Subject Name Solutions

4341102 – Summer 2023

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define signal and give its classification.

Solution

A signal is a physical quantity that varies with time, space, or any other independent variable and contains information.

Classification of Signals:

Classification Criteria	Types of Signals
Time Domain	Continuous-time signals, Discrete-time signals
Amplitude	Analog signals, Digital signals
Nature	Deterministic signals, Random signals
Symmetry	Even signals, Odd signals
Energy/Power	Energy signals, Power signals

Mnemonic

"CADEN" (Continuous/Discrete, Analog/Digital, Deterministic/Random, Even/Odd, Energy/Power)

Question 1(b) [4 marks]

Explain continuous and discrete time signals.

Solution

Continuous-time Signals	Discrete-time Signals
Defined for all values of time	Defined only at specific time instants
Represented as x(t)	Represented as x[n] or x(nT)
Example: Analog signals like sinusoidal wave	Example: Digital signals like sampled speech
Continuous curve on graph	Series of points on graph
Processing requires analog circuits	Processing can be done with digital processors

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Signals] {-{-}{} B[Continuous{-}time]}
    A {-{-}{} C[Discrete{-}time]}
    B {-{-}{} D[Defined for all t]}
    C {-{-}{} E[Defined at specific instants nT]}
    D {-{-}{} F["Example: sin(t)"]}
    E {-{-}{} G["Example: sin(nT)"]}
{Highlighting}
{Shaded}
```

Mnemonic

"CAD" - Continuous signals are Analog and Defined for all time; Discrete signals are digital and defined at specific points.

Question 1(c) [7 marks]

Explain Unit Impulse and Unit Step function.

Solution

Unit Impulse Function ((t))	Unit Step Function (u(t))
Infinitely high at t=0, zero elsewhere	Value is 1 for t$\geq 0, 0 for t < 0$
Area under curve = 1	Integral gives ramp function
Used to represent instantaneous events	Used to represent sudden transitions
Mathematical basis for LTI system analysis	Used for system response analysis
Laplace transform = 1	Laplace transform = 1/s

Diagram:

```
             |     \^{}
             |     |
             |     |
Unit         |     |               Unit
Impulse      |  (t)| Area = 1      Step        u(t)
             |     |               Function    {-{-}{-}{-}{-}{-}{-}{-}{-}{-}}
             |     |                           |
            +{-{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}                  +{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{
           {-1  0  1  t                        {-}1  0  1  t    }
```

Properties:

- **Sampling property**: (t) (t-t$_0)dt = f(t_0)$
- **Unit step is integral of impulse**: u(t) = ( )d from -$\infty to t$
- **Impulse is derivative of unit step**: (t) = du(t)/dt

Mnemonic

"SHARP-FLAT" - Impulse is Sharp and momentary; Step is Flat and persistent.

Question 1(c) OR [7 marks]

Explain block diagram of digital communication system.

Solution

Block Diagram of Digital Communication System:

```
flowchart LR
    A[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[Destination]}
```

Explanation:

Block	Function
Source	Generates the message to be transmitted
Source Encoder	Converts message to digital form, removes redundancy
Channel Encoder	Adds controlled redundancy for error detection/correction
Digital Modulator	Maps digital bits to signals suitable for transmission
Channel	Physical medium through which signal travels
Digital Demodulator	Recovers digital data from received signal
Channel Decoder	Detects/corrects errors using added redundancy
Source Decoder	Reconstructs original message from received bits
Destination	Receives the transmitted message

Mnemonic

"SECDCSD" - "Seven Engineers Can Design Communication Systems Diligently"

Question 2(a) [3 marks]

A signal has a bit rate of 8000 bit/second and a baud rate of 1000 baud. How many data elements are carried by each signal element?

Solution

Number of data elements (bits) per signal element: = Bit rate $\div Baudrate = 8000 bits/second \div 1000 baud = 8 bits/signalelement$

Parameter	Value	Relation
Bit rate	8000 bits/sec	Given
Baud rate	1000 baud	Given
Bits/signal	8 bits	Bit rate $\div Baudrate$

Mnemonic

"Bits Divided By Bauds" (BDBB)

Question 2(b) [4 marks]

Explain Energy and power signals.

Solution

Energy Signals	Power Signals
Finite total energy	Infinite total energy but finite average power
Zero average power	Non-zero average power
E = $\int \lvert x(t)\rvert^2 dt (finite)$	P = lim(T$\to \infty$)$1/2T$ $\int \lvert x(t)\rvert^2 dt (finite)$
Examples: Pulse, Decaying exponential	Examples: Sine wave, Square wave
Localized in time	Exist for all time

Diagram:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Signals] {-{-}{} B[Energy Signals]}
    A {-{-}{} C[Power Signals]}
    B {-{-}{} D[Finite Energy]}
    B {-{-}{} E[Zero Average Power]}
    C {-{-}{} F[Infinite Energy]}
    C {-{-}{} G[Finite Average Power]}
    D {-{-}{} H[Example: Pulse]}
    G {-{-}{} I[Example: Sine Wave]}
{Highlighting}
{Shaded}
```

Mnemonic

"FEZIL" - Finite Energy is Zero in Long-term; Power signals are Infinite in Length

Question 2(c) [7 marks]

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

Solution

FSK Modulator and Demodulator:

```
flowchart TD
    subgraph Modulator
        A[Digital Input] {-{-} B[Voltage Controlled Oscillator]}
        B {-{-} C[FSK Output]}
    end
    subgraph Demodulator
        D[FSK Input] {-{-} E[Bandpass Filter 1nFrequency f1]}
        D {-{-} F[Bandpass Filter 2nFrequency f2]}
        E {-{-} G[Envelope Detector 1]}
        F {-{-} H[Envelope Detector 2]}
        G {-{-} I[Comparator]}
        H {-{-} I}
        I {-{-} J[Digital Output]}
    end
```

Waveforms:

```
Digital Input: \_\_\_\_\_   \_\_\_\_\_   \_\_\_\_\_
                 0     1     0     1     0

FSK Output:  /{//MMMMMM///MMMMMM///}
             f1    f2    f1    f2    f1

Received at BPF1: /{//\_\_\_\_\_///\_\_\_\_\_///}
                   f1          f1          f1

Received at BPF2: \_\_\_\_\_MMMMMM\_\_\_\_\_MMMMMM\_\_\_\_\_
                        f2          f2

Digital Output: \_\_\_\_\_   \_\_\_\_\_   \_\_\_\_\_
                 0     1     0     1     0
```

Key Principles:

- **Bit 0**: Transmitted as frequency f_1
- **Bit 1**: Transmitted as frequency f_2
- **Demodulation**: Uses bandpass filters to separate frequencies
- **Detection**: Envelope detectors recover the digital signal

Mnemonic

"FIST" - Frequency Is Shifted for Transmission

Question 2(a) OR [3 marks]

A signal carries 4 bit/signal elements. If 1000 signal elements sent per second. Find the bit rate.

Solution

Bit rate = Number of bits per signal element $\times Signalelementspersecond Bitrate = 4bits/signalelement \times 1000signalelements/second Bitrate = 4000bits/second$

Parameter	Value	Relation
Bits per symbol	4	Given
Symbol rate	1000 symbols/sec	Given
Bit rate	4000 bits/sec	Bits/symbol $\times Symbolrate$

Mnemonic

"BBS" - Bit rate equals Bits per symbol times Symbol rate

Question 2(b) OR [4 marks]

Explain Even and Odd signals.

Solution

Even Signals	Odd Signals
Symmetric around y-axis	Anti-symmetric around y-axis
x(-t) = x(t)	x(-t) = -x(t)
Example: cos(t)	Example: sin(t)
Fourier transform is real	Fourier transform is imaginary
Sum of even signals is even	Sum of odd signals is odd

Diagram:

```
Even Signal x(t)             Odd Signal x(t)
    |                            |
    |     *     *                |     *
    |   *         *              |   *   {}
    | *             *            | *      {}
{-{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}   {-}{-}{-}{-}+{-}{-}{-}{-}{-}{-
    |                            |        /     *
    |                            |      /   *
    |                            |     *
```

Properties:

- Any signal can be expressed as sum of even and odd components
- Even component: $x_1(t) = [x(t) + x(-t)]/2$
- Odd component: $x_2(t) = [x(t) - x(-t)]/2$

Mnemonic

"SAME-FLIP" - Even signals are the SAME when flipped; Odd signals FLIP their sign.

Question 2(c) OR [7 marks]

Explain the block diagram of QPSK modulator and de-modulator with constellation diagram.

Solution

QPSK Modulator and Demodulator:

```
flowchart TD
    subgraph Modulator
        A[Binary Input] {-{-} B[Serial to ParallelnConverter]}
        B {-{-} C[Even Bits]}
        B {-{-} D[Odd Bits]}
        C {-{-} E[Multiplier]}
        D {-{-} F[Multiplier]}
        G["cos(2 ft)"] {-{-} E}
        H["sin(2 ft)"] {-{-} F}
        E {-{-} I[Summer]}
        F {-{-} I}
        I {-{-} J[QPSK Output]}
    end

    subgraph Demodulator
        K[QPSK Input] {-{-} L[Multiplier 1]}
        K {-{-} M[Multiplier 2]}
        N["cos(2 ft)"] {-{-} L}
        O["sin(2 ft)"] {-{-} M}
        L {-{-} P[Integrator 1]}
        M {-{-} Q[Integrator 2]}
        P {-{-} R[Decision Device 1]}
        Q {-{-} S[Decision Device 2]}
        R {-{-} T[Parallel to SerialnConverter]}
        S {-{-} T}
        T {-{-} U[Binary Output]}
    end
```

Constellation Diagram:

```
             Q
             |
      01     |     00
      •      |      •
             |
{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}}
             |
      11     |     10
      •      |      •
             |             I
```

Key Characteristics:

- **Input**: 2 bits determine each symbol
- **Phases**: 4 phases $(0°, 90°, 180°, 270°)$
- **Bits to phases**:
  - 00: 45°
  - 01: 135°
  - 11: 225°
  - 10: 315°
- **Bandwidth efficiency**: 2 bits per symbol

Mnemonic

"QUADrature" - 4 phases for 4 possible 2-bit combinations

Question 3(a) [3 marks]

Explain the working of ASK modulator with block diagram and output waveforms.

Solution

ASK Modulator Block Diagram:

```
flowchart LR
    A[Digital Input] {-{-} B[Multiplier]}
    C["Carrier Generator{nsin(2 ft)"] {-}{-} B}
    B {-{-} D[ASK Output]}
```

Waveforms:

```
Digital Input: \_\_\_\_\_   \_\_\_\_\_   \_\_\_\_\_
                 0     1     0     1     0

Carrier:      /{/////////////}

ASK Output:   \_\_\_\_\_/{//\_\_\_\_\_///\_\_\_\_\_}
                 0     1     0     1     0
```

Working Principle:

- Digital 1: Carrier signal is transmitted
- Digital 0: No signal (or low amplitude) is transmitted
- Output amplitude varies with input digital signal

Mnemonic

"ASKY" - Amplitude Switches the Carrier? Yes!

Question 3(b) [4 marks]

Draw the constellation diagram of 8-PSK and 16-QAM.

Solution

8-PSK Constellation Diagram:

```
                  Q
                  |
        011  •    |    • 000
              {   |   /}
         110 •  { | /  • 001}
                 {|/}
        {-{-}{-}{-}{-}{-}{-}{-}+{-}{-}{-}{-}{-}{-}{-}{-} I}
                /|{}
         101 •  / | {  • 010}
              /   |   {}
        100  •    |    • 011
                  |
```

16-QAM Constellation Diagram:

```
                Q
        •   •   |   •   •
                |
        •   •   |   •   •
```

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

Key Differences:

- **8-PSK**: 8 symbols, equal amplitude, phases at 45°$intervals$
- **16-QAM**: 16 symbols, varying amplitudes and phases

Mnemonic

"P-Phase Q-Quantity" - PSK varies Phase only; QAM varies both amplitude (Quantity) and phase

Question 3(c) [7 marks]

Draw the ASK and FSK modulation waveform for the sequence of 1100101101.

Solution

Modulation Waveforms:

```
Binary Input:       \_\_\_\_\_   \_\_\_\_\_
               1  1  0  0  1  0  1  1  0  1

Carrier:       /{////////////////}

ASK Output:    /{/////\_\_\_\_\_///\_\_\_\_\_/////}
               1  1  0  0  1  0  1  1  0  1

FSK Output:    MMMMMMMMMM/{///MMMMM////MMMMMMMMMM}
               1  1  0  0  1  0  1  1  0  1
               f2 f2 f1 f1 f2 f1 f2 f2 f1 f2
```

Key Characteristics:

- **ASK**: Carrier present for bit 1, absent for bit 0
- **FSK**: Higher frequency (f$_2$)$forbit1, lowerfrequency(f_1)forbit0$

Table of Modulation Methods:

Modulation	Bit 0	Bit 1	Parameter Varied
ASK	Zero or low amplitude	High amplitude	Amplitude
FSK	Frequency f_1	Frequency f_2	Frequency

Mnemonic

"AFRO" - Amplitude For 1, Remove for 0 (ASK); Frequency Rises for 1, Off-peak for 0 (FSK)

Question 3(a) OR [3 marks]

Explain the working of PSK modulator with block diagram and output waveforms.

