

# Subject Name Solutions

4331104 – Winter 2024

Semester 1 Study Material

*Detailed Solutions and Explanations*

## Question 1(a) [3 marks]

What is modulation? What is the need of it?

### Solution

Modulation is the process of varying one or more properties (amplitude, frequency, or phase) of a high-frequency carrier signal according to the instantaneous value of a lower frequency message signal.

#### Need for modulation:

- **Antenna size reduction:** Allows practical antenna size ( $\propto 1/\lambda$ )
- **Multiplexing:** Enables multiple signals to share same medium
- **Interference reduction:** Shifts signal to suitable frequency band
- **Range extension:** Increases transmission distance

### Mnemonic

“AMIR” - Antenna, Multiplexing, Interference, Range

## Question 1(b) [4 marks]

Derive the expression for DSBFC of AM wave.

### Solution

DSBFC (Double Sideband Full Carrier) AM wave derivation:

#### Mathematical derivation:

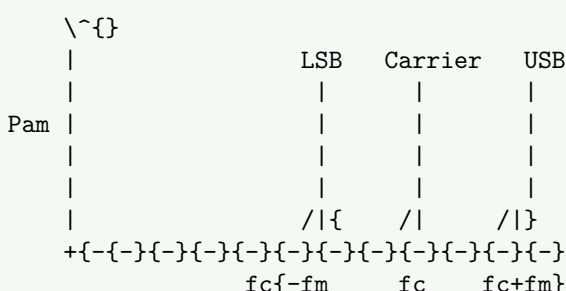
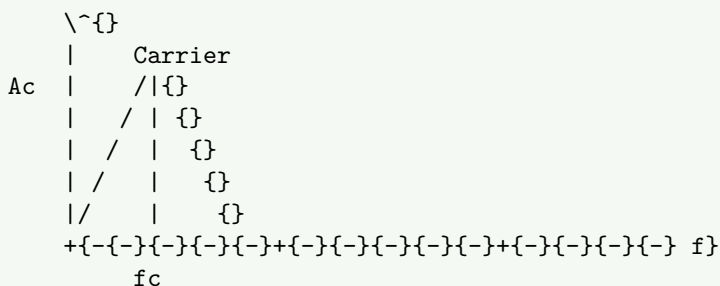
- Carrier signal:  $c(t) = A_c \cos(\omega_c t)$
- Message signal:  $m(t) = A_m \cos(\omega_m t)$
- AM signal:  $s(t) = A_c[1 + m(t)]\cos(\omega_c t)$
- Where  
 $\mu = \text{modulation index} = A_m/A_c$

**Substituting message signal:**  $s(t) = A_c[1 + \cos(\omega_m t)]\cos(\omega_c t)$   $s(t) = A_c \cos(\omega_c t) + A_c \cos(\omega_m t)\cos(\omega_c t)$

**Using trigonometric identity:**  $\cos(A)\cos(B) = \frac{1}{2}[\cos(A+B) + \cos(A-B)]$

**Final expression:**  $s(t) = A_c \cos(\omega_c t) + (A_c/2)[\cos((\omega_c + \omega_m)t) + \cos((\omega_c - \omega_m)t)]$

#### Diagram:



### Question 1(c) [7 marks]

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

#### Solution

##### Noise Classification:

Type	Source	Characteristics
External Noise	Environmental sources	Outside communication system
Internal Noise	Components	Generated within system

##### Types of internal noise:

###### 1. Flicker Noise:

- **Source:** Occurs in active devices
- **Characteristics:** Inversely proportional to frequency ( $1/f$ )
- **Effect:** Dominant at low frequencies

###### 2. Shot Noise:

- **Source:** Random electron flow across junctions
- **Characteristics:** Independent of frequency (white noise)
- **Effect:** Random current fluctuations in diodes/transistors

###### 3. Thermal Noise:

- **Source:** Random motion of electrons due to temperature
- **Characteristics:** Present in all conductors, resistors
- **Formula:**  $P_n = kTB$  ( $k$ =Boltzmann constant,  $T$ =temperature,  $B$ =bandwidth)
- **Effect:** Sets noise floor in receivers

#### Mnemonic

“FST” - Flicker decreases with Frequency, Shot is from electron flow, Thermal depends on Temperature

### Question 1(c) OR [7 marks]

Describe EM wave also write at least one application of different band of spectrum.

#### Solution

**EM Wave:** Electromagnetic waves are energy propagating through space as time-varying electric and magnetic fields, traveling at speed of light ( $3 \times 10^8 m/s$ ).

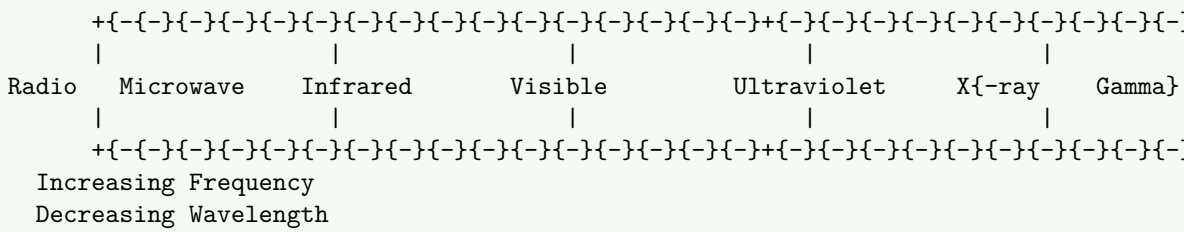
##### Characteristics:

- Transverse waves with E and H fields perpendicular to each other
- No medium required for propagation
- Described by wavelength ( $\lambda$ ) and frequency ( $f$ )
- Relation:  $c = f \times \lambda$

##### EM Spectrum and Applications:

Frequency Band	Frequency Range	Application
ELF	3Hz-30Hz	Submarine communication
VLF	3kHz-30kHz	Navigation systems
LF	30kHz-300kHz	AM broadcasting
MF	300kHz-3MHz	AM radio broadcasting
HF	3MHz-30MHz	Shortwave radio
VHF	30MHz-300MHz	FM radio, TV broadcasting
UHF	300MHz-3GHz	TV, mobile phones, WiFi
SHF	3GHz-30GHz	Satellite communication, radar
EHF	30GHz-300GHz	Millimeter wave communication
Infrared	300GHz-400THz	Remote controls, thermal imaging
Visible	400THz-800THz	Fiber optic communication
Ultraviolet	800THz-30PHz	Sterilization, authentication
X-Rays	30PHz-30EHZ	Medical imaging
Gamma Rays	>30EHZ	Cancer treatment

### Diagram:



### Mnemonic

“RMIUXG” - Radio, Microwave, Infrared, Ultraviolet, X-ray, Gamma

## Question 2(a) [3 marks]

State advantages of SSB over DSB.

### Solution

Advantages of SSB over DSB:

Parameter	SSB Advantage
<b>Bandwidth</b>	50% less bandwidth requirement
<b>Power</b>	Power saving of 83.33%
<b>Transmitter</b>	Less power amplification needed
<b>Receiver</b>	Simpler design without phase distortion
<b>SNR</b>	Better signal-to-noise ratio
<b>Fading</b>	Less susceptible to selective fading

### Mnemonic

“BP TRFS” - Bandwidth, Power, Transmitter, Receiver, Fading, SNR

## Question 2(b) [4 marks]

Explain generation of FM wave using FET reactance modulator.

### Solution

**FET Reactance Modulator:**

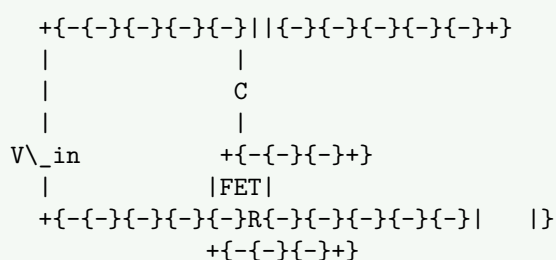
**Working principle:**

- Uses FET as voltage-controlled reactance
- Changes effective capacitance based on modulating signal
- Connected across LC tank circuit of oscillator

**Circuit operation:**

1. Modulating signal applied to gate of FET
2. FET drain-source resistance varies with gate voltage
3. Capacitive reactance changes with modulating signal
4. Oscillator frequency deviates with input signal

**Diagram:**



|  
LC  
Circuit

**Key features:**

- **Simple design:** Fewer components than other modulators
- **Linearity:** Good for wide-band FM generation
- **Stability:** Temperature stable compared to varactor diodes

**Mnemonic**

“LOVE FM” - LC Oscillator with Voltage-controlled Element for FM

**Question 2(c) [7 marks]**

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

**Solution**

**Power in AM signal:**

For AM signal  $s(t) = A_c[1 + \cos(mt)]\cos(ct)$

**Total power calculation:**

1. Power in carrier:  $P_c = A_c^2/2$
1. Power in sidebands:  $P_s = \frac{1}{2}A_c^2/4$  (total for both sidebands)
1. Total power:  $P_t = P_c + P_s = A_c^2/2 \times (1 + \frac{1}{2})$

**For 100% modulation ( $m=1$ ):**

- $P_t = P_c \times (1 + 1/2) = 1.5 \times P_c$
- Carrier power = 66.67% of total
- Sideband power = 33.33% of total

**Power savings:**

1. **In DSB-SC:**
  - Carrier is suppressed
  - Power saved = 66.67%
2. **In SSB:**
  - Carrier + one sideband suppressed
  - Power saved = 66.67% + 16.67% = 83.33%

**Comparative Table:**

Modulation	Carrier Power	Sideband Power	Total Power	Power Saving
AM ( $m=1$ )	100%	50%	150%	0%
DSB-SC	0%	50%	50%	66.67%
SSB	0%	25%	25%	83.33%

**Mnemonic**

“CST” - Carrier power, Sideband power, Total power

**Question 2(a) OR [3 marks]**

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

**Solution**

**Time Domain and Frequency Domain Display of AM Wave:**

**Time Domain:**

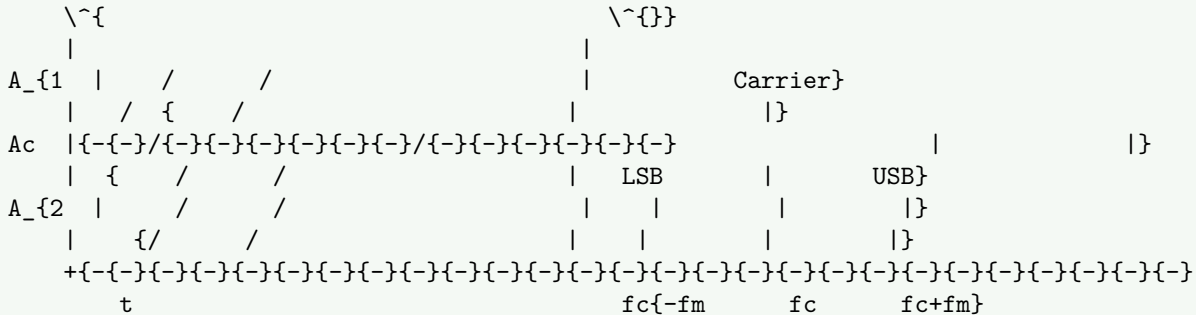
- Shows amplitude variations over time
- Envelope follows modulating signal
- Maximum amplitude:  $A_1 = A_c(1 + m)$
- Minimum amplitude:  $A_2 = A_c(1 - m)$
- Modulation index:  $m = (A_1 - A_2)/(A_1 + A_2)$

### Frequency Domain:

- Shows power distribution across frequencies
- Carrier at center frequency  $f_c$
- Upper sideband at  $f_c + f_m$
- Lower sideband at  $f_c - f_m$
- Bandwidth =  $2f_m$

### Diagram:

Time Domain:



### Mnemonic

“TEF” - Time domain shows Envelope, Frequency domain shows spectral components

## Question 2(b) OR [4 marks]

Explain pre-emphasis & de-emphasis circuit.

### Solution

#### Pre-emphasis and De-emphasis Circuits:

##### Purpose:

- Improve SNR for high-frequency components
- Compensate for higher noise in high frequencies
- Used primarily in FM systems

##### Pre-emphasis:

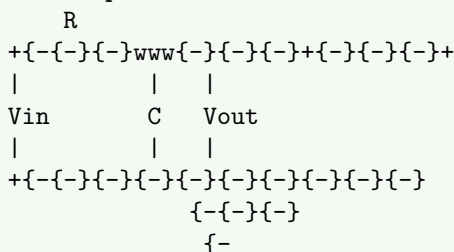
- Applied at transmitter
- Boosts high-frequency components
- Typically +6dB/octave above 2.1kHz
- Circuit: High-pass RC network (resistor in series, capacitor in parallel)

##### De-emphasis:

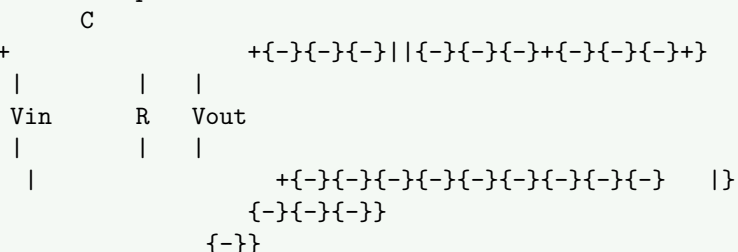
- Applied at receiver
- Attenuates high-frequency components
- Restores original signal balance
- Circuit: Low-pass RC network (resistor in parallel, capacitor in series)

### Diagrams:

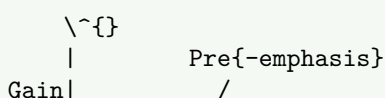
Pre-emphasis:

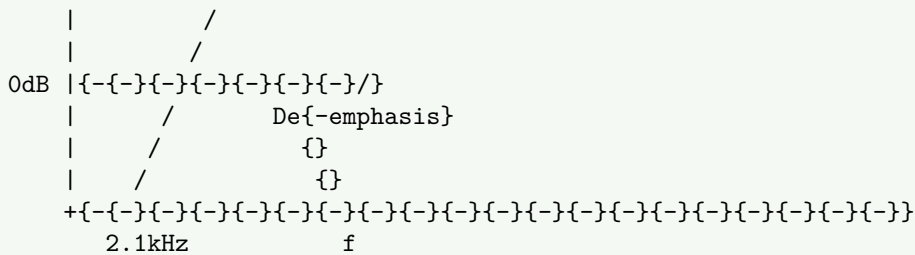


De-emphasis:



### Frequency response:





### Mnemonic

“HIGH-LOW” - HIGHer frequencies boosted at transmitter, LOWered at receiver

## Question 2(c) OR [7 marks]

Compare narrowband FM and wideband FM.

### Solution

#### Comparison of Narrowband FM and Wideband FM:

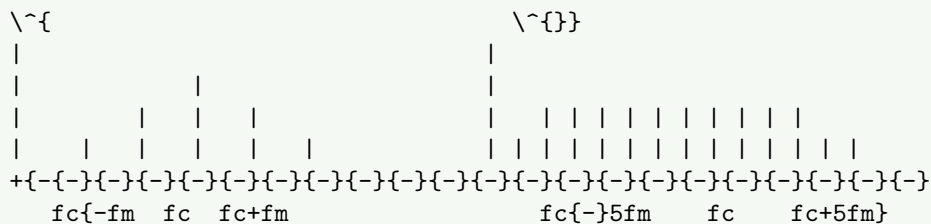
Parameter	Narrowband FM	Wideband FM
<b>Modulation Index ( )</b>	« 1 (typically <0.5)	» 1 (typically >5)
<b>Bandwidth</b>	2fm (twice message bandwidth)	2fm( +1) (Carson’s rule)
<b>Significant Sidebands</b>	Only first pair of sidebands	Multiple sidebands
<b>Applications</b>	Mobile communication, two-way radio	FM broadcasting, high-fidelity audio
<b>Signal Quality</b>	Lower fidelity, less noise immunity	Higher fidelity, better noise immunity
<b>Power Efficiency</b>	Higher	Lower
<b>Spectrum Utilization</b>	Efficient	Less efficient
<b>Circuit Complexity</b>	Simpler	More complex

#### Bandwidth calculation:

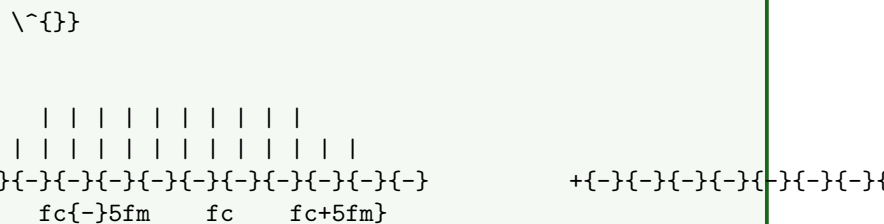
- Narrowband FM:  $BW = 2f_m$
- Wideband FM:  $BW = 2f_m( +1)$  (Carson’s rule)

#### Spectrum diagram:

Narrowband FM:



Wideband FM:



### Mnemonic

“BASPCB” - Bandwidth, Applications, Sidebands, Power, Complexity, Beta

## Question 3(a) [3 marks]

Define any FOUR characteristics of radio receiver.

### Solution

#### Characteristics of Radio Receiver:

##### 1. Sensitivity:

- Ability to amplify weak signals

- Measured in microvolts ( V)
- Typically 1-10 V for good receivers

## 2. Selectivity:

- Ability to separate desired signal from adjacent channels
- Determined by bandwidth of IF amplifier
- Measured in dB at specific frequency offsets

## 3. Fidelity:

- Accuracy in reproducing original signal
- Depends on bandwidth and distortion
- Measured as frequency response flatness

## 4. Image Frequency Rejection:

- Ability to reject signals at image frequency ( $f_i = f_s \pm 2f_{IF}$ )
- Measured in dB
- Higher values indicate better performance

### Additional characteristics:

- Signal-to-noise ratio (SNR)
- Automatic gain control (AGC) range
- Dynamic range

### Mnemonic

“SFID” - Sensitivity, Fidelity, Image rejection, selectivity Determines quality

## Question 3(b) [4 marks]

Explain Diode Detector circuit.

### Solution

#### Diode Detector Circuit:

##### Purpose:

- Extracts original message signal from AM wave
- Also called envelope detector

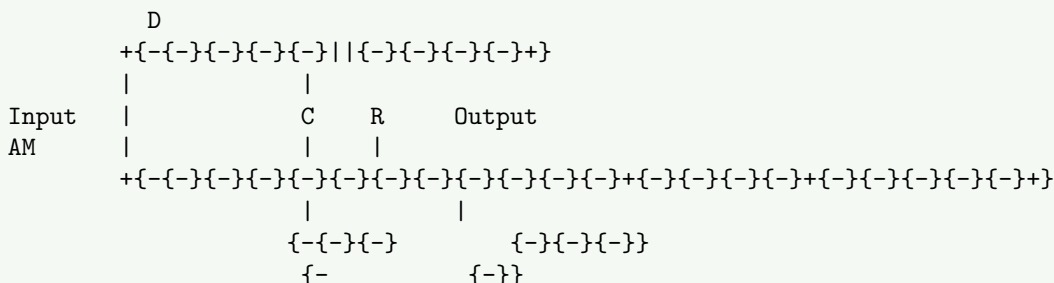
##### Circuit components:

- Diode: Rectifies AM signal
- RC network: Filters carrier frequency
- R & C values:  $RC \gg 1/f_c$  and  $RC \ll 1/f_m$

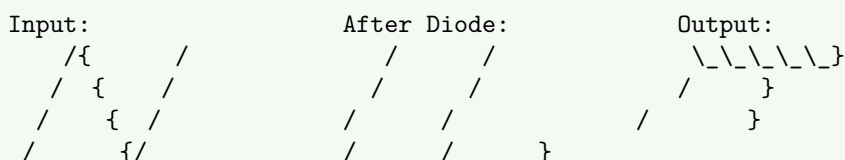
##### Operation:

1. Diode conducts during positive half-cycles
2. Capacitor charges to peak value
3. Capacitor discharges through resistor
4. RC time constant critical for proper demodulation

##### Diagram:



##### Waveforms:



##### Limitations:

- Distortion for high modulation index
- Poor performance at low signal levels

**Mnemonic**

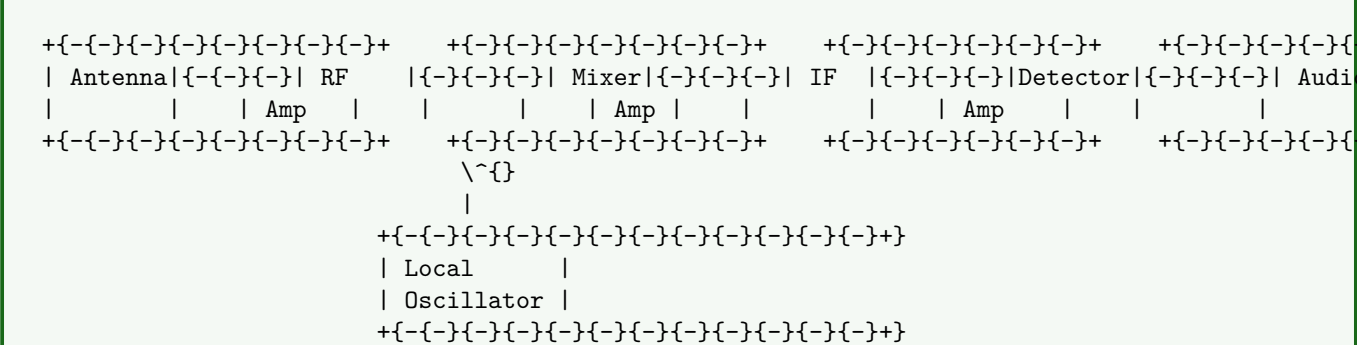
“DRCO” - Diode Rectifies, Capacitor holds peaks, Output follows envelope

Question 3(c) [7 marks]

Draw and explain block diagram of super heterodyne receiver.

## Solution

**Super Heterodyne Receiver:  
Block Diagram:**



**Function of each block:**

1. **RF Amplifier:**
  - Amplifies weak RF signals
  - Provides selectivity
  - Improves signal-to-noise ratio
2. **Local Oscillator:**
  - Generates stable frequency fLO
  - $f_{LO} = f_{RF} + f_{IF}$  (for high-side injection)
  - Tuned with RF amplifier
3. **Mixer:**
  - Combines RF signal with local oscillator
  - Produces sum and difference frequencies
  - Difference frequency = IF (intermediate frequency)
4. **IF Amplifier:**
  - Fixed frequency amplification (typically 455kHz for AM)
  - Provides most of receiver gain and selectivity
  - Multiple stages for better performance
5. **Detector:**
  - Demodulates IF signal
  - Extracts original message signal
  - Diode detector for AM, discriminator for FM
6. **Audio Amplifier:**
  - Amplifies demodulated signal
  - Drives speaker or headphones

Working principle:

- Converts any RF frequency to fixed IF for efficient amplification
- IF frequency =  $|\text{fRF} - \text{fLO}|$

### Advantages:

- Better selectivity and sensitivity
- Stable gain at all frequencies
- Reduced tracking problems



### Mnemonic

“RLMIDS” - RF amp, Local oscillator, Mixer, IF amp, Detector, Speaker

### Question 3(a) OR [3 marks]

Describe AGC principle and its application in Radio receiver.

#### Solution

##### AGC (Automatic Gain Control) Principle:

###### Definition:

- Circuit that automatically adjusts receiver gain based on signal strength
- Maintains constant output level despite varying input signals

###### Working principle:

1. Detects received signal strength
2. Generates control voltage proportional to signal
3. Applies negative feedback to reduce gain for strong signals
4. Increases gain for weak signals

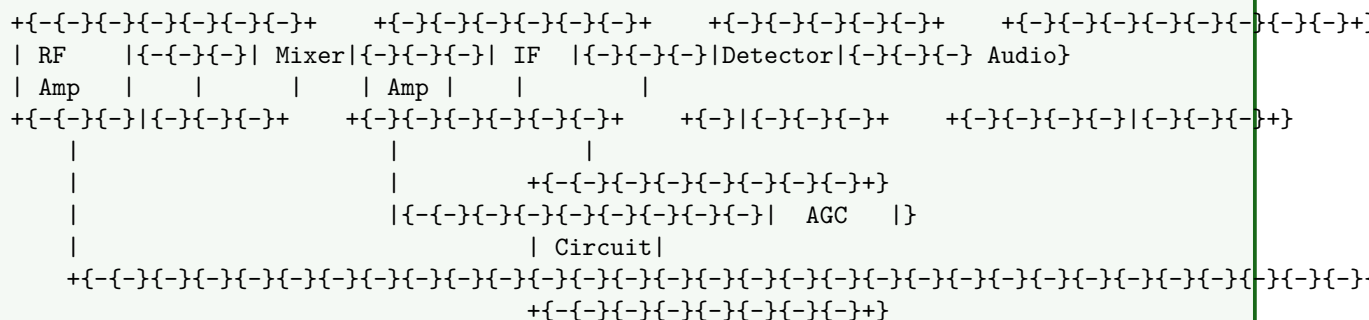
###### Application in Radio Receiver:

- **Prevents overloading:** Protects against strong signal distortion
- **Compensates fading:** Maintains constant volume during signal fading
- **Controls IF amplifier:** Primarily applied to IF stages
- **Improves dynamic range:** Handles wide range of signal strengths

###### Types:

- **Simple AGC:** Direct feedback from detector
- **Delayed AGC:** Only activates above threshold level
- **Amplified AGC:** Uses additional amplifier for better control

###### Diagram:



### Mnemonic

“FADS” - Fading compensation, Automatic adjustment, Dynamic range, Signal consistency

### Question 3(b) OR [4 marks]

Write short-note on intermediate frequency

#### Solution

##### Intermediate Frequency (IF):

###### Definition:

- Fixed frequency to which incoming RF signal is converted in superheterodyne receivers
- Result of mixing (heterodyning) RF signal with local oscillator

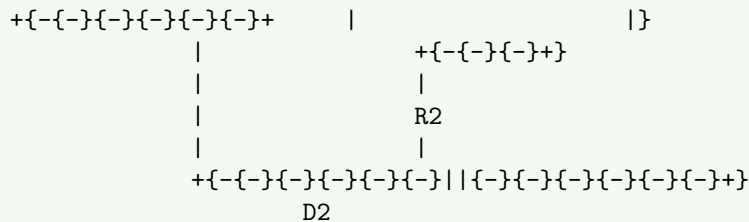
###### Standard IF values:

- **AM radio:** 455 kHz
- **FM radio:** 10.7 MHz
- **TV receivers:** 38-41 MHz

###### Importance:

- **Consistent gain:** Amplifiers operate at fixed frequency

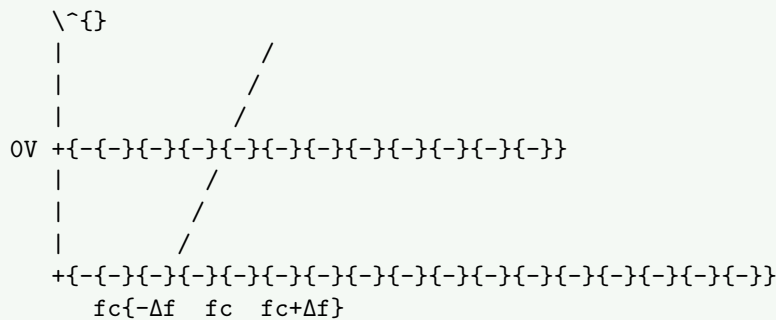




#### Characteristics:

- **Linear response** over moderate frequency range
- **Balanced design** reduces amplitude variations
- **High sensitivity** to frequency changes
- **Limitations** at extreme frequency deviations

#### S-curve response:



#### Mnemonic

“PSDO” - Phase shift Demodulates, Signal frequency determines Output

### Question 4(a) [3 marks]

Compare analog and digital communication techniques

#### Solution

##### Comparison of Analog vs. Digital Communication:

Parameter	Analog Communication	Digital Communication
<b>Signal</b>	Continuous waveform	Discrete binary values
<b>Bandwidth</b>	Less bandwidth required	More bandwidth required
<b>Noise Immunity</b>	Poor, noise accumulates	Excellent, error correction possible
<b>Power Efficiency</b>	Less efficient	More efficient
<b>Quality</b>	Degrades with distance	Maintains quality until SNR threshold
<b>Multiplexing</b>	FDM primarily used	TDM primarily used
<b>System Complexity</b>	Simpler	More complex
<b>Cost</b>	Lower	Higher but decreasing
<b>Examples</b>	AM/FM radio, analog TV	Mobile networks, digital TV, internet

#### Mnemonic

“BNPQ MCE” - Bandwidth, Noise immunity, Power, Quality, Multiplexing, Complexity, Efficiency

### Question 4(b) [4 marks]

Explain Adaptive delta modulation with its application.

## Solution

### Adaptive Delta Modulation (ADM):

#### Definition:

- Improved version of Delta Modulation (DM)
- Uses variable step size adjusted to signal slope

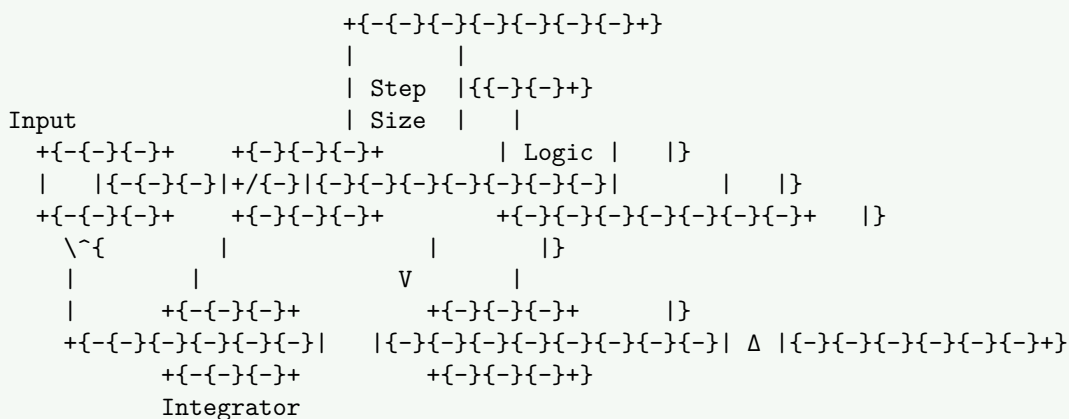
#### Working principle:

1. Compares input signal with predicted value
2. Outputs binary 1 or 0 based on comparison
3. Adjusts step size based on consecutive bits
4. Increases step size for rapid changes
5. Decreases step size for slow changes

#### Advantages over Delta Modulation:

- Reduces slope overload distortion
- Minimizes granular noise
- Better dynamic range
- Lower bit rate for same quality

#### Diagram:



#### Applications:

- **Speech transmission:** Voice over digital networks
- **Audio compression:** Music storage and transmission
- **Telemetry systems:** Remote data collection
- **Military communications:** Secure transmission

## Mnemonic

“VSOOG” - Variable Step size Overcomes Granular noise & slope overload

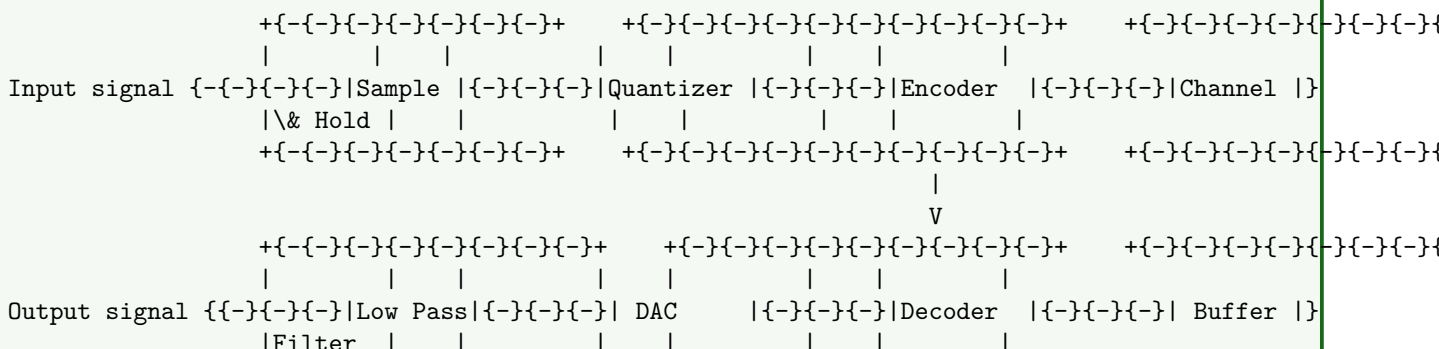
## Question 4(c) [7 marks]

Draw & explain block diagram of PCM system.

## Solution

### Pulse Code Modulation (PCM) System:

#### Block Diagram:



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- Samples analog signal at regular intervals
- Nyquist rate ( $f_s \geq 2f_{max}$ )
- Holds value until next sample

2. **Quantizer:**

- Divides amplitude range into discrete levels
- Maps each sample to nearest level
- Introduces quantization error

3. **Encoder:**

- Converts quantized levels to binary code
- n-bit encoder gives  $2^n$  quantization levels
- Common formats: 8-bit, 16-bit

1. **Decoder:**
  - Converts binary to quantized levels
  - Reverses encoder operation
2. **Digital-to-Analog Converter (DAC):**
  - Converts discrete levels to analog values
  - Produces staircase approximation of signal
3. **Low-Pass Filter:**
  - Smooths staircase output
  - Removes high-frequency components
  - Reconstructs original waveform

- Sampling rate: Typically 8 kHz (voice), 44.1 kHz (CD audio)
- Resolution: 8-bit (256 levels) to 24-bit (16.8M levels)
- Bit rate = Sampling rate  $\times$  bitspersample

“SQEC-DFL” - Sample, Quantize, Encode, Channel - Decode, Filter, Listen

- Difference between actual and quantized value
  - Maximum error =  $\frac{Q}{2}$  (where  $Q$  = step size)
  - Signal-to-quantization-noise ratio:  $SQNR = 6.02n + 1.76$  dB
- Diagram:**
- 
- The diagram illustrates the quantization process. It shows a continuous 'Original Signal' being sampled and then quantized into discrete levels, resulting in a 'Quantized Output'. The quantization levels are represented by horizontal segments of a staircase. The diagram is labeled with 'Time' on the x-axis and shows the signal being sampled at regular intervals, with the quantized output being a series of discrete steps.

**Mnemonic**

“DEBS” - Digitization Enables Binary Storage

“DEBS” - Digitization Enables Binary Storage

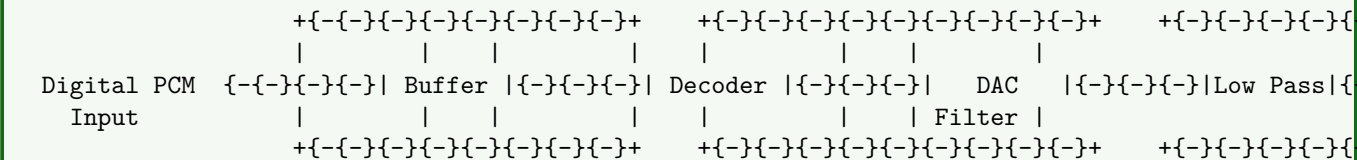
**Question 4(b) OR [4 marks]**

### Explain PCM receiver.

### Solution

**PCM Receiver:**  
**Block Diagram:**

Block Diagram:



### Components and their functions:

1. **Buffer:**
  - Temporarily stores received PCM data
  - Compensates for timing variations
  - Provides protection against jitter
2. **Decoder:**
  - Converts binary code to quantized amplitude levels
  - Detects and corrects transmission errors (if error coding used)
  - Outputs discrete amplitude values
3. **Digital-to-Analog Converter (DAC):**
  - Converts digital values to analog voltage levels
  - Creates staircase approximation of original signal
  - Resolution determined by bit depth ( $2^n$  levels)
4. **Low-Pass Filter:**
  - Smooths the staircase waveform
  - Removes high-frequency components
  - Reconstructs continuous analog signal

### Waveforms in PCM Receiver:

Digital Input	Decoded Values	DAC Output	Final Output
1001	{-}{-}{-}{-}	\_	/}
0110	{- {-}	\_    \_	/ }
1010	{-}{-} {-}	\_    \_	/ }
0101	{- {-} {-}	\_    \_	/ }

**Performance factors:**

- **SNR:** Determined by quantization bits ( $6.02n + 1.76$  dB)
- **Bandwidth:** Depends on sampling rate and filter characteristics
- **Distortion:** Related to quantization error

**Mnemonic**

“BDFL” - Buffer stores, Decoder converts, Filter smooths, Listen to output

**Question 4(c) OR [7 marks]**

What is sampling? Explain types of sampling in brief.

**Solution****Sampling:**

**Definition:** Sampling is the process of converting a continuous-time signal into a discrete-time signal by taking measurements (samples) at regular time intervals.

**Mathematical expression:**  $x[n] = x(nT_s)$ , where  $n = 0, 1, 2, \dots$

- $x[n]$  is discrete-time sample
- $x(t)$  is continuous-time signal
- $T_s$  is sampling period ( $1/f_s$ )

**Nyquist Theorem:**

- Sampling frequency ( $f_s$ ) must be at least twice the highest frequency component ( $f_{max}$ ) in the signal
- $f_s \geq 2f_{max}$
- Prevents aliasing (distortion due to overlap of spectrum)

**Types of Sampling:**

Type	Description	Characteristics
<b>Ideal Sampling</b>	Instantaneous samples at regular intervals	- Theoretical concept- Represented by impulse train- Infinite bandwidth required
<b>Natural Sampling</b>	Signal multiplied by pulse train with finite width	- Samples have same shape as signal- Width determined by sampling pulse- Used in analog systems
<b>Flat-Top Sampling</b>	Sample-and-hold technique	- Holds sampled value until next sample- Creates staircase approximation- Common in practical systems

**Sampling Rates:**

- **Under-sampling:**  $f_s < 2f_{max}$  (causes aliasing)
- **Critical sampling:**  $f_s = 2f_{max}$  (minimum required rate)
- **Over-sampling:**  $f_s > 2f_{max}$  (improves reconstruction quality)

**Diagram:**

Original Signal:       $\{ \text{continuous waveform} \}$

Ideal Sampling:       $| \quad | \quad | \quad | \quad | \quad |$

Natural Sampling:

Flat-top Sampling:       $\{ \text{staircase approximation} \}$

**Mnemonic**

“INF” - Ideal (impulses), Natural (pulse-shaped), Flat-top (staircase)

**Question 5(a) [3 marks]**

List the need of Multiplexing.

## Solution

### Need for Multiplexing:

Need	Description
<b>Bandwidth Utilization</b>	Efficiently uses available transmission bandwidth
<b>Cost Reduction</b>	Shares expensive transmission medium among multiple users
<b>Infrastructure Optimization</b>	Reduces physical connections and hardware requirements
<b>Spectrum Efficiency</b>	Maximizes use of limited frequency spectrum
<b>Network Capacity</b>	Increases number of channels/users on single medium
<b>Flexibility</b>	Allows dynamic allocation of resources based on demand

## Mnemonic

“BCSINF” - Bandwidth, Cost, Spectrum, Infrastructure, Network capacity, Flexibility

## Question 5(b) [4 marks]

Explain working of DPCM.

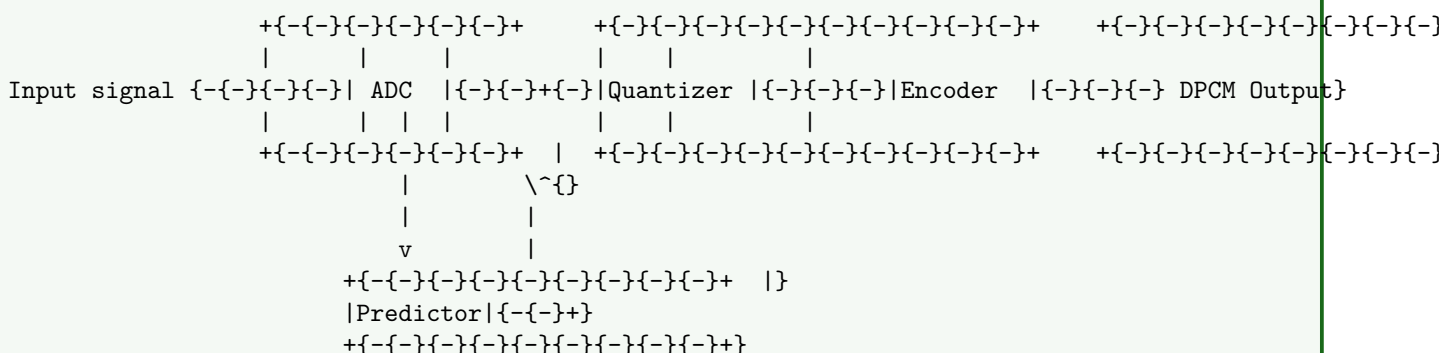
## Solution

### Differential Pulse Code Modulation (DPCM):

#### Definition:

- Enhanced version of PCM that encodes difference between current and predicted sample
- Exploits correlation between adjacent samples to reduce bit rate

#### Block Diagram:



#### Working principle:

- Current sample is predicted based on previous sample(s)
- Only the difference (error) between actual and predicted value is encoded
- Smaller difference requires fewer bits than full amplitude
- Predictor uses previous reconstructed values for prediction

#### Advantages:

- Reduced bit rate:** Typically 25-50% lower than PCM
- Better SNR:** For same bit rate as PCM
- Correlation utilization:** Exploits signal redundancy

#### Limitations:

- Error propagation:** Errors affect subsequent samples
- Complexity:** More complex than simple PCM
- Signal dependency:** Performance varies with signal characteristics

## Mnemonic

“PDQE” - Predict sample, Difference calculated, Quantize error, Encode result



Question 5(c) [7 marks]

The binary data 1011001 is to be transmitted using following line coding techniques: (i) Unipolar RZ and NRZ (ii) Polar RZ and NRZ (iii) AMI (iv) Manchester. Draw all the waveforms.

## Solution

### Line Coding of Binary Data: 1011001

**Waveforms:**

Binary Data:    1    0    1    1    0    0    1

### 1. Unipolar NRZ:

[illegible]

2. Unipolar RZ:

$\begin{array}{cccccccc} \diagup & \diagdown & \diagup & \diagdown & \diagup & \diagdown & \diagup & \diagdown \\ \diagdown & \diagup & \diagdown & \diagup & \diagdown & \diagup & \diagdown & \diagup \end{array}$

### 3. Polar NRZ:

\_\_\_\_\_

4. Polar RZ:

5. AMI:

## 6. Manchester:

\\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_ \\\_

### Characteristics of Each Coding:

Coding Technique	Description	Advantages	Disadvantages
<b>Unipolar NRZ</b>	1 = high voltage 0 = zero voltage No return to zero	Simple implementation	DC component, no clock recovery
<b>Unipolar RZ</b>	1 = high for half bit 0 = zero voltage Returns to zero	Self-clocking	Requires more bandwidth
<b>Polar NRZ</b>	1 = positive voltage 0 = negative voltage No return to zero	No DC component	Poor clock recovery
<b>Polar RZ</b>	1 = positive for half bit 0 = negative for half bit Returns to zero	Self-clocking, no DC component	Requires more bandwidth
<b>AMI</b>	1 = alternating +/- voltage 0 = zero voltage	No DC component, error detection	Long strings of zeros problematic
<b>Manchester</b>	1 = transition low to high 0 = transition high to low	Self-clocking, no DC component	Requires double bandwidth

### Mnemonic

“UPRMA” - Unipolar, Polar, Return-to-zero, Manchester, AMI line coding techniques

Question 5(a) OR [3 marks]

Explain polar RZ and NRZ format

## Solution

### Polar RZ and NRZ Line Coding:

### Polar NRZ (Non-Return to Zero):

- Binary 1: Positive voltage (+V) for entire bit duration
- Binary 0: Negative voltage (-V) for entire bit duration
- Signal remains at level during entire bit period
- No transition to zero between consecutive similar bits

### Characteristics of Polar NRZ:

- **Bandwidth efficiency:** Requires minimum bandwidth
- **DC component:** Zero average for equal 1s and 0s
- **Clock recovery:** Poor for long sequences of same bit
- **Error detection:** No inherent capability

### Polar RZ (Return to Zero):

- Binary 1: Positive voltage (+V) for half bit, zero for remainder
- Binary 0: Negative voltage (-V) for half bit, zero for remainder
- Signal returns to zero during each bit period

### Characteristics of Polar RZ:

- **Bandwidth:** Requires twice the bandwