Subject Name Solutions

4341102 – Summer 2025

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Draw block diagram of digital communication system.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Information Source] {-{-}{} B[Source Encoder]}
    B {-{-}{} C[Channel Encoder]}
    C {-{-}{} D[Digital Modulator]}
    D {-{-}{} E[Channel]}
    E {-{-}{} F[Digital Demodulator]}
    F {-{-}{} G[Channel Decoder]}
    G {-{-}{} H[Source Decoder]}
    H {-{-}{} I[Information Sink]}

    J[Noise Source] {-{-}{} E}
{Highlighting}
{Shaded}
```

Key Components:

- **Information Source**: Generates message signal
- **Source Encoder**: Converts analog to digital
- **Channel Encoder**: Adds error correction codes
- **Digital Modulator**: Converts digital bits to analog signal

Mnemonic

"Source Channel Modulator travels through Channel to Demodulator Channel Sink"

Question 1(b) [4 marks]

Write the function of transmitter and receiver of digital communication system.

Solution

Component	Function
Transmitter	Converts information signal into suitable form for transmission
Source Encoder	Analog to digital conversion, sampling, quantization
Channel Encoder	Error detection and correction coding
Digital Modulator	Converts digital bits to analog waveform

Component	Function
Receiver	Recovers original information from received signal
Digital Demodulator	Converts received analog signal to digital bits
Channel Decoder	Error detection and correction
Source Decoder	Digital to analog conversion

Key Functions:

- **Signal Processing**: Encoding, modulation, filtering
- **Error Control**: Detection and correction of transmission errors
- **Signal Recovery**: Demodulation and decoding at receiver

Mnemonic

"Transmitter Encodes Modulates, Receiver Demodulates Decodes"

Question 1(c) [7 marks]

Define and explain with example: Continues time and discrete time signals, Real and complex signals and even and odd signals.

Solution

Signal Type	Definition	Example
Continuous Time	Signal defined for all time values	x(t) = sin(2 t)
Discrete Time	Signal defined only at specific time instants	x[n] = sin(2 n/8)
Real Signal	Signal with real values only	x(t) = 5cos(t)
Complex Signal	Signal with real and imaginary parts	x(t) = 3 + j4sin(t)

Even and Odd Signals:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A["Signal x[n]"] {-{-}{} B\{"Check x[{-}n]"\}}
    B {-{-}{} C["x[n] = x[{-}n]{}br/{}EVEN SIGNAL"]}
    B {-{-}{} D["x[n] = {-}x[{-}n]{}br/{}ODD SIGNAL"]}

    C {-{-}{} E["Example: cos[n]"]}
    D {-{-}{} F["Example: sin[n]"]}
{Highlighting}
{Shaded}
```

Properties:

- **Even Signal**: Symmetric about y-axis, x(t) = x(-t)
- **Odd Signal**: Anti-symmetric about origin, x(t) = -x(-t)
- **Complex Signal**: z(t) = x(t) + jy(t)
- **Discrete Signal**: Sampled version of continuous signal

Mnemonic

"Continuous Everywhere, Discrete Specific, Real Simple, Complex Combined"

Question 1(c OR) [7 marks]

Define and explain with example: Unit step function, Unit impulse function, Unit ramp function

Solution

Function	Definition	Mathematical Form
Unit Step	u(t) = 1 for t$\geq 0, 0 for t < 0$	u(t) = 1 for t$\geq$ 0
Unit Impulse	(t) = $\infty for t = 0, 0 elsewhere$	(t)dt = 1
Unit Ramp	r(t) = t for t$\geq 0, 0 for t < 0$	r(t) = t $\cdot$ u(t)

```
Unit Step Function:        Unit Impulse Function:      Unit Ramp Function:

    1 |{-{-}{-}{-}                   |                          |  /}
      |                         | |                       | /
    0 |\_\_\_\_                    0 |\_|\_\_\_\_                 0 |/\_\_\_\_
      0    t                    0    t                    0    t
```

Applications:

- **Unit Step**: Switch operations, system response analysis
- **Unit Impulse**: System impulse response, convolution
- **Unit Ramp**: System ramp response, integration

Properties:

- **Step**: Derivative of ramp, integral of impulse
- **Impulse**: Derivative of step function
- **Ramp**: Integral of step function

Mnemonic

"Step Sudden, Impulse Instant, Ramp Rising"

Question 2(a) [3 marks]

Define: bit rate, baud rate and bandwidth.

Solution

Parameter	Definition	Unit
Bit Rate	Number of bits transmitted per second	bps (bits per second)
Baud Rate	Number of signal changes per second	Baud (symbols per second)
Bandwidth	Range of frequencies in signal	Hz (Hertz)

Relationship:

- Bit Rate = Baud Rate $\times log_2(M)$
- M = number of signal levels
- Bandwidth   Baud Rate

Key Points:

- **Higher bit rate**: More data transmission
- **Baud rate**: Symbol transmission rate
- **Bandwidth**: Frequency spectrum occupied

Mnemonic

"Bits Baud Bandwidth - Data Symbol Frequency"

Question 2(b) [4 marks]

Explain Energy and power signal.

Solution

Signal Type	Definition	Mathematical Form
Energy Signal	Finite energy, zero average power	E = $\int$
Power Signal	Finite average power, infinite energy	P = lim(T$\to\infty$)1/$T \int$

Classification:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Signal] {-{-}{} B\{Energy Finite?\}}
    B {-{-}{}|Yes| C[Energy Signal{}br/{}P = 0]}
    B {-{-}{}|No| D\{Power Finite?\}}
    D {-{-}{}|Yes| E[Power Signal{}br/{}E = ]}
    D {-{-}{}|No| F[Neither Energy{}br/{}nor Power]}
{Highlighting}
{Shaded}
```

Examples:

- **Energy Signal**: Exponentially decaying signal e^(-t)u(t)
- **Power Signal**: Sinusoidal signal sin(t)
- **Neither**: Ramp signal t · u(t)

Properties:

- Energy and power signals are mutually exclusive
- Periodic signals are generally power signals
- Non-periodic finite duration signals are energy signals

Mnemonic

"Energy Ends, Power Persists"

Question 2(c) [7 marks]

Give the comparison between ASK, FSK and PSK modulation techniques and draw their waveforms.

Solution

Parameter	ASK	FSK	PSK
Full Form	Amplitude Shift Keying	Frequency Shift Keying	Phase Shift Keying
Varied Parameter	Amplitude	Frequency	Phase
Bandwidth	Narrow	Wide	Narrow
Noise Immunity	Poor	Good	Excellent
Power Efficiency	Poor	Good	Excellent
Implementation	Simple	Moderate	Complex

```
ASK Waveform:
Data:    1    0    1    1    0
        \_\_\_       \_\_\_  \_\_\_
       |   |     |   ||   |
    \_\_\_|   |\_\_\_\_\_|   ||   |\_\_\_\_\_

FSK Waveform:
       {              }
      {                   }
    {                   }

PSK Waveform:
       \_\_\_       \_\_\_ \_\_\_
      |   |     |   |   |
    \_\_|   |\_\_\_\_\_|   |   |\_\_\_\_\_
      phase shift at data change
```

Applications:

- **ASK**: Optical communication, simple radio systems
- **FSK**: Telephone modems, radio systems
- **PSK**: Satellite communication, wireless systems

Advantages:

- **ASK**: Simple implementation, low cost
- **FSK**: Good noise performance, constant envelope
- **PSK**: Best noise performance, bandwidth efficient

Mnemonic

"ASK Amplitude, FSK Frequency, PSK Phase"

Question 2(a OR) [3 marks]

A bit rate of signal generator from 8-bit generator is 1600 bps. Calculate the baud rate of signal.

Solution

Given:

- Bit rate = 1600 bps
- Number of bits per symbol = 8 bits

Formula: Baud Rate = Bit Rate / Number of bits per symbol
Calculation: Baud Rate = 1600 bps / 8 bits Baud Rate = 200 Baud
Result: The baud rate of the signal is **200 Baud**.
Explanation:

- Each symbol carries 8 bits of information
- 1600 bits per second $\div 8 bits per symbol = 200 symbols per second$
- Therefore, baud rate = 200 Baud

Mnemonic

"Bit Rate divided by Bits per Symbol gives Baud"

Question 2(b OR) [4 marks]

Find whether the signals are even or odd: 1. x(t) = e^(-5t) 2. x(t) = sin 2t 3. x(t) = cos 5t

Solution

Signal	Test x(-t)	Result	Type
x(t) = e^(-5t)	x(-t) = e^(5t) $\neq x(t) \neq -x(t)$	Neither	Neither Even nor Odd
x(t) = sin 2t	x(-t) = sin(-2t) = -sin 2t = -x(t)	-x(t)	**Odd Signal**
x(t) = cos 5t	x(-t) = cos(-5t) = cos 5t = x(t)	x(t)	**Even Signal**

Test Procedure:

1. **Even Signal Test**: Check if x(t) = x(-t)
2. **Odd Signal Test**: Check if x(t) = -x(-t)

Properties Used:

- **Exponential**: e^(-at) is neither even nor odd (a > 0)
- **Sine Function**: sin(-x) = -sin(x) $\rightarrow Oddfunction$
- **Cosine Function**: cos(-x) = cos(x) $\rightarrow Evenfunction$

Results:

- **Signal 1**: Neither even nor odd
- **Signal 2**: Odd signal
- **Signal 3**: Even signal

Mnemonic

"Cosine Even, Sine Odd, Exponential Neither"

Question 2(c OR) [7 marks]

Explain the Principle of QPSK signal. Draw its modulator and demodulator diagram. Also draw constellation diagram and waveforms of its.

Solution

QPSK Principle: QPSK (Quadrature Phase Shift Keying) uses four different phase states to represent 2 bits per symbol.

Bits	Phase	I	Q
00	45°	+1	+1
01	135°	-1	+1
10	-45°	+1	-1
11	-135°	-1	-1

QPSK Modulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Data Stream] {-{-}{} B[Serial to Parallel]}
    B {-{-}{} C[I Channel]}
    B {-{-}{} D[Q Channel]}
    C {-{-}{} E[Mixer 1]}
    D {-{-}{} F[Mixer 2]}
    G["Carrier cos( t)"] {-{-}{} E}
    H["Carrier sin( t)"] {-{-}{} F}
    E {-{-}{} I[Adder]}
    F {-{-}{} I}
    I {-{-}{} J[QPSK Output]}
{Highlighting}
{Shaded}
```

Constellation Diagram:

```
        Q
        |
   01   |   00
  ({-1,1)| (1,1)}
        |
  {-{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-} I}
        |
  ({-1,{-}1)|(1,{-}1)}
   11   |   10
        |
```

QPSK Demodulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[QPSK Input] {-{-}{} B[Mixer 1]}
    A {-{-}{} C[Mixer 2]}
    D["cos( t)"] {-{-}{} B}
    E["sin( t)"] {-{-}{} C}
    B {-{-}{} F[LPF]}
    C {-{-}{} G[LPF]}
    F {-{-}{} H[Decision Device]}
    G {-{-}{} I[Decision Device]}
    H {-{-}{} J[Parallel to Serial]}
    I {-{-}{} J}
    J {-{-}{} K[Data Output]}
{Highlighting}
{Shaded}
```

Advantages:
- **Bandwidth Efficient**: 2 bits per symbol
- **Good Noise Performance**: Constant envelope
- **Widely Used**: Standard in digital communication

Applications:
- Satellite communication
- Digital TV broadcasting
- Wireless communication systems

Mnemonic

"QPSK - Quadrature Phase, 2 bits, 4 phases"

Question 3(a) [3 marks]

Draw the block diagram of FSK modulator

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Data] {-{-}{} B[Switch]}
    C[Oscillator 1{br/{}f1] {-}{-}{} B}
    D[Oscillator 2{br/{}f2] {-}{-}{} B}
    B {-{-}{} E[FSK Output]}

    F[Data = 1] {-.{-}{} C}
    G[Data = 0] {-.{-}{} D}
{Highlighting}
{Shaded}
```

Components:

- **Digital Data Input**: Binary data stream (0s and 1s)
- **Two Oscillators**: f$_1 for bit `1', f_2 for bit `0'$
- **Electronic Switch**: Selects frequency based on input bit
- **FSK Output**: Frequency modulated signal

Operation:

- **Bit '1'**: Switch connects oscillator 1 (higher frequency)
- **Bit '0'**: Switch connects oscillator 2 (lower frequency)
- **Output**: Continuous frequency shifting based on data

Mnemonic

"FSK - Frequency Switch based on data Keys"

Question 3(b) [4 marks]

Draw and explain block diagram of PSK modulator.

Solution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Data] {-{-}{} B[Balanced Modulator]}
    C["Carrier Oscillator{br/{}cos( t)"] {-}{-}{} B}
    B {-{-}{} D[PSK Output]}

    E[Data = 1] {-.{-}{} F[0^ phase]}
    G[Data = 0] {-.{-}{} H[180^ phase]}
{Highlighting}
{Shaded}
```

Components and Function:

Component	Function
Digital Data	Binary input stream (0s and 1s)
Carrier Oscillator	Generates reference carrier signal
Balanced Modulator	Multiplies data with carrier
PSK Output	Phase modulated signal

Operation:

- **Data '1'**: Output = +cos(t) (0°$phase$)
- **Data '0'**: Output = -cos(t) (180°$phase$)
- **Phase Shift**: 180°$difference between$'1'and'0'

Mathematical Expression:

- PSK Signal: s(t) = A · d(t) · cos(t)
- Where d(t) = +1 for '1', -1 for '0'

Advantages:

- **Constant Envelope**: Better noise immunity
- **Bandwidth Efficient**: Occupies same bandwidth as ASK
- **Simple Detection**: Coherent detection required

Mnemonic

"PSK - Phase Shift using balanced modulator Key"

Question 3(c) [7 marks]

Explain the block diagram of ASK modulator and de-modulator with waveform.

Solution

ASK Modulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Data] {-{-}{} B[Multiplier]}
    C["Carrier cos( t)"] {-{-}{} B}
    B {-{-}{} D[ASK Output]}
{Highlighting}
{Shaded}
```

ASK Demodulator:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[ASK Input] {-{-}{} B[Multiplier] }
    C[Local Carrier] {-{-}{} B}
    B {-{-}{} D[Low Pass Filter]}
    D {-{-}{} E[Decision Device]}
    E {-{-}{} F[Digital Output]}
    G[Threshold] {-{-}{} E}
{Highlighting}
{Shaded}
```

Waveforms:

```
Digital Data:
    1    0    1    1    0
  \_\_\_       \_\_\_  \_\_\_
```

```
  |   |      |   ||   |
\_\_|   |\_\_\_\_\_|   ||   |\_\_\_\_\_

Carrier Signal:




ASK Output:
```

Modulation Process:

Data Bit	Carrier	ASK Output
'1'	A · cos(t)	A · cos(t)
'0'	A · cos(t)	0

Demodulation Process:

1. **Multiplication**: ASK signal $\times Localcarrier$
1. **Low Pass Filtering**: Remove high frequency components
2. **Decision**: Compare with threshold to recover data

Applications:

- **Optical Communication**: LED/Laser on-off keying
- **Simple Radio Systems**: AM radio modification
- **Short Range Communication**: IR remote controls

Advantages/Disadvantages:

Advantages	Disadvantages
Simple implementation	Poor noise performance
Low cost	Bandwidth inefficient
Easy detection	Susceptible to fading

Mnemonic

"ASK - Amplitude Switch, multiply and filter Key"

Question 3(a OR) [3 marks]

Write Principle and draw the constellation diagram of MSK.

Solution

MSK Principle: MSK (Minimum Shift Keying) is a form of continuous-phase FSK where the frequency deviation is exactly half the bit rate.

Key Properties:

- **Continuous Phase**: No phase discontinuities
- **Minimum Frequency Separation**: $\Delta f = Rb/2$
- **Constant Envelope**: Good for nonlinear amplifiers

Constellation Diagram:

```
        Q
        |
  (I=0,

Q=1)

        |
   {-{-}{-}{-}+{-}{-}{-}{-}   I}
```

```
        |
   (I=0,

Q={-1)}

        |


Points rotate continuously
between 1 on I and Q axes
```

Mathematical Representation:

- **Bit '1'**: $\mathrm{f}_1 = fc + Rb/4$
- **Bit '0'**: $\mathrm{f}_2 = fc - Rb/4$
- **Frequency Deviation**: $\Delta\mathrm{f} = \mathrm{Rb}/2$

Characteristics:

- **Spectral Efficiency**: Better than conventional FSK
- **Continuous Phase**: Reduces out-of-band radiation
- **Orthogonal Detection**: Can be detected as OQPSK

Mnemonic

"MSK - Minimum Shift, Continuous phase Key"

Question 3(b OR) [4 marks]

Draw and explain the constellation diagram of 16-QAM

Solution

16-QAM Constellation:

```
           Q
           |
          |
           |
        {-3{-}1 1 3   I}
           |
          |
           |
          |
           |
```

16-QAM Mapping Table:

Bits	I	Q	Amplitude	Phase
0000	-3	-3	$\sqrt{18}$	225°
0001	-3	-1	$\sqrt{10}$	198.4°
0010	-3	+1	$\sqrt{10}$	161.6°
0011	-3	+3	$\sqrt{18}$	135°
0100	-1	-3	$\sqrt{10}$	251.6°
0101	-1	-1	$\sqrt{2}$	225°
...	...	...	...	...

Key Features:

- **16 Symbol Points**: 4 bits per symbol
- **Gray Coding**: Adjacent symbols differ by 1 bit
- **Variable Amplitude**: Different power levels
- **High Data Rate**: 4 times QPSK data rate

Signal Representation: s(t) = I(t) · cos(t) - Q(t) · sin(t)

Applications:

- **Digital Cable TV**: High data rate transmission
- **Microwave Links**: Point-to-point communication
- **WiFi Systems**: 802.11 standards

Advantages:

- **High Spectral Efficiency**: 4 bits per symbol
- **Good BER Performance**: With proper coding
- **Flexible Implementation**: Software defined radio

Trade-offs:

- **Higher Complexity**: More complex than QPSK
- **Power Variation**: Requires linear amplifiers
- **Noise Sensitivity**: Higher than constant envelope schemes

Mnemonic

"16-QAM - 16 points, 4 bits, Quadrature Amplitude Modulation"

Question 3(c OR) [7 marks]

Compare Bits PER Symbol for digital modulation techniques-ASK, FSK, PSK, QPSK,8-PSK, MSK and 16-QAM

Solution

Bits per Symbol Comparison:

Modulation	Bits per Symbol	Symbol Rate	Data Rate Relationship
ASK	1	Rs = Rb	Rb = Rs ×1
FSK	1	Rs = Rb	Rb = Rs ×1
PSK (BPSK)	1	Rs = Rb	Rb = Rs ×1
QPSK	2	Rs = Rb/2	Rb = Rs ×2
8-PSK	3	Rs = Rb/3	Rb = Rs ×3
MSK	1	Rs = Rb	Rb = Rs ×1
16-QAM	4	Rs = Rb/4	Rb = Rs ×4

Detailed Analysis:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Digital Modulation] {-{-}{} B[M{-}ary Modulation]}
    B {-{-}{} C["Bits per Symbol = log_{2}(M)"]}
    C {-{-}{} D[Higher M = More bits per symbol]}
    D {-{-}{} E[Higher Data Rate]}
    E {-{-}{} F[But Higher Complexity]}
{Highlighting}
{Shaded}
```

Bandwidth Efficiency:

Modulation	M	Bits/Symbol	Bandwidth Efficiency
ASK, FSK, PSK	2	1	1 bit/s/Hz
QPSK	4	2	2 bits/s/Hz
8-PSK	8	3	3 bits/s/Hz
16-QAM	16	4	4 bits/s/Hz

Power Requirements:

Modulation	Relative Power	BER Performance
PSK	Reference	Best
ASK	+3dB penalty	Poor
FSK	Same as PSK	Good
QPSK	Same as PSK	Same as PSK
8-PSK	+2.5dB penalty	Moderate
16-QAM	+4dB penalty	Good with coding

Trade-offs:

- **Higher M**: More bits per symbol but higher complexity
- **Bandwidth vs Power**: Trade-off between spectral and power efficiency
- **Implementation**: Higher order modulation needs better hardware

Applications:

- **Low Rate**: ASK, FSK, PSK for simple systems
- **Medium Rate**: QPSK for balanced performance
- **High Rate**: 8-PSK, 16-QAM for high-speed systems

Formula: Bits per Symbol $= \log_2(M), where M = number of symbols$

Mnemonic

"More symbols, More bits, More complexity"

Question 4(a) [3 marks]

Define probability and write it Significance of in communication

Solution

Definition of Probability: Probability is the measure of likelihood that an event will occur, expressed as a number between 0 and 1.

P(Event) = Number of favorable outcomes / Total number of possible outcomes

Significance in Communication:

Application	Significance
Error Analysis	Calculate bit error rate (BER)
Channel Modeling	Noise and fading statistics
Coding Theory	Error correction probability
Signal Detection	Detection and false alarm rates

Key Applications:

- **BER Calculation**: P(error) = Q($\sqrt{(2Eb/N0)}$)
- **Channel Capacity**: Shannon's theorem uses probability
- **Information Theory**: Entropy based on probability
- **System Design**: Performance prediction

Mathematical Tools:

- **Gaussian Distribution**: For noise analysis
- **Rayleigh Distribution**: For fading channels
- **Poisson Distribution**: For arrival processes

Mnemonic

"Probability Predicts Performance in communication systems"

Question 4(b) [4 marks]

Explain Huffman code with suitable example

Solution

Huffman Coding Principle: Variable length coding where frequently occurring symbols get shorter codes.

Algorithm:

1. List symbols with probabilities
2. Combine two lowest probability symbols
3. Repeat until single symbol remains
4. Assign codes: left = 0, right = 1

Example:

Symbol	Probability	Huffman Code
A	0.4	0
B	0.3	10
C	0.2	110
D	0.1	111

Huffman Tree Construction:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A1[1.0] {-{-}{} B1[A: 0.4]}
    A1 {-{-}{} C1[0.6]}
    C1 {-{-}{} D1[B: 0.3] }
    C1 {-{-}{} E1[0.3]}
    E1 {-{-}{} F1[C: 0.2]}
    E1 {-{-}{} G1[D: 0.1]}
{Highlighting}
{Shaded}
```

Code Assignment:

- **A**: 0 (1 bit)
- **B**: 10 (2 bits)

- **C**: 110 (3 bits)
- **D**: 111 (3 bits)

Average Code Length: L $= 0.4\times1 + 0.3 \times 2 + 0.2 \times 3 + 0.1 \times 3 = 1.9 bits/symbol$

Advantages:

- **Optimal**: Minimum average code length
- **Prefix Property**: No code is prefix of another
- **Efficient**: Reduces transmission bandwidth

Mnemonic

"Huffman - Frequent symbols get Shorter codes"

Question 4(c) [7 marks]

Explain concept and key features of Internet of Things (IoT).

Solution

IoT Concept: Internet of Things is the network of physical devices embedded with sensors, software, and connectivity to collect and exchange data.

IoT Architecture:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Physical Devices] {-{-}{} B[Connectivity Layer]}
    B {-{-}{} C[Data Processing]}
    C {-{-}{} D[Application Layer]}
    D {-{-}{} E[Business Layer]}

    F[Sensors] {-{-}{} A}
    G[Actuators] {-{-}{} A}
    H[WiFi/Bluetooth] {-{-}{} B}
    I[Cellular/LoRa] {-{-}{} B}
    J[Cloud Computing] {-{-}{} C}
    K[Edge Computing] {-{-}{} C}
{Highlighting}
{Shaded}
```

Key Features:

Feature	Description	Example
Connectivity	Devices connected to internet	WiFi, 4G, 5G
Intelligence	Smart decision making	AI algorithms
Sensing	Data collection from environment	Temperature, humidity
Actuation	Control physical processes	Motors, valves
Interoperability	Devices work together	Standard protocols

IoT Protocol Stack:

Layer	Protocols	Function
Application	HTTP, CoAP, MQTT	Data exchange
Transport	TCP, UDP	Reliable transmission
Network	IPv6, 6LoWPAN	Routing
Physical	WiFi, ZigBee, LoRa	Connectivity

Applications:

- **Smart Home**: Automated lighting, security
- **Industrial IoT**: Manufacturing automation
- **Healthcare**: Remote patient monitoring
- **Smart Cities**: Traffic management, utilities

Challenges:

- **Security**: Device vulnerabilities, data privacy
- **Scalability**: Billions of devices
- **Interoperability**: Different standards
- **Power Consumption**: Battery-operated devices

Benefits:

- **Automation**: Reduced human intervention
- **Efficiency**: Optimized resource usage

- **Real-time Monitoring**: Instant data access
- **Cost Reduction**: Predictive maintenance

Technologies:

- **Communication**: WiFi, Bluetooth, Cellular, LoRa
- **Processing**: Edge computing, cloud computing
- **Analytics**: Big data, machine learning
- **Security**: Encryption, authentication

Mnemonic

"IoT - Internet of Things, Smart Connected Devices everywhere"

Question 4(a OR) [3 marks]

Define error correction code and list common error correcting code.

Solution

Error Correction Code Definition: Error correction codes are techniques that add redundant bits to data to detect and correct transmission errors automatically.

Common Error Correcting Codes:

Code Type	Description	Capability
Hamming Code	Single error correction	Correct 1-bit error
Reed-Solomon	Block code for burst errors	Correct multiple errors
BCH Code	Binary cyclic code	Correct t errors
Convolutional Code	Continuous encoding	Good for noisy channels
Turbo Code	Iterative decoding	Near Shannon limit
LDPC Code	Low density parity check	Excellent performance

Applications:

- **Memory Systems**: ECC RAM
- **Storage Devices**: Hard drives, CDs
- **Communication**: Satellite, cellular
- **Broadcasting**: Digital TV, radio

Mnemonic

"Error Correction Codes - Hamming Reed BCH Convolutional Turbo LDPC"

Question 4(b OR) [4 marks]

Explain Shanon Fano code with suitable example

Solution

Shannon-Fano Coding Algorithm: Top-down approach that divides symbols into two groups with approximately equal probabilities.

Algorithm Steps:

1. Arrange symbols in decreasing probability order
2. Divide into two groups with nearly equal total probability
3. Assign '0' to first group, '1' to second group
4. Repeat for each subgroup

Example:

Symbol	Probability	Shannon-Fano Code
A	0.4	00
B	0.3	01
C	0.2	10
D	0.1	11

Construction Tree:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A1[A,B,C,D: 1.0] {-{-}{} B1[A,B: 0.7]}
    A1 {-{-}{} C1[C,D: 0.3]}
    B1 {-{-}{} D1[A: 0.4]}
    B1 {-{-}{} E1[B: 0.3]}
    C1 {-{-}{} F1[C: 0.2]}
    C1 {-{-}{} G1[D: 0.1]}
{Highlighting}
{Shaded}
```

Code Assignment:

- Group 1 (A,B): Code starts with '0'
- Group 2 (C,D): Code starts with '1'
- A: 00, B: 01, C: 10, D: 11

Comparison with Huffman:

- **Shannon-Fano**: Top-down approach
- **Huffman**: Bottom-up approach
- **Huffman**: Always optimal
- **Shannon-Fano**: May not be optimal

Average Code Length: L $= 0.4 \times 2 + 0.3 \times 2 + 0.2 \times 2 + 0.1 \times 2 = 2.0 bits/symbol$

Mnemonic

"Shannon-Fano - Split groups, assign codes Top-down"

Question 4(c OR) [7 marks]

Explain different standard formats of audio signal.

Solution

Audio Signal Formats:

Format	Full Form	Compression	Quality	File Size
WAV	Waveform Audio File	Uncompressed	Highest	Largest
MP3	MPEG Layer 3	Lossy	Good	Small
AAC	Advanced Audio Coding	Lossy	Better than MP3	Small
FLAC	Free Lossless Audio Codec	Lossless	Original	Medium
OGG	Ogg Vorbis	Lossy	Good	Small

Audio Parameters:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Audio Signal] {-{-}{} B[Sampling Rate]}
    A {-{-}{} C[Bit Depth]}
    A {-{-}{} D[Channels]}
    A {-{-}{} E[Compression]}

    B {-{-}{} F[44.1 kHz CD Quality]}
    C {-{-}{} G[16{-}bit Standard]}
    D {-{-}{} H[Mono/Stereo]}
    E {-{-}{} I[Lossy/Lossless]}
{Highlighting}
{Shaded}
```

Sampling Standards:

Standard	Sampling Rate	Bit Depth	Application
CD Quality	44.1 kHz	16-bit	Consumer audio
Studio Quality	48 kHz	24-bit	Professional recording
High Resolution	96 kHz	24-bit	Audiophile
Telephone	8 kHz	8-bit	Voice communication

Compression Types:

- **Lossless**: Original quality preserved (FLAC, ALAC)
- **Lossy**: Some quality lost for smaller size (MP3, AAC)
- **Uncompressed**: No compression (WAV, AIFF)

Applications:

- **Broadcasting**: AAC for digital radio
- **Streaming**: MP3, AAC for internet
- **Professional**: WAV, FLAC for studios
- **Mobile**: AAC for smartphones

File Size Comparison (3-minute song):

- **WAV**: 30 MB
- **FLAC**: 20 MB
- **MP3**: 3 MB
- **AAC**: 2.5 MB

Quality vs Size Trade-off:

- **Highest Quality**: WAV (uncompressed)
- **Best Balance**: AAC (lossy compressed)
- **Smallest Size**: Low bitrate MP3
- **Lossless Compressed**: FLAC

Mnemonic

"WAV MP3 AAC FLAC - Wave, Layer3, Advanced, Free Lossless"

Question 5(a) [3 marks]

Explain E1 carrier multiplexing hierarchy.

Solution

E1 Carrier System: European digital transmission standard for multiplexing voice channels.
E1 Hierarchy:

Level	Name	Bit Rate	Voice Channels	Multiplexing
E0	Basic Channel	64 kbps	1	-
E1	Primary Rate	2.048 Mbps	30	$30 \times E0 + 2$
E2	Secondary Rate	8.448 Mbps	120	$4 \times E1$
E3	Tertiary Rate	34.368 Mbps	480	$4 \times E2$
E4	Quaternary Rate	139.264 Mbps	1920	$4 \times E3$

E1 Frame Structure:

```
Frame (125  s, 256 bits)
|TS0|TS1|TS2|...|TS15|TS16|TS17|...|TS31|
 32 time slots  8 bits = 256 bits

TS0: Synchronization + Alarm
TS16: Signaling (voice channels)
TS1{-15, 17{-}31: 30 voice channels}
```

Multiplexing Process:

- **Level 1**: 30 voice channels + 2 control $\rightarrow E1$
- **Level 2**: 4 E1 streams $\rightarrow E2$
- **Level 3**: 4 E2 streams $\rightarrow E3$
- **Level 4**: 4 E3 streams $\rightarrow E4$

Applications:

- **ISDN**: Primary rate interface
- **Cellular**: Base station connectivity
- **Enterprise**: Private branch exchange (PBX)
- **Internet**: Digital subscriber line (DSL)

Mnemonic

"E1 - 30 voices, 2.048 Mbps, European standard"

Question 5(b) [4 marks]

Compare FDMA with TDMA.

Solution

FDMA vs TDMA Comparison:

Parameter	FDMA	TDMA
Full Form	Frequency Division Multiple Access	Time Division Multiple Access
Domain	Frequency	Time
Channel Allocation	Each user gets different frequency	Each user gets different time slot
Bandwidth per User	Narrow bandwidth continuously	Full bandwidth for short duration
Guard Bands	Required between frequencies	Not required
Synchronization	Not critical	Critical
Flexibility	Less flexible	More flexible
Handoff	Simple	Complex
Near-Far Effect	Less problematic	More problematic

FDMA System:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Total Bandwidth] {-{-}{} B[User 1: f1]}
    A {-{-}{} C[User 2: f2]}
    A {-{-}{} D[User 3: f3]}
    A {-{-}{} E[User N: fn]}

    F[Guard Band] {-{-}{} B}
    F {-{-}{} C}
    F {-{-}{} D}
{Highlighting}
{Shaded}
```

TDMA System:

