in case of a polarized capacitor, watch the orientation of the positive and negative poles. A healthy, good quality capacitor (disconnected) can hold a charge for a long time. From seconds to several hours and some for several days depending on its size. A capacitor, in combination with other components, can be used as a filter that blocks DC or AC, being it current, frequency, etc.

5.1 Capacitor Codes

I guess you really like to know how to read all those different codes. Not to worry, it is not as difficult as it appears to be. Except for the electrolytic and large types of capacitors, which usually have the value printed on them like 470μF 25V or something, most of the smaller caps have two or three numbers printed on them, some with one or two letters added to that value. Check out the little table below.

Table : 5.1 Capacitor value codes

Capacitor Value Codes

3rd Digit	Multiplier	Letter	Tolerance
0	1	D	0.5 pF
1	10	F	1 %
2	100	G	2 %
3	1,000	H	3 %
4	10,000	J	5 %
5	100,000	K	10 %
6,7	Not Used	M	20 %
8	.01	P	+100, -0 %
9	.1	Z	+80, -20 %

Have a look at Table 5.2. As you can see it all looks very simple. If a capacitor is marked like this 105, it just means 10+5zeros = 10 + 00000 = 1.000.000pF = 1000 nF = 1 μF. And that's exactly the way you write it too. Value is in pF (PicoFarads). The letters added to the value is the tolerance and in some cases a second letter is the temperature coeficient mostly only used in military applications, so basically industrial stuff.

So, for example, it you have a ceramic capacitor with 474J printed on it it means: 47+4zeros = 470000 = 470.000pF, J=5% tolerance. (470.000pF = 470nF = 0.47μF)

Pretty simple, huh? The only major thing to get used to is to recognize if the code is µF nF, or pF.

Other capacitors may just have 0.1 or 0.01 printed on them. If so, this means a value in µF. Thus 0.1 means just 0.1 µF. If you want this value in nanoFarads just move the comma three places to the right which makes it 100nF.

But the average hobbyist uses only a couple types like the common electrolytic and ceramic capacitors and depending on the application, a more temperature stable type like metal-film or polypropylene.

Table : 5.2 Capacitor value codes

X=value	F	10 pF	2%	
	G	12 pF	--	
	H	15 pF	--	
	S	20 pF	--	
	K	22 pF	--	
NPO	L	27 pF	--	
	-	33 pF	--	
	P	47 pF	--	
	Q	56 pF	--	
	S	82 pF	--	
	-	100 pF	--	
	-	150 pF	--	
	J	180 pF	10%	
	K	220 pF	--	
	L	270 pF	--	
	M	330 pF	--	
	N	390 pF	--	
	A	470 pF	--	
	Q	560 pF	--	
	R	680 pF	--	
	F	1KpF	--	(1.0nF)
	-	1N5	--	(1.5nF)

The larger the plate area and the smaller the area between the plates, the larger the capacitance. Which also depends on the type of insulating material between the plates which is the smallest with air. (You see this type of capacitor sometimes in high-voltage circuits and are called 'spark-caps'.) Replacing the air space with an insulator will increase the capacitance many times over. The capacitance ratio using an insulator material is called.

5.2 Dielectric Constant

While the insulator material itself is called just Dielectric. Using the table in Table 5.3, if a Polystyrene dielectric is used instead of air, the capacitance will be increased 2.60 times.

Table : 5.3 Dielectric constant of materials

Dielectric Constant of Materials			
Air	1.00	Paper	3.00
Alsimag 196	5.70	Plexiglass	2.80
Bakelite	4.90	Polyethylene	2.30
Cellulose	3.70	Polystyrene	2.60
Fiber	6.00	Porcelain	5.57
Formica	4.75	Pyrex	4.80
Glass	7.75	Quartz	3.80
Mica	5.40	Steatite	5.80
Mycalex	7.40	Teflon	2.10

Look below for a more detailed explanation for the most commonly used caps.

5.2.1 Electrolytic

Made of electrolyte, basically conductive salt in solvent. Aluminum electrodes are used by using a thin oxidation membrane. Most common type, polarised capacitor. Applications: Ripple filters, timing circuits. Cheap, readily available, good for storage of charge (energy). Not very accurate, marginal electrical properties, leakage, drifting, not suitable for use in hf circuits, available in very small or very large values in μF. They WILL explode if the rated working voltage is exceeded or polarity is reversed, so be careful. When you use this type capacitor in one of your projects, the rule-of-thumb is to choose one which is twice the supply voltage. Example, if your supply power is 12 volt you would choose a 24volt (25V) type. This type has come a long way and characteristics have constantly improved over the years. It is and always will be an all-time favorite; unless something better comes along to replace it. But I don't think so for this decade; polarized capacitors are heavily used in almost every kind of equipment and consumer electronics.

Figure : 5.1 Electrolytic

5.2.2 Tantalum

Made of Tantalum Pentoxide. They are electrolytic capacitors but used with a material called tantalum for the electrodes. Superior to electrolytic capacitors, excellent temperature and frequency characteristics. When tantalum powder is baked in order to solidify it, a crack forms inside. An electric charge can be stored on this crack. Like electrolytics, tantalums are polarized so watch the '+' and '-' indicators. Mostly used in analog signal systems because of the lack of current-spike-noise. Small size fits anywhere, reliable, most common values readily available. Expensive, easily damaged by spikes, large values exists but may be hard to obtain. Largest in my own collection is 220µF/35V, beige color.

