NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

ALARM SYSTEMS BY USING WITH ELECTRONIC COMPONENTS

Graduation Project
EE – 400

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TABLE OF CONTENTS

ACKNOWLEDGEMENT....i
ABSTRACT....ii
INTRODUCTION....iii

CHAPTER:1....1
1.TRANSISTORS....1
1.1 Introduction to transistors?....1
1.2 History of Transistors....1
1.3 How do transistors work?....1
1.4 How do holes and electrons conduct in transistors?....2
1.5 Transistor amplification....4
1.6 NPN Transistor Operation....4
1.7 FET's as transistors....10
1.8 How are semiconductors made?....10
1.9 Construction....11

CHAPTER :2....13
2.RESISTORS....13
2.1 Introduction....13
2.2 Type of Resistors....13
2.3 Low power resistors....16
2.4 High power resistors....17
2.5 Variable resistors....17
2.6 Resistor Color Coding....18

CHAPTER:3....23
3.CAPACITOR....23
3.1 How Charge is Stored in The Dielectric....23
3.2 Changing and Discharging a Capacitor....24
3.3 The Farad Unit of Capacitance....27
3.4 Typical Capacitors....30
3.5 Electrolytic Capacitors....35
3.6 Capacitor Color Coding....37
3.7 Parallel Capacitances....39
3.8 Series Capacitances....40
3.9 Stray Capacitive and Inductive Effects....41
3.10 How to read a capacitor....45
3.11 Capacitor codes....46

CHAPTER:4....48
4 DIODES....48
4.1 Semiconductor Diodes....48
4.2 Special Purpose Diodes....50

CHAPTER:5..55
5 CD4001 BC OF GATE 55
5.1 General Description..55
5.2 Features...55
5.3 Ordering Code...55
5.4Connection Diagrams..56
5.6 Schematic Diagrams...56
5.7 Absolute Maximum Ratings 57
5.8Recommended Operating Conditions..57
5.9 DC Electrical Characteristics..57
5.10 AC Electrical Characteristics...58
5.11 AC Electrical Characteristics...58
5.12 Typical Transfer Characteristics..59
5.13 Typical Performance Characteristics..60
5.14 Typical Performance Characteristics..61
5.15 Physical Dimensions..62

CHAPTER:6..65
6.1 Flip flop 65
6.2 Master-Slave D Flip-flops..68
6.3 Master-Slave JK Flip-flops Circuit Structure and Operation..............70
6.4 Edge-triggered D Flip-flops 72
6.5 Edge-triggered JK Flip-flops 77
6.6 T Flip-flops Edge-triggered T Flip-flop 79
6.7 Latch and Flip-flop Summary 81

CHAPTER: 7..82
7 THE CIRCUIT OF ALARM SYSTEMS AND PICTURES.......................82
7.1 Low Power Alarm...82
7.2 High Power Alarm..84
7.3 Pulsed Tone Alarm...84
7.4 One Shot Alarm...85
7.5 Picture..86

CONCLUSION..88
REFERENCES..89

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ABSTRACT

Electronic components are internal organs of electronic and electrical circuit. For the engineering knowledge of electronic components is very important to design many applications with electronic devices.

Electronic devices makes easier for the activication of people. We can say some applications for example , robotic devices , communication systems , illumating systems...etc. Also there are many kind of these application . In the real life everytime we need to these electronic devices.

While working in the topic of electrical and electronic components. Everyone, technicians or engineers should be very careful because small mistakes can cause big damages in application.

Therefore these reasons electronic and electrical very important for our life. We can not think a life less electronic and electric.

INTRODUCTION

For most part,the subject of electronic devices means semiconductor devices such as transistor, diodes and integrated circuits. They are used for amplifiers,oscillators,rectifiers and digital circuits which include just about everything in electronics. The semiconductors are a group of chemical elements with special electrical characteristic most common are are silicon (si) and germanium (Ge) with Si used for almost all semiconductors components.The semiconductors have unique atomic structure that allows the addition of specific impurity elements to produce very useful features that can be applied in electronic circuits.

Resistors are probably the most common components in electronic equipment.A resistor is manufactured with specific value of ohms for its resistance (R). The purpose of using a resistor in circuit is either to reduce current I to a specific value or to provide a desied voltageV.The feature of resistance that the effect is the same for dc and ac circuits.

Capacitance is the ability of a dielectric to store electric charge. The more the charge that is stored for a given voltage , the higher the value o capacitance.Its symbol is C and units is the Farad (F) .Acapacitor consists of an insulator betwen two conductors. Common types are air,ceramic,mica,paper,plastic and electrolytic capacitors. Capacitors used in electronic circuits are small and economical.

CHAPTER: 1

1.TRANSISTORS

1.1 Introduction to transistors?

Transistors, I was once told, "were the fastest acting fuse known to mankind". This of course was a reference to the fact an early transistor was intolerant of fault conditions whereas in years gone by, vacuum tubes (valves) would cop a lot of abuse. Just remember that fact. [one of "murphy's laws" - The component exists to protect the fuse]

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.

1.2 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.

1.3 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.

1.4 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 1.4.1 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.

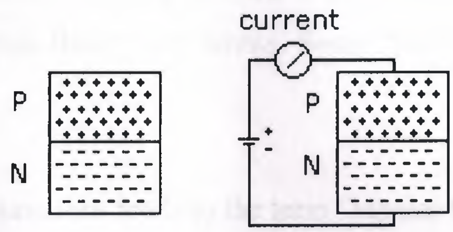


Figure 1.4.1 - electron flow in a p-n juction of a diode

Some very interesting points emerge here. As depicted in figure 1.4.1 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 1.4.2 below.

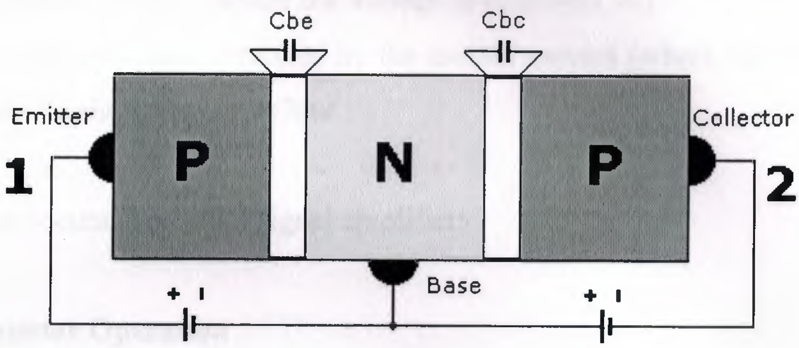


Figure 1.4.2. - sandwich construction of a PNP transistor

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.

1.5 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

$P = I^2 X R$

that amplification occurs. See small signal amplifiers

1.6 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 show below figure: 1.6.1:

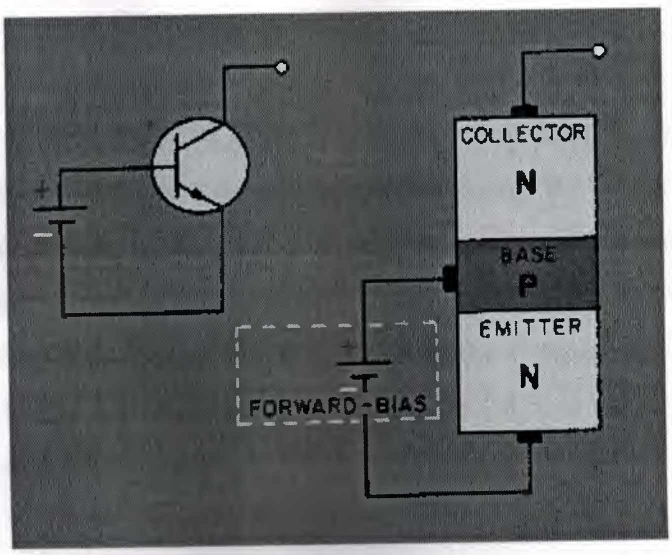


Figure: 1.6.1

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). The voltage on the collector must also be more positive than the base, as shown below figure:1.6.2:

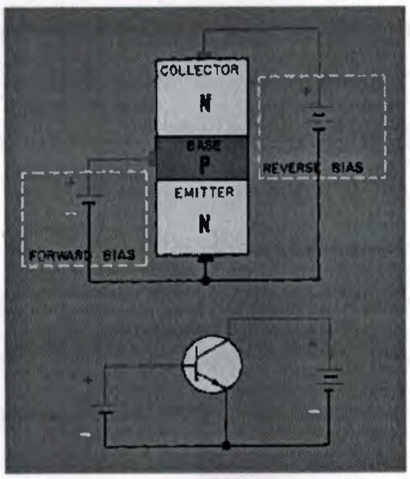


Figure: 1.6.2

We now have a properly biased NPN transistor.

In summary, the base of the NPN transistor must be positive with respect to the emitter, and the collector must be more positive than the base.

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 1.6.3, is mainly by majority carrier electrons from the N material (emitter).

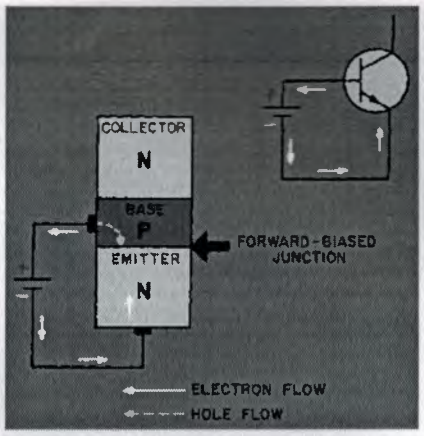


Figure 1.6.3. - The forward-biased junction in an NPN transistor

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 (fig. 1.6.4), 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.

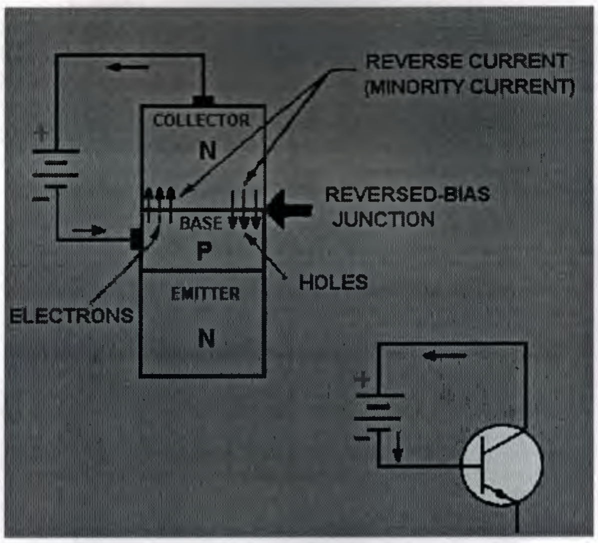


Figure 1.6.4. - The reverse-biased junction in an NPN transistor.

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 1.6.5 during the discussion.

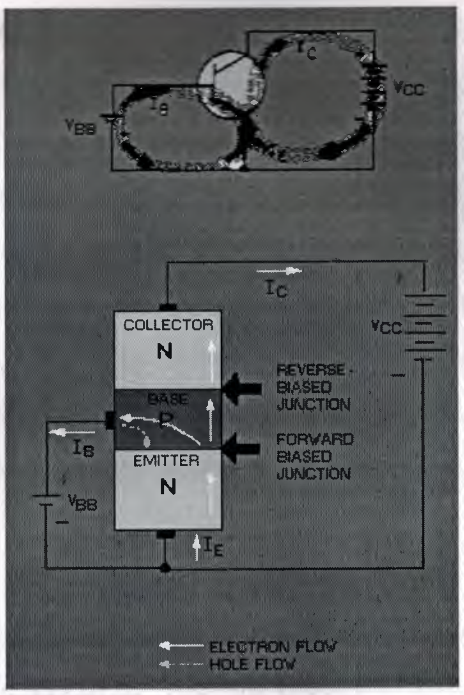


Figure 1.6.5. - NPN transistor operation.

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.

1.7 FET's as transistors

In figure 1.7 below I have depicted the schematics of the two most popular types. A J-FET and a dual gate mosfet. Typical types might be MPF-102 for a J-FET and the old RCA 40673 for the dual gate.

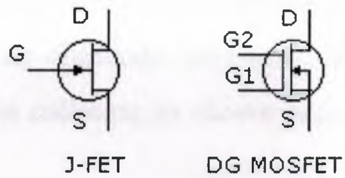


Figure 1.7. - schematic of J-FET transistor and dual gate mosfet transistor

The FET of course is characterised by its extremely high input impedance. Some people claim the FET is a superior device to a bipolar transistor. I consider that to be a subjective opinion with the proviso that FET development has led to some amazing developments, particularly with power-fets.

I won't go into any length about how FETS operate except to point out the principal differences to NPN and PNP transistors. A bipolar transistor has moderate input impedance (depending on configuration) while some FETs can and do have input impedances measured in megohms. Bipolar transistors are essentially "current" amplifiers while FETS could be considered voltage amplifiers.

1.8 How are semiconductors made?

Strictly speaking this tutorial presented by Harris Semiconductor applies more to integrated circuits but the principle remains much the same.
The process of manufacturing semiconductors, or integrated circuits (commonly called ICs, or chips) typically consists of more than a hundred steps, during which hundreds of copies of an integrated circuit are formed on a single wafer.

Generally, the process involves the creation of eight to 20 patterned layers on and into the substrate, ultimately forming the complete integrated circuit. This layering process creates electrically active regions in and on the semiconductor wafer surface.

1.9 CONSTRUCTION

The very first transistors were known as point-contact transistors. Their construction is similar to the construction of the point-contact diode covered in chapter 1. The difference, of course, is that the point-contact transistor has two P or N regions formed instead of one. Each of the two regions constitutes an electrode (element) of the transistor. One is named the emitter and the other is named the collector, as shown in figure 1.9, view A.

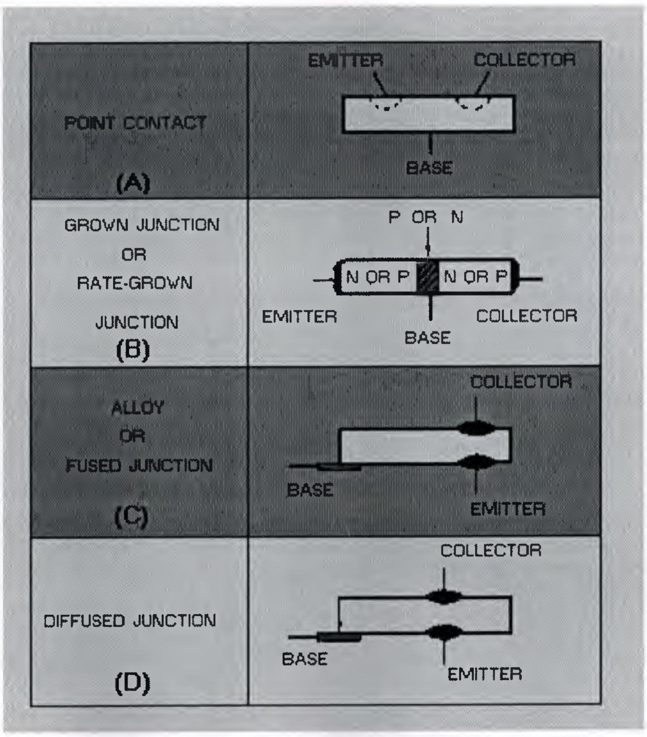


Figure 1.9. - Transistor constructions

Point-contact transistors are now practically obsolete. They have been replaced by junction transistors, which are superior to point-contact transistors in nearly all respects. The junction transistor generates less noise, handles more power, provides higher current and voltage gains, and can be mass-produced more cheaply than the point-contact transistor. Junction transistors are manufactured in much the same manner as the PN junction diode discussed earlier. However, when the PNP or NPN material is grown (view B), the impurity mixing process must be reversed twice to obtain the two junctions required in a transistor. Likewise, when the alloy-junction (view C) or the diffused-junction (view D) process is used, two junctions must also be created within the crystal.

Although there are numerous ways to manufacture transistors, one of the most important parts of any manufacturing process is quality control. Without good quality control, many transistors would prove unreliable because the construction and processing of a transistor govern its thermal ratings, stability, and electrical characteristics. Even though there are many variations in the transistor manufacturing processes, certain structural techniques, which yield good reliability and long life , are common to all processes: (1) Wire leads are connected to each semiconductor electrode; (2) the crystal is specially mounted to protect it against mechanical damage; and (3) the unit is sealed to prevent harmful contamination of the crystal.

CHAPTER :2

2.RESISTORS

2.1 Introduction

The resistor is one of the most diverse and easiest of all the electrical components you will find in your average radio or TV set. This is because it has been around for many years and plays such a vital role that it will continue to in many new shapes and sizes to come. Today there are many different resistors in circulation, all of which will be explained shortly but for now lets go over some of the most important details.

The resistor is a component that has one purpose and that is to resist current and voltage by means of combining conductive material with a nonconductive one to form a substance that allows electrons to flow through its self but not as efficiently as a typical wire. The unit of measuring how much the resistor will oppose current is measured in ohms and to determine the outcome of the resistor we would use mathematical formulas known as ohms law.

There are three main types of resistors, which can then be broken down into other categories but lets first look at the three main types.

2.2 TYPES OF RESISTORS

The two main characteristics of a resistor are its resistance *R* in ohms and its power rating *W* in watts. Resistors are available in a very wide range of *R* values, from a fraction of an ohm to many kilohms (kΩ) and megohms (MΩ). One kilohm is 1000 Ω, and one megohm is 1,000,000 Ω. More details of very small and large units are given in Chap. 3. The power rating for resistors may be as high as several hundred watts or as low as *1/10* W.

The *R* is the resistance value required to provide the desired current 7 or voltage. Also important is the wattage rating, because it specifies the maximum power the resistor can dissipate without excessive heat. Dissipation means that the power is wasted, since the resultant heat is not used. Too much heat can make the resistor burn. The wattage rating of the resistor is generally more than the actual power dissipation, as a safety factor.

Most common in electronic equipment are carbon resistors with a power rating of 1 W or less. The construction is illustrated in Fig. 2.2.1, while Fig. 2.2.2 shows a group of resistors to be mounted on a printed-circuit (PC) board. The resistors can be inserted automatically by machine.

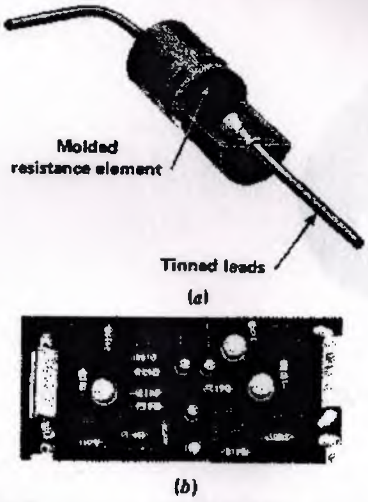


Figure:2.2.1

Fig. 2.2.1 Carbon-composition resistors, (a) Internal construction. Length is 3/4 in. without leads for 1-W power rating. Color stripes give R in ohms. Tinned leads have coating of solder, *(b)* Group of resistors and transistors mounted on printed-circuit (PC) board. The printed-circuit conductors are on the opposite side. *(Direct Positive Imagery)*

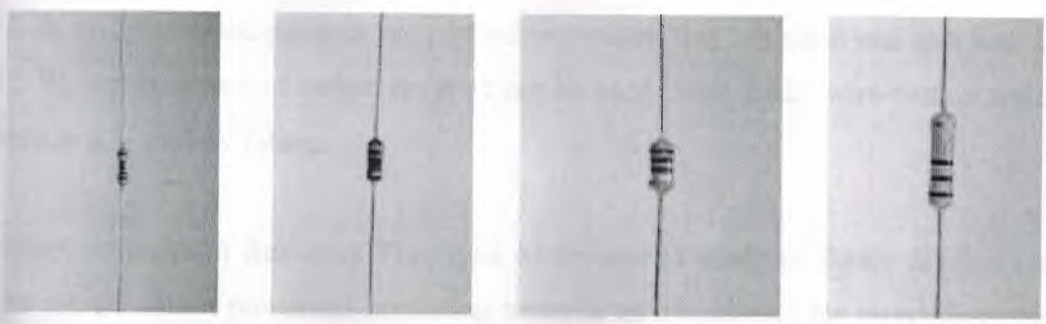


Figure:2.2.2

Fig. 2.2.2 Typical carbon resistors commonly used on PC board. Leads are cut and formed for insertion into holes with 0.5 in. spacing.

Resistors with higher R values usually have lower wattage ratings because they have less current. As an example, a common value is 1 MΩ at $^1/4$ W, for a resistor only *1/2* in. long. The lower the power rating, the smaller the actual physical size of the resistor. However, the resistance value is not related to physical size.

Wire-Wound Resistors In this construction, a special type of wire called *resistance wire* is wrapped around an insulating core, as shown in Fig. 2.2.3. The length of wire and its specific resistivity determine the R of the unit.

(a) (b)

Fig. 2.2.3 Large wire-wound resistors with 50-W power rating.

Since they are generally for high-current applications with low resistance and appreciable power, wire-wound resistors are available in wattage ratings from 5 W up to 100 W or more. The resistance can be less than 1 Ω up to several thousand ohms.

In addition, wire-wound resistors are used where accurate, stable resistance values are necessary. Examples are precision resistors for the function of an ammeter shunt or a precision potentiometer to adjust for an exact amount of R.

For 2 W or less, carbon resistors are preferable because they are small and cost less. Between 2 and 5 W, combinations of carbon resistors can be used. Also, small wire-wound resistors are available in a 3- or 4-W rating.

Carbon-Composition Resistors This type of resistor is made of finely divided carbon or graphite mixed with a powdered insulating material as a binder, in the proportions needed for the desired R value. As shown in Fig. 2.2.3 large, the resistor element is enclosed in a plastic case for insulation and mechanical strength. Joined to the two ends of the carbon resistance element are metal caps with leads of tinned copper wire for soldering the connections into a circuit. These are called *axial leads* because they come straight out from the ends. Carbon resistors are commonly available in R values of 1Ω to 20 MΩ. Examples are 10 ft, 220 ft, 4.7 kΩ, and 68 kΩ. The power rating is generally *1/10, 1/8, 1/4,* 1, or 2 W.

Film-Type Resistors There are two kinds of film-type resistors. The carbon-film type has a thin coating around an insulator. Metal-film resistors have a'spiral around a ceramic substrate (Fig. 2.2.4). Their advantage is more precise *R* values. The film-type resistors use metal end caps for the terminal leads, which ihakes the ends a little larger than the body.

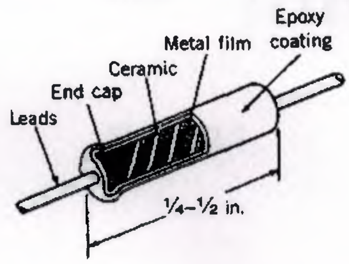


Fig. 2.2.4 Construction of metal-film resistor. *(Stackpole Corporation)*

Chip Resistors These have a carbon coating fired onto a solid ceramic substrate. The purpose is to have more precise *R* values and greater stability with temperature changes. They are often made in a small square with leads to fit a printed circuit (PC) board.