```
gantt
    title TDMA Time Slots
    dateFormat X
    axisFormat \%s

    section Frame
    User 1 :done, u1, 0, 1
    User 2 :done, u2, 1, 2
    User 3 :done, u3, 2, 3
    User 4 :done, u4, 3, 4
```

Advantages/Disadvantages:

FDMA Advantages	FDMA Disadvantages
Simple implementation	Waste of bandwidth due to guard bands
No synchronization needed	Less flexible
Continuous transmission	Difficult to accommodate varying rates

TDMA Advantages	TDMA Disadvantages
Efficient bandwidth usage	Complex synchronization
Flexible data rates	Battery life issues (burst transmission)
Easy to add/remove users	Near-far problem

Applications:

- **FDMA**: AMPS (1G), satellite communication
- **TDMA**: GSM (2G), satellite communication

Mnemonic

"FDMA Frequency, TDMA Time - different domains for multiple access"

Question 5(c) [7 marks]

Explain CDMA technique in detail.

Solution

CDMA Principle: Code Division Multiple Access allows multiple users to share the same frequency and time by using unique spreading codes.

CDMA System Architecture:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[User Data] {-{-}{} B[Spreading Code]}
    B {-{-}{} C[Modulator]}
    C {-{-}{} D[Channel]}
    D {-{-}{} E[Correlator]}
    E {-{-}{} F[Despreading]}
    F {-{-}{} G[Data Recovery]}

    H[Pseudo{-random Code] {-}{-}{} B}
    I[Same PN Code] {-{-}{} F}
{Highlighting}
{Shaded}
```

Spreading Process:

Parameter	Before Spreading	After Spreading
Data Rate	Rb	Rb
Chip Rate	-	Rc (= N $\times Rb$)
Bandwidth	Rb	Rc
Processing Gain	1	N = Rc/Rb

CDMA Properties:

```
Original Data:    1  0  1
PN Code:         101 010 101
XOR Result:      101 010 101
(Spread Signal)

At Receiver:
Received:        101 010 101
Same PN Code:    101 010 101
XOR Result:       1   0   1
(Original Data)
```

Key Features:

Feature	Description	Benefit
Spreading	Data XOR with PN code	Bandwidth expansion
Processing Gain	Rc/Rb ratio	Interference rejection
Soft Handoff	Simultaneous connections	Better quality
Power Control	Dynamic power adjustment	Near-far solution

CDMA Advantages:

- **Capacity**: Higher user capacity than FDMA/TDMA
- **Security**: Encrypted by spreading code
- **Soft Handoff**: No call dropping during handoff
- **Anti-jamming**: Spread spectrum immunity
- **No Frequency Planning**: Same frequency reuse

CDMA Disadvantages:

- **Near-Far Problem**: Requires power control
- **Complexity**: More complex than FDMA/TDMA
- **Self Interference**: Users interfere with each other
- **Breathing Effect**: Coverage varies with loading

Mathematical Analysis:

- **Processing Gain**: G = Rc/Rb = $10\log_{10}(Rc/Rb)dB$
- **Capacity**: M $\approx 1 + G/(Eb/I_0)$
- **BER**: Depends on number of active users

Power Control:

- **Open Loop**: Based on received signal strength
- **Closed Loop**: Base station commands mobile
- **Requirement**: $\pm 1 dB accuracy needed$

Applications:

- **IS-95 (cdmaOne)**: 2G CDMA standard
- **WCDMA**: 3G UMTS system
- **GPS**: Satellite navigation
- **WiFi**: Spread spectrum option

PN Code Properties:

- **Autocorrelation**: High for synchronized, low for unsynchronized
- **Cross-correlation**: Low between different codes
- **Balance**: Equal number of 1s and 0s
- **Run Length**: Distribution of consecutive bits

Mnemonic

"CDMA - Code Division, same frequency/time, unique codes for Multiple Access"

Question 5(a OR) [3 marks]

Draw block diagram of Time Division Multiplexing technique (TDM).

Solution

TDM Block Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Input 1] {-{-}{} E[Multiplexer]}
    B[Input 2] {-{-}{} E}
    C[Input 3] {-{-}{} E}
    D[Input N] {-{-}{} E}

    E {-{-}{} F[TDM Signal]}
    F {-{-}{} G[Channel]}
    G {-{-}{} H[Demultiplexer]}

    H {-{-}{} I[Output 1]}
    H {-{-}{} J[Output 2] }
    H {-{-}{} K[Output 3]}
    H {-{-}{} L[Output N]}

    M[Clock/Sync] {-{-}{} E}
    N[Clock/Sync] {-{-}{} H}
{Highlighting}
{Shaded}
```

TDM Frame Structure:

```
|{{-}{-}{-}{-} Frame Period T {-}{-}{-}{-}|}
|Ch1|Ch2|Ch3|...|ChN|Sync|
 TS1 TS2 TS3     TSN

Each time slot = T/N
Frame Rate = 1/T
```

Components:

- **Multiplexer**: Samples inputs sequentially
- **Clock/Synchronization**: Controls switching timing
- **Channel**: Transmission medium
- **Demultiplexer**: Separates multiplexed signal

Operation:

- Each input channel gets dedicated time slot
- Sampling rate must satisfy Nyquist criterion
- Frame synchronization required at receiver

Mnemonic

"TDM - Time Division, sequential sampling, Multiplexing"

Question 5(b OR) [4 marks]

Write a short not on classification of multiplexing techniques.

Solution

Classification of Multiplexing Techniques:

Mermaid Diagram (Code)

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

```
    A[Multiplexing] {-{-}{} B[Analog Multiplexing]}
    A {-{-}{} C[Digital Multiplexing]}

    B {-{-}{} D[FDM {-} Frequency Division]}
    B {-{-}{} E[WDM {-} Wavelength Division]}

    C {-{-}{} F[TDM {-} Time Division]}
    C {-{-}{} G[CDM {-} Code Division]}
    C {-{-}{} H[SDM {-} Space Division]}

    F {-{-}{} I[Synchronous TDM]}
    F {-{-}{} J[Asynchronous TDM]}
{Highlighting}
{Shaded}
```

Detailed Classification:

Type	Method	Domain	Application
FDM	Frequency separation	Frequency	Radio, TV broadcasting
TDM	Time slot allocation	Time	Digital telephony
CDM	Code separation	Code	CDMA cellular
WDM	Wavelength separation	Wavelength	Optical fiber
SDM	Space separation	Space	MIMO systems

Synchronous vs Asynchronous TDM:

Parameter	Synchronous TDM	Asynchronous TDM
Time Slots	Fixed allocation	Dynamic allocation
Efficiency	Lower	Higher
Complexity	Simple	Complex
Bandwidth Waste	May occur	Minimal

Selection Criteria:

- **Nature of Signal**: Analog $\rightarrow FDM, Digital \rightarrow TDM$
- **Bandwidth**: Limited $\rightarrow TDM, Abundant \rightarrow FDM$
- **Synchronization**: Critical $\rightarrow Synchronous, Flexible \rightarrow Asynchronous$
- **Application**: Voice $\rightarrow TDM, Data \rightarrow StatisticalTDM$

Modern Techniques:

- **OFDM**: Orthogonal Frequency Division Multiplexing
- **MIMO**: Multiple Input Multiple Output
- **Carrier Aggregation**: Multiple frequency bands

Mnemonic

"FDM TDM CDM WDM SDM - Frequency Time Code Wave Space Division Multiplexing"

Question 5(c OR) [7 marks]

Describe the procedure to troubleshoot the code division multiplexing circuit

Solution

CDMA Troubleshooting Procedure:
1. System Overview Check:

Mermaid Diagram (Code)

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

```
    A[CDMA System] {-{-}{} B[Transmitter Section]}
    A {-{-}{} C[Channel Section]}
    A {-{-}{} D[Receiver Section]}

    B {-{-}{} E[Data Input OK?]}
    B {-{-}{} F[PN Code Generation OK?]}
    B {-{-}{} G[Spreading Function OK?]}

    C {-{-}{} H[Path Loss Measurement]}
    C {-{-}{} I[Interference Check]}

    D {-{-}{} J[Correlation OK?]}
    D {-{-}{} K[Despreading OK?]}
    D {-{-}{} L[Data Recovery OK?]}
{Highlighting}
{Shaded}
```

2. Step-by-Step Troubleshooting:

Step	Parameter	Test Method	Expected Result
1	Input Data	Verify data stream	Clean digital signal
2	PN Code	Check code generation	Proper sequence
3	Spreading	Monitor XOR output	Spread spectrum signal
4	Transmission**	Measure power level	Adequate signal strength
5	Reception	Check received signal	Above noise floor
6	Correlation	Verify correlator output	Peak at correct timing
7	Despreading	Check XOR with local PN	Despread signal
8	Data Recovery**	Verify output data	Original data recovered

3. Common Problems and Solutions:

Problem	Symptoms	Possible Causes	Solutions
No Signal	Zero output	Power supply failure	Check power connections
High BER	Many bit errors	Poor correlation	Adjust timing/power
Interference	Degraded performance	Other users/noise	Power control adjustment
Sync Loss	Intermittent signal	PN code mismatch	Verify code sequences

4. Test Equipment Required:

Equipment	Purpose	Measurement
Spectrum Analyzer	Signal analysis	Power spectral density
BER Tester	Error measurement	Bit error rate
Power Meter	Power measurement	Transmitted/received power
Oscilloscope	Waveform analysis	Time domain signals
Vector Analyzer	Modulation quality	EVM, constellation

5. Measurement Procedures:
Processing Gain Verification:

```
Gp = 10 log_{1}_{0}(Rc/Rb) dB
Where: Rc = chip rate, Rb = bit rate
```

BER vs Eb/N0 Measurement:

```
BER = Q(\sqrt(2Eb/N0))
Measure at various power levels
```

Near-Far Effect Check:

- Measure power levels of different users
- Verify power control operation
- Check dynamic range requirements

6. Performance Optimization:

Parameter	Optimization Method	Target Value
Power Control	Adjust loop gain	$\pm 1 dB accuracy$
Code Selection	Choose orthogonal codes	Low cross-correlation
Timing	Synchronize PN generators	<0.5 chip accuracy
Filtering	Bandlimit signals	Minimize ISI

7. Documentation:

- Record all measurements
- Document problem symptoms
- Note solutions applied
- Create troubleshooting log

Systematic Approach:

1. **Isolate**: Identify faulty section
2. **Measure**: Use appropriate test equipment
3. **Analyze**: Compare with specifications
4. **Correct**: Apply appropriate solution
5. **Verify**: Confirm problem resolution

Safety Considerations:

- Power levels within safe limits
- Proper grounding procedures
- RF exposure guidelines
- Equipment calibration status

Mnemonic

"CDMA Troubleshoot - Check Data, PN code, Spreading, Channel, Correlation, Recovery"