Figure : 5.2 Tantalum

5.2.3 Super Capacitors

The Electric Double Layer capacitor is a real miracle piece of work. Capacitance is 0.47 Farad (470,000 µF). Despite the large capacitance value, its physical dimensions are relatively small. It has a diameter of 21 mm (almost an inch) and a height of 11 mm (1/2 inch). Like other electrolytics the super capacitor is also polarized so exercise caution in regards to the break-down voltage. Care must be taken when using this capacitor. It has such large capacitance that, without precautions, it would destroy part of a powersupply such as the bridge rectifier, volt regulators, or whatever because of the huge inrush current at charge. For a brief moment, this capacitor acts like a short circuit when the capacitor is charged. Protection circuitry is a must for this type.(See figure 5.3 Super Capacitor)

Figure : 5.3 Super Capacitors

5.2.4 Polyester Film

This capacitor uses a thin polyester film as a dielectric. Not as high a tolerance as polypropeylene, but cheap, temperature stable, readily available, widely used. Tolerance is approx 5% to 10%. Can be quite large depending on capacity or rated voltage and so may not be suitable for all applications.

Figure : 5.4 Polyester Film

5.2.5 Polypropylene

Mainly used when a higher tolerance is needed then polyester caps can offer. This polypropylen film is the dielectric. Very little change in capacitance when these capacitors are used in applications within frequency range 100KHz. Tolerance is about 1%. Very small values are available.

Figure : 5.5 Polypropylene

5.2.6 Polystyrene

Polystyrene is used as a dielectric. Constructed like a coil inside so not suitable for high frequency applications. Well used in filter circuits or timing applications using a couple hundred KHz or less. Electrodes may be redish of color because of copper leaf used or silver when aluminum foil is used for electrodes.

Figure : 5.6 Polystyrene

5.2.7 Metalized Polyester Film

Dielectric made of Metal-Oxide. Good quality, low drift, temperature stable. Because the electrodes are thin they can be made very very small. Good all-round capacitor.

Figure : 5.7 Metalized Polyester Film

5.2.8 Epoxy

Manufactured using epoxy based polymers as dielectric. Widely availble, stable, cheap. Can be quite large depending on capacity or rated voltage and so may not be suitable for all applications.

Figure : 5.8 Epoxy

5.2.9 Ceramic

Constructed with materials such as titanium acid barium for dielectric. Internally these capacitors are not constructed as a coil, so they are well suited for use in high frequency applications. Typically used to by-pass high frequency signals to ground. They are shaped like a disk, available in very small capacitance values and very small sizes. Together with the electrolytics the most widely available and used capacitor around. Comes in very small size and value, very cheap, reliable. Subject to drifting depending on ambient temperature. NPO types are the temperature stable types. They are identified by a black stripe on top.

Figure : 5.9 Ceramic

5.2.10 Multilayer Ceramic

Dielectric is made up of many layers. Small in size, very good temperature stability, excellent frequency stable characteristics. Used in applications to filter or bypass the high frequency to ground. They don't have a polarity. *Multilayer caps suffer from high-Q internal (parallel) resonances - generally in the VHF range. The CK05 style 0.1µF/50V caps for example resonate around 30MHz. The effect of this resonance is effectively no apparent capacitance near the resonant frequency.

As with all ceramic capacitors, be careful bending the legs or spreading them apart to close to the disc body or they may get damaged.

Figure : 5.10 Multilayer Ceramic

5.2.11 Silver-Mica

Mica is used as a dielectric. Used in resonance circuits, frequency filters, and military RF applications.

Highly stable, good temperature coefficient, excellent for endurance because of their frequency characteristics, no large values, high voltage types available, can be expensive but worth the extra dimes.

Figure : 5.11 Silver-Mica

5.2.12 Adjustable Capacitors

Also called trimmer capacitors or variable capacitors. It uses ceramic or plastic as a dielectric.

Most of them are color coded to easily recognize their tunable size. The ceramic type has the value printed on them. Colors are: yellow (5pF), blue (7pF), white (10pF), green (30pF), brown (60pf). There are a couple more colors like red, beige, and purple which are not listed here. Anyways, you get the idea...

Figure : 5.12 Adjustable Capacitors

5.2.13 Tuning or 'air-core' Capacitors

They use the surrounding air as a dielectric. I have seen these variable capacitor types of incredible dimensions, especially the older ones. Amazing it all worked. Mostly used in radio and radar equipment. This type usually have more (air) capacitors combined (ganged) and so when the adjustment axel is turned, the capacitance of all of them changes simultaneously. The one on the right has a polyester film as a dielectric contant and combines two independant capacitors plus included is a trimmer cap, one for each side.

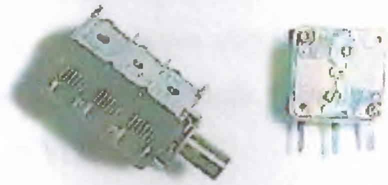


Figure : 5.13 Tuning or 'air-core' capacitors.

Chapter : 6 CD4001 BC OF GATE

6.1 General Description

The CD4001BC and CD4011BC quad gates are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. They have equal source and sink current capabilities and conform to standard B series output drive. The devices also have buffered outputs which improve transfer characteristics by providing very high gain. All inputs are protected against static discharge with diyotes to VDD and VSS.

6.2 Features

-Low power TTL: Fan out of 2 driving 74L compatibility: or 1 driving 74LS
-5V–10V–15V parametric ratings
-Symmetrical output characteristics
-Maximum input leakage 1 μA at 15V over full temperature range

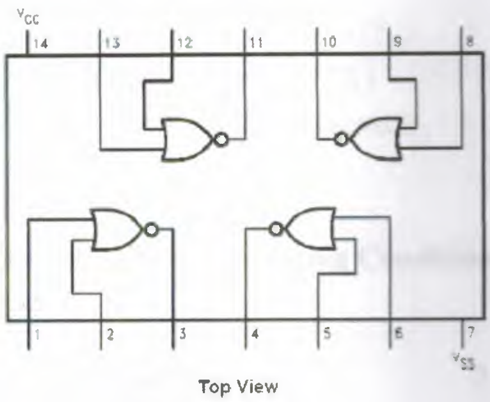
6.3 Ordering Code

Order Number	Package Number	Package Description
CD4001BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4001BCSJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
CD4001BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
CD4011BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4011BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

