Principles of Electronic Communication (4331104) - Winter 2022 Solution

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Question 1(a) [3 marks]

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 with a modulating signal containing information.

Need for modulation:

- **Antenna size reduction**: Makes practical antenna size possible ($\lambda = c/f$)
- **Multiplexing**: Allows multiple signals to share the medium
- **Noise reduction**: Improves SNR by shifting to higher frequency bands
- **Range extension**: Increases transmission distance

Mnemonic

"AMEN: Antenna size, Multiplexing, Eliminate noise, New range"

Question 1(b) [4 marks]

Derive voltage equation for Amplitude modulation.

Solution

For AM, the carrier signal is modulated by the message signal.

Mathematical derivation:

- **Carrier signal**: $e_c(t) = A_c \cos(2\pi f_c t)$
- **Message signal**: $e_m(t) = A_m \cos(2\pi f_m t)$
- **Instantaneous amplitude**: $A_i = A_c + e_m(t)$
- **AM signal**: $e_{AM}(t) = A_i \cos(2\pi f_c t)$
- **Substituting**: $e_{AM}(t) = [A_c + A_m \cos(2\pi f_m t)] \cos(2\pi f_c t)$
- **Expanding**: $e_{AM}(t) = A_c \cos(2\pi f_c t) + A_m \cos(2\pi f_m t) \cos(2\pi f_c t)$
- **Final equation**: $e_{AM}(t) = A_c \cos(2\pi f_c t) + \frac{A_m}{2} \cos(2\pi (f_c + f_m)t) + \frac{A_m}{2} \cos(2\pi (f_c - f_m)t)$

Mnemonic

"CAT: Carrier, Addition, Three components (carrier + 2 sidebands)"

Question 1(c) [7 marks]

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

Solution

Noise classification:

Table 1. Noise Classification

Type	Sources	Characteristics
External Noise	Atmospheric, Space, Industrial, Man-made	Originates outside communication system
Internal Noise	Thermal, Shot, Transit-time, Flicker	Originates inside components

Types of Internal Noise:

- **Flicker Noise**:
  - Occurs at low frequencies (below 1 kHz)
  - Inversely proportional to frequency (1/f noise)
  - Common in semiconductor devices and carbon resistors
- **Shot Noise**:
  - Caused by random fluctuations of current carriers
  - White noise with constant power density
  - Occurs in active devices like diodes and transistors
- **Thermal Noise**:
  - Due to random motion of electrons in a conductor
  - Directly proportional to temperature and bandwidth
  - Present in all passive components
  - Also called Johnson noise or white noise

Mnemonic

"FAST: Flicker (low frequency), Active (shot), Semiconductor (flicker), Temperature (thermal)"

Question 1(c) OR [7 marks]

Write application of different band of EM wave spectrum.

Solution

EM Spectrum Applications:

Table 2. EM Spectrum Applications

Frequency Band	Frequency Range	Applications
ELF (Extremely Low Frequency)	3Hz – 30Hz	Submarine communication
VLF (Very Low Frequency)	3kHz – 30kHz	Navigation, time signals
LF (Low Frequency)	30kHz – 300kHz	AM radio, navigation
MF (Medium Frequency)	300kHz – 3MHz	AM broadcasting, maritime
HF (High Frequency)	3MHz – 30MHz	Shortwave radio, amateur radio
VHF (Very High Frequency)	30MHz – 300MHz	FM radio, TV broadcasting, air traffic control
UHF (Ultra High Frequency)	300MHz – 3GHz	TV broadcasting, mobile phones, WiFi, Bluetooth
SHF (Super High Frequency)	3GHz – 30GHz	Satellite communication, radar, WiFi
EHF (Extremely High Frequency)	30GHz – 300GHz	Radio astronomy, 5G, millimeter-wave radar
Infrared	300GHz – 400THz	Remote controls, thermal imaging, fiber optics
Visible Light	400THz – 800THz	Fiber optics, LiFi, photography
Ultraviolet	800THz – 30PHz	Sterilization, fluorescence, security
X-rays	30PHz – 30EHz	Medical imaging, security screening
Gamma rays	>30EHz	Medical treatments, nuclear detection

Mnemonic

"Every Very Lovely Monkey Has Visited Uncle Sam's House Easily In Visible Upper Xtra Gamma"

Question 2(a) [3 marks]

State advantages of SSB over DSB.

Solution

Advantages of SSB over DSB:

Table 3. Advantages of SSB

Advantage	Description
Bandwidth Efficiency	Uses half the bandwidth (only one sideband)
Power Efficiency	Requires less transmitter power (83.33% power saving)
Reduced Fading	Less susceptible to selective fading
Less Distortion	Reduced intermodulation distortion
Simplified Receiver	Simpler circuit design possible

Mnemonic

"BPFDS: Bandwidth, Power, Fading, Distortion, Simple"

Question 2(b) [4 marks]

Explain generation of FM using Phase lock loop technique.

Solution

A Phase-Locked Loop (PLL) generates FM signals by applying the modulating signal to the VCO control input.
PLL FM Modulator:

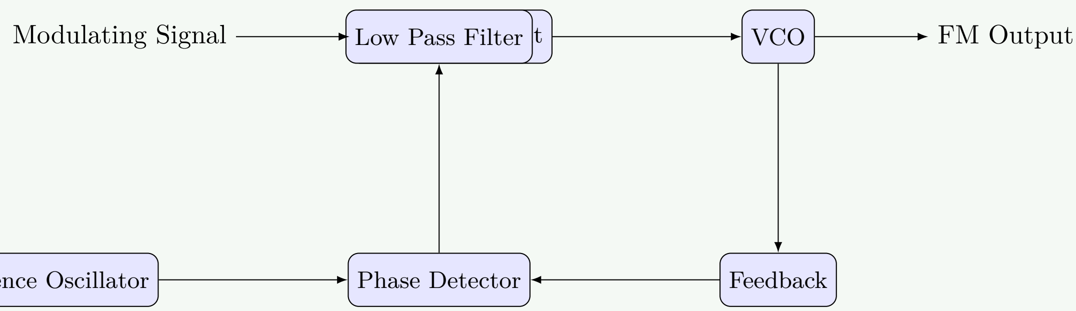

Figure 1. FM Generation using PLL

Operation:

- **Reference Oscillator**: Provides stable reference frequency
- **Phase Detector**: Compares reference and feedback signals
- **Low Pass Filter**: Removes high-frequency components
- **VCO**: Generates output frequency that varies with control voltage
- **Modulating Signal**: Added to control voltage to produce FM output

Mnemonic

"PROVE: Phase detector, Reference oscillator, Output VCO, Voltage controlled"

Question 2(c) [7 marks]

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

Solution

Power in AM:
The AM wave equation: $e_{AM}(t) = A_c[1 + m\cos(2\pi f_m t)]\cos(2\pi f_c t)$
Power derivation:

- **Total power**: $P_T = P_c\left(1 + \frac{m^2}{2}\right)$
- Where $P_c = \frac{A_c^2}{2R}$ (carrier power) and m is modulation index

Power distribution:

- **Carrier power**: $P_c = \frac{A_c^2}{2R}$
- **Total sideband power**: $P_{SB} = \frac{m^2 P_c}{2}$
- **Each sideband**: $P_{LSB} = P_{USB} = \frac{m^2 P_c}{4}$

Power savings:

- **In DSB-SC**: No carrier power, so savings $= \frac{P_c}{P_T} \times 100\% = \frac{1}{1+\frac{m^2}{2}} \times 100\%$
  - For m=1, savings = 66.67%
- **In SSB**: No carrier and one sideband, so savings $= \frac{P_c + P_{SB}/2}{P_T} \times 100\%$
  - For m=1, savings = 83.33%

Mnemonic

"CEPTS: Carrier Eliminated Provides Tremendous Savings"

Question 2(a) OR [3 marks]

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

Solution

Time and Frequency Domain of AM:

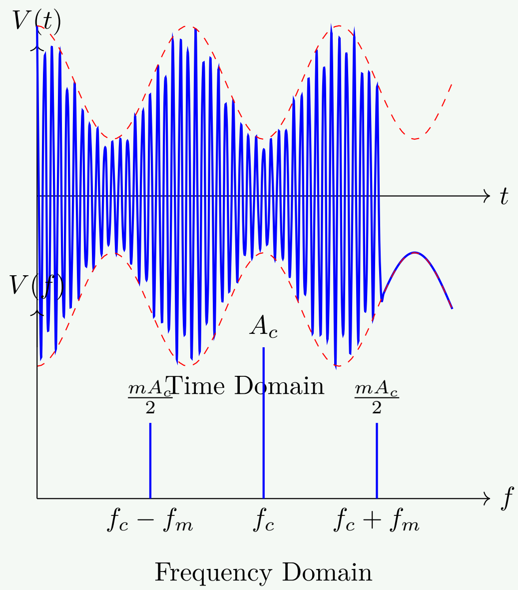

Figure 2. Time and Frequency Domain of AM

Time Domain:
- Shows amplitude variation of carrier with time
- Envelope follows modulating signal
- Upper and lower envelopes = carrier peak $\times(1 \pm m)$

Frequency Domain:
- Shows frequency components and their amplitudes
- Carrier at frequency f_c with amplitude A_c
- Two sidebands at $f_c \pm f_m$ with amplitude $mA_c/2$
- Bandwidth $= 2f_m$ (twice the modulating frequency)

Mnemonic

"EBS: Envelope in time, Bandwidth in frequency, Sidebands symmetric"

Question 2(b) OR [4 marks]

Explain pre-emphasis & de-emphasis circuit.

Solution

Pre-emphasis and De-emphasis:

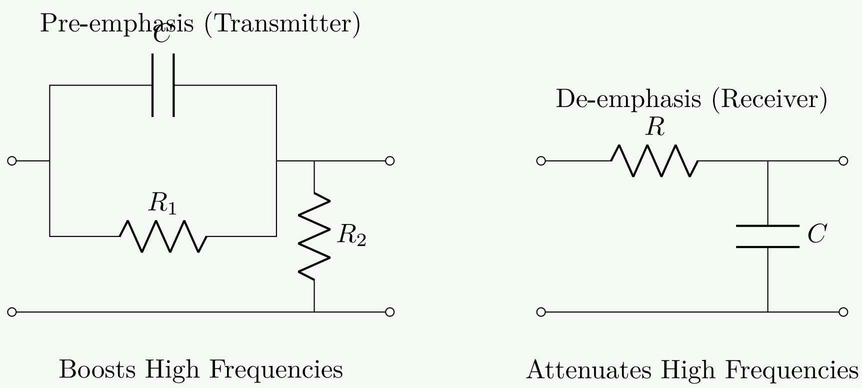

Figure 3. Pre-emphasis and De-emphasis Circuits

Operation:

- **Pre-emphasis**: High-pass network (Time constant $\tau = 75\mu s$). Boosts high frequencies to improve SNR.
- **De-emphasis**: Low-pass network (Time constant $\tau = 75\mu s$). Attenuates high frequencies to restore original signal and reduce noise.

Mnemonic

"BETH: Boost (pre-emphasis), Emphasizes Treble, Helps SNR"

Question 2(c) OR [7 marks]

Compare AM, FM and PM.

Solution

Comparison of AM, FM and PM:

Table 4. Comparison of AM, FM, and PM

Parameter	AM	FM	PM
Definition	Amplitude varies	Frequency varies	Phase varies
Equation	$A_c[1 + m\cos(\omega_m t)]\cos(\omega_c t)$	$A_c\cos[\omega_c t + m_f \sin(\omega_m t)]$	$A_c\cos[\omega_c t + m_p\cos(\omega_m t)]$
Bandwidth	$2f_m$ (Narrow)	$2(\Delta f + f_m)$ (Wide)	$2(m_p + 1)f_m$ (Wide)
Efficiency	Low	High	High
Noise	Poor	Excellent	Excellent
Complexity	Simple	Complex	Complex
Applications	Broadcasting	Radio, TV	Satellite

Mnemonic

"BANCP-MAP: Bandwidth, Amplitude, Noise, Complexity, Power, Modulation, Applications, Parameters"

Question 3(a) [3 marks]

Define any FOUR characteristics of radio receiver.

Solution

Radio Receiver Characteristics:

Table 5. Receiver Characteristics

Characteristic	Definition
Sensitivity	Minimum signal strength required for acceptable output
Selectivity	Ability to separate desired signal from adjacent signals
Fidelity	Accuracy in reproducing the original signal without distortion
Image rejection	Ability to reject image frequency interference
SNR	Ratio of desired signal to unwanted noise
Stability	Ability to maintain tuned frequency without drift

Mnemonic

"SFIS-SS: Sensitivity, Fidelity, Image rejection, Selectivity, SNR, Stability"

Question 3(b) [4 marks]

Draw the block diagram of FM receiver. What is the use of Limiter in FM receiver.

Solution

FM Receiver Block Diagram:

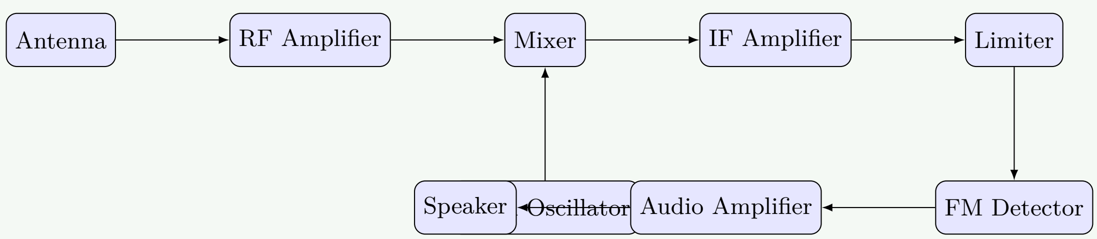

Figure 4. FM Receiver Block Diagram

Use of Limiter in FM Receiver:
- **Primary function**: Removes amplitude variations (noise) from the FM signal.
- **Operation**: Clips the signal peaks to provide a constant amplitude output to the detector.
- **Benefits**: Eliminates AM noise/interference, improves SNR, and ensures the FM detector responds only to frequency changes.

Mnemonic

"CARE: Clips Amplitude, Removes noise, Ensures constant signal"

Question 3(c) [7 marks]

Draw and explain block diagram of super heterodyne receiver.

Solution

Super Heterodyne Receiver:

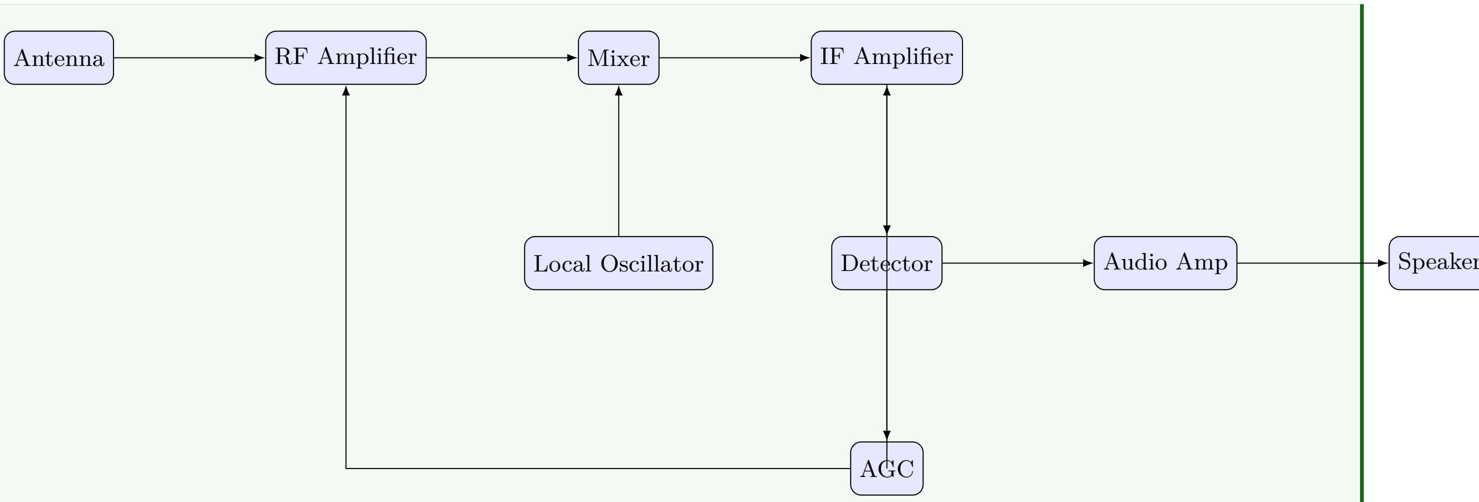

Figure 5. Super Heterodyne Receiver

Function of each block:

- **Antenna**: Captures RF signals.
- **RF Amplifier**: Amplifies weak signals, improves SNR and selectivity.
- **Mixer**: Mixes incoming RF with LO frequency to produce Intermediate Frequency (IF).
- **Local Oscillator**: Generates frequency $f_{LO} = f_{RF} + f_{IF}$.
- **IF Amplifier**: Provides major amplification and selectivity at fixed frequency (e.g., 455 kHz).
- **Detector**: Demodulates the signal to extract audio.
- **AGC**: Automatic Gain Control maintains constant output despite fading.
- **Audio Amplifier**: Boosts power to drive speaker.

Mnemonic

"ARLMIDAS: Antenna Receives, Local Mixes, IF Delivers, Audio Sounds"

Question 3(a) OR [3 marks]

Draw and explain block diagram for envelope detector.

Solution

Envelope Detector:

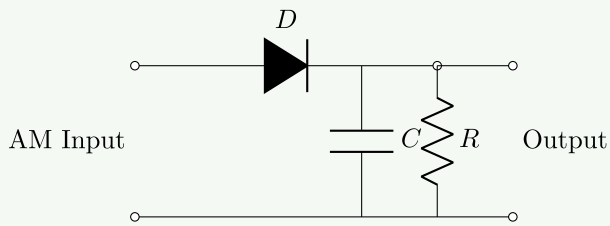

Figure 6. Envelope Detector

Operation:

1. **Diode (D)**: Rectifies AM signal (allows only positive half-cycles).
2. **Capacitor (C)**: Charges to peak of input, filters carrier frequency.
3. **Resistor (R)**: Discharges capacitor, allowing it to follow the modulating signal envelope.
4. **RC constant**: Selected such that $\frac{1}{f_c} \ll RC \ll \frac{1}{f_m}$.

Mnemonic

"DRIVER: Diode Rectifies, RC Values Extract Envelope, Restores audio"

Question 3(b) OR [4 marks]

What is IF? Explain its importance in brief.

Solution

Intermediate Frequency (IF):
Definition: IF is a fixed frequency to which incoming RF signals are converted in superheterodyne receivers.
Importance of IF:

Table 6. Importance of IF

Aspect	Importance
Fixed Frequency	Allows optimized amplification at one frequency
Improved Selectivity	Fixed-tuned filters provide better adjacent channel rejection
Stable Gain	Consistent amplification across entire tuning range
Image Rejection	Helps reject image frequency interference
Simplified Tuning	Only local oscillator needs to be tuned for different stations

Typical IF Values:
- AM receivers: 455 kHz
- FM receivers: 10.7 MHz

Mnemonic

"FIGS-ST: Fixed frequency, Improved selectivity, Gain stability, Simplified tuning"

Question 3(c) OR [7 marks]

Explain phase discriminator circuit for FM detection.

Solution

Phase Discriminator (Foster-Seeley):

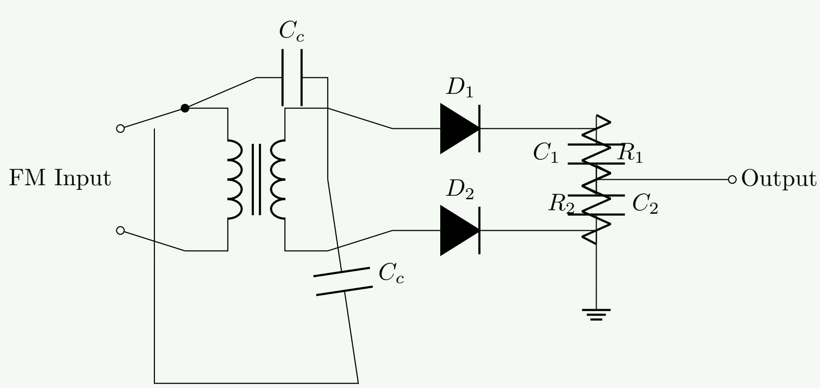

Figure 7. Phase Discriminator

Operation:

1. **Center-tapped transformer** and capacitor create phase difference dependent on frequency.
2. **Resonance**: At f_c, phase shift is 90 degrees, D_1 and D_2 conduct equally, output is 0.
3. **Off-Resonance**: At $f > f_c$ or $f < f_c$, phase shift changes, one diode conducts more.
4. **Output**: Differential voltage proportional to frequency deviation.

Advantages: Good linearity, reduced distortion.

Mnemonic

"PERFECT: Phase Ensures Rectification For Extracting Carrier Transitions"

Question 4(a) [3 marks]

Explain quantization process and its necessity.

Solution

Quantization Process:
Quantization matches the continuous amplitude range to a finite number of discrete levels.

1. Sampling converts continuous-time to discrete-time.
2. Amplitudes are divided into finite levels ($L = 2^n$).
3. Each sample is assigned to the nearest level.
4. Difference is quantization error.

Necessity:

Table 7. Necessity of Quantization

Necessity	Explanation
Digital Processing	Enables digital storage and manipulation
Error Control	Allows error detection and correction
Noise Immunity	Digital signals more resistant to noise
Storage Efficiency	More efficient than storing analog values

Mnemonic

"DENSE: Digital conversion, Error control, Noise immunity, Storage, Efficient transmission"

Question 4(b) [4 marks]

Give difference between DM and ADM.

Solution

Difference between DM and ADM:

Table 8. DM vs ADM

Parameter	Delta Modulation (DM)	Adaptive Delta Modulation (ADM)
Step Size	Fixed	Variable (adapts to signal)
Slope Overload	Common at steep signals	Reduced with adaptive step
Granular Noise	High for small signals	Reduced with smaller steps
Complexity	Simple	Moderate
Bit Rate	Higher for good quality	Lower for same quality

Mnemonic

"SAVAGES: Step size, Adaptable, Variable tracking, Avoids overload, Granular noise reduction"

Question 4(c) [7 marks]

Draw & explain block diagram of PCM system.

Solution

PCM System Block Diagram:

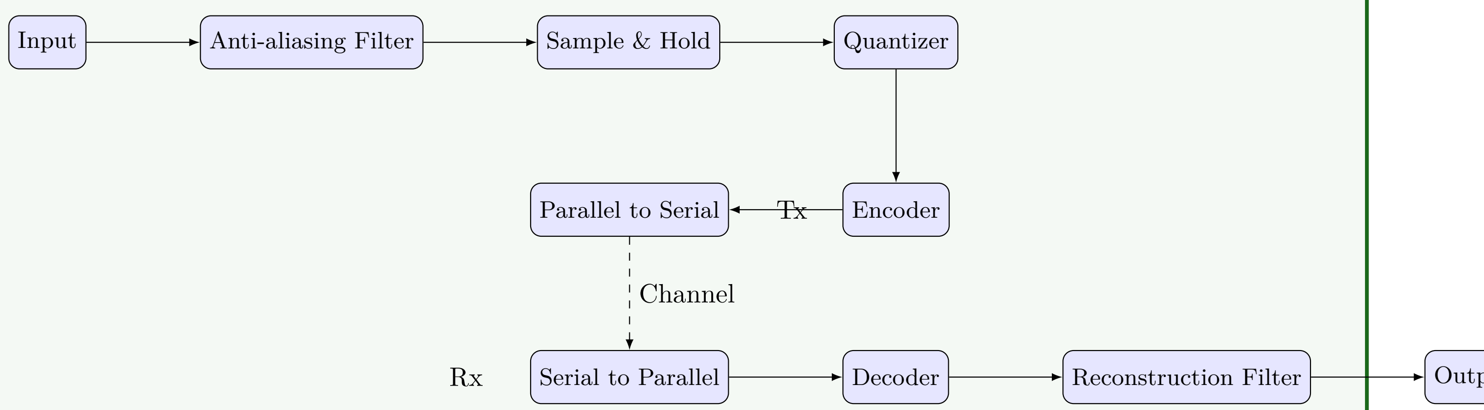

Figure 8. PCM System

PCM Transmitter:
- **Anti-aliasing Filter**: Limits bandwidth.
- **Sample & Hold**: Discretizes time.
- **Quantizer**: Discretizes amplitude.
- **Encoder**: Converts levels to binary.

PCM Receiver:
- **Decoder**: Converts binary back to amplitude levels.
- **Reconstruction Filter**: Recovers analog signal.

Mnemonic

"SAFE-PETS: Sample, Amplify, Filter, Encode, Pulse train, Extract, Transform, Smooth"

Question 4(a) OR [3 marks]

Define quantization. Explain non uniform quantization in brief.

Solution

Quantization: Process of converting continuous amplitude samples into discrete values.
Non-uniform Quantization:
- Uses unequal step sizes.
- **Small steps** for small variance signals (improves SNR for weak signals).
- **Large steps** for large variance signals.
- Implemented using **Companding** (Compressing + Expanding).

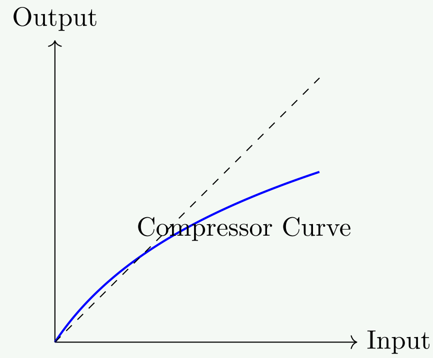

Figure 9. Non-uniform Quantization (Companding)

Mnemonic

"CLASP: Compressed Levels, Adaptive Steps, Small steps for small signals, Perceptual matching"

Question 4(b) OR [4 marks]

Explain Adaptive delta modulation with its application.

Solution

Adaptive Delta Modulation (ADM):

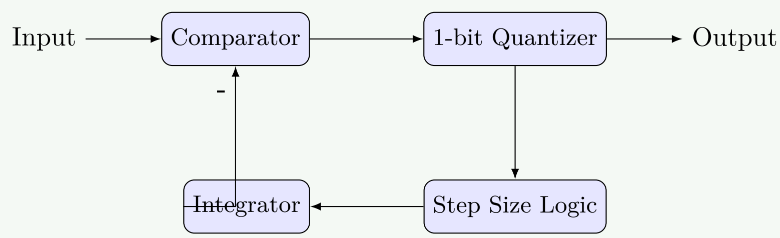

Figure 10. Adaptive Delta Modulation

Operation:
- Step size is NOT fixed.
- If sequence of bits is same (1111 or 0000), step size increases to prevent **Slope Overload**.
- If sequence alternates (1010), step size decreases to reduce **Granular Noise**.

Applications: Digital voice, audio compression.

Mnemonic

"ADAPT: Automatically Decides Appropriate Pulse Transitions"

Question 4(c) OR [7 marks]

What is sampling? Explain types of sampling in brief.

Solution

Sampling: Converting continuous-time signal to discrete-time.
Types of Sampling:

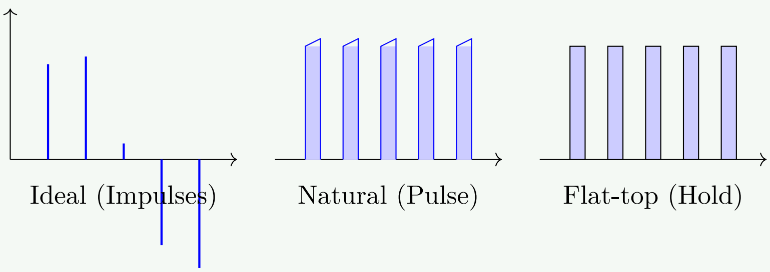

Figure 11. Types of Sampling

- **Ideal**: Instantaneous impulses (Theoretical).
- **Natural**: Pulse follows signal shape during width.
- **Flat-top**: Amplitude held constant during pulse width (Sample & Hold).

Mnemonic

"INFS: Ideal (impulses), Natural (follows signal), Flat-top (constant), Sufficient rate"

Question 5(a) [3 marks]

Define bit rate and baud rate.

Solution

Bit Rate and Baud Rate:

Table 9. Bit Rate vs Baud Rate

Parameter	Definition	Formula
Bit Rate (R_b)	Number of bits per second	$R_b = \text{Baud} \times \log_2 M$
Baud Rate	Number of signal symbols per second	$\text{Baud} = f_s$

- For Binary (M=2), Bit Rate = Baud Rate.
- For QPSK (M=4), Bit Rate = 2 × Baud Rate.

Mnemonic

"BBSM: Bits per second, Baud for Symbols, Modulation determines relationship"

Question 5(b) [4 marks]

Explain working of DPCM.

Solution

Differential Pulse Code Modulation (DPCM):

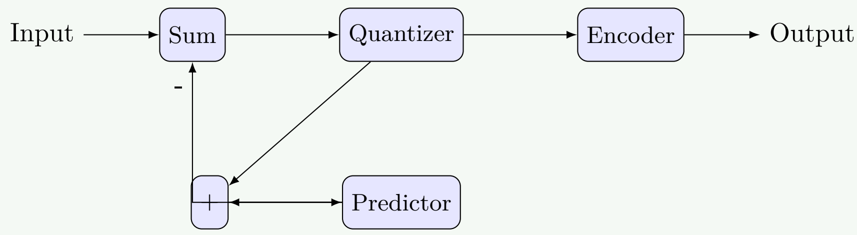

Figure 12. DPCM Transmitter

Working: Encodes the **difference** between current sample and predicted value. Improves efficiency as difference has smaller dynamic range than original signal.

Mnemonic

"DEEP: Difference Encoded, Efficient Prediction, Exploits correlation, Preserves quality"

Question 5(c) [7 marks]

The binary data 1011001 is to be transmitted... Draw all the waveforms.

Solution

Line Coding Waveforms (Data: 1 0 1 1 0 0 1):

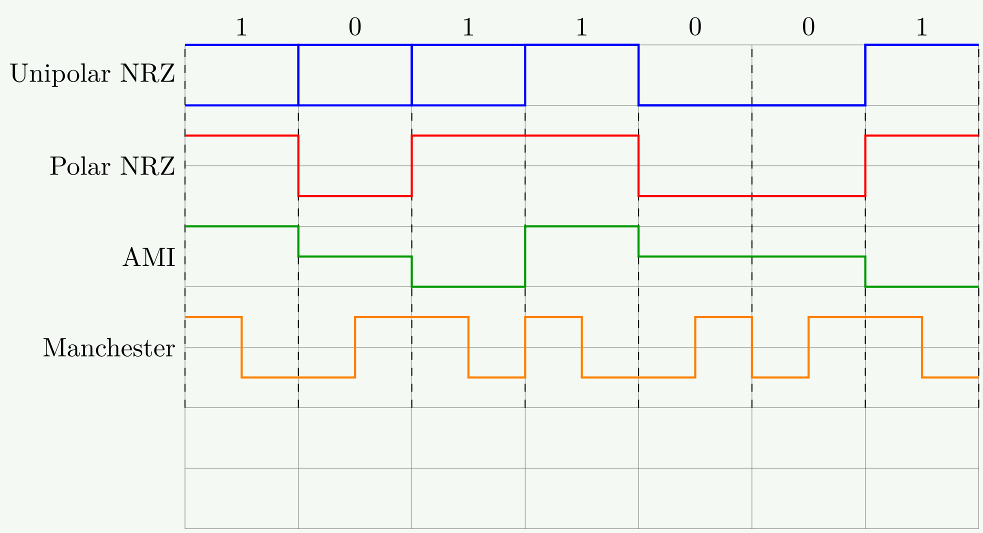

Figure 13. Line Coding Waveforms

Mnemonic

"UPAM: Unipolar, Polar, AMI, Manchester encoding options"

Question 5(a) OR [3 marks]

Compare RZ and NRZ coding with example.

Solution

Comparison of RZ and NRZ:

Table 10. RZ vs NRZ

Parameter	RZ	NRZ
Signal levels	Returns to zero in bit	Maintains level
Bandwidth	Higher	Lower
Sync	Better (more transitions)	Poorer
DC component	Present	More significant

Mnemonic

"BPSIDC: Bandwidth, Power, Synchronization, Implementation, DC component"

Question 5(b) OR [4 marks]

Explain delta modulation in brief.

Solution

Delta Modulation (DM):
Principle: Encodes only the difference (delta) between current sample and previous sample using 1 bit.

- If Input > Pred: Output 1 (Count Up)
- If Input < Pred: Output 0 (Count Down)

Limitations: Slope Overload and Granular Noise.

Mnemonic

"SIDE: Single-bit, Integrates Differences, Encodes changes"

Question 5(c) OR [7 marks]

Explain PCM-TDM system.

Solution

PCM-TDM System:

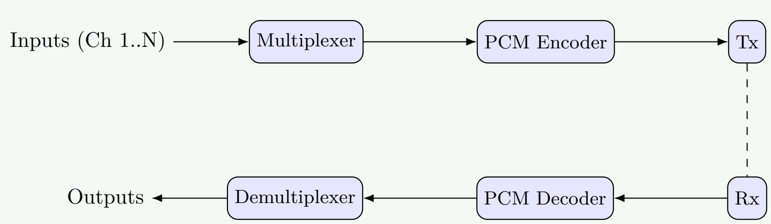

Figure 14. PCM-TDM Block Diagram

Operation: Samples from multiple channels are interleaved in time (TDM) and then PCM encoded using a shared encoder.
Hierarchy: Filtering → Multiplexing → Quantizing → Framing → Transmission.

Mnemonic

"MOST-FDR: Multiplex, Quantize, Sample, Transmit, Frame, Demultiplex, Reconstruct"