Fusible Resistors This type is a wire-wound resistor made to burn open easily when the power rating is exceeded. It then serves the dual functions of a fuse and a resistor to limit the current.

2.3 Low power resistors

The carbon film resistor is composed up of a resistive material like graphite that is then cut into blocks or wrapped, or grafted in a desired way. For example, the length of the resistive material will determine how much resistance there will be while the width of the resistive material will determine what kind of power it can handle, the wider the more power it can handle. The schematic symbol can be seen in the picture to the right while the different types of carbon film resistors can be seen below. There are some three distinct types of carbon film resistors which as follows:

-The standard film resistor (A)- a circular resistor with two pins extending from opposite sides or the barrel- shaped resistor.

-The chip resistor (B)- this type of resistor was introduced in the late 80's to accommodate for the ever shrinking computer components where there can be up to 6 layers per circuit board.

-The network resistor (C)- this type of resistor comes in (SIPP) form and can contain up to 12 resistors in a compact space that can not compare

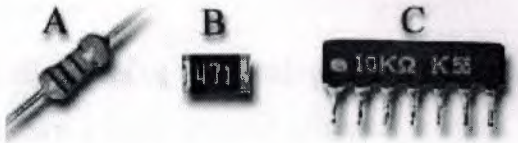


Figure: 2.3

2.4 High power resistors

The most common wire wound resistor is composed up a fairly resistive wire wrapped around a ceramic cylinder and typically has a power range form 5 to 50 watts and is most often found in power supplies and amplifiers. It is common to find these components to heat up to levels that burns to the touch and is why they are made up of ceramic, a fire resistant material. The schematic symbol is the same of the carbon film resistor so it is also quite easy to remember.

The box to the right shows some typical wire wound resistors and more information can be found on each one by clicking on its figure: 2.4.

Figure: 2.4

2.5 Variable resistors

The variable resistor is a very important component that is found in many electrical for such things as tone and bass controls as well as volume. This is due to the fact that resistors can be joined together with other components to form filters for a desired levels. They can also be found in computer monitors for color or positioning as well as the dimming switch for your lamps.

This is done through digital to analog and analog to digital circuits, one great advantage to this is that you are able to turn a knob instead of typing a value in every time you want to change the tint or brightness.

The schematic for the variable resistor has stayed the same for quite some time and can be seen at the illustration to the upper right. As you see it looks somewhat like a typical resistor but is an arrow coming out from one side pointing to the center of the resistor. For more details on such questions like How does it work?, How do I use it?, and other such questions click on any illustration of your choice below.

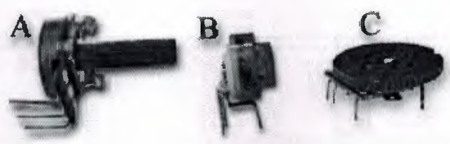


Figure: 2.5

2.6 RESISTOR COLOR CODING

Because carbon resistors are small physically, they are color-coded to mark their R value in ohms. The basis of this system is the use of colors for numerical

Figure:2.6

Table 2.6 Color Code

Color	Band 1 1st Figure	Band 2 2nd Figure	Band 3 3rd Figure	Band 4 Tolerance
Black	0	0	10^0	
Brown	1	1	10^1	1%
Red	2	2	10^2	2%
Orange	3	3	10^3	
Yellow	4	4	10^4	
Green	5	5	10^5	
Blue	6	6	10^6	
Violet	7	7	10^7	
Gray	8	8	10^8	
White	9	9	10^9	
Gold			10^{-1}	5%
Silver			10^{-2}	10%
None				20%

values, as listed in Table 2.6. In memorizing the colors, note that the darkest colors, black and brown, are for the lowest numbers, zero and one, whereas white is for nine. The color coding is standardized by the Electronic Industries Association (EIA). These colors are also used for small capacitors, as summarized in App. B on all the color codes.

Resistance Color Stripes The use of bands or stripes is the most common system for color-coding carbon resistors, as shown in Fig. 2.6.1. Color stripes are printed at one end of the insulating body, which is usually tan. Reading from left to right, the first band close to the edge gives the first digit in the numerical value of R. The next band marks the second digit. The third band is the decimal multiplier, which gives the number of zeroes after the two digits.

In Fig. 2.6.2 a, the first stripe is red for 2 and the next stripe is green for 5. The red multiplier in the third stripe means add two zeroes to 25, or "this multiplier is 10^2." The result can be illustrated as follows:

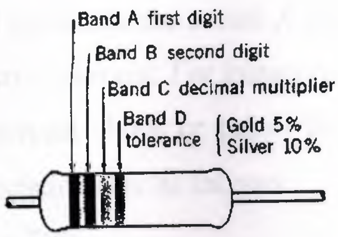


Fig. 2.6.1 How to read color stripes on carbon resistors for R in ohms.

$$\underset{2}{\overset{\text{Red}}{\downarrow}} \quad \underset{5}{\overset{\text{Green}}{\downarrow}} \quad \times \quad \underset{100}{\overset{\text{Red}}{\downarrow}} \quad = 2500$$

Therefore, this R value is 2500 Ω.

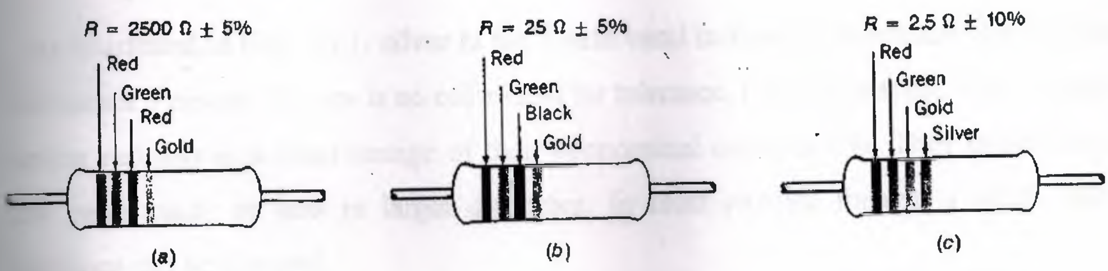


Fig. 2.6.2 Examples of color-coded R values, with percent tolerance.

The example in Fig. *2.6.2b* illustrates that black for the third stripe just means "do not add any zeroes to the first two digits." Since this resistor has red, green, and black stripes, the R value is 25 Ω.

Resistors under 10 Ω For these values, the third stripe is either gold or silver, indicating a fractional decimal multiplier. When the third stripe is gold, multiply the first two digits by 0.1. In Fig. 2.6.2c, the *R* value is

25x0.1 = 2.5 Ω

Silver means a multiplier of 0.01. If the third band in Fig. 2-6c were silver, the *R* value would be

25 x 0.01 = 0.25 Ω

It is important to realize that the gold and silver colors are used as decimal multipliers only in the third stripe. However, gold and silver are used most often as a fourth stripe to indicate how accurate the *R* value is.

Resistor Tolerance The amount by which the actual *R* can be different from the color-coded value is the *tolerance,* usually given in percent. For instance, a 2000-Ω resistor with ±10 percent tolerance can have resistance 10 percent above or below the coded value. This *R,* therefore, is between 1800 and 2200Ω. The calculations are as follows:

10 percent of 2000 is 0.1 x 2000 = 200

For +10 percent, the value is

2000 + 200 = 2200 Ω

For —10 percent, the value is

2000 - 200 = 1800 Ω

As illustrated in Fig. 2.6.1, silver hi the fourth band indicates a tolerance of ±10 percent; gold indicates ± 5 percent. If there is no color band for tolerance, it is ±20 percent. The inexact value of carbon resistors is a disadvantage of their economical construction. They usually cost only a few cents each, or less in larger quantities. In most circuits, though, a small difference in resistance can be tolerated.

It should be noted that some resistors have five stripes, instead of four. In this case, the first three stripes give three digits, followed by the decimal multiplier in the fourth stripe and tolerance in the fifth stripe. These resistors have more precise values, with tolerances of 0.1 to 2 percent.

Wire-Wound-Resistor Marking Usually, wire-wound resistors are big enough physically to have the R value printed on the insulating case. The tolerance is generally ±5 percent, except for precision resistors, which have a tolerance of ±1 percent or less.

Some small wire-wound resistors may be color-coded with stripes, however, like carbon resistors. In this case, the first stripe is double the width of the others to indicate a wire-wound resistor. This type may have a wattage rating of 3 or 4W.

Preferred Resistance Values In order to minimize the problem of manufacturing different R values for an almost unlimited variety of circuits, specific values are made in large quantities so that they are cheaper and more easily available than unusual sizes. For resistors of ±10 percent, the preferred values are 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, and 82 with their decimal multiples. As examples, 47, 470, 4700, and 47,000 are preferred values. In this way, there is a preferred value available within 10 percent of any R value needed in a circuit.

CHAPTER :3

3 CAPACITOR

3.1 HOW CHARGE IS STORED IN THE DIELECTRIC

It is possible for dielectric materials such as air or paper to hold an electric charge because free electrons cannot flow through an insulator. However, the charge must be applied by some source. In Fig. 3.1a, the battery can charge the capacitor shown. With the dielectric contacting the two conductors connected to the potential difference *V*, electrons from the voltage source accumulate on the side of the capacitor connected to the negative terminal of *V*. The opposite side of the capacitor connected to the positive terminal of *V* loses electrons.

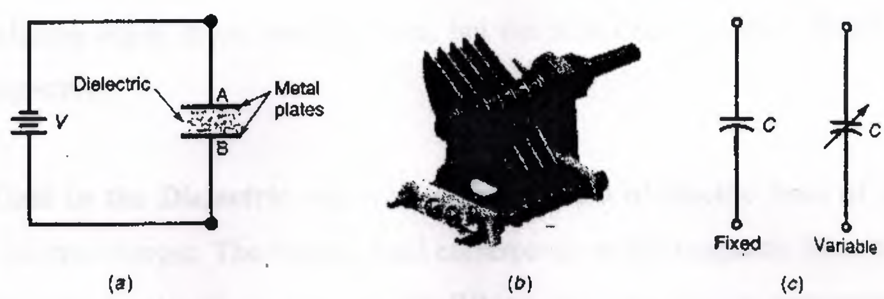


Figure:3.1

Fig. 3.1 Capacitance stores the charge in the dielectric between two conductors. *(a)* Structure, *(b)* Air-dielectric variable capacitor. Length is 2 in. (c) Schematic symbols for fixed and variable capacitors.

As a result, the excess of electrons produces a negative charge on one side of the capacitor, while the opposite side has a positive charge. As an example, if 6.25 X 10^{18} electrons are accumulated, the negative charge equals 1 coulomb (C). The charge on only one plate need be considered, as the number of electrons accumulated on one plate is exactly the same as the number taken from the opposite plate.

What the voltage source does is simply redistribute some electrons from one side of the capacitor to the other. This process is called *charging* the capacitor. Charging continues until the potential difference across the capacitor is equal to the applied voltage. Without any series resistance, the charging is instantaneous. Practically, however, there is always some series resistance. This charging current is transient, or temporary, as it flows only until the capacitor is charged to the applied voltage. Then there is no current in the circuit.

The result is a device for storing charge in the dielectric. Storage means that the charge remains even after the voltage source is disconnected. The measure of how much charge can be stored is the capacitance *C*. More charge stored for a given amount of applied voltage means more capacitance. Components made to provide a specified amount of capacitance are called *capacitors*, or by their old name *condensers*.

Electrically, then, capacitance is the ability to store charge. Physically, a capacitor consists simply of two conductors separated by an insulator. For example, Fig. 20-Ib shows a capacitor using air for the dielectric between the metal plates. There are many types with different dielectric materials, including paper, mica, and ceramics, but the schematic symbols shown in Fig. 20-Ic apply to all capacitors.

Electric Field in the Dielectric Any voltage has a field of electric lines of force between the opposite electric charges. The electric field corresponds to the magnetic lines of force of the magnetic field associated with electric current. What a capacitor does is concentrate the electric field in the dielectric between the plates. This concentration corresponds to a magnetic field concentrated in the turns of a coil. The only function of the capacitor plates and wire conductors is to connect the voltage source *V* across the dielectric. Then the electric field is concentrated in the capacitor, instead of being spread out in all directions.

Electrostatic Induction The capacitor has opposite charges because of electrostatic induction by the electric field. Electrons that accumulate on the negative side of the capacitor provide electric lines of force that repel electrons from the opposite side. When this side loses electrons, it becomes positively charged. The opposite charges induced by an electric field correspond to the idea of opposite poles induced in magnetic materials by a magnetic field.

3.2 CHARGING AND DISCHARGING A CAPACITOR

These are the two main effects with capacitors. Applied voltage puts charge in the capacitor. The accumulation of charge results in a buildup of potential difference across the capacitor plates.

When the capacitor voltage equals the applied voltage, there is no more charging. The charge remains in the capacitor, with or without the applied voltage connected.

The capacitor discharges when a conducting path is provided across the plates, without any applied voltage. Actually, it is only necessary that the capacitor voltage be more than the applied voltage. Then the capacitor can serve as voltage source, temporarily, to produce discharge current in the discharge path. The capacitor discharge continues until the capacitor voltage drops to zero or is equal to the applied voltage.

Applying the Charge In Fig. 3.2.a, the capacitor is neutral with no charge because it has not been connected to any source of applied voltage and there is no electrostatic field in the dielectric. Closing the switch in Fig. 3.2.b, however, allows the negative battery terminal to repel free electrons in the conductor to plate A. At the same time, the positive terminal attracts free electrons from plate B. The side of the dielectric at plate A accumulates electrons because they cannot flow through the insulator, while plate B has an equal surplus of protons.

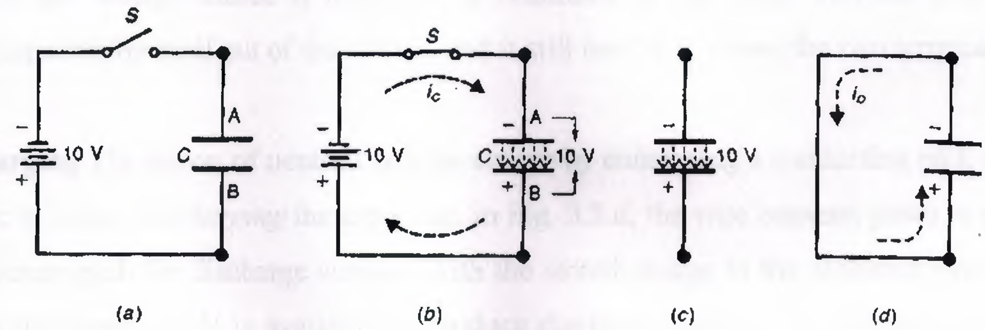


Fig. 3.2

Figure:3.2 Storing electric charge in a capacitance, *(a)* Capacitor without any charge, *(b)* Battery charges capacitor to applied voltage of 10 V. (c) Stored charge remains in capacitor, providing 10 V without the battery, *(d)* Discharging the capacitor

Remember that the opposite charges have an associated potential difference, which is the voltage across the capacitor. The charging process continues until the capacitor voltage equals the battery voltage, which is 10 V in this example. Then no further charging is possible because the applied voltage cannot make free electrons flow in the conductors.

Note that the potential difference across the charged capacitor is 10 V between plates A and B. There is no potential difference from each plate to its battery terminal, however, which is the reason why the capacitor stops charging.

Storing the Charge The negative and positive charges on opposite plates have an associated electric field through the dielectric, as shown by the dotted lines in Fig. *3.2.b* and *c*. The direction of these electric lines of force is shown repelling electrons from plate B, making this, side positive. It is the effect of electric lines of force through the dielectric that results in storage of the charge. The electric field distorts the molecular structure so that the dielectric is no longer neutral. The dielectric is actually stressed by the invisible force of the electric field. As evidence, the dielectric can be ruptured by a very intense field with high voltage across the capacitor.

The result of the electric field, then, is that the dielectric has charge supplied by the voltage source. Since the dielectric is an insulator that cannot conduct, the charge remains in the capacitor even after the voltage source is removed, as illustrated in Fig. 3.2.c. You can now take this charged capacitor by itself out of the circuit, and it still has 10 V across the two terminals.

Discharging The action of neutralizing the charge by connecting a conducting path across the dielectric is called *discharging* the capacitor. In Fig. 3.2.d, the wire between plates A and B is a low-resistance path for discharge current. With the stored charge in the dielectric providing the potential difference, 10 V is available to produce discharge current. The negative plate repels electrons, which are attracted to the positive plate through the wire, until the positive and negative charges are neutralized. Then there is no net charge. The capacitor is completely discharged, the voltage across it equals zero, and there is no discharge current. Now the capacitor is in the same uncharged condition as in Fig. 3.2.a. It can be charged again, however, by a source of applied voltage.

Nature of the Capacitance A capacitor has the ability to store the amount of charge necessary to provide a potential difference equal to the charging voltage. If 100 V were applied in Fig. 3.2, the capacitor would charge to 100 V. The capacitor charges to the applied voltage because, when the capacitor voltage is less, it takes on more charge. As soon as the capacitor voltage equals the applied voltage, no more charging current can flow. Note that any charge or discharge current flows through the conducting wires to the plates but not through the dielectric.

Charge and Discharge Currents In Fig. 3.2.b, i_c is in the opposite direction from i_D in Fig. 3.2.*d.* In both cases the current shown is electron flow. However, ic is charging current to the capacitor and i_D is discharge current from the capacitor. The charge and discharge currents must always be in opposite directions. In Fig. 3.2.b, the negative plate of C accumulates electrons from the voltage source. In Fig. 3.2.d, the charged capacitor serves as a voltage source to produce electron flow around the discharge path.

More charge and discharge current result with a higher value of C for a given amount of voltage. Also, more V produces more charge and discharge current with a given amount of capacitance. However, the value of C does not change with the voltage, as the amount of C depends on the physical construction of the capacitor.

3.3 THE FARAD UNIT OF CAPACITANCE

With more charging voltage, the electric field is stronger and more charge is stored in the dielectric. The amount of charge Q stored in the capacitance is therefore proportional to the applied voltage. Also, a larger capacitance can store more charge. These relations are summarized by the formula

$$Q = CV \quad \text{coulombs}$$

where Q is the charge stored in the dielectric in coulombs (C), and V is the voltage across the plates of the capacitor, and C is the capacitance in farads.

The C is a physical constant, indicating the capacitance in terms of how much charge can be stored for a given amount of charging voltage. When one coulomb is stored in the dielectric with a potential difference of one volt, the capacitance is *one farad.*

Practical capacitors have sizes in millionths of a farad, or smaller. The reason is that typical capacitors store charge of microcoulombs or less. Therefore, the common units are

1 microfarad = 1 ju,F = 1 x 10^{-6} F 1

1 picofarad = 1 pF = 1 x 10~[12] F

Larger Plate Area Increases Capacitance As illustrated in Fig. 3.3, when the area of each plate is doubled, the capacitance in Fig, 3.3.b stores twice the charge of Fig. 3.3.a. The potential difference in both cases is still 10 V. This voltage produces a given strength of electric field. A larger plate area, however, means that more of the dielectric surface can contact each plate, allowing more lines of force through the dielectric between the plates and less flux leakage outside the dielectric. Then the field can store more charge in the dielectric. The result of larger plate area is more charge stored for the same applied voltage, which means the capacitance is larger.

Thinner Dielectric Increases Capacitance As illustrated in Fig. 3.3.c, when the distance between plates is reduced one-half, the capacitance stores twice the charge of Fig. 3.3.a. The potential difference is still 10 V, but its electric field has greater flux density in the thinner dielectric. Then the field between opposite plates can store more charge in the dielectric. With less distance between the plates, the stored charge is greater for the same applied voltage, which means the capacitance is greater.

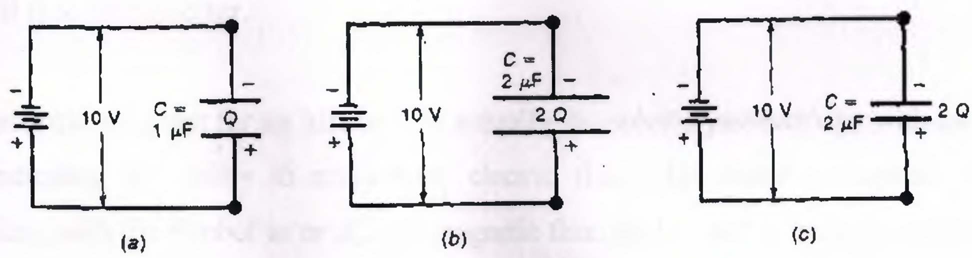


Figure: 3.3

Fig. 3.3 Increasing stored charge and capacitance by increasing the plate area and decreasing the distance between plates, (a) Capacitance of 1 *pF.* *(b)* A 2-ju.F capacitance with twice the plate area and the same distance, (c) A 2 *pF* capacitance with one-half the distance and the same plate area.

Dielectric Constant K_e This indicates the ability of an insulator to concentrate electric flux. Its numerical value is specified as the ratio of flux in the insulator compared with the flux in air or vacuum. The dielectric constant of air or vacuum is 1, since it is the reference.

Mica, for example, has an average dielectric constant of 6, meaning it can Provide a density of electric flux six times as great as that of air or vacuum for the same applied voltage and equal

Table 3.3 Dielectric Materials

Air or vacuum	1	20
Aluminum oxide	7	
Ceramics	80-1200	600-1250
Glass	8	335-2000
Mica	3-8	600-1500
Oil	2-5	275
Paper Plastic film	2-6 2-3	1250
Tantalum oxide	25	

physical size. Insulators generally have a dielectric constant K_ϵ greater than 1, as listed in Table 3.3. Higher values of K_ϵ allow greater values of capacitance.

It should be noted that the aluminum oxide and tantalum oxide listed in Table 3.3 are used for the dielectric in electrolytic capacitors. Also, the plastic film is used instead of paper for the rolled-foil type of capacitor.

The dielectric constant for an insulator is actually its *relative permittivity,* with the symbol e_r or K_ϵ indicating the ability to concentrate electric flux. This factor corresponds to relative permeability, with the symbol μr or K_m for magnetic flux. Both e_r and μ_r are pure numbers without units, as they are just ratios.

These physical factors for a parallel-plate capacitor are summarized by the formula

$$C = K_\epsilon \times \frac{A}{d} \times 8.85 \times 10^{-12}\ \mathrm{F}$$

where A is the area in square meters of either plate, d is the distance in meters between plates, K_e is the dielectric constant, or relative permittivity, as listed in Table 3.3, and C is capacitance in farads. The constant factor 8.85 x 10^{-12} is the absolute permittivity of air or vacuum, in SI, since the farad is an SI unit.