Solution

PSK Modulator Block Diagram:

```
flowchart LR
    A[Digital Input] {-{-} B[Polar Convertern0-1, 1+1]}
    B {-{-} C[Multiplier]}
    D["Carrier Generator{nsin(2 ft)"] {-}{-} C}
```

```
    C {-{-} E[PSK Output]}
```

Waveforms:

```
Digital Input: \_\_\_\_\_   \_\_\_\_\_   \_\_\_\_\_
                 0     1     0     1     0

Carrier:      /{/////////////}

PSK Output:   {//////////////}
               0     1     0     1     0
               180^  0^    180^  0^    180^
```

Working Principle:

- Digital 1: Carrier signal with $0° phase$
- Digital 0: Carrier signal with $180° phase (inverted)$
- Amplitude remains constant, only phase changes

Mnemonic

"PSKIT" - Phase Shift Keeps Information True

Question 3(b) OR [4 marks]

Draw the MSK modulation waveform for the sequence of 1101001101.

Solution

MSK Modulation Waveform:

```
Binary Input:     \_\_\_\_\_   \_\_\_\_\_
               1  1  0  1  0  0  1  1  0  1

MSK Output:    {//MMMMM//MMMMM////MMMMM}
               1  1  0  1  0  0  1  1  0  1
```

Characteristics of MSK:

- Continuous phase transitions (no phase jumps)
- Frequency shifts between $f_1 and f_2$
- Minimum frequency separation: $\Delta f = 1/(2T)$
- Smoother transitions than FSK

Feature	MSK Characteristic
Phase continuity	Continuous, no abrupt changes
Frequency deviation	Minimum possible (1/2T)
Spectral efficiency	Better than conventional FSK
Bandwidth	1.5 times bit rate

Mnemonic

"MINIMUM SMOOTH" - MSK uses Minimum frequency separation with Smooth transitions

Question 3(c) OR [7 marks]

Draw BPSK and QPSK modulation waveform for 1100101011.

Solution

BPSK and QPSK Modulation Waveforms:

```
Binary Input:          \_\_\_\_\_   \_\_\_\_\_
```

```
                  1  1  0  0  1  0  1  0  1  1

BPSK Output:      /{////////////////}
                  0^  0^ 180^180^ 0^ 180^ 0^ 180^ 0^  0^

QPSK (I channel): /{//\_\_\_\_\_///\_\_\_\_\_///}
                  11   00    10    01    11

QPSK (Q channel): /{/////\_\_\_\_\_///\_\_\_\_\_}
                  11   00    10    01    11

QPSK (combined):  {///MMMMM///MMMMM///}
                  11   00    10    01    11
```

Key Differences:

- **BPSK**: 1 bit per symbol, 2 phases ($0° and 180°$)
- **QPSK**: 2 bits per symbol, 4 phases ($45°, 135°, 225°, 315°$)
- **QPSK Pairs**: 00, 01, 10, 11 map to different phases

Modulation	Bits/Symbol	Number of Phases	Bandwidth Efficiency
BPSK	1	2	1 bit/Hz
QPSK	2	4	2 bits/Hz

Mnemonic

"ONE-TWO" - ONE bit for BPSK, TWO bits for QPSK

Question 4(a) [3 marks]

Encode the data using Huffman code for below probability sequence. P = { 0.4, 0.2, 0.2, 0.1, 0.1}

Solution

Huffman Coding Process:

Symbol	Probability	Huffman Code
A	0.4	0
B	0.2	10
C	0.2	11
D	0.1	110
E	0.1	111

Huffman Tree:

```
              [1.0]
             /     {}
            /       {}
         [0.6]       [0.4] A:0
        /     {}
       /       {}
    [0.4]      [0.2] B:10
   /     {}
  /       {}
[0.2] C:11 [0.2]
          /     {}
         /       {}
    [0.1] D:110 [0.1] E:111
```

Mnemonic

"Higher Probability Means Shorter Code"

Question 4(b) [4 marks]

Define Probability and Entropy.

Solution

Concept	Definition	Formula	Significance
Probability	Measure of likelihood of an event occurring	P(A) = Number of favorable outcomes / Total number of possible outcomes	Used to model uncertainty in communication
Entropy	Measure of uncertainty or randomness in a system	H(X) = -$\sum P(xi)log_2 P(xi)$	Indicates average information content

Key Characteristics:

- **Probability Range**: $0 \leq P(A) \leq 1$
- **Entropy Units**: Bits (using $\log_2$)
- **Maximum Entropy**: When all events are equally likely
- **Minimum Entropy**: When outcome is certain (probability = 1)

Mnemonic

"PURE" - Probability Underpins Randomness Estimation

Question 4(c) [7 marks]

Explain CDMA technique in detail.

Solution

CDMA (Code Division Multiple Access):

```
flowchart LR
    A[User Data] {-{-} B[Spreadingnwith Unique Code]}
    B {-{-} C[Modulation]}
    C {-{-} D[Transmission]}
    D {-{-} E[Reception]}
    E {-{-} F[Demodulation]}
    F {-{-} G[Despreading withnMatching Code]}
    G {-{-} H[Original User Data]}
```

Table of CDMA Characteristics:

Feature	Description
Access Method	Multiple users share same frequency and time
Separation	Users distinguished by unique spreading codes
Spreading Codes	Orthogonal or pseudo-orthogonal sequences
Processing Gain	Ratio of spread bandwidth to original bandwidth
Multiple Access	Uses code space rather than frequency or time division
Interference Rejection	Inherent ability to reject narrowband interference

Key Advantages:

- **Capacity**: Higher than FDMA/TDMA in many scenarios
- **Security**: Inherent encryption through spreading codes
- **Multipath Rejection**: Rake receivers can combine multipath components
- **Soft Handoff**: Mobile can communicate with multiple base stations

Mnemonic

"CODES" - Capacity Optimized with Direct-sequence Encoding Schemes

Question 4(a) OR [3 marks]

Encode the data using Shanon Fano code for below probability sequence. P = { 0.5, 0.25, 0.125, 0.125}

Solution

Shannon-Fano Coding Process:

Symbol	Probability	Shannon-Fano Code
A	0.5	0
B	0.25	10
C	0.125	110
D	0.125	111

Shannon-Fano Tree:

```
              [1.0]
             /     {}
            /       {}
     [0.5] A       [0.5]
                  /     {}
                 /       {}
           [0.25] B     [0.25]
                       /     {}
                      /       {}
               [0.125] C     [0.125] D
                Code:110     Code:111
```

Mnemonic

"Split For Optimum" - Shannon-Fano splits groups for optimum coding

Question 4(b) OR [4 marks]

Define Information and Channel Capacity.

Solution

Concept	Definition	Formula	Significance
Information	Measure of reduction in uncertainty	I(x) = -$\log_2 P(x)$	Less probable events carry more information
Channel Capacity	Maximum rate at which information can be transmitted with arbitrarily small error	C = B $\log_2(1 + S/N)$	Fundamental limit of reliable communication

Key Points:

- **Information Units**: Bits (using $\log_2$)
- **Channel Capacity Units**: Bits per second
- **Factors Affecting Capacity**:
  - Bandwidth (B)
  - Signal-to-Noise Ratio (S/N)

Mnemonic

"INCHES" - Information Numerically Calculated, Hopping through Efficient Shannon limit

Question 4(c) OR [7 marks]

Explain TDMA technique in detail.

Solution

TDMA (Time Division Multiple Access):

```
flowchart LR
    A[User 1] {-{-} B[Time Slot 1]}
    C[User 2] {-{-} D[Time Slot 2]}
    E[User 3] {-{-} F[Time Slot 3]}
    G[User 4] {-{-} H[Time Slot 4]}
    B {-{-} I[Multiplexer]}
    D {-{-} I}
    F {-{-} I}
    H {-{-} I}
    I {-{-} J[Transmission Channel]}
    J {-{-} K[Demultiplexer]}
    K {-{-} L[Time Slot 1]}
    K {-{-} M[Time Slot 2]}
    K {-{-} N[Time Slot 3]}
    K {-{-} O[Time Slot 4]}
    L {-{-} P[User 1]}
    M {-{-} Q[User 2]}
    N {-{-} R[User 3]}
    O {-{-} S[User 4]}
```

Table of TDMA Characteristics:

Feature	Description
Access Method	Multiple users share same frequency at different time slots
Frame Structure	Time divided into frames, frames into slots
Guard Time	Short periods between slots to prevent overlap
Synchronization	Precise timing required between transmitter and receiver
Efficiency	High spectrum utilization
Power Consumption	Transmitter on only during assigned slots

TDMA Frame Structure:

```
|{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} TDMA Frame {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
| TS1 | TS2 | TS3 | TS4 | TS1 | TS2 | TS3 | TS4 | ...
|User1|User2|User3|User4|User1|User2|User3|User4| ...
```

Mnemonic

"TIME" - Transmission In Measured Epochs

Question 5(a) [3 marks]

Explain T1 carrier system.

Solution

T1 Carrier System:

Characteristic	Specification
Data Rate	1.544 Mbps
Channels	24 voice channels
Voice Sampling	8000 samples/second
Sample Size	8 bits per sample
Frame Size	193 bits ($24 \times 8 + 1$)
Frame Rate	8000 frames/second

T1 Frame Structure:

```
|{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} T1 Frame (193 bits) {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
| F | Ch1 | Ch2 | Ch3 | ... | Ch24 | F | Ch1 | Ch2 | ... |
| 1 |  8  |  8  |  8  | ... |  8   | 1 |  8  |  8  | ... |
```

Mnemonic

"T1-24-8-8" - T1 has 24 channels, 8 bits, 8kHz

Question 5(b) [4 marks]

Explain Time Division Multiplexing technique (TDM) in detail.

Solution

Time Division Multiplexing (TDM):

```
flowchart LR
    A[Signal 1] {-{-} E[Multiplexer]}
    B[Signal 2] {-{-} E}
    C[Signal 3] {-{-} E}
    D[Signal 4] {-{-} E}
    E {-{-} F[Transmission Channel]}
    F {-{-} G[Demultiplexer]}
    G {-{-} H[Signal 1]}
    G {-{-} I[Signal 2]}
    G {-{-} J[Signal 3]}
    G {-{-} K[Signal 4]}
```

Table of TDM Characteristics:

Feature	Description
Principle	Multiple signals share a single channel by taking turns
Time Allocation	Each signal assigned a fixed time slot
Synchronization	Precise timing required between multiplexer and demultiplexer
Interleaving	Samples from different sources interleaved in time
Types	Synchronous TDM and Asynchronous (Statistical) TDM

TDM Frame Structure:

```
|{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} TDM Frame {-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
| S1 | S2 | S3 | S4 | S1 | S2 | S3 | S4 | ... |
```

Mnemonic

"TWIST" - Time Windows Interleaving Signals Together

Question 5(c) [7 marks]

Explain security components of information security in detail.

Solution

Information Security Components:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Information Security] {-{-}{} B[Confidentiality]}
    A {-{-}{} C[Integrity]}
    A {-{-}{} D[Availability]}
    B {-{-}{} E[Encryption]}
    B {-{-}{} F[Access Control]}
    C {-{-}{} G[Digital Signatures]}
    C {-{-}{} H[Hashing]}
    D {-{-}{} I[Redundancy]}
    D {-{-}{} J[Backup Systems]}
{Highlighting}
{Shaded}
```

Table of Security Components:

Component	Description	Implementation Methods
Confidentiality	Ensuring information is accessible only to authorized users	Encryption, Access control, Authentication
Integrity	Maintaining accuracy and consistency of data	Digital signatures, Hashing, Checksums
Availability	Ensuring information is accessible when needed	Redundancy, Backup systems, Disaster recovery
Authentication	Verifying identity of users	Passwords, Biometrics, Digital certificates
Non-repudiation	Preventing denial of sending/receiving information	Digital signatures, Audit trails

Common Security Threats:

- **Malware**: Viruses, worms, trojans, ransomware
- **Social Engineering**: Phishing, pretexting
- **Man-in-the-Middle Attacks**: Intercepting communications
- **Denial-of-Service**: Preventing legitimate access

Mnemonic

"CIA" - Confidentiality, Integrity, Availability

Question 5(a) OR [3 marks]

Explain E1 carrier system.

Solution

E1 Carrier System:

Characteristic	Specification
Data Rate	2.048 Mbps
Channels	32 time slots (30 voice + 2 signaling)
Voice Sampling	8000 samples/second
Sample Size	8 bits per sample
Frame Size	256 bits (32×8)
Frame Rate	8000 frames/second

E1 Frame Structure:

```
|{{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-} E1 Frame (256 bits) {-}{-}{-}{-}{-}{-}{-}{-}{-}{-
| TS0 | TS1 | TS2 | ... | TS15 | TS16 | TS17 | ... | TS31 |
|  8  |  8  |  8  | ... |  8   |  8   |  8   | ... |  8   |
```

Special Time Slots:

- **TS0**: Frame alignment signal
- **TS16**: Signaling channel

Mnemonic

"E1-32-8-8" - E1 has 32 channels, 8 bits, 8kHz

Question 5(b) OR [4 marks]

Explain Frequency Division Multiplexing technique (FDM) in detail.

Solution

Frequency Division Multiplexing (FDM):

```
flowchart LR
    A[Signal 1] {-{-} B[Modulator 1nf1]}
    C[Signal 2] {-{-} D[Modulator 2nf2]}
    E[Signal 3] {-{-} F[Modulator 3nf3]}
    G[Signal 4] {-{-} H[Modulator 4nf4]}
    B {-{-} I[Combiner/Mixer]}
    D {-{-} I}
    F {-{-} I}
    H {-{-} I}
    I {-{-} J[Transmission Channel]}
    J {-{-} K[Filters/Separators]}
    K {-{-} L[Demodulator 1nf1]}
    K {-{-} M[Demodulator 2nf2]}
    K {-{-} N[Demodulator 3nf3]}
    K {-{-} O[Demodulator 4nf4]}
    L {-{-} P[Signal 1]}
    M {-{-} Q[Signal 2]}
    N {-{-} R[Signal 3]}
    O {-{-} S[Signal 4]}
```

Table of FDM Characteristics:

Feature	Description
Principle	Multiple signals share a single channel by using different frequency bands
Guard Bands	Unused frequency bands between channels to prevent interference

Channel Bandwidth	Each signal allocated a specific frequency range
Implementation	Uses modulators to shift signals to different frequency bands
Applications	Radio broadcasting, television, cable systems

FDM Spectrum:

```
  Power
    \^{}
    |    \_\_\_      \_\_\_      \_\_\_      \_\_\_
    |   /   {    /       /       /   }
    |  /     {  /       /       /     }
    | /       {/       /       /       }
    +{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-
        Ch1      Ch2      Ch3      Ch4
      |{{-}{-}{-}|{-}|{-}{-}{-}|{-}|{-}{-}{-}|{-}|{-}{-}{-}|}
             GB      GB      GB
```

Mnemonic

"FROG" - FRequencies Organized with Gaps

Question 5(c) OR [7 marks]

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

Solution

Internet of Things (IoT) Concept:

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph TD
    A[Internet of Things] {-{-}{} B[Connected Devices]}
    A {-{-}{} C[Data Collection]}
    A {-{-}{} D[Data Analytics]}
    A {-{-}{} E[Automation]}
    B {-{-}{} F[Sensors]}
    B {-{-}{} G[Actuators]}
    C {-{-}{} H[Cloud Storage]}
    D {-{-}{} I[AI/Machine Learning]}
    E {-{-}{} J[Smart Applications]}
{Highlighting}
{Shaded}
```

Table of IoT Key Features:

Feature	Description
Connectivity	Devices connected to internet and each other
Intelligence	Smart processing, decision-making capabilities
Sensing	Gathering data from environment through sensors
Expressing	Taking actions through actuators
Energy Efficiency	Low power consumption for battery-operated devices
Security	Protection against unauthorized access and attacks
Scalability	Ability to add more devices to the network

IoT Architecture Layers:

```
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|    Application   |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|  Data Analytics  |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|  Data Processing |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|  Data Transport  |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
|    Perception    |
+{-{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}+}
```

IoT Applications:

- Smart homes and buildings
- Healthcare monitoring
- Industrial automation
- Smart cities
- Agriculture monitoring
- Supply chain management

Mnemonic

s "CASED" - Connected, Automated, Sensing, Expressing, Data-driven