Basic Electronics Notes

information communication technology (Nairobi Institute of Business Studies)

(NAIROBI CAMPUS)

COMPUTER SCIENCES DEPARTMENT

CERTIFICATE IN ICT MODULE I

UNIT NAME: BASIC ELECTRONICS

COURSE OBJECTIVES

At the end of this course students will be able to:

1. **Understand basic electronics concepts.**
2. **Design electronic circuits**
3. **Minimize digital circuits using Boolean and karnaugh maps**

COURSE SCHEDULE.

NO	TOPIC	SUBTOPICS
1	INTRODUCTION TO ELECTRICAL CIRCUITS	• Basic electrical quantities and their units
2	SIMPLE D.C. CIRCUITS	• d.c. circuit diagrams, resistors in series, resistors in parallel, serial-parallel connection, • resistivity of metal conductors
3	SIMPLE A.C. CIRCUITS	• series and parallel circuits • Terms used in A.C. circuits: cycle, periodic time, frequency, peak value, amplitude • Effects of passive elements on voltage and current
		•
4	ELECTRONIC COMPONENTS	• Resistor, capacitor, diode, inductor • Characteristics of electronic components

		• Application of electronic components
5	SEMI-CONDUCTOR THEORY	• Structure of an atom, electrons in conductors and semi-conductors • Semi-conductor materials: silicon and Germanium • Formation of P-type and N-type materials, operation of PNP and NPN transistors, forward and reverse biasing of junction diodes
6	MEMORIES	• Computer memory types • Semiconductor memories: RAM,ROM, Flash memory • Magnetic memories: magnetic drum, magnetic core, magnetic tapes, magnetic disks • Optical storage: magnetic optic memory, holographic memory
7	NUMBER SYSTEMS	• Decimal numbers, binary numbers, octal numbers, hexadecimal numbers • Representation of decimal number to binary, octal and hexadecimal • Representation of binary number to octal, decimal and hexadecimal • Conversion of octal numbers to other number systems • Conversion of hexadecimal numbers to other number systems • Binary arithmetic: addition, subtraction, multiplication and division
8	BINARY CODES	• 8421 BCD,Excess-3,Gray code, Importance of binary codes

		• **Representation of decimal numbers in BCD** • **BCD arithmetic: addition,subtraction,multiplication,division**
9	**LOGIC GATES AND BOOLEAN ALGEBRA**	• **AND Gate, OR Gate, NAND Gate, NOR Gate, NOT Gate (Inverter), Exclusive OR, Exclusive NOR, Laws of Boolean algebra.** • **Minimization of logic expressions: Boolean algebra,Karnaugh maps**
10	**EMERGING TRENDS**	• **Challenges of emerging trends, coping with emerging trends.**

ASSESSMENTS

1. **Continuous assessment test (CAT 1) - 15 %**
2. **Continuous assessment test (CAT 2) - 15 %**
3. **Mock Exams- 70%**
4. **Assignments/Group work**
5. **End of Course final exams- 100%**
6. **All the tests and assignments are compulsory i.e. must be done by all students.**

REFERENCES

1. **DC green digital electronics.**

Table of Contents

CHAPTER 1

INTRODUCTION TO ELECTRICAL CIRCUITS

Introduction to Electrical circuits

It is the study of flow of electrons in electrical circuits.

Electronics is a branch of science that deals with the study of flow and control of electrons and study of their behavior and effects in vacuums, gases and semi-conductors and in devices using such electrons.

Application of Electronics

1. Entertainment and communications
   Electronic gadgets/devices are widely used
2. Medical services
   Electronic systems are widely used by doctors in the diagnosis and treatment of various diseases.
3. Industrial application
   Electronic circuits are used in industrial applications such as control of weight quality and moisture content of material.

Basic Electrical Quantities and Their Units

Quantity	**Symbol**	**Unit**	**Unit symbol**
Voltage	V	Volt	V
Resistance	R	Ohm	Ω
Current	I	Ampere	A
Capacitance	C	Farad	F
Charge	Q	Coulombs	C
Impendence	Z	Ohm	Ω
Inductance	L	Henry	H
Power	P	Watt	W

VOLTAGE

Electrical voltage is defined as electrical potential difference between two points of an electric field.

Volt is the electrical unit of voltage

Voltage series

The total voltage of several sources or voltage drops in series is their sum.

$V_T = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots V_n$

Where V_T = voltage drop in volts (total voltage)

V_1, V_2…………V_n voltage sources

Voltage is parallel

Voltage source/voltage drops in parallel have equal voltage

I.e. $V_T= V_1 = V_2 = V_3 = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ V_n$

Where V_T= total voltage/equivalent voltage

Voltage calculations with Ohm's law

Ohm's law

Current through a conductor between two points is directly proportional to the potential difference or voltages across the two points and inversely proportional to the resistance between them.

The potential difference (voltage) across a conductor is proportional to the current through it.

Directly proportional means both variables increases and decreases at the same time.

Inversely proportion means one variable increases while the other decreases.

Ohm's law is given by:

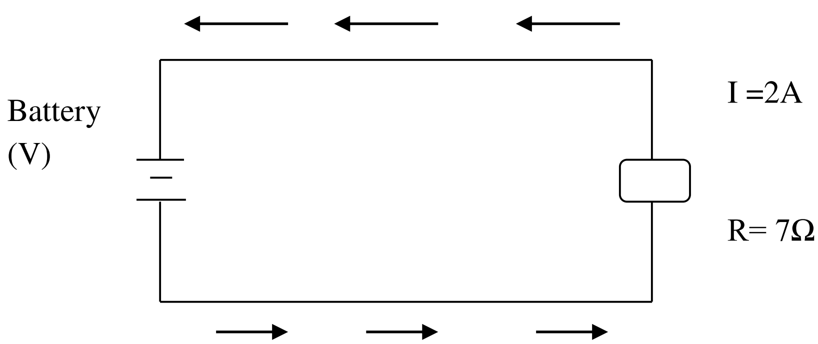
$V= IR$

Or $E = IR$

Where, V= voltage

I= Electrical current

R= Resistance in Ohms



The amount of voltage provided by the battery is:

$$V = IR$$

$$= 2 \times 7 = 14\ V$$

Examples

What is the potential difference across a resistor of 1000 Ω when current of 0.25 A flows through it?

$$V = IR$$

$$= 0.25 \times 100 = 25V$$

Materials that obey ohm's law are called ohmic because the potential differences across it vary linearly with the current.

Electrical Resistance

Resistance is an electrical quantity that measures how a device or material reduces the electric current flowing through it.

SI unit of electrical resistance is the ohm (Ω). It is designated a Greek capital letter Omega (Ω).

Insulators have high value of electrical resistance. In order to express resistance of these materials much bigger units are used such as: mega ohm (M Ω) and kilo ohm (K Ω)

1 Ω = 0.001 K Ω

1 Ω = 0.000001 M Ω

Smaller units of resistance are: milliohm (mΩ) and micro ohm (μΩ)

1 Ω = 1, 000, mΩ

1 Ω = 1000 000 μΩ

Factors Affecting Electrical Resistance

1. Nature of material
   Different materials have different numbers of free electrons available for producing current.

2. Length of material
   Resistance of any conductor is directly proportional to its length
3. Cross-sectional area of material
   Resistance of any conductor is inversely proportional to its cross-sectional area of a conductor. Decreases its resistance and vice-versa.
4. Temperature of material
   Resistance of any conductor increases with increase in temperature and vice-versa.

$$\text{Resistance (R)} = \frac{\text{length (L)}}{\text{Cross-sectional area (A)}}$$

$R \ \alpha \ \frac{L}{A}$

$R = \frac{\rho L}{A}$

ρ = resistivity

Example

A potential difference of I0V is connected to a uniform resistance wire of length 3 meters and a cross-sectional area of $0.09m^2$ with 0.01A current flowing in the wire. Determine the resistivity of the material.

From $R = \frac{\rho L}{A}$

R= V/1 = 10/0.01 = 1000 Ω

1000 Ω = ρ x3/0.09

$\rho = 1000 \text{ x } \frac{0.03}{3}$

= 30

Conductance

It is the degree to which an object conducts electricity, calculated as the ratio of the current which flows to the potential difference present. This is the reciprocal of the resistance, and is measured in Siemens.

$G = \frac{I}{V}$ or $G = \frac{1}{R}$ and $R = \frac{I}{G}$ OR $R = \frac{V}{R}$

Example

A voltage (V) of 5 volts generates a current (I) of 0.30 amps in a particular length of wire. Calculate its conductance. (Answer = 0.06 Siemens)

Electric Power

It is the rate of energy consumption in an electric circuit. Electric power is the rate at which electric energy is transferred. SI unit of the power is watts (W)

$P = I^2R$

$P = IV$

Where,

P = Electric power in watts

I = current in watts

R = resistance in Ohms

An ac voltage of 4V is connected to a 100 Ω resistance R. calculate the power in watts.

$P = I^2R$ $I = V/R = 4/100 = 0.04$

$P = 0.04^2\ (100)$

$= 0.16W$

Also from $P = IV$

$P = 0.04 \times 4 = 0.16W$

Electrical current

Current is a measure of amount of charge moving past a given point per unit time.

Electric current is designated by the symbol I; the SI unit of electrical current is ampere (A)

In electrical circuits, current is expressed in smaller units called:

Milliamperes (mA)

Microamperes (μA)

1A = 1, 000,000 μA

1A = 1000 mA

Example

2 mA is equivalent to how many amperes?

Solution:

1A = 1000mA

? = 2mA

2/1000 x 1 = 0.002A

A current of 4mA flows through a resistor (R) when a potential difference (pd) of 16v is connected. Determine the value of resistance.

1a = 1000 mA

? = 4mA

4/1000 x 1 = 0.004A

V = IR R = $\frac{V}{I} = \frac{16}{0.004}$ = 4000Ω

Electrical charge

Tiny pieces of matter can sometimes attract or repel each other. Matter that behaves in this way is said to possess electrical charge.

Amount of charge is measured in coulombs (C). Symbol used to represent amount of charge is Q

Types of electric charge

1. Positive (+ve) charge: they have more protons than electrons
2. Negative (-ve) charge: they have more electrons than protons

Materials that contain equal number of positive and negative is said to be neutral. Charge in motion represents current.

Capacitance

It is the ability of a material or surface to store electrical charge.

A capacitor is a device formed with two or more separated conductors that store charge and electric energy.

SI unit of capacitance is farad (F). Charge Q on a capacitor is directly proportional to the potential difference across the capacitor.

Q = CV

Where,

Q = charge measured in Columbus

C = capacitance measured in farads

V = voltage measured in volts

Farad is a large unit such that capacitance is usually measured in smaller units such as micro farads (μF), pico farads (pf), nano farads (nf) are used.

Factors affecting capacitance of a capacitor

1. Surface area of the metal plate
2. Thickness of the di-electric between the plates (distance between the plates)
3. Type of dielectric used.

Inductance

It is the ability to store energy in a magnetic field and coils are a very common way to create inductance.

An inductor is a passive electronic component that stores energy in the form of magnetic fields.

An indicator consists of a wire loop/coil

Factors affecting inductance

1. Number of turns in the coil
2. Radius of the coil
3. Type of material around which the point is wound (type of core material)

Electromotive force (EMF)

It is a measure of energy (voltage) that causes current passing through a circuit. It can also be defined as voltage developed by any source of electrical energy such as a battery.

Magnetic Flux

It is the measure of magnetic field passing through a given surface such as conducting coil.

Flux lines

These are magnetic lines of force.

Current through a conductor produces magnetic field around it.

Strength of this field depends upon value of current passing through a conductor.

If a changing flux line is linked with a coil over a conductor, an emf will be induced in it.

Factors affecting inductance

1. Number of wire wraps/turns in the coil
   All other factors being equal, a greater number of turns of wire in coil result in greater inductance.

Fewer turns of wires in a coil result in less inductance. More turns of wire means that the coil will generate a better amount of magnetic field force for a given amount of coil.

2. Coil area: all other factors being equal, greater coil area results in greater inductance and less area results in less inductance.

Passive electronic components

These are components that cannot increase the strength of a signal i.e. by themselves they cannot produce a gain in signal strength.

Passive components are not capable of producing wave forms for themselves nor when connected with other passive components. They include: resistors, capacitors, diodes and inductors.

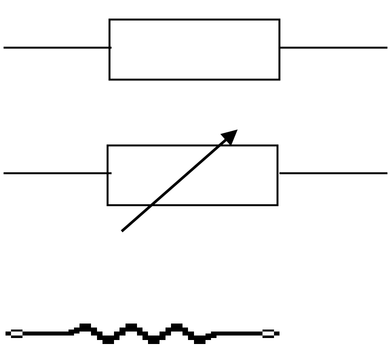
Active components

These are those electronics components that require an energy source to operate e.g. transistors which are integrated circuits.

Resistors

These are passive electronic components that are specially designed to have controlled amounts of resistance.

Resistor symbols



Uses of resistors

1. Limiting current: they limit the amount of current in part of a circuit. Too much current can destroy many sensitive electronic components such as transistors, light emitting diode

(LED) and integrated circuits (IC's). by putting a resistor at the input to a sensitive part, current that reaches the point is controlled.

2. Reducing and controlling voltage
   Resistors can also be used to reduce the voltage supplied to different parts of a circuit.

Example

If you have a 9V power supply, but you need to provide 5V to power a particular integrated circuit, then you can set up a circuit to divide the voltage in a way that provides 5V at the output.

You can use the output voltage volt of the voltage dividers as the supply voltage for the integrated circuit.

Types of resistors

1. **Fixed resistors**

These resistors supply a constant factor determined resistance but the actual resistance of any given resistor may vary up/down from its normal value by some percentage known as the resistance tolerance.

Categories of fixed resistors

a. High precision resistors
   They come with just 1% of their nominal values
b. Standard precision resistors
   They can vary from 2% to 20% of their nominal value.
   Markings on the resistor packages tell you just how far off the actual resistance may be, for instance $\pm 2\%, \pm 5\%$ ± 10 or $\pm 20\%$

2. **Variable resistors**

A variable resistor or a potentiometer or a rheostat allows you to control, adjust the resistance from virtually 0Ω to a factory-determined maximum value.

A potentiometer is used to vary the amount of current supplied to that part of the circuit.

Resistor Color Coding

Color coding identifies the nominal Value and tolerance of most resistors. Other resistors have values stamped on them.

The color code starts near the edge of the one side of the resistor and consists of several stripes or bands of color.

Each color represents a number and the position of the band indicates how to use that number.

Standard-precision resistors use for color bands

The first three bands indicate the nominal value of the resistor and the forth indicates tolerance.

High precision resistors use five color bands.

The first four bands indicate the value and the fifth indicates the tolerance

Using a special decoder ring, you can decipher/identify the nominal value of a standard precision resistor as follows:

a. The first band gives you the first digit
b. The second band gives you the second digit
c. The third band gives you the multiples as a number of zeros except when it is gold or silver.
a. If the third band is gold, you multiply by 0.1
b. If the third band is silver, you multiply by 0.01s

You get the nominal value of the resistance by putting the first two digits together side by side and apply the multiples. If no forth band exists, you can assume the tolerance is $\pm 20\%$

Color	No	Tolerance
Black	0	$\pm 20\%$
Brown	1	$\pm 1\%$
Red	2	$\pm 2\%$
Orange	3	$\pm 3\%$
Yellow	4	$\pm 4\%$
Green	5	n/a
Blue	6	n/a
Violet	7	n/a
Grey	8	n/a
White	9	n/a
Gold	0.1	$\pm 5\%$
Silver	0.01	$\pm 10\%$

Examples

a. Red, red, yellow, gold

$AB \times 10^c \pm D\%$

$= 22 \times 10^4 \pm 5\%$

$= 220{,}000\Omega \ \pm 5\%$

b. Orange, blue, green, gold

$AB \times 10^c \pm 0\%$

$36 \times 10^5 \pm 5\%$

$= 3, 600, 000\Omega \pm 5\%$ or $3.6 \times 10^6\Omega \pm 5\%$

Determine the color code of the following resistor

$2.4 \times 10^7 \ \Omega \pm 10\%$

24×10^6 -2 $\pm 10\%$

2 = red, 4 = yellow, 6 = blue

10% silver

= red, yellow, blue, silver

Exercise

The following is an outline of the colors of two resistors. Determine the resistance in each case

i) White, red, yellow, silver
ii) Yellow, violet, brown gold
iii) Orange, white, gold, silver

Determine the color code of the following resistor

$5.3 \times 10^{10} \pm 5\%$

CHAPTER 2

SIMPLE D.C. CIRCUITS

Circuit diagrams

A circuit consists of a number of components connected together in such a way as to carry out a specific task.

A task must have a source of electrical power. Most electronic circuits make use of very low power and can be operated from small DC supplies.

Types of Circuits

Series circuits

In series, all the components are connected one after the other in the circuit.

Parallel circuit

In parallel circuit, components are connected in different branches of the electrical circuit.

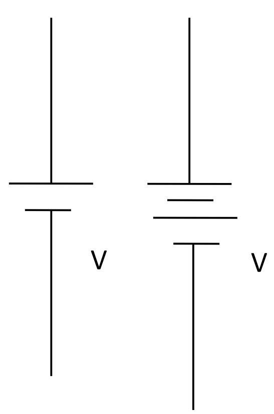
Types of current

Direct current (DC)

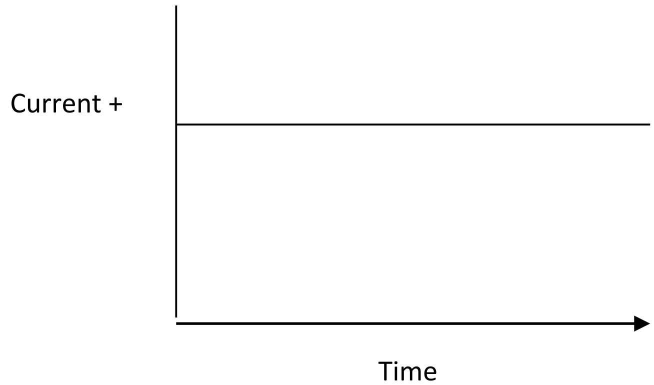
It moves in one direction from positive to the negative

It has a uniform direction flow and amount of voltage of electricity.

Symbols used in diagrams for batteries and DC power supply.



Illustrations of DC wave form



CHAPTER 3

SIMPLE A.C. CIRCUITS

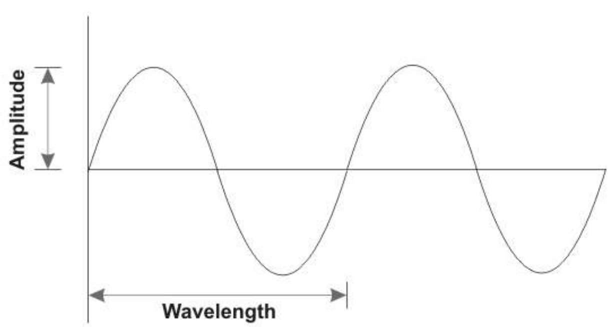
Alternating Current (AC

Unlike direct current (DC) which moves in one direction, alternating current moves in both directions.

AC is voltage which changes its polarity at regular intervals of time.

Current flaws first in one direction and then in the opposite direction during the second cycles.

AC current wave form is sinusoidal wave



Terminologies used in AC circuits

a. Cycle

It is one complete set of positive and negative values of alternating current

b. Periodic time/period

   It is the time taken by an alternating current to complete one cycle and it is denoted by T Periodic time is the reciprocal of the number of cycles/ the inverse of the frequency e.g. if AC makes 50 cycles in 1 second, then its periodic time is 1/50 = 0.02 sec

c. Frequency

   This is the number of the waveforms per second made by an alternating current. Frequency is measured in hertz.

$$Hz = \frac{\text{F (number of cycles}}{Time\ in\ secs}$$

d. Amplitude

   This is the peak value of the wave form measured from zero to the maximum positive/the negative value of the AC voltage.

e. Peak to peak value
   It is the sum of positive and negative peak values.

f. Phase

   It is the fraction of time period which has elapsed/passed since an alternating current last passed a given reference point. The reference point is taken as the starting point itself.

Comparison of DC current and AC current

1. AC can easily be stepped up or down for transmission over long distances
2. AC machines are smaller than DC machines
3. The protective devices include fuses, circuit breakers in AC are simple than in DC circuits.
4. DC power can be stored unlike AC

CHAPTER 4

ELECTRONIC COMPONENTS

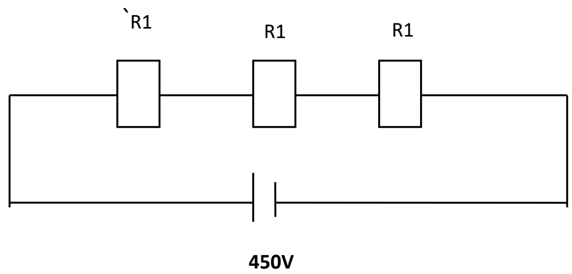
RESISTORS IN SERIES

To calculate the combined (total) resistance of resistors in series, you add up the values of individual resistors.

$R_T = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots\ldots\ldots R_N$

EXAMPLE

The figure below shows a simple electric circuit with three resistors of R_1 (50Ω), R_2 (40Ω), R_3 (60Ω) and a voltage of 450V



Determine the:

a. Total resistance
b. Current across the resistors
c. Voltage across each resistor

NB: Resistors in series receive similar currents

$R_T = R_1 + R_2 + R_3$

$= 50\Omega + 40\Omega + 60\Omega + 150\Omega$

To calculate voltage drop across each resistor, proceed as follows:

$I_T = \frac{V}{R} = \frac{450}{150} = 3A$

From V = IR,

R_1 V = IR, = 3 x 50 = 150V

R_2 V =IR_2 = 3 x 40 = 120 V

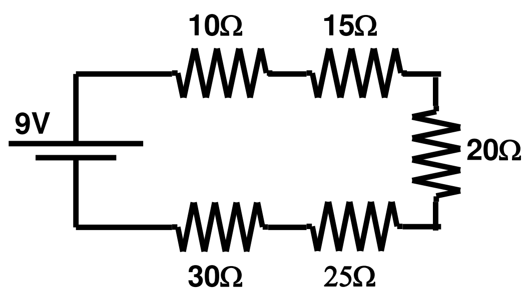
R_3 V = IR_3 = 3 x 60 = 180V

I.e. for resistors in parallel, current in same across all.

Exercises

Determine the:

a. Total resistance
b. Current across the resistors
c. Voltage across each resistor



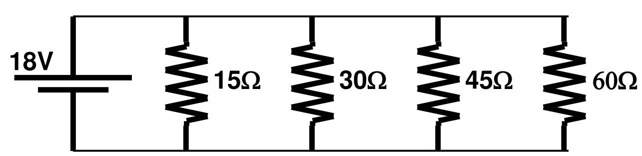
Resistors in Parallel

To calculate total resistance of resistors in parallel, the following formula is used:

$$R_T = \frac{1}{{}^1/_{R_1} + {}^1/_{R_2} + {}^1/_{R_3} + \cdots \ldots \ldots {}^1/_{R_N}}$$

Example

A circuit consists of 4 resistors R_1, R_2, R_3 and R_4 connected in parallel as shown in the figure below:



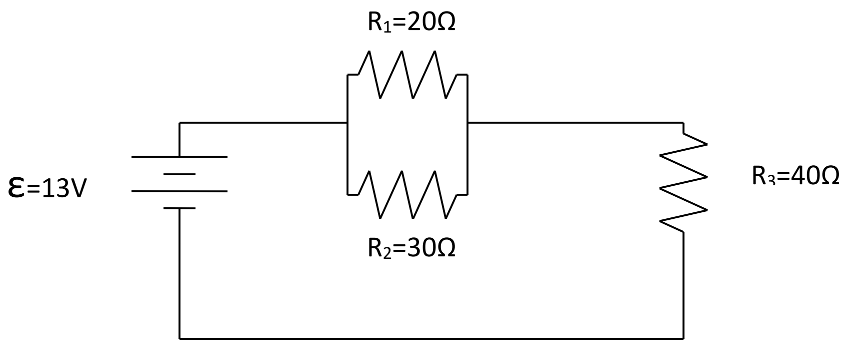
Determine:

i) Total resistance
ii) Current through each resistor

NB: For resistors in parallel, voltage is similar.

Exercise

Consider the circuit below, which is a combination of series and parallel:

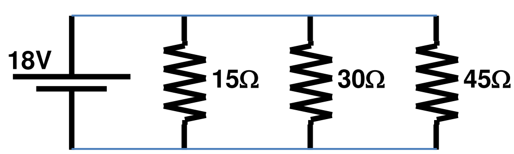


Find
(a) The total resistance,
(b) The total current in the circuit,
(c) The voltage across each resistor, and
(d) The current through each resistor.

Determine:

i) Total resistance

ii) Current through each resistor



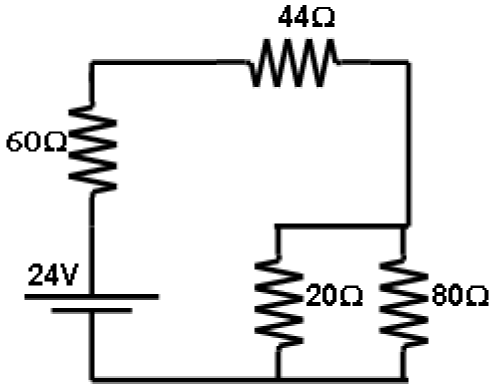
Resistors in series – parallel

In the circuit below determine

i) Total resistance.

ii) Current across each resistor

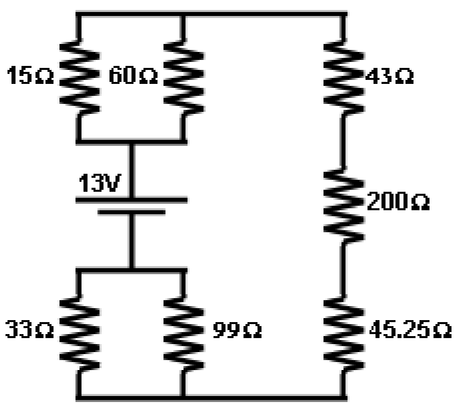
iii) Voltage drop across each resistor



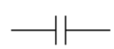
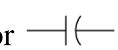
Exercise

In the circuit below determine

i) Total resistance.
ii) Current across each resistor
iii) Voltage drop across each resistor



CAPACITORS

A capacitor is used to store charge. The symbol of the capacitor is  or 

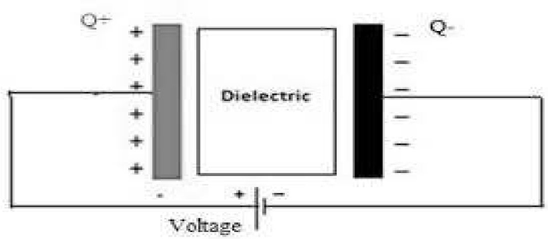
Capacitor construction and operation

A capacitor consists of two conductive plates with an insulative material between them.

The insulating material is commonly known as dielectric.

Current continues until the voltage charge across the capacitor plate becomes the same as the source voltage.

The positive plate of the capacitor and the positive terminal of the battery are also at equal positive potential.



Farad is a large unit such that capacitance is usually measured in smaller units such as the micro farad (μF), pico farad (pF) and nano farad (nF)

1F = 1000000 μF

1F = 1000000000 nF

1F = 1000000 pF

Capacitors in Parallel

Like resistors, capacitors can be joined together in two basic ways i.e. parallel and series.

A parallel connection results in bigger capacitor plate area which means they can hold more charge for the same voltage.

The formula for the total capacitance is a parallel circuit is $C_T = C_1 + C_2 + C_3 + \ldots\ldots\ldots C_N$

Parallel connected capacitors always have the same voltage drop (potential difference) across each of them.

The total potential difference (V) or equivalent capacitance is:

$V_T = V_1 = V_2 = V_3$

Charge on each capacitor is:

$Q = CV$

Where,

Q = charge measured in Columbus

C = capacitance measured in farads

V = voltage measured in volts

$Q_1 = C_1V_T$

$Q_2 = C_2V_T$

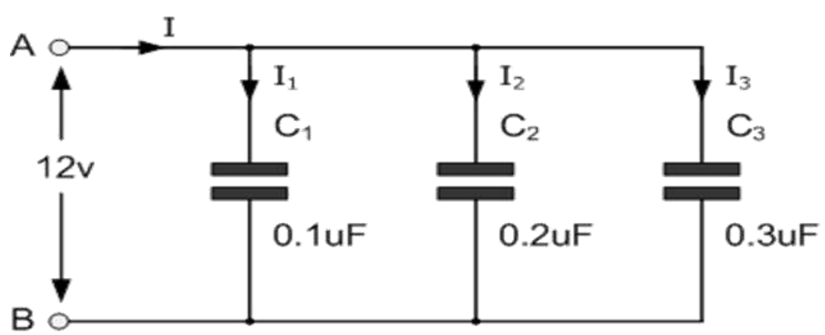
$Q_3 = C_3V_T$

Capacitors in the parallel do not have the same charge unless they have similar capacitances (C).

Examples

In the circuit shown below, calculate the:

a. Total capacitance
b. Charge on each capacitor



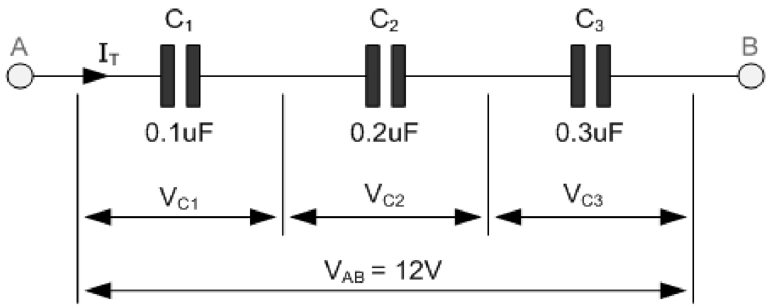
a) $C_T = 0.1 + 0.2 + 0.3 = 0.6\mu F$
b) From charge (Q) = CV
   $Q_1 = C_1V_T = 0.1 \times 10^{-6} \times 12 = 12X10^{-5}$
   $Q_2 = C_2V_T = 0.2 \times 10^{-6} \times 12 = 24X10^{-5}$
   $Q_3 = C_3V_T = 0.3 \times 10^{-6} \times 12 = 36X10^{-5}$

Capacitors in parallel receive same voltage $C_1=C_2=C_3=12V$

Capacitors in series

When capacitors are arranged in series, total capacitance is gotten as:

$$C_T = \frac{1}{{}^1/_{C_1} + {}^1/_{C_2} + {}^1/_{C_3} + \cdots \ldots \ldots . {}^1/_{C_N}}$$



Determine

i) Total capacitance
ii) Charge stored on each capacitor
iii) Voltage drop across each capacitor

Solution

$$C_T = \frac{1}{{}^{1}/_{0.1} + {}^{1}/_{0.2} + {}^{1}/_{0.3}}$$

$$C_T = \frac{1}{{}^{11}/_{0.6}}$$

$C_T = 1 \text{ x } \frac{0.6}{11} = 0.054\mu F$

Capacitors in series store the same charge

Q = CV

$Q = 0.054 \text{ x } 10^{-6} \text{ x } 12 = 0.648 \text{ x } 10^{-6}C$

Voltage drop on each capacitor

From $v = \frac{Q}{C}$

$C_1 = 0.648 \text{ x } 10^{-6}C / 0.1 \text{ X } 10^{-6} = 6.48V$

$C_2 = 0.648 \text{ x } 10^{-6}C / 0.2 \text{ X } 10^{-6} = 3.24V$

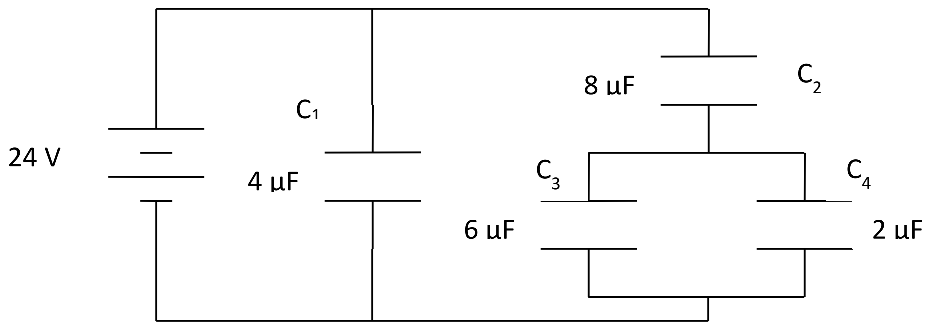
$C_2 = 0.648 \text{ x } 10^{-6}C / 0.3 \text{ X } 10^{-6} = 2.16V$

Capacitor in series store similar charge

Points to note

1. When capacitors are in parallel, to get total capacitance treat them as resistors in series and when capacitors are in series treat them as resistors in parallel.
2. Capacitors in series store similar charge but get different voltage drops.
3. Capacitors in parallel get similar voltage but store different charge

Capacitors in series-parallel



(a) Find the equivalent (total) capacitance of the capacitors above.
(b) Determine the total charge in the circuit.
(c) Determine the charge on each capacitor.
(d) Determine the electrical energy (voltage) stored each capacitor.

CHAPTER 5

SEMI-CONDUCTOR THEORY

Forms of Matter

In nature, matter is found in form of either elements or compounds.

Element

It is a part of matter which cannot be broken down any further by chemical means into simpler substances.

Elements contain similar atoms e.g. hydrogen, sodium, oxygen

Compound

It is a substance that consists of more than one element in a chemical combination e.g. water is formed when hydrogen and oxygen combine chemically.

The smallest part of a compound is called a molecule.

Atom and Molecule

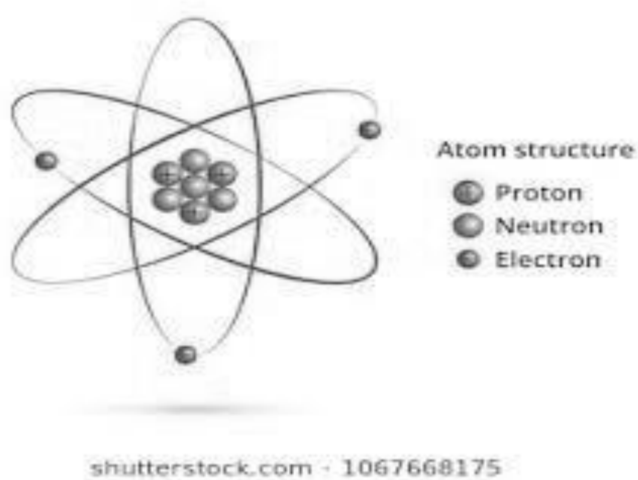
Atoms of most elements cannot exist by themselves hence; they generally combine to form molecules.

Molecules are composed of one or more atoms and are called monatomic, diatomic and triatomic.

Structure of an atom

An atom is made up of sub-atomic particles. The main one being the proton, electron and neutron.

The protons and the neutrons occupy the nucleus while the electrons move in orbits in high speed.



Electrons are negatively charged while protons are positively charged and neutrons are neutral.

Atoms have equal number of protons and electrons hence are overall neutral.

Atomic number refers to the number of protons an atom has. Electrons are arranged in shells.

Electrons in shells near the nucleus experience the highest attraction while those in outer shells experience least nuclear attraction.

Number of electrons in a shell is given by $2n^2$ where n is the shell number starting from the nucleus e.g. an atom with 2 shells $2n^2 = 2\,x1^2 = 2$

NB: The maximum number of electrons in the outer most shell of an atom cannot exceed 8. The maximum number of electrons in the shell just prior to the outermost shell cannot exceed 18.

The atomic number of copper is 29. Give its electronic distribution.

Bond formation

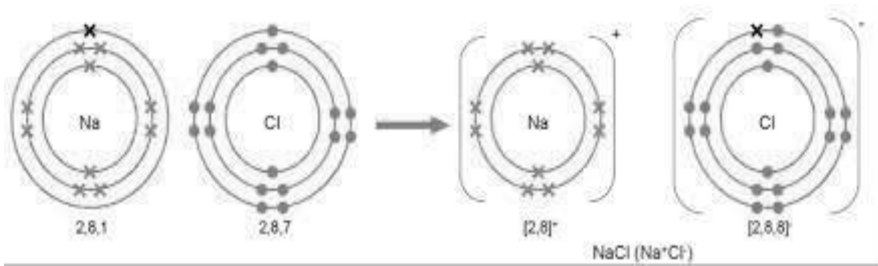
Most atoms do not have 8 electrons in the outermost shell. As such, atoms combine with other atoms to attain octet (8) or duplet (2) states which are stable states.

Bond is the force that holds atoms together.

Types of Bonds

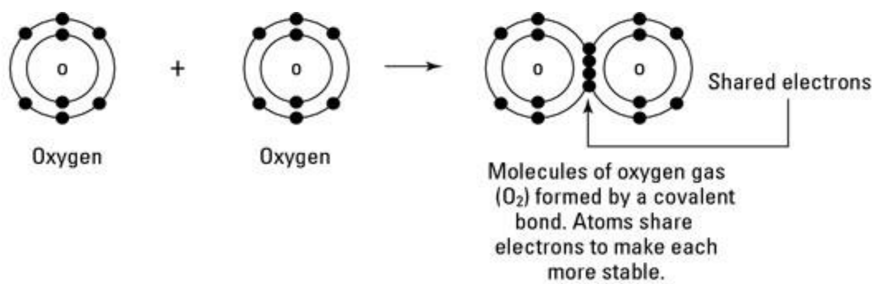
a. Ionic bond

This bond is formed when there is complete transfer of electron from one atom to another e.g. sodium chloride



b. Covalent bond

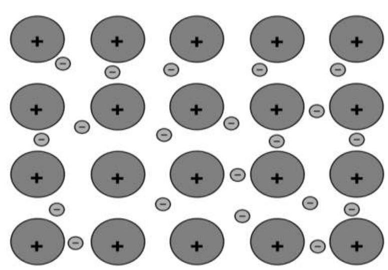
This bond occurs when atoms share electrons e.g. oxygen



c. Metallic bond

Metallic bonds refer to bond that holds metal atoms together.

