Subject Name Solutions

4331104 – Winter 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Classify Noise signal and explain thermal noise.

Solution

Noise signals can be classified as:

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

Thermal Noise:

- **Definition**: Random motion of electrons in a conductor due to temperature
- **Characteristics**: White noise with uniform power across frequency spectrum
- **Formula**: N = kTB (k=Boltzmann constant, T=Temperature, B=Bandwidth)

Mnemonic

"Temperature Excites Random Movements" (TERM)

Question 1(b) [4 marks]

Comparison between Pre-emphasis and De-emphasis technique.

Solution

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 s (standard)	75 s (matches pre-emphasis)

Diagram/Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Pre{-}emphasis Circuit]}
    B {-{-}{} C[Modulator]}
    C {-{-}{} D[Transmission]}
    D {-{-}{} E[Demodulator]}
    E {-{-}{} F[De{-}emphasis Circuit]}
    F {-{-}{} G[Output]}
    style B fill:\#f96,stroke:\#333
    style F fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Mnemonic

"Pump Up Before Transmit, Pull Down After Receive" (PUBTAR)

Question 1(c) [7 marks]

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) = Ac cos(2 fct)
2. Let the modulating signal be: m(t) = Am cos(2 fmt)
3. AM signal: s(t) = Ac[1 + · m(t)/Am]cos(2 fct) where
   = modulation
   index
4. Substituting m(t): s(t) = Ac[1 + · cos(2 fmt)]cos(2 fct)
5. Using trigonometric identity cos(A) · cos(B) = ½cos(A+B) + ½cos(A-B): s(t) = Ac · cos(2 fct) + (Ac/2) · cos(2 (fc+fm)t) + (Ac/2) · cos(2 (fc-fm)t)

Frequency Spectrum:

Component	Frequency	Amplitude
Carrier	fc	Ac
Upper Sideband	fc + fm	Ac/2
Lower Sideband	fc - fm	Ac/2

Diagram:

```
              f
fc{-fm   fc    fc+fm}

LSB    Carrier   USB
```

Mnemonic

"Carrier Standing Between Twins" (CSBT)

Question 1(c) OR [7 marks]

Explain block diagram of Communication System.

Solution

Block Diagram of Communication System:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Transducer] {-{-}{} B[Transmitter]}
    B {-{-}{} C[Channel/Medium]}
    C {-{-}{} D[Receiver]}
    D {-{-}{} E[Output Transducer]}
    F[Noise Source] {-{-}{} C}
    style F fill:\#f66,stroke:\#333
{Highlighting}
{Shaded}
```

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

Mnemonic

"Input Transmits Through Channel, Receives Output" (ITCRO)

Question 2(a) [3 marks]

Discuss power distribution among sidebands and carrier in amplitude modulation.

Solution

Power Distribution in AM Signal:

Component	Power Formula	Percentage (for m=1)
Carrier	Pc = $(Ac^2/2)$	67%
Upper Sideband	PUSB = $(Pc \cdot m^2)/4$	16.5%
Lower Sideband	PLSB = $(Pc \cdot m^2)/4$	16.5%
Total Power	PT = $Pc(1+m^2/2)$	100%

Diagram:

```
   Power

 100\%


  67\%



16.5\%
      LSB    C    USB

   0\%
       Components of AM
```

Mnemonic

"Carrier Takes Two-Thirds" (CTTT)

Question 2(b) [4 marks]

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:

Purpose	Explanation
Improve SNR	Boosts high frequencies before transmission to overcome noise
Reduce Noise	High frequencies in FM are more susceptible to noise
Maintain Fidelity	Ensures overall frequency response remains flat

Signal Modification Process:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Audio Input] {-{-}{} B[Pre{-}emphasis at Transmitter]}
    B {-{-}{} C["Boosted High Frequencies{}br /{}(Above 2kHz)"]}
    C {-{-}{} D[FM Modulation]}
    D {-{-}{} E[Transmission]}
    E {-{-}{} F[FM Demodulation at Receiver]}
    F {-{-}{} G[De{-}emphasis]}
    G {-{-}{} H["Restored Original{}br /{}Frequency Response"]}
    style B fill:\#f96,stroke:\#333
    style G fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Mnemonic

"Boost High, Cut High, Keep Original" (BHCKO)

Question 2(c) [7 marks]

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	Simple design
Indirect FM	Phase modulation to produce FM	Better stability
PLL FM	Using phase locked loop	High frequency stability
Armstrong method	Using mixers and filters	Excellent linearity

PLL FM Modulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Modulating Signal] {-{-}{} B[VCO]}
    B {-{-}{} C[Phase Detector]}
    D[Reference Oscillator] {-{-}{} C}
    C {-{-}{} E[Loop Filter]}
    E {-{-}{} B}
    B {-{-}{} F[FM Output]}
    style B fill:\#f96,stroke:\#333
    style C fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Working Principle:

1. **Phase Detector** compares VCO output with reference oscillator
2. **Loop Filter** removes high-frequency components
3. **VCO** (Voltage Controlled Oscillator) frequency changes with modulating signal
4. Modulating signal directly controls the VCO
5. PLL ensures high stability and linearity

Mnemonic

"Phase Detector Compares, Filter Smooths, VCO Varies" (PDCFV)

Question 2(a) OR [3 marks]

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 the bandwidth	**Complex Circuitry**: Requires complex filtering
Power Efficiency: Uses about 1/3 the power	**Difficult Demodulation**: Needs carrier recovery
Reduced Fading: Less susceptible to selective fading	**Distortion**: May distort low frequencies
Less Interference: Narrower channel means less overlap	**Cost**: More expensive than DSB systems

Mnemonic

"Power and Bandwidth Saved, But Complex Circuits Needed" (PBSCN)

Question 2(b) OR [4 marks]

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

Solution

DSBSC Frequency Spectrum:

```
               f
     fc{-fm       fc+fm}

      LSB         USB
```

SSB (Upper Sideband) with Pilot Carrier:

```
                f
               fc        fc+fm

          Pilot Carrier   USB
```

Comparison Table:

Spectrum Type	Bandwidth	Components	Power Efficiency
DSBSC	2fm	LSB + USB	Medium (no carrier power)
SSB	fm	USB or LSB	High (one sideband only)
SSB with Pilot	fm + small	USB/LSB + reduced carrier	Good (minimal carrier power)

Mnemonic

"Two Sides, One Side, or One Side Plus Pilot" (TSOSP)

Question 2(c) OR [7 marks]

Write a short-note on: Pulse modulation.

Solution

Pulse Modulation Techniques:
Pulse modulation is a process where continuous analog signal is sampled and converted into pulses.

Type	Description	Principle	Application
PAM (Pulse Amplitude Modulation)	Amplitude of pulses varies with signal	Sampling and holding	Intermediate step for PCM
PWM (Pulse Width Modulation)	Width/duration of pulses varies	Comparing with ramp	Motor control, power control
PPM (Pulse Position Modulation)	Position of pulses varies	Timing shift	Optical communication, radar
PCM (Pulse Code Modulation)	Digital representation using binary code	Quantizing and encoding	Digital telephony, CDs

Waveform Comparison:

```
Original Signal:
   /{      /      /}
  /  {    /      /  }
 /    {  /      /    }
/      {/      /      }

PAM:
   |      |      |
   |      |      |
   |      |      |
   |      |      |

PWM:
   \_\_\_\_    \_\_\_\_\_    \_\_
  |    |  |     |  |  |
  |    |  |     |  |  |
\_\_|    |\_\_|     |\_\_|  |\_\_

PPM:
   \_     \_     \_
  | |   | |   | |
  | |   | |   | |
\_\_|\_|\_\_\_|\_|\_\_\_|\_|\_\_\_\_\_
```

Mnemonic

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

Question 3(a) [3 marks]

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

Solution

Automatic Gain Control (AGC):

- **Definition**: Circuit that automatically adjusts gain to maintain constant output level
- **Purpose**: Compensates for varying signal strength in receivers
- **Types**: Simple AGC, Delayed AGC, Amplified AGC

Input-Output Characteristic Curve:

```
    Output

  Max {- {-} {-} {-} {-} {-} {-} {-} {-} {-} {-} {-} {-} {-}}

                    /
                   /
                  /
                 /
                /  With AGC

           /
          /
         /
        /
   Min /
      /  Without AGC
     /
    /
   /
               Input
     Min            Max
```

Working: As input increases, gain decreases to keep output nearly constant after threshold

Mnemonic

"Strong Signals Get Less Gain" (SSLG)

Question 3(b) [4 marks]

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

Solution

Balanced Ratio Detector:

Feature	Description
Definition	FM demodulator using a balanced circuit to convert frequency variations to amplitude variations
Key Components	Two diodes, transformer with center-tapped secondary, balanced capacitors
Advantages	Superior noise immunity, AM rejection, stability
Applications	FM receivers, broadcast receivers

Circuit Diagram:

```
     +{-{-}{-}{-}{-}+     +{-}{-}{-}{-}{-}+}
     |     |{-{-}{-}{-}{-}|     |}
     |  T  |     |  D1 |
     |     |{-{-}+{-}{-}|     |}
in{-{-}|     |  |  +{-}{-}{-}{-}{-}+}
     |     |  |
     |     |  |  +{-{-}{-}{-}{-}+}
     |     |{-{-}{-}{-}{-}|     |}
     +{-{-}{-}{-}{-}+     |  D2 |}
                |     |
                +{-{-}{-}{-}{-}+}
                  |
                  v
                output
```

Working Principle:

- Transformer creates phase-shifted signals for the diodes
- Diodes charge capacitors with different polarities
- As frequency deviates, voltage ratio changes proportionally
- Output is proportional to frequency deviation

Mnemonic

"Balanced Diodes Transform Frequency To Voltage" (BDTFV)

Question 3(c) [7 marks]

Explain working of various types of FM demodulator circuits.

Solution

Types of FM Demodulator Circuits:

Demodulator Type	Working Principle	Advantages	Disadvantages
Slope Detector	Uses slope of tuned circuit response	Simple design	Poor linearity, poor AM rejection
Foster-Seeley Discriminator	Uses phase shifts in transformer	Good linearity	Sensitive to amplitude variations
Ratio Detector	Modified discriminator with amplitude limiting	Good AM rejection	Moderate linearity
PLL Demodulator	Phase comparison with VCO	Excellent linearity, good noise immunity	Complex circuit
Quadrature Detector	Phase shifting and multiplication	Simple IC implementation	Limited bandwidth

PLL FM Demodulator Circuit:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[FM Input] {-{-}{} B[Phase Detector]}
    C[VCO] {-{-}{} B}
    B {-{-}{} D[Loop Filter]}
    D {-{-}{} C}
    D {-{-}{} E[Demodulated Output]}
    style B fill:\#f96,stroke:\#333
    style C fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Working Principle:

1. Phase detector compares incoming FM with VCO output
2. Error voltage is filtered to remove high frequencies
3. VCO is forced to track input frequency
4. Filter output is proportional to frequency deviation
5. This output is the demodulated FM signal

Mnemonic

"Frequency Variations Drive Phase Errors" (FVDPE)

Question 3(a) OR [3 marks]

Explain characteristics of a Radio receiver.

Solution

Characteristics of a Radio Receiver:

Characteristic	Definition	Importance
Sensitivity	Ability to amplify weak signals	Determines maximum reception range
Selectivity	Ability to separate desired signal from adjacent signals	Prevents interference
Fidelity	Accuracy in reproducing original signal	Ensures sound quality
Image Frequency Rejection	Ability to reject image frequency	Prevents duplicate reception

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Selectivity] {-{-}{} B[Ideal Receiver Characteristics]}
    C[Sensitivity] {-{-}{} B}
    D[Fidelity] {-{-}{} B}
    E[Image Rejection] {-{-}{} B}
    style B fill:\#f96,stroke:\#333
{Highlighting}
{Shaded}
```

Mnemonic

"Select Signals Faithfully, Ignore Mirrors" (SSFIM)

Question 3(b) OR [4 marks]

Explain types of distortions occur in AM detector circuit.

Solution

Types of Distortions in AM Detector Circuit:

Distortion Type	Cause	Effect	Prevention
Diagonal Distortion	Incorrect time constant	Inability to follow envelope	Proper RC time constant
Negative Peak Clipping	Improper biasing	Loss of information	Proper diode biasing
Harmonic Distortion	Non-linear diode characteristics	Audio distortion	High-quality diodes
Frequency Distortion	Improper filtering	Uneven frequency response	Proper filter design

Diagram:

```
Normal Detection:
    /{      /      /}
   /  {    /      /  }
  /    {  /      /    }
 /      {/      /      }

Diagonal Distortion:
    /{      /      /}
   /  {    /      /  }
  /    {  /      /    }
 /      \_      \_      \_

Negative Peak Clipping:
    /{      /      /}
   /  {    /      /  }
  /    {  /      /    }
\_/\_\_\_\_\_\_{/\_\_\_\_\_\_/\_\_\_\_\_\_}
```

Mnemonic

"Diagonal Negative Harmonics Frequency - Distortion Types" (DNHF)

Question 3(c) OR [7 marks]

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

Solution

Superheterodyne AM Receiver:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Antenna] {-{-}{} B[RF Amplifier]}
```

```
    B {-{-}{} C[Mixer]}
    D[Local Oscillator] {-{-}{} C}
    C {-{-}{} E[IF Amplifier]}
    E {-{-}{} F[Detector]}
    F {-{-}{} G[AF Amplifier]}
    G {-{-}{} H[Speaker]}
    I[AGC] {-{-}{} B}
    I {-{-}{} E}
    F {-{-}{} I}
    style C fill:\#f96,stroke:\#333
    style E fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Function of Each Block:

Block	Function	Key Characteristics
RF Amplifier	Amplifies weak RF signals	Improves sensitivity, selectivity
Local Oscillator	Generates signal at fixed frequency above incoming signal	Stability is critical
Mixer	Combines RF and local oscillator to produce IF	Key to superheterodyne principle
IF Amplifier	Amplifies intermediate frequency	Main gain stage, fixed frequency
Detector	Extracts audio from modulated signal	Typically diode detector
AF Amplifier	Amplifies audio to drive speaker	Power amplification
AGC	Maintains constant output level	Controls gain of RF and IF amplifiers

Key Advantages:

- Fixed IF frequency allows optimized amplification
- Better selectivity and sensitivity
- Easier tuning

Mnemonic

"Radio Mixing Local Intermediate Detected Audio Signals" (RMLIDAS)

Question 4(a) [3 marks]

Explain quantization process used in analog to digital conversion.

Solution

Quantization Process:

Step	Description	Purpose
1. **Sampling**	Converting continuous signal to discrete-time	Prepare for quantization
2. **Level Allocation**	Dividing amplitude range into discrete levels	Create digital steps
3. **Assignment**	Mapping each sample to nearest quantization level	Convert to digital value
4. **Encoding**	Converting levels to binary code	Final digital representation

Diagram:

```
Analog Signal:
    /{}
   /  {}
  /    {}
 /      {}

Quantized Signal:
    \_\_
   |  |
  \_|  |\_
 |      |
```

Types of Quantization:

- **Uniform**: Equal step sizes
- **Non-uniform**: Varying step sizes
- **Adaptive**: Adjusts based on signal

Mnemonic

"Sample Levels Assign Binary" (SLAB)

Question 4(b) [4 marks]

Give the comparison of Sampling techniques.

Solution

Comparison of Sampling Techniques:

Sampling Technique	Description	Advantages	Disadvantages
Ideal Sampling	Instantaneous sampling of signal	Perfect representation	Practically impossible
Natural Sampling	Top of pulse follows signal amplitude	No flat tops	Difficult implementation
Flat-top Sampling	Sample and hold circuit	Easy implementation	Additional distortion

Diagram:

```
Original Signal:
    /{      /      /}
   /  {    /      /  }
  /    {  /      /    }
 /      {/      /      }

Ideal Sampling:
   |      |      |
   |      |      |
   |      |      |
   |      |      |

Natural Sampling:
   /{     /     /}
   |      |      |
   |      |      |
   |      |      |

Flat{-top Sampling:}
   \_\_\_     \_\_\_     \_\_\_
   |       |       |
   |       |       |
   |       |       |
```

Mnemonic

"Ideal Natural Flat - Sampling Types" (INF)

Question 4(c) [7 marks]

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

Solution

PCM Transmitter Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input Signal] {-{-}{} B[Low{-}pass Filter]}
    B {-{-}{} C[Sample \& Hold]}
    C {-{-}{} D[Quantizer]}
    D {-{-}{} E[Encoder]}
    E {-{-}{} F[Multiplexer]}
    F {-{-}{} G[Line Coder]}
    G {-{-}{} H[Channel]}
    style D fill:\#f96,stroke:\#333
    style E fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

PCM Receiver Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Channel] {-{-}{} B[Line Decoder]}
```

```
    B {-{-}{} C[Demultiplexer]}
    C {-{-}{} D[Decoder]}
    D {-{-}{} E[Reconstruction Filter]}
    E {-{-}{} F[Output Signal]}
    style C fill:\#f96,stroke:\#333
    style D fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Working of PCM System:

Block	Function
Low-pass Filter	Limits bandwidth to avoid aliasing
Sample & Hold	Samples analog signal at regular intervals
Quantizer	Assigns discrete levels to samples
Encoder	Converts quantized values to binary code
Multiplexer	Combines multiple PCM channels
Line Coder	Prepares signal for transmission
Demultiplexer	Separates channels at receiver
Decoder	Converts binary back to quantized values
Reconstruction Filter	Smooths out staircase to recover analog

Mnemonic

"Filter, Sample, Quantize, Encode, Multiplex, Transmit" (FSQEMT)

Question 4(a) OR [3 marks]

State and explain Nyquist theorem.

Solution

Nyquist Theorem:

- **Statement**: To perfectly reconstruct a bandlimited signal, the sampling frequency must be at least twice the highest frequency component in the signal.

Concept	Formula	Explanation
Sampling Rate	fs $\geq 2fmax$	Minimum required sampling frequency
Nyquist Rate	2fmax	Minimum sampling rate to avoid aliasing
Nyquist Interval	1/(2fmax)	Maximum time between samples

Diagram:

```
Proper Sampling (fs { 2fmax):}
  *   *   *   *   *   *   *
 /|{  /|  /|  /|  /|  /|}
/ | {/| | /| | /| | /| | /| | }
  |   |   |   |   |   |   |

Undersampling (fs { 2fmax):}
  *       *       *       *
 /|{     /|      /|      /|}
/ | {   / |     / |     / | }
  |       |       |       |
  |       |       |       |
  * Aliasing occurs! *    *
```

Consequences:

- **Undersampling**: Aliasing occurs
- **Critical sampling**: No margin for error
- **Oversampling**: Better reconstruction but more data

Mnemonic

"Double Maximum Frequency Stops Aliasing" (DMFSA)

Question 4(b) OR [4 marks]

Compare DM, ADM and DPCM.

Solution

Comparison of DM, ADM and DPCM:

Parameter	Delta Modulation (DM)	Adaptive Delta Modulation (ADM)	Differential PCM (DPCM)
Principle	1-bit quantization of difference	Variable step size DM	Multi-bit quantization of difference
Bit Rate	Lowest	Low	Medium
Complexity	Simple	Moderate	Complex
Signal Quality	Low	Medium	High
Problems	Slope overload, granular noise	Reduced slope overload	Prediction errors
Applications	Speech transmission	Voice communications	Audio, video compression

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Analog Signal] {-{-}{} B[DM: Fixed steps]}
    A {-{-}{} C[ADM: Variable steps]}
    A {-{-}{} D[DPCM: Multi{-}bit coding]}
    style B fill:\#f69,stroke:\#333
    style C fill:\#6f9,stroke:\#333
    style D fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Mnemonic

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

Question 4(c) OR [7 marks]

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

Solution

DPCM Transmitter:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Sampler]}
    B {-{-}{} C[Subtractor]}
    C {-{-}{} D[Quantizer]}
    D {-{-}{} E[Encoder]}
    E {-{-}{} F[Transmission Channel]}
    E {-{-}{} G[Decoder]}
    G {-{-}{} H[Predictor]}
    H {-{-}{} C}
    style C fill:\#f96,stroke:\#333
    style H fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

DPCM Receiver:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Received Signal] {-{-}{} B[Decoder]}
    B {-{-}{} C[Adder]}
    C {-{-}{} D[Predictor]}
    D {-{-}{} C}
    C {-{-}{} E[Reconstructed Output]}
    style C fill:\#f96,stroke:\#333
    style D fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Working Principle:

Component	Function
Sampler	Converts analog to discrete-time signal
Predictor	Estimates current sample from previous samples
Subtractor	Computes difference between actual and predicted
Quantizer	Assigns levels to difference signal
Encoder	Converts to binary code
Decoder	Converts binary to quantized differences
Adder	Combines difference with prediction

Key Advantages:
- **Reduced bit rate**: Encodes differences which are smaller
- **Better quality**: Uses signal correlation
- **Compatibility**: Similar to PCM framework

Mnemonic

"Predict Subtract Quantize Difference" (PSQD)

Question 5(a) [3 marks]

Describe TDMA frame.

Solution

TDMA (Time Division Multiple Access) Frame:

Component	Description	Purpose
Time Slots	Individual segments assigned to users	Allows multiple users to share channel
Guard Time	Small gap between slots	Prevents overlap between users
Preamble	Synchronization bits at start	Helps receiver synchronize
Control Bits	Special bits for system control	Manages frame operation

Diagram:

```
 Sync  User1 User2 User3 User4 Ctrl


 Header          Time slots
```

TDMA Frame Structure:

- Each user transmits in assigned time slot
- Full frame repeats cyclically
- Frame length depends on number of users

Mnemonic

"Slots In Time Divide Access" (SITDA)

Question 5(b) [4 marks]

Draw and explain 4 level digital multiplexing hierarchies.

Solution

4-Level Digital Multiplexing Hierarchy:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Level 1: Primary {- 24/30 Channels] {-}{-}{} B[Level 2: Secondary {-} 96/120 Channels]}
    B {-{-}{} C[Level 3: Tertiary {-} 672/480 Channels]}
    C {-{-}{} D[Level 4: Quaternary {-} 4032/1920 Channels]}
    style A fill:\#f96,stroke:\#333
    style B fill:\#6f9,stroke:\#333
    style C fill:\#69f,stroke:\#333
    style D fill:\#96f,stroke:\#333
{Highlighting}
{Shaded}
```

Hierarchy Details:

Level	Name	North American System	European System
Level 1	Primary (T1/E1)	24 channels, 1.544 Mbps	30 channels, 2.048 Mbps
Level 2	Secondary (T2/E2)	96 channels, 6.312 Mbps	120 channels, 8.448 Mbps
Level 3	Tertiary (T3/E3)	672 channels, 44.736 Mbps	480 channels, 34.368 Mbps
Level 4	Quaternary (T4/E4)	4032 channels, 274.176 Mbps	1920 channels, 139.264 Mbps

Mnemonic

"Primary, Secondary, Tertiary, Quaternary Levels" (PSTQ)

Question 5(c) [7 marks]

Draw and explain block diagram of PCM-TDM system.

Solution

PCM-TDM System Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    subgraph "Transmitter"
    A1[Input 1] {-{-}{} B1[LPF]}
    B1 {-{-}{} C1[Sampler]}
    A2[Input 2] {-{-}{} B2[LPF]}
    B2 {-{-}{} C2[Sampler]}
    A3[Input 3] {-{-}{} B3[LPF]}
    B3 {-{-}{} C3[Sampler]}
    C1 {-{-}{} D[TDM Multiplexer]}
    C2 {-{-}{} D}
    C3 {-{-}{} D}
    D {-{-}{} E[Quantizer]}
    E {-{-}{} F[Encoder]}
    F {-{-}{} G[Line Coder]}
    end

    G {-{-}{} H[Transmission Channel]}

    subgraph "Receiver"
    H {-{-}{} I[Line Decoder]}
    I {-{-}{} J[Decoder]}
    J {-{-}{} K[TDM Demultiplexer]}
    K {-{-}{} L1[LPF]}
    K {-{-}{} L2[LPF]}
    K {-{-}{} L3[LPF]}
    L1 {-{-}{} M1[Output 1]}
    L2 {-{-}{} M2[Output 2]}
    L3 {-{-}{} M3[Output 3]}
    end

    style D fill:\#f96,stroke:\#333
    style K fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Working of PCM-TDM System:

Block	Function
Low-Pass Filter	Limits signal bandwidth to prevent aliasing
Sampler	Converts analog to discrete-time signal
TDM Multiplexer	Combines samples from multiple channels
Quantizer	Assigns discrete levels to samples
Encoder	Converts to binary code
Line Coder	Prepares signal for transmission
Line Decoder	Recovers binary information
Decoder	Converts binary to quantized values
TDM Demultiplexer	Separates channels at receiver
Reconstruction Filter	Smooths out staircase to recover analog

Key Features:

- Multiple analog channels share a single digital transmission link
- Each channel is sampled sequentially
- Samples are interlaced in time
- Frame synchronization ensures proper demultiplexing

Mnemonic

"Many Analog Channels Share Digital Link" (MACSDL)

Question 5(a) OR [3 marks]

List advantages and disadvantages of digital communication.

Solution

Advantages and Disadvantages of Digital Communication:

Advantages	Disadvantages
Noise Immunity: Better resistance to noise	**Bandwidth**: Requires more bandwidth
Error Detection: Can detect/correct errors	**Complexity**: More complex circuitry
Multiplexing: Efficient channel sharing	**Synchronization**: Requires precise timing
Security: Easier encryption	**Quantization Noise**: Inherent in A/D conversion
Integration: Compatible with computers	**Cost**: Initial setup cost is higher
Regeneration: Signal can be regenerated	**Conversion**: A/D conversion adds delay

Mnemonic

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

Question 5(b) OR [4 marks]

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

Solution

Channel Coding Techniques:

Technique	Purpose
Block Coding	Fixed-length blocks with parity
Convolutional Coding	Continuous encoding with memory
Turbo Coding	Parallel concatenated codes
LDPC Coding	Low-density parity check
Reed-Solomon	Powerful block code

Block Coding Example: Hamming Code (7,4)
This code takes 4 data bits and adds 3 parity bits to create a 7-bit codeword.

Step	Description	Example
1. **Data Bits**	Original message	1011
2. **Bit Positions**	Number positions 1 to 7	Positions 3,5,6,7 for data
3. **Parity Bits**	Calculate for positions 1,2,4	P1=1, P2=0, P4=1
4. **Codeword**	Combine parity and data	1011011

Error Detection:

- If a single bit error occurs, recalculating parity bits identifies error position
- Example: 1**0**11011 → 1**1**11011$(Error at position 2)$

Mnemonic

"Parity Bits Protect Data Bits" (PBPDB)

Question 5(c) OR [7 marks]

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

Solution

Basic Time Domain Digital Multiplexing:
Time Division Multiplexing (TDM) is a technique that allows multiple digital signals to share a common transmission medium by allocating unique time slots to each signal.

Operating Principle	Implementation
Channel Allocation	Each source gets periodic time slots
Frame Structure	Slots organized into frames with sync bits
Synchronization	Transmitter and receiver must maintain timing
Throughput	Dependent on number of channels and sampling rate

TDM System Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A1[Source 1] {-{-}{} C[Multiplexer]}
    A2[Source 2] {-{-}{} C}
    A3[Source 3] {-{-}{} C}
    C {-{-}{} D[Transmission Medium]}
    D {-{-}{} E[Demultiplexer]}
    E {-{-}{} F1[Destination 1]}
    E {-{-}{} F2[Destination 2]}
    E {-{-}{} F3[Destination 3]}

    style C fill:\#f96,stroke:\#333
    style E fill:\#69f,stroke:\#333
{Highlighting}
{Shaded}
```

Advantages of TDM System:

Advantage	Explanation
Efficient Utilization	Channel used continuously
Reduced Crosstalk	No frequency overlap between channels
Flexibility	Easy to add/remove channels
Compatible with Digital	Works naturally with digital systems
Simple Hardware	No complex filters needed

Disadvantages of TDM System:

Disadvantage	Explanation
Synchronization	Requires precise timing
Buffering	May need storage between samples
Overhead	Sync bits reduce efficiency
Delay	Must wait for time slot
Wasted Capacity	Empty slots if channel inactive

Mnemonic

"Time Slots Shared But Sync Required" (TSSBSR)