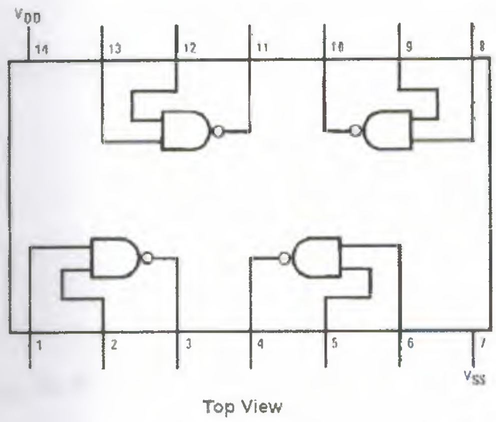
6.4 Connection Diagrams

Pin Assignments for DIP, SOIC and SOP | Pin Assignments for DIP and SOIC

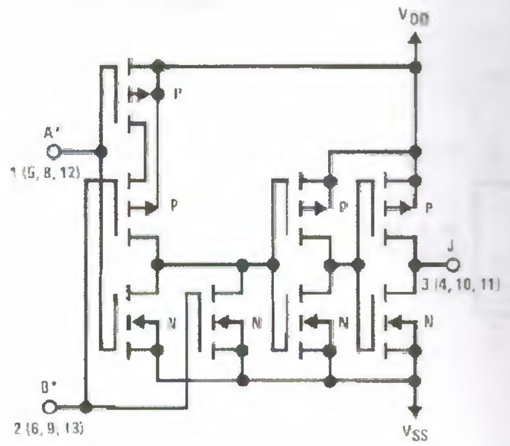
CD4011BC



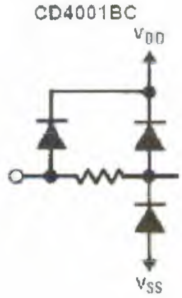
CD4001BC



6.5 Schematic Diagrams



CD4001BC



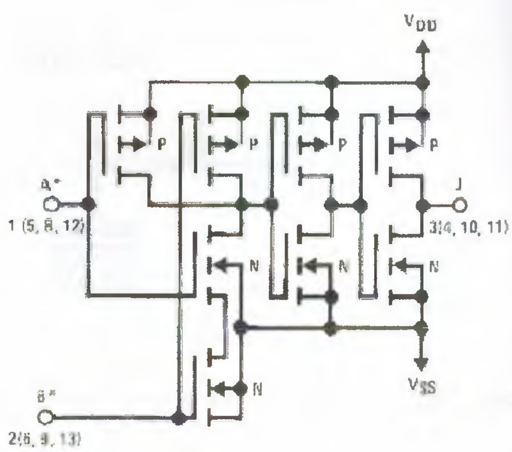
1/4 of device shown

$J = \overline{A + B}$

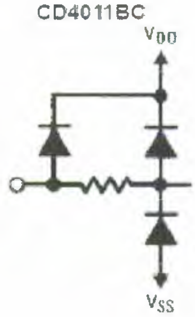
Logical "1" = HIGH

Logical "0" = LOW

All inputs protected by standard CMOS protection circuit.



CD4011BC



1/4 of device shown

$J = \overline{A \cdot B}$

Logical "1" = HIGH

Logical "0" = LOW

All inputs protected by standard CMOS protection circuit.

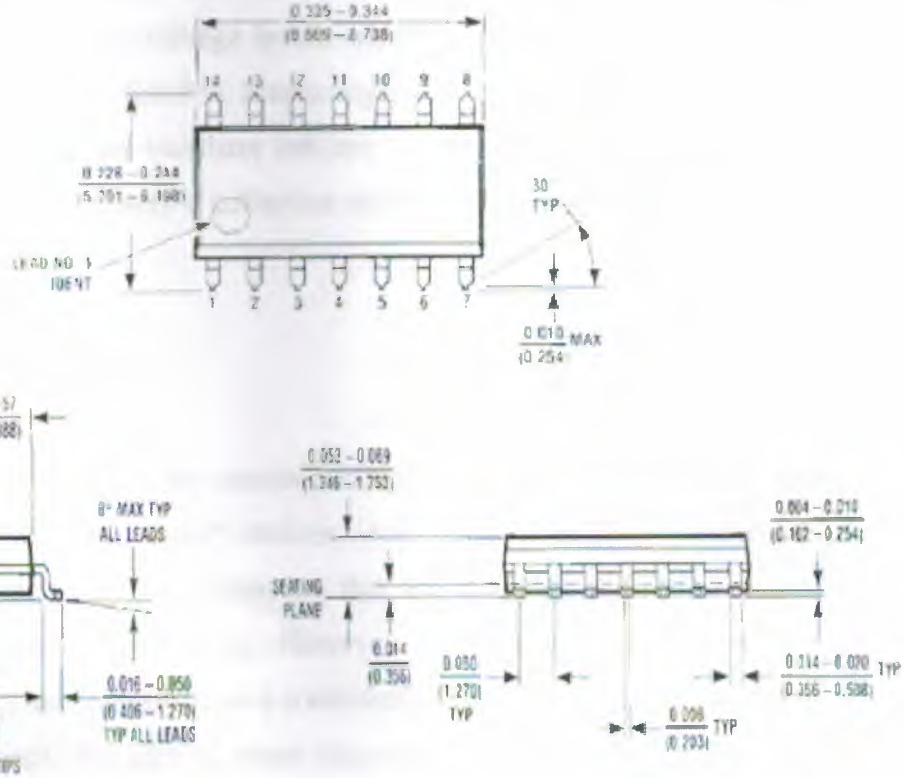
6.6 Absolute Maximum Ratings

Voltage at any Pin	$-0.5V$ to V_{DD} $+0.5V$
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
V_{DD} Range	-0.5 V_{DC} to $+18$ V_{DC}
Storage Temperature (T_S)	$-65°C$ to $+150°C$
Lead Temperature (T_L)	
(Soldering, 10 seconds)	260°C

6.7 Recommended Operating Conditions

Operating Range (V_{DD})	3 V_{DC} to 15 V_{DC}
Operating Temperature Range	
CD4001BC, CD4011BC	$-55°C$ to $+125°C$

6.8 Physical Dimensions



14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow Package Number M14A

Chapter : 7 TRANSISTORS

7.1 Introduction to Transistors

Generally transistors fall into the category of bipolar transistor, either the more common NPN bipolar transistors or the less common PNP transistor types. There is a further type known as a FET transistor which is an inherently high input impedance transistor with behaviour somewhat comparable to valves. Modern field effect transistors or FET's including JFETS and MOSFETS now have some very rugged transistor devices. I am often asked about the term "bipolar" - see later.

7.2 History of Transistors

The transistor was developed at Bell Laboratories in 1948. Large scale commercial use didn't come until much later owing to slow development. Transistors used in most early entertainment equipment were the germanium types. When the silicon transistor was developed it took off dramatically. The first advantages of the transistor were relatively low power consumption at low voltage levels which made large scale production of portable entertainment devices feasible. Interestingly the growth of the battery industry has paralleled the growth of the transistor industry. In this context I include integrated circuits which of course are simply a collection of transistors grown on the one silicon substrate.

7.3 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.

7.4 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 7.1 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.

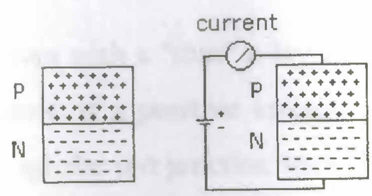


Figure : 7.1. Electron flow in a p-n juction of a diode

Some very interesting points emerge here. As depicted in figure 7.1 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 7.2 below.

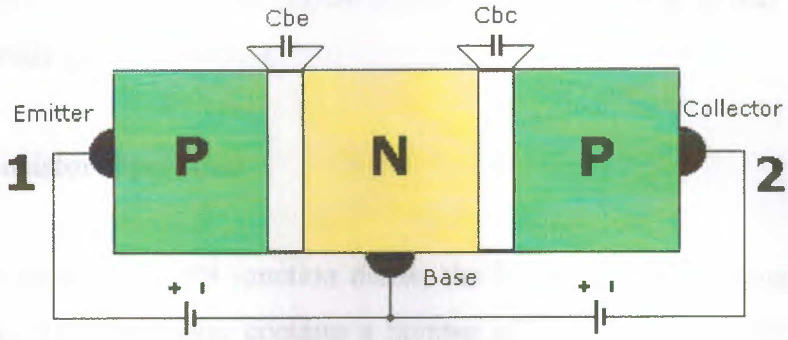


Figure : 7.2 Sandwich construction of a PNP transistor

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. Consider the base to be a bit like a tap or faucet handle.

7.5 Transistor Aplification

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 $P = I^2 X R$ that amplification occurs. See small signal amplifiers.

7.6 NPN Transistor Operation

Just as in the case of the PN junction diode, the N material comprising the two end sections of the NP N transistor contains a number of free electrons, while the center P section contains an excess number of holes. The action at each junction between these sections is the same as that previously described for the diode; that is, depletion regions develop and the junction barrier appears. To use the transistor as an amplifier, each of these junctions must be modified by some external bias voltage. For the transistor to function in this capacity, the first PN junction (emitter-base junction) is biased in the forward, or low-resistance, direction. At the same time the second PN junction (base-collector junction) is biased in the reverse, or high-resistance, direction. A simple way to remember how to properly bias a transistor is to observe the NPN or PNP elements that make up the transistor. The letters of these elements indicate what polarity voltage to use for correct bias. For instance, notice the NPN transistor below:

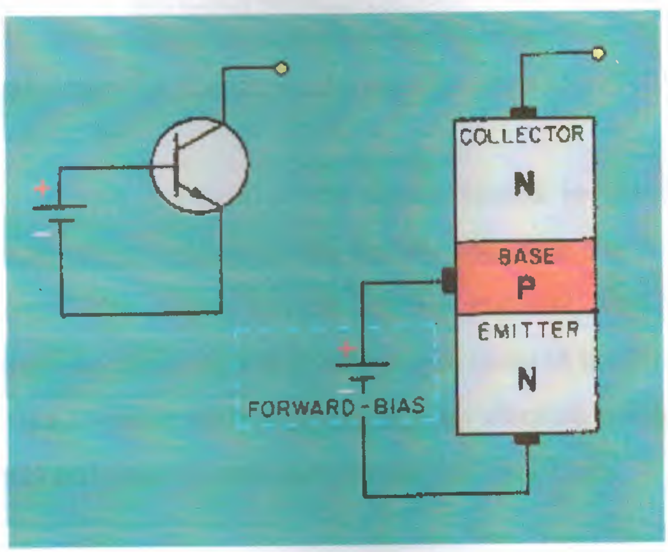


Figure : 7.3 NPN transistor

The emitter, which is the first letter in the NPN sequence, is connected to the negative side of the battery while the base, which is the second letter (NPN), is connected to the positive side. However, since the second PN junction is required to be reverse biased for proper transistor operation, the collector must be connected to an opposite polarity voltage (positive) than that indicated by its letter designation (NPN).

NPN FORWARD-BIASED JUNCTION. - An important point to bring out at this time, which was not necessarily mentioned during the explanation of the diode, is the fact that the N material on one side of the forward-biased junction is more heavily doped than the P material. This results in more current being carried across the junction by the majority carrier electrons from the N material than the majority carrier holes from the P material. Therefore, conduction through the forward-biased junction, as shown in figure 4, is mainly by majority carrier electrons from the N material (emitter).

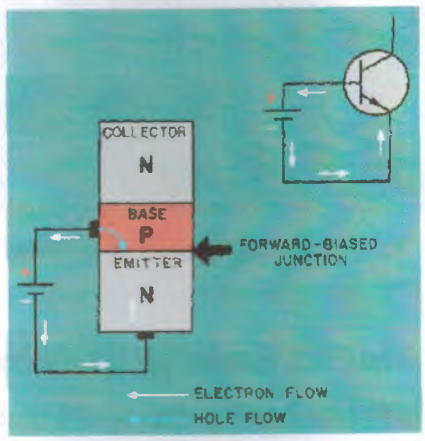


Figure : 7.4 The forward-biased junction in an NPN transistor

With the emitter-to-base junction in the figure biased in the forward direction, electrons leave the negative terminal of the battery and enter the N material (emitter). Since electrons are majority current carriers in the N material, they pass easily through the emitter, cross over the junction, and combine with holes in the P material (base). For each electron that fills a hole in the P material, another electron will leave the P material (creating a new hole) and enter the positive terminal of the battery.

NPN REVERSE-BIASED JUNCTION. - The second PN junction (base-to-collector), or reverse-biased junction as it is called (figure 7.5), blocks the majority current carriers from crossing the junction. However, there is a very small current, mentioned earlier, that does pass through this junction. This current is called minority current, or reverse current. As you recall, this current was produced by the electron-hole pairs. The minority carriers for the reverse-biased PN junction are the electrons in the P material and the holes in the N material. These minority carriers actually conduct the current for the reverse-biased junction when electrons from the P material enter the N material, and the holes from the N material enter the P material. However, the minority current electrons (as you will see later) play the most important part in the operation of the NPN transistor.

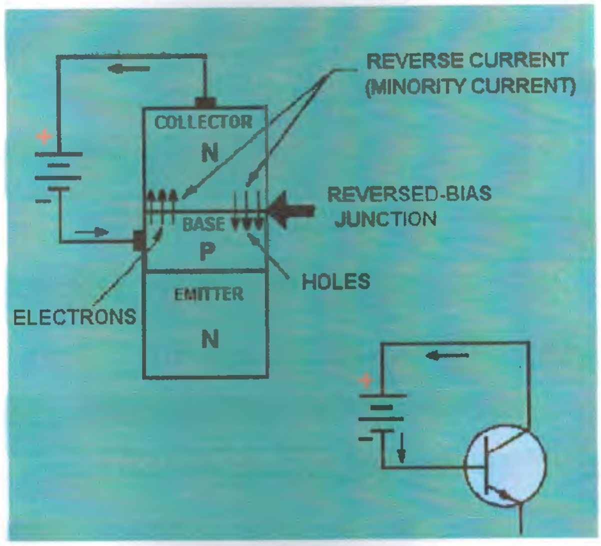


Figure : 7.5 The reverse-biased junction in an NPN transistor.

At this point you may wonder why the second PN junction (base-to-collector) is not forward biased like the first PN junction (emitter-to-base). If both junctions were forward biased, the electrons would have a tendency to flow from each end section of the N P N transistor (emitter and collector) to the center P section (base). In essence, we would have two junction diodes possessing a common base, thus eliminating any amplification and defeating the purpose of the transistor. A word of caution is in order at this time. If you should mistakenly bias the second PN junction in the forward direction, the excessive current could develop enough heat to destroy the junctions, making the transistor useless. Therefore, be sure your bias voltage polarities are correct before making any electrical connections.

NPN JUNCTION INTERACTION. - We are now ready to see what happens when we place the two junctions of the NPN transistor in operation at the same time. For a better understanding of just how the two junctions work together, refer to figure 7.6 during the discussion.

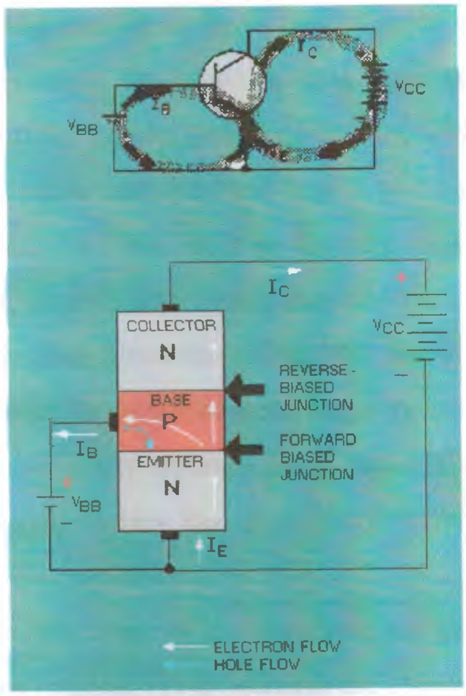


Figure : 7.6 NPN transistor operation.

The bias batteries in this figure have been labeled V_{CC} for the collector voltage supply, and V_{BB} for the base voltage supply. Also notice the base supply battery is quite small, as indicated by the number of cells in the battery, usually 1 volt or less. However, the collector supply is generally much higher than the base supply, normally around 6 volts. As you will see later, this difference in supply voltages is necessary to have current flow from the emitter to the collector.

As stated earlier, the current flow in the external circuit is always due to the movement of free electrons. Therefore, electrons flow from the negative terminals of the supply batteries to the N-type emitter. This combined movement of electrons is known as emitter current (I_E). Since electrons are the majority carriers in the N material, they will move through the N material emitter to the emitter-base junction. With this junction forward biased, electrons continue on into the base region. Once the electrons are in the base, which is a P-type material, they become minority carriers. Some of the electrons that move into the base recombine with available holes. For each electron that recombines, another electron moves out through the base lead as base current I_B (creating a new hole for eventual combination) and returns to the base supply battery V

The electrons that recombine are lost as far as the collector is concerned. Therefore, to make the transistor more efficient, the base region is made very thin and lightly doped. This reduces the opportunity for an electron to recombine with a hole and be lost. Thus, most of the electrons that move into the base region come under the influence of the large collector reverse bias. This bias acts as forward bias for the minority carriers (electrons) in the base and, as such, accelerates them through the base-collector junction and on into the collector region. Since the collector is made of an N-type material, the electrons that reach the collector again become majority current carriers. Once in the collector, the electrons move easily through the N material and return to the positive terminal of the collector supply battery V_{CC} as collector current (I_C).

To further improve on the efficiency of the transistor, the collector is made physically larger than the base for two reasons: (1) to increase the chance of collecting carriers that diffuse to the side as well as directly across the base region, and (2) to enable the collector to handle more heat without damage.

In summary, total current flow in the **NPN** transistor is through the emitter lead. Therefore, in terms of percentage, I_E is 100 percent. On the other hand, since the base is very thin and lightly doped, a smaller percentage of the total current (emitter current) will flow in the base circuit than in the collector circuit. Usually no more than 2 to 5 percent of the total current is base current (I_B) while the remaining 95 to 98 percent is collector current (I_C). A very basic relationship exists between these two currents:

$$I_E = I_B + I_C$$

In simple terms this means that the emitter current is separated into base and collector current. Since the amount of current leaving the emitter is solely a function of the emitter-base bias, and because the collector receives most of this current, a small change in emitter-base bias will have a far greater effect on the magnitude of collector current than it will have on base current. In conclusion, the relatively small emitter-base bias controls the relatively large emitter-to-collector current.

Chapter : 8 ALERT SYSTEM AGAINST THIEF

Aim of this project is alert the owners of building. It can alert are two ways;

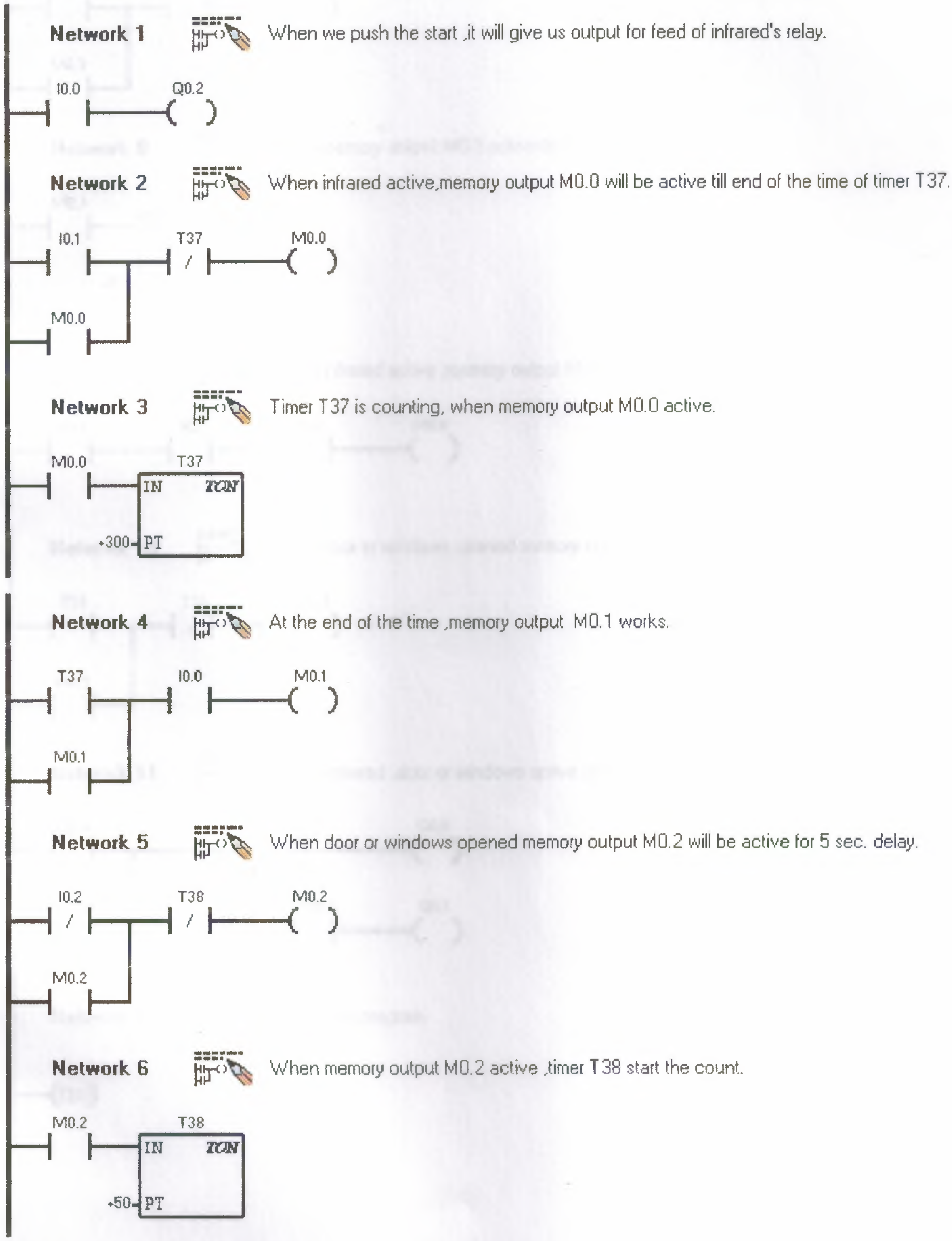
- By infrared sensor
- By door and windows switch.

When if there is any moving in the house or in bulding it will give us output. And if door or windows switch opened it will give us output.