In metals, when there is slight temperature increase, metal atoms lose electrons easily. This results in protons occupying center and electrons become free. Protons at the center are surrounded by electrons.

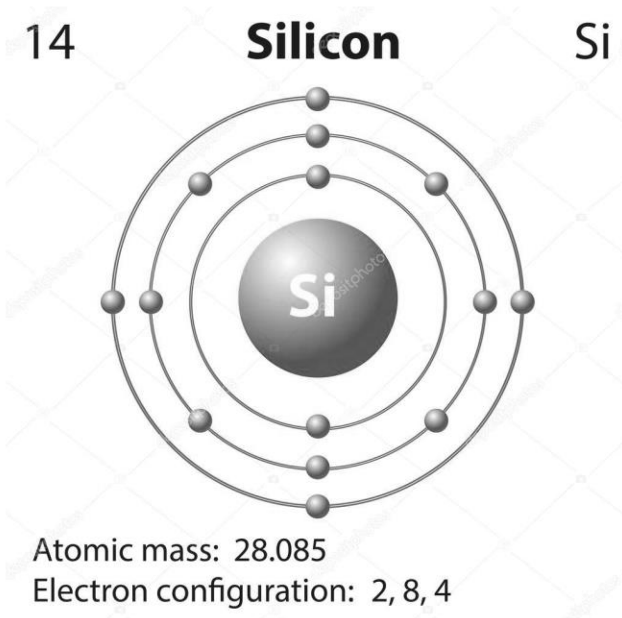


Conductors are able to transmit electric current since they posses free electrons (valence electrons)

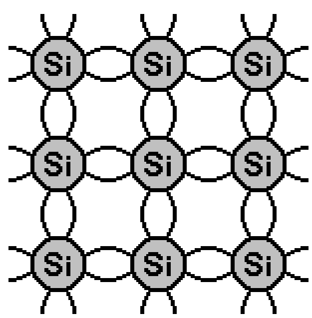
Semi-conductors

A semi-conductor is a material whose electrical properties lie in between those of insulators and good conductors examples of semi-conductors are silicon and germanium.

Silicon electronic configuration



Structure of pure silicon



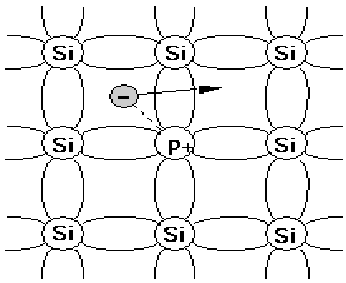
pure silicon does not conduction pure silicon, there is no free electron for conducting. However, it can conduct due to thermally excited electrons.

Intrinsic semi-conductors are semi-conductors which have not been doped (no impurity added).

Conduction in intrinsic semi-conductor is due to thermally excited electrons.

An N-type semi conductor is formed when a semi-conductor is doped with a pentavalent element e.g. phosphorus, a timony and arsenic.

A pentavalent atom has 5 electrons in outermost energy level and once introduced to a semi-conductor, a single electron is left free in each bond between the impurity and silicon



Thus, an N-type material is formed when a semi conductor is doped with a pentavalent material. Conduction in an N-type material is due to free electrons which are majority carriers.

P-types extrinsic semi-conductor is formed when a semi-conductor is doped with a trivalent (an element with three electrons in outer most energy shell). Trivalent impurities include: indium, aluminium, boron.

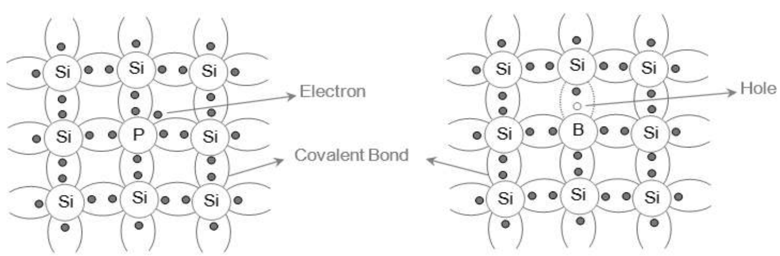


Figure 1 2-D Crystal Lattice of Silicon Doped with (a) Phosphorous (b) Boron

In P-type materials current is conducted by holes (positive charges)

In P-type material, the majority carriers are holes.

Majority and minority carriers

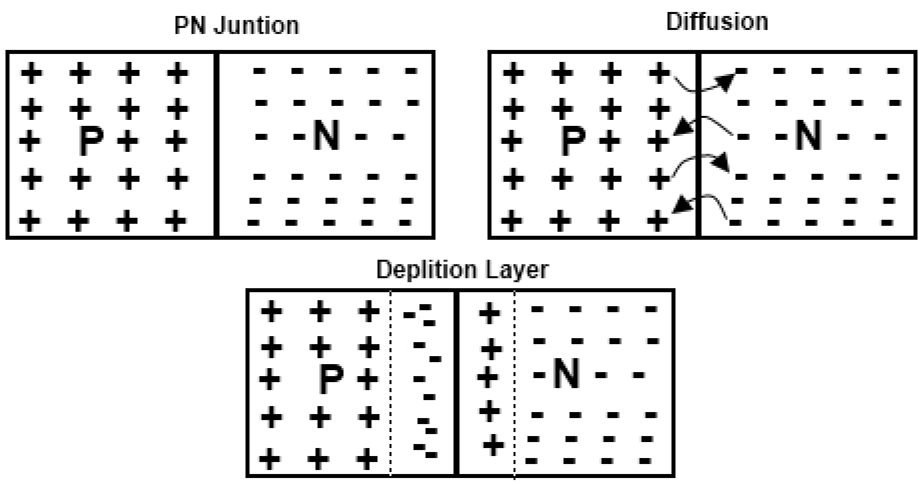
In an N-type material, majority carriers are electrons since the impurity used is pentavalent and introduces free electronics.

In an N-type material, holes are few and hence are minority carriers.

In P-type material, majority carriers are holes as the trivalent impurity results in deficiency of electrons. Electrons are few and are minority carriers.

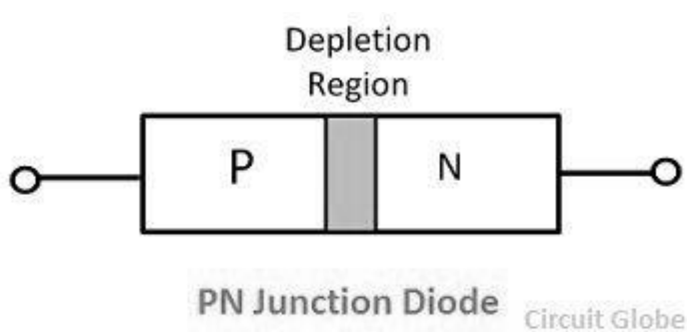
The P-N junction Diode

When a P-type material and N-type material are combined, a P-N junction diode is formed.

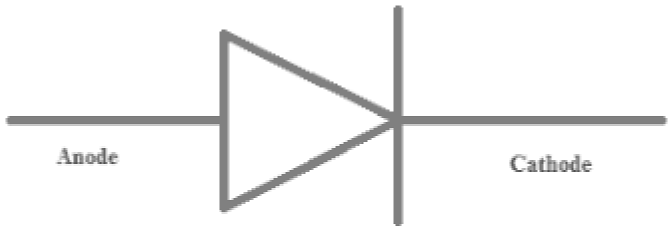


Once combined, + charge from P-material drift to the N-material and –ve charge from N-material drift to P-material and neutralize each other at the junction till no further movement of charge is possible. This creates a region with no charge called the depletion layer.

The P-N junction now behaves as a switch. When a P-N junction is connectedto an external voltage, it behaves as a switch.

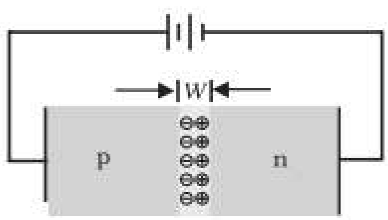


PN junction diode (Diode symbol/normal diode)



a. **Forward- biased P-N junction**

This is when the P-N junction can conduct an electric current.



p-n junction diode under forward bias.

When a P-N junction diode is connected to external voltage such that the positive terminal of the battery is connected to the P-material and the negative terminal of the battery is connected to the N-material, the depletion layer is closed.

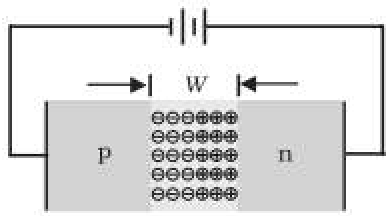
This is because, the holes (+ve) charge is P-material repel (+ve) current and move towrds N-material and electrons in N-material move towards P-material since like charges repel i.e. when a P-N junction is forward biased, the depletion layer is closed and current flows.

b. **Reverse-biased P-N Junction**

This is when the P-N junction is connected to external voltage since such that it cannot conduct current.

When the (+ve) terminal of the battery is connected to N-material and (-ve) terminal of battery is connected to P-material, since unlike charges attract, holes in P-material move towrds negative terminal of the battery and electrons in N-material move towards +ve terminal of the battery.

The depletion region widens and current cannot be conducted.



Silicon and germanium are the major semi-conductors used to manufacture the P-N junction diodes. For a silicon, P-N junction when forward biased it starts to conduct when an external voltage of about 0.6V is provided.

Germanium on the other hand starts to conduct when a voltage of 0.2V is applied.

When voltage exceeds 0.6 V for silicon, P-N junction diode current measures exponentially due to:

a. Zener effect
   Increased voltage results in breaking of covalent bonds of the material.
b. Avalanche effect
   Some charge carriers break covalent bonds.

Four accepter elements that would form a ptype material- Monday exe

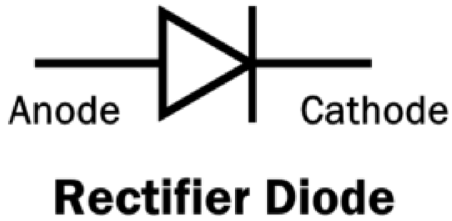
Acceptors are elements added in the doping process that have one less electron in the valence shell than the substrate semiconductor material. With one less electron, this dopant “accepts” or pulls away an electron from the base semiconductor.

An atom which substitutes for a regular atom of the material but has one less valence electron may be expected to be an acceptor atom. For example, atoms of boron, aluminum, gallium, or indium are acceptors.

Types of diodes

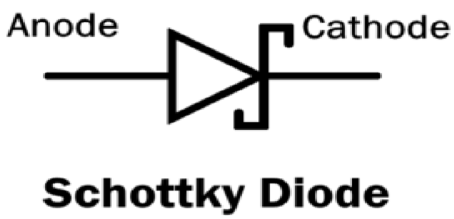
Rectifier Diode: used to convert alternating current to dc current

Symbol



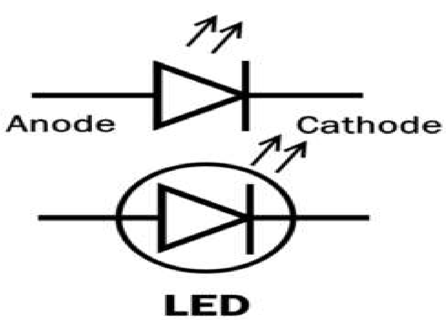
Schottky Diode: uses low voltage to start conducting than the normal diode

Symbol



Light Emitting Diode (LED): it converts current to light energy when forward biased.

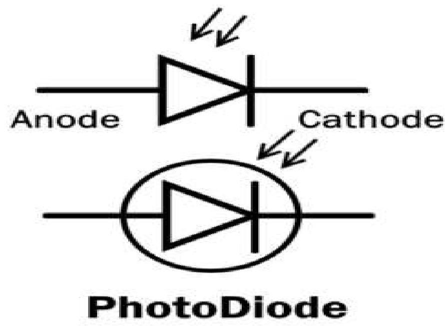
Symbol



Photodiode

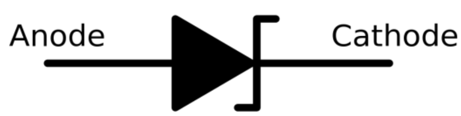
The photodiode is a type of P-N junction diode that converts the light energy into electrical current. Its operation is opposite to that of an LED.

