Principles of Electronic Communication (4331104) - Winter 2024 Solution

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Question 1 [a marks]

3 What is modulation? What is the need of it?

Solution

Modulation is the process of varying one or more properties (amplitude, frequency, or phase) of a high-frequency carrier signal according to the instantaneous value of a lower frequency message signal.

Need for modulation:

- **Antenna size reduction**: Allows practical antenna size ($\lambda/4$).
- **Multiplexing**: Enables multiple signals to share same medium.
- **Interference reduction**: Shifts signal to suitable frequency band.
- **Range extension**: Increases transmission distance.

Mnemonic

”AMIR” - Antenna, Multiplexing, Interference, Range

Question 1 [b marks]

4 Derive the expression for DSBFC of AM wave.

Solution

DSBFC (Double Sideband Full Carrier) AM wave derivation:

Mathematical derivation:

- Carrier signal: $c(t) = A_c \cos(\omega_c t)$
- Message signal: $m(t) = A_m \cos(\omega_m t)$
- AM signal: $s(t) = A_c[1 + \mu m(t)] \cos(\omega_c t)$
- Where μ = modulation index = A_m/A_c

Substituting message signal:

$$s(t) = A_c[1 + \mu \cos(\omega_m t)] \cos(\omega_c t)$$
$$s(t) = A_c \cos(\omega_c t) + \mu A_c \cos(\omega_m t) \cos(\omega_c t)$$

Using trigonometric identity:

$$\cos(A) \cos(B) = \frac{1}{2}[\cos(A + B) + \cos(A - B)]$$

Final expression:

$$s(t) = A_c \cos(\omega_c t) + \frac{\mu A_c}{2}[\cos((\omega_c + \omega_m)t) + \cos((\omega_c - \omega_m)t)]$$

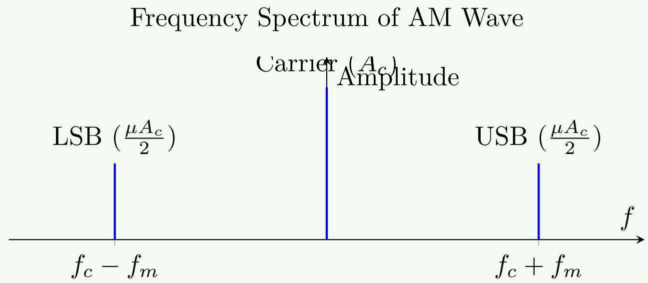


Figure 1. Spectrum of DSBFC AM Wave

Question 1 [c marks]

7 Classify Noise signal and explain flicker noise, shot noise and thermal noise.

Solution

Noise Classification:

Type	Source	Characteristics
External Noise	Environmental sources	Outside communication system
Internal Noise	Components	Generated within system

Table 1. Types of Noise

Types of internal noise:

1. **Flicker Noise:**
   - **Source**: Occurs in active devices.
   - **Characteristics**: Inversely proportional to frequency ($1/f$).
   - **Effect**: Dominant at low frequencies.
2. **Shot Noise:**
   - **Source**: Random electron flow across junctions.
   - **Characteristics**: Independent of frequency (white noise).
   - **Effect**: Random current fluctuations in diodes/transistors.
3. **Thermal Noise:**
   - **Source**: Random motion of electrons due to temperature.
   - **Characteristics**: Present in all conductors, resistors.
   - **Formula**: $P_n = kTB$ (k = Boltzmann constant, T = temperature, B = bandwidth).
   - **Effect**: Sets noise floor in receivers.

Mnemonic

"FST" - Flicker decreases with Frequency, Shot is from electron flow, Thermal depends on Temperature

Question 1 [c marks]

7 Describe EM wave also write at least one application of different band of spectrum.

Solution

EM Wave: Electromagnetic waves are energy propagating through space as time-varying electric and magnetic fields, traveling at speed of light (3×10^8 m/s).
Characteristics:

- Transverse waves with E and H fields perpendicular to each other.
- No medium required for propagation.
- Described by wavelength (λ) and frequency (f).
- Relation: $c = f \times \lambda$.

EM Spectrum and Applications:

Frequency Band	Frequency Range	Application
ELF	3Hz-30Hz	Submarine communication
VLF	3kHz-30kHz	Navigation systems
LF	30kHz-300kHz	AM broadcasting
MF	300kHz-3MHz	AM radio broadcasting
HF	3MHz-30MHz	Shortwave radio
VHF	30MHz-300MHz	FM radio, TV broadcasting
UHF	300MHz-3GHz	TV, mobile phones, WiFi
SHF	3GHz-30GHz	Satellite communication, radar
EHF	30GHz-300GHz	Millimeter wave communication
Infrared	300GHz-400THz	Remote controls, thermal imaging
Visible	400THz-800THz	Fiber optic communication
Ultraviolet	800THz-30PHz	Sterilization, authentication
X-Rays	30PHz-30EHz	Medical imaging
Gamma Rays	>30EHz	Cancer treatment

Table 2. EM Spectrum and Applications

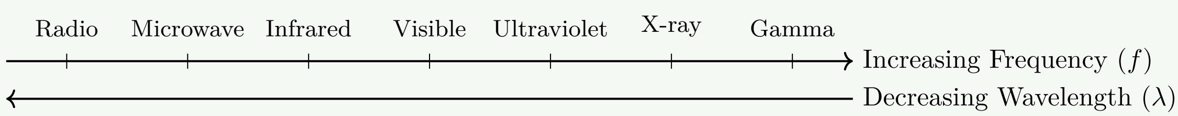


Figure 2. Electromagnetic Spectrum

Mnemonic

"RMIUXG" - Radio, Microwave, Infrared, Ultraviolet, X-ray, Gamma

Question 2 [a marks]

3 State advantages of SSB over DSB.

Solution

Advantages of SSB over DSB:

Parameter	SSB Advantage
Bandwidth	50% less bandwidth requirement
Power	Power saving of 33-83% over AM/DSB
Transmitter	Less power amplification needed
Receiver	Simpler design without phase distortion
SNR	Better signal-to-noise ratio
Fading	Less susceptible to selective fading

Mnemonic

"BP TRFS" - Bandwidth, Power, Transmitter, Receiver, Fading, SNR

Question 2 [b marks]

4 Explain generation of FM wave using FET reactance modulator.

Solution

FET Reactance Modulator:
Working principle:

- Uses FET as voltage-controlled reactance.
- Changes effective capacitance based on modulating signal.
- Connected across LC tank circuit of oscillator.

Circuit operation:

1. Modulating signal applied to gate of FET.
2. FET drain-source resistance varies with gate voltage.
3. Capacitive reactance changes with modulating signal.
4. Oscillator frequency deviates with input signal.

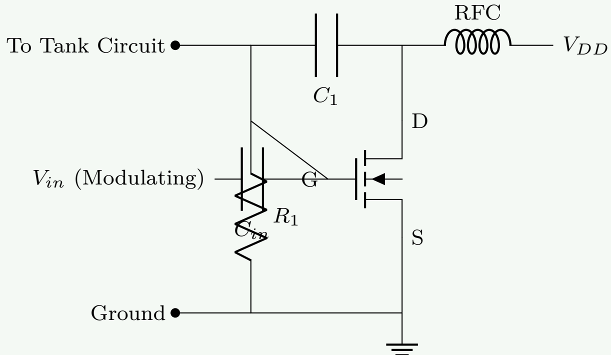


Figure 3. FET Reactance Modulator

Key features:

- **Simple design**: Fewer components than other modulators.
- **Linearity**: Good for wide-band FM generation.
- **Stability**: Temperature stable compared to varactor diodes.

Mnemonic

"LOVE FM" - LC Oscillator with Voltage-controlled Element for FM

Question 2 [c marks]

7 Derive the equation for total power in AM, calculate percentage of power savings in DSB and SSB.

Solution

Power in AM signal:
For AM signal $s(t) = A_c[1 + \mu \cos(\omega_m t)] \cos(\omega_c t)$
Total power calculation:

1. Power in carrier: $P_c = A_c^2/2$
2. Power in sidebands: $P_s = \mu^2 A_c^2/4$ (total for both sidebands)
3. Total power: $P_t = P_c + P_s = \frac{A_c^2}{2}(1 + \frac{\mu^2}{2})$

For 100% modulation ($\mu = 1$):

- $P_t = P_c \times (1 + 0.5) = 1.5 \times P_c$
- Carrier power = 66.67% of total
- Sideband power = 33.33% of total

Power savings:

1. **In DSB-SC:**
   - Carrier is suppressed.
   - Power saved = 66.67%
2. **In SSB:**
   - Carrier + one sideband suppressed.
   - Power saved = 66.67% + 16.67% = 83.33%

Comparative Table:

Modulation	Carrier Power	Sideband Power	Total Power	Power Saving
AM ($\mu = 1$)	100%	50%	150%	0%
DSB-SC	0%	50%	50%	66.67%
SSB	0%	25%	25%	83.33%

Mnemonic

"CST" - Carrier power, Sideband power, Total power

Question 2 [a marks]

3 Draw and explain Time domain and Frequency domain display of AM wave.

Solution

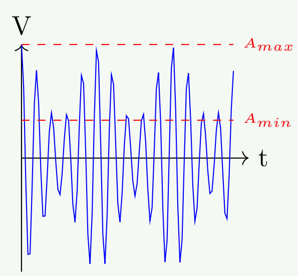
Time Domain and Frequency Domain Display of AM Wave:

Time Domain:

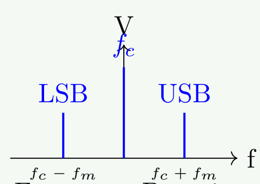
- Shows amplitude variations over time.
- Envelope follows modulating signal.
- Maximum amplitude: $A_{max} = A_c(1 + \mu)$
- Minimum amplitude: $A_{min} = A_c(1 - \mu)$
- Modulation index: $\mu = (A_{max} - A_{min})/(A_{max} + A_{min})$

Frequency Domain:

- Shows power distribution across frequencies.
- Carrier at center frequency f_c.
- Upper sideband at $f_c + f_m$.
- Lower sideband at $f_c - f_m$.
- Bandwidth = $2f_m$.



Time Domain



Frequency Domain

Figure 4. AM Time and Frequency Domain Representations

Mnemonic

"TEF" - Time domain shows Envelope, Frequency domain shows spectral components

Question 2 [b marks]

4 Explain pre-emphasis & de-emphasis circuit.

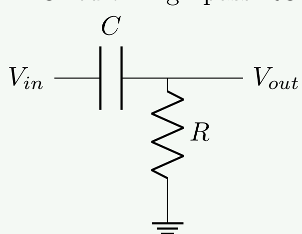
Solution

Pre-emphasis and De-emphasis Circuits:
Purpose:

- Improve SNR for high-frequency components.
- Compensate for higher noise in high frequencies.
- Used primarily in FM systems.

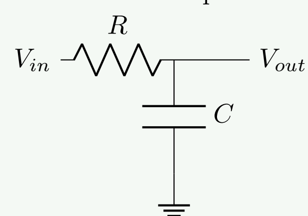
Pre-emphasis:

- Applied at transmitter.
- Boosts high-frequency components.
- Typically +6dB/octave above 2.1kHz.
- Circuit: High-pass RC network.



De-emphasis:

- Applied at receiver.
- Attenuates high-frequency components.
- Restores original signal balance.
- Circuit: Low-pass RC network.



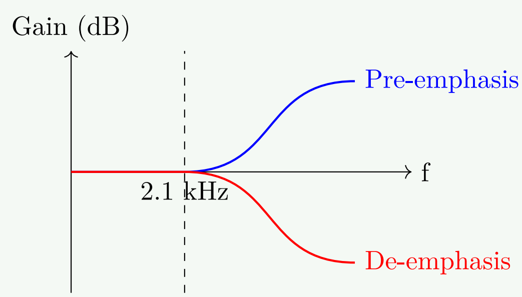


Figure 5. Pre-emphasis and De-emphasis Frequency Response

Mnemonic

"HIGH-LOW" - HIGHer frequencies boosted at transmitter, LOWered at receiver

Question 2 [c marks]

7 Compare narrowband FM and wideband FM.

Solution

Comparison of Narrowband FM and Wideband FM:

Parameter	Narrowband FM	Wideband FM
Modulation Index (β)	$\beta \ll 1$ (typically < 0.5)	$\beta \gg 1$ (typically > 5)
Bandwidth	$2f_m$ (twice message bandwidth)	$2f_m(\beta + 1)$ (Carson's rule)
Significant Sidebands	Only first pair of sidebands	Multiple sidebands
Applications	Mobile communication, two-way radio	FM broadcasting, high-fidelity audio
Signal Quality	Lower fidelity, less noise immunity	Higher fidelity, better noise immunity
Power Efficiency	Higher	Lower
Spectrum Utilization	Efficient	Less efficient
Circuit Complexity	Simpler	More complex

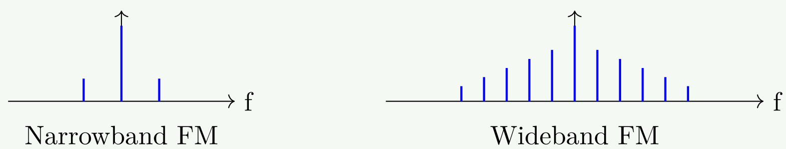


Figure 6. Spectrum Comparison

Mnemonic

"BASPCB" - Bandwidth, Applications, Sidebands, Power, Complexity, Beta

Question 3 [a marks]

3 Define any FOUR characteristics of radio receiver.

Solution

Characteristics of Radio Receiver:

1. **Sensitivity:**
   - Ability to amplify weak signals.
   - Measured in microvolts (μV).
   - Typically 1-10μV for good receivers.
2. **Selectivity:**
   - Ability to separate desired signal from adjacent channels.
   - Determined by bandwidth of IF amplifier.
   - Measured in dB at specific frequency offsets.
3. **Fidelity:**
   - Accuracy in reproducing original signal.
   - Depends on bandwidth and distortion.
   - Measured as frequency response flatness.
4. **Image Frequency Rejection:**
   - Ability to reject signals at image frequency ($f_i = f_s \pm 2f_{IF}$).
   - Measured in dB.
   - Higher values indicate better performance.

Mnemonic

"SFID" - Sensitivity, Fidelity, Image rejection, selectivity Determines quality

Question 3 [b marks]

4 Explain Diode Detector circuit.

Solution

Diode Detector Circuit:
Purpose:

- Extracts original message signal from AM wave.
- Also called envelope detector.

Circuit components:

- Diode: Rectifies AM signal.
- RC network: Filters carrier frequency.
- R & C values: $RC \gg 1/f_c$ and $RC \ll 1/f_m$.

Operation:

1. Diode conducts during positive half-cycles.
2. Capacitor charges to peak value.
3. Capacitor discharges through resistor.
4. RC time constant critical for proper demodulation.

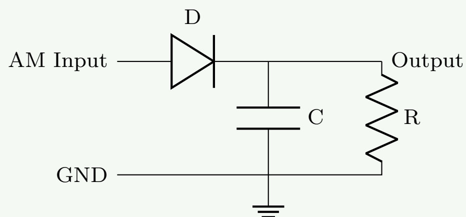
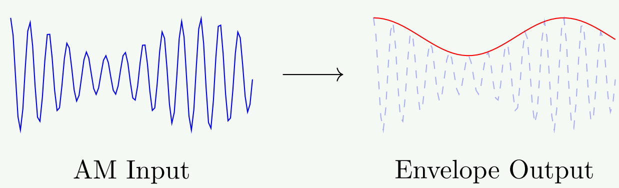


Figure 7. Diode Detector

Waveforms:



Mnemonic

"DRCO" - Diode Rectifies, Capacitor holds peaks, Output follows envelope

Question 3 [c marks]

7 Draw and explain block diagram of super heterodyne receiver.

Solution

Super Heterodyne Receiver:
Block Diagram:

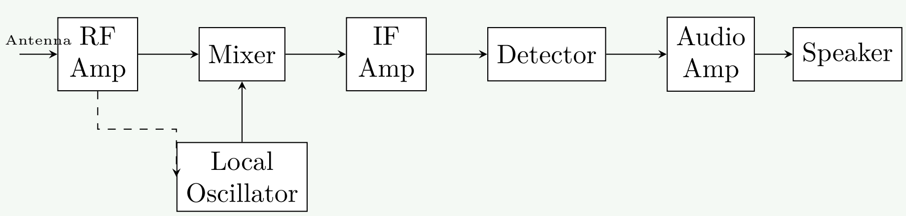


Figure 8. Superheterodyne Receiver Block Diagram

Function of each block:

1. **RF Amplifier:** Amplifies weak RF signals, provides selectivity, improves SNR.
2. **Local Oscillator:** Generates stable frequency $f_{LO} = f_{RF} + f_{IF}$ (high-side injection).
3. **Mixer:** Combines RF with LO to produce IF ($f_{IF} = |f_{RF} - f_{LO}|$).
4. **IF Amplifier:** Fixed frequency amplification (455kHz for AM), provides gain and selectivity.
5. **Detector:** Demodulates IF signal to extract message.
6. **Audio Amplifier:** Amplifies message for speaker.

Advantages: Better selectivity/sensitivity, stable gain, reduced tracking problems.

Mnemonic

"RLMIDS" - RF amp, Local oscillator, Mixer, IF amp, Detector, Speaker

Question 3 [a marks]

3 Describe AGC principle and its application in Radio receiver.

Solution

AGC (Automatic Gain Control) Principle:

Definition:

- Circuit that automatically adjusts receiver gain based on signal strength.
- Maintains constant output level despite varying input signals.

Working principle:

1. Detects received signal strength.
2. Generates control voltage proportional to signal.
3. Applies negative feedback to reduce gain for strong signals.
4. Increases gain for weak signals.

Application in Radio Receiver:

- **Prevents overloading:** Protects against strong signal distortion.
- **Compensates fading:** Maintains constant volume during signal fading.
- **IF amplifier control:** Primarily applied to IF stages.
- **Improves dynamic range:** Handles wide range of signal strengths.

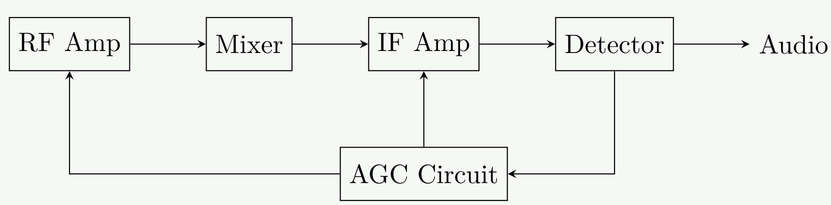


Figure 9. AGC in Superheterodyne Receiver

Mnemonic

"FADS" - Fading compensation, Automatic adjustment, Dynamic range, Signal consistency

Question 3 [b marks]

4 Write short-note on intermediate frequency

Solution

Intermediate Frequency (IF):
Definition:

- Fixed frequency to which incoming RF signal is converted in superheterodyne receivers.
- Result of mixing (heterodyning) RF signal with local oscillator.

Standard IF values:

- **AM radio:** 455 kHz
- **FM radio:** 10.7 MHz
- **TV receivers:** 38-41 MHz

Importance:

- **Consistent gain:** Amplifiers operate at fixed frequency.
- **Better selectivity:** Narrowband filters at fixed frequency.
- **Simplified design:** Easier to design efficient fixed-frequency stages.

Selection criteria:

- High enough to provide good image rejection.
- Low enough for practical filter Q and gain.
- Should avoid harmonics of common signals.

Image frequency calculation:

- High-side injection: $f_{image} = f_{RF} + 2f_{IF}$
- Low-side injection: $f_{image} = f_{RF} - 2f_{IF}$

Mnemonic

"CIGS" - Conversion, Improved selectivity, Gain stability, Simplified design

Question 3 [c marks]

7 Explain phase discriminator circuit for FM detection.

Solution

Phase Discriminator for FM Detection:
Purpose:

- Converts frequency variations in FM signal to amplitude variations.
- Demodulates FM signal to recover original message.

Working principle:

1. Input FM signal splits into two paths.
2. Reference path goes directly to center tap.
3. Phase-shifted path passes through LC network.
4. Phase shift varies with frequency deviation.
5. Two diodes produce voltages proportional to phase difference.
6. Output voltage varies with input frequency.

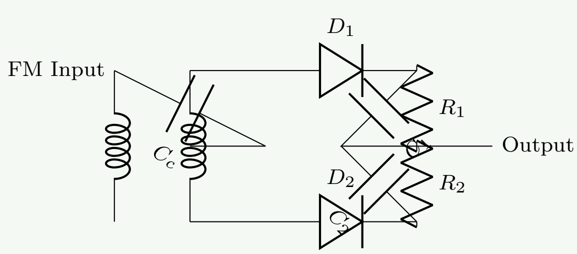


Figure 10. Foster-Seeley Discriminator

S-curve response:

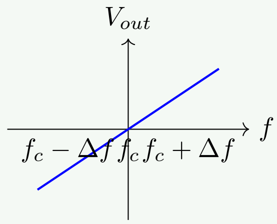


Figure 11. Discriminator S-Curve

Mnemonic

"PSDO" - Phase shift Demodulates, Signal frequency determines Output

Question 4 [a marks]

3 Compare analog and digital communication techniques

Solution

Comparison of Analog vs. Digital Communication:

Parameter	Analog Communication	Digital Communication
Signal	Continuous waveform	Discrete binary values
Bandwidth	Less bandwidth required	More bandwidth required
Noise Immunity	Poor, noise accumulates	Excellent, error correction possible
Power Efficiency	Less efficient	More efficient
Quality	Degrades with distance	Maintains quality until SNR threshold
Multiplexing	FDM primarily used	TDM primarily used
System Complexity	Simpler	More complex
Cost	Lower	Higher but decreasing

Mnemonic

"BNPQ MCE" - Bandwidth, Noise immunity, Power, Quality, Multiplexing, Complexity, Efficiency

Question 4 [b marks]

4 Explain Adaptive delta modulation with its application.

Solution

Adaptive Delta Modulation (ADM):
Working principle:

- Improved version of Delta Modulation (DM).
- Uses variable step size adjusted to signal slope.
- Increases step size for rapid changes (prevents slope overload).
- Decreases step size for slow changes (prevents granular noise).

Block Diagram:

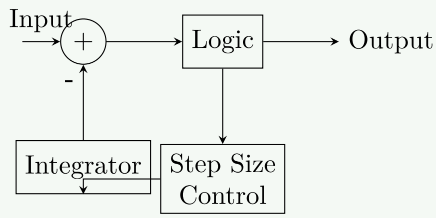


Figure 12. Adaptive Delta Modulation

Applications:

- Speech transmission.
- Audio compression.
- Telemetry systems.
- Military communications.

Mnemonic

"VSOG" - Variable Step size Overcomes Granular noise & slope overload

Question 4 [c marks]

7 Draw & explain block diagram of PCM system.

Solution

Pulse Code Modulation (PCM) System:
Block Diagram:

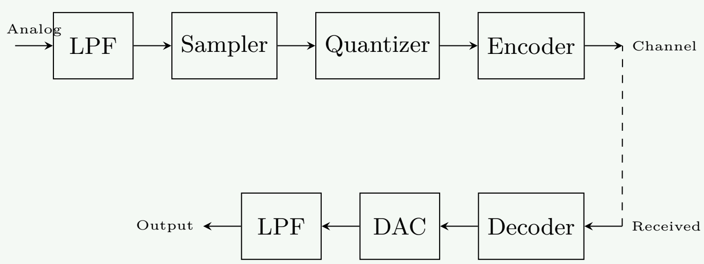


Figure 13. PCM System Block Diagram

Transmitter components:

1. **Sample & Hold:** Samples analog signal at Nyquist rate ($f_s \geq 2f_{max}$).
2. **Quantizer:** Divides amplitude into discrete levels, maps samples to nearest level.
3. **Encoder:** Converts quantized levels to binary code.

Receiver components:

1. **Decoder:** Converts binary to quantized levels.
2. **DAC:** Produces staircase approximation.
3. **Low-Pass Filter:** Smooths output, reconstructs original waveform.

Mnemonic

"SQEC-DFL" - Sample, Quantize, Encode, Channel - Decode, Filter, Listen

Question 4 [a marks]

3 Explain quantization process and its necessity.

Solution

Quantization Process and its Necessity:
Definition: Process of mapping continuous amplitude values to discrete levels.
Types:

- **Uniform quantization:** Equal step size.
- **Non-uniform quantization:** Variable step size.

Necessity:

- **Digital representation:** Enables conversion to binary.
- **Storage efficiency:** Allows finite storage.
- **Processing capability:** Enables DSP.
- **Transmission benefits:** Error correction/encryption.

Quantization error: Max error = $\pm Q/2$ (Q = step size). $SQNR = 6.02n + 1.76$ dB.

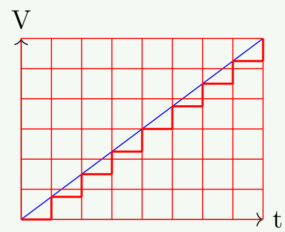


Figure 14. Quantization Staircase

Mnemonic

"DEBS" - Digitization Enables Binary Storage

Question 4 [b marks]

4 Explain PCM receiver.

Solution

PCM Receiver:

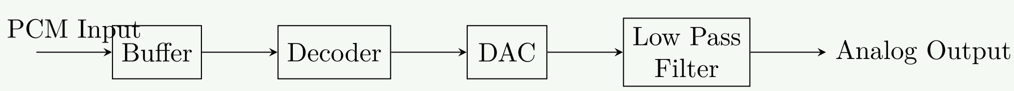


Figure 15. PCM Receiver

Components:

- **Buffer:** Stores data, reduces jitter.
- **Decoder:** Converts binary to quantized levels.
- **DAC:** Creates staircase waveform.
- **Low-Pass Filter:** Smooths waveform.

Mnemonic

"BDFL" - Buffer stores, Decoder converts, Filter smooths, Listen to output

Question 4 [c marks]

7 What is sampling? Explain types of sampling in brief.

Solution

Sampling: Process of converting continuous-time signal into discrete-time signal.
Nyquist Theorem: $f_s \geq 2f_{max}$ to prevent aliasing.
Types of Sampling:

- **Ideal Sampling:** Instantaneous impulses (theoretical).
- **Natural Sampling:** Pulses follow signal shape.
- **Flat-Top Sampling:** Sample-and-hold (staircase).

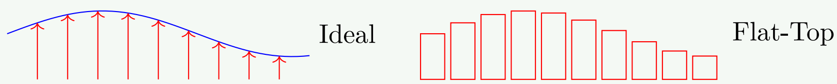


Figure 16. Sampling Types

Mnemonic

"INF" - Ideal (impulses), Natural (pulse-shaped), Flat-top (staircase)

Question 5 [a marks]

3 List the need of Multiplexing.

Solution

Need for Multiplexing:

- **Bandwidth Utilization**: Efficient use of medium.
- **Cost Reduction**: Shares expensive medium.
- **Infrastructure Optimization**: Fewer wires/connections.
- **Spectrum Efficiency**: Maximizes frequency use.
- **Network Capacity**: More users/channels.
- **Flexibility**: Dynamic resource allocation.

Mnemonic

"BCSINF" - Bandwidth, Cost, Spectrum, Infrastructure, Network capacity, Flexibility

Question 5 [b marks]

4 Explain working of DPCM.

Solution

Differential Pulse Code Modulation (DPCM):

- Encodes difference between current and predicted sample.
- Reduces bit rate by exploiting signal correlation.

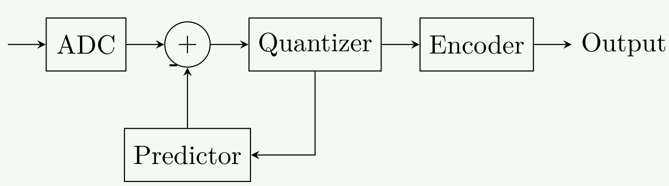


Figure 17. DPCM Transmitter

Mnemonic

"PDQE" - Predict sample, Difference calculated, Quantize error, Encode result

Question 5 [c marks]

7 The binary data 1011001 is to be transmitted using following line coding techniques: (i) Unipolar RZ and NRZ (ii) Polar RZ and NRZ (iii) AMI (iv) Manchester. Draw all the waveforms.

Solution

Line Coding of Binary Data: 1011001

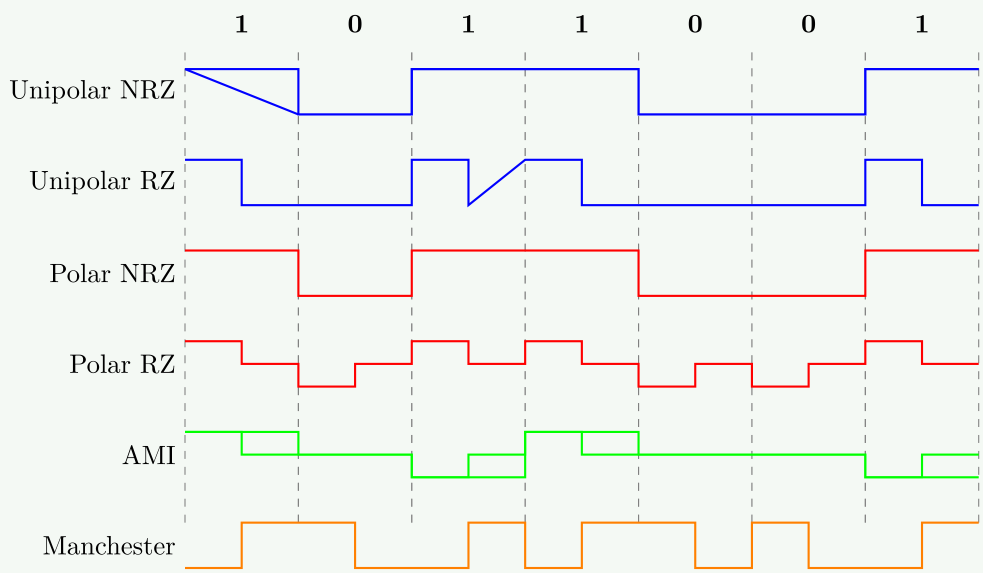


Figure 18. Line Coding Waveforms

Mnemonic

"UPRMA" - Unipolar, Polar, Return-to-zero, Manchester, AMI

Question 5 [a marks]

3 Explain polar RZ and NRZ format

Solution

Polar RZ and NRZ Line Coding:
Polar NRZ:

- Binary 1: $+V$, Binary 0: $-V$
- No return to zero.
- Simple but poor clock recovery.

Polar RZ:

- Binary 1: $+V$ for half bit, 0 for rest.
- Binary 0: $-V$ for half bit, 0 for rest.
- Self-clocking, requires more bandwidth.

Mnemonic

"HZRT" - Half bit active + Zero Return in RZ, full Time in NRZ

Question 5 [b marks]

4 Explain delta modulation in brief.

Solution

Delta Modulation (DM):

- Simplest differential encoding.
- 1 bit per sample (tracks slope).
- Susceptible to slope overload and granular noise.

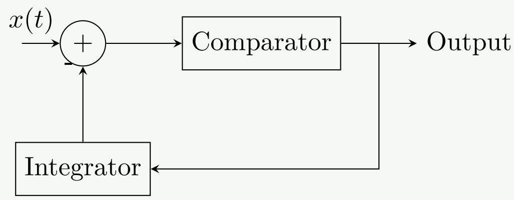


Figure 19. Delta Modulator

Mnemonic

"1BSG" - 1 Bit per Sample, Slope overload and Granular noise limitations

Question 5 [c marks]

7 Explain PCM-TDM system.

Solution

PCM-TDM System:

- Combines PCM (Analog to Digital) with TDM (Multiplexing).
- Multiple analog channels → PCM → Time Multiplexed.

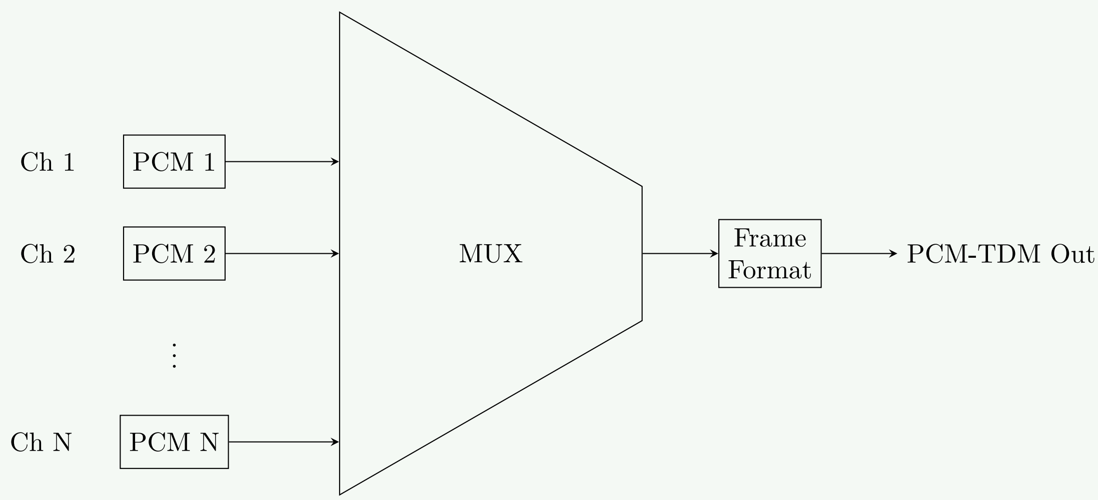


Figure 20. PCM-TDM System

TDM Frame:

One Frame ($1/f_s$)

Sync	Ch 1	Ch 2	···	Ch N

Mnemonic

"MSQT" - Multiplex, Sample, Quantize, Transmit