Department of Electronics & Communication Engineering.

Course : Basic Electronics-17EC15/25. **Sem.: 2nd (2017-18)**

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Contents

Introduction

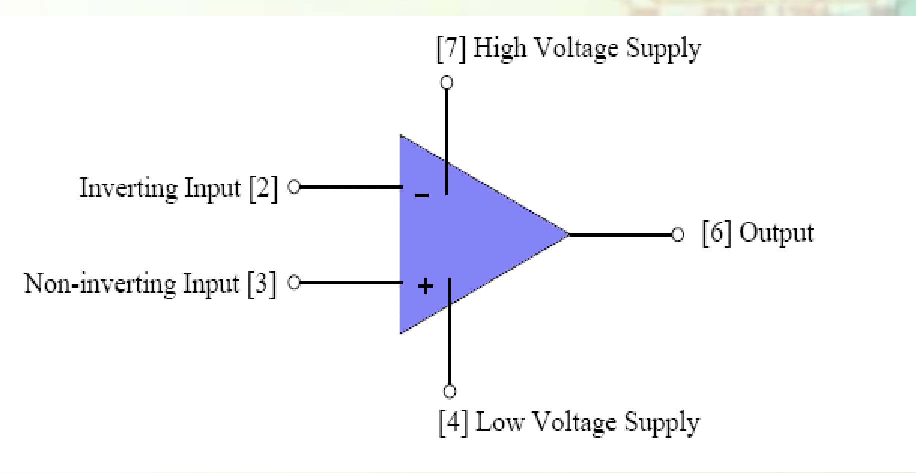
• Operational Amplifiers are represented both schematically and realistically as below.

• Originally invented in early 1940s using vacuum tube technology Initial purpose was to execute math operations in analog electronic calculating machines Shrunk in size with invention of transistor.

• Most now made on integrated circuit (IC).

• Only most demanding applications use discrete components.

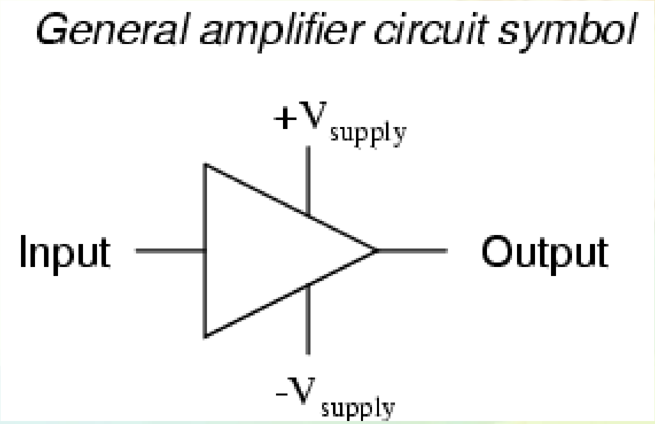
• Huge variety of applications, low cost, and ease of mass production make them extremely popular.

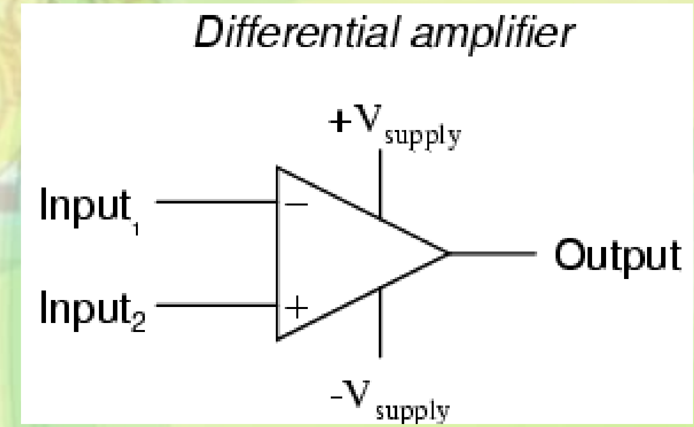


Amplifiers

Single-ended Amplifier

Differential Amplifier amplifies difference between inputs

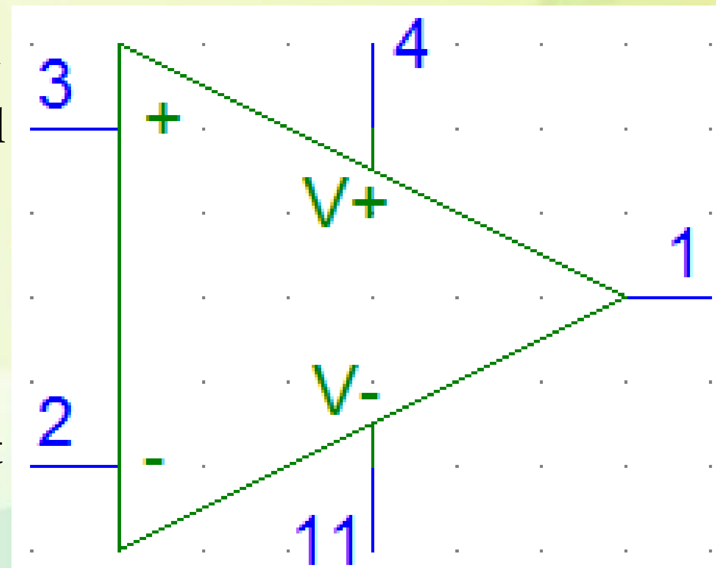




Terminals on an Op- Amp

Positive power supply (Positive rail)

Non-inverting
Input terminal



Output terminal

Inverting input
terminal

Negative power supply
(Negative rail)

Typical Op-Amp Parameters

Parameter	Variable	Typical Ranges	Ideal Values
Open-Loop Voltage Gain	A	10^5 to 10^8	∞
Input Resistance	Ri	10^5 to 10^{13} W	∞ W
Output Resistance	Ro	10 to 100 W	0 W
Supply Voltage	Vcc/V^+ -Vcc/V^-	5 to 30 V -30V to 0V	N/A N/A

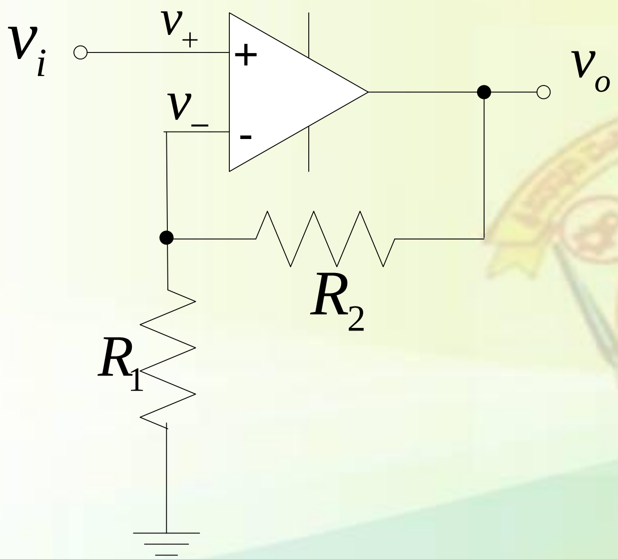
Characteristics of an Ideal Op-Amp

	Ideal Op-Amp	Typical Op-Amp
Input Resistance	Infinity	$10^6\ \Omega$ (bipolar) $10^9\ \Omega$ - $10^{12}\ \Omega$ (FET)
Input Current	0	10^{-12} – 10^{-8} A
Output Resistance	0	100 – 1000 Ω
Operational Gain	Infinity	10^5 - 10^9
Common Mode Gain	0	10^{-5}
Bandwidth	Infinity	Attenuates and phases at high frequencies (depends on slew rate)
Temperature	Independent	Bandwidth and gain

Characteristics of Non-ideal Op-Amp

- Output voltage is limited by supply voltage(s)
- Finite gain ($\sim 10^5$)
- Limited frequency response
- Finite input resistance (not infinite)
- Finite output resistance (not zero)
- Finite slew rate
- Input bias currents
- Input bias current offset
- Input offset voltage
- Finite common mode rejection ratio (CMRR)

Non-inverting Op-Amp



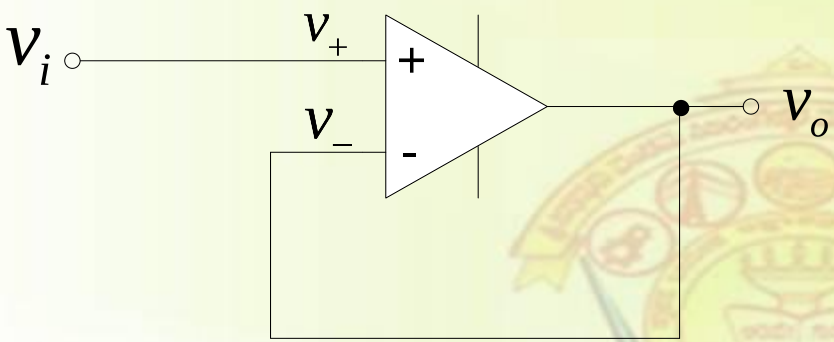
Closed-loop voltage gain

$$A_F = \frac{v_o}{v_i}$$

$$v_i = v_+ = v_- = \frac{R_1}{R_1 + R_2} v_o$$

$$A_F = \frac{v_o}{v_i} = 1 + \frac{R_2}{R_1}$$

Voltage Follower



Closed-loop voltage gain

$$A_F = \frac{v_o}{v_i}$$

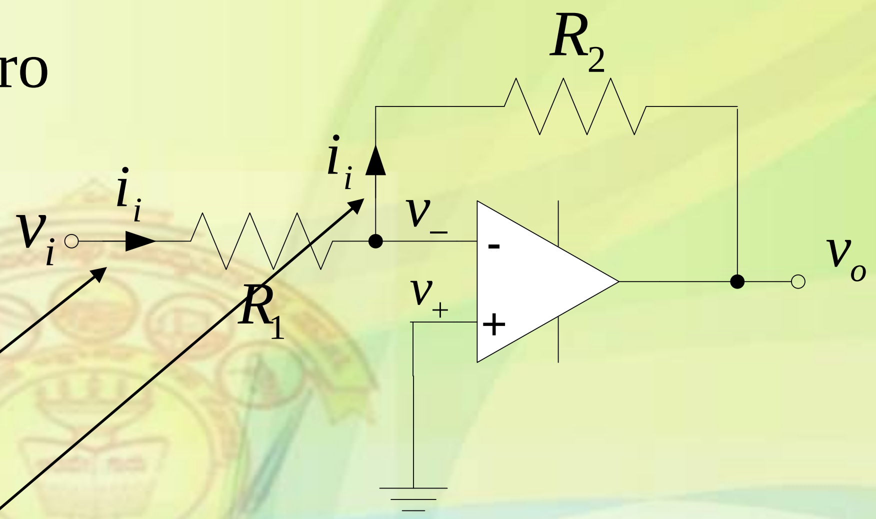
$$v_i = v_+ = v_- = v_o$$

$$A_F = \frac{v_o}{v_i} = 1$$

Used as a "line driver" that transforms a high input impedance (resistance) to a low output impedance. Can provide substantial current gain.

