Principles of Electronic Communication (4331104) - Winter 2023 Solution

Milav Dabgar

January 20, 2023

Question 1 [a marks]

3 Classify Noise signal and explain thermal noise.

Solution

Classification of Noise Signals:

Type of Noise	Source	Characteristics
External Noise	Outside communication system	Atmospheric, Space, Industrial
Internal Noise	Inside communication system	Thermal, Shot, Transit time, Flicker

Table 1. Noise Classification

Thermal Noise:

- **Definition**: Random motion of electrons in a conductor due to temperature. also known as Johnson-Nyquist noise.
- **Characteristics**: White noise with uniform power across frequency spectrum.
- **Formula**: $N = kTB$
  - k: Boltzmann constant (1.38×10^{-23} J/K)
  - T: Temperature in Kelvin
  - B: Bandwidth in Hertz

Mnemonic

"TERM" - Temperature Excites Random Movements

Question 1 [b marks]

4 Comparison between Pre-emphasis and De-emphasis technique.

Solution

Comparison of Pre-emphasis and De-emphasis:

Parameter	Pre-emphasis	De-emphasis
Definition	Boosting high-frequency components before transmission	Attenuating high-frequency components at receiver
Location	Transmitter side	Receiver side
Purpose	Improves SNR for high frequencies	Restores original signal frequency response
Circuit	High-pass filter with RC circuit	Low-pass filter with RC circuit
Time Constant	75 μs (standard)	75 μs (matches pre-emphasis)

Table 2. Pre-emphasis vs De-emphasis

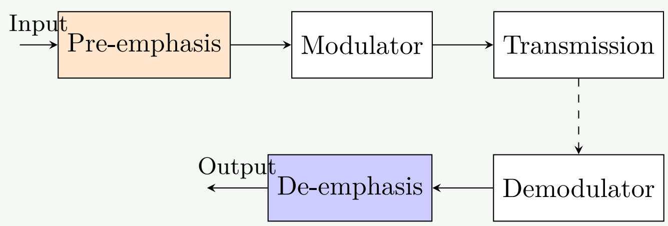


Figure 1. Pre-emphasis and De-emphasis in FM System

Mnemonic

"PUBTAR" - Pump Up Before Transmit, Pull Down After Receive

Question 1 [c marks]

7 Derive mathematical expression of AM signal and with help of it explain frequency spectrum of AM signal.

Solution

Mathematical Expression Derivation:
1. Let the carrier signal be:

$$c(t) = A_c \cos(2\pi f_c t)$$

2. Let the modulating signal be:

$$m(t) = A_m \cos(2\pi f_m t)$$

3. The Amplitude Modulated signal $s(t)$ is given by:

$$s(t) = A_c[1 + \mu \frac{m(t)}{A_m}] \cos(2\pi f_c t)$$

where $\mu = \frac{A_m}{A_c}$ is the modulation index. 4. Substituting $m(t)$:

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

5. Expanding the expression:

$$s(t) = A_c \cos(2\pi f_c t) + \mu A_c \cos(2\pi f_m t) \cos(2\pi f_c t)$$

6. Using trigonometric identity $\cos(A)\cos(B) = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$:

$$s(t) = A_c \cos(2\pi f_c t) + \frac{\mu A_c}{2}[\cos(2\pi(f_c + f_m)t) + \cos(2\pi(f_c - f_m)t)]$$

This is the mathematical expression of AM signal.
Frequency Spectrum:

Component	Frequency	Amplitude
Carrier	f_c	A_c
Upper Sideband (USB)	$f_c + f_m$	$\frac{\mu A_c}{2}$
Lower Sideband (LSB)	$f_c - f_m$	$\frac{\mu A_c}{2}$

Table 3. AM Spectrum Components

Frequency Spectrum of AM Wave

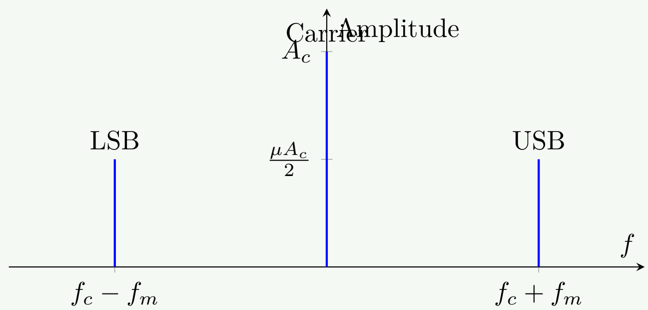


Figure 2. AM Frequency Spectrum

Mnemonic

"CSBT" - Carrier Standing Between Twins

Question 1 [c marks]

7 Explain block diagram of Communication System.

Solution

Block Diagram of Communication System:

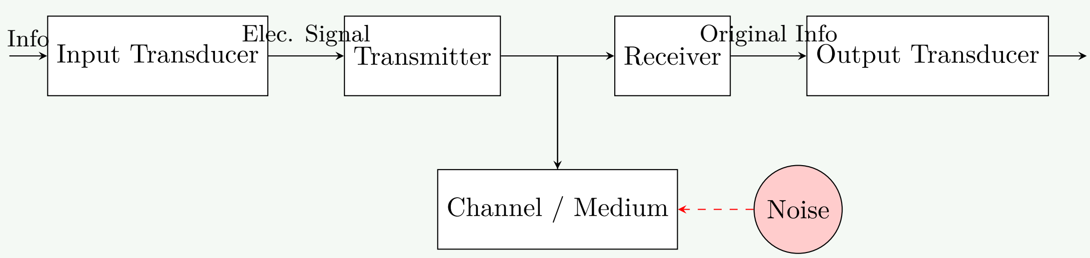


Figure 3. Elements of Communication System

Components and Functions:

Block	Function	Example
Input Transducer	Converts original information to electrical signal	Microphone, Camera
Transmitter	Processes signal for efficient transmission (modulation, amplification)	Radio transmitter
Channel/Medium	Path through which signal travels	Air, Fiber, Cable
Receiver	Extracts original signal (amplification, filtering, demodulation)	Radio receiver
Output Transducer	Converts electrical signal back to original form	Speaker, Display
Noise Source	Unwanted signals that distort the information	Atmospheric, Thermal

Table 4. System Components

Mnemonic

"ITCRO" - Input Transmits Through Channel, Receives Output

Question 2 [a marks]

3 Discuss power distribution among sidebands and carrier in amplitude modulation.

Solution

Power Distribution in AM Signal:
Total power P_t is the sum of carrier power P_c and sideband power P_{SB}.

Component	Power Formula	Percentage ($m = 1$)
Carrier	$P_c = \frac{A_c^2}{2R}$	66.7%
Upper Sideband	$P_{USB} = \frac{P_c \mu^2}{4}$	16.65%
Lower Sideband	$P_{LSB} = \frac{P_c \mu^2}{4}$	16.65%
Total Power	$P_T = P_c(1 + \frac{\mu^2}{2})$	100%

Table 5. AM Power Distribution

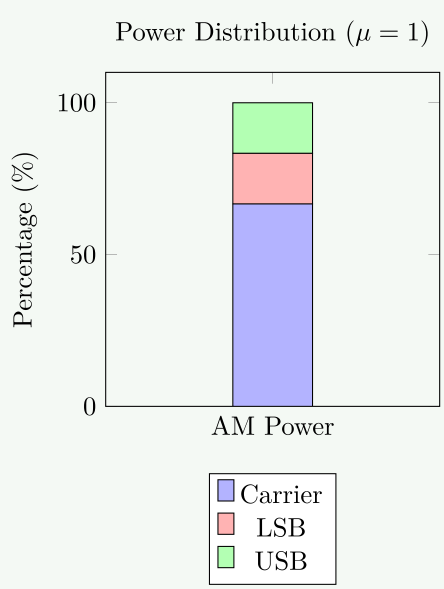


Figure 4. Power Breakdown

Mnemonic

"CTTT" - Carrier Takes Two-Thirds

Question 2 [b marks]

4 Why pre-emphases and de-emphases are used? Briefly describe how the signals are modified at transmitter side and receiver side.

Solution

Purpose of Pre-emphasis and De-emphasis:
Used primarily in FM to improve the Signal-to-Noise Ratio (SNR) for high-frequency components relative to the noise floor.

- **Improve SNR**: Boosts high frequencies before transmission to overcome noise.
- **Reduce Noise**: High frequencies in FM are more susceptible to noise.
- **Maintain Fidelity**: De-emphasis restores the original flat frequency response.

Signal Modification Process:

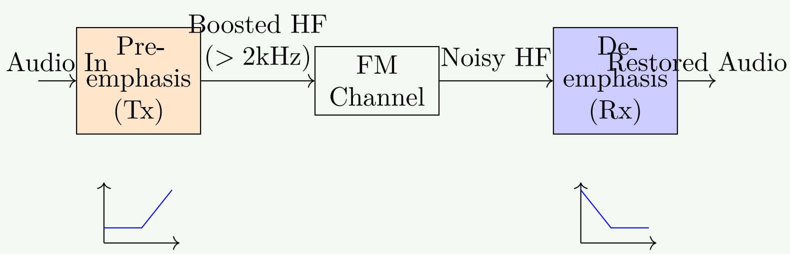


Figure 5. Signal Modification Flow

Mnemonic

"BHCKO" - Boost High, Cut High, Keep Original

Question 2 [c marks]

7 Explain FM generation techniques. Explain Phase locked loop FM modulator in detail.

Solution

FM Generation Techniques:

Technique	Principle	Advantages
Direct FM	Varying capacitance in oscillator (e.g., Varactor)	Simple design
Indirect FM	Phase modulation to produce FM	Better frequency stability
PLL FM	Using phase locked loop	High frequency stability
Armstrong	Using mixers and multipliers	Excellent linearity

Table 6. FM Generation Methods

PLL FM Modulator:

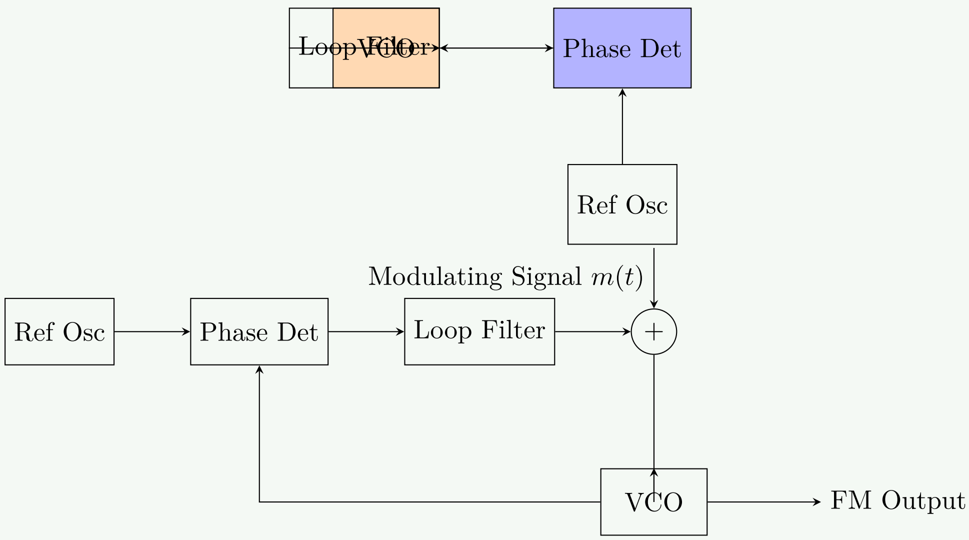


Figure 6. PLL FM Modulator

Working Principle:

1. **Phase Detector** compares VCO frequency with stable Reference Oscillator.
2. **Loop Filter** provides DC control measure, blocking high frequency variations.
3. **Modulating Signal** is added to the control voltage.
4. This varies the **VCO** frequency according to message signal (FM).
5. The PLL feedback ensures the center frequency remains stable (locked to reference) over long term, while allowing short-term deviations for modulation (if loop bandwidth is small).

Mnemonic

"PDCFV" - Phase Detector Compares, Filter Smooths, VCO Varies

Question 2 [a marks]

3 State advantages and disadvantage of SSB over DSB.

Solution

Advantages and Disadvantages of SSB over DSB:

Advantages of SSB	Disadvantages of SSB
Bandwidth Efficiency: Uses only half bandwidth (f_m) compared to DSB.	**Complex Circuitry**: Requires sharp filters for sideband suppression.
Power Efficiency: Uses about 1/3 to 1/6 power for same SNR.	**Difficult Demodulation**: Requires precise carrier re-insertion (coherent detection).
Reduced Fading: Less susceptible to selective fading.	**Low Freq Distortion**: Practical filters attenuate low frequencies.
Less Interference: Narrower channel usage.	**Cost**: Higher transmitter/receiver cost.

Table 7. SSB vs DSB

Mnemonic

"PBSCN" - Power and Bandwidth Saved, But Complex Circuits Needed

Question 2 [b marks]

4 Sketch the frequency spectrum of DSBSC and SSB amplitude modulated wave and pilot carrier.

Solution

Frequency Spectrum Comparison:

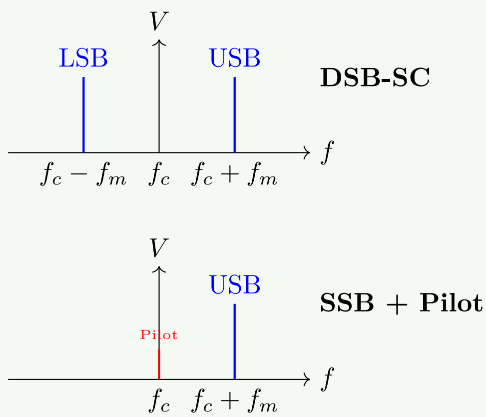


Figure 7. DSB-SC vs SSB with Pilot Carrier Spectrum

- **DSB-SC**: Carrier suppressed, inputs power only in sidebands. Bandwidth $2f_m$.
- **SSB + Pilot**: Only one sideband transmitted + reduced carrier for synchronization. Bandwidth f_m.

Mnemonic

"TSOSP" - Two Sides, One Side, or One Side Plus Pilot

Question 2 [c marks]

7 Write a short-note on: Pulse modulation.

Solution

Pulse Modulation Techniques:
Process where continuous analog signal is sampled and converted into pulses parameters.

Type	Principle	Application
PAM	Amplitude of pulses varies with signal	TDM, intermediate step for PCM
PWM	Width/duration of pulses varies	Motor control, power delivery
PPM	Position/timing of pulses varies	Optical communication, RF control
PCM	Digital binary code representation	Computing, Digital Audio, Telephony

Table 8. Pulse Modulation Types

Waveform Comparison:

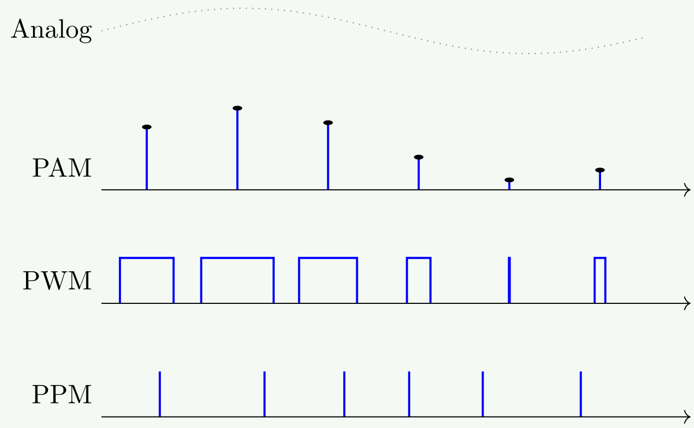


Figure 8. Pulse Modulation Waveforms

Mnemonic

"AWPC" - Amplitude, Width, Position, Code - All Pulse Types

Question 3 [a marks]

3 What is AGC? Draw and explain input-output characteristic curve of simple AGC circuit.

Solution

Automatic Gain Control (AGC):

- **Definition**: A circuit that automatically adjusts receiver gain to maintain a relatively constant output signal level despite variations in input signal strength.
- **Purpose**: Prevents overloading on strong signals and fading on weak signals.

Input-Output Characteristics:

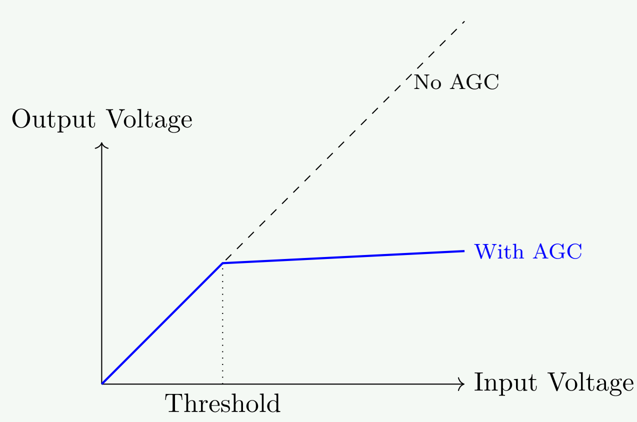


Figure 9. AGC Characteristics

Explanation: Linear response for weak signals (below threshold). Above threshold, gain is reduced to flatten output.

Mnemonic

"SSLG" - Strong Signals Get Less Gain

Question 3 [b marks]

4 Write a short-note on balanced ratio detector for FM demodulation.

Solution

Balanced Ratio Detector:

- FM demodulator deriving output from the ratio of diode currents.
- **Key Components**: Center-tapped transformer, two diodes, large electrolytic capacitor (for AM rejection).
- **Advantage**: Provides inherent immunity to Amplitude variations (AM Rejection) without a separate limiter.

Circuit Diagram:

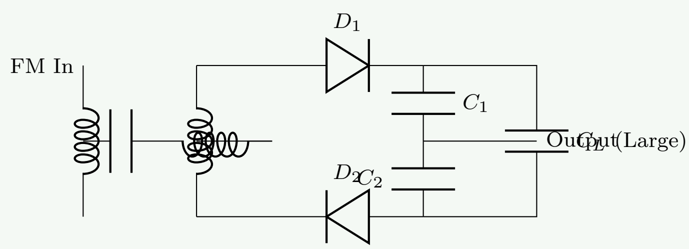


Figure 10. Ratio Detector Circuit

Mnemonic

"BDTFV" - Balanced Diodes Transform Frequency To Voltage

Question 3 [c marks]

7 Explain working of various types of FM demodulator circuits.

Solution

Types of FM Demodulators:

Type	Working Principle	Pros/Cons
Slope Detector	Uses non-linear region of tuned circuit	Simple / Poor linearity
Foster-Seeley	Phase shift differentiation	Good linearity / No AM rejection
Ratio Detector	Ratio of diode voltages	Good AM rejection / Med linearity
PLL Demodulator	Phase locking to input	Excellent linearity / Complex
Quadrature	Phase shift & multiplication	Easy IC integration

Table 9. FM Demodulator Types

PLL FM Demodulator Diagram:

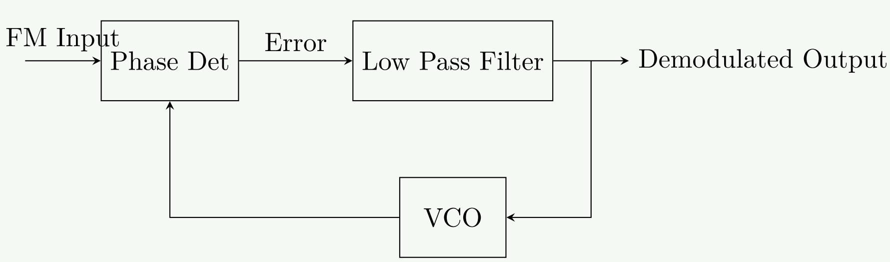


Figure 11. PLL Demodulator

Working: The error voltage required to keep the VCO locked to the input FM signal is proportional to the frequency deviation, thus recovering the original message.

Mnemonic

"FVDPE" - Frequency Variations Drive Phase Errors

Question 3 [a marks]

3 Explain characteristics of a Radio receiver.

Question 3 [b marks]

4 Explain types of distortions occur in AM detector circuit.

Solution

Distortions in AM Detector:

Distortion	Cause	Remedy
Diagonal Clipping	RC time constant too large (cant discharge fast enough)	Reduce R or C
Negative Peak Clipping	Modulation index high + AC/DC load mismatch	Adjust biasing / load
Harmonic Distortion	Non-linear diode characteristics	Better diodes

Table 11. AM Detector Distortions

Waveforms:

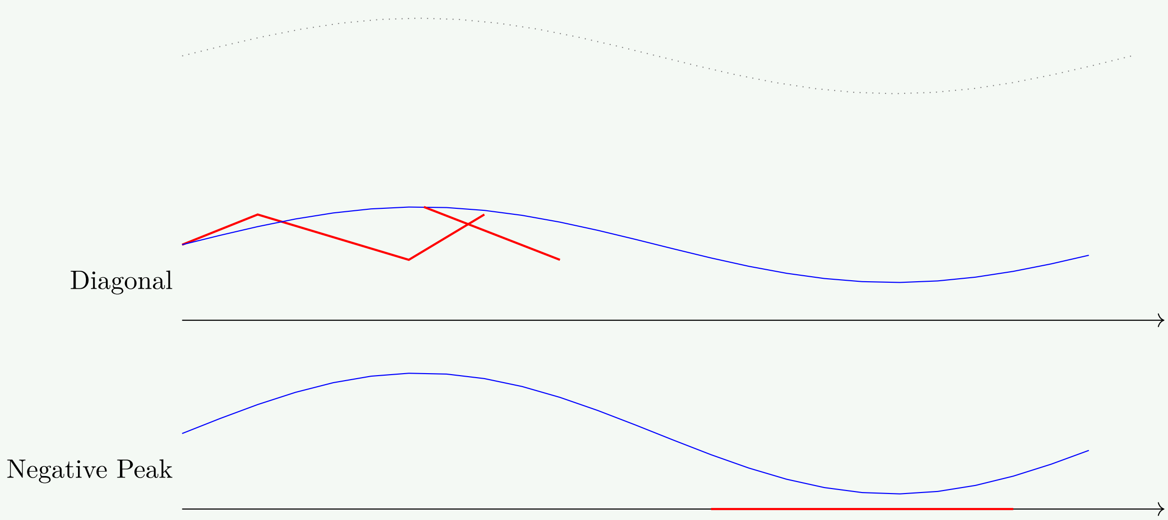


Figure 13. Distortion Types

Mnemonic

"DNHF" - Diagonal Negative Harmonics Frequency

Question 3 [c marks]

7 Draw the block diagram of a Superheterodyne AM receiver and explain it.

Solution

Superheterodyne AM Receiver:

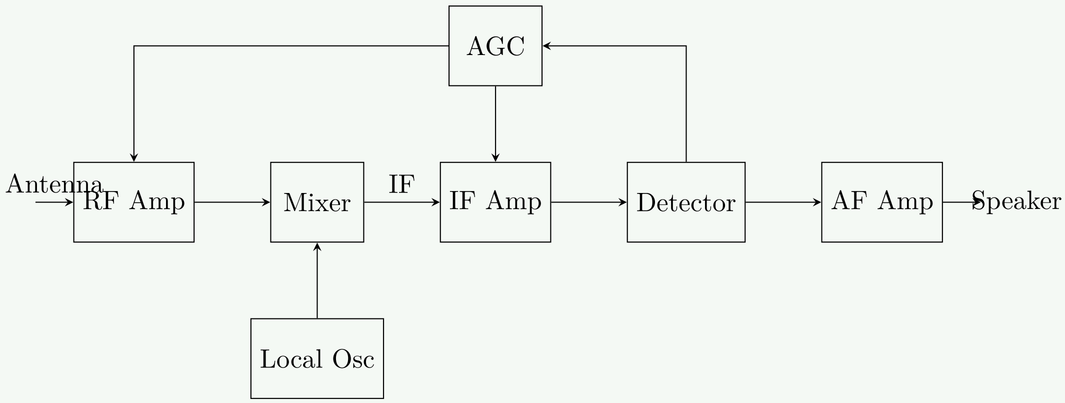


Figure 14. Superheterodyne Receiver

Function of Blocks:

RF Amp: Selects and amplifies desired RF signal.
Mixer: Mixes RF (f_s) and LO (f_o) to produce IF ($f_o - f_s$).
IF Amp: Main amplification stage at fixed Intermediate Frequency (455 kHz).
Detector: Demodulates AM signal to Audio.
AGC: Maintains constant volume.

Mnemonic

"RMLIDAS" - Radio Mixing Local Intermediate Detected Audio Signals

Question 4 [a marks]

3 Explain quantization process used in analog to digital conversion.

Solution

Quantization Process:

1. **Sampling**: Discretize time.
2. **Level Allocation**: Divide amplitude range into L discrete levels.
3. **Assignment**: Map each sample value to nearest level.
4. **Encoding**: Convert level index to binary.

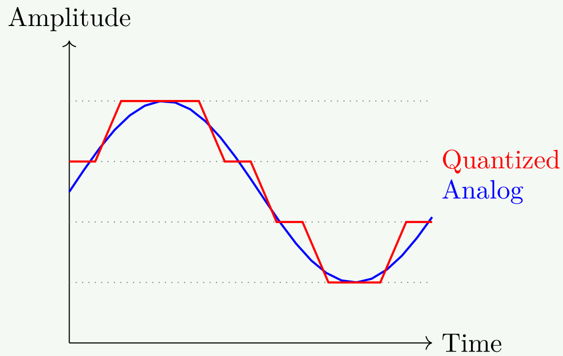


Figure 15. Quantization Staircase

Mnemonic

"SLAB" - Sample Levels Assign Binary

Question 4 [b marks]

4 Give the comparison of Sampling techniques.

Solution

Sampling Techniques:

Technique	Description	Pros/Cons
Ideal	Instantaneous impulses	Theoretical only
Natural	Pulse top follows signal shape	Complex generation
Flat-top	Pulse top is flat (Sample & Hold)	Easy to generate / Aperture error

Table 12. Sampling Types

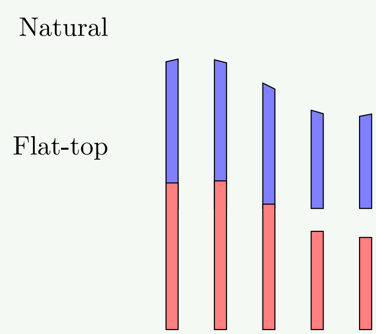


Figure 16. Natural vs Flat-top Sampling

Mnemonic

"INF" - Ideal Natural Flat

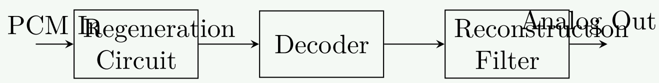
Question 4 [c marks]

7 Draw and explain block diagram of a PCM transmitter and receiver.

Solution

Pulse Code Modulation (PCM):
Transmitter:

Receiver:



Mnemonic

"FSQEMT" - Filter, Sample, Quantize, Encode, Multiplex, Transmit

Question 4 [a marks]

3 State and explain Nyquist theorem.

Solution

Nyquist Sampling Theorem: To perfectly reconstruct a band-limited signal, the sampling frequency f_s must be at least twice the maximum frequency component f_{max} present in the signal.

$$f_s \geq 2f_{max}$$

- $2f_{max}$ is called the **Nyquist Rate**.
- If $f_s < 2f_{max}$, **Aliasing** occurs (overlapping of spectral components).

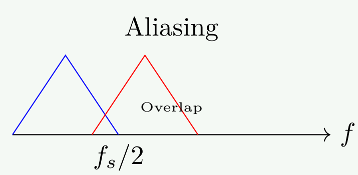


Figure 17. Effect of Undersampling (Aliasing)

Mnemonic

"DMFSA" - Double Maximum Frequency Stops Aliasing

Question 4 [b marks]

4 Compare DM, ADM and DPCM.

Solution

Comparison:

Feature	Delta Mod (DM)	Adaptive DM	DPCM
Bits/Sample	1 Bit	1 Bit	> 1 Bit
Step Size	Fixed	Variable	Fixed/Adaptive
Errors	Slope Overload, Granular	Reduced errors	Quantization noise
Complexity	Lowest	Moderate	High

Table 13. DM vs ADM vs DPCM

Mnemonic

"SAMD" - Single-bit, Adaptive-bit, Multi-bit Difference

Question 4 [c marks]

7 Explain working of Differential PCM (DPCM) transmitter and receiver.

Solution

DPCM Principle: Encodes the *difference* between the actual sample and a predicted value (based on previous samples) rather than the absolute sample value.

DPCM Transmitter:

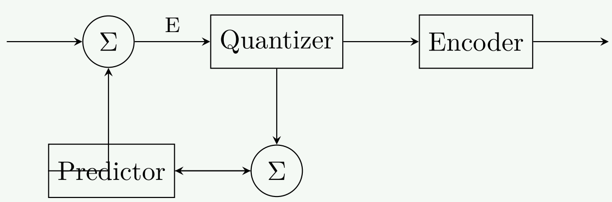


Figure 18. DPCM Transmitter

DPCM Receiver:

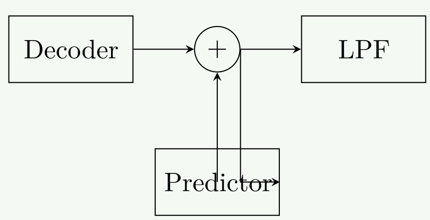


Figure 19. DPCM Receiver

Mnemonic

"PSQD" - Predict Subtract Quantize Difference

Question 5 [a marks]

3 Describe TDMA frame.

Solution

TDMA Frame Structure:
Time Division Multiple Access allows multiple users to share same frequency by allocating unique time slots.

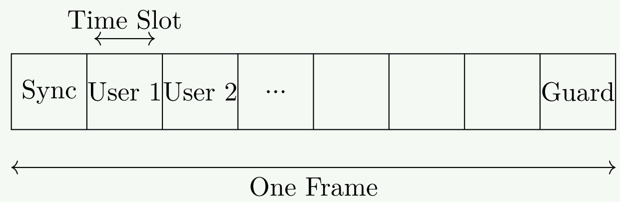


Figure 20. TDMA Frame

Components: Preamble (Sync), Information Message, Guard Bits (Gap).

Mnemonic

"SITDA" - Slots In Time Divide Access

Question 5 [b marks]

4 Draw and explain 4 level digital multiplexing hierarchies.

Solution

Digital Multiplexing Hierarchy (North American T-carrier):

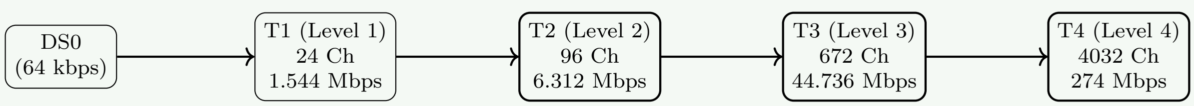


Figure 21. T-Carrier Hierarchy

Mnemonic

"PSTQ" - Primary, Secondary, Tertiary, Quaternary Levels

Question 5 [c marks]

7 Draw and explain block diagram of PCM-TDM system.

Solution

PCM-TDM Block Diagram:

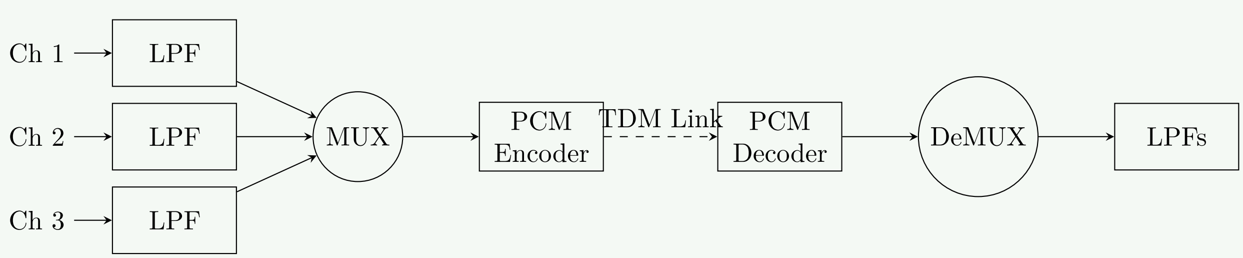


Figure 22. PCM-TDM System

Process:
1. Multiple analog channels are band-limited by LPF.
2. Commutator sequentially samples each channel (AM-TDM).
3. Composite TDM signal enters single PCM Encoder.
4. Coded bits are transmitted interleaved.

Mnemonic

"MACSDL" - Many Analog Channels Share Digital Link

Question 5 [a marks]

3 List advantages and disadvantages of digital communication.

Solution

Advantages and Disadvantages:

Advantages	Disadvantages
Better Noise Immunity	Higher Bandwidth Required
Error Detection & Correction	System Complexity
Easy to Multiplex (TDM)	Synchronization Required
Secure (Encryption)	Quantization Noise

Table 14. Digital Communication Pros/Cons

Mnemonic

"NEMBB" - Noise-resistant, Error-correcting, Multiplex-friendly But Bandwidth-hungry

Question 5 [b marks]

4 List Channel Coding Techniques, explain any one of them with example.

Solution

Channel Coding Techniques:
- Linear Block Codes (e.g., Hamming)
- Cyclic Codes (e.g., CRC)
- Convolutional Codes
- Turbo Codes

Example: Hamming Code (7,4)
- Takes 4 data bits, adds 3 parity bits ($n = 7, k = 4$).
- Can correct 1 bit error.
- Parity bits placed at positions $2^0, 2^1, 2^2$...
- If Data = 1010, Encoded = $p_1p_21p_4010$. Parity calculated based on XOR of specific positions.

Mnemonic

"PBPDB" - Parity Bits Protect Data Bits

Question 5 [c marks]

7 Discuss basic time domain digital multiplexing. State advantages & disadvantages of TDM system.

Solution

Time Division Multiplexing (TDM): Technique where multiple distinct signals are transmitted over a single channel by interleaving them in time domain.

Advantages:

- Full bandwidth utilized by one user at a time (no intermodulation).
- Flexible signal handling (digital).
- Simple circuitry compared to FDM.

Disadvantages:

- Strict synchronization required.
- Wasted bandwidth if slots are empty.
- Multipath distortion affects TDM more than FDM.

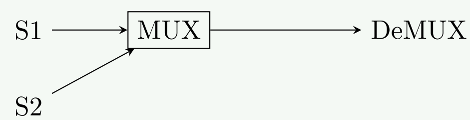


Figure 23. Basic TDM

Mnemonic

"TSSBSR" - Time Slots Shared But Sync Required