Dielectric Strength Table 3.3 also lists breakdown-voltage ratings for typical dielectrics. Dielectric strength is the ability of a dielectric to withstand a potential difference without arcing across the insulator. This voltage rating is important because rupture of the insulator provides a conducting path through the dielectric. Then it cannot store charge, because the capacitor has been short-circuited. Since the breakdown voltage increases with greater thickness, capacitors with higher voltage ratings have more distance between the plates. This increased distance reduces the capacitance, however, all other factors remaining the same.

3.4 TYPICAL CAPACITORS

Commercial capacitors are generally classified according to the dielectric. Most common are air, mica, paper, and ceramic capacitors, plus the electrolytic type. Electrolytic capacitors use a molecular-thin oxide film as the dielectric, resulting in large capacitance values in little space. These types are compared in Table 3.4 and discussed in the sections that follow.

Except for electrolytic capacitors, capacitors can be connected to a circuit without regard to polarity, since either side can be the more positive plate. Electrolytic capacitors are marked to indicate the side that must be connected to

Table 3.4 Types of Capacitors

Air	Meshed plates	10-400 pF	400 (0.02-in. air gap)
Ceramic	Tubular	0.5-1600 pF	500-20,000
	Disk	0.002-0.1 *nF*	
Electrolytic	Aluminum	5-1000 *ffF*	10-450
	Tantalum	0.01-300 /iF	6-50
Mica	Stacked sheets	10-5000 pF	500-20,000
Paper or plastic film	Rolled foil	0.001-1 ju,F	200-1600

the positive side of the circuit. It should be noted that it is the polarity of the charging source that determines the polarity of the capacitor voltage. Failure to observe the correct polarity can damage the dielectric and lead to the complete destruction of the capacitor.

Mica Capacitors Thin mica sheets as the dielectric are stacked between tinfoil sections for the conducting plates to provide the required capacitance. Alter-Tiate strips of tinfoil are connected together and brought out as one terminal for one set of plates, while the opposite terminal connects to the other set of interlaced plates. The entire unit is generally in a molded

Bakelite case. Mica capacitors are often used for small capacitance values of 50 to 500 pF; their length is % in. or less with about Vs-in. thickness. Typical mica capacitors are shown in Fig. 3.4.1.

(a) (b)

Figure: 3.4.1

Fig. 3.4.1 Mica capacitors about % in. wide, *(a)* Fixed *C*, color coded in pF units, *(b)* Variable trimmer capacitor of 6 to 60 pF.

Paper Capacitors In this construction, two rolls of tinfoil conductor separated by a tissue-paper insulator are rolled into a compact cylinder. Each outside lead connects to its roll of tinfoil as a plate. The entire cylinder is generally placed in a cardboard container coated with wax or encased in plastic. Paper capacitors are often used for medium capacitance values of 0.001 to 1.0 μF, approximately. The physical size for 0.05 μF is typically 1 in. long with 3/4-in. diameter. Paper capacitors are shown in Fig. 3.4.2.

A black band at one end of a paper capacitor indicates the lead connected to the outside foil. This lead should be used for the ground or low-potential side of the circuit to take advantage of shielding by the outside foil. There is no required polarity, however, since the capacitance is the same no matter which side is grounded. It should also be noted that in the schematic symbol for *C* the curved line usually indicates the low-potential side of the capacitor.

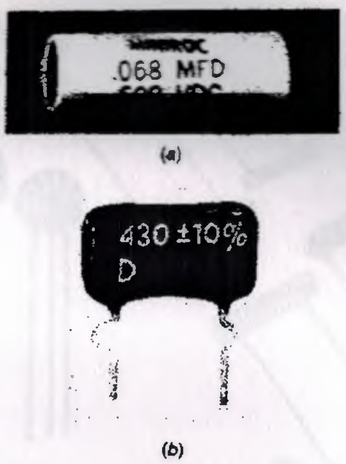


Figure:3.4.2

Fig. 3.4.2 Paper or plastic-film capacitors, (a) Tubular type 1 in. long. Capacitor C is 0.068s/u,F. *(b)* Encapsulated type with leads for printed-circuit board. Capacitor *C* is 430 pF.

Plastic Capacitors Many capacitors of foil construction use a plastic film instead of tissue paper. Two types are Teflon[1] and Mylar[1] plastic film. These feature very high insulation resistance, of over 1000 *MΩ*, low losses, and longer service life without voltage breakdown, compared with paper capacitors. The plastic capacitors are available in sizes of 0.001 to 1.0 µ,F, like paper capacitors.

Ceramic Capacitors The ceramic dielectric materials are made from earth fired under extreme heat. By use of titanium dioxide, or several types of silicates, very high values of dielectric constant K_ϵ can be obtained.

In the disk form, silver is fired onto both sides of the ceramic, to form the conductor plates. With a K_e value of 1200, the disk ceramics feature capacitance values up to 0.01 µF in much less space than a paper capacitor.

For tubular ceramics, the hollow ceramic tube has a silver coating on the inside and outside surfaces. With values of 1 to 500 pF, these capacitors have the same applications as mica capacitors but are smaller. Typical ceramic capacitors are shown in Fig. 3.4.3.

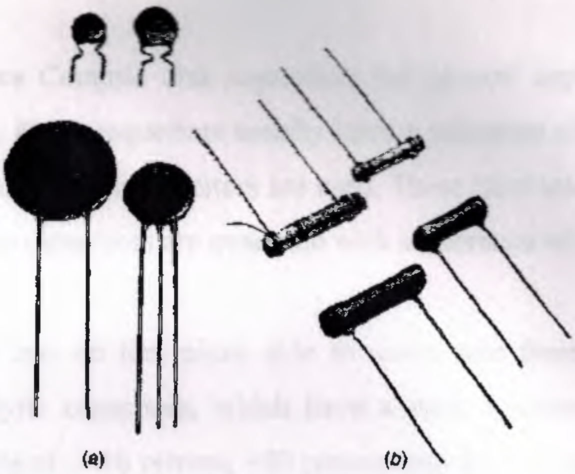


Figure: 3.4.3

Fig. 3.4.3 Ceramic capacitors, (a) Disk type. Values from 33 pF to 0.02 μF. (b) Tubular type. Values in pF units.

Chip Capacitors These are very small, typically Vi in. square or less with a ceramic dielectric. Capacitance values are about 10 pF to 4 μF. The construction has alternate layers of ceramic and a deposited conducting material.

Temperature Coefficient Ceramic capacitors are often used for temperature compensation, to increase or decrease capacitance with a rise in temperature. The temperature coefficient is given in parts per million (ppm) per degree.

Celsius, with a reference of 25°C. As an example, a negative 750 ppm unit is stated as N750. A positive temperature coefficient of the same value would be stated as P750. Units that do not change in capacitance are labeled NPO.

Variable Capacitors Figure 3.4b shows a variable air capacitor. In this construction, the fixed metal plates connected together form the *stator*. The movable plates connected together on the shaft form the *rotor*. Capacitance is varied by rotating the shaft to make the rotor plates mesh with the stator plates. They do not touch, however, since air is the dielectric. Full mesh is maximum capacitance. Moving the rotor completely out of mesh provides minimum capacitance.
A common application is the tuning capacitor in radio receivers. When you tune to different stations, the capacitance varies as the rotor moves in or out of mesh. Combined with an inductance, the variable capacitance then tunes the receiver to a different resonant frequency for each station. Usually two or three capacitor sections are *ganged* on one common shaft.

Capacitance Tolerance Ceramic disk capacitors for general applications usually have a tolerance of ±20 percent. Paper capacitors usually have a tolerance of ±10 percent. For closer tolerances, mica or ceramic tubular capacitors are used. These have tolerance values of ±2 to 20 percent. Silver-plated mica capacitors are available with a tolerance of ±1 percent.

The tolerance may be less on the minus side to make sure there is enough capacitance, particularly with electrolytic capacitors, which have a wide tolerance. For instance, a 20μF electrolytic with a tolerance of —10 percent, +50 percent may have a capacitance of 18 to 30 μF. However, the exact capacitance value is not critical in most applications of capacitors for filtering, ac coupling, and bypassing.

Voltage Rating of Capacitors This rating specifies the maximum potential difference that can be applied across the plates without puncturing the dielectric. Usually the voltage rating is for temperatures up to about 60°C. Higher tempera-hires result in a lower voltage rating. Voltage ratings for general-purpose paper, nuca, and ceramic capacitors are typically 200 to 500 V. Ceramic capacitors with ratings of 1 to 5 kV are also available.

Electrolytic capacitors are commonly used in 25-, 150-, and 450-V ratings. In addition, 6- and 10-V electrolytic capacitors are often used in transistor circuits. For applications where a lower voltage rating is permissible, more capacitance can be obtained in a smaller physical size.
The potential difference across the capacitor depends upon the applied voltage and is not necessarily equal to the voltage rating. A voltage rating higher than the potential difference applied across the capacitor provides a safety factor for long life in service. With electrolytic capacitors, however, the actual capacitor voltage should be close to the rated voltage to produce the oxide film that provides the specified capacitance.
The voltage ratings are for dc voltage applied. The breakdown rating is lower for ac voltage because of the internal heat produced by continuous charge and discharge.

Capacitor Applications In most electronic circuits, a capacitor has dc voltage applied, combined with a much smaller ac signal voltage. The usual function of the capacitor is to block the dc voltage but pass the ac signal voltage, by means of the charge and discharge current. These applications include coupling, bypassing, and filtering for ac signal.

3.5 ELECTROLYTIC CAPACITORS

These capacitors are commonly used for C values ranging from 5 to 5000 /^F, because electrolytics provide the most capacitance in the smallest space with least cost.

Construction Figure 3.5.1 shows the aluminum-foil type. The two aluminum electrodes are in an electrolyte of borax, phosphate, or carbonate. Between the two aluminum strips, absorbent gauze soaks up electrolyte to provide the required electrolysis that produces an oxide film. This type is considered a wet electrolytic, but it can be mounted in any position.

When dc voltage is applied to form the capacitance in manufacture, the electrolytic action accumulates a molecular-thin layer of aluminum oxide at the junction between the positive aluminum foil and the electrolyte. The oxide film is an insulator. As a result, capacitance is formed between the positive aluminum electrode and the electrolyte in the gauze separator. The negative aluminum electrode simply provides a connection to the electrolyte. Usually, the metal can itself is the negative terminal of the capacitor, as shown in Fig. 3.5.1c.

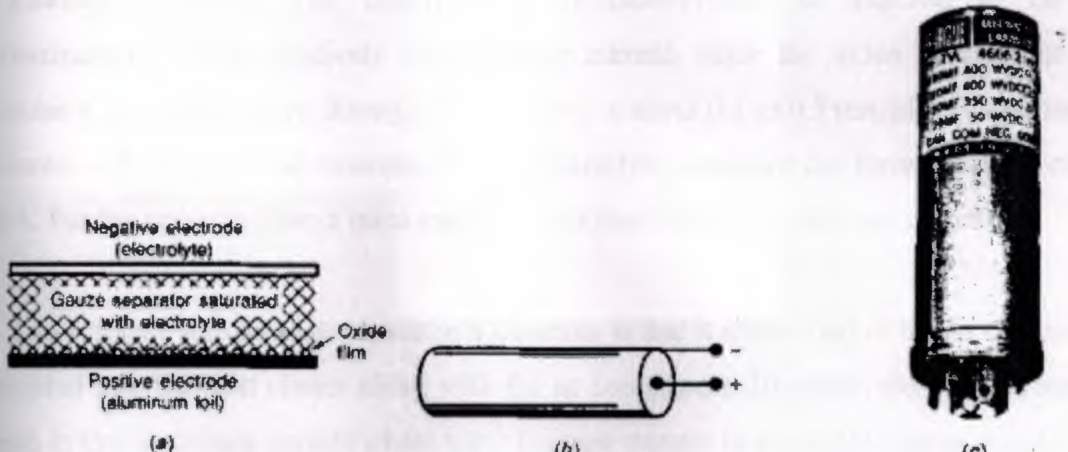


Figure:3.5.1

Fig. 3.5.1 Construction of aluminum electrolytic capacitor. *(a)* Internal electrodes, *(b)* Foil rolled into cartridge, *(c) Typical* capacitor with multiple sections.

Because of the extremely thin dielectric film, very large C values can be obtained. The area is increased by using long strips of aluminum foil and gauze, which are rolled into a compact cylinder with very high capacitance. For example, an electrolytic capacitor the same size as a 0.

μF paper capacitor, but rated at 10 V breakdown, may have 1000 μF of capacitance or more. Higher voltage ratings, up to 450 V, are used, with typical *C* values up to 5000 μF. The very high C values have lower voltage ratings.

Polarity Electrolytic capacitors are used in circuits that have a combination of dc voltage and ac voltage. The dc voltage maintains the required polarity across the electrolytic capacitor to form the oxide film. A common application is for electrolytic filter capacitors to eliminate 60-Hz ac ripple in a dc power supply. Another use is for audio coupling capacitors in transistor amplifiers. In both these applications, for filtering or coupling, electrolytics are needed for large *C* with a low-frequency ac component, while the circuit has a dc component for the required voltage polarity. Incidentally, the difference between filtering an ac component out or coupling it into a circuit is only a question of parallel or series connections. The filter capacitors for a power supply are typically 40 to 400μ*F*. Audio capacitors are usually 5 to 10 μF.

If the electrolytic is connected in opposite polarity, the reversed electrolysis forms gas in the capacitor. It becomes hot and may explode. This is a possibility only with electrolytic capacitors.

Leakage Current The disadvantage of electrolytics, in addition to the required polarization, is their relatively high leakage current, since the oxide film is not a perfect insulator. Leakage current through the dielectric is about 0.1 to 0.5 mA/μF of capacitance for the aluminum-foil type. As an example, a 10μF electrolytic capacitor can have a leakage current of 5 mA. For the opposite case, a mica capacitor has practically zero leakage current.

The problem with leakage current in a capacitor is that it allows part of the dc component to be coupled into the next circuit along with the ac component. However, electrolytics are generally used in low-resistance circuits where some leakage current is acceptable because of the small *IR* drop.

Nonpolarized Electrolytics This type is available for applications in circuits without any dc polarizing voltage, as in the 60-Hz ac power line. One application is the starting capacitor for ac motors. A nonpolarized electrolytic actually contains two capacitors, connected internally in series-opposing polarity.

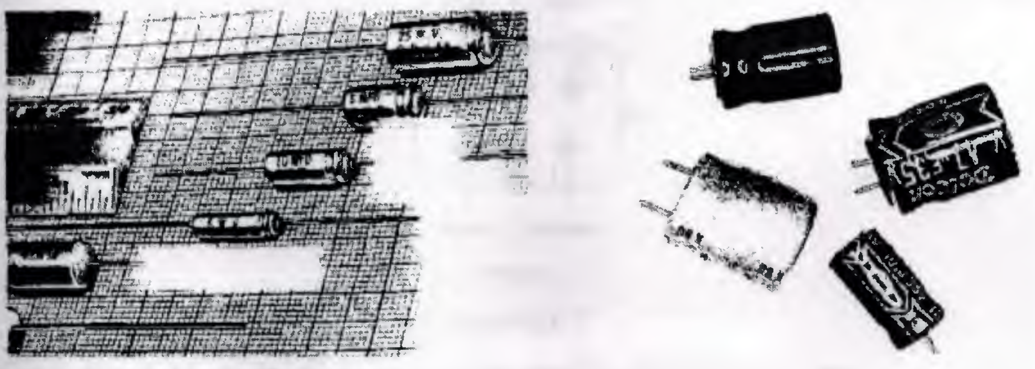
Tantalum Capacitors This is another form of electrolytic capacitor, using tantalum (Ta) instead of aluminum. Titanium (Ti) is also used. Typical tantalum capacitors are shown in Fig. 3-8. They feature:

1-Larger C in a smaller size

2-Longer shelf life

3-Less leakage current

However, tantalum electrolytics cost more than the aluminum type. Methods of construction for tantalum capacitors include the wet-foil type and a solid chip or slug. The solid tantalum is processed in manufacture to have an oxide film as the dielectric. Referring back to Table 3.4, note that tantalum oxide has a dielectric constant of 25, compared with 7 for aluminum oxide.



(a) (b)

Figure:3.5.2

Fig. 3.5.2 Low-voltage electrolytic capacitors. These are tantalum type, with *C* of 5 to 25 μF. (a) With axial leads, *(b)* Miniature type with radial leads for printed-circuit board. Height about ½ in. without leads.

3.6 CAPACITOR COLOR CODING

Mica and tubular ceramic capacitors are color-coded to indicate their capacitance value. Since coding is necessary only for very small sizes, the color-coded capacitance value is always in pF units. The colors used are the same as for resistor coding, from black for 0 up to white for 9. Mica capacitors generally use the six-dot system shown in Fig. 3.6.1. Read the top row first from left to right, then the bottom row, in reverse order right to left. White for the first dot indicates the new EIA coding, but the capacitance value is read from the next three dots. As an example, if the colors are red, green, and brown for dots 2, 3, and 4, the capacitance is 250 pF. If the first dot is silver, it indicates a paper capacitor, but the capacitance is still read from dots 2, 3, and 4. Dot 5 specifies tolerance, while dot 6 gives the EIA class. There are seven classes from A to G, specifying temperature coefficient, leakage resistance, and additional variable factors. Appendix B has more detailed information on the tolerance and class coding.

For tubular ceramic capacitors, the system shown in Fig. 3.6.2 is used with color dots or bands. The wide color band specifying temperature coefficient indicates the left end, which is the side connected to the inner electrode. Capacitance is read from the next three colors, in either dots or stripes. For instance, brown, black and brown for bands or dots 2, 3, and 4 means 100 pF.

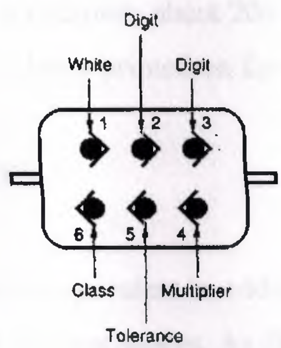


Figure3.6.1

Fig. 3.6.1 Six-dot color code for mica capacitors.

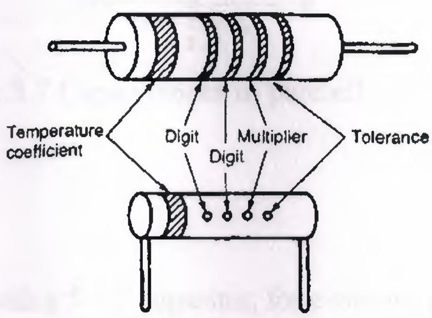


Figure:3.6.2

Fig. 3.6.2 Color code for ceramic tubular capacitors

For tubular ceramic capacitors, the system shown in Fig. 3.6.2 is used with color dots or bands. The wide color band specifying temperature coefficient indicates the left end, which is the side

connected to the inner electrode. Capacitance is read from the next three colors, in either dots or stripes. For instance, brown, black and brown for bands or dots 2, 3, and 4 means 100 pF.

Gray and white are used as decimal multipliers for very small values, with gray for 0.01 and white for 0.1. For instance, green, black, and white in dots 2, 3, and 4 means 50 x 0.1, or 5 pF. The color codes for tolerance and temperature coefficient of ceramic capacitors are listed in App. B.

In reading the color-coded capacitance value, keep in mind that mica capacitors generally range from 10 to 5000 pF. The small tubular ceramic capacitors are usually 0.5 to 1000 pF. With paper and ceramic disc capacitors, the capacitance and voltage rating is generally printed on the case. Where no voltage rating is specified, it is usually about 200 to 600 V. Electrolytic capacitors have the capacitance, voltage rating, and polarity printed on the case.

3.7 PARALLEL CAPACITANCES

Connecting capacitances in parallel is equivalent to adding the plate areas. Therefore, the total capacitance is the sum of the individual capacitances. As illustrated in Fig. 3.7,

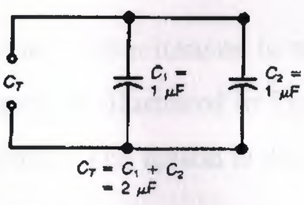


Fig: 3.7 Capacitances in parelell

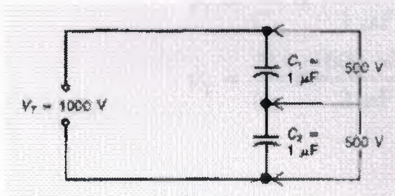
$C_T = C_1 + C_2 + \cdots + \text{etc.}$

A 10μF capacitor in parallel with a 5-/uF capacitor, for example, provides a 15μF capacitance for the parallel combination. The voltage is the same across the parallel capacitors. Note that adding parallel capacitances is opposite to the case of inductances in parallel, and resistances in parallel.

3.8 SERIES CAPACITANCES

Connecting capacitances in series is equivalent to increasing the thickness of the dielectric. Therefore, the combined capacitance is less than the smallest individual value. As shown in Fig.3.8.1 , the combined equivalent capacitance is calculated by the reciprocal formula

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \text{etc.}$$



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_T = 0.5\ \mu F$$

Fig. 3.8.1 Capacitances in series.

Any of the short-cut calculations for the reciprocal formula apply. For example, the combined capacitance of two equal capacitances of 10 /uF in series is 5/tiF.

Capacitors are used in series to provide a higher working voltage rating for the combination. For instance, each of three equal capacitances in series has one-third the applied voltage.

Division of Voltage across Unequal Capacitances In series, the voltage across each *C* is inversely proportional to its capacitance, as illustrated in Fig. 3.8.2. The smaller capacitance has the larger proportion of the applied voltage. The reason is that the series capacitances all have the same charge because they are in one current path.
With equal charge, a smaller capacitance has a greater potential difference.

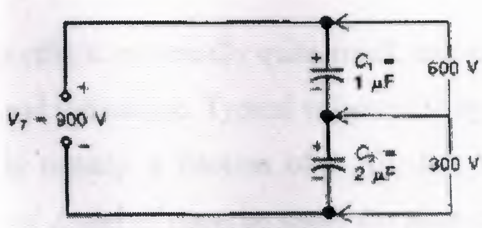


Fig. 3.8.2 With series capacitors, the smaller C has more voltage for the same charge

We can consider the amount of charge in the series capacitors in Fig. 3.8.2. Let the charging current be 600 juA flowing for 1 s. The charge Q equals 7 X t or 600 /u,C. Both Ci and C_2 have Q equal to 600 /u,C, as they are in the same series path for charging current.

Although the charge is the same in Cl and C_2, they have different voltages because of different capacitance values. For each capacitor $V = QIC$. For the two capacitors in Fig. 3.8.2, then:

$$V_1 = \frac{Q}{C_1} = \frac{600\ \mu C}{1\ \mu F} = 600\ V$$

$$V_2 = \frac{Q}{C_2} = \frac{600\ \mu F}{2\ \mu F} = 300\ V$$

Charging Current for Series Capacitances The charging current is the same in all parts of the series path, including the junction between C_1 and C_2, even though this point is separated from the source voltage by two insulators. At the junction, the current is the resultant of electrons repelled by the negative plate of C_2 and attracted by the positive plate of C_1 The amount of current in the circuit is determined by the equivalent capacitance of C_1 and C_2 in series. In Fig.3.8.2, the equivalent capacitance is 2/3 μF.

3.9 STRAY CAPACITIVE AND INDUCTIVE EFFECTS

These two important characteristics can be evident in all circuits with all types of components. A capacitor has a small amount of inductance in the conductors. A coil has some capacitance between windings. A resistor has a small amount of inductance and capacitance. After all, a capacitance physically is simply an insulator between two conductors having a difference of potential. An inductance is basically just a conductor carrying current.

Actually, though, these stray effects are usually quite small, compared with the concentrated or lumped values of capacitance and inductance. Typical values of stray capacitance may be 1 to 10 pF, while stray inductance is usually a fraction of 1 μH. For very high radio frequencies, however, when small values of L and C must be used, the stray effects become important. As another example, any wire cable has capacitance between the conductors.

A practical case of problems caused by stray L and C is the example of a long cable used for RF signals. If the cable is rolled in a coil to save space, a serious change in the electrical characteristics of the line will take place. Specifically, for twin-lead or coaxial cable feeding the antenna input to a television receiver, the line should not be coiled, as the added L or C can affect the signal. Any excess line should be cut off, leaving just the little slack that may be needed. This precaution is not so important with audio cables.

Stray Circuit Capacitance The wiring and the components in a circuit have capacitance to the metal chassis. This stray capacitance C_s is typically 5 to 10 pF. To reduce C_s, the wiring should be short, with the leads and components placed high off the chassis. Sometimes, for very high frequencies, the stray capacitance is included as part of the circuit design. Then changing the placement of components or wiring affects the circuit operation. Such critical *lead dress* is usually specified in the manufacturer's service notes.

Leakage Resistance of a Capacitor Consider a capacitor charged by a dc voltage source. After the charging voltage is removed, a perfect capacitor would keep its charge indefinitely. Because there is no perfect insulator, after a long period of time, however, the charge will be neutralized by a small leakage current through the dielectric and across the insulated case between terminals. For paper, ceramic, and mica capacitors, though, the leakage current is very slight or, inversely, the leakage resistance is very high. As shown in Fig. 3.9.1, the leakage resistance R_l is indicated by a high resistance in parallel with the capacitance C. For paper, ceramic, or mica capacitors R_l is 100 MΩ or more. However, electrolytic capacitors may have a leakage resistance of 0.5 MΩ or less.

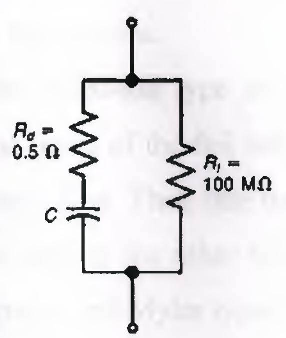


Figure:3.9.1

Fig. 3.9.1 Equivalent circuit of a capacitor; R_l is leakage resistance and R_d is absorption loss dissipated in dielectric.

Absorption Losses in Capacitors With ac voltage applied to a capacitor, the continuous charge, discharge, and reverse charging action cannot be followed instantaneously in the dielectric. This corresponds to hysteresis in magnetic materials. With a high-frequency charging voltage applied to the capacitor, there may be a difference between the amount of ac voltage applied and the ac voltage stored in the dielectric. The difference can be considered *absorption loss* in the dielectric. With higher frequencies, the losses increase. In Fig. 3.9.1, the small value of 0.5Ω for R_d indicates a typical value for paper capacitors. For ceramic and mica capacitors, the dielectric losses are even smaller. These losses need not be considered for electrolytic capacitors because they are generally not used for radio frequencies.

Power Factor of a Capacitor The quality of a capacitor hi terms of minimum loss is often indicated by its power factor. The lower the numerical value of the power factor, the better is the quality of the capacitor. Since the losses are in the dielectric, the power factor of the capacitor is essentially the power factor of the dielectric, independent of capacitance value or voltage rating. At radio frequencies, approximate values of power factor are 0.000 for air or vacuum, 0.0004 for mica, about 0.01 for paper, and 0.0001 to 0.03 for ceramics.

The reciprocal of the power factor can be considered the Q of the capacitor, similar to the idea of Q of a coil. For instance, a power factor of 0.001 corresponds to a Q of 1000. A higher Q therefore means better quality for the capacitor.

Inductance of a Capacitor Capacitors with a coiled construction, particularly paper and electrolytic capacitors, have some internal inductance. The larger the capacitor, the greater is its series inductance. Mica and ceramic capacitors have very little inductance, however, which is why they are generally used for radio frequencies.
For use above audio frequencies, the rolled-foil type of capacitor must have a noninductive construction. This means the start and finish of the foil winding must not be the terminals of the capacitor. Instead, the foil windings are offset. Then one terminal can contact all layers of one foil at one edge, while the opposite edge of the other foil contacts the second terminal. Most rolled-foil capacitors, including the paper and Mylar types, are constructed this way.

Distributed Capacitance of a Coil As illustrated in Fig. 3.9.2, a coil has distributed capacitance C_d between turns. Note that each turn is a conductor separated from the next turn by an insulator, which is the definition of capacitance. Furthermore, the potential of each turn is different from the next, providing part of the total voltage as a potential difference to charge C_d. The result then is the equivalent circuit shown for an RF coil. The L is the inductance and R_e its effective ac resistance in series with L, while the total distributed capacitance C_d for all turns is across the entire coil.

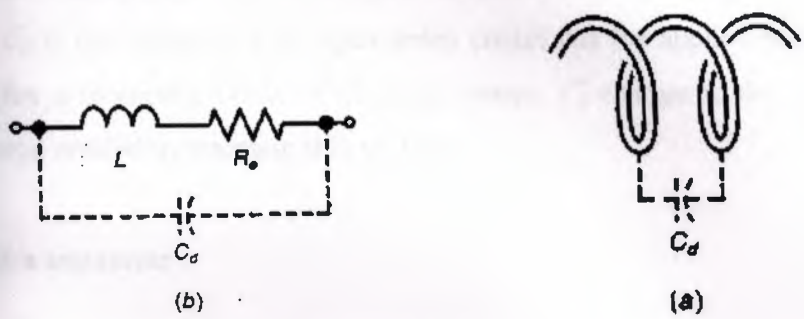


Figure:3.9.2

Fig. 3.9.2 Equivalent circuit of an RF coil, (a) Distributed capacitance C_j between turns of wire. *(b)* Equivalent circuit

Special methods for minimum C_d include *space-wound* coils, where the turns are spaced far apart; the honeycomb or *universal* winding, with the turns crossing each other at right angles; and the *bank winding*, with separate sections called *pies*. These windings are for RF coils. In audio and power transformers, a grounded conductor shield, called a *Faraday screen*, is often placed between windings to reduce capacitive coupling.

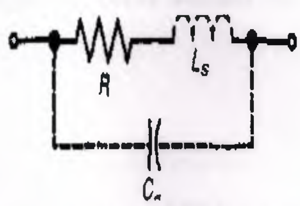


Fig: 3.9.3 High frequency equivalent circuit of resistors

Reactive Effects in Resistors As illustrated by the high-frequency equivalent circuit in Fig. 28-16, a resistor can include a small amount of inductance and capacitance. For carbon-composition resistors, the inductance is usually negligible. However, approximately 0.5 pF of capacitance across the ends may have an effect, particularly with large resistances used for high radio frequencies. Wire-wound resistors definitely have enough inductance to be evident at radio frequencies. However, special resistors are available with double windings in a nonin-ductive method based on cancellation of opposing magnetic fields.

Capacitance of an Open Circuit An open switch or a break in a conducting wire has capacitance C_0 across the open. The reason is that the open consists of an insulator between two conductors. With a voltage source in the circuit, C_0 charges to the applied voltage. Because of the small C_0 in the order of picofarads, the capacitance charges to the source voltage in a short time. This charging of C_0 is the reason why an open series circuit has the applied voltage across the open terminals. After a momentary flow of charging current, C_0 charges to the applied voltage and stores the charge needed to maintain this voltage.

3.10 How to read a capacitor

Reading capacitors requires for you to have the following information:

1. Printing from the capacitor
2. Type of capacitor

If the printing from the capacitor has the complete, obvious value on it, like 3,300 uF, you are home free and don't have to think any more. That is typical only for large valued capacitors with lots of space for printing. Some tantalum capacitors have this as well, though, and they aren't so big. In general, it helps to know what type of capacitor you have so that you can at least figure out about how large the value should be.

But down to business.

Typically, the numbers are in a mn(nnn) x 10^3 format where you have some group of significant digits followed by a single digit multiplier (i.e. 332 corresponds to 33 x 10^2 or 3300). BUT, they don't tell you what the base value is. ALMOST ALWAYS, this base value is pF. Why? Well, nF doesn't sound cool, I guess and by the time something becomes uF or mF sized, you can just print the whole number on the capacitor. Some capacitors are always going to be exceptions to this rule, so you need to pay attention. For example, some of the film capacitors are marked .047; what is .047? Well, .047 is .047uF. Others in the box are marked 473, which means 47 x 10^3 pF or 47nF or .047uF, the normal designation. Also, I've run into some silver mica caps that were marked 10 (as in 10pF, not 1 x 10^0 or 1 pF). It helps to know what capacitance value to expect based upon the physical size of the capacitor in these cases.

Table of typical ranges of values for different types of capacitors:

Type of capacitor	Typical range of values	Working Voltage Range
Silver Mica		
Ceramic:		
Single Layer	1pF - 47nF	50V - 6KV
Multilayer or Stacked:		
C0G/NP0	10pF - 27nF	50V - 200V
X7R	1nF - 580nF	50V - 200V
Z5U	1nF - 2.2uF	50V, 100V
Metallized Film:		
Polyester	1nF - 15uF	50V - 1500V
Polycarbonate	100pF - 15uF	63V - 1000V
Polypropylene	100pF - 10uF	63V - 2000V
Polystyrene	10pF - 47nF	30V - 630V
Metallised paper	1nF - 0.47uF	250VAC
Electrolytics:		
Aluminum Oxide	.1uF - 68000uF	up to 450V
Tantalum Bead	0.1uF - 150uF	6.3V - 35V

3.11 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.

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 %

Fig: 3.11.1

Have a look at Fig.3.11.1 and Fig. 3.11.2. 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 coefficient 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.

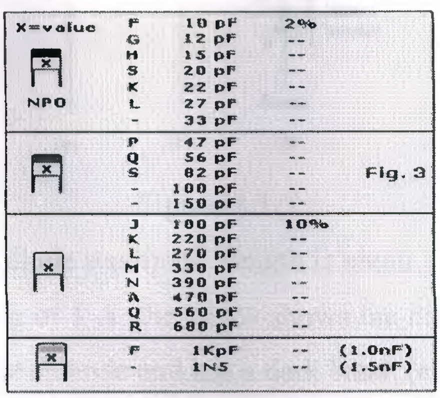


Fig : 3.11.2

CHAPTER :4

4. DIODES

4.1 SEMICONDUCTOR DIODES

A diode is essentially a PN junction. The standard symbol is an arrow to indicate the direction of hole current and a bar, as shown in Fig. 4.1.1. The arrow is at the anode, which must be positive for current flow, while the bar is the cathode. Conventional current is in the direction of the arrow for the flow of hole charges.

Electron flow is the opposite way, against the arrow. The practical use of diodes is to serve as a one-way valve. Current can flow only when positive voltage at the anode with respect to cathode, provides forward voltage. With the reverse polarity, no forward current can flow. This feature is the basis for the general use of the diode as a rectifier to change ac input to dc output.

Two small semiconductor diodes are shown in Fig. 4.1.1. In Fig. 4.1.1 la, the symbol is on the diode to indicate anode and cathode. For the diode in Fig. 28-1 *lb*, the colored band at one end indicates the cathode side. Some diodes may have a + sign at the cathode end to show this is where positive dc output can be obtained in a rectifier circuit. Any mark at one end indicates the cathode side. The cathode has positive dc output when the ac input is applied to the anode.

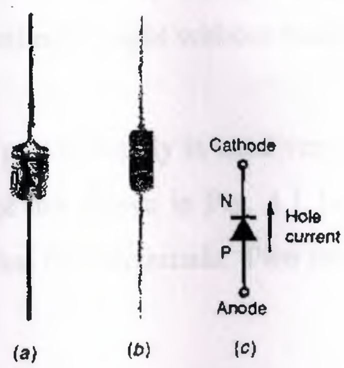


Figure:4.1.1

Fig. 4.1.1 Semiconductor diode rectifiers. Length is about *V-i* in. without leads, *(a)* Silicon power diode with current rating of 1 A. the arrow shows the direction of the hole current, *(b)* Germanium detector diode. The cathode end has a dark band, (c) Schematic symbol for diode.

Type Numbers The numbering system for diodes uses the letter N for semiconductors, the prefix 1 before the N and numbers after the N for individual types. The 1 means one junction. As an example, the 1N3196 is a popular silicon diode. The IN indicates a semiconductor diode, while the 3196 specifies the individual characteristics, which are listed in semiconductor handbooks, specification sheets, and application notes. There is no special indication for Si or Ge, but practically all rectifier diodes are made of silicon. In schematic diagrams, diodes are usually labeled D, CR, or X and Y. The CR stands for crystal rectifier.

Rectifier Packaging The plastic package shown in Fig. 4.1.1 is very common with rectifiers for currents of about 1 A. Even smaller diodes can be used for less current. Two other types of rectifiers are shown in Fig. 4.1.2. The metal can in Fig. 4.1.2a is called "top-hat" style. The type in Fig. 4.1.2b uses a stud mount that screws directly into a metal mounting for the cathode connection. Note the diode symbols printed directly on the unit to indicate the anode and cathode terminals. The stud mount types generally have high current ratings.

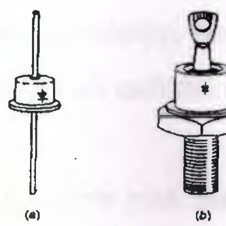


Figure:4.1.2

Fig. 4.1.2 Rectifier packages, (a) "Top-hat" style. Height is 3/8 in. without leads, *(b)* heavy-duty rectifier for stud mounting. Height without stud is *1/2* in.

Bridge Rectifiers This type of power supply is used very often, even though it requires four diodes. Connections for the bridge are shown in Fig. 4.1.3a, while typical packages are in Fig. 4.1.3b and c. Note that the bridge has four terminals. Two are connections for the ac input and two for the dc output.

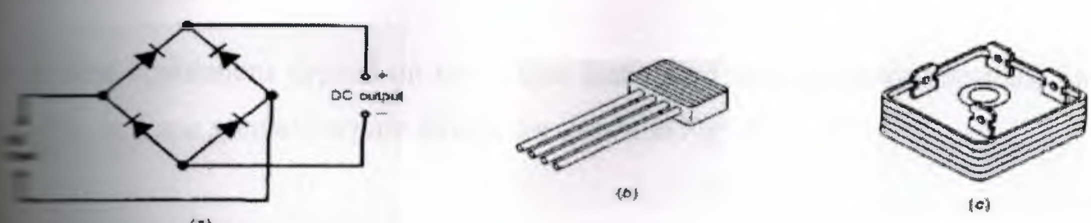


Figure:4.1.3

Fig. 4.1.3 The bridge rectifier, (a) Schematic with four diodes as a full-wave bridge, *(b)* Typical package. Length is $^3/4$ in. (c) Heavy-duty package for mounting on heat sink. Size is 1 in. square.

Rectifier Ratings The two most important ratings are for maximum forward current I_F and maximum peak inverse voltage (PIV). Ratings for maximum I_f can be a fraction of one ampere up to 25 A or more. The PIV rating for popular diodes is typically about 1000 V. The peak inverse voltage is the value that can be used across the diode in reverse polarity, negative at the anode, without disrupting the electrical characteristics of the junction. The PIV rating must be at least double the value of the dc voltage output. The reason is that the dc output and ac input are in series-aiding polarity across the diode when the anode. is negative.

4.2 SPECIAL-PURPOSE DIODES

A semiconductor diode is just a PN junction. Since forward current flows only one way, the main use is rectification. Besides having polarity, however, the PN junction has additional properties that are useful. Popular applications include:

1. *Capacitive diode or varactor.* With reverse bias, the diode junction has capacitance that can be varied by the dc voltage.
2. *Voltage-reference diode.* The reverse breakdown voltage provides a steady dc value for voltage regulation.
3. *Tunnel diode.* This type has a negative resistance characteristic.
4. *Photoelectric diodes.* Semiconductors have characteristics related to light.

The internal *R* can be changed by light input. Also, the light-emitting diode (LED) can emit light.

All these applications depend on the unique features of semiconductor materials. Schematic symbols for these special-purpose diodes are shown in Fig. 4.2.1

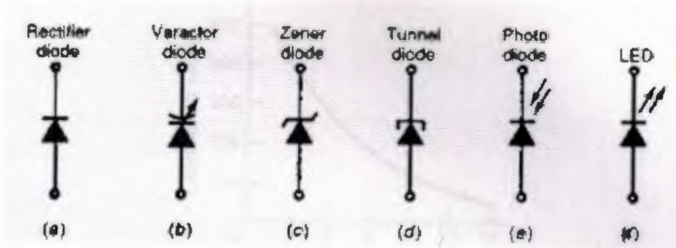


Figure:4.2.1

Fig. 4.2.1 Schematic symbols for popular types of diodes. Note that the photodi-ode in (e) needs light input to vary its *R*, whereas the LED in (*f*) generates light output.

Varactor Diodes This type is also called a *varicap* or *capacitive diode*. With reverse voltage, the barrier voltage enables the junction to serve as a capacitance because of the separated charges in the depletion zone. The *C* values are in the picofarad (10^{-12} F) range. Most important, the amount of junction capacitance can be controlled by varying the reverse voltage.

Two outline drawings of a varactor are illustrated in Fig. 4.2.3a. A mark at one end indicates the cathode. The schematic symbol is in Fig. 4.2.3*b*. The graph in Fig. 4.2.4 shows that C_v of the varactor can be varied from 400 to 20 pF, with reverse voltages of 3 to 18 V. The reverse voltage is negative at the anode of the varactor. Its C decreases with more reverse voltage.

The circuit diagram in Fig. 4.2.5 on the next page illustrates how a varactor provides *electronic tuning* by varying the frequency of the oscillator *Q*1. The *LC* tuned circuit determines the oscillator frequency. Across the tuned circuit, the varactor provides C_v as part of the capacitance that determines the resonant frequency. When C_v is varied by a dc control voltage applied as reverse bias, the oscillator is tuned to different frequencies determined by the capacitive diode.

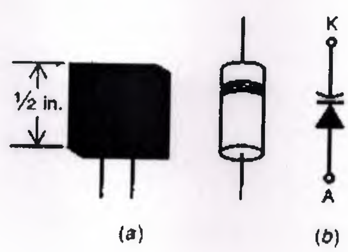


Fig. 4.2.2 The capacitive diode or varactor. (a) Outline, *(b)* Schematic symbol.

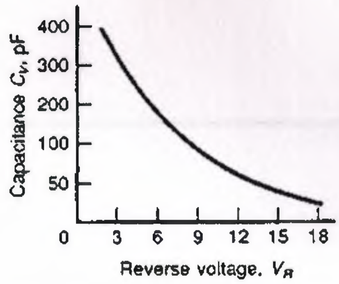


Fig. 4.2.3 Operating characteristics of varactor with reverse voltage applied.

Zener Diodes These are voltage-reference diodes. They are named after C. A. Zener, who analyzed the voltage breakdown of insulators. Zener diodes are designed for a specific reverse breakdown voltage, typically 3 to 100 V. Series diodes can be used for a higher rating. At the breakdown value, the reverse thin mica washer. Both sides are coated with silicone grease for heat dissipation to the chassis.

FAIRCHILD
SEMICONDUCTOR®

1N4001 - 1N4007

Features

- Low forward voltage drop.
- High surge current capability.

DO-41
COLOR BAND DENOTES CATHODE

General Purpose Rectifiers

Absolute Maximum Ratings*

T_A = 25°C unless otherwise noted

Symbol	Parameter	Value							Units
		4001	4002	4003	4004	4005	4006	4007	
V_{RRM}	Peak Repetitive Reverse Voltage	50	100	200	400	600	800	1000	V
$I_{F(AV)}$	Average Rectified Forward Current, .375 " lead length @ T_A = 75°C	1.0							A
I_{FSM}	Non-repetitive Peak Forward Surge Current 8.3 ms Single Half-Sine-Wave	30							A
T_{stg}	Storage Temperature Range	-55 to +175							°C
T_J	Operating Junction Temperature	-55 to +175							°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	3.0	W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	50	°C/W

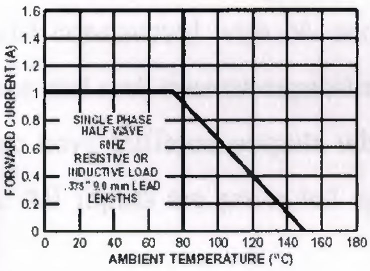
Electrical Characteristics

T_A = 25°C unless otherwise noted

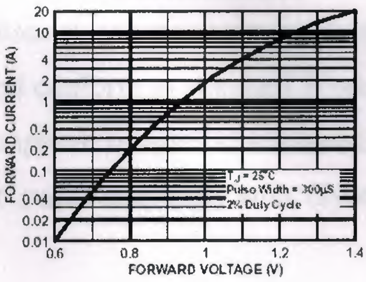
Symbol	Parameter	Device							Units
		4001	4002	4003	4004	4005	4006	4007	
V_F	Forward Voltage @ 1.0 A	1.1							V
I_{rr}	Maximum Full Load Reverse Current, Full Cycle T_A = 75°C	30							µA
I_R	Reverse Current @ rated V_R T_A = 25°C T_A = 100°C	5.0 500							µA µA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz	15							pF

Typical Characteristics

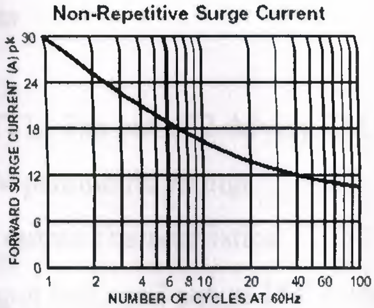
Forward Current Derating Curve



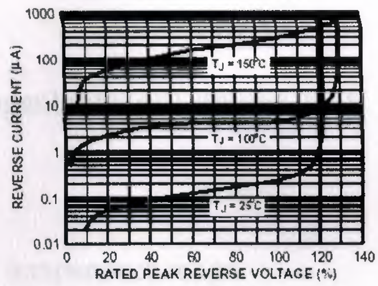
Forward Characteristics



Non-Repetitive Surge Current



Reverse Characteristics



CHAPTER: 5

5. CD4001 BC OF GATE

5.1 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.

5.2 Features

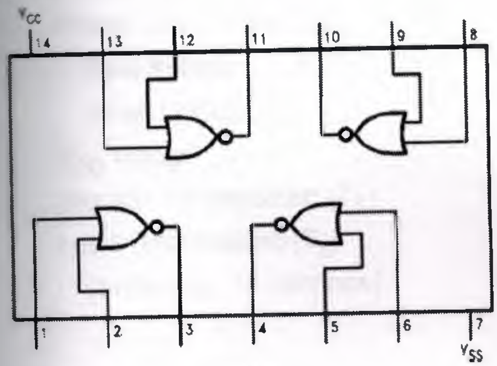
_Low power TTL: Fan out of 2 driving 74L compatibility: or 1 driving 74LS
_5V–10V–15V parametric ratings
_Symmetrical output characteristics
_Maximum input leakage 1 μA at 15V over full temperature range

5.3 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

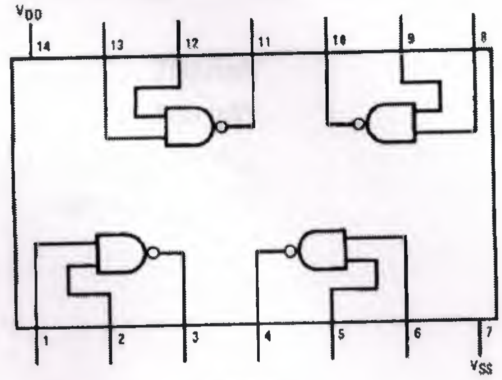
5.4 Connection Diagrams

Pin Assignments for DIP, SOIC and SOP
CD4011BC



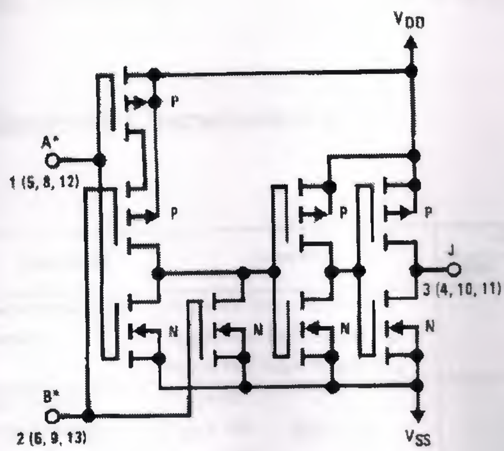
Top View

Pin Assignments for DIP and SOIC
CD4001BC

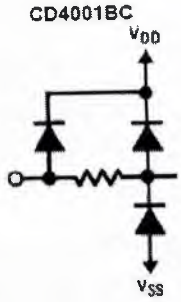


Top View

5.6 Schematic Diagrams



CD4001BC



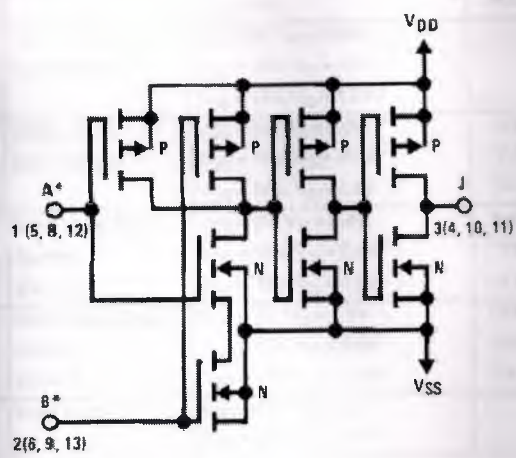
$^1/_4$ of device shown

$J = \overline{A + B}$

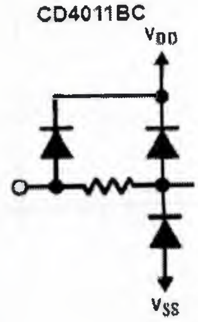
Logical "1" = HIGH

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.

5.7 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

5.8Recommended Operating Conditions

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

5.9 DC Electrical Characteristics

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
[illegible]	Quiescent Device Current	$V_{DD} = 5V$, $V_{IN} = V_{DD}$ or V_{SS}		0.25		0.004	0.25		7.5	µA
		$V_{DD} = 10V$, $V_{IN} = V_{DD}$ or V_{SS}		0.5		0.005	0.50		15	
		$V_{DD} = 15V$, $V_{IN} = V_{DD}$ or V_{SS}		1.0		0.006	1.0		30	
[illegible]	LOW Level Output Voltage	$V_{DD} = 5V$		0.05		0	0.05		0.05	V
		$V_{DD} = 10V$ $\|I_O\| < 1$ µA		0.05		0	0.05		0.05	
		$V_{DD} = 15V$		0.05		0	0.05		0.05	
[illegible]	HIGH Level Output Voltage	$V_{DD} = 5V$	4.95		4.95	5		4.95		V
		$V_{DD} = 10V$ $\|I_O\| < 1$ µA	9.95		9.95	10		9.95		
		$V_{DD} = 15V$	14.95		14.95	15		14.95		
[illegible]	LOW Level Input Voltage	$V_{DD} = 5V$, $V_O = 4.5V$		1.5		2	1.5		1.5	V
		$V_{DD} = 10V$, $V_O = 9.0V$		3.0		4	3.0		3.0	
		$V_{DD} = 15V$, $V_O = 13.5V$		4.0		6	4.0		4.0	
[illegible]	HIGH Level Input Voltage	$V_{DD} = 5V$, $V_O = 0.5V$	3.5		3.5	3		3.5		V
		$V_{DD} = 10V$, $V_O = 1.0V$	7.0		7.0	6		7.0		
		$V_{DD} = 15V$, $V_O = 1.5V$	11.0		11.0	9		11.0		
[illegible]	LOW Level Output Current (Note 3)	$V_{DD} = 5V$, $V_O = 0.4V$	0.64		0.51	0.88		0.36		mA
		$V_{DD} = 10V$, $V_O = 0.5V$	1.6		1.3	2.25		0.9		
		$V_{DD} = 15V$, $V_O = 1.5V$	4.2		3.4	8.8		2.4		
[illegible]	HIGH Level Output Current (Note 3)	$V_{DD} = 5V$, $V_O = 4.6V$	−0.64		−0.51	−0.88		−0.36		mA
		$V_{DD} = 10V$, $V_O = 9.5V$	−1.6		−1.3	−2.25		−0.9		
		$V_{DD} = 15V$, $V_O = 13.5V$	−4.2		−3.4	−8.8		−2.4		
[illegible]	Input Current	$V_{DD} = 15V$, $V_{IN} = 0V$		−0.10		-10^{-5}	−0.10		−1.0	µA
		$V_{DD} = 15V$, $V_{IN} = 15V$		0.1		10^{-5}	0.10		1.0	

5.10 AC Electrical Characteristics

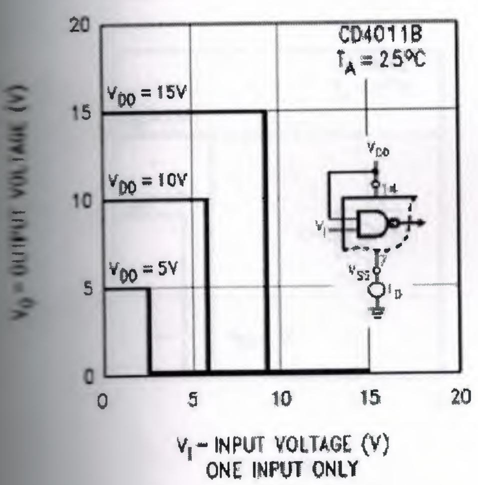
Symbol	Parameter	Conditions	Typ	Max	Units
t_{PHL}	Propagation Delay Time, HIGH-to-LOW Level	V_{DD} = 5V	120	250	ns
		V_{DD} = 10V	50	100	
		V_{DD} = 15V	35	70	
t_{PLH}	Propagation Delay Time, LOW-to-HIGH Level	V_{DD} = 5V	110	250	ns
		V_{DD} = 10V	50	100	
		V_{DD} = 15V	35	70	
t_{THL}, t_{TLH}	Transition Time	V_{DD} = 5V	90	200	ns
		V_{DD} = 10V	50	100	
		V_{DD} = 15V	40	80	
C_{IN}	Average Input Capacitance	Any Input	5	7.5	pF
C_{PD}	Power Dissipation Capacity	Any Gate	14		pF

5.11 AC Electrical Characteristics

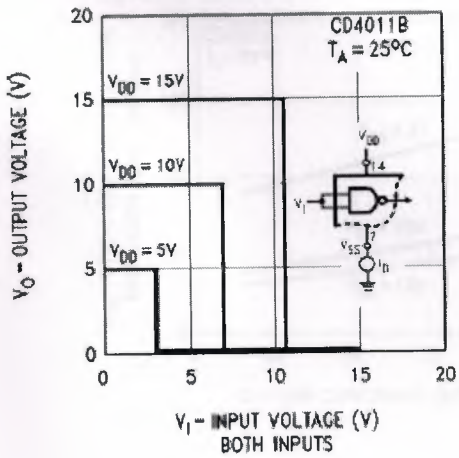
Symbol	Parameter	Conditions	Typ	Max	Units
t_{PHL}	Propagation Delay, HIGH-to-LOW Level	V_{DD} = 5V	120	250	ns
		V_{DD} = 10V	50	100	
		V_{DD} = 15V	35	70	
t_{PLH}	Propagation Delay, LOW-to-HIGH Level	V_{DD} = 5V	85	250	ns
		V_{DD} = 10V	40	100	
		V_{DD} = 15V	30	70	
t_{THL}, t_{TLH}	Transition Time	V_{DD} = 5V	90	200	ns
		V_{DD} = 10V	50	100	
		V_{DD} = 15V	40	80	
C_{IN}	Average Input Capacitance	Any Input	5	7.5	pF
C_{PD}	Power Dissipation Capacity	Any Gate	14		pF

5.12 Typical Performance Characteristics

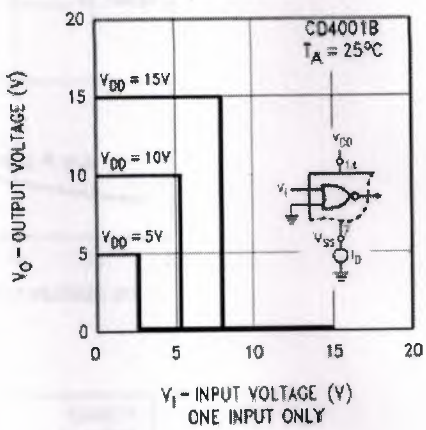
Typical
Transfer Characteristics



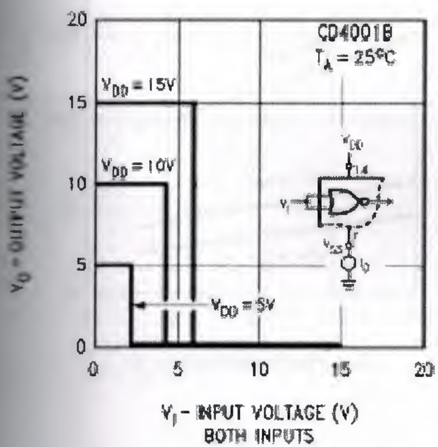
Typical
Transfer Characteristics

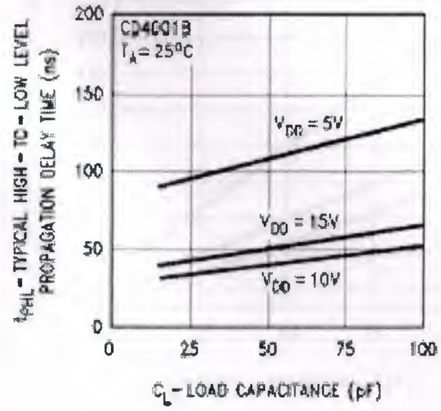


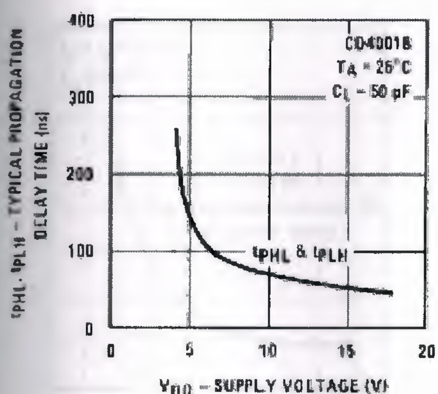
Typical
Transfer Characteristics

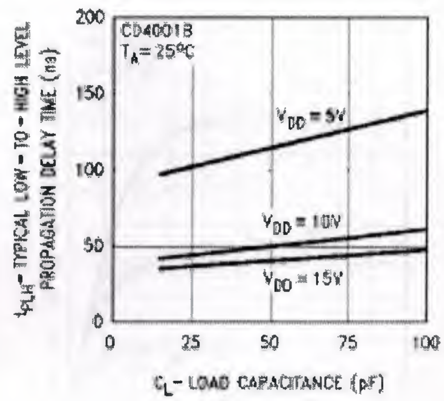


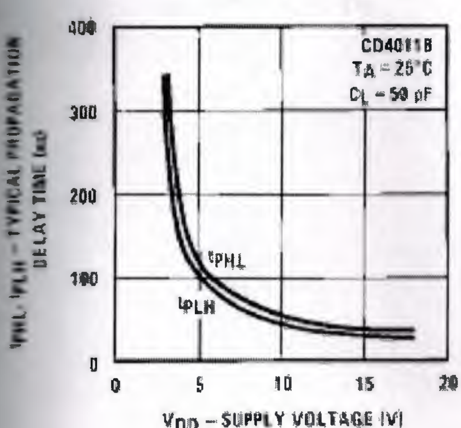
5.13 Typical Transfer Characteristics

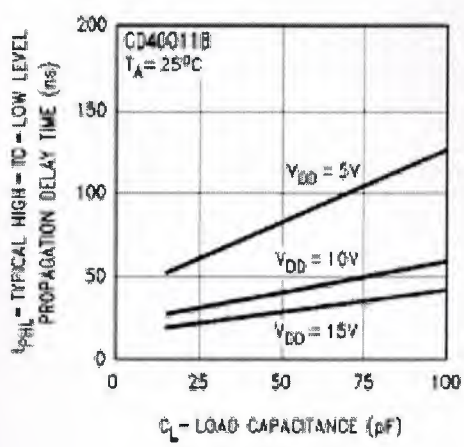




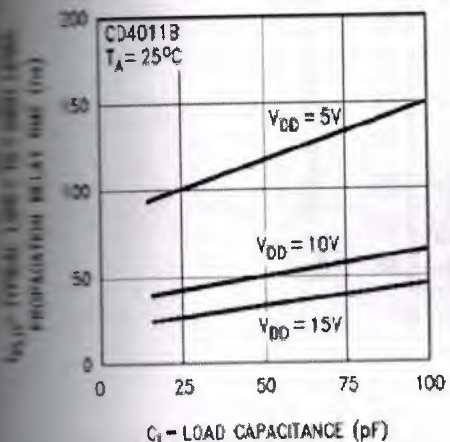


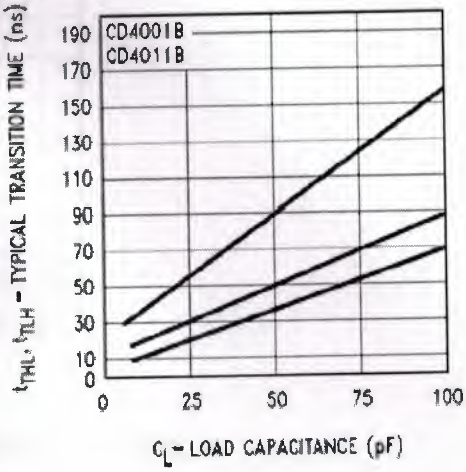


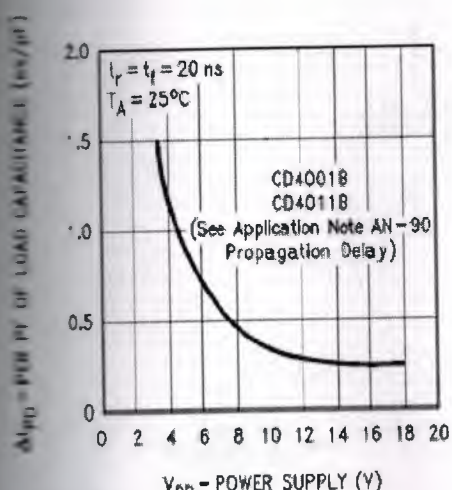


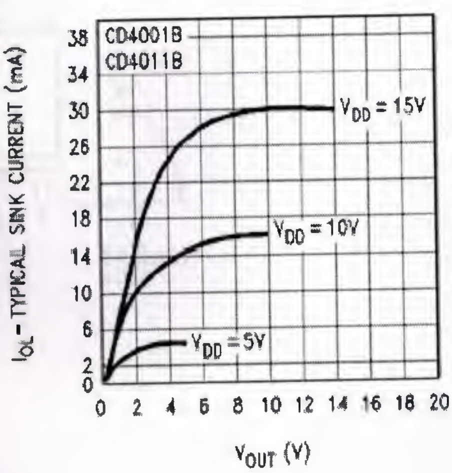


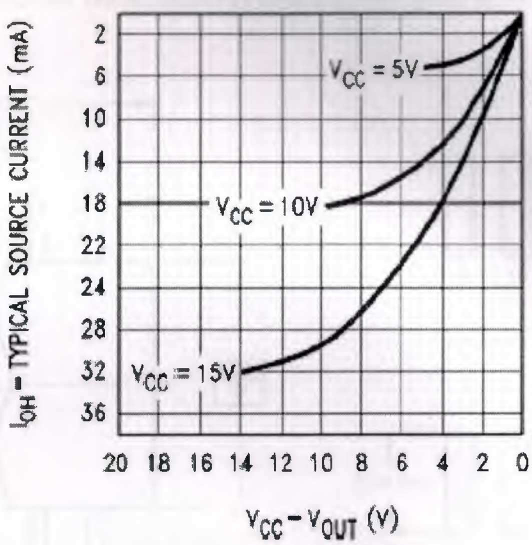
Typical Performance Characteristics



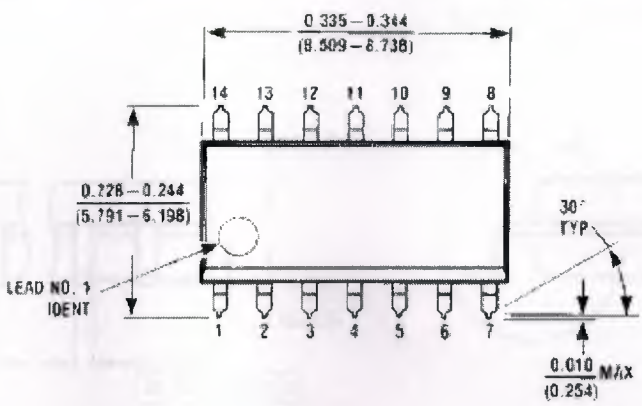


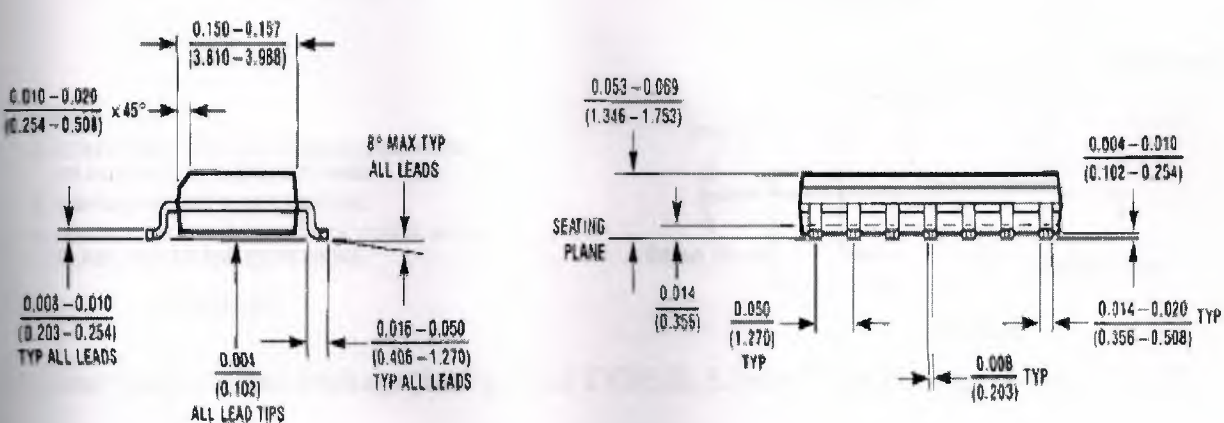






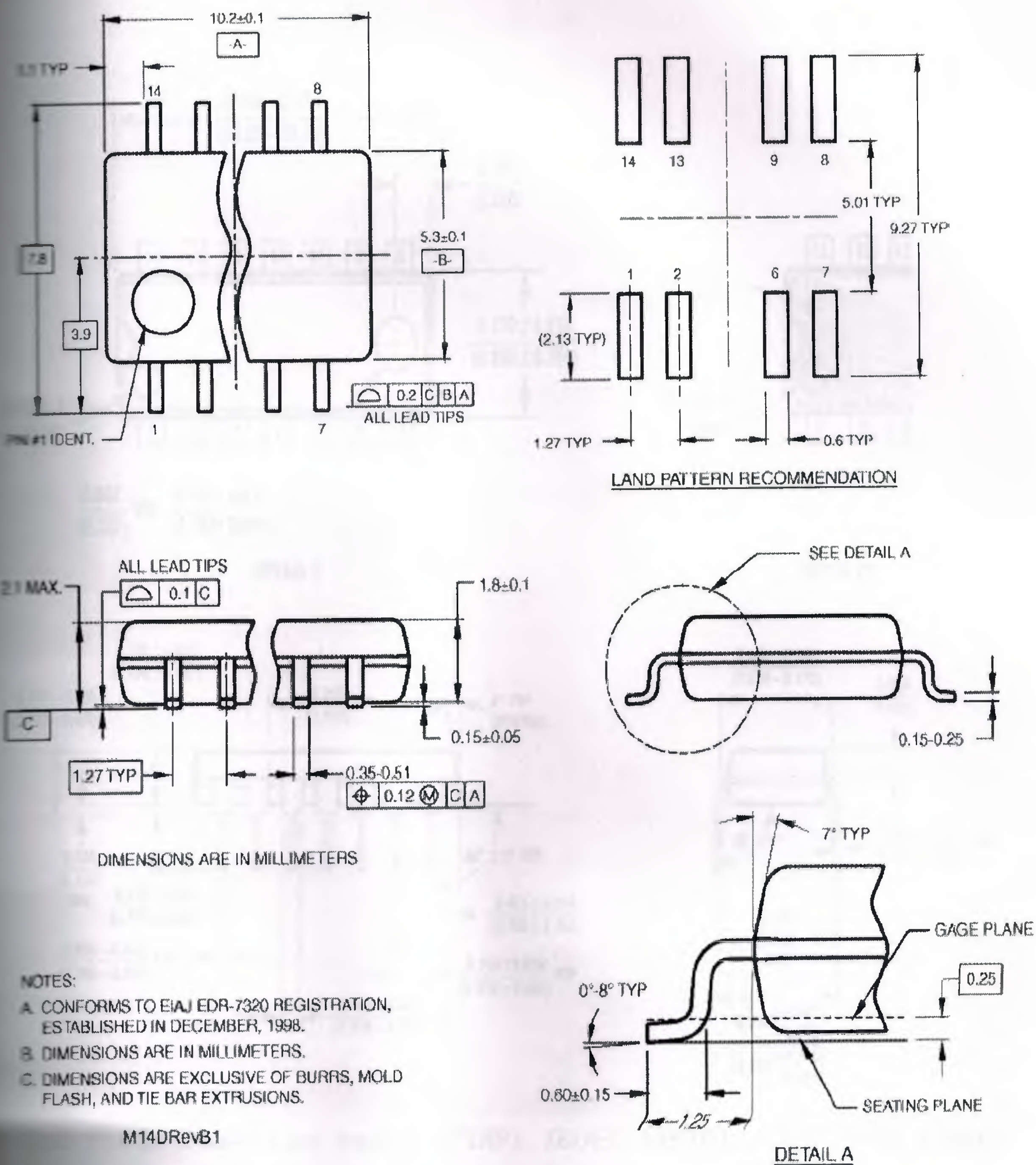
5.15 Physical Dimensions inches (millimeters) unless otherwise noted





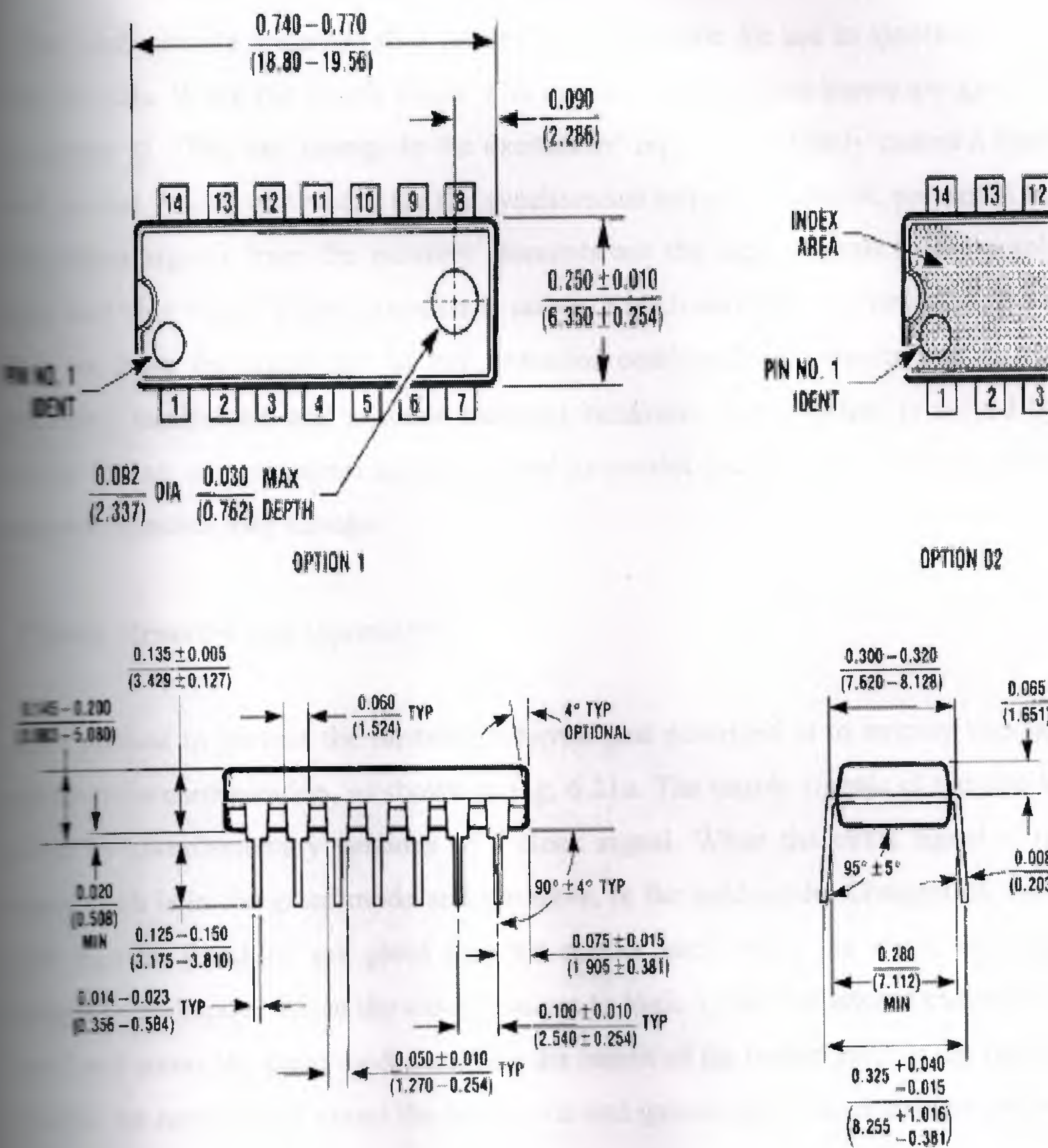
14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow Package Number M14A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide Package Number M14D

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



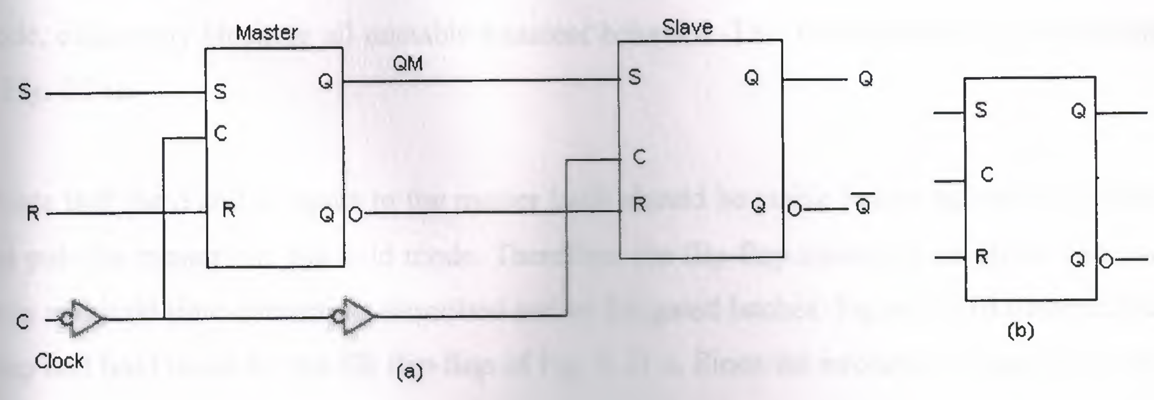
14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide Package Number N14A

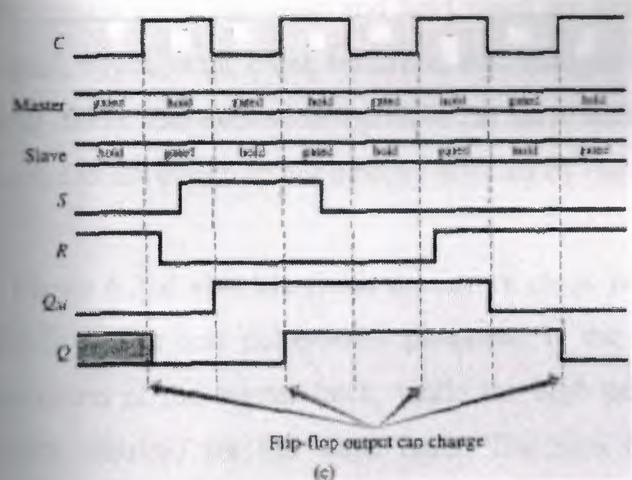
6.1 Flip-Flops:

The latch circuits presented thus far are not appropriate for use in synchronous sequential logic circuits. When the enable signal C is active, the excitation inputs are gated directly to the output Q. *Thus,* any change in the excitation^ input immediately causes a change in the latch output. Recall our model for the synchronous sequential circuit, presented in Fig. 6.1. The output signals from the memory elements are the input signals to the combinational logic, and vice versa. When its enable is active, a latch acts like a combinational circuit, too! Thus we have the possibility of two cascaded combinational circuits feeding each other, generating oscillations and unstable transient behavior. This problem is solved by using a special timing control signal called a *clock* to restrict the times at which the stales of the memory elements may change.

Circuit Structure and Operation

One method to prevent the unstable behavior just described is to employ two latches in a *niaster-slave* configuration, as shown hi Fig. 6.21a. The enable signals of the two latches are driven by complementary versions of a clock signal. When the clock signal C is low, the master latch is in the gated mode and the slave, in the hold mode. Changes on the excitation input signals S and j!^ are gated into the master latch while the slave latch ignores any changes on its inputs. When the clock changes to logic 1. the two latches exchange roles. The slave latch enters the gated mode, .sending the output of the master latch *to* the flip-flop output Q, while the master latch enters the hold mode and ignores any further changes on its inputs.





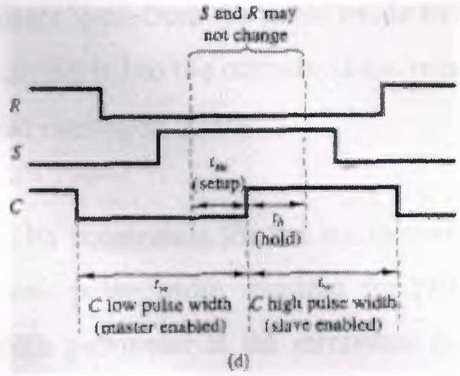


Figure 6.21 Master-stave SR flip-flop, (a) Logic diagram, (b) Pulse-triggered device logic symbol, (c) Timing behavior, (d) Timing constraints.

Master—slave flip-flops like the one in Fig. 6.21a are sometimes called *pulse triggered* because they require both logic 0 →1 and 1→ 0 transitions on the clock input in order to operate properly. On one transition the master operates, that is, enters the enabled mode; on the other transition, the slave operates. The logic symbol of Fig. 6.21b indicates the pulse-triggered nature of the device by showing the clock edge transition that enables the slave at the flip-flop output terminals Q and Q. In Fig. 6-21b, the rising transition indicates that the flip-flop outputs O and Q change on the positive edge of a pulse on the clock signal.

Timing Characteristics

If the SR flip-flop is used in a synchronous sequential circuit, an unstable oscillation cannot occur because, at all times, either the master latch or the slave latch is in the hold mode, effectively blocking all unstable transient behavior. This timing behavior is "illustrated in Fig. 6.21c.

Note that the S and R inputs to the master latch should be stable before the clock transition that puts the master into the hold mode. Therefore, the flip-flop inputs are subject to the same setup and hold time constraints described earlier for gated latches. Figure 6.21d illustrates the setup and hold times for the SR flip-flop of Fig. 6.21 a. Since the excitation inputs affect only the master latch, the setup and hold times are defined relative to the rising edge of the clock signal, which is the clock transition that changes the master latch from the gated mode to the hold mode. The excitation inputs of the slave latch are connected to the outputs of the master latch and are therefore not directly affected by the external excitation inputs.

Figure 6.21d also illustrates minirnurn clock pulse-width constraints for the master—slave flip-flop. The low pulse-width parameter is the minimum pulse width required for proper operation of the master latch, while the high pulse-width parameter is the minimum pulse width required for the slave latch. The sum of these two pulse widths determines the minimum period of any clock signal to be used for the flip-flop.

Excitation Table and Characteristic Equation

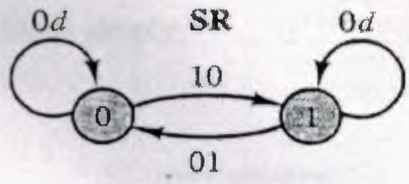
The excitation table and state diagram for the SR master-slave flip-flop are presented in Figs. 6.22a and b, respectively. Note that the columns S, R, and Q of the excitation table denote the conditions on the flip-flop signals *before* the clock pulse is applied. The column Q^* denotes the flip-flop output *after* the clock pulse has been applied. Comparing this table to Fig. 6.11 a, we see that the operation of the master—slave SR flip-flop is similar to that of the simple SR latch. Likewise, the state diagrams are identical, although the latch changes states immediately when 5 or R changes, whereas all flip-flop state changes are triggered by clock pulses. Consequently, the same characteristic equation describes the operation of both devices:

$$Q^* = S + RQ$$

The difference is that the latch output reacts immediately to any input changes, while the flip-flop output changes are controlled by the clock pulse C. Note that both negative and positive edges are required for C.

S	R	Q	C	Q^*	
0	0	0	⎍	0	No change
0	0	1	⎍	1	
0	1	0	⎍	0	Reset
0	1	1	⎍	0	
1	0	0	⎍	1	Set
1	0	1	⎍	1	
1	1	0	⎍	×	Not allowed
1	1	1	⎍	×	

(a)



(b)

Figure 6.22 SR master-slave flip-flop characteristics, (a) Excitation table, (b) State diagram.

6.2 Master-Slave D Flip-flops

We can build a master-slave D flip-flop from two D latches as shown in Fig. 6,23a. Note that this flip-flop operates in the same manner as the SR version of Fig. 6.22. The master latch is gated when the clock is low and the slave, when the clock is high. The logic symbol for this pulse-triggered device is shown in Fig. 6.23b. Note that the logic symbol indicates that the outputs change on the positive edge of a pulse on the clock signal.

The excitation table of the master-slave D flip-flop is given in Fig. 6.24a and the state diagram in Fig. 6.24b. The behavior of this device is illustrated on the timing diagram of Fig. 6.24c. At the top of the diagram, the gated latch is indicated by the symbols M and S for master and slave. When C — Q, the master is gated so that its input is passed to the slave. On the 0 —> 1 transition of C, the master "latches" the input value on D (designated by the x symbol) and holds this value. Since the slave is gated while $C = 1$, the latched value in the master is passed to the flip-flop output Q. On the falling edge of the clock C, the slave "latches" the data from the master, as shown by the symbols x on signal Q_M in the diagram. Note that delays r_{pLH} and r_{pHL} have been included in the timing diagram.

The overall behavior of the D flip-flop output Q can be summarized by noting that Q will assume the value of D on the rising edge of the clock C. Therefore, the characteristic equation for a master—slave D flip-flop is simply

$$Q^*=D$$

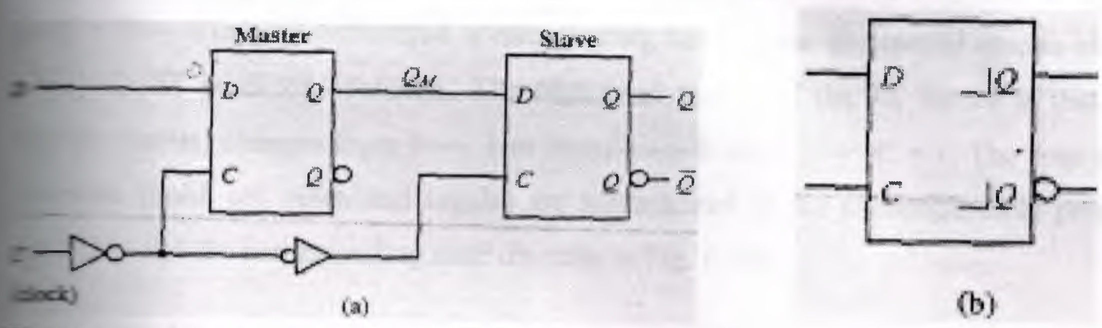
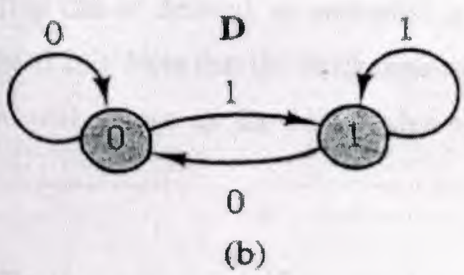


Figure 6.23 Master-slave D flip-flop, (a) Logic diagram, (b) Logic symbol.

D	Q	C	Q^*	
0	0	$\sqcap$	0	Store 0
0	1	$\sqcap$	0	
1	0	$\sqcap$	1	Store 1
1	1	$\sqcap$	1	

(a)



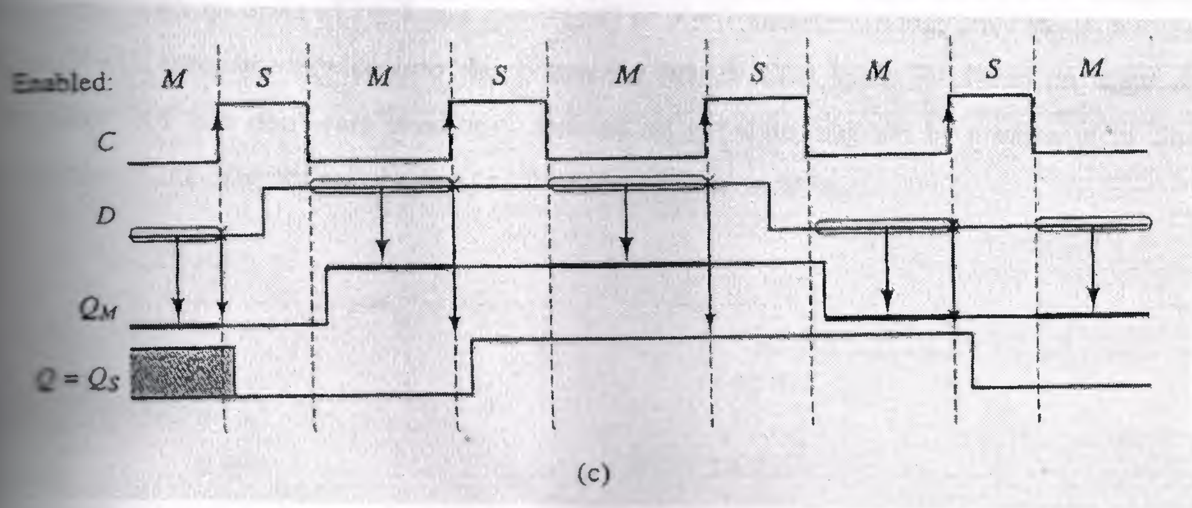


Figure 6.24 Master-slave D flip-flop characteristics, (a) Excitation table, (b) State diagram, (c) Timing diagram.

6.3 Master-Slave JK Flip-flops Circuit Structure and Operation

The JK flip-flop may be considered an extension of the SR design examined earlier. The JK operates as an SR flip-flop whose inputs are assigned $J = S$ and $K = R$. However, whereas the $S = R$— 1 input combination is not allowed, the JK uses this special case to incorporate a very useful mode of operation. The additional feature/of the JK device is that its state *toggles,* that is, changes from $0 \rightarrow 1$ or from $1 \rightarrow 0$ when $J = K = 1$. The four modes of operation (hold, set, reset, and toggle) are summarized in the excitation table presented in Fig. 6.25a and the corresponding state diagram in Fig. 6.25b.

By plotting the next state Q'' on a K-map, as shown in Fig. 6.25c, the characteristic equation of the JK flip-flop can be derived:

$$Q'' = KQ + JQ$$

From this equation, the logic diagram for the flip-flop can be derived, as presented in Fig. 6.26a. The logic symbol for this device is shown in Fig. 6.26b. Note that the clock input.signal is,inverted-_withm the^ device itself so that the slave will change on the falling edge of the clock.

Examine the state diagram of Fig. 6.25b. The JK flip-flop will change from the 0 state to the 1 state with an input of / = 1 and K= 0 (set) or J= 1 and K= 1 (toggle). That is, a logic 1 on J will force the device into the 1 state no matter what value is placed on input K. Therefore, AT is a don't-care condition, denoted on the state diagram by a value of d. The remainder of the diagram may be derived from the excitation table.

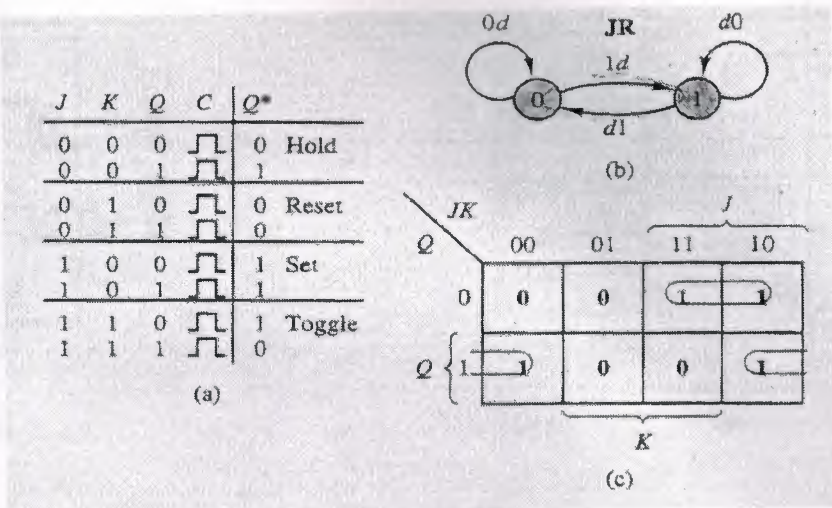


Figure 6.25 Putse-lriggsred JK Hip-flop characteristics, (a) Excitation table, (D) State diagram, **(c)** K-map for Q*.

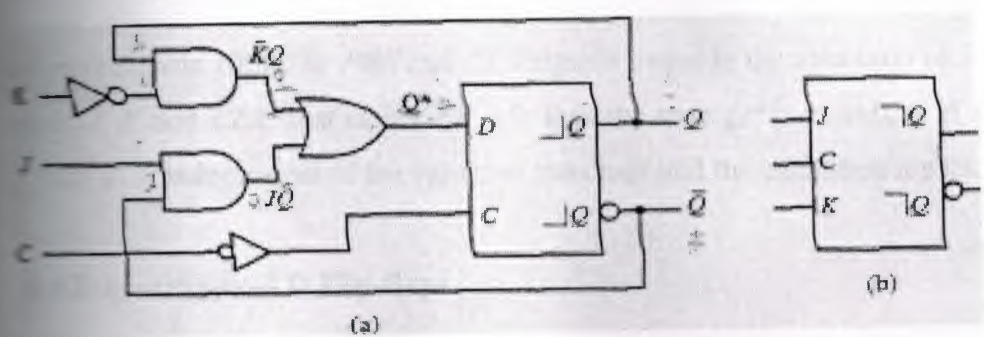


Figure 6.26 Pulse-triggered JK flip-flop, (a) Logic diagram, (b) Logic symbol.