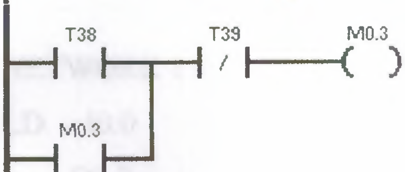
Table 8.1 Inputs, Outputs, and Timers that used in the Program

INPUT	TIMER	OUTPUT
I0.0 : Start and stop switch	**Timer On-Delay** **T37 :** For 30 seconds	**Q0.0 :** For alarm
I0.1: Infrared sensor	**Timer On-Delay** **T38 :** For 5 seconds	**Q0.1 :** For lamp
I0.2 : Door and windows sensor	**Timer On-Delay** **T39 :** For 15 seconds	**Q0.2 :** Relay of feeder the infrared

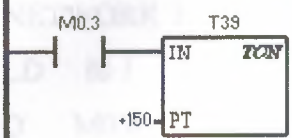
8.1 Ladder Diagram



Network 7 At the end of counting timer T38, memory output M0.3 will be active for alert system stop.

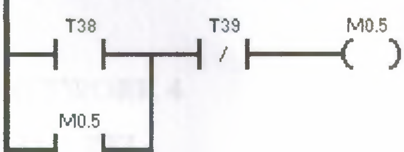


Network 8 When memory output M0.3 active timer T39 will start count.



Network 9 When infrared active ,memory output M0.4 will be active.

Network 10 when door or windows opened memory output M0.5 will be active.



Network 11 When infrared ,door or windows active alert system will work.

Network 12 End of the program.

8.2 Statement List

```
NETWORK 1
LD    I0.0
=     Q0.2

NETWORK 2
LD    I0.1
O     M0.0
AN    T37
=     M0.0

NETWORK 3
LD    M0.0
TON   T37, +300

NETWORK 4
LD    T37
O     M0.1
A     I0.0
=     M0.1

NETWORK
LDN   I0.2
O     M0.2
AN    T38
=     M0.2

NETWORK 6
LD    M0.2
TON   T38, +50

NETWORK 7
LD    T38
```

```
O     M0.3
AN     T39
=     M0.3

NETWORK 8
LD    M0.3
TON    T39, +150

NETWORK 9
LD    M0.1
A     I0.1
A     I0.2
=     M0.4

NETWORK 10
LD    T38
O     M0.5
AN     T39
=     M0.5

NETWORK 11
LD    M0.4
O     M0.5
=     Q0.0
A     SM0.5
=     Q0.1

NETWORK 12
MEND
```