Symbol



Zener diode : It is a type of diode, which not only allows the flow of current in the forward direction but also in reverse direction.

Symbol



TRANSISTORS

The transistor is the most important example of an **active element**. It is a device that can amplify and produce an output signal with **more power** than the input signal. The additional power comes from an external source i.e. the power supply.

Active components such as transistors and silicon-controlled rectifiers (SCRs) use electricity to control electricity. What are passive components? Like resistors, transformers, and diodes don't need an external power source to function. These components use some other property to control the electrical signal. An active element is **an element capable of generating electrical energy**. The essential role of this active element is to magnify an input signal to yield a significantly larger output signal.

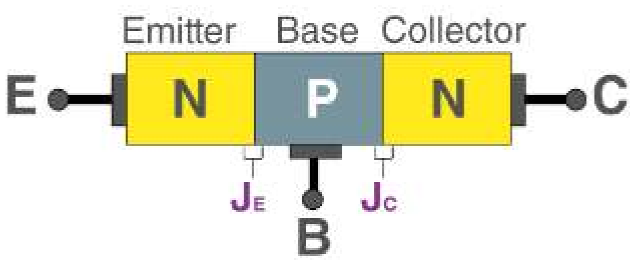
A passive element is **an electrical component that does not generate power, but instead dissipates, stores, and/or releases it**. Passive elements include resistances, capacitors, and coils (also called inductors).

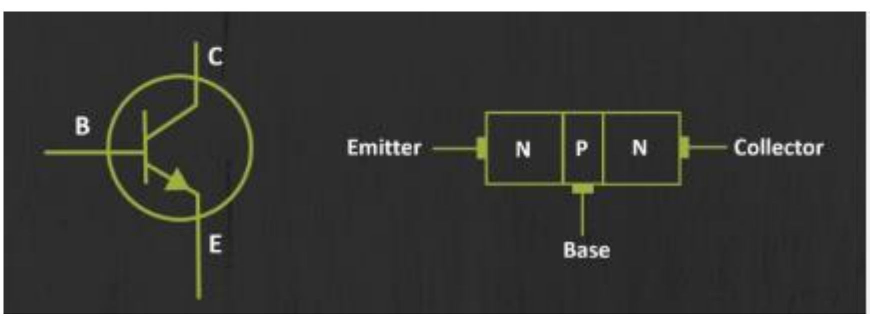
The **transistor** is the essential ingredient of every electronic circuit: amplifiers, oscillators and computers. Integrated circuits (**IC**s), which have replaced circuits constructed from individual, discrete transistors, are themselves **arrays of transistors** and other components built as a single chip of semiconductor material.

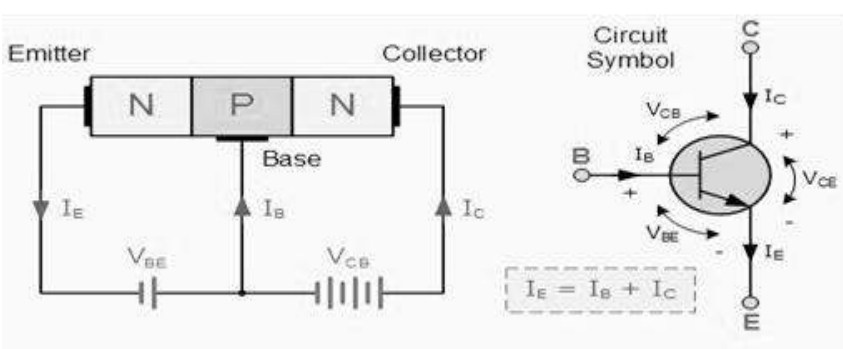
Bipolar Junction Transistors (BJT)

A bipolar junction transistor is **a three-terminal semiconductor device that consists of two p-n junctions which are able to amplify or magnify a signal**. It is a current controlled device. The three terminals of the BJT are the base, the collector, and the emitter.

Standard Bipolar Transistor or BJT, comes in two basic forms. An NPN (Negative-Positive-Negative) type and a PNP (Positive-Negative-Positive) type, with the most commonly used transistor type being the NPN Transistor.







A signal of a small amplitude applied to the base is available in the amplified form at the collector of the transistor. This is the amplification provided by the BJT. Note that it does require an external source of DC power supply to carry out the amplification process.

In order for either PNP or NPN transistors to work, the emmitter base junction must be forward biased and collector base junction reverse biased.

The emitter is heavily doped and the base is lightly doped.

Construction of Bipolar Junction Transistor

BJT is a semiconductor device that is constructed with 3 doped semiconductor Regions i.e. Base, Collector & Emitter separated by 2 p-n Junctions.

Bipolar transistors are manufactured in two types, **PNP** and **NPN**, and are available as separate components, usually in large quantities. The prime use or function of this type of transistor is to amplify current. This makes them useful as switches or amplifiers. They have a wide application in electronic devices like mobile phones, televisions, radio transmitters, and industrial control.

Operation of Bipolar Junction Transistor

There are three operating regions of a bipolar junction transistor:

- Active region: The region in which the transistors operate as an amplifier.
- Saturation region: The region in which the transistor is fully on and operates as a switch such that collector current is equal to the saturation current.
- Cut-off region: The region in which the transistor is fully off and collector current is equal to zero.

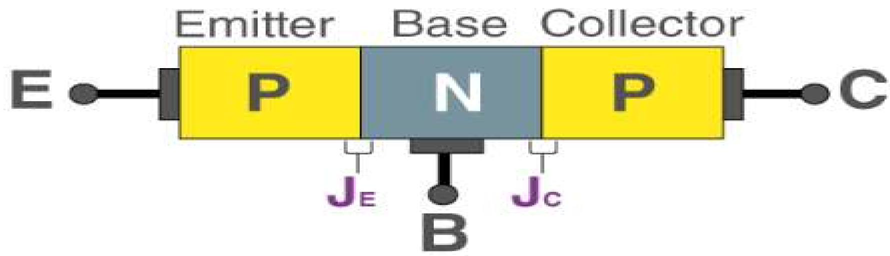
Types of Bipolar Junction Transistor

There are two types of bipolar junction transistors:

- PNP bipolar junction transistor
- NPN bipolar junction transistor

PNP BJT

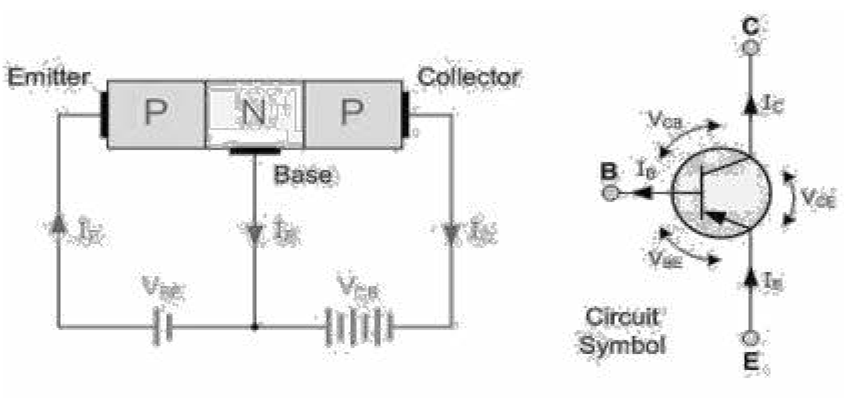
In PNP BJT, the n-type semiconductor is sandwiched between the two p-type semiconductors. The two p-type semiconductors act as emitter and collector respectively while the n-type semiconductor acts as a base. This is shown in the figure below.



The PNP Transistor

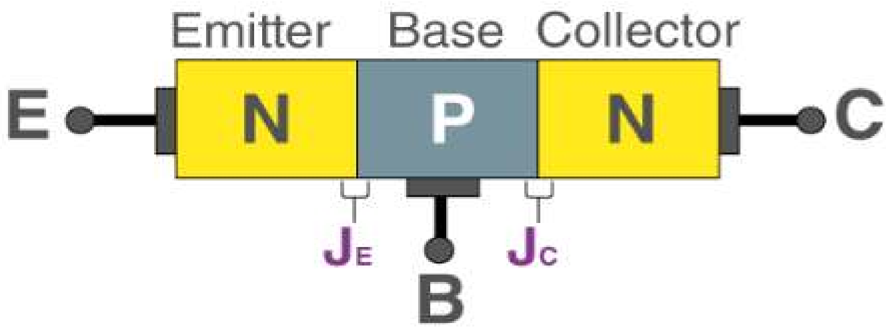
The PNP Transistor is the exact opposite to the NPN Transistor. The construction of a PNP transistor consists of two P-type semiconductor materials either side of the N-type material as shown below.

A PNP Transistor Configuration



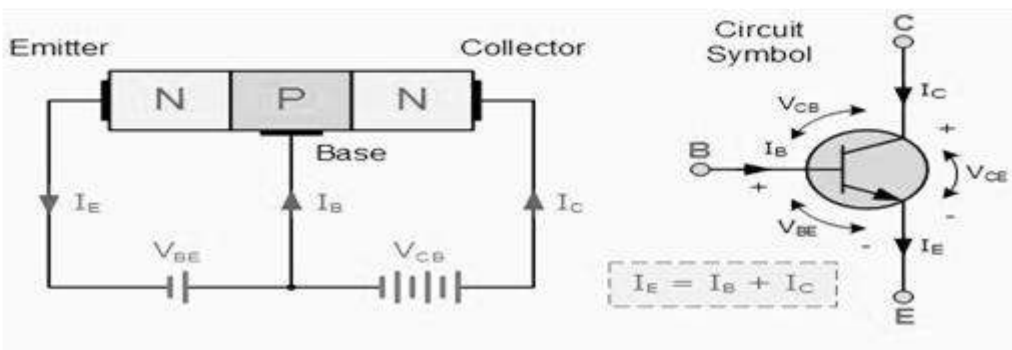
NPN BJT

In NPN BJT, p-type semiconductor is sandwiched between the two n-type semiconductors. The two n-type semiconductors act as emitter and collector respectively while the p-type semiconductor acts as a base. This is shown in the figure below.



Current entering the emitter, base, and collector has the sign convention of positive while the current that leaves the transistor has the sign convention of negative.

Forward-biased NPN BJT

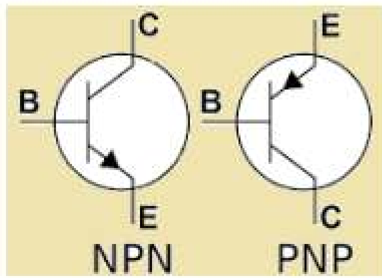


The emmitter-base junction is forward-biased since the the negative V_{EE} is repelled by the electrons in the emitter and they cross the lightly doped base.

Some electrons are lost in the few holes in base about 2% but 98% cross and enter the collector region, the collector is forward biased to electrons from emitter due to positive V_{CC} voltage which attracts them.

Function of Bipolar Junction Transistor

BJTs are of two types namely NPN and PNP based on doping types of the three main terminals. An NPN transistor consists of two semiconductor junctions that have a thin p-doped anode region and PNP transistor also consists of two semiconductor junctions that have a thin n- doped cathode region.



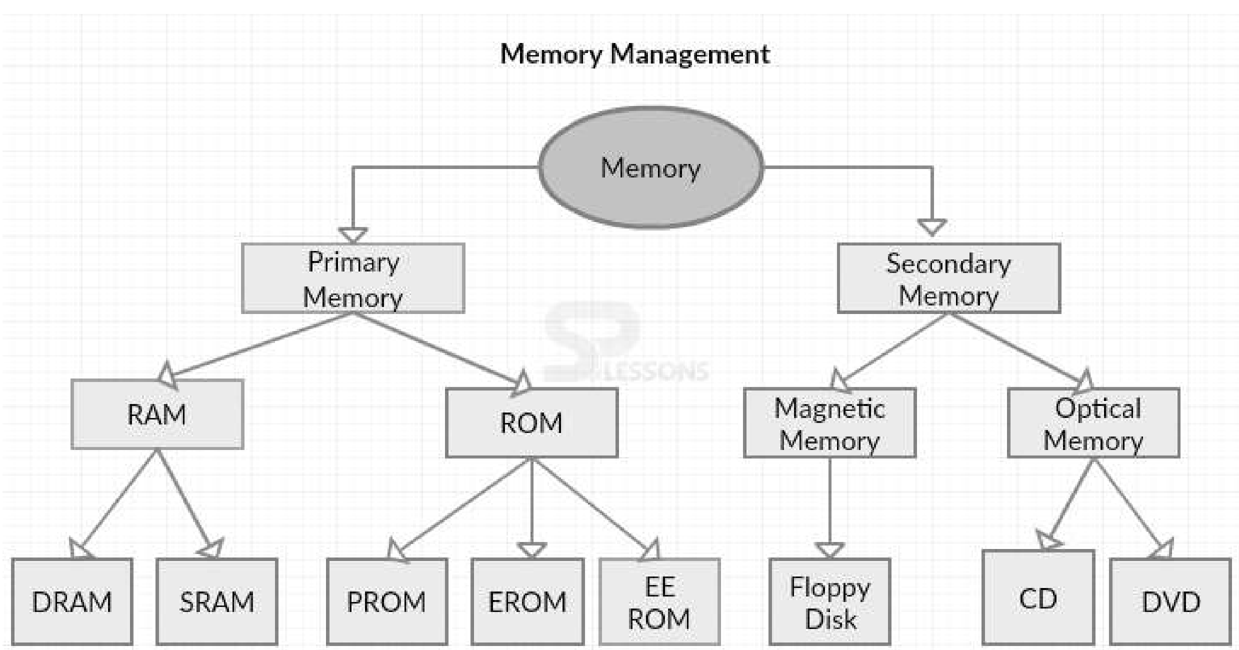
The flow of charge in a Bipolar transistor is due to the diffusion of charge carriers between the two regions belonging to different charge concentrations. Regions of BJT are known as the base, collector, and emitter.

