كلية المامون الجامعة

قسم تقنيات الهندسة الكهربائية

Communication system

Eng. BILAL LATEEF ALTAMIMI

Lecture 1

Course plan

- Introduction to Communication Systems
- Signals and Spectra
- Analog Modulation Techniques
- Digital Modulation Techniques
- Communication Channels and Their Characteristics

Communication systems

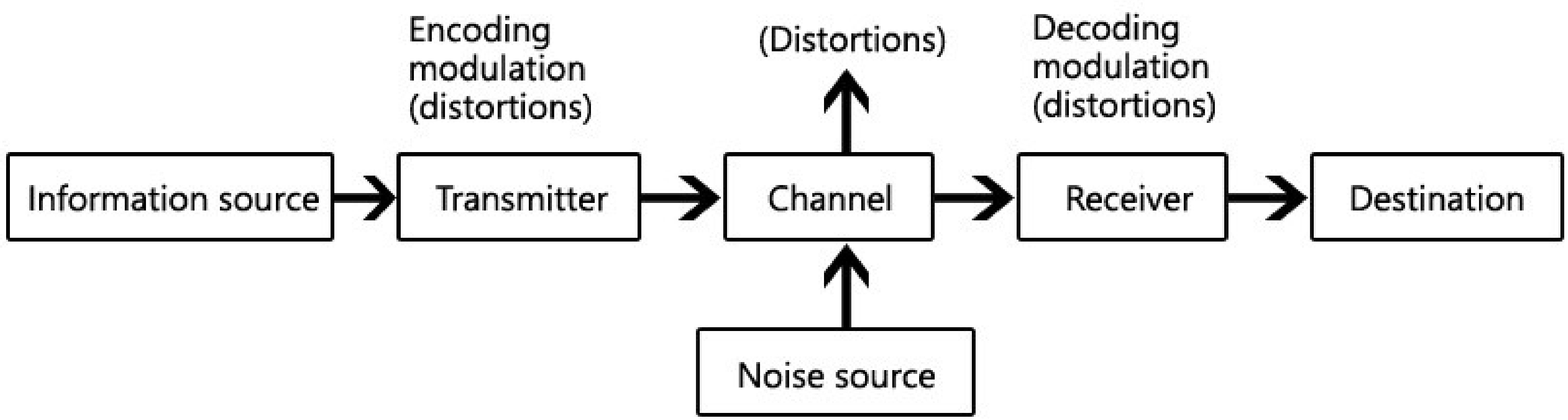
- Definition and significance of communication systems
- Basic elements: Transmitter, Channel, Receiver
- Types of communication: Analog & Digital
- Overview of wired and wireless communication
- Applications in modern technology

Communication system

Is a combination of hardware and software that enables the transmission, reception, and processing of information between entities. It includes transmitters, channels, and receivers, ensuring efficient data transfer.

Basic elements of communication system

1.Transmitter 2. Channel 3.Receiver



Transmitter

- **A transmitter is a key component of a communication system that converts information into a signal for transmission. It processes and modulates the input signal to ensure efficient and accurate delivery to the receiver.**

Functions of a Transmitter

- **Signal Generation** – Converts the input message (audio, video, or data) into an electrical signal.
- **Modulation** – Alters the signal using modulation techniques (AM, FM, PSK, etc.) to match the transmission medium.
- **Amplification** – Boosts the signal strength for long-distance transmission.
- **Frequency Conversion** – Adjusts the signal frequency for compatibility with the channel.
- **Transmission** – Sends the processed signal through wired or wireless channels.

Types of communication

- **Analog Communication** : Information is transmitted using continuous signals that vary in amplitude or frequency. a wave that can take on any value within a range.

- **Advantages**: Simpler to implement in some cases can be more accurate for certain types of signals
- **Disadvantages**: Susceptible to noise and interference signal quality degrades over distance less efficient use of bandwidth

wired communication

- Uses physical cables, such as Ethernet or fiber optic cables, to transmit data as electrical or optical signals.

- Examples of wired technologies, Ethernet , Fiber optic , USB

- Common uses: Connecting computers in offices or homes , High-bandwidth applications like gaming or video streaming , Industrial settings where reliability is crucial

wired communication

- **Advantages:**

✓ Speed: Generally offers faster data transfer speeds.

✓ Reliability: Less susceptible to interference, resulting in a more stable connection.

✓ Security: Data is more secure as it's confined to the physical cable.

wired communication

- Disadvantages:
  - Mobility: Devices are tethered to the cable, limiting movement.
  - Installation: Can be more complex and expensive due to cabling requirements.

Wireless Communication

- Uses radio waves, infrared signals, or other wireless technologies to transmit data.

- Examples of wireless technologies : Wi-Fi , Bluetooth Cellular networks (3G, 4G, 5G)Infrared

- Common uses: connecting mobile devices like smartphones and laptops Home networks Public Wi-Fi hotspots

Wireless Communication

- **Advantages:**

✓ Mobility: Devices can move freely within the network range.

✓ Convenience: Easier and cheaper to set up, especially in areas where cabling is difficult.

✓ Scalability: Easily add new devices to the network

Wireless Communication

- **Disadvantages:**
- Speed: Generally slower than wired connections, although speeds are constantly improving.
- Reliability: More susceptible to interference, which can affect connection stability.
- Security: Data is more vulnerable to interception

Lecture 2

Modulation

The process of changing some characteristic (e.g. amplitude, frequency or phase) of a carrier wave in accordance with the intensity of the signal

Modulation

❑ Why modulation is necessary ?

- **Practical antenna length.**

$$\text{wavelength} = \frac{\text{velocity}}{\text{frequency}} = \frac{3\times10^8}{\text{frequency (Hz)}} \text{ metres}$$

- **Operating range.** To enable long-distance transmission, using high-frequency carrier wave. High-frequency carrier waves ensure better propagation.
- **Minimized Interference** : Modulation helps in reducing noise and signal overlap.
- **Multiplexing**: Multiple signals can be transmitted simultaneously without interference.
- **Better Bandwidth Utilization** – Allows efficient use of available frequency spectrum

Types of Modulation Methods

- **Amplitude Modulation (AM)** – Varies the amplitude of the carrier wave according to the message signal.
- **Frequency Modulation (FM)** – Varies the frequency of the carrier wave based on the message signal.
- **Phase Modulation (PM)** – Changes the phase of the carrier wave in response to the message signal.

Amplitude Modulation

- the amplitude of high frequency carrier wave is changed in accordance with the intensity of the signal.
- The amplitude of the carrier wave changes according to the intensity of the signal.
- The amplitude variations of the carrier wave is at the signal frequency fs .
- The frequency of the amplitude modulated wave remains the same i.e. carrier frequency fc

Types of Amplitude Modulation (AM)

- **Double Sideband Full Carrier (DSB-FC)** : Standard AM with both sidebands and a carrier.
- **Double Sideband Suppressed Carrier (DSB-SC)**: Both sidebands remain, but the carrier is removed.
- **Single Sideband (SSB)**:Only one sideband (either upper or lower) is transmitted, saving bandwidth.
- **Vestigial Sideband (VSB)** : A partial second sideband is retained for better signal recovery, used in TV broadcasting.
- **Amplitude Modulation Vestigial Carrier (AM-VSB)**: Similar to VSB but retains a small carrier for synchronization.
- **Quadrature Amplitude Modulation (QAM)** : Combines AM with phase modulation for increased data capacity.

Basic Principles of Amplitude Modulation

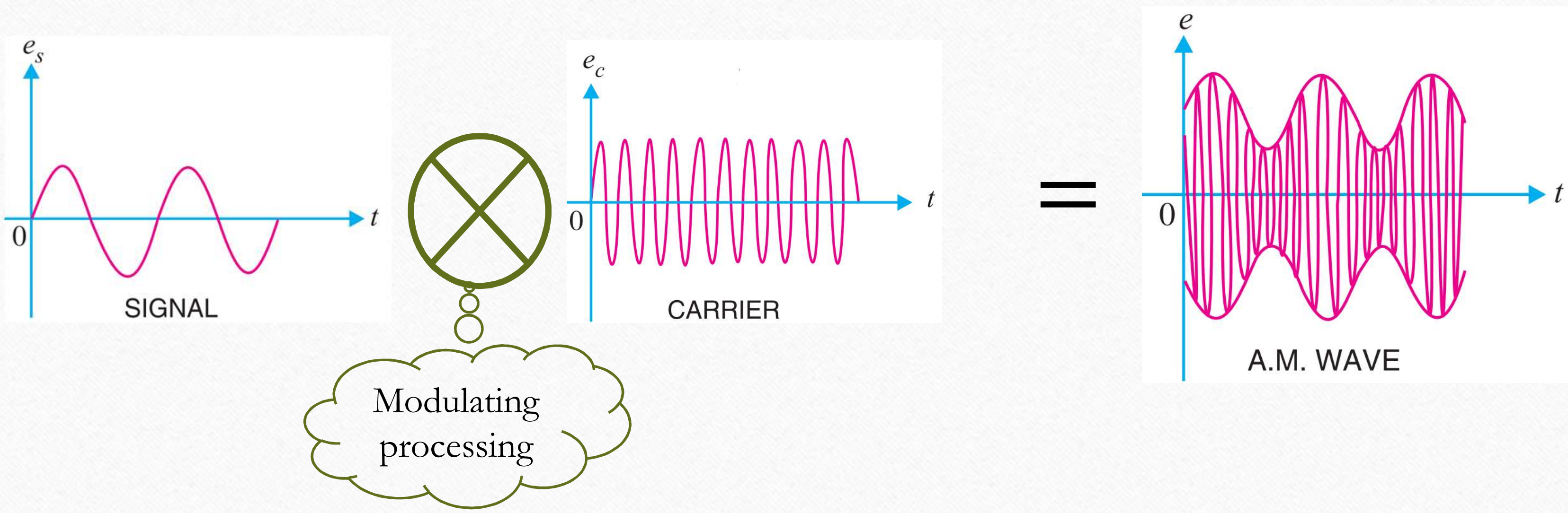
Based on Double Sideband Full Carrier (DSB-FC)

- $v_{AM} = V_c \sin(2\pi f_c t) + (V_m \sin(2\pi f_m t))(\sin 2\pi f_c t)$

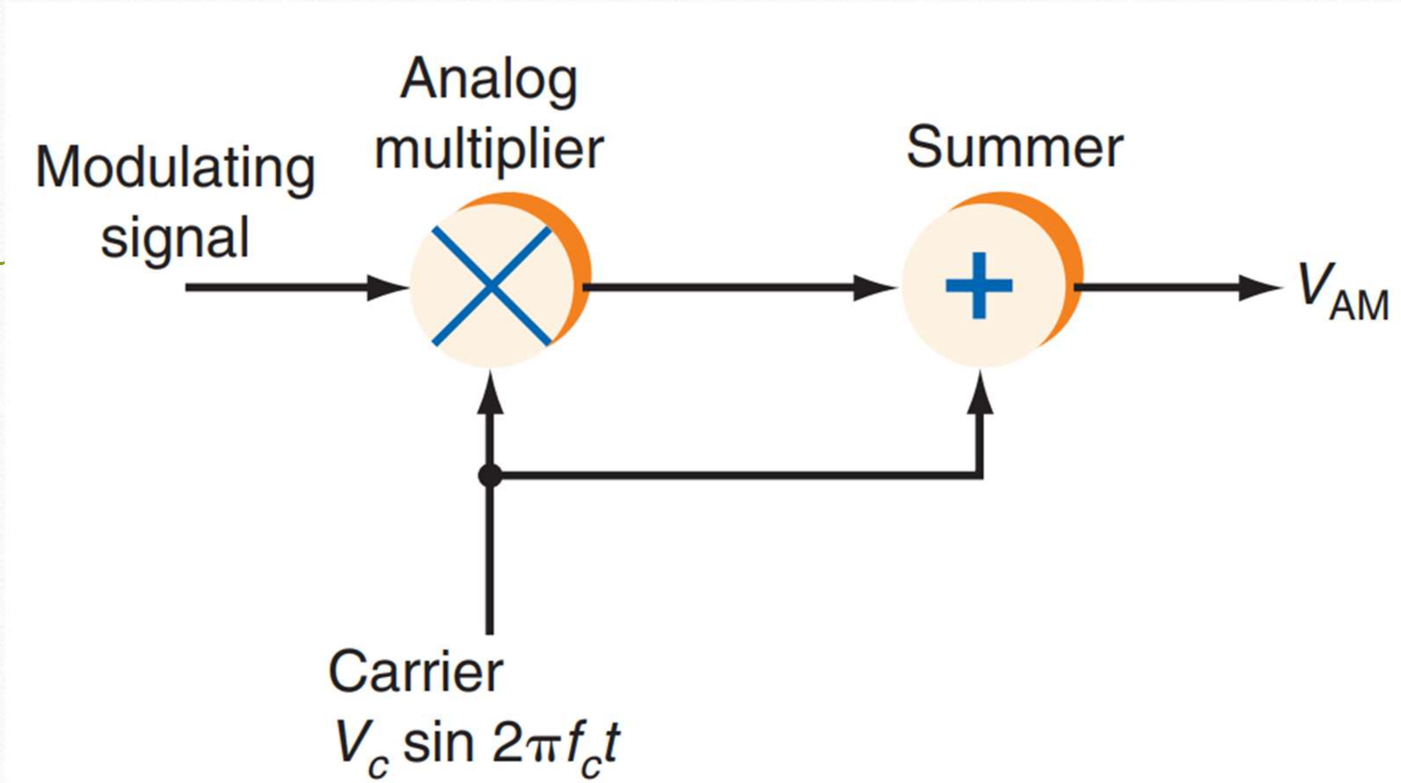
Where :

- ✓ **($V_c \sin(2\pi f_c t)$)** the first term is the sine wave carrier
- ✓ **($V_m \sin(2\pi f_m t))(\sin 2\pi f_c t)$** second term is the product of the sine wave carrier and modulating signals.
- ✓ v_{AM} is the instantaneous value of the amplitude modulation voltage.

Basic Principles of Amplitude Modulation



Eng. BILAL LATEEF ALTAMIMI



Block diagram of a circuit to produce AM

The modulation index

- The modulation index m is the ratio of the modulating signal amplitude to the carrier amplitude : $\mu = \frac{V_m}{V_c}$ or $\mu = \frac{V_{max} - Vmin}{V_{max} + Vmi_n}$
- $\vee_{AM} = V_c \sin(2\pi f_c t)[1 + (\mu \sin(2\pi f_m t)]$
- To measure of how much the carrier wave's amplitude varies due to the modulating signal.
- To determine the extent of modulation and affects signal quality and power distribution.

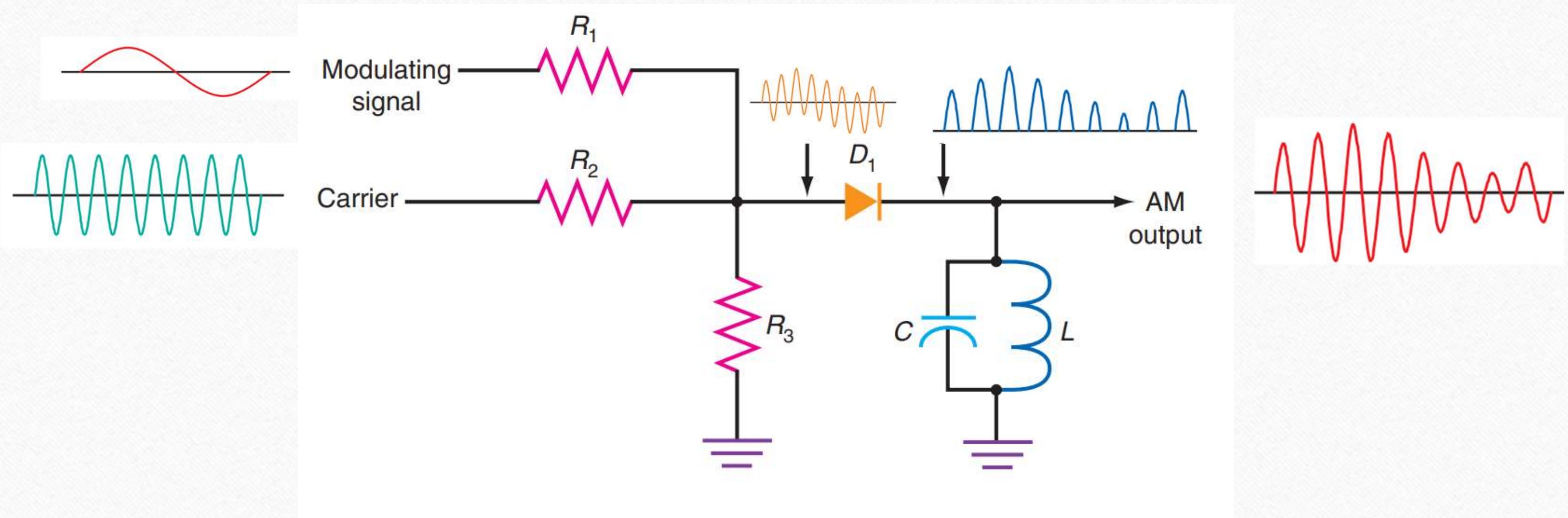
The modulation index

- To determine the extent of modulation and affects signal quality and power distribution.

- **Under-Modulation ($\mu<1$)**: The carrier signal is dominant. The message signal is weak. No distortion, but inefficient transmission.
- **Critical or 100% Modulation ($\mu=1$):** Maximum signal strength without distortion. Ideal condition for AM transmission.
- **Over-Modulation ($\mu>1$):** The message signal is too strong. Causes distortion and loss of information. Leads to carrier phase reversal and sideband splatter (harmonics interfering with nearby channels).

Lecture 3

Diode Modulator



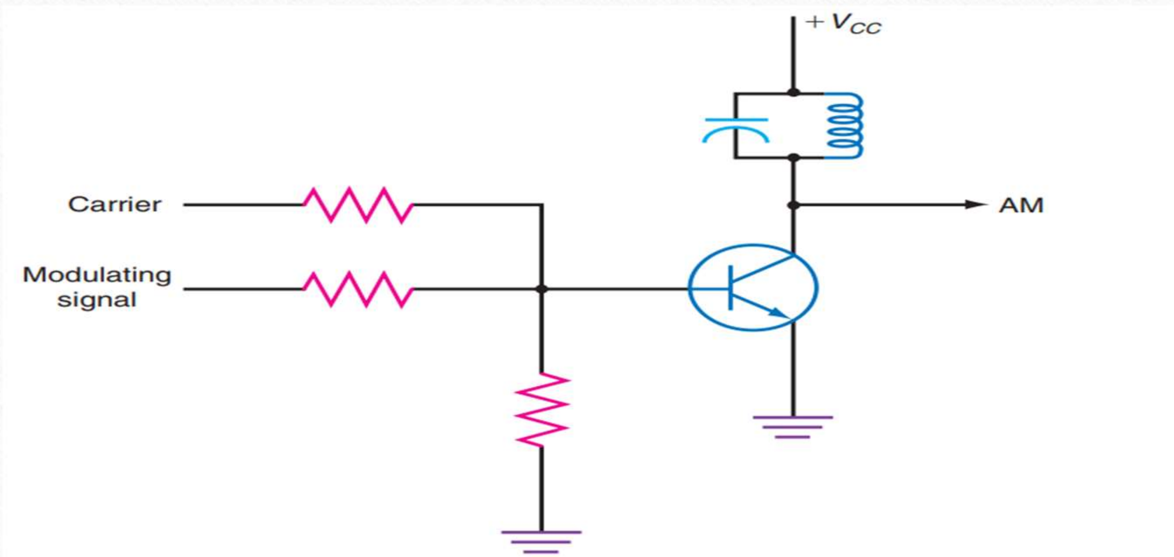
Eng. BILAL LATEEF ALTAMIMI

Diode Modulator

Low-Level AM:The simplest amplitude modulators.

- ❑consists of a resistive mixing network
- ❑The mixed signals appear across R3
- ❑LC tuned circuit.
- ❑These positive-going pulses are applied to the parallel-tuned circuit.
- ❑L and C, which are resonant at the carrier frequency.
- ❑Each time the diode conducts, a pulse of current l ows through the tuned circuit.
- ❑The coil and capacitor repeatedly exchange energy, causing an oscillation, or "ringing," at the resonant frequency.

Simple transistor modulator



Simple transistor modulator

The transistor acts as a mixer, combining the carrier and message signals to produce an amplitude-modulated output.

- **Principle:**

- **Carrier Input:** A high-frequency carrier signal is applied to the base of the transistor.
- **Modulating Signal Input:** The low-frequency message signal (audio or data) is fed into the base or emitter.
- **Mixing Process:** The transistor operates in a non-linear region, allowing multiplication of the two signals, resulting in amplitude modulation.
- **Output:** The modulated signal is taken from the collector, which contains the carrier along with the sidebands (modulated output).

Lecture 4

Basic Filter

❖ ***Filters are essential components in signal processing, used to modify the amplitude and phase of input signals based on frequency.***

➢ **Filter types:**

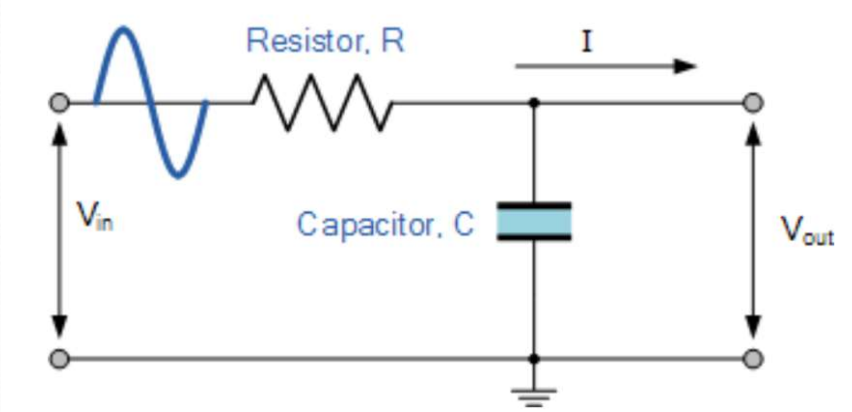
1. **Low-Pass Filter (LPF)**
2. **High-Pass Filter (HPF)**
3. **Band-Pass Filter (BPF)**
4. **Band-Stop Filter (BSF) or Notch Filter**

**** Each filter type has a unique frequency response, characterized by mathematical equations and graphical representations.***

Low-Pass Filter (LPF)

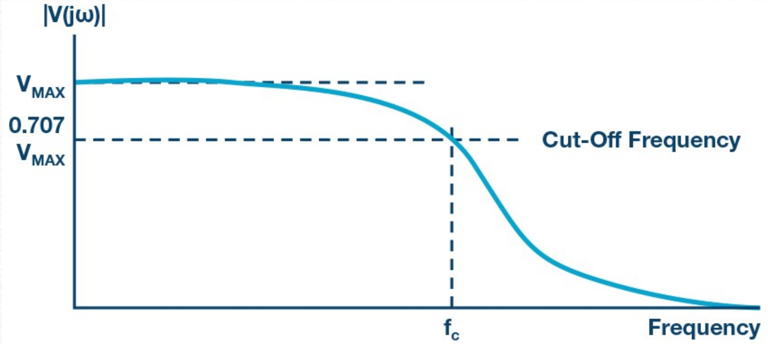
- used to pass low-frequency waves and attenuate high frequency waves.
- The capacitor represent electrical impedances that vary according to the frequency . $X_c = \frac{1}{\omega C}$

,



RC Low-Pass Filter (LPF)

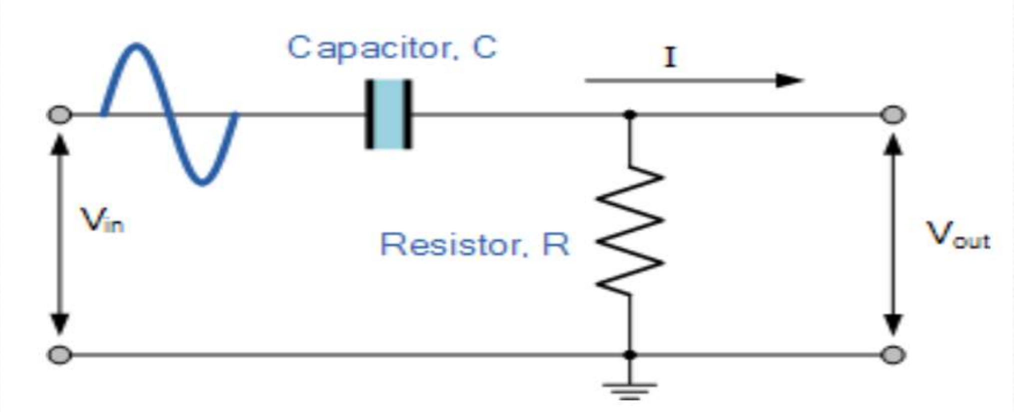
- The gain ratio between input signal and output signal $\frac{v_{out}}{v_{in}} = \frac{1}{1+j\omega RC}$
- The cutoff frequency can be drive from above equation when the gain = $\frac{1}{\sqrt{2}}$, fc= $\frac{1}{2\pi RC}$



High-Pass Filter (LPF)

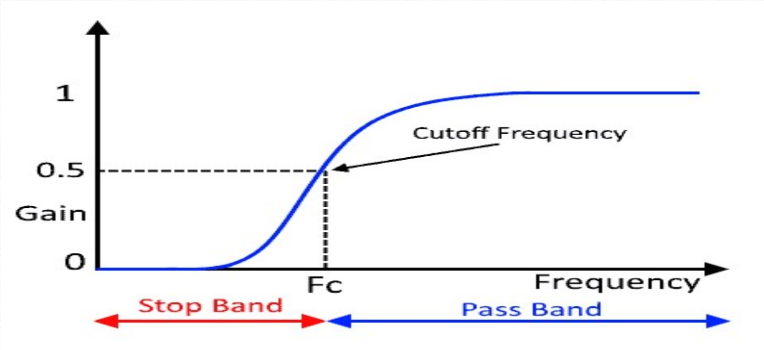
- used to pass high-frequency waves and attenuate high frequency waves.
- The capacitor represent electrical impedances that vary according to the frequency . $X_c = \frac{1}{\omega c}$

,



RC High-Pass Filter (LPF)

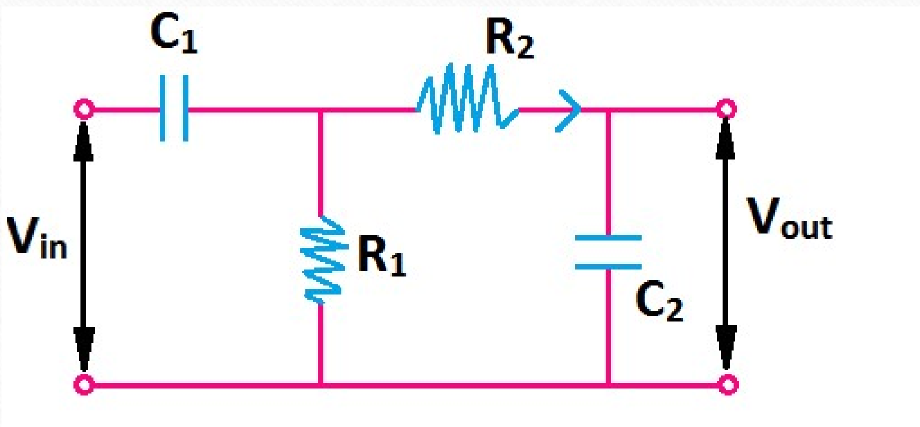
- The gain ratio between input signal and output signal $\frac{v_{out}}{v_{in}} = \frac{\omega RC}{1+j\omega RC}$
- The cutoff frequency can be drive from above equation when the gain = $\frac{1}{\sqrt{2}}$, fc= $\frac{1}{2\pi RC}$



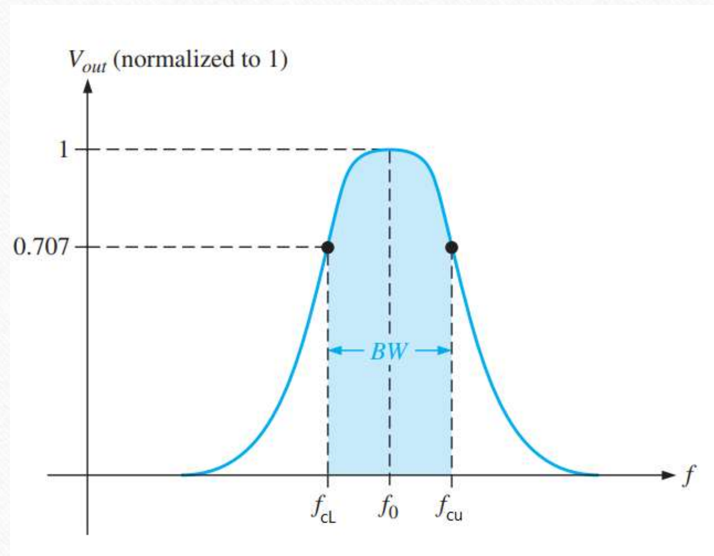
Band-Pass Filter(BPF)

- passes signals lying within a band between a lower-frequency limit and an upper-frequency limit.
- bandwidth (BW)=$f_{cu} - f_{cL}$
- $f_o=\sqrt{f_{cu}\ fcL}$
- Quality Factor The quality factor (Q) of a band-pass filter is the ratio of the center frequency to the bandwidth. $Q=\frac{f_0}{BW}$

Band-Pass Filter(BPF)



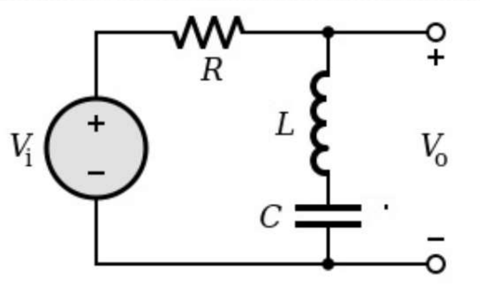
A simple Band Pass Filter Circuit



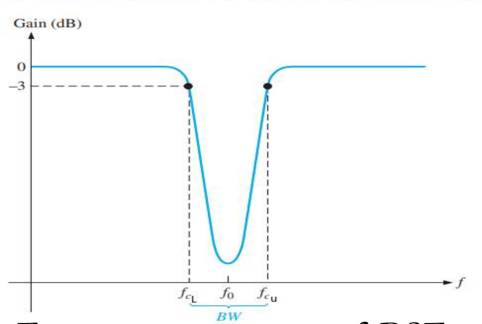
Frequency response of BPF

Band-stop Filter(BSF)

- When the signal is given an input, a low pass filter allows the low frequencies to pass through the circuit and a high pass filter allows the high frequencies to pass through the circuit.
- The main function of the bandstop filter is eliminating or stopping the particular band of frequencies.



Band Stop Filter using RLC



Frequency response of BSF

Lecture 5

The Power calculation in AM

- the total power (Pt) transmitted is the sum of the carrier power (Pc) and the power in the sidebands. The total transmitted power depends on the **modulation index**.

- $P_t = P_c\left(1+\frac{m^2}{2}\right)$

Where:

- **Pt = Total transmitted power**
- **Pc = Carrier power**
- ***m*** **= Modulation index**

Steps to Compute the total power in AM

- Determine the Carrier Power (Pc): This is the power of the unmodulated carrier signal.
- Find the Modulation Index (m): This represents the ratio of the peak amplitude of the modulating signal to the peak amplitude of the carrier signal.
- Calculate the Total Transmitted Power (Pt) using the formula above.

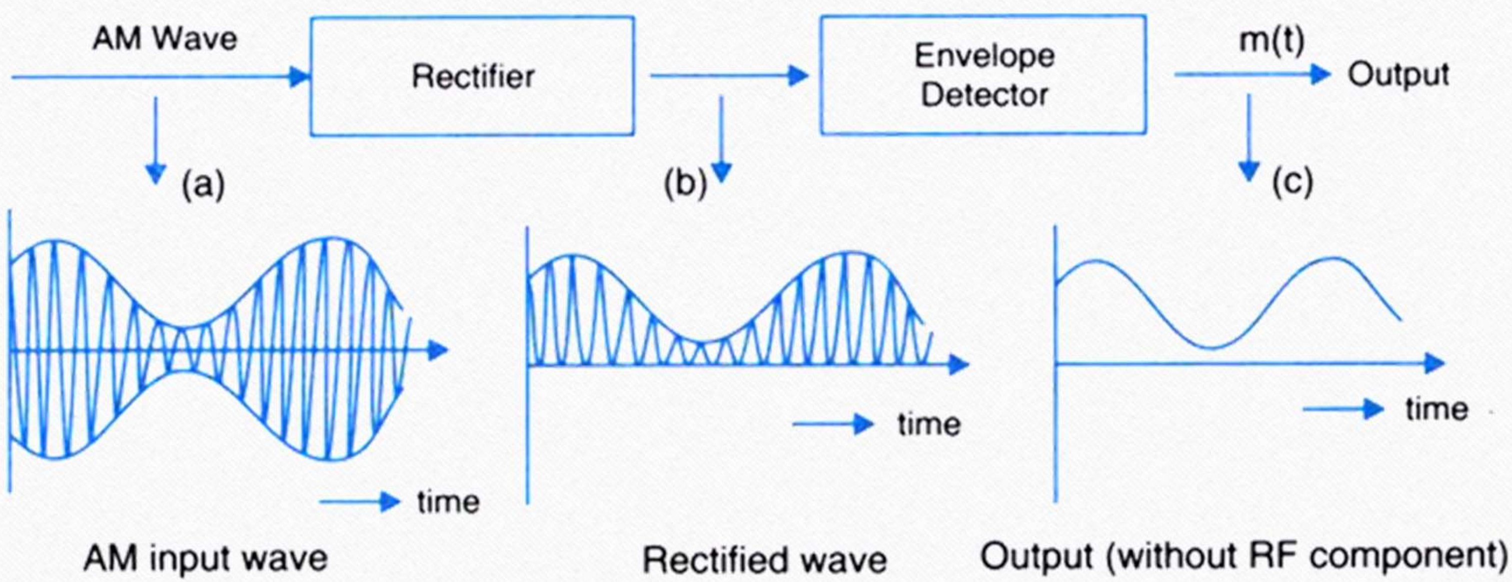
AM demodulation

- This process is crucial in communication systems.
- The demodulation process reverses this by extracting the original information signal from the modulated carrier wave.
- extracting the original information-bearing signal from an amplitude-modulated (AM) carrier wave.
- recovering the original audio or data signal encoded onto the carrier wave by varying its amplitude.

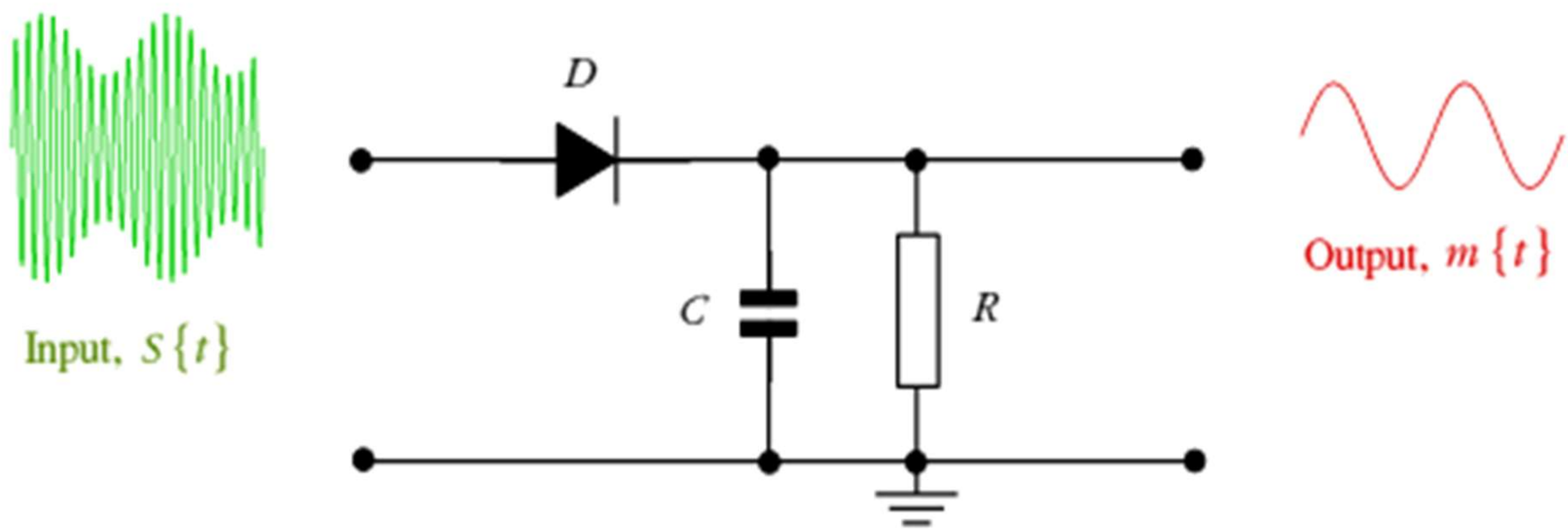
Techniques of AM Demodulation

1. **Envelope Detection:** The simplest and most popular AM demodulation method. It uses a diode, capacitor, and resistor to rectify the AM signal and filter out the high-frequency carrier, leaving the baseband signal.
2. **Synchronous Detection**: Also known as coherent detection
3. **Product Demodulation**: product demodulation multiplies the incoming AM signal with a local oscillator signal.
4. **Square Law Detection**: This method exploits the non-linear characteristics of certain components, such as diodes or transistors, to generate a squared version of the AM signal.
5. **Digital Signal Processing (DSP)**: The incoming AM signal is sampled and converted to a digital format, then processed using algorithms to extract the baseband signal.

Envelope Detection



Envelope Detection



The principle work of Envelope Detection circuit

- The diode rectifies the AM signal, removing negative portions of the wave.
- The capacitor smooths out the variations, effectively following the envelope of the modulated signal.
- The resistor ensures that the capacitor discharges appropriately to track rapid changes in the message signal.