8.3 Pulsed Tone Alarm

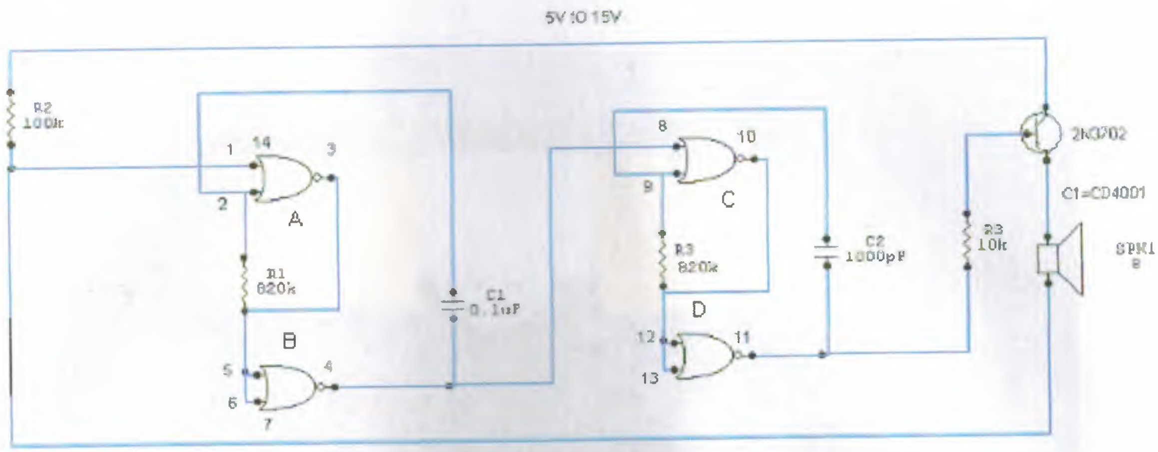
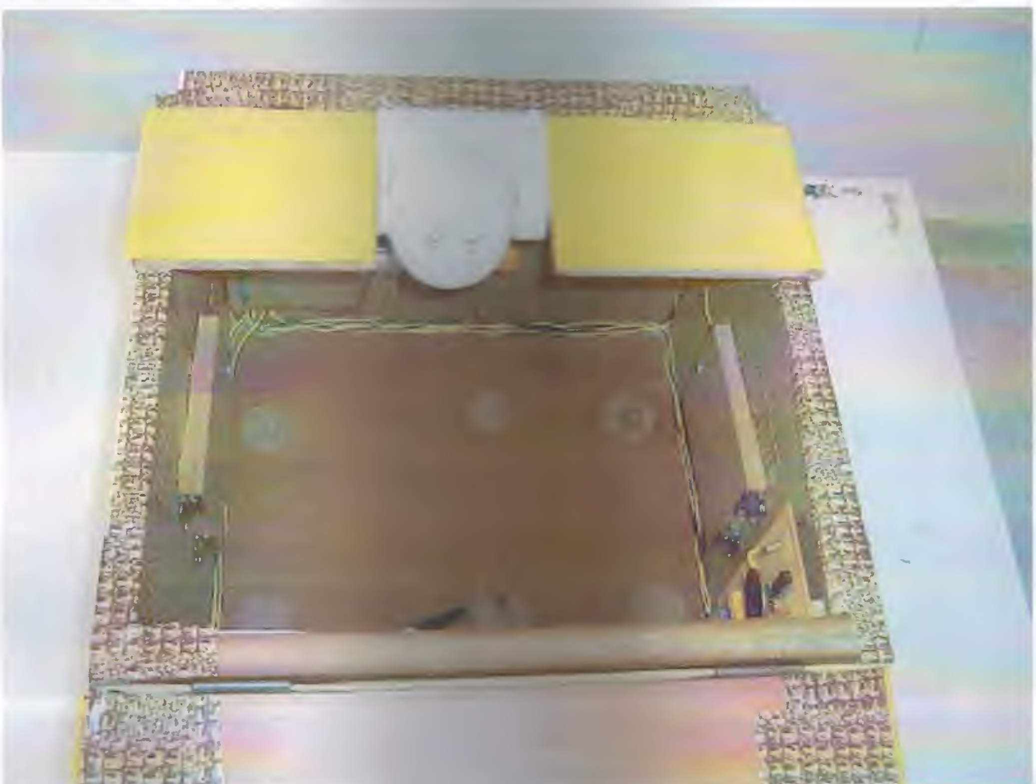
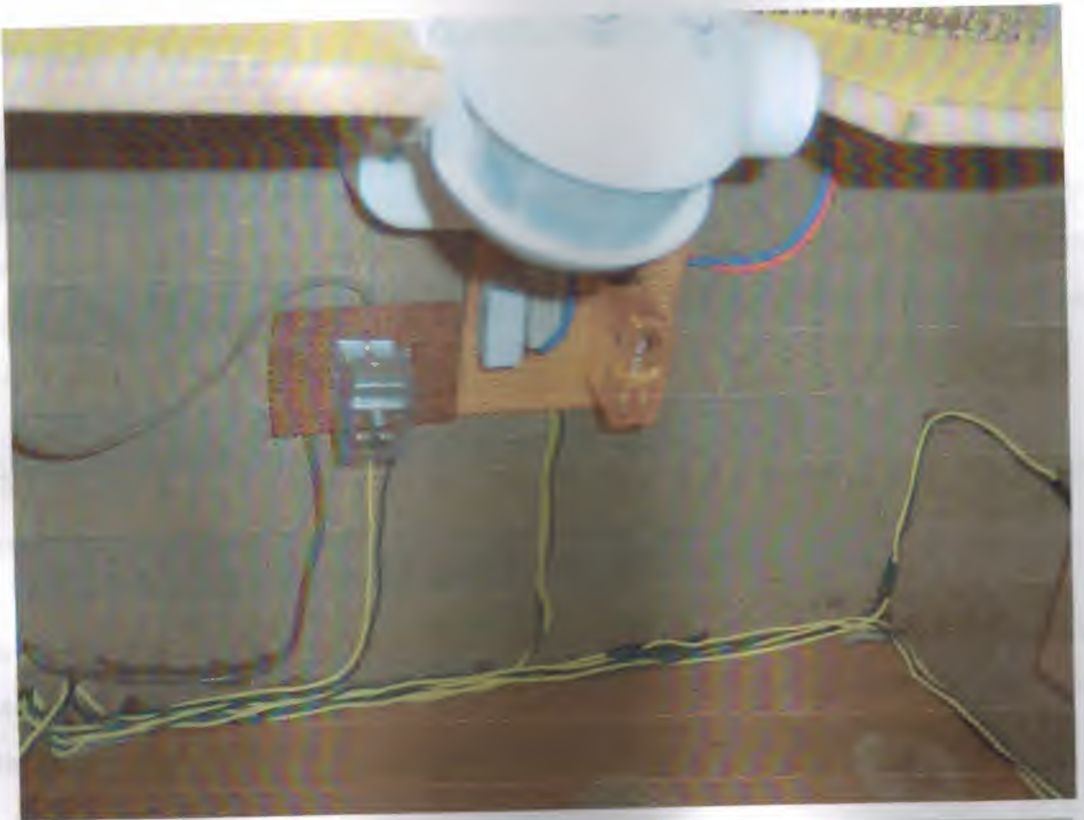


Figure : 8.1 Pulsed tone alarm generator

Figure 8.1 shows the circuit of a low power pulsed tone alarm generator. Gates A and B are wired as a fixed frequency astable multivibrator that operates at frequency of about 6Hz and is gated on via S1 and gates C and D are wired as an 800Hz astable multibrator that is gated on and off by the output of the A B astable.The output of the 800Hz astable feeds to the speaker via Q1 and Rx.Thus when S1 is closed the tone in the speaker comprises an 800Hz note that is pulsed on and off at a rate of 6 Hz.

8.4 Pictures





CONCLUSION

Security is one of the most important concept in today's life. For this, there are many real life applications. The security is very important thing for human's life. When you sleep or you are outside, worrying about your valuable things, for this reason we need solution for security.

This project is alert system against thief for security of building. It is very simple application of security systems.

In this project S-7 200 PLC was used, for controlling of sensor, switch position,lamp and buzer. S-7 200 PLC provides many advantages at the automation. The devices used for this project;

- Infrared sensor
- Siren circuit
- Door and windows switch
- Lamp
- Relay

The project has three inputs and three outputs. When the inputs are activeted the circuit will give output (buzer and lamp on).

Some future applications may be added;

- Camera
- Photocell

REFERENCES

[1] http://www.electronics-tutorials.com/basics/transistors.htm author Ian C. Purdie

[2] http:// www.fairchildsemi.com

[3] Grob, Bernard, ''Basic Electronics'', McGraw Hill, Seventh Edition, 1993,

[4] C. W., ''Power Electronics'', McGraw Hill, Second Edition,

[5] E. C., Rusch R. J., "Electric Circuits And Machines", McGraw Hill, Seventh Edition, 1993,

[6] "Electronic Components and Tecnology" , S. J. Sangwine Second Edition ,1994