The emitter region is highly doped when compared to other layers. Both collector and base layers have the same charge carrier concentrations. Among these junctions, the base-emitter junction is forward biased, and the base-collector junction is reverse biased. Forward biased means p-doped region has more potential than the n-doped side.

CHAPTER 6

COMPUTER MEMORIES

Computer Memory types



Semi-conductor memories are either random access memories (RAM) or read only memory (ROM).
ROM is used to store non-volatile, permanent or semi-permanent data such as the basic input output system (BIOS)
RAM is employed to store data temporarily and it may either be static or dynamic. Dynamic RAM is much cheaper per bit stored than static RAM.

A semi-conductor memory consists of a matrix of memory cells and a number of digital circuits that provide such functions as address selection and control.

The basic requirements for both ROM and RAM are that:

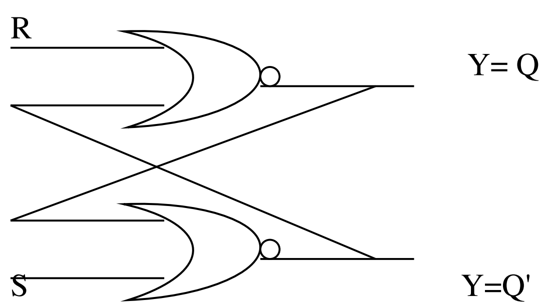
a. Any location in memory can be addressed
b. Data can be read out of an addressed location
c. For RAM, only data can be written into any location.

Memory cell: the basic unit of RAM storage

Memory wall:the part that divides memory into cells

<u>Flip-flop (the circuit that is used to create RAM)</u>

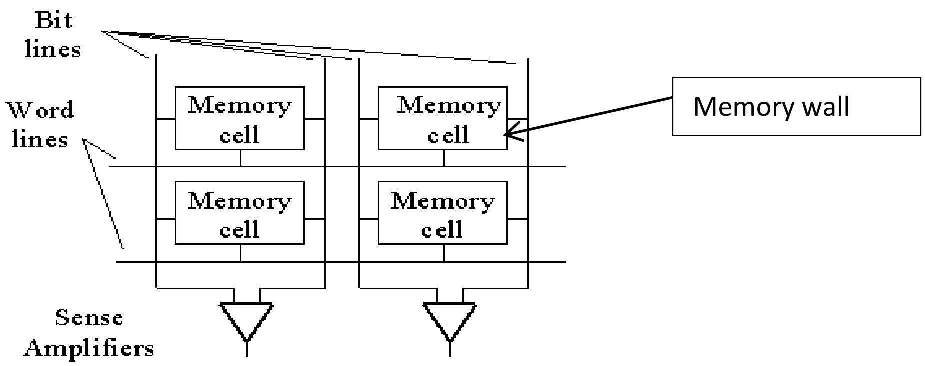
NOR GATE FLIP FLOP



TRUTH TABLE

R	S	Q	ACTION
0	0	Last Value	No Change
0	1	1	Set
1	0	0	Reset
1	1	?	Forbidden

RAM structure

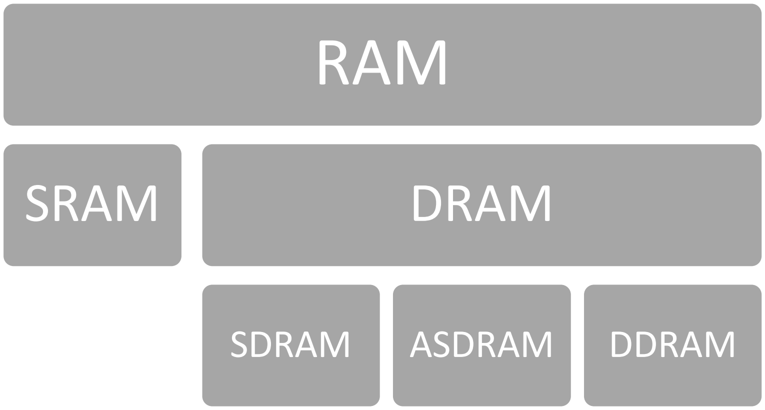


Categories of RAM

Data can be accessed in any RAM location hence the name random access memory.

RAM Types

1. SRAM
2. DRAM



SRAM: Static Random Access Memory. It can store data as long as the power supply is on. It does not need refreshing.

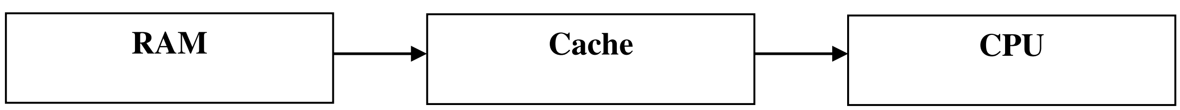
DRAM: Dynamic Random Access Memory. Dynamic means refreshing i.e. in order for it to store data it needs refreshing

SDRAM: Synchronous Dyanmic Random Access Memory.Its operation is synchronized with a clock.

ASDRAM: Assynchronous Dynamic Random Access Memory is a form of DRAM whose operation is not synchronized with a clock.

DDRAM (D^2 RAM): Double data rate dynamic random access memory is a form of DRAM which operates at twice the clock speed.

Cache: A type of RAM that is put between the CPU and main RAM to increase CPU speed.



Read-Only Memory (ROM)

Read-Only Memory stores data on a permanent basis

Types of ROM

1. PROM: Programmable ROM; once data/information is written it can not be altered.
2. EPROM: Erasable ROM; once information is written, it can be edited using special means e.g. ultraviolet light.
3. EEPROM (flash Memory): Electrically erasable PROM; data can be deleted by passage of electric current and other programmed again.

SECONDARY STORAGE

Hard disk

This is data stored in form of magnetic fields of magnetised and non-magnetic sports.

Advantages of hard disk

1. It can be used to transfer to another computer

2. It stores a lot of data

Holographic memory

It uses the principle of light to store data, hence it is also called optical memory

Magnetic tapes

Data is recorded in form of magnetisable material e.g. iron oxide

Optical disk

It is also called laser. It uses laser beam technology and it consists of rotating disk which is coated with a thick metal or some other metal or some other materials that is highly reflective e.g. DVD's, CD. Data is stored in form of lauds (I's) and holes (0's)

CHAPTER 7

NUMBER SYSTEMS

A number system relates quantities using symbols. The base or radix of a number system represents the number of a basic symbols in that particular ne system.

In decimal system (Denary), the base is 10 because of the use of the numbers 0, 1,2,3,4,5,6,7,8 9.

Binary number system.

This is a system that uses only two digits which are zero's and ones.The binary number system is in base 2 as it uses the digits 0 and 1.

The bit- it is the smallest unit of data that a computer uses. It can either be zero or one.

The binary equivalent for some decimal numbers ae given below.

Decimal	Binary
0	0
1	1
2	10

3	11
4	100
5	101
6	110
7	111
8	1000

Each digit in a binary number has a value or weight. The least significant bit has a value of 1, the second from the right has a value of 2, next 4 e.t.c.

16	8	4	2	1
2^4	2^3	2^2	2^1	2^0

Decimal to binary conversion

The decimal number is divided by two progressively and the reminders are written after each division. Then the remainders are taken in the reverse order to form the binary number

Example

a. Convert 21_{10} to its binary equivalent

b. Convert 33_{10} to its binary equivalent

Converting decimal fractions to binary

The fraction is mutlplied by 2 and the carry in the integer posistion is written after each multiplication. Then they are written in the forward order to get the correspondingbinary equivalent.

Example

Convert 0.4375_{10} to its binary equivalent.

Exe.Determine the binary equivalent of each of the following:-

i) 54.45_{10}

ii) 20.125_{10}

Binary to decimal conversion

The bits are multiplied by their weights indicated and the sum of these weighted bits gives equivalent decimal digit.

Example 1

Convert 1001_2 to its decimal equivalent

Example 2

Convert 110110_2 to its decimal equivalent.

Example 3

Convert 1011.101_2 to its decimal equivalent

Example 4

Convert 0.0110_2 to its decimal equivalent

Octal number system

The octal number system has a base of eight. It has 8 basic symbols. The first 8 decimal digits 0, 1, 2, 3, 4, 5, 6, 7 are used in this system

Decimal to octal conversion

The decimal number is divided by 8 progressively and each time the remainder is written and finally the remainders are written in reverse order to form the octal number.

If the number has a fraction past, that part is multiplied by 8 and the carry in the integer part is taken.

Finally the carriers are taken in the forward order.

Example 1

Convert 19_{10} to its octal equivalent

Example 2

Convert 19.11_{10} to its octal equivalent

Example 3

Convert 1265.46_{10} to its octal equivalent

Octal to decimal conversion

The weights of digit position in octal number is as follows:

8^4	8^3	8^2	8^1	8^0	8^{-1}	8^{-2}	8^{-3}

To convert from octal to decimal, multiply each octal digit by its weight and add the resulting products.

Example 1

Convert 537_8 to its decimal equivalent

Example 2

Convert 22.34_8 to its decimal equivalent

Example 3

Convert 714.256_8 to its decimal equivalent

Octal to binary conversion

For the conversion of an octal number to a binary, each digit of the given octal number is converted to its 3-bit binary equivalent (use 421 code).

Example 1

Convert the octal number 527_8 to its binary equivalent.

Example 2

Convert the octal number 623534_8 to binaryS

Binary to octal conversion

For binary to octal conversion, groups of 3-bits are made from right to left. After forming the groups, each 3-bit binary group is replaced by its octal equivalent

Example 1

Convert the binary number 1101110_2 to its octal equivalent.

Example 2

Convert 01011.010011_2 to its octal equivalent

Octal to hexadecimal conversion

First convert the octal number into binary and then from binary into hexadecimal.

Example 1

Convert 345_8 into its hexadecimal equivalent

Hexadecimal number system

Hexadecimal number system has a base of 16. It has 16 symbols from 0-9 and A-F

Decimal	Hexadecimal	Binary

0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Decimal to hexadecimal conversion

The decimal number is divided by 16 and the carriers are taken after each division and then written in the reverse order.

Example 1

Convert 2479_{10} to its hexadecimal equivalent.

Example 2

Convert 876_{10} to its hexadecimal equivalent

Hexadecimal to decimal conversion

Each digit of the hexadecimal number is multiplied by its weight and the products are added.

Example 1

Convert 976_{16} to its decimal equivalent

Example 2

Convert 81.21_{16} to its decimal equivalent.

Example 3

Convert $3C4.21F_{16}$ to its decimal equivalent

Hexadecimal to binary conversion

Each digit of the given hexadecimal number is converted to its 4-bit binary equivalent

(use 8421 code).

Example 1

Convert $5D_{16}$ to its binary equivalent

Example 2

Convert $AF9_{16}$ to its binary equivlaent.

Binary to hexadecimal conversion

Groups of 4-bits are made from the right to the left. After forming the groups, each 4-bit binary group is replaced hexadecimal equivalent.

Example 1

Convert 1010000100111111_2 to its hexadecimal equivalent.

Example 2

Convert 100101110.11011_2 to hexadecimal

Octal to hexadecimal conversion

Convert 3768 to tis hexadecimal equivalent

Hexadecimal to octal conversion

First convert the hexadecimal to its equivalent binary using 8421 system, then convert the binary by grouping into 3-bits to octal.

Example

Convert $3C4.21F_{16}$ to its octal equivalent

BINARY ARITHMATIC

Binary Addition

To perform binary addition the following table is used

$0 + 0 = 0$

$0 + 1 = 1$

$1 + 0 = 1$

$1 + 1 = 0$ plus a carry over of 1

Example 1

1010_2+1101_2

Example 2

11_2+11_2

Exaple 3

10101_2+1101_2

Example 4

Perform the following binary operation

$111101_2+11011_2+1001_2$

Binary subtraction

To perform binary subtraction, the following binary subtraction rules should be followed:

1-1 = 0

0-1= 1 with a borrow of 1

Examples

a. 110001_2 - 111_2

b. 10101_2-1011_2

c. Perform the following binary arithmetic

$10110101_2+110011_2-11101_2$

One's compliment (1s compliment)

One's compliment of a binary number is a number that results when we change each 0 to 1 and 1 to 0.

Examples

Binary number	1's complement
0101	1010
1001	0110
1101	0010
0001	1110

One's complement subtraction steps

a. Write the first number

b. Write the 1's compliment of the second number

c. Add the two numbers

d. The last carry that arises from addition is said to be "end around carry"

e. End around carry should be added with the sum to get the final answer

f. If there is no end around carry, find out the one's compliment of the sum and put a negative sign before the result as the result is negative

Example

a. Using is complement 7_{10}-3_{10}

b. 3_{10}-7_{10}

Two's complement (2's complement)

Two's complement results when we add 1 to one's complement of given number i.e.

Binary Number	1's complement	2's complement
1010	0101	0110
0101	1010	1011
1001	0110	0111
0001	1110	1111

Two's complement subtractions steps

a. Write the first number

b. Write down the two's complement of the second number

c. Add the two numbers

d. If there is a carry, discard it, the remaining part will be the result (positive)

e. If there is no carry, find out the 2's complement of the sum and put a negative sign before the result (negative)

Example

Using 2's complement evaluate

$10_{10}-8_{10}$

$4_{10}-5_{10}$

Binary Multiplication

The table for binary multiplication is given below:

0 x 0 = 0	1 x 0 =0
0 x 1	1 x 1= 1

Example

1011_2 x 110_2

10101_2 x 1101_2

OCTAL ARITHMETIC

Octal Addition

Steps- add the numbers every time the sum adds up to 8 or more more there is a carry

Example

123_8 +527_8

Octal Subtraction

In octal system, when you borrow 1 it is equivalent to 8. When you use the borrow , the column you borrow from is reduced by one.

Consider the subtruction of 1 from 10 in decimal, binary and octal number systems.

Decimal	Binary	Octal
$10_{10} - 1_{10} = 9_{10}$	$10_2 - 1_2 = 1_2$	$10_8 - 1_8 = 7_8$

Example

a. $46_8 - 7_8$

b. $532_8 - 174_8$

Hexadecimal Arithmetic

Examples

$EA6_{16} + 424_{16}$

Evaluate the following arithmetic operation giving your answer in octal

$A1_{16} + 6C_{16}$

CHAPTER 8

BINARY CODES

Digital data is represented, stored, transmitted as group of binary bits. This group is known as binary code.

The binary code is used to represent numbers as well as alphanumeric letters.

Classification of codes

1. Weighted binary codes

In weighted binary codes, each position of a number represents a specific weight. The bits are multiplied witht the weights indicated and the sum of this is weighted bits gives the equivalent decimal digits.

2. Sequential codes

Sequential code is one where each succeeding code word is one number greater than its preceding code word. Such a code facilitates mathematical manipulation of data.

3. Binary Coded Decimal (BCD)

In this code, each decimal digit 0 through 9 is coded by a 4-bit binary number. It is also called the natural binary code because of the 842 and 1 weights attached to it.

Advantage of BCD

Easy to convert to and from decimal

It helps in arihmetic involving signed numbers

Disadvantages

i) Less efficient than pure binary number in the sense that it requires more bits to represent e.g. the decimal number 14 can be represented as 1110 in pure binary but also as 00010100 in BCD.

ii) Arithmetic operations are more complex than they are in pure binary.

BCD Addition

It is performed by individually adding the corresponding digits of the decimal numbers expressed in 4-bit binary groups starting from the least significant digit (LSD)

If there is no carry and the sum is not an illegal code, no correction is needed.

Examples

Perform the following decimal addition in BCD

25 + 13

BCD Subtraction

Example

38 – 15

Excess-3 code (XS-3)

In this code, a digit is representes by adding 3 to the number and then converting it to a (four bit) 4- bit binary number.

Example

a. Find XS-3 represantation of a decimal number 4

b. Convert 85 to its excess-3 equivalent.

Gray code

It is a code that is used to convert the decimal number into 8-bit binary sequence. This conversion is carried in a manner that the adjacent digits of the decimal number differ from each other one bit.

Examples

Decimal Number	8-bit Gray code

0	00000000
1	00000001
3	00000011
2	00000010

Converting binary to gray code

To convert binary to grey code, you use the X-OR function

A	B	AΘB
0	0	0
0	1	1
1	0	1
1	1	0

Example

Convert 11101_2 to Gray code

Alphanumeric Codes

Computers, printers and other devices must process both alphanumeric and alphabetic data. Information coding systems have been developed to represent alphanumeric information as a series of 1's and 0's (ones and zeros)

The characters to be coded are alphabets, numerals and special characters such as +, -, 1, *, ?

In order to code a character, a string of binary digits is used. In order to ensure uniformity in coding two standard codes have been used.

These are:

ASCII: American Standard Code for Information Interchange.

EBCDIC: Extended Binary Coded Decimal Interchange Code.

ASCII

It is a 7-bit code that is used to code two types of information.

One type is the printable characters such as the alphabets, digits and special characters.

The other type is known as control character which represents the coded information to control the operation of a digital computer and are non-printed.

EBCDIC

It uses 8-bits to encode each character for 256 distinctive characters.

ERROR DETECTION AND PARITY

The movement of digital data from one location to another can result in transmission errors, the receiver not receiving the same signal as transmitted by the transmitter as a result of electrical noise in the transmission process e.g. the transmitted signal 1011 may be incorrectly received as 1101.

In order to detect such errors a parity bit is often used.

Parity bit: It is a binary digit 0 or 1 that is added to a group of data to be transmitted to make its sum odd or even for checking its integrity for transmission or storage.

Also it is an extra 0 or 1 that is attached to a group (code group) at transmission.

Odd Parity

With odd parity, the parity bit chosen so that the total number of 1's including the parity bit is odd.

The number of (one) 1-bit must add up to an odd number

e.g. 10000000

111110+1

10010010

Even Parity

The value of the bit is chosen so that the total number of 1's in the code group including the parity bit is even number

Example

10000001

10010011

If a computer uses an even parity and the number of 1-bit add up to odd number, then it will know there was an error during transmission.

CHAPTER 9

LOGIC GATES AND BOOLEAN ALGEBRA

Logic gates are electronic circuits because they are made up of a number of electronic devices and components.

A logic gate or just a gate is an electronic circuit which operates one or more signals to produce an output signal.

The output is high only for certain combination of input signals.

Logic gates are the fundamentals building blocks of digital systems.

The name logic gate is derived from the ability of such a device to make decision, in the sense that it produces one output level when some combinations of input levels are present and a different output level when other combinations of input levels are present.

The fact that the computers are able to perform very complex logic operations stems from the way elementary gates are interconnected.

Logic design is the interconnection of gates to perform a variety of logical operations.

Inputs and outputs of logic gates can occur only in two levels which are termed as high or low, true or false, on and off or simply 1 and 0.

Truth table

It is a table which has all the possible combination of input variables and the corresponding outputs.

Logic gate truth table shows each possible input to the gate or circuit and the resultant output depending upon the combination of the inputs.

A logic circuit with n numbers of inputs would have 2^n possible inputs combinations of both on and off.

Consider a 2 input logic circuit with input variables labelled A and B. There are four possible input combinations of OFF and ON or 2^2.

A three input logic circuit would have 8 possible input combinations or 2^3.

INPUTS AND OUTPUTS

Gates have two or more inputs except a NOT gate which has only one input.

All gates have only one output.

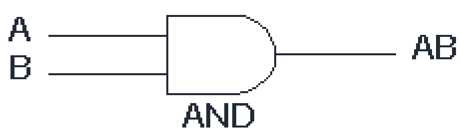
Usually, the letters ABCD are used to label inputs and Q is used to label output. Gates are identified by their functions e.g. NOT, AND, NOR, EX- OR (Exclusive –OR), EX-NOR (exclusive NOR).

Capital letters are normally used to make it clear that the term refers to a logic gate.

The inverting circle

Some gate symbols hav e a circle on their output which means that their functions includes inverting of the output.

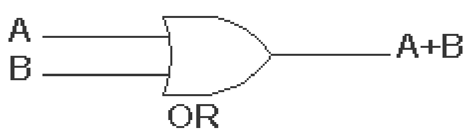
AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

The AND gate is an electronic circuit that gives a high output (1) only if all its inputs are high. A dot (.) is used to show the AND operation i.e. A.B. Bear in mind that this dot is sometimes omitted i.e. AB

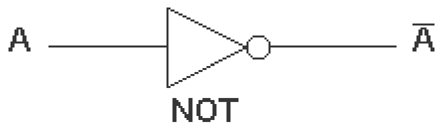
OR gate



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

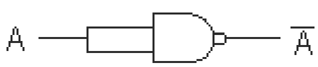
The OR gate is an electronic circuit that gives a high output (1) if one or more of its inputs are high. A plus (+) is used to show the OR operation.

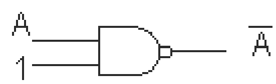
NOT gate



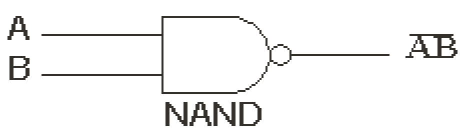
NOT gate	
A	$\overline{A}$
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an *inverter*. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.





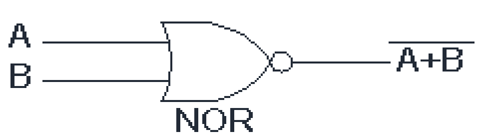
NAND gate



2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if any of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

NOR gate

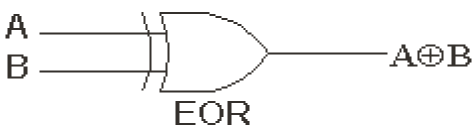


2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if any of the inputs are high.

The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

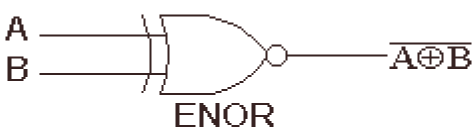
EXOR gate



2 Input EXOR gate		
A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

The 'Exclusive-OR' gate is a circuit which will give a high output if either, but not both, of its two inputs are high. An encircled plus sign (⊕) is used to show the EOR operation.

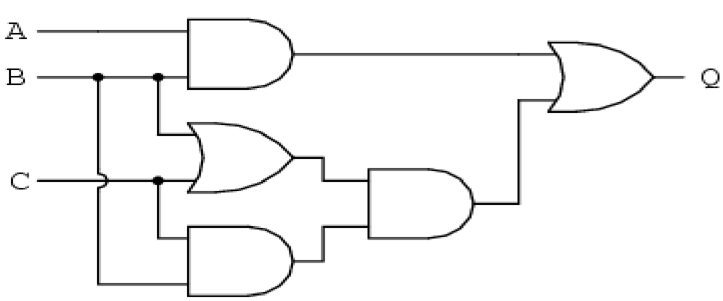
EXNOR gate



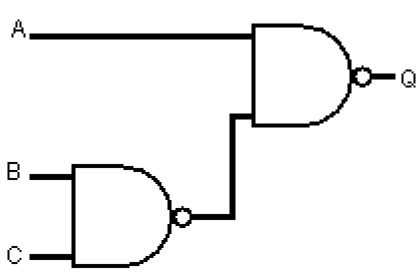
2 Input EXNOR gate		
A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

The 'Exclusive-NOR' gate circuit does the opposite to the EOR gate. It will give a low output if either, but not both, of its two inputs are high. The symbol is an EXOR gate with a small circle on the output. The small circle represents inversion.

Represent the output of the following gate on a truth table.



EXE: Represent the following on a truth table.



Drawing logic gates given the functions

i. F=A$\overline{B}$ + AB

ii. F=$\overline{A}\,\overline{B}$+ A $\overline{B}$+ $\overline{A}$B

The above gates can be simplified first using boolean algebra or karnaugh map.

Simplificatiion of logic expressions using Boolean algebra

Sometimes given a logic function, one is required to simplify it first either using boolean algebra rules or Karnaugh maps.

BOOLEAN ALGEBRA

It is a tool for simplifying digital circuits.

Basic identities of Boolean algebra

1. Basic identities of Boolean algebra

$A+0=A$ $A0=0$

$A+1=1$ $A1=A$

$A+\overline{A}=1$ $A\overline{A}=0$

$A+A=A$ $AA=A$

$\overline{\overline{A}}=A$

$A+B=B+A$ $AB=BA$ (Communicative Property)

$A+(B+C)=(A+B)+C$ $A(BC)=(AB)C$ (Associative Property)

$A(B+C)=AB+AC$ $(A+B)(A+C)=A+BC$ (Distributive Property)

$\overline{A+B}=\overline{A}\,\overline{B}$ (De Morgan's Law)

$\overline{AB}=\overline{A}+\overline{B}$ (De Morgan's Law)

Thus, given a logic function, Boolean algebra can be used to simplify it

Simplify the following expression as much as possible and represent on a logic circuit.

iii. $\overline{\overline{A(A+B)}+B\overline{A}}$.

iv. $\overline{A+B}+\overline{A}B$

v. A$\overline{B}$ + AB

vi. $\bar{A}\,\bar{B} + A\,\bar{B} + \bar{A}B$

Karnaugh Maps

Functions of the form ABC + BCD are called sum of products of inputs A, B and C and BCD is a product of inputs B, C and D. SOP is also called a miniterm.

Functions of the firm (A+B+C)(A+B+C) are called products of sums (POS) because inputs A, B and C are added before being multiplied. They are also called maxterms.

Miniterms are majorly used in maps called Karnaugh maps that can be used instead of Borlean algebra.

Rules for using Karnaugh maps

1. Insert 1 in the corresponding position of every mini term in the squares
2. Combine the 1's in groups of 2's, 4's or 8
3. For each group, move horizontal and vertically and write down the variables that are not changing(constant)

Karnaugh maps can be drwan for 2, 3,4 inputs

2-input karnaugh map

B \ A	0	1
0		
1		

Simplify

i) F= $A\bar{B} + AB$

ii) F= $\bar{A}\,\bar{B} + A\,\bar{B} + \bar{A}B$

3-input karnaugh map

C \ AB	00	01	11	10
0				
1				

Exe: simplify using K-map

i. $\bar{A}B\bar{C}+\bar{A}BC+A\bar{B}C+ABC$

ii. $A.\bar{B}.\bar{C}+\bar{A}.\bar{B}.C+A.\bar{B}.C$

4-input karnaugh map

CD \ AB	00	01	11	10
00				
01				
11				
10				

Exe:simplify the following

$A\bar{B}\bar{C}D + ABCD + ABCD + ABCD + ABCD$

Simplifying function given as a sum of terms

Using the K-Map (Boolean algebra) simplify the following:-

i. ΣM(0,1,2,4,5,6,8,9,12,13,14)

ii. Σ m (0,1,2,3,8,9,10,11)

<u>Logic gate from truth table</u>

sensor inputs

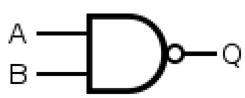
A	B	C	Output	
0	0	0	0	
0	0	1	0	
0	1	0	0	
0	1	1	1	$\overline{A}BC = 1$
1	0	0	0	
1	0	1	1	$A\overline{B}C = 1$
1	1	0	1	$AB\overline{C} = 1$
1	1	1	1	$ABC = 1$

$\text{Output} = \overline{A}BC + A\overline{B}C + AB\overline{C} + ABC$

<u>Making other gates by using NAND gates</u>

NAND and NOR gates are universal gates, meaning that any other gate can be represented as a combination of NAND and NOR gates.

A NAND gate is an inverted AND gate. It has the following truth table:



Q = NOT(A AND B)

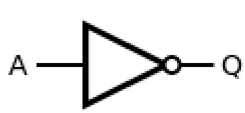
Truth Table

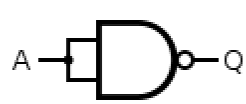
Input A	Input B	Output Q
0	0	1
0	1	1
1	0	1
1	1	0

<u>NOT</u>

A NOT gate is made by joining the inputs of a NAND gate together. Since a NAND gate is equivalent to an AND gate followed by a NOT gate, joining the inputs of a NAND gate leaves only the NOT gate.

Desired NOT Gate NAND Construction





Q = NOT(A) = A NAND A

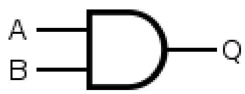
Truth TABLE

Input A	Output Q
0	1
1	0

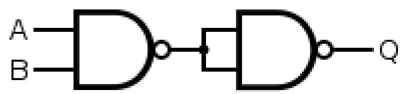
AND

An AND gate is made by following a NAND gate with a NOT gate as shown below. This gives a NOT NAND, i.e. AND.

Desired AND Gate



NAND Construction



Q = A AND B = (A NAND B) NAND (A NAND B)

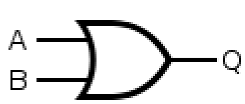
Truth Table

Input A	Input B	Output Q
0	0	0
0	1	0
1	0	0
1	1	1

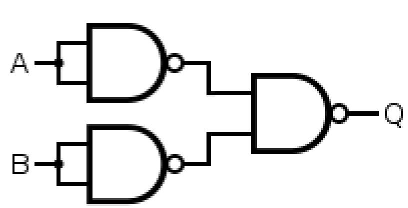
OR

If the truth table for a NAND gate is examined or by applying De Morgan's Laws, it can be seen that if any of the inputs are 0, then the output will be 1. To be an OR gate, however, the output must be 1 if any input is 1. Therefore, if the inputs are inverted, any high input will trigger a high output.

Desired OR Gate



NAND Construction



Q = A OR B = (A NAND A) NAND (B NAND B)

Truth Table

Input A	Input B	Output Q

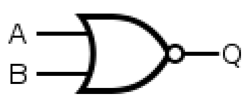
0	0	0
0	1	1
1	0	1
1	1	1

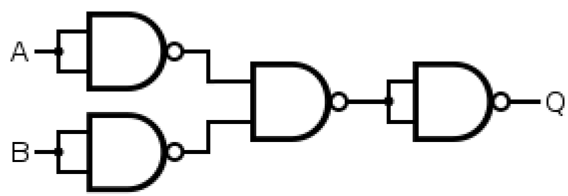
NOR

A NOR gate is simply an inverted OR gate. Output is high when neither input A nor input B is high.

Desired NOR Gate

NAND Construction





Q = A NOR B

= [(A NAND A) NAND (B NAND B)] NAND [(A NAND A) NAND (B NAND B)]

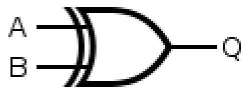
Truth Table

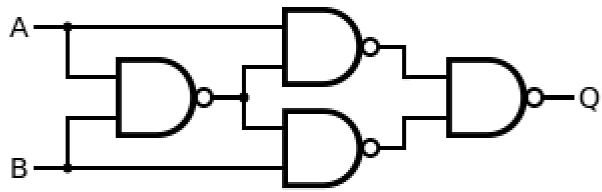
Input A	Input B	Output Q
0	0	1
0	1	0
1	0	0
1	1	0

XOR

An XOR gate is constructed similarly to an OR gate, except with an additional NAND gate inserted such that if both inputs are high, the inputs to the final NAND gate will also be high, and the output will be low. This construction has a propagation delay three times that of a single NAND gate and uses four gates.

Desired XOR Gate NAND Construction





Q = A XOR B

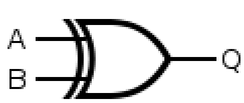
= [A NAND (A NAND B)] NAND
[B NAND (A NAND B)]

Truth Table

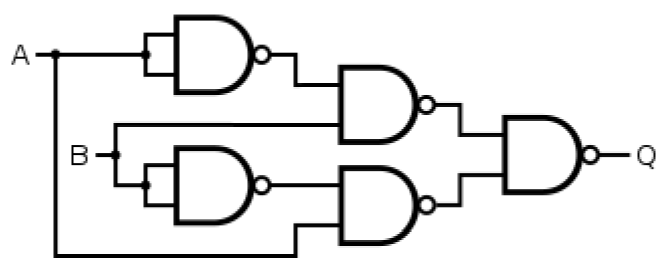
Input A	Input B	Output Q
0	0	0
0	1	1
1	0	1
1	1	0

Alternatively, the B-input of the XNOR gate with the 3-gate propagation delay can be inverted. This construction uses five gates instead of four.

Desired Gate



NAND Construction



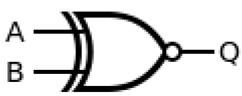
Q = A XOR B

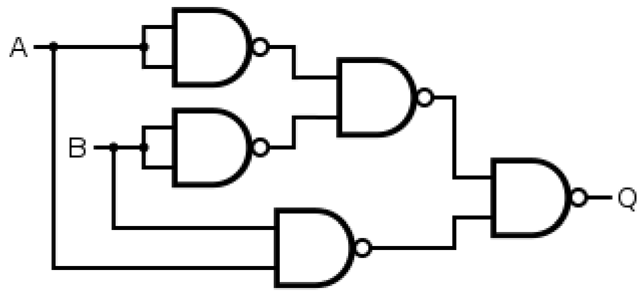
= [B NAND (A NAND A)] NAND
[A NAND (B NAND B)]

XNOR

An XNOR gate is made by connecting the output of 3 NAND gates (connected as an OR gate) and the output of a NAND gate to the respective inputs of a NAND gate. This construction entails a propagation delay three times that of a single NAND gate and uses five gates.

Desired XNOR Gate NAND Construction





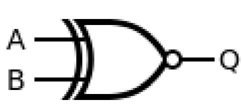
Q = A XNOR B = [(A NAND A) NAND (B NAND B)] NAND (A NAND B)

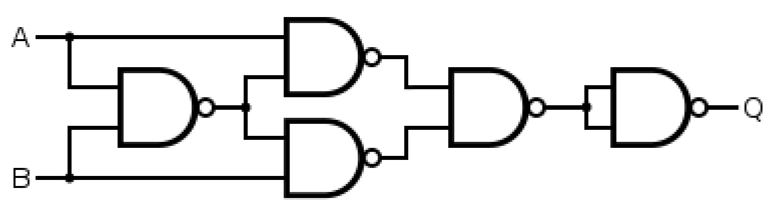
Truth Table

Input A	Input B	Output Q
0	0	1
0	1	0
1	0	0
1	1	1

Alternatively, the 4-gate version of the XOR gate can be used with an inverter. This construction has a propagation delay four times (instead of three times) that of a single NAND gate.

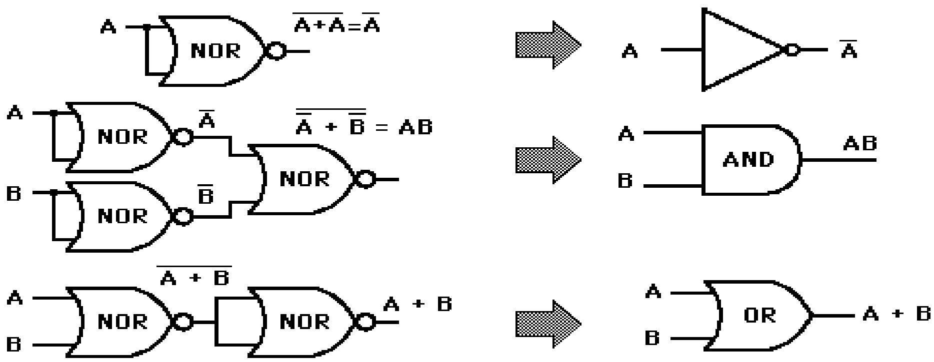
Desired Gate NAND Construction





Q = A XNOR B = { [A NAND (A NAND B)] NAND [B NAND (A NAND B)] } NAND { [A NAND (A NAND B)] NAND [B NAND (A NAND B)] }

Using NOR gate to make other gates



CHAPTER 10

EMERGING TRENDS IN ELECTRONICS

The era of electronics began with the invention of the transistor in 1947 and silicon-based semiconductor technology. Seven decades later, we are surrounded by electronic devices and, much as we try to deny it, we rely on them in our everyday lives.

The performance of silicon-based devices has improved rapidly in the past few decades, mostly due to novel processing and patterning technologies, while nanotechnology has allowed for miniaturization and cost reduction.

For many years silicon remained the only option in electronics. But recent developments in materials-engineering and nanotechnology have introduced new pathways for electronics. While traditional silicon electronics will remain the main focus, alternative trends are emerging. These include:

1. **2-D electronics**

Interest in the field started with the discovery of graphene, a structural variant of carbon. Carbon atoms in graphene form a hexagonal two-dimensional lattice, and this atom-thick layer has attracted attention due to its high electrical and thermal conductivity, mechanical flexibility and very high tensile strength. Graphene is the strongest material ever tested.

2. **Organic electronics**
3. The development of conducting polymers and their applications resulted in another Nobel prize in 2000, this time in chemistry. Alan J. Heeger, Alan G. MacDiarmid and Hideki Shirakawa proved that plastic can conduct electricity.