Inverting Amplifier

Current into op-amp is zero



$$v_- = v_+ = 0$$

$$i_i = \frac{v_i - 0}{R_1} = \frac{v_i}{R_1}$$

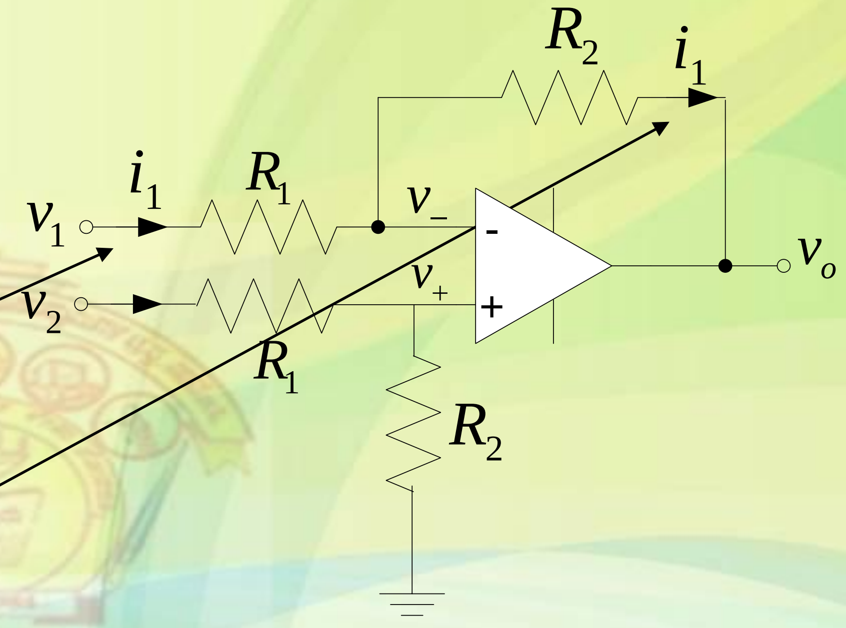
$$i_i = \frac{0 - v_0}{R_2} = \frac{-v_0}{R_2}$$

$$\frac{v_i}{R_1} = \frac{-v_0}{R_2}$$

$$A_F = \frac{v_o}{v_i} = -\frac{R_2}{R_1}$$

Differential Amplifier

Current into op-amp is zero



$$v_- = v_+$$

$$i_1 = \frac{v_1 - v_-}{R_1}$$

$$i_1 = \frac{v_- - v_0}{R_2}$$

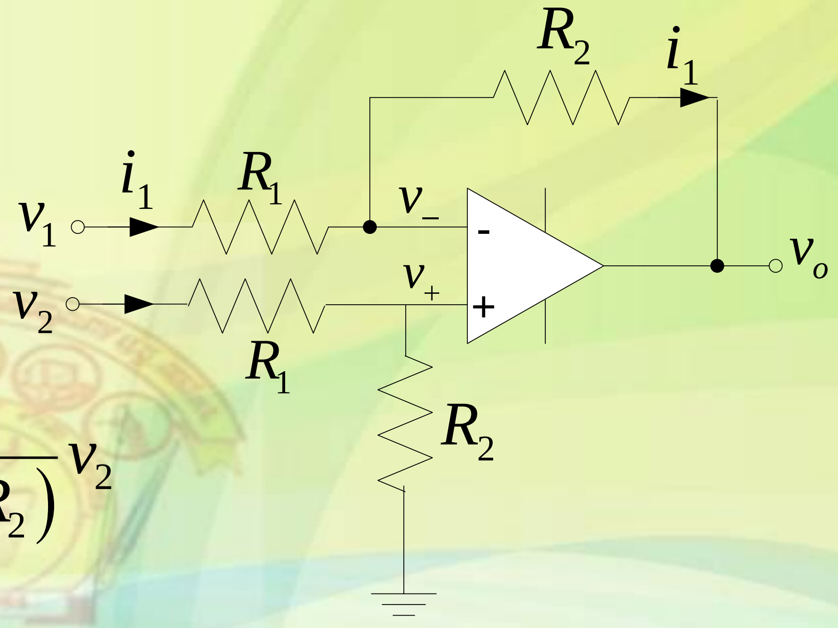
$$v_+ = \frac{R_2}{R_1 + R_2} v_2$$

$$\frac{v_1 - v_+}{R_1} = \frac{v_+ - v_0}{R_2}$$

$$\frac{v_1 - \frac{R_2}{R_1 + R_2} v_2}{R_1} = \frac{\frac{R_2}{R_1 + R_2} v_2 - v_0}{R_2}$$

Differential Amplifier

$$\frac{v_1 - \frac{R_2}{R_1+R_2}v_2}{R_1} = \frac{\frac{R_2}{R_1+R_2}v_2 - v_0}{R_2}$$

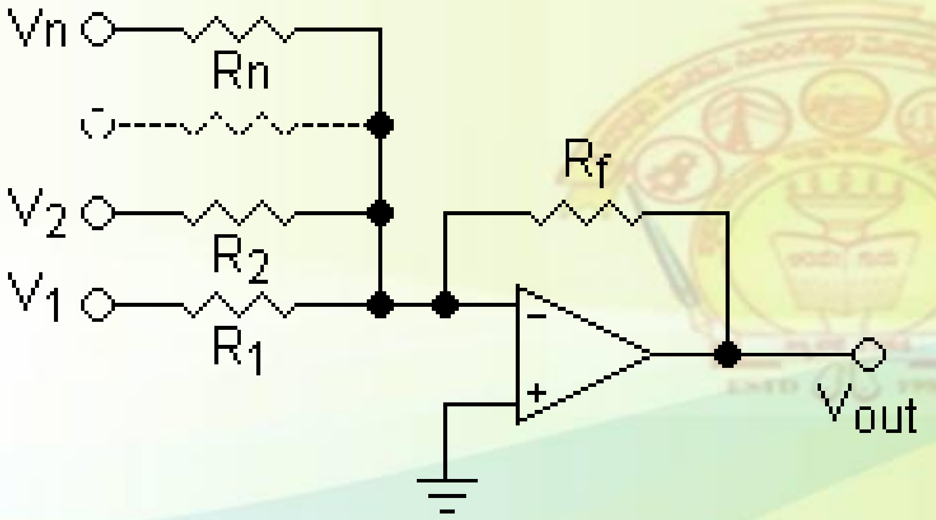


$$v_0 = -\frac{R_2}{R_1}v_1 + \frac{R_2}{R_1+R_2}v_2 + \frac{R_2^2}{R_1\left(R_1+R_2\right)}v_2$$

$$v_0 = -\frac{R_2}{R_1}v_1 + \frac{R_2}{R_1+R_2}\left(1+\frac{R_2}{R_1}\right)v_2$$

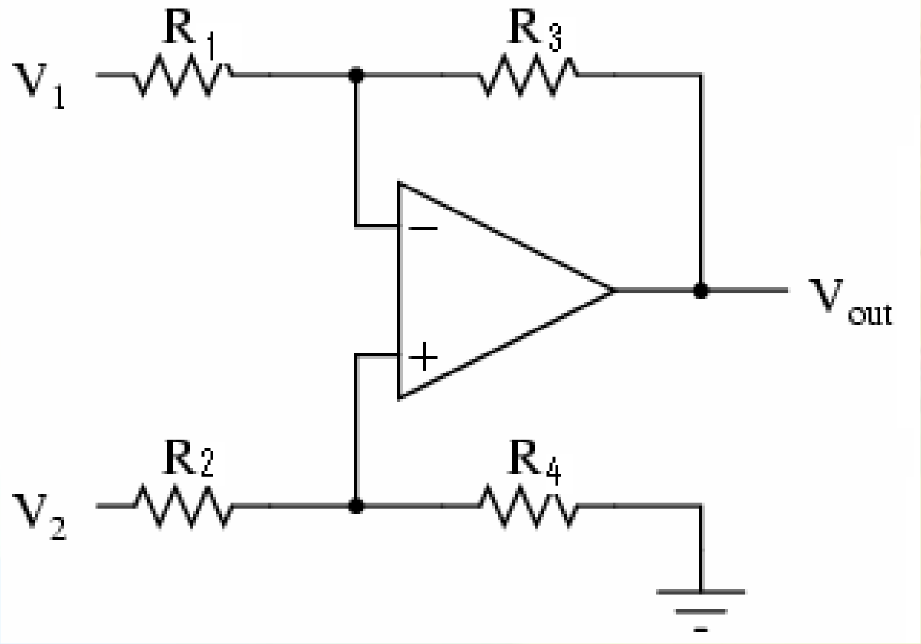
$$v_0 = \frac{R_2}{R_1}\left(v_2 - v_1\right)$$

Summer/Adder Op-Amp



$$V_{\text{out}} = -R_{\text{f}}\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \cdots + \frac{V_n}{R_n}\right)$$

Subtractor Op-amp

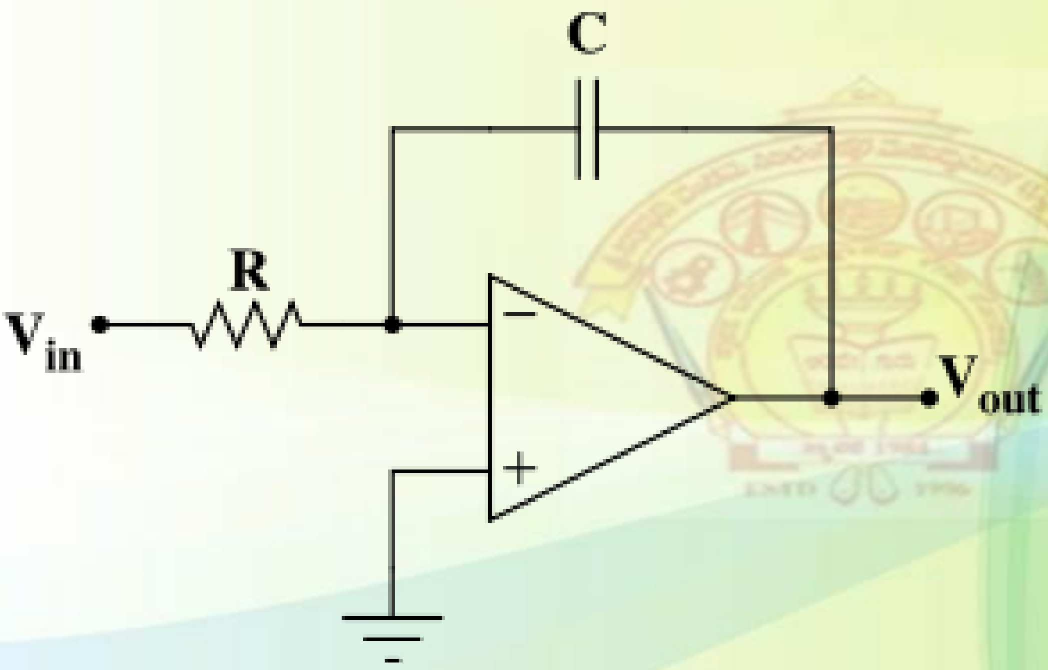


$$V_{out} = \frac{V_2(R_3 + R_1)R_4}{(R_4 + R_2)R_1} - \frac{V_1 R_3}{R_1}$$

If all resistors are equal:

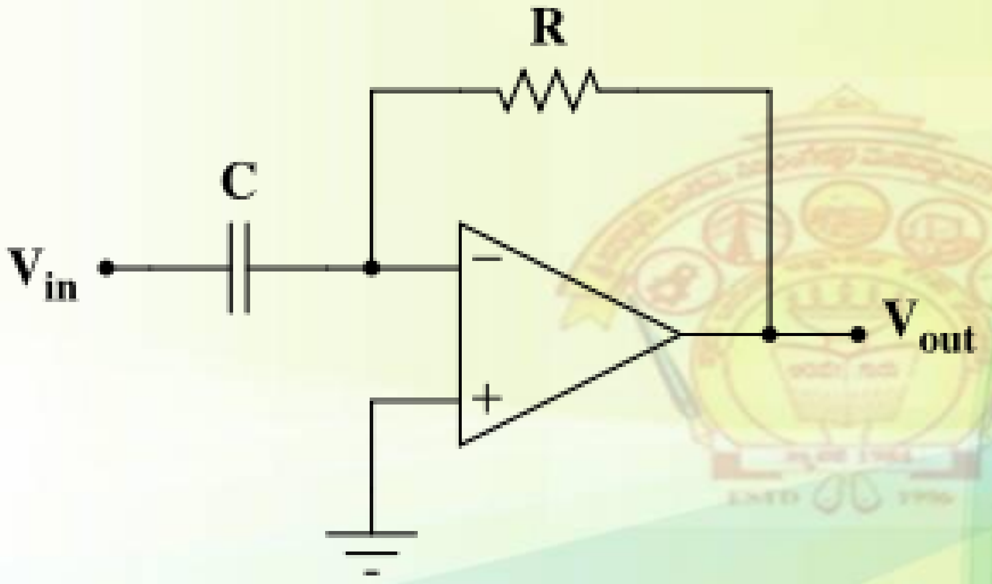
$$V_{out} = V_2 - V_1$$

Integrating Op-Amp



$$V_{\text{out}} = \int_0^t -\frac{V_{\text{in}}}{RC}\,dt + V_{\text{initial}}$$

Differentiating Op-Amp



$$V_{\text{out}} = -RC\left(\frac{dV_{\text{in}}}{dt}\right)$$

(where V_{in} and V_{out} are functions of time)

Communication Systems:

- Introduction
- Elements of Communication Systems
- Modulation: Amplitude Modulation
- Spectrum Power
- AM Detection (Demodulation)
- Frequency Modulation
- Phase Modulation
- Amplitude and Frequency Modulation: A comparison.

Information, Messages, Signals

- Information: general intuitive term.
- Message: a physical manifestation of the information as produced by the source.
- Various sources of messages (people, machines, measuring instruments, etc.).
- Analog message: a physical time-variable quantity usually in smooth and continuous form.
- Digital message: ordered sequence of symbols selected from finite set of elements.
- Signal: physical embodiment of the information.

Signal ≈ Message

- Electrical signal: voltage or current representing the message.

Elements of a Communication System

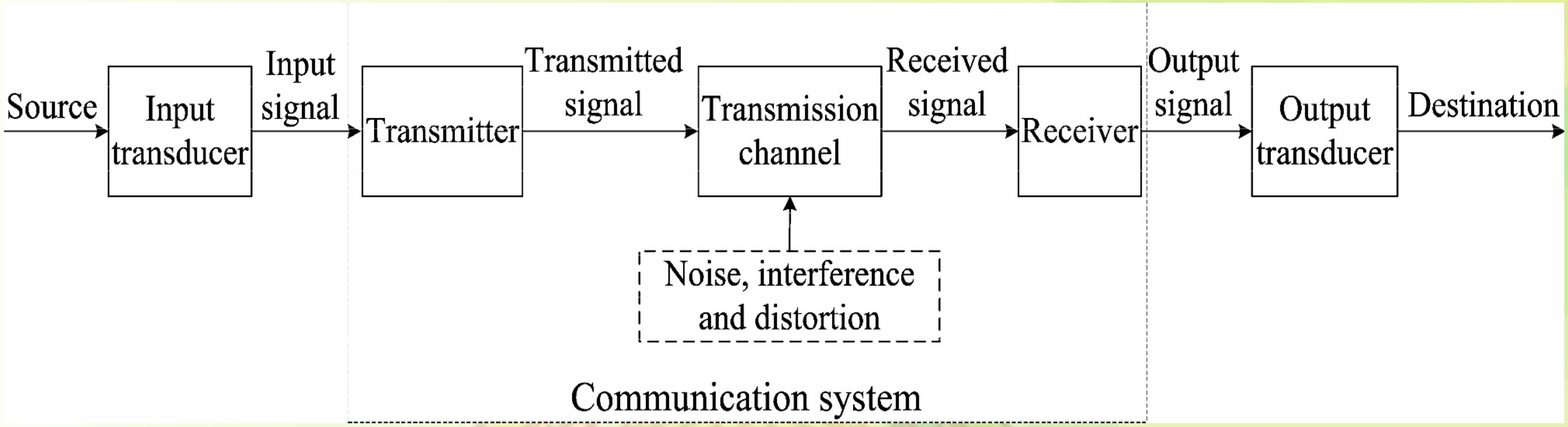


Figure 1. Block-diagram of a communication system with input and output transducers.

- Input transducer converts the message to an electrical signal.
- The transmitter converts the input signal to transmitted signal suited for the transmission channel.
- Transmission cannel is the electric medium that bridges the distance from source to destination.
- The receiver converts the received signal in a form appropriate for the output transducer.
- Output transducer converts the output electrical signal the desired message form.

Basic operations in the transmitter

- Modulation
- Coding

Basic operations in the receiver

- Amplification
- Filtering
- Demodulation
- Decoding

Effects of the channel on the transmitted signal

- Attenuation: decreasing the signal strength;
- Distortion of the signal waveform: caused by channel characteristics (linearity, frequency response, etc.)
- Noise: contamination of random natural signals added to the transmitted signal
- Interference: contaminations of extraneous signal of human sources – machinery, power lines, digital switching circuits, etc.

Modulation

Modulation Methods

- Modulating signal – represents the message.
- Carrier wave – suits the application.
- Usually the modulation signal is much slower than the carrier wave.
- Modulation – altering one or more of the parameters (amplitude, frequency, phase, pulse width) of the carrier in correspondence with the modulating signal.
- Demodulation – extraction of modulating signal from modulated signal; reverse operation to modulation.
- Continuous wave modulation – when the carrier is sinusoidal.
- Pulse modulation – the carrier is pulse train.

Need for Modulation

• The baseband signals are incompatible for direct transmission. For such a signal, to travel longer distances, its strength has to be increased by modulating with a high frequency carrier wave, which doesn't affect the parameters of the modulating signal.

Advantages of Modulation

• The antenna used for transmission, had to be very large, if modulation was not introduced. The range of communication gets limited as the wave cannot travel to a distance without getting distorted.

Following are some of the advantages for implementing modulation in the communication systems.

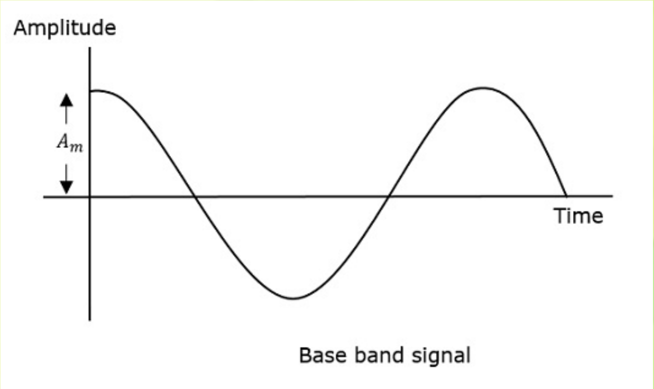
• Antenna size gets reduced.
• No signal mixing occurs.
• Communication range increases.
• Multiplexing of signals occur.
• An adjustment in the bandwidth is allowed.
• Reception quality improves.

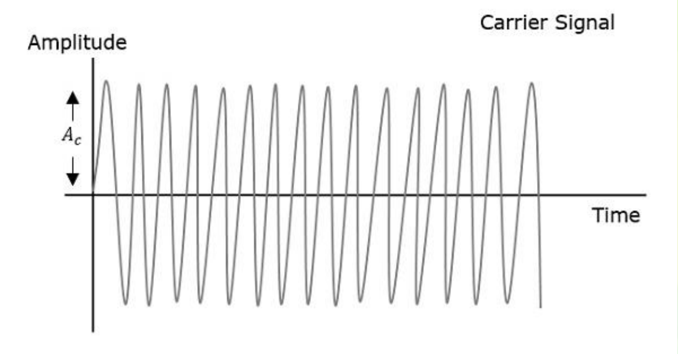
Modulation Benefits and Applications

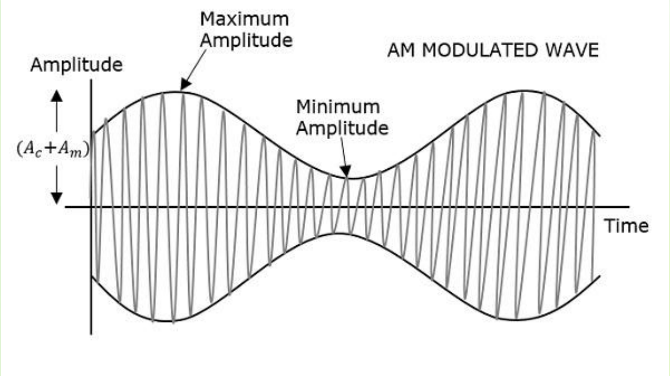
- Modulation for efficient transmission
- Modulation to overcome hardware limitation
- Modulation to overcome noise and interference;
- Modulation for frequency assignment
- Modulation for multiplexing: frequency division; time division, multiple access
- Coding methods and benefits

Amplitude Modulation

"The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal." Which means, the amplitude of the carrier signal which contains no information varies as per the amplitude of the signal, at each instant, which contains information. This can be well explained by the following figures.







Mathematical Expression

Following are the mathematical expression for these waves.

Time-domain Representation of the Waves

Let modulating signal be : $m(t)=A_m\cos(2\pi f_m t)$

Let carrier signal be : $c(t)=A_c\cos(2\pi f_c t)$

Where A_m = maximum amplitude of the modulating signal

A_c = maximum amplitude of the carrier signal

The standard form of an Amplitude Modulated wave is defined as −

$S(t)=A_c[1+K_a m(t)] \cos(2\pi f_c t)$

$S(t)=A_c[1+\mu\cos(2\pi f_m t)]\cos(2\pi f_c t)$

Where, $\mu=K_a A_m$

Modulation Index

A carrier wave, after being modulated, if the modulated level is calculated, then such an attempt is called as Modulation Index or Modulation Depth. It states the level of modulation that a carrier wave undergoes.

Bandwidth of Amplitude Modulation

The bandwidth is the difference between lowest and highest frequencies of the signal.

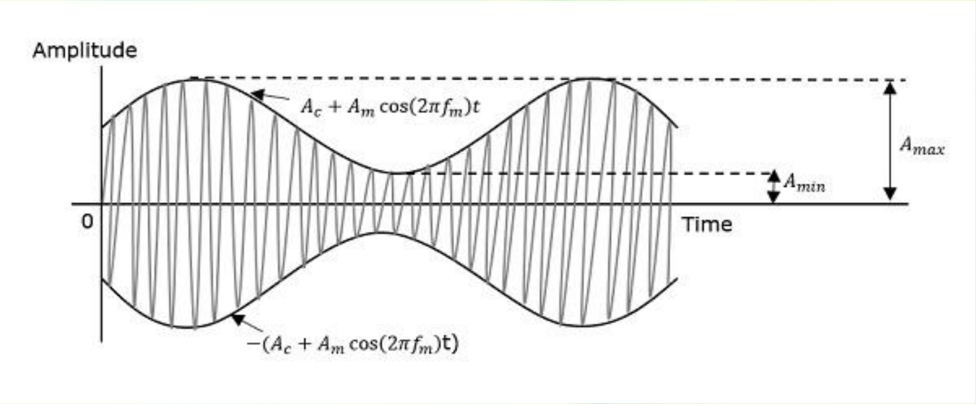
For amplitude modulated wave, the bandwidth is given by

$BW = f_{USB} - f_{LSB}$

$= (f_c + f_m) - (f_c - f_m)$

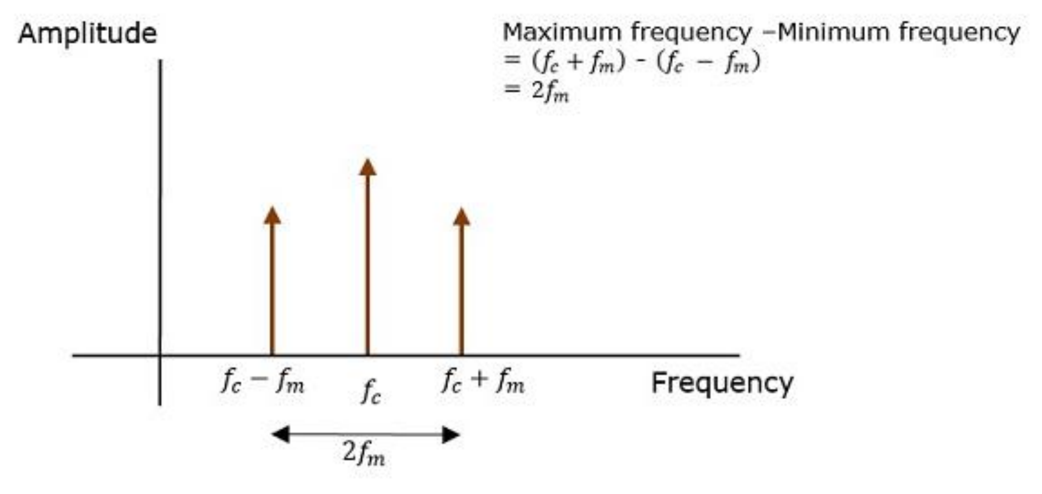
$= 2f_m = 2W$

Where W is the message bandwidth



Sideband

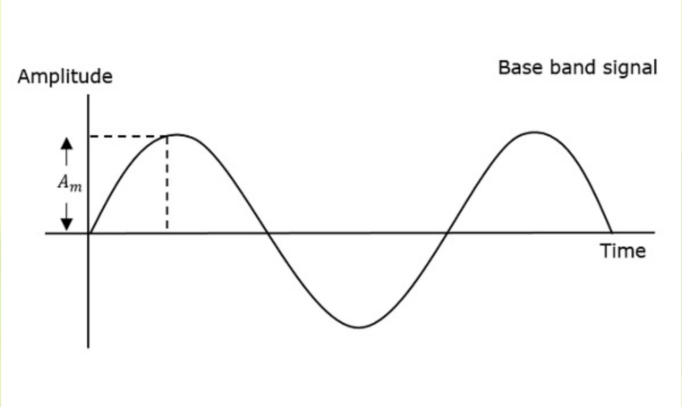
A Sideband is a band of frequencies, containing powers, which are the lower and higher frequencies of the carrier frequency. Both the sidebands contain the same information. The representation of amplitude modulated wave in the frequency domain is as shown in the following figure.

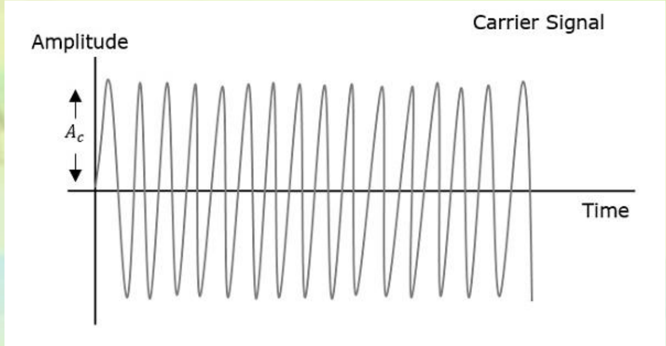


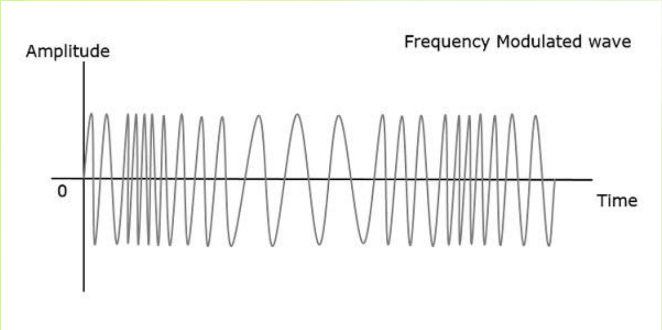
Both the sidebands in the image contain the same information. The transmission of such a signal which contains a carrier along with two sidebands can be termed as Double Sideband Full Carrier system, or simply DSB-FC.

Frequency Modulation

- In Frequency Modulation (FM), the frequency of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.
- The amplitude and the phase of the carrier signal remains constant whereas the frequency of the carrier changes. This can be better understood by observing the following figures.







Equation for FM WAVE

The equation for FM wave is −

$s(t)=A_c \cos [W_c t+2\pi k_f m(t)]$

Where,

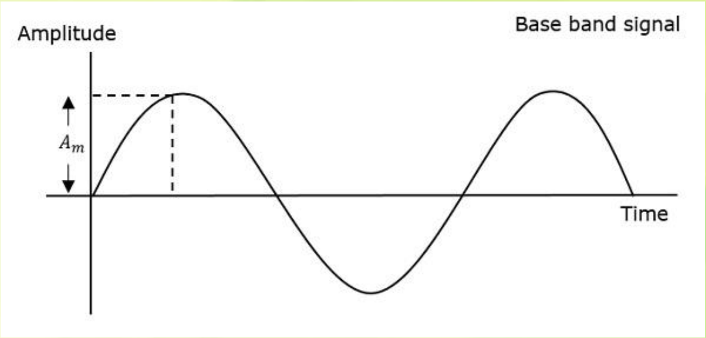
A_c = the amplitude of the carrier

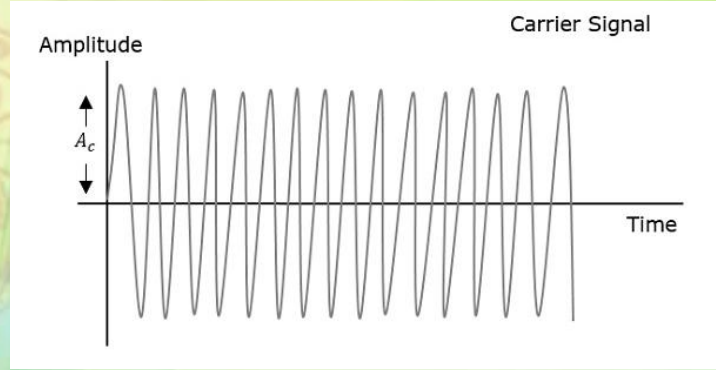
w_c = angular frequency of the carrier = $2\pi f_c$

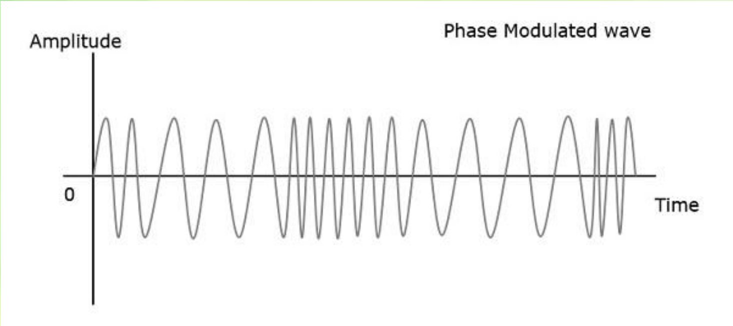
$m(t)$ = message signal.

Phase Modulation

- In Phase Modulation (PM), the phase of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.
- The amplitude and the frequency of the carrier signal remains constant whereas the phase of the carrier changes. This can be better understood by observing the following figures.







Difference Between AM and FM	
Amplitude Modulation (AM)	**Frequency Modulation (FM)**
First successful audio transmission was carried out in mid-1870s	Developed in 1930 by Edwin Armstrong, in the United States
The radio wave is called as a carrier wave and the frequency and phase remain same	The radio wave is called a carrier wave, but the amplitude and phase remain same.
Has poor sound quality, but can transmit longer distance.	Has higher bandwidth with better sound quality
The frequency range of AM radio varies from 535 to 1705 KHz	The frequency range of FM is 88 to 108 MHz in higher spectrum
More susceptible to noise	Less susceptible to noise.

Queries …?