PRINCIPLES OF COMMUNICATION SYSTEMS

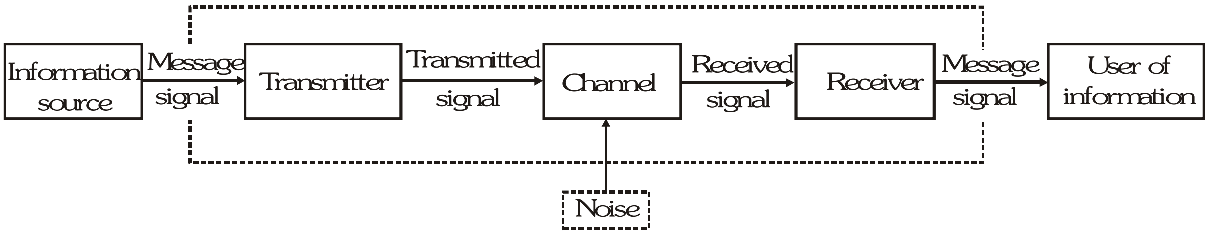
1. INTRODUCTION

Communication means transmission of information. Everyone experiences the need to impart or recieve information continuously in the surrounding and for this , we speak, listen,send message by a messenger, use coded signalling methods through smoke or flags or beating of drum etc. and these days we are using telephones, TV, radio, satellite communication etc. The aim of this chapter is to introduce the concepts of communication namely the mode of communication, the need for modulation, production and detection of amplitude modulation.

Elements of a Communication System :

Every communication system has three essential elements-

(i) transmitter (ii) medium/channel (iii) receiver



Transmitter converts the message signal into an electric signal and transmits through channel. The receiver receives the transmitted signal and reconstructs the original message signal to the end user. There are two basic modes of communication: (i) point-to-point and (ii) broadcast.

In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver as in telephony. In the broadcase mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are most common examples of braoadcast mode of communication. However the communication system can be classified as follows :

Types of Communication Systems

On the basis of nature of Information
(1) Speech Transmission (Radio)
(2) Picture Transmission (TV)
(3) Fascimile Transmission (FAX)
(4) Data Transmission (Internet)

On the basis of signal transmitted
(1) Analog
(2) Digital

On the basis of transmission Channel
(1) Line communication
(a) Two wire Transmission line
(b) Coaxial cable
(c) Optical fibre
(2) Space communication

On the basis of type of modulation
(1) Continuous wave modulation
(a) Amplitude
(b) Frequency
(c) phase
(2) Pulse Modulation
(a) PAM
(b) PTM — PPM, PWM
(c) PCM

Basic terminology Used in Electronic Communication systems :

(i) Transducer. Transducer is the device that converts one form of energy into another. Microphone, photo detectors and piezoelectric sensors are types of transducer. They convert information into electrical signal.

(ii) Signal Signal is the information converted in electrical form. Signals can be analog or digital. Sound and picture signals inTV are analog.

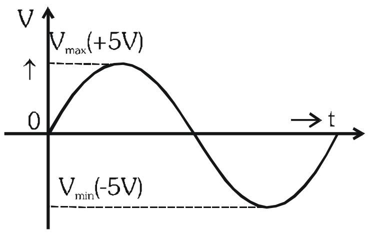
It is defined as a single–valued function of time which has a unique value at every instant of time.

(1) Analog Signal :–

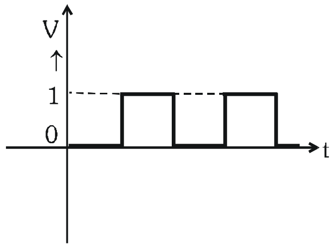
A continuously varying signal (Voltage or Current) is called an analog signal. A decimal number with system base 10 is used to deal with analog signal.

(2) Digital Signal :–

A signal that can have only discrete stepwise values is called a digital signal. A binary number system with base 2 is used to deal with digital signals.



An Analog Signal



An Digital Signal

(iii) Noise : There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.

(iv) Transmitter : A transmitter processes the incoming message signal to make it suitable for trans-mission through a channel and subsequent reception.

(v) Receiver : A receiver extracts the desired message signals from the received signals at the channel output.

(vi) Attenuation : It is the loss of strength of a signals while propagating through a medium. It is like damping of oscillations.

(vii) Amplification : It is the process of increasing the amplitude (and therefore the strength) of a signal using an electronic circuit called the amplifier. Amplification is absolutely necessary to compensate for the attenuation of the signal in communication systems.

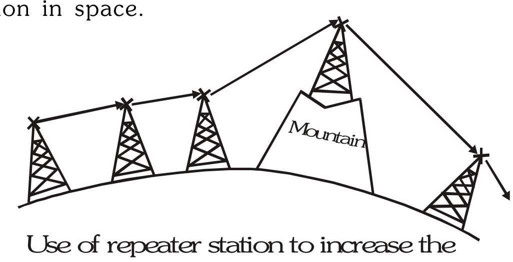
(viii) Range : It is the largest distance between the source and the destination upto which the signal gets received with sufficient strength.

(ix) Bandwidth : It is the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.

(x) Modulation : The original low frequency message/information signal connot be transmitted to long distances. So, at the transmitter end, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation.

(xi) Demodulation : The process of retrieval of original information from the carrier wave at the receiver end is termed as demodulation. This process is the reverse of modulation.

(xii) Repeater : A repeater acts as a receiver and a transmitter. A repeater picks up the signal which is comming from the transmitter, amplifies and retransmits it with a change in carrier frequency. Repeaters are necessary to extend the range of a communication system as shown in figure A communication satellite is basically a repeater station in space.



Use of repeater station to increase the range of communication

BANDWIDTH

Bandwidth of signals :

Different signals used in a comminication system such as voice, music, picture, computer data etc. all have different ranges of frequency. The difference of maximum and minimum frequency in the range of each signal is called bandwidth of that signal.

Bandwidth can be of message signal as well as of transmission medium.

(i) Bandwidth for analog signals

Bandwdith for some analog sinals are listed below :

Signal	Frequency range	Bandwidth required
Speech	300-3100 Hz	3100-300 =2800 Hz
Music	High frequencies produced by musical instrument Audible range =20 Hz - 20 kHz	20 kHz
Picture	-	4.2 MHz
TV	Contains both voice and picture	6 MHz

(ii) Bandwidth for digital signal

Basically digital signals are rectanglar waves and these can be splitted into a superposition of sinusoidal waves of frequencies ν_0, $2\nu_0$, $3\nu_0$, $4\nu_0$, $n\nu_0$, where n is an integer extending to infinity. This implies that the infinite band width is required to reproduce the rectangular waves. However, for practical purposes, higher harmonics are neglected for limiting the bandwidth

Band width of Transmission Medium

Different types of transmission media offer different band width in which some of are listed below

Frequency Bands			
	Service	Frequency range	Remarks
1	Wire (most common : Coaxial Cable)	750 MHz (Bandwidth)	Normally operated below 18 GHz
2	Free space (radio waves)	Few hundred kHz to GHz	
	(i) Standard AM broadcast	540kHz -1600 kHz	
	(ii) FM	88-108 MHz	
	(iii) Television	54-72 MHz 76-88 MHz 174-216 MHz 420-890 MHz	VHF (Very) high frequencies) TV UHF (Ultra hight frequency) TV
	(iv) Cellular mobile radio	896-901 MHz 840-935 MHz	Mobile to base Station Base station to mobile
	(v) Satellite Communication	5.925-6.425 GHz 3.7 - 4.2 GHz	Uplinking Downlinking
3	Optical communication using fibres	1THz-1000 THz (microwaves-ultra violet)	One single optical fibre offers bandwidth > 100 GHz

Propagation of Electromagnetic Waves :

In case of radio waves communication, an antenna at the transmitter radiates the electromagnetic waves (em waves). The em waves travel through the space and reach the receiving antenna at the other end. As the em wave travels away from the transmitter, their strength keeps on decreasing. Many factors influence the propagation of em waves including the path they follow. The composition of the earth's atmosphere also plays a vital role in the propagation of em waves, as summarised below.

Table 4 Layers of atmosphere and their interaction with the propagating em waves

Atmospheric stratum (layer)	Height over earth's surface (approx)	Exists during	Frequencies most likely affected
1. Troposphere	10 km	Day and night	VHF (upto several GHz)
2. Ionosphere			
(i) D (part of stratosphere)	65-75 km	Day only	Reflects LF, absorbs MF & HF to some degree
(ii) E (part of stratosphere)	100 km	Day only	Helps surface waves, reflects HF
(iii) F_1 (Part of Mesosphere)	170-190 km	Daytime, merges with F_2 at night	Partially absorbs HF waves yet allowing them to reach F_2
(iv) F_2 (Thermosphere)	300 km at night, 250-400 km during daytime	Day and night	Efficiently reflects HF waves particularly at night

Ground Wave Propagation :

(a) The radio waves which travel through atmosphere following the surface of earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation.

(b) The ground wave transmission becomes weaker with increase in frequency because more absorption of ground waves takes place at higher frequency during propagation through atmosphere.

(c) The ground wave propagation is suitabel for low and medium frequency i.e. upto 2 or 3 MHz only.

(d) The ground wave propagation is generally used for local band broadcasting and is commonly called medium wave.

(e) The maximum range of ground or surface wave propagation depends on two factors :

(i) The frequency of the radio waves and

(ii) Power of the transmitter

Sky Wave Propagation :

(a) The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.

(b) The ionoopheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

(c) The highest frequency of radiowaves which when sent straight (i.e. normally) towards the layer of ionosphere gets refelcted from ionosphere and returns to the earth is called critical frequency. . If is given by $f_c = 9\ (N_{max})^{1/2}$, where N is the number density of electron/m^3.

Space wave propagation :

(a) The space waves are the radiowaves of very high frequency (i.e. between 30 MHz. to 300 MHz or more).

(b) the space waves can travel through atmosphere from transmitter antenna to receiver antenna either derectly or after reflection from ground in the earth's troposphere region. That is why the space wave propagation is also called as tropospherical propagation or line of sight propagation.

(c) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

(d) If the transmitting antenna is at a height h_T, then you can show that the distance to the horizontal d_T is given as $\boxed{d_T = \sqrt{2Rh_T}}$, where R is the radius of the earth (approximately 6400 km). d_T is also called the radio maximum line-of sight distance d_m between the two antennas having heights h_T and h_R above the earth is given by :

$$\boxed{d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}}$$

where h_R is the height of receiving antenna.

Modulation

* It is a process by which any electrical signal called input / baseband or modulating signal, is mounted onto another signal of high frequency which is known as carrier signal.
* It is defined as the process by which some characteristic (called parameter) of carrier signal is varied in accordance with the instantaneous value of the baseband signal.
* The signal which results from this process is known as modulated signal.

Need for Modulation :

(i) To aviod interference :

If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

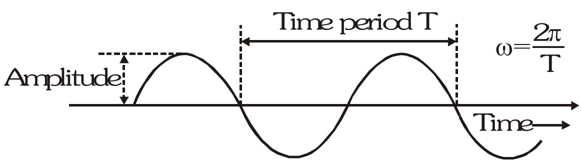
(ii) To design antennas of practicable size :

The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. This minimum size becomes impracticable because the frequency of the modulating signal can be upto 5 kHz which corresponds to a wavelength of $3 \quad 10^8/5 \quad 10^3$ = 60 km. This will require an antenna of the minimum height of $\lambda/4$ = 15 km. This size of an antenna is not practical.

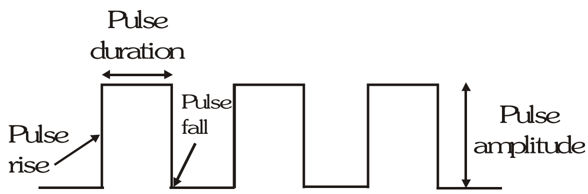
(iii) Effective Power Radiated by an Antenna :

A theoretical study of radiation from a linear antenna (length ℓ) shows that the power radiated is proportional to (frequency)^2 i.e. $(\ell/\lambda)^2$. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

The above discussion suggests that there is a need for translating the original low frequency baseband message signal into high frequency wave before transmission. In doing so, we take the help of a high frequency signal, which we already know now, is known as the carrier wave, and a process known as modulation which attaches information to it. The carrier wave may be continuous (sinusoidal) or in the form of pulses, as shown in figure



(a)



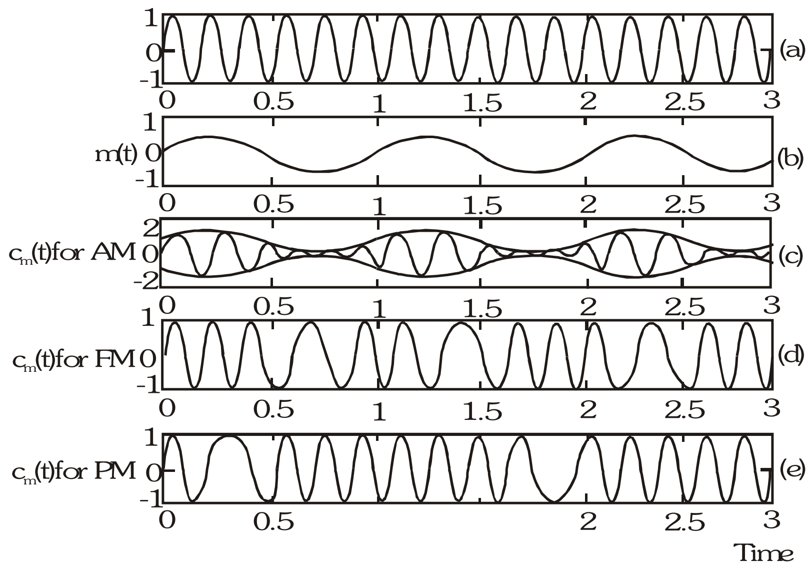
(b)

Carrier wave : Sinusoidal

A sinusoidal carrier wave can be represented as

$c(t) = A_C \sin(\omega_c t + \phi)$

where c(t) is the signal strength (voltage or current), A_C is the amplitude, ω_c (= $2\pi f_c$) is the angular frequency and ϕ is the initial phase of the carrier wave. Thus, modulation can be affected by varying, any of three parameters, viz A_c, ω_c and ϕ, of the carrier wave can as per the parameter of the message or information signal. This results in three types of modulation : (i) Amplitude modulation (AM) (ii) Frequency modulation (FM) and (iii) Phase modulation (PM), as shown in figure.



Modulation of a carrier wave : (a) a sinusoidal carrier wave
(b) a modulating signal : (c) amplitude modulatin :
(d) frequency modulation : and (e) phase modulation

Carrier Wave Pulses :

Similarly, the significant characteristics of a pulse are : Pulse Amplitude, Pulse duration or pulse Width, and pulse Position (denoting the time of rise or fall of the pulse amplitude) Hence, different types of pulse modulation are (a) pulse amplitude modulation (PAM), (b) Pulse duration modulation (PDM) or pulse width modulation (PWM), and (c) Pulse position modulation (PPM).

Ex.1 A separate high freq. wave (i.e. carrier wave) is needed in modulation why ?

Ans. This is because we cannot change any of the characteristics (amplitude, frequency or phase) of the audio signal as this would change the message to be communicated. So keeping the audio signal same, the amplitude of freq. or phase of the high freq. carrier wave is modified in accordance with the modulating (i.e. audio signal) signal.

Amplitude Modulation :

In amplitude modulation the amplitude of the carrier is varied in accordance with the information signals. Let $c(t) = A_c \sin\omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message or the modulating signal where $\omega_m = 2\pi f_m$ is the angular frequency of the message signal. The modulated signal $c_m(t)$ can be written as

$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$

$$= A_c\left(1 + \frac{A_m}{A_c}\sin\omega_m t\right)\sin\omega_c t \qquad .....(1)$$

Note that the modulated signal now contains the message signal & it can be written as :

$$c_m(t) = A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t \qquad ......(2)$$

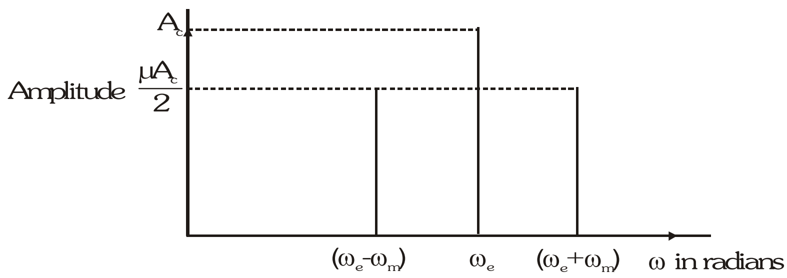
Here **$\mu = A_m/A_c$ is the modulation index**

In paractice, μ is kept ≤ 1 to avoid distortion.

Using the trignomatric relation $\sin A \sin B = ½ (\cos (A - B) - \cos (A + B))$, we can write $c_m(t)$ of eq. (15.4)as

$$c_m(t) = A_c \sin\omega_c t + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2}\cos(\omega_c + \omega_m)t \qquad ......(3)$$

Here $\omega_c - \omega_m$ and $\omega_c + \omega_m$ are respectively called the called the lower side and upper side frequencies. The modulated signal now consists of the carrier wave of frequency ω_c plus two sinusoidal waves each with a frequency slightly different from, know as side bands. The frequency spectrum of the amplitude modulated signal is shown in figure :



As long as the broadcast frequencies (carrier waves) are sufficiently spaced out so that sidebands do not overlap, different stations can operate without interfering with each other.

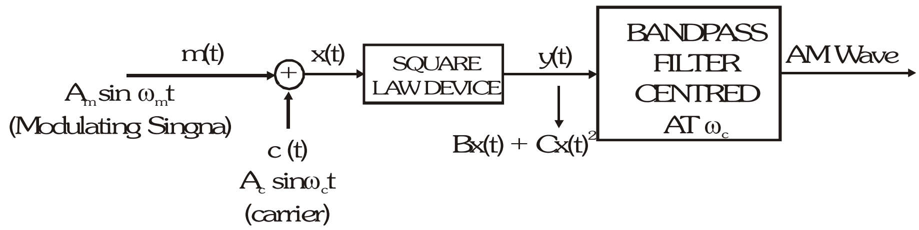
Ex.2 A message signal of frequency 10 kHz and peak voltage of 10 volts is used to modulate a carrier of frequency 1 Mhz and peak voltage of 20 volts. Determine (a) modulation index, (b) the side bands produced.

Sol. (a) Modulation index = 10/20 = 0.5

(b) The side bands are at (1000 + 10 kHz) = 1010 kHz and (1000–10 kHz) = 990 kHz.

Producation of Amplitude modulated Wave :

Ampitude modulation can be produced by a veriety of methods. A conceptually simple method is shown in the block diagram of figure.



Here the modulating signal $A_m \sin \omega_m t$ is added to the carrier signal $A_c \sin \omega_c t$ to produce the signal x (t). This signal $x(t) = A_m \sin \omega_m t + A_c \sin\omega_c t$ is passed through a square law device which is a non-linear device which produces an output

$$y(t) = B\,x(t) + Cx^2(t) \qquad \text{......(4)}$$

where B and C are constants. Thus,

$$y(t) = BA_m \sin\omega_m t + BA_c \sin \omega_c t + C\,[A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin\omega_m t \sin\omega_c t] \qquad \text{......(5)}$$

$$= BA_m \sin\omega_m t + BA_c \sin \omega_c t$$

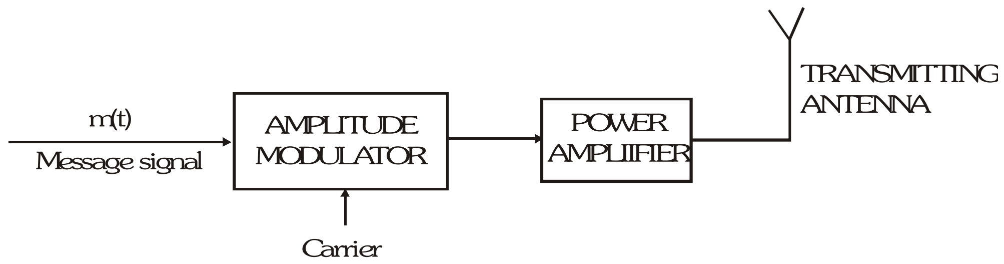
$$\frac{CA_m^2}{2} + A_c^2 - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t$$

$$+ CA_m A_c \cos(\omega_c - \omega_m) t - CA_m A_c \cos(\omega_c + \omega_m) t \qquad \text{......(6)}$$

where the trigonometric relations $\sin^2 A = (1 - \cos 2A)/2$ and the relation for sinA sinB mentioned earlier are used.

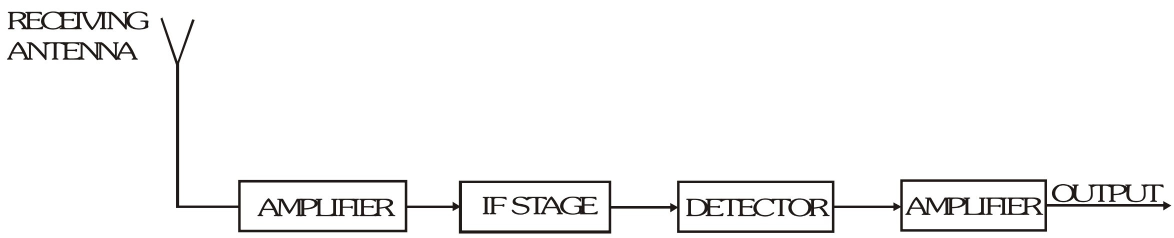
In equation (6), there is a dc term C/2 $(A_m^2 + A_c^2)$ and sinusoids of frequencies ω_m, $2\omega_m$, $\omega_c - \omega_m$ and $\omega_c + \omega_m$. The output of the band pass filter therefore is of the same form as equation (3) and is therefore an AM wave.

It is to be mentioned that the modulated signal connot be transmitted as such. The modulator is to be followed by a power amplifier which provides the necesary power and then the modulated signal is fed to an antenna of appropriate size for radiation as shown in figure.

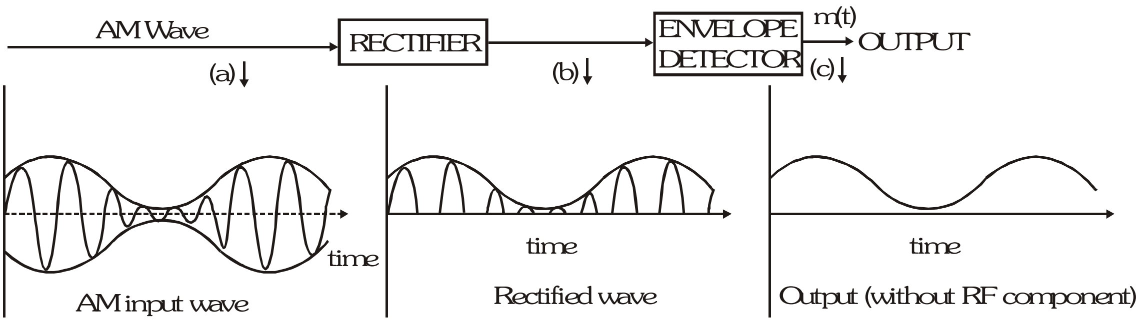


Detection of Amplitude Modulated Wave :

The transmitted message gets attenuated in propagating through the channel. The receiving antenna is therefore to be followed by an amplifier and a detector. In addition, to facilitate further processing, the carrier frequency is usually changed to a lower frequency by what is called an intermediate frequency (IF) stage preceding the detection. The detected signal may not be strong enough to be made use of and hence in required to be amplified. A block diagram of a typical receiver is shown in figure.



Detection is the process of recovering the modulating signal from the modulated carrier wave. We just saw that the modulated carrier wave contains the frequencies ω_c and $\omega_c \pm \omega_m$. In order to obtain the original message signal m(t) of angular frequency ω_m, a simple method is shown in the from of a block diagram in figure.



The modulated signal of the form given in (a) of above figure is passed through a rectifier to produce the output shown in (b). This envelope of signal (b) is the message signal In order to retrieve m(t), the signal is passed through an envelope detector (which may consist of a simple RC circuit).

The internet

Students must be quite familiar with internet these days. The information provided by different these days. The information provided by different bodies all over the world is centralised at one place. Which is then used by anyone having a computer and internet facility. It's main uses are :

(a) Emial (b) File transfer (c) WWW - World Wide Web

(d) E-commerce (e) Chatting

Facsimile (FAX) :

FAX is abbreviation for facsimile which means exact reproduction. A fax machine sends a printed document or a photograph besides speech, music or coded data from one place to another by data communication system which, as we already know, consists of three elements.

Transmitter Transmission channel Receiver

It scans the contents of a document (as an image, not test) to create electronic signals. These signals arethen sent to the destination (another FAX machine) in an orderly manner using telephone lines. At the destination, the signals are reconverted into a replica of the original document.

Mobile telephony

The concept of mobile telephony was developed first in 1970's and it was fully implemented in the following decade. The central concept of this system is to divide the serice area into a suitable number of cells centred on an office called MTSO (Mobile Telephone Switching Office). Each cell contains a low-power transmitter called a base station and castomers. When a mobile receiver crosses the coverage area of one base station, it is necessary for the mobile user to be transferred to another base station. This procedure is called handover or handoff. This process is carried out very rapidly, to the extent that the consumer does not even notice it. Mobile telephones operate typically in the UHF range of frequencies (about 800-950 MHz).

SOLVED EXAMPLE

Ex.1 Suppose a pure Si crystal has 5 10^{28} atoms m^{-3}. It is doped by 1 ppm concentration of pentavalent As. Calculate the number of electrons and hole. (Given that n_i = 1 5 10^{16} m^{-3}.)

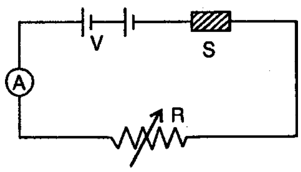
Sol Here $n_e \approx N_D = \left(\frac{5\times10^{28}}{10^6}\right) = 5 \quad 10^{22}\ m^{-3}$

$$n_h = \frac{n_i^2}{n_e} = \frac{\left(1\cdot5\times10^{16}\right)^2}{5\times10^{22}} = \frac{2\cdot25\times10^{32}}{5\times10^{22}} = 4\ 5 \quad 10^9\ m^{-3}$$

Ex.2 Pure Si at 300K has equal electron (n_e) and hole (n_h) concentrations of 1.5 10^{16} m^{-3}. Doping in indium increases n_h to 4.5 10^{22} m^{-3}. Calculate n_e is in the doped Si.

Sol. At thermal equilibrium $n_e n_h = n_i^2 \Rightarrow n_e = \frac{n_i^2}{n_h} = \frac{(1.5\times10^{16})^2}{4.5\times10^{22}} = 5 \quad 10^9\ m^{-3}$

Ex.3 The diagram shows a piece of pure semiconductor S, in series with a variable resistor R, and a source of constant voltage V. Would you increase or decrease the value of R to keep the reading of ammeter (A) constant, when semiconductor S is heated ? Give reason.



Sol. Value of R should be increased with the increase in temperature of semiconductor as circuit resistance decreases and current tends to increase.

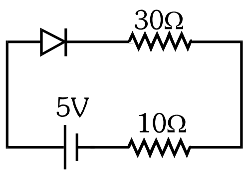
Ex.4 A p–n junction diode can withstand current up to 10 mA under forward bias, the diode has a potential drop of 0.5V across it which is assumed to be independent of current what is the maximum voltage of battery used to forward bias the diode when a resistance of 200Ω is connected in series with it.

Sol. Potential drop is 0.5 and current is 10 mA.

so resistance of diode is $= \frac{0.5}{10\times10^{-3}} = 50\Omega$ Total resistance of circuit is = 200 + 50 = 250Ω

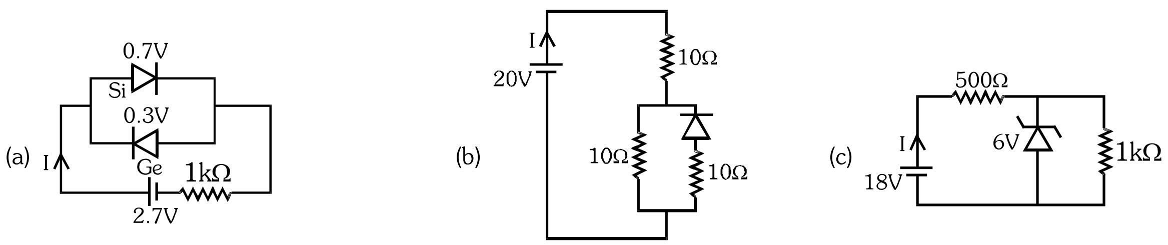
So maximum current is $\frac{V_{max.}}{250} = 10 \quad 10^{-3} \Rightarrow V_{max.} = 2.5$ volt

Ex.5 If current in given circuit is 0.1A then calculate resistance of P–N junction.



Sol. Let resistance of PN junction be R then $I = \frac{5}{R+30+10} = 0.1 \Rightarrow R = 10\Omega$

Ex.6 What is the value of current I in given circuits

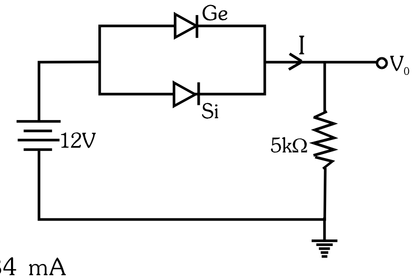


Sol. (a) $I = \frac{2.7-0.7}{1\times10^3} = 2mA$ (b) $I = \frac{20}{10+10} = 1\ A$ (c) $I = \frac{18-6}{500} = 24\ mA$

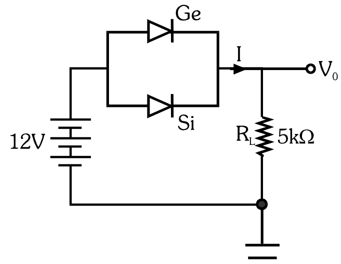
Ex.7 For half wave rectifier if load resistance R_L is 2kΩ and P–N junction resistance R_d is 2kΩ determine rectification efficiency.

Sol. $\eta_{HWR} = 40.6\left(\dfrac{R_L}{R_d + R_L}\right) = 40.6 \quad \dfrac{2k\Omega}{(2+2)k\Omega} = 20.3\ \%$

Ex.8 Calculate the value of V_0 and I if the Si diode and the Ge diode start conducting at 0 7V and 0 3 volt respectively, in the given circuit. If the Ge diode connection be reversed, What will be the new values of V_0 and I ?



Sol. V_0 = 12 – 0 3 = 11 7 V ⇒ Current $I = \dfrac{V_0}{R_L} = \dfrac{11\cdot7}{5\times10^3}$ = 2 34 mA



On reversing the connections of Ge diode the output voltage

V_0' = 12 – 0 7=11 3 V

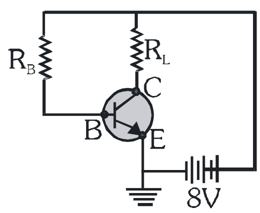
The current in load $I' = \dfrac{V'_0}{R_L} = \dfrac{11\cdot3}{5\times10^3}$ = 2 26 mA

Ex.9 A common emitter amplifier has a voltage gain of 50, an input impedance of 200Ω and an output impedance of 400Ω. Calculate the power gain of the amplifier.

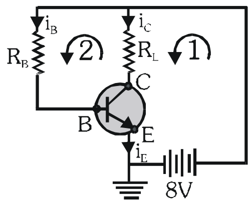
Sol. Voltage gain $= (\beta)\left(\dfrac{R_0}{R_i}\right) = 50 \Rightarrow \beta = \dfrac{50\times R_i}{R_0} = \dfrac{50\times200}{400} = 25$

Power gian $= (\beta^2)\left(\dfrac{R_0}{R_i}\right) = (25)^2\left(\dfrac{400}{200}\right) = 625 \quad 2 = 1250$

Ex.10 An n-p-n transistor in a common emitter mode is used as a simple voltage amplifier with a collector connected to load resistance R_L and to the base through a resistance R_B. The collector-emitter voltage V_{CE} = 4V, the base-emitter voltage V_{BE} = 0.6V, current through collector is 4 mA and the current amplification factor β = 100. Calculate the values of R_L and R_B.



Sol.



Given, i_c = 4 mA

applying Kirchhoff's second law in loop 1,

$V_{CE} = 8 - i_C R_L \Rightarrow R_L = \dfrac{8 - V_{CE}}{i_C} = \dfrac{8-4}{4\times10^{-3}} = 1 \quad 10^3\ \Omega = 1\ k\Omega$

$I_B = \dfrac{I_C}{\beta} = \dfrac{4mA}{100} = 4 \quad 10^{-5}$ A

$\because \quad V_{BE} = 8 - I_B R_B \Rightarrow R_B = \dfrac{8 - V_{BE}}{I_B} = \dfrac{8-0.6}{4\times10^{-5}} = 185\ k\Omega$

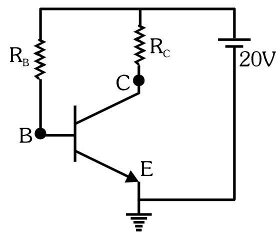
Ex.11 A transistor has a current amplification factor (current gain) of 50. In a CE amplifier circuit, the collector resistance is chosen as 5kΩ and the input resistance is 1kΩ. Calculate the output voltage if input voltage is 0 01V.

Sol. For transistor amplifier $V_0 = \beta\left(\dfrac{R_C}{R_B}\right) V_i = (50)\left(\dfrac{5}{1}\right)$ (0 01) = 2 5 V

Ex.12 In a transistor connected in common emitter mode $R_0 = 4\ k\Omega$, $R_i = 1\ k\Omega$, $i_C = 1$ mA and $i_b = 20\ \mu A$. Find the voltage gain.

Sol. Voltage gain $A_V = \beta\left(\frac{R_0}{R_i}\right) = \left(\frac{i_c}{i_b}\right)\left(\frac{R_0}{R_i}\right) = \left(\frac{1\times10^{-3}}{20\times10^{-6}}\right)\left(\frac{4}{1}\right) = 200$

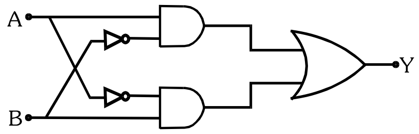
Ex.13 For given CE biasing circuit, if voltage across collector–emitter is 12V and current gain is 100 and base current is 0.04mA then determine the value of collector resistance R_C.



Sol. $\because \quad V_{CE} = V_{CC} - I_C \quad R_C$

$$\therefore\ R_C = \frac{V_{CC}-V_{CE}}{I_C} = \frac{V_{CC}-V_{CE}}{\beta I_B} = \frac{20-12}{100\times0.04\times10^{-3}} = 2\,k\Omega$$

Ex.14 Write down the actual logic operation carried by the following circuit. Explain your answer.



Sol. XOR operation

$\because \quad Y = \overline{A}B + A\overline{B}$ which is boolean expression for XOR gate