7476 Dual Pulse-triggered JK Flip-flop Module

Several pulse-triggered JK flip-flops are available as standard TTL modules [1]. Figure 6.27 shows the logic symbol of the SN7476. This device packages two flip-flops that operate in the manner displayed in Fig. 6.26. Included in the configuration are asynchronous set signals *PRE*

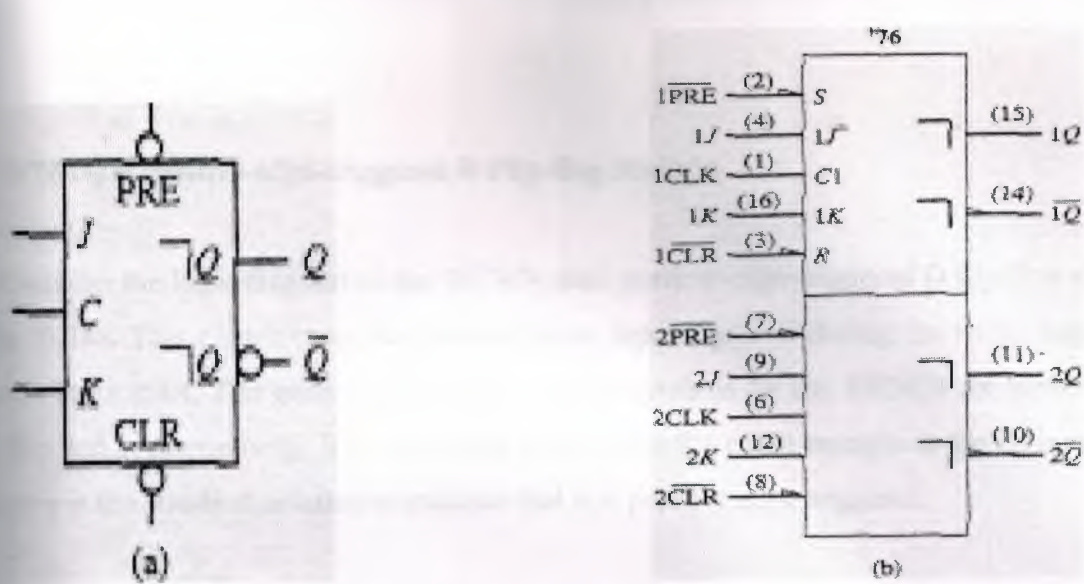


Figure 6.27

Figure :6.27 Dual pulse-triggered JK flip-flops, the 7476. (a) Generic logic symbol, (b) IEEE standard logic symbol. *Source:* The TTL Data Book Volume 2, Texas Instruments Inc., 1985.

and reset signals *CLR.The PRE* and *CLR* signals override the operation of ihe pulse-triggered inputs *J, K,* and *CLK;* that is, if $CLR = 0$, then the state Q^* goes to 0, or if $PRE = 0$, the state Q^* sets to 1, independent of the values of the clock and the excitation inputs.

6.4 Edge-triggered D Flip-flops

All the pulse-triggered flip-flops described in Section 6.4.3 require both a rising and falling edge on the clock for proper operation. The master-slave arrangement introduced a buffering mechanism to eliminate unstable transient conditions in sequential circuits with feedback elements. Another approach to solving the problem of unstable transients is to design the flip-flop circuitry so that it is sensitive to its excitation inputs only during rising or failing transitions of the clock. A circuit with this design feature is called *positive edge triggered* if it responds to a 0 →1 clock transition or *negative edge triggered* if it responds to a 1 →0 clock transition. The edge-sensitive feature eliminates unstable transients by drastically reducing the period during which the input excitation signals are applied to the internal latches.

Commercially available D flip-flop modules normally have a positive-edge-triggered clock control signal..

7474 Dual Positive-edge-triggered D Flip-flop Module

Consider the logic diagram of the SN7474 dual positive-edge-triggered D flip-flop shown in Fig- 6.28a. This circuit examines the excitation input signal *D* during the rising edge of the clock input *CLK*, The generic and IEEE standard symbols for the SN7474 are shown in Fig: 6.2Sb and c, respectively. It is important to note that the small triangle at the Cl input to the device is the standard notation to indicate that it is positive edge triggered.

The modes of operation of the SN7474 are shown in the excitation table of Fig. 6.29. Note that the asynchronous preset and clear signals, *CLR* and

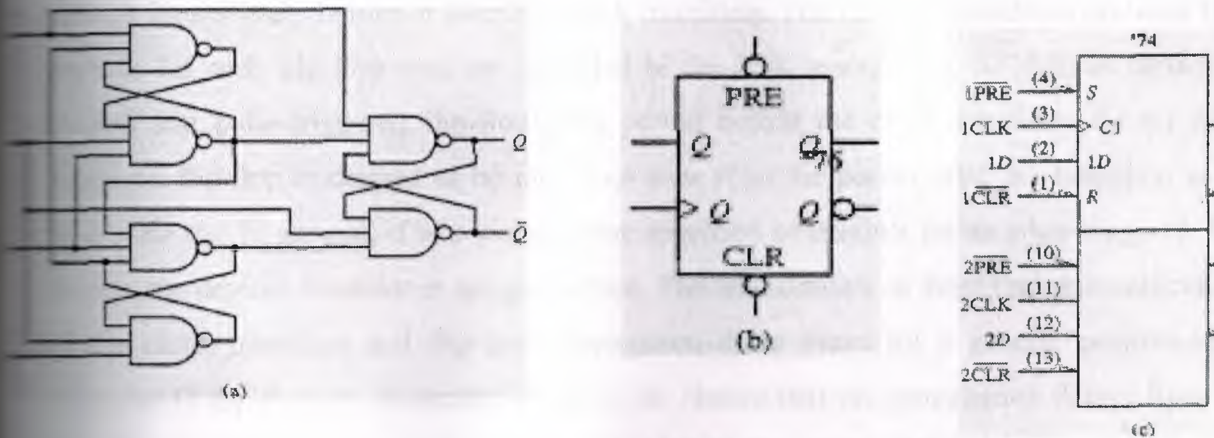


Figure 6.28

Figure :6.28 SN7474 dual positive-edge-triggered D flip-flop, (a) Logic diagram, (b) Generic logic symbol, (c) IEEE standard logic symbol. Source: The TTL Data Book Volume 2. Texas Instruments Inc., 1985.

Inputs				Outputs		
$\overline{PRE}$	$\overline{CLR}$	D	CLK	Q	$\bar{Q}$	Mode
L	H	×	×	H	L	Set
H	L	×	×	L	H	Clear
L	L	×	×	H	H	Not allowed
H	H	H	↑	H	L	Clocked operation
H	H	L	↑	L	H	Clocked operation
H	H	×	L	Q_0	$\bar{Q}_0$	Hold

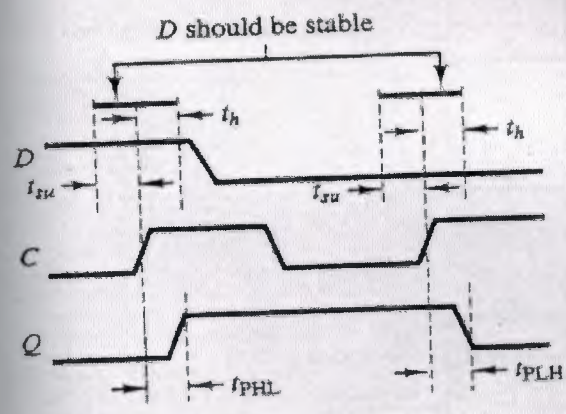
Figure 6.29

Figure :6.29 SN7474 excitation table. *Source:* The TTL Data Book Volume 2, Texas Instruments Inc., 1985.

PRE, override the clocked operation of the circuit. When both *CLR* and *PRE* are inactive (high), the clock *CLK* takes control of the device. While *CLK* is low, the flip-flop is in the hold mode. However, on a 0 → 1 transition of the clock, denoted by f, the data input *D* is transferred to the flip-flop output *Q*.

Edge-triggered Flip-flop Timing Characteristics

To insure proper operation of any edge-triggered flip-flop, the excitation inputs should not change immediately before or after the clock transition. The precise limitations on these time periods for each flip-flop type are specified hi the TTL manual [1]. As defined earlier for latches and pulse-triggered flip-flops, the period before the clock transition for an edge-triggered flip-flop is denned to be the *setup time* (t_{su}) the period after the transition is the *hold time* (t_h). In general, if w/e violate these specified constraints for an edge-triggered TTL device, the device's behavior is not guaranteed. The relationships of these timing specifications to the clock transition and flip-flop propagation delay times for a generic positive-edge-triggered D flip-flop are illustrated in Fig. 6.30. Notice that the propagation delays from the time the clock crosses its rising-edge threshold until the output *Q* changes are called r_{PHL} and $£_{PLH}$, as defined earlier. Let us examine the specific case of the SN7474. For this device, the values for both I_{PHL} andr_{pLH}, from the TTL manual [1], are listed hi Fig. 6.30basOns.



(a)

To Output Q from:	Delay Parameter	Value (ns)
Clock	t_{PLH}	25
	t_{PHL}	40
PRE	t_{PLH}	25
	t_{PHL}	40
CLR	t_{PLH}	25
	t_{PHL}	40

(b)

Input Pin	Constraint	Minimum Value (ns)
D	t_{su}	20
D	t_h	5
Clock	t_w low	30
Clock	t_w high	37
CLR	t_w low	30
PRE	t_w low	30

(c)

Figure 6.30

Figure :6.30 SN7474 flip-flop timing specifications [1]. (a) Timing diagram. (b) Propagation delays, (c) Timing constraints. *Source:* The TTL Data Book Volume 2, Texas Instruments Inc., 1985.

In other words, for the SN7474, the value of *D is* sampled and transferred to the flip-flop output *Q* at the exact instant the clock reaches its threshold value. You should always make sure that the input is either logic 1 or 0 at this instant hi time so that the flip-flop's output *Q* will be the value you have planned hi your system design. Tuning constraints for the SN7474 are listed in Fig. 6.30c.

74175 and 74273 Positive-edge-triggered D Flip-flop Modules

Two other members of the TTL family of positive-edge-triggered D fiip-flops are illustrated in Fig. 6.31. The SN74175 quad D flip-flop, shown hi Fig. 6.31a,

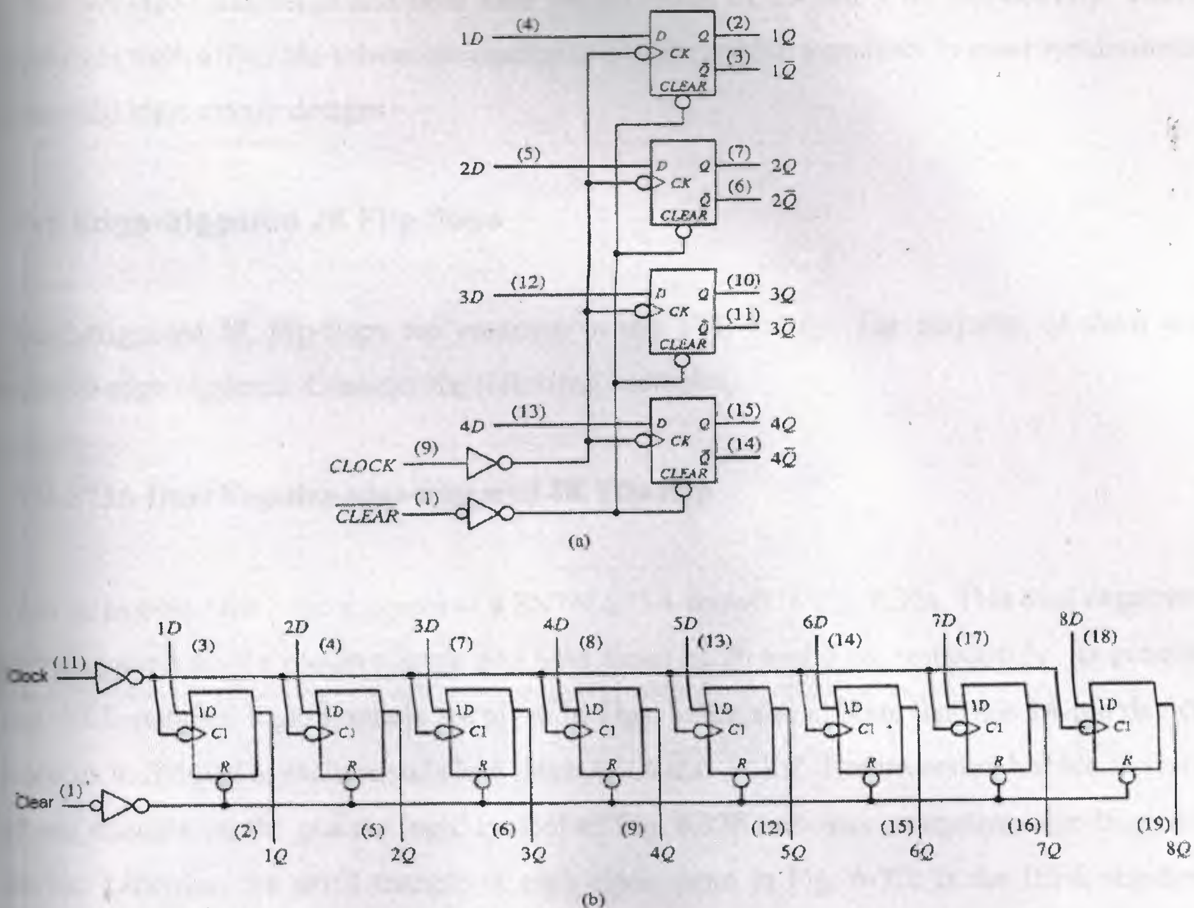


Figure :6.31

Figure 6.31 Positive-edge-triggered D flip-flop packages, (a) SN74175. (b) SN74273, *Saurce:T'eTTL* Data Book Volume 2, Texas Instruments Inc., 1985.

has common clock and clear controls, as well as both true *(Q)* and complemented *(Q)* outputs. The SN74273 octal D flip-flop, shown in Fig. 6.31b, has the same common clock *and clear lines, but brings only the true outputs (Q) to the outside world through the packag3* pins. In the logic diagrams for these two devices, note the logic symbols used for the D flip-flops. The clock input *CK* displays the small triangle that signifies that the flip-flop is edge triggered. The inversion bubble in front of the triangle indicates a negative-edge-triggered device. But since the input signal *CLOCK* is inverted by the NOT gate at the bottom of the logic diagram, from the standpoint of the external package pins, the flip-flops appear to be positive edge triggered.

The SN74273 has setup and hold time requirements of 20 and 5 ns, respectively. These values are well within the tolerances needed to avoid unstable transients in most synchronous sequential logic circuit designs.

6.5 Edge-triggered JK Flip-flops

Edge-triggered JK flip-flops are common in the TTL family. The majority 'of them are negative edge triggered. Consider the following examples.

74LS73A Dual Negative-edge-triggered JK Flip-flop

Let us examine the logic diagram of a SN74LS73A shown in Fig. 6.32a, This dual negative-edge-triggered device requires setup and hold times of 20 and 0 ns, respectively. Its generic and IEEE standard logic symbols are given in Figs. 6.32b and c. Note that this 14-pin device features individual asynchronous clear lines *1CLR* and *2CLR*. The inversion bubble in front of the triangle on the generic logic symbol of Fig. 6.32b indicates a negative-edge-triggered device. Likewise, the small triangle at each clock input in Fig. 6-32c is the IEEE standard notation for a negative-edge-triggered flip-flop.

74276 Quad Negative-edge-triggered JK Flip-flop

Suppose your design requires four JK flip-flops. Consider using the SN74276 shown in Fig. 6.32d. It features common preset and clear control signals. Each flip-flop brings its true output signal *Q* to a device package pin. Each flip-flop features individual excitation inputs / and *K*, as welt as *its* own negative-edge-triggered clock.

74111 Dual JK Flip-flop with Data Lockout

The SN74111 shown in Fig. 6.32e *is* a special implementation of the JK flip-flop. It contains a *data-lockout* feature that combines a positive-edge-triggered master latch followed by a negative pulse-tri%2fit&i slave.. Tfeat Ya, ict Ymaster latch operates on the leading edge of the clock, While the clock remains high,

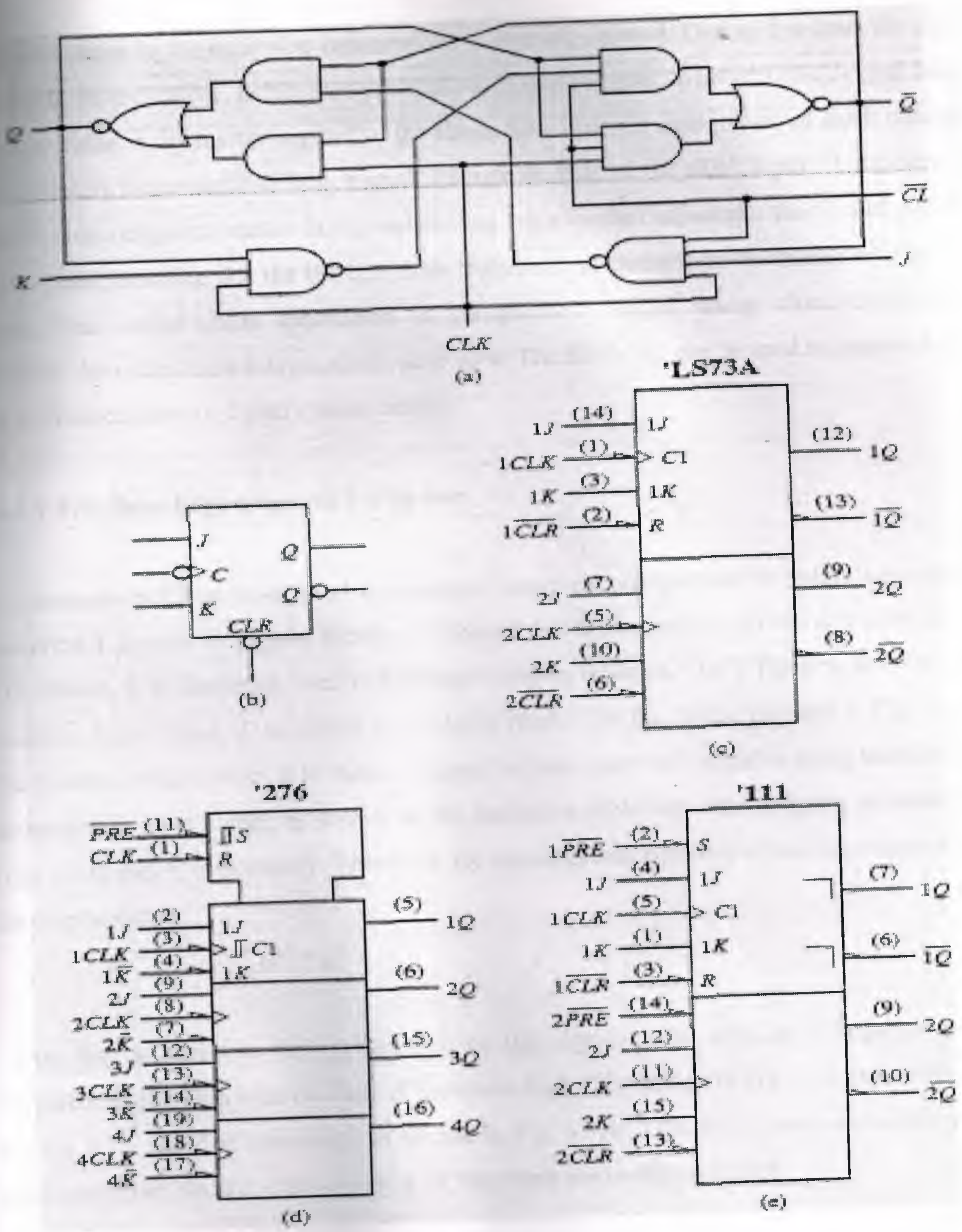


Figure:6.32

Figure 6.32 Edge-triggered JK flip-flops, (a) Logic diagram (SN74LS73A). (b) Generic logic symbol (SN74LS73A). (c) IEEE standard symbol (SN74LS73A). (d) SN74276. (e) SN74111. *Source:* The TTL Data Book Volume 2, Texas Instruments inc., 1985.

further changes to the excitation inputs of the master are ignored. During this time, the slave latch is in the hold mode, holding the previous value of the master. When the clock signal falls, the new value in the master is gated to the slave. Note that this combination of clock controls is denoted by the presence of both a small triangle in front of the clock input Cl, denoting a positive-edge-triggered master latch, andafaUing edge symbol adjacentto the (2 and Q flip-flop outputs, denoting that the slave is pulse triggered and changes on the falling edge of the clock. This device finds application in complicated designs where clock distribution networks introduce time delays called *clock skew.* The SN74111 can be used to minimize the effect of clock skew in digital system design.

6.6 T Flip-flops Edge-triggered T Flip-flop

A common building block used in sequential logic circuits that counts pulses on a signal line is the T *(trigger* or *toggle),* flip-flop. Although this device is not available as a stand-alone TTL device, it is frequently used in building counting modules. The T flip-flop has only one excitation input signal, *T,* as shown on the logic symbol for the device pictured in Fig. 6.33a. The function of this device is to change (toggle) its state upon each negative-going transition of its excitation input signal, as shown in the excitation table and state diagram presented in Figs. 6.34a and b, respectively. Therefore, the characteristic equation of the edge-triggered T flip-flop is simply

$$Q'' = Q$$

One way to visualize the construction of this device is to consider a negative-edge-triggered JK flip-flop with its *J* and *K* inputs set high. The device in Fig. 6.33a behaves as if it were a JK flip-flop connected as shown in Fig. 6.33b. This is the most commonly used implementation, since a wide variety of JK flip-flops are readily available.

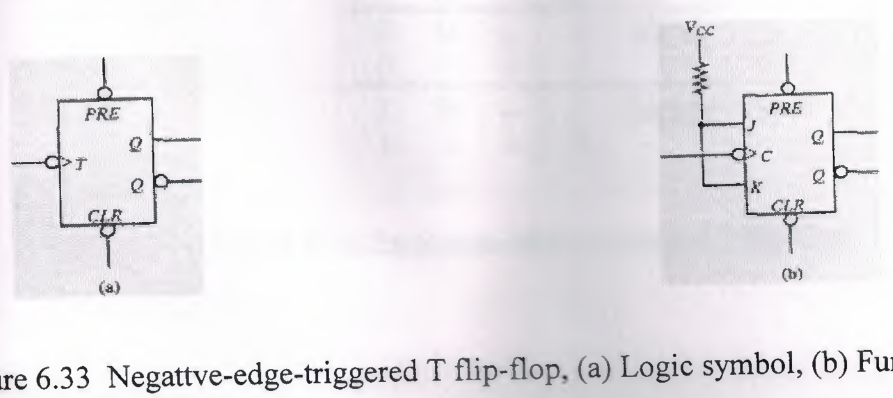


Figure 6.33 Negattve-edge-triggered T flip-flop, (a) Logic symbol, (b) Functional equivalent.

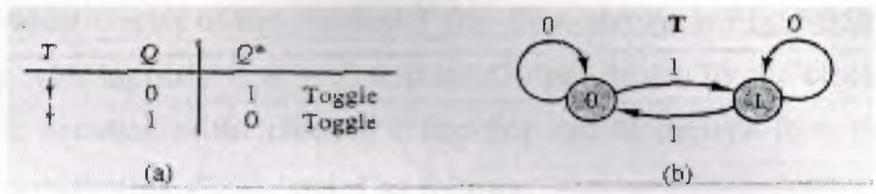


Figure 6.34 Edge-triggered T flip-flop characteristics, (a) Excitation table, (b) State diagram.

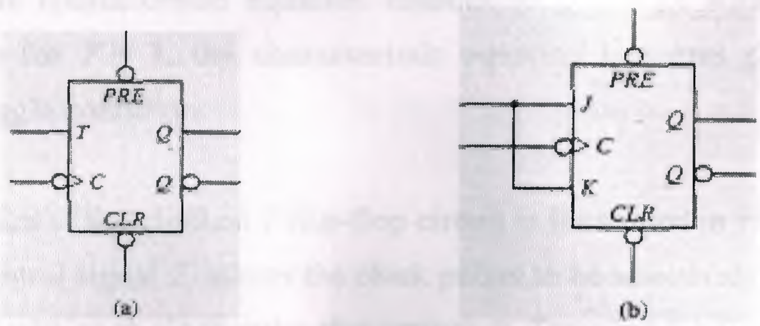


Figure 6.35 Clocked T flip-flop, (a) Logic symbol, (b) Functional equivalent.

Clocked T Flip-flops

Some versions of the T flip-flop operate under ciock pulse control, as illustrated in Fig. 6.35a. In this case, the flip-flop toggles if $T = I$ when the clock makes a high-to-low transition and holds its present state if $T = 0$ when the flip-flop is clocked. The operation of a clocked T flip-flop is described by the excitation table given in Fig. 6.36.

T	Q	C	Q^*	
0	0	↓	0	Hold
0	1	↓	1	
1	0	↓	1	Toggle
1	1	↓	0	

Figure 6.36 Excitation tabie of clocked T flip-flop.

The equivalent circuit of the clocked T flip-flop, shown in Fig. 6.35b, is simply a JK flip-flop with inputs $J = K = T$, and its C input driven by the clock signal. The characteristic equation of the clocked T flip-flop can be derived from that of the JK flip-flop by substituting T for J and K as follows:

$$Q^{*} = JQ + KQ$$
$$= TQ + TQ$$

For $T = 0$, the characteristic equation reduces to $Q'' = Q$, which is the hold condition, while for $T = 1$, the characteristic equation becomes $Q'' = Q$, which represents the toggle condition.

Another variation of the clocked T flip-flop circuit is illustrated in Fig. 6.37a. In this circuit the control signal T_c allows the clock pulses to be selectively applied to the input terminal T, with each clock pulse that arrives at T causing the flip-flop to change state. A detailed timing diagram is offered in Fig. 6.37b.

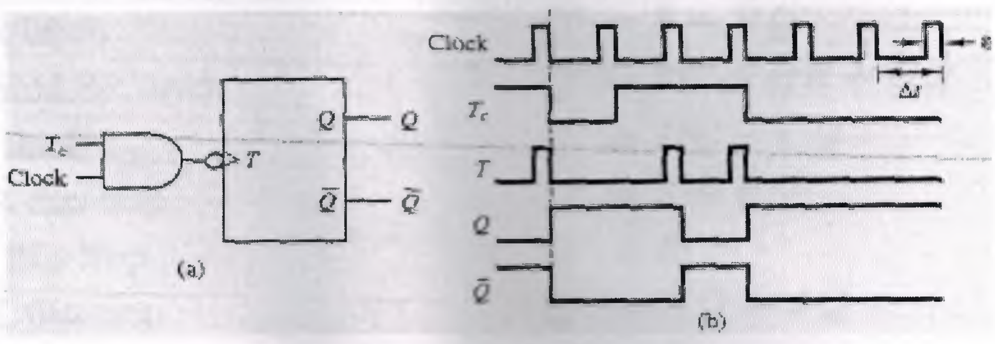


Figure:6.37

Figure 6.37 The clocked T flip-flop, (a) Logic symbol, (ta) Timing diagram.

6.7 Latch and Flip-flop Summary

In the previous sections we have examined latch and flip-flop memory devices. Latch circuits are used primarily in situations where data are to be captured from signal lines and stored. The simple SR latch captures random pulses on its S and R inputs, since each pulse sets or resets the state of the latch. The gated SR and D latches change state only during times in which the latch is enabled. Therefore, gated latches are used to capture data that arrive and stabilize before the end of an enable pulse.

Flip-flops are used primarily for sequential circuit designs in which all state changes are to be synchronized to transitions of a clock signal. Most of these circuits utilize JK or D flip-flops, depending on which requires the smallest number of gates to derive the excitation inputs for each given design. SR flip-flops are rarely used, since JK flip-flops provide the same operating modes and add the additional toggle mode, eliminating the problem of having to avoid the condition $S = R — 1$. T flip-flops are used mainly in counter designs.

Table 6.3 summarizes the characteristic equations of the different latch and flip-flop devices discussed in this chapter. Since pulse-triggered flip-flops

TABLE 6.3 SUMMARY OF LATCH AND FLIP-FLOP CHARACTERISTICS

Device	Characteristic Equation
SR latch	$Q^* = S + \bar{R}Q$
Gated SR latch	$Q^* = SC + \bar{Q}R + \bar{C}Q$
D latch	$Q^* = DC + \bar{C}Q$
SR flip-flop	$Q^* = S + \bar{R}Q$
D flip-flop	$Q^* = D$
JK flip-flop	$Q^* = \bar{K}Q + J\bar{Q}$
T flip-flop (edge-triggered)	$Q^* = \bar{Q}$
T flip-flop (clocked)	$Q^* = T\bar{Q} + \bar{T}Q$

have the same characteristic equation as corresponding edge-triggered flip-flops, there is a single entry in the table for the D and JK flip-flops. We will use these characteristic equations in later chapters as we analyze and design various sequential circuits. The reader is referred to [2] through [5] for further information on the design and characteristics of latches and flip-flops.

CHAPTER: 7

7. THE CIRCUIT OF ALARM SYSTEMS AND PICTURES

7.1 Low Power Alarm:

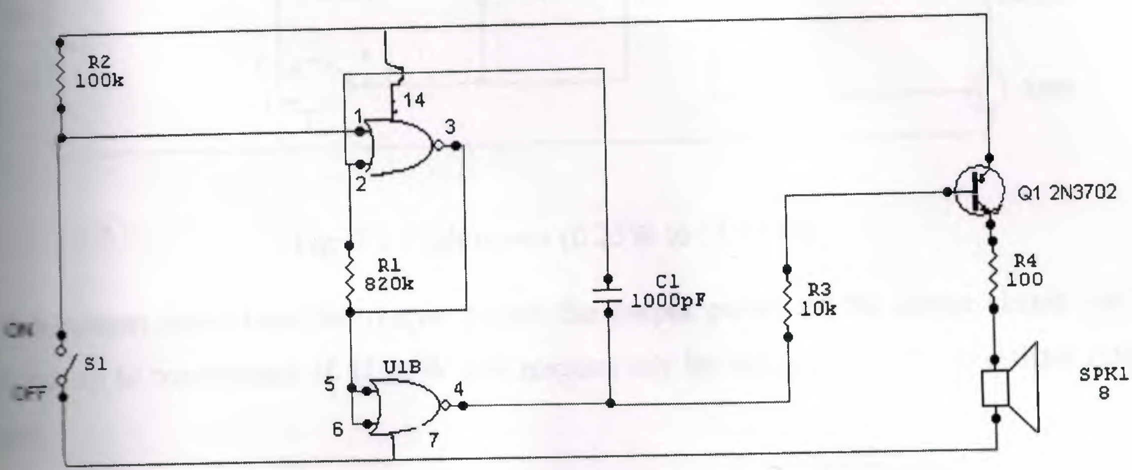


Fig :7.1 Low power 800Hz alarm generator

Fig 1 shows how the i.c can be used as the basics of a low power fixed frequency (monotone) alarm call generator.here , two of the Gates of the i.c are wired as an 800Hz gated estable multivibrator with its output fed to speaker via limiting resistor Rx and booster transistor Q1.The speaker and Rx should have a total resistance of about 100 Ohm.With switch S1 open the generator is inoperative , and the circuit consumes a standby current of only 1uA or so.With S1 closed the generator is operative and drives the speaker .Output power depends on the supply voltage and speaker Rx values used but approximates 160mW when a 100 Ohm speaker (Rx=zero) is used with a 9V supply.

7.2 High Power Alarm:

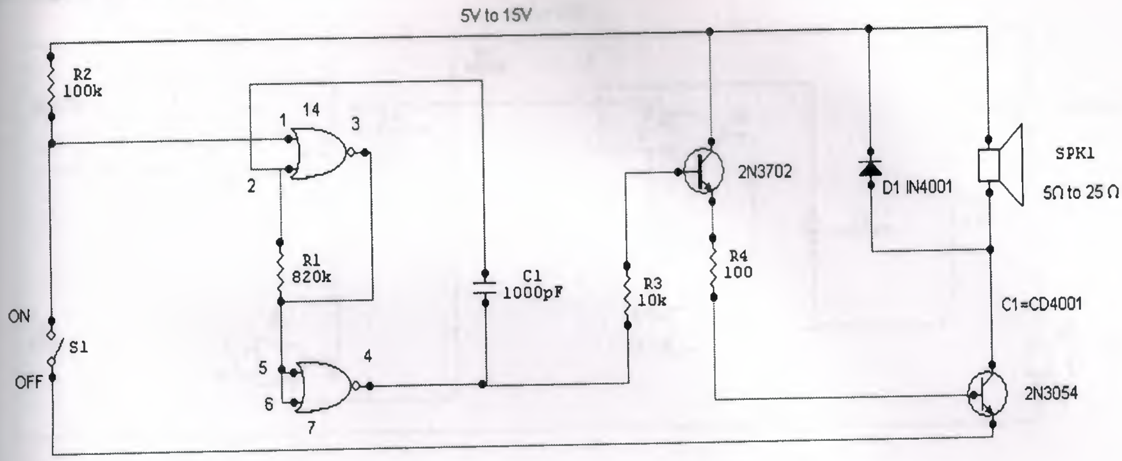


Fig: 7.2 High power (0.25W to 11.25W).

In this system show how the output power the output power of the above circuit can be boosted up to maximums of 11.25W and respectively by using alternative transistor output stages.

7.3 Pulsed Tone Alarm:

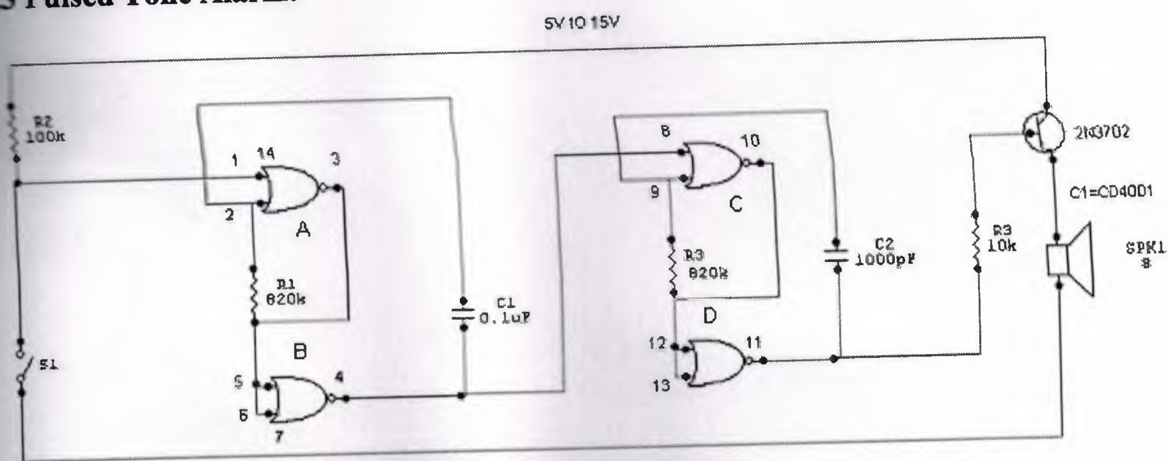


Fig :7.3 Pulsed tone alarm generator

Fibg 2 shows the circuit of a low power pulsed tone alarm generator.Here . 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 6Hz.

One Shot Alarm:

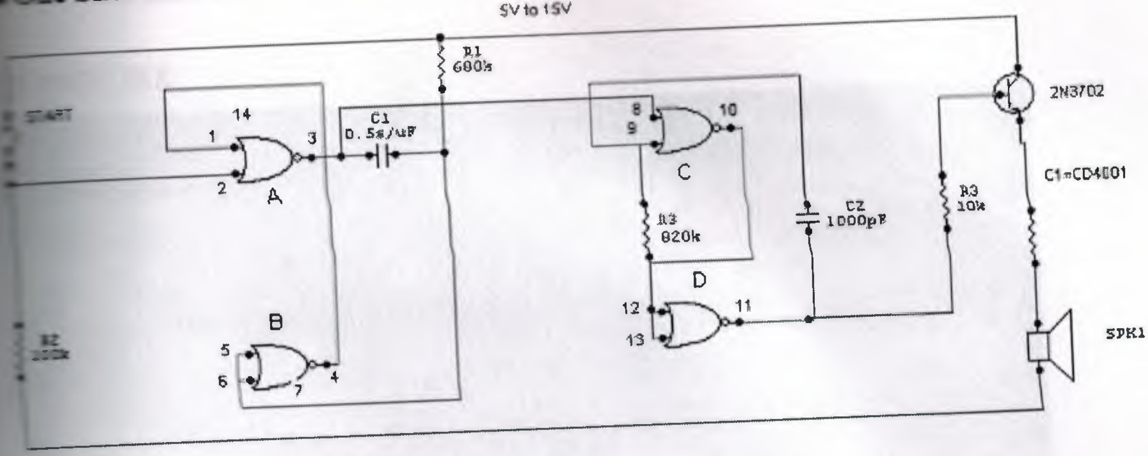
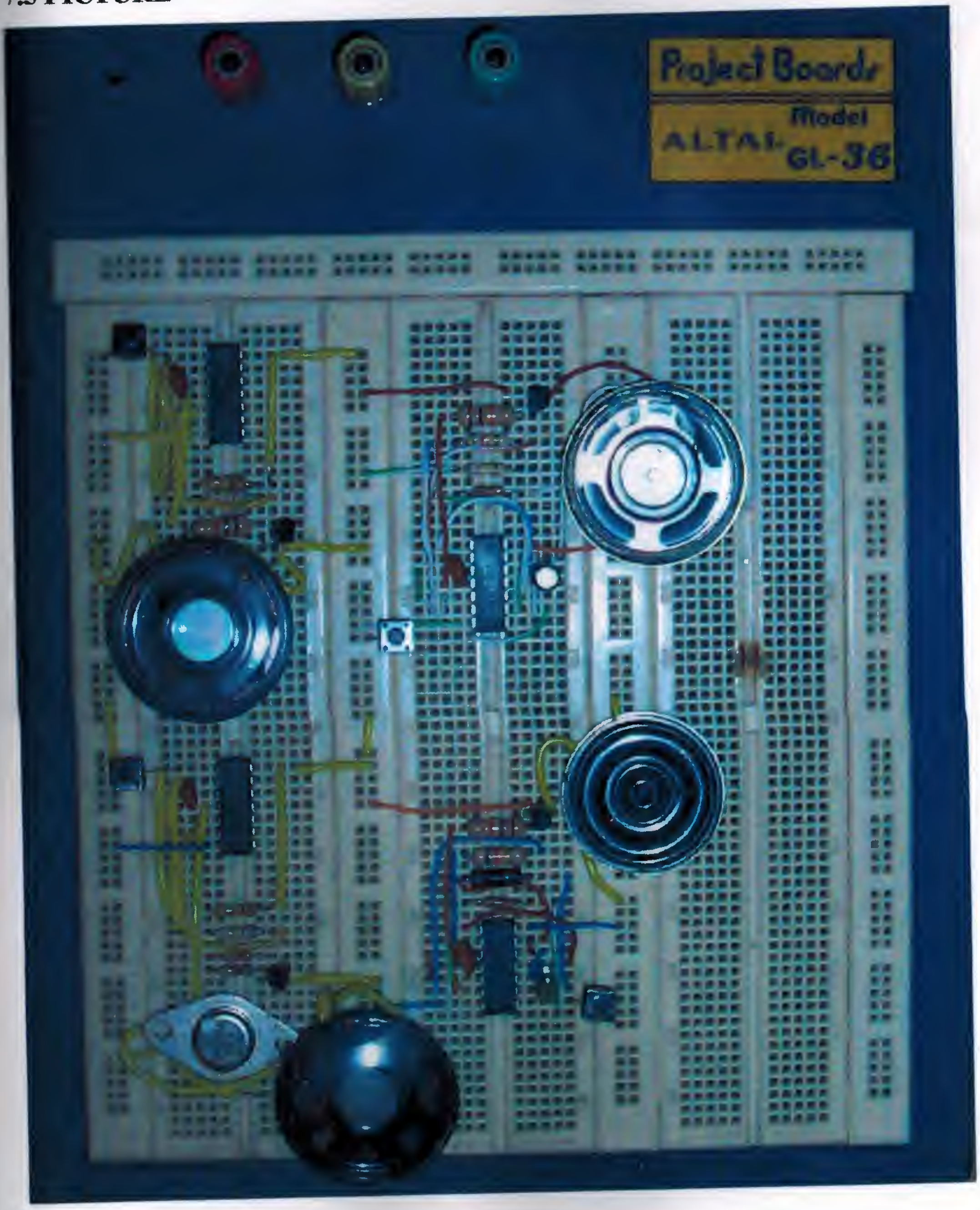
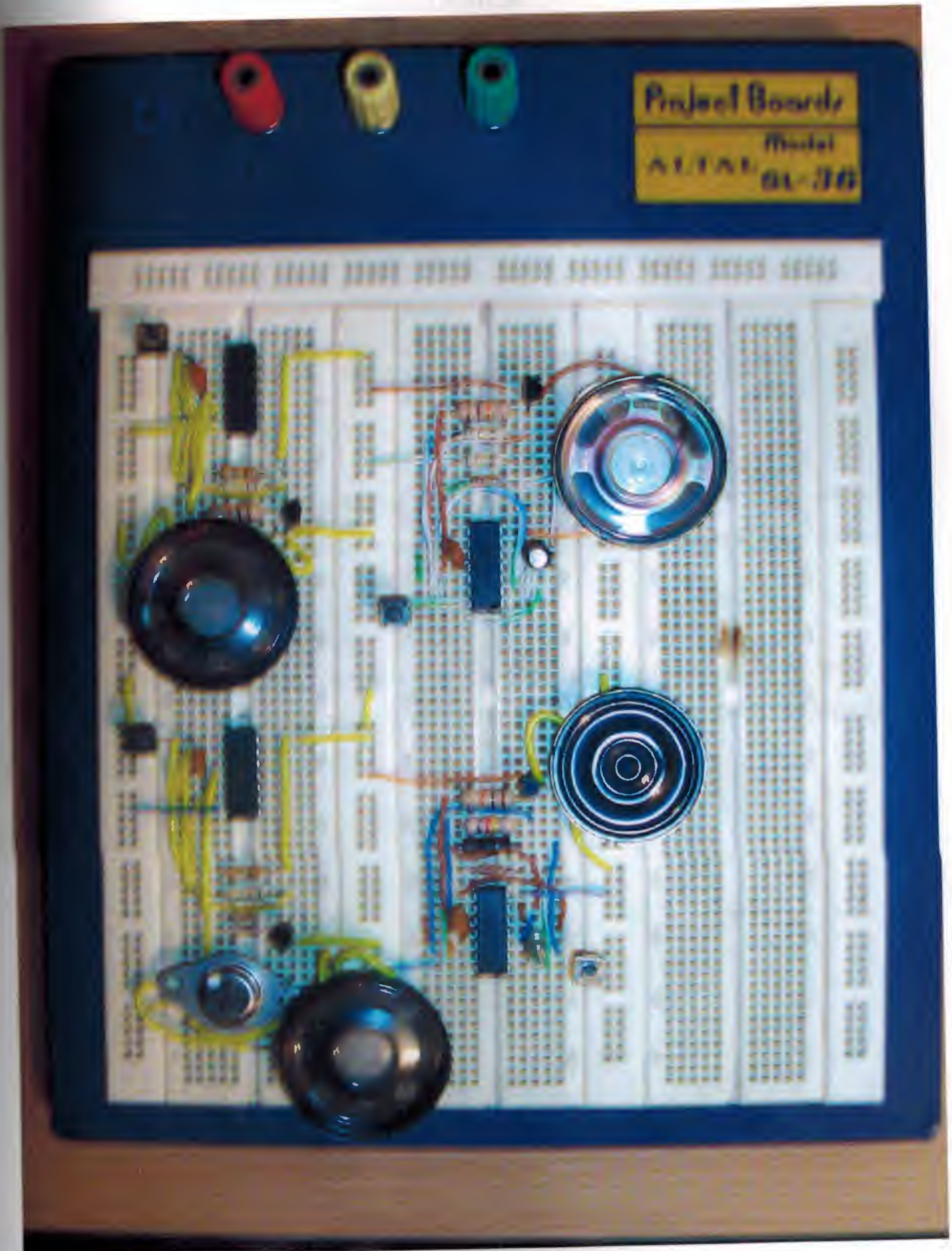


Fig :7.4 One –shot alarm generator

In the fig :4 circuit gates A and B are wired as a gated monostable or one-shot multivibrator which is triggered by momentarily closing switch S1.Consequently , the circuit action is such that the alarm is normally off , but turns on as soon as S1 momentarily closes period is roughly equal to 0.5 seconds per uF of C1 value.C1 must have a leakage resistance less than one megohm.

7.5 PICTURE




Project Boards
Model
ALTAI
SL-36

CONCLUSION

The aim of my project to make alarm systems.With these systems is help the people in life for the warning.

On the alarm system we learned how we can used the electrical component with electricity and we understood these electrical component also in real life beneficial for electric devices and these devices aid to us in our life.

In my working I used transistor , resistor , diodes, capacitors and used these materials and make alarm systems and it is working.

While working in the topic of electrical and electronic components. Everyone, technicians or engineers should be very careful because small mistakes can cause big damages in application.

I hope in the future we doing many systems like these circuits but on different types with the product of electric and electronics. I believe that people will develop this coverts in the time , fortunetely become one of them.

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