Subject Name Solutions

4331104 – Summer 2025

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Compare Analog Signal and Digital Signal.

Solution

Parameter	Analog Signal	Digital Signal
Nature	Continuous waveform	Discrete values (0 and 1)
Amplitude	Infinite variations	Fixed discrete levels
Noise Effect	More susceptible	Less susceptible
Bandwidth	Requires less bandwidth	Requires more bandwidth
Security	Less secure	More secure

- **Signal Type**: Analog signals are continuous, Digital signals are discrete
- **Noise Resistance**: Digital signals have better noise immunity

Mnemonic

"ABCD - Analog Bad for noise, Continuous; Digital Discrete, Clean signals"

Question 1(b) [4 marks]

Compare PAM, PWM and PPM.

Solution

Parameter	PAM	PWM	PPM
Full Form	Pulse Amplitude Modulation	Pulse Width Modulation	Pulse Position Modulation
Modulated Parameter	Amplitude	Width/Duration	Position/Time
Noise Immunity	Poor	Good	Excellent
Bandwidth	Minimum	Medium	Maximum
Power Consumption	High	Medium	Low

Diagram:

```
PAM: | |  |  | | |     Amplitude varies
PWM: | | |  | | |     Width varies
PPM: | |   | | | |      Position varies
```

- **Modulation Parameter**: Each type modulates different pulse characteristics
- **Applications**: PWM used in motor control, PPM in radio control systems

Mnemonic

"PAM-Amplitude, PWM-Width, PPM-Position - AWP"

Question 1(c) [7 marks]

Indicate the need of Modulation in detail. Calculate the height of antenna if the frequency of Carrier signal is 1 MHz.

Solution

Need for Modulation:

Reason	Explanation
Antenna Size Reduction	Makes practical antenna sizes possible
Frequency Translation	Shifts signal to suitable frequency range
Multiplexing	Allows multiple signals on same medium
Noise Reduction	Improves signal-to-noise ratio
Power Efficiency	Better power utilization

Antenna Height Calculation: For efficient radiation, antenna height = /4
$= c/f = (3 \times 10^8)/(1 \times 10^6) = 300 meters$
Antenna height = /4 = 300/4 = **75 meters**

- **Practical Antenna**: Without modulation, antenna would be impractically large
- **Frequency Shifting**: Allows better propagation characteristics

Mnemonic

"AFMNP - Antenna, Frequency, Multiplexing, Noise, Power"

Question 1(c) OR [7 marks]

Write frequency bands with applications domains of EM Wave spectrum. Calculate Wavelength range of ELF band.

Solution

Band	Frequency Range	Wavelength	Applications
ELF	30-300 Hz	$10^6 - 10^7 m$	Submarine communication
VLF	3-30 kHz	$10^4 - 10^5 m$	Navigation, time signals
LF	30-300 kHz	$10^3 - 10^4 m$	AM broadcasting
MF	300 kHz-3 MHz	100-1000 m	AM radio
HF	3-30 MHz	10-100 m	Short wave radio

ELF Wavelength Calculation:

- Lower frequency: f$_1 = 30Hz, _1 = c/f_1 = (3 \times 10^8)/30 =$
- Upper frequency: f$_2 = 300Hz, _2 = c/f_2 = (3 \times 10^8)/300 =$

ELF Wavelength range: 10$^6 to 10^7 meters$

- **Application Domain: Each band suited for specific applications**
- **Propagation: Lower frequencies have better ground wave propagation**

Mnemonic

"Every Valuable Learning Makes Happiness - ELF to HF bands"

Question 2(a) [3 marks]

Compare AM and FM.

Solution

Parameter	AM	FM
Modulated Parameter	Amplitude	Frequency
Bandwidth	2fm	2(Δf + fm)
Noise Immunity	Poor	Good
Power Efficiency	Low (33.33%)	High
Circuit Complexity	Simple	Complex

- **Bandwidth**: FM requires much wider bandwidth than AM
- **Quality**: FM provides better audio quality

Mnemonic

"AM-Amplitude simple, FM-Frequency complex but better quality"

Question 2(b) [4 marks]

Draw waveform of Amplitude Modulated wave.

Solution

Diagram:

```
Carrier Signal:

Modulating Signal:

AM Wave:          . . .  . . .

                      Envelope follows
                      modulating signal
```

Characteristics:

- **Envelope**: The envelope follows the modulating signal
- **Carrier Frequency**: Remains constant throughout
- **Amplitude Variation**: Amplitude varies with modulating signal

Mnemonic

"Envelope Follows Message - EFM"

Question 2(c) [7 marks]

Define Amplitude Modulation and Derive mathematical expression for Double Sideband Full Carrier (DSBFC) Amplitude Modulation (AM) signal.

Solution

Definition: Amplitude Modulation is the process where amplitude of carrier signal varies according to instantaneous amplitude of modulating signal.
Mathematical Derivation:
Let carrier signal: ec(t) = Ec cos(ct) Let modulating signal: em(t) = Em cos(mt)
AM Signal Expression: eAM(t) = [Ec + Em cos(mt)] cos(ct) eAM(t) = Ec cos(ct) + Em cos(mt) cos(ct)
Using trigonometric identity: cos A cos B = ½[cos(A+B) + cos(A-B)]
Final AM Expression: eAM(t) = Ec cos(ct) + (Em/2) cos(c + m)t + (Em/2) cos(c - m)t
Components:

- **Carrier Component**: Ec cos(ct)
- **Upper Sideband**: (Em/2) cos(c + m)t

- **Lower Sideband**: (Em/2) cos(c - m)t

Mnemonic

"Carrier Plus Upper Lower Sidebands - CPULS"

Question 2(a) OR [3 marks]

Compare Pre-emphasis and De-emphasis.

Solution

Parameter	Pre-emphasis	De-emphasis
Location	At transmitter	At receiver
Function	Boosts high frequencies	Attenuates high frequencies
Frequency Response	High pass characteristic	Low pass characteristic
Purpose	Improve S/N ratio	Restore original signal
Time Constant	75 s (FM broadcasting)	75 s (FM broadcasting)

- **Noise Reduction**: Combined effect reduces noise in received signal
- **Frequency Response**: Complementary characteristics

Mnemonic

"Pre-Boost, De-Cut - Noise Reduction Circuit"

Question 2(b) OR [4 marks]

Draw waveform of Frequency Modulated wave.

Solution

Diagram:

```
Modulating Signal:

Carrier Signal:

FM Wave:
                      Higher freq  Lower freq
                      when mod +ve when mod {-ve}
```

Characteristics:

- **Constant Amplitude**: Amplitude remains constant
- **Frequency Variation**: Frequency varies with modulating signal
- **Phase Continuity**: Phase remains continuous

Mnemonic

"Constant Amplitude, Variable Frequency - CAVF"

Question 2(c) OR [7 marks]

Define Frequency Modulation and Derive mathematical expression for FM wave.

Solution

Definition: Frequency Modulation is the process where frequency of carrier signal varies according to instantaneous amplitude of modulating signal.
Mathematical Derivation:
Let modulating signal: em(t) = Em cos(mt) Instantaneous frequency: fi = fc + kf $\times Emcos(mt)$
Where kf = frequency sensitivity
Instantaneous angular frequency: i = 2 [fc + kf Em cos(mt)] i = c + 2 kf Em cos(mt)
Phase calculation: (t) = dt = ct + (2 kf Em/ m) sin(mt)
Let modulation index: mf = 2 kf Em/ m = Δf/fm
Final FM Expression: eFM(t) = Ec cos[ct + mf sin(mt)]
Parameters:

- **Modulation Index**: mf = Δf/fm
- **Frequency Deviation**: Δf = kf Em
- **Bandwidth**: BW = 2(Δf + fm) (Carson's rule)

Mnemonic

"Frequency Varies with Message - FVM"

Question 3(a) [3 marks]

Illustrate Slope detection method of FM demodulation.

Solution

Slope Detection Principle:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[FM Signal] {-{-}{} B[Tuned Circuit]}
    B {-{-}{} C[Envelope Detector]}
    C {-{-}{} D[Audio Output]}
{Highlighting}
{Shaded}
```

Working:

- **Tuned Circuit**: Converts frequency variations to amplitude variations
- **Slope Operation**: Uses slope of resonance curve
- **Envelope Detection**: Extracts amplitude variations

Characteristics:

- **Simple Circuit**: Easy to implement
- **Linear Range**: Limited linear range
- **Output Distortion**: Higher distortion compared to other methods

Mnemonic

"Slope Converts Frequency to Amplitude - SCFA"

Question 3(b) [4 marks]

Explain different Characteristics of radio receiver.

Solution

Characteristic	Definition	Importance
Sensitivity	Minimum input signal for satisfactory output	Better weak signal reception
Selectivity	Ability to select desired signal and reject others	Reduces interference
Fidelity	Faithfulness of reproduction	Better audio quality
Image Frequency Rejection	Rejection of image frequency	Prevents false signals

Mathematical Relations:

- **Sensitivity**: Measured in V for standard output
- **Selectivity**: Q = f_0/BW
- **Image Rejection Ratio**: IRR = 1 + (2 fIFRC)^2

Mnemonic

"Sensitive Selective Faithful Image-free - SSFI"

Question 3(c) [7 marks]

Write short note on Super heterodyne receiver with suitable block diagram.

Solution

Block Diagram:

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]}
    E {-{-}{} I[AGC]}
    I {-{-}{} B}
    I {-{-}{} E}
{Highlighting}
{Shaded}
```

Working Principle:

- **RF Amplifier**: Amplifies received RF signal
- **Mixer**: Converts RF to fixed IF frequency
- **Local Oscillator**: Provides mixing frequency
- **IF Amplifier**: Main amplification at fixed frequency
- **Detector**: Recovers modulated signal
- **AGC**: Maintains constant output level

Advantages:

- **High Sensitivity**: Better sensitivity than TRF
- **Good Selectivity**: Better selectivity
- **Stable Gain**: Stable gain characteristics

IF Frequency Selection: Standard IF: 455 kHz for AM, 10.7 MHz for FM

Mnemonic

"Mix RF to IF for Better Selectivity - MRIBS"

Question 3(a) OR [3 marks]

Illustrate working of FM demodulator using Phase Locked Loop.

Solution

PLL FM Demodulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[FM Input] {-{-}{} B[Phase Detector]}
    C[VCO] {-{-}{} B}
    B {-{-}{} D[Loop Filter]}
    D {-{-}{} C}
    D {-{-}{} E[Audio Output]}
{Highlighting}
{Shaded}
```

Working Principle:

- **Phase Detector**: Compares input FM with VCO output
- **VCO**: Voltage Controlled Oscillator tracks input frequency

- **Loop Filter**: Removes high frequency components
- **Lock Condition**: VCO frequency equals input frequency

Advantages:

- **Linear Demodulation**: Excellent linearity
- **Low Distortion**: Minimum distortion
- **Good Tracking**: Excellent frequency tracking

Mnemonic

"Phase Lock Tracks Frequency - PLTF"

Question 3(b) OR [4 marks]

Discuss Block diagram of basic FM receiver.

Solution

FM Receiver Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[FM Antenna] {-{-}{} B[RF Amplifier]}
    B {-{-}{} C[Mixer]}
    D[Local Oscillator] {-{-}{} C}
    C {-{-}{} E[IF Amplifier 10.7MHz]}
    E {-{-}{} F[Limiter]}
    F {-{-}{} G[FM Detector]}
    G {-{-}{} H[De{-}emphasis]}
```

```
    H {-{-}{} I[AF Amplifier]}
    I {-{-}{} J[Speaker]}
{Highlighting}
{Shaded}
```

Block Functions:

- **RF Amplifier**: Amplifies weak FM signal (88-108 MHz)
- **Mixer**: Converts to IF frequency (10.7 MHz)
- **Limiter**: Removes amplitude variations
- **FM Detector**: Recovers audio signal
- **De-emphasis**: Restores original frequency response

Key Differences from AM Receiver:

- **Higher IF**: 10.7 MHz vs 455 kHz
- **Limiter Stage**: Additional limiter stage
- **De-emphasis**: Pre/de-emphasis network

Mnemonic

"FM needs Higher IF and Limiting - FHIL"

Question 3(c) OR [7 marks]

Write short note on Envelope detector using diode with suitable circuit diagram and waveform.

Solution

Circuit Diagram:

```
      D1
AM {-{-}||{-}{-}+{-}{-}{-}{-} Audio Output}
     |    |
     |    R
     |    |
     |    C
     |    |
    GND  GND
```

Working Principle:

```
AM Input:    . . .  . . .


Diode Output:
(After filtering)

Audio Output:
```

Operation:

- **Diode Conduction**: Conducts during positive half cycles
- **Capacitor Charging**: Charges to peak value
- **RC Discharge**: Discharges through RC circuit
- **Envelope Following**: Output follows envelope

Design Considerations:

- **Time Constant**: RC » 1/fc but RC « 1/fm
- **Diode Selection**: Fast recovery diode preferred
- **Load Resistance**: Should be much larger than diode resistance

Advantages:

- **Simplicity**: Very simple circuit
- **Low Cost**: Economical solution
- **High Efficiency**: Good detection efficiency

Mnemonic

"Diode Charges, RC Follows Envelope - DCRF"

Question 4(a) [3 marks]

Illustrate under sampling, over sampling and critical sampling.

Solution

Type	Condition	Result
Under Sampling	fs < 2fm	Aliasing occurs
Critical Sampling	fs = 2fm	Just adequate, no margin
Over Sampling	fs > 2fm	No aliasing, safe margin

Diagram:

```
Original Signal:

Under Sampling:        . .      Aliasing
Critical Sampling:     .   .    Just OK
Over Sampling:        . . .    Safe
```

- **Aliasing Effect**: Under sampling causes frequency overlap
- **Nyquist Rate**: Minimum sampling rate = 2fm
- **Practical Rate**: Usually 2.5 to 5 times message frequency

Mnemonic

"Under-Alias, Critical-Just, Over-Safe - UCO"

Question 4(b) [4 marks]

State Sampling theorem and define Nyquist rate, Nyquist interval and aliasing error.

Solution

Sampling Theorem: "A continuous signal can be completely recovered from its samples if sampling frequency is at least twice the highest frequency component of the signal."

Definitions:

Term	Definition	Formula
Nyquist Rate	Minimum sampling frequency	fs = 2fm
Nyquist Interval	Maximum sampling interval	Ts = 1/(2fm)
Aliasing Error	Frequency overlap due to under sampling	fa =

Mathematical Expression:

- **Sampling Frequency**: fs $\geq 2fm(Nyquistcriterion)$
- **Sampling Period**: Ts = 1/fs
- **Aliasing Condition**: fs < 2fm

Practical Applications:

- **Digital Audio**: fs = 44.1 kHz for fm = 20 kHz
- **Telephone System**: fs = 8 kHz for fm = 4 kHz

Mnemonic

"Sample at twice message frequency - S2M"

Question 4(c) [7 marks]

Discuss Ideal, Natural and Flat top sampling.

Solution

Types of Sampling:

Type	Characteristics	Mathematical Expression
Ideal Sampling	Impulse train multiplication	$xs(t) = x(t) \cdot T(t)$
Natural Sampling	Variable width pulses	Top follows signal
Flat Top Sampling	Constant amplitude pulses	Sample and hold

Waveforms:

```
Original:

Ideal:       ↑ ↑ ↑ ↑ ↑ ↑     Impulses

Natural:     | |  | |  | |     Variable width

Flat Top:    | |  | |  | |     Constant width
```

Frequency Spectrum:

- **Ideal Sampling**: Exact spectral replication
- **Natural Sampling**: Slight spectral modification

- **Flat Top Sampling**: Aperture effect present

Practical Implementation:

- **Ideal**: Theoretical only
- **Natural**: Used in PAM systems
- **Flat Top**: Sample-and-hold circuits, ADC systems

Aperture Effect: In flat-top sampling: $|Sa(fT/2)| = |\sin(fT/2)/(fT/2)|$

Mnemonic

"Ideal-Impulse, Natural-Variable, Flat-Constant - IVF"

Question 4(a) OR [3 marks]

Illustrate the working of Delta modulator with suitable block diagram.

Solution

Delta Modulator Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
```

```
    A[Input Signal] {-{-}{} B[Comparator]}
    B {-{-}{} C[1{-}bit Quantizer]}
    C {-{-}{} D[Output]}
    C {-{-}{} E[Integrator]}
    E {-{-}{} F[Delay]}
    F {-{-}{} B}
{Highlighting}
{Shaded}
```

Working Principle:

- **Comparison**: Input compared with previous integrated output
- **1-bit Quantization**: Output is +Δ or -Δ
- **Integration**: Integrator approximates input signal
- **Feedback**: Previous output fed back for comparison

Output Characteristics:

- **Binary Output**: Only 1 bit per sample
- **Step Size**: Fixed step size Δ
- **Tracking**: Output tracks input in steps

Mnemonic

"Compare, Quantize, Integrate, Feedback - CQIF"

Question 4(b) OR [4 marks]

Write disadvantages of Delta modulation (DM) with suitable explanation.

Solution

Major Disadvantages:

Disadvantage	Explanation	Solution
Slope Overload	Cannot track fast changes	Increase step size
Granular Noise	Quantization noise in flat regions	Decrease step size
High Bit Rate	Requires high sampling rate	Use ADPCM
Limited Dynamic Range	Fixed step size limitation	Adaptive techniques

Slope Overload Condition: When $|dx/dt| > \Delta fs$, slope overload occurs
Granular Noise: Occurs when input signal changes slowly or remains constant
Waveforms:

```
Slope Overload:    /      Input too fast
                  /       DM output lags

Granular Noise:   \_\_\_\_     Flat input
                         DM oscillates
```

Performance Parameters:

- **Slope Overload**: Maximum slope = Δfs
- **Granular Noise**: Depends on step size
- **SNR**: Limited by both effects

Mnemonic

"Slope-Overload, Granular-Noise, High-Bitrate - SOG-H"

Question 4(c) OR [7 marks]

Describe functions of each block of pulse code modulation (PCM) transmitter and receiver.

Solution

PCM Transmitter Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Analog Input] {-{-}{} B[LPF]}
    B {-{-}{} C[Sample \& Hold]}
    C {-{-}{} D[Quantizer]}
    D {-{-}{} E[Encoder]}
    E {-{-}{} F[Digital Output]}
{Highlighting}
{Shaded}
```

PCM Receiver Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    G[Digital Input] {-{-}{} H[Decoder]}
    H {-{-}{} I[DAC]}
    I {-{-}{} J[LPF]}
    J {-{-}{} K[Analog Output]}
{Highlighting}
{Shaded}
```

Transmitter Block Functions:

Block	Function
LPF	Anti-aliasing filter, removes frequencies > fm
Sample & Hold	Samples at fs $\geq 2fmandholdsvalue$
Quantizer	Converts to discrete amplitude levels
Encoder	Converts quantized samples to binary code

Receiver Block Functions:

Block	Function
Decoder	Converts binary code to quantized levels
DAC	Digital to Analog conversion
LPF	Reconstruction filter, removes sampling frequency

Technical Specifications:

- **Quantization Levels**: L = $2^n (n = numberofbits)$
- **Quantization Error**: $\Delta/2$ maximum
- **Bit Rate**: fb = n $\times fs$

PCM Advantages:

- **Noise Immunity**: Excellent noise performance
- **Regeneration**: Can be regenerated without error accumulation
- **Multiplexing**: Easy to multiplex multiple channels

Mnemonic

"Low-pass, Sample, Quantize, Encode - LSQE for TX; Decode, Convert, Filter - DCF for RX"

Question 5(a) [3 marks]

Discuss block diagram of TDM-PCM system in brief.

Solution

TDM-PCM System Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Channel 1] {-{-}{} D[Commutator]}
    B[Channel 2] {-{-}{} D}
    C[Channel 3] {-{-}{} D}
    D {-{-}{} E[PCM Encoder]}
    E {-{-}{} F[Transmission]}
    F {-{-}{} G[PCM Decoder]}
    G {-{-}{} H[Decommutator]}
    H {-{-}{} I[Channel 1]}
    H {-{-}{} J[Channel 2]}
    H {-{-}{} K[Channel 3]}
{Highlighting}
{Shaded}
```

System Operation:

- **Commutator**: Sequential sampling of multiple channels
- **PCM Encoder**: Converts samples to digital format
- **Time Division**: Each channel gets fixed time slot
- **Decommutator**: Separates channels at receiver

Frame Structure:

- **Time Slot**: Each channel assigned specific time
- **Frame Period**: Complete cycle for all channels
- **Synchronization**: Frame synchronization bits added

Advantages:

- **Bandwidth Efficiency**: Efficient spectrum utilization
- **Multiple Channels**: Multiple channels on single link

Mnemonic

"Time Division Multiple Access - TDMA"

Question 5(b) [4 marks]

Write short note on Adaptive delta modulation (ADM).

Solution

ADM Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Comparator]}
    B {-{-}{} C[Logic Circuit]}
    C {-{-}{} D[Step Size Control]}
    D {-{-}{} E[Integrator]}
```

```
    E {-{-}{} F[Delay]}
    F {-{-}{} B}
    C {-{-}{} G[Output]}
{Highlighting}
{Shaded}
```

Working Principle:

- **Adaptive Step Size**: Step size changes based on input characteristics
- **Slope Overload Prevention**: Increases step size for fast changes
- **Granular Noise Reduction**: Decreases step size for slow changes
- **Logic Control**: Algorithm controls step size adaptation

Step Size Control:

- **Increase**: When consecutive bits are same (slope overload detected)
- **Decrease**: When alternate pattern occurs (granular region)

Advantages over Standard DM:

- **Better SNR**: Improved signal-to-noise ratio
- **Dynamic Range**: Better dynamic range
- **Automatic Adaptation**: Self-adjusting characteristics

Mnemonic

"Adaptive Step size Reduces both Slope-overload and Granular noise - ASRSG"

Question 5(c) [7 marks]

Define Line coding. Draw NRZ (unipolar), RZ (unipolar), Manchester coding waveforms for "1 0 1 1 1 0 1 1".

Solution

Definition: Line coding is the process of converting digital data into digital signals suitable for transmission over communication channels.

Waveform Diagrams:

```
Data:        1  0  1  1  1  0  1  1

NRZ Unipolar:

                \_\_          \_\_

RZ Unipolar:



Manchester:

                \_\_  \_\_ \_\_ \_\_ \_\_
             Transition at middle of each bit
```

Characteristics:

Coding Type	Logic 1	Logic 0	Bandwidth
NRZ Unipolar	+V	0V	fb
RZ Unipolar	+V for T/2, 0V for T/2	0V	2fb
Manchester	High-to-Low transition	Low-to-High transition	2fb

Properties:

- **NRZ**: No return to zero, simple but no self-synchronization
- **RZ**: Return to zero, easy clock recovery but double bandwidth
- **Manchester**: Self-synchronizing, used in Ethernet

Applications:

- **NRZ**: Simple digital systems
- **RZ**: Magnetic recording
- **Manchester**: Ethernet, some wireless standards

Mnemonic

"NRZ-Simple, RZ-Return, Manchester-Transition - SRT"

Question 5(a) OR [3 marks]

Describe concept of Time division digital multiplexing.

Solution

TDM Concept: Time Division Multiplexing is a technique where multiple digital signals are transmitted over a single channel by allocating different time slots to each signal.

TDM Frame Structure:

```
Frame: |CH1|CH2|CH3|CH4|SYNC|CH1|CH2|CH3|CH4|SYNC|
          Frame Period
```

Working Principle:

Component	Function
Time Slots	Fixed duration allocated to each channel
Frame	Complete cycle containing all channels
Synchronization	Maintains proper channel separation
Multiplexer	Combines multiple inputs sequentially

Key Features:

- **Fixed Time Slot**: Each channel gets predetermined time
- **Sequential Sampling**: Channels sampled one after another
- **Digital Transmission**: Suitable for digital signals
- **Bandwidth Sharing**: Efficient spectrum utilization

Applications:

- **Telephone System**: T1, E1 systems
- **Digital Hierarchy**: PDH, SDH systems

Mnemonic

"Time slots Share Single Channel - TSSC"

Question 5(b) OR [4 marks]

Write short note on Differential PCM (DPCM).

Solution

DPCM Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input] {-{-}{} B[Difference]}
    C[Predictor] {-{-}{} B}
    B {-{-}{} D[Quantizer]}
    D {-{-}{} E[Encoder]}
    E {-{-}{} F[Output]}
    D {-{-}{} G[Local Decoder]}
    G {-{-}{} H[Adder]}
    C {-{-}{} H}
    H {-{-}{} C}
{Highlighting}
{Shaded}
```

Working Principle:

- **Prediction**: Predicts current sample from previous samples
- **Difference Signal**: Transmits difference between actual and predicted
- **Quantization**: Quantizes difference signal only
- **Local Decoder**: Maintains same reference as receiver

Prediction Algorithms:

Type	Formula	Application
Zero Order	$\hat{x}(n) = x(n-1)$	Simple predictor
First Order	$\hat{x}(n) = ax(n-1)$	Better prediction
Higher Order	$\hat{x}(n) = \Sigma ai(n-i)$	Optimum prediction

Advantages:

- **Reduced Bit Rate**: Lower bit rate than PCM
- **Better SNR**: Better SNR for same bit rate
- **Predictive Coding**: Exploits signal correlation

Applications:

- **Image Compression**: JPEG standards
- **Video Coding**: Motion compensation
- **Speech Coding**: Speech compression systems

Comparison with PCM:

- **Bit Rate**: DPCM requires fewer bits
- **Complexity**: More complex than PCM
- **Quality**: Better quality at same bit rate

Mnemonic

"Predict Difference, Quantize Less - PDQL"

Question 5(c) OR [7 marks]

Write short note on 4 level digital multiplexing Hierarchy.

Solution

Digital Multiplexing Hierarchy:

Level Structure:

Level	Name	Bit Rate	Voice Channels	Application
Level 0	DS-0	64 kbps	1	Basic voice channel
Level 1	DS-1/T1	1.544 Mbps	24	Primary multiplex
Level 2	DS-2/T2	6.312 Mbps	96	Secondary multiplex
Level 3	DS-3/T3	44.736 Mbps	672	Tertiary multiplex

Multiplexing Structure:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[24  DS{-0] {-}{-}{} B[DS{-}1]}
    C[4  DS{-1] {-}{-}{} D[DS{-}2]}
    E[7  DS{-2] {-}{-}{} F[DS{-}3]}
    G[6  DS{-3] {-}{-}{} H[DS{-}4]}
{Highlighting}
{Shaded}
```

Frame Structure for T1:

- **Frame Length**: 193 bits (192 data + 1 framing)
- **Frame Rate**: 8000 frames/second
- **Time Slot**: 8 bits per channel
- **Framing Bit**: Synchronization pattern

T1 Frame Format:

```
|F|CH1|CH2|...|CH24|F|CH1|CH2|...|CH24|
 ↑              ↑
Framing       193 bits total
```

Multiplexing Process:

- **Level 1**: 24 voice channels $\times 64 kbps + overhead = 1.544 Mbps$
- **Level 2**: 4 T1 streams + overhead = 6.312 Mbps
- **Level 3**: 7 T2 streams + overhead = 44.736 Mbps
- **Synchronization**: Each level adds synchronization bits

Applications:

- **Telephone Network**: Primary application in telephone systems
- **Data Communication**: High-speed data transmission
- **Internet Backbone**: Internet service provider connections

International Standards:

- **North American**: T1/T3 hierarchy (DS series)
- **European**: E1/E3 hierarchy (different bit rates)
- **ITU-T**: International recommendations

Advantages:

- **Standardization**: Well-defined international standards
- **Scalability**: Easy to scale up capacity
- **Interoperability**: Compatible across different vendors

Mnemonic

"Digital Signal hierarchy: 0-1-2-3 levels Build Communication Systems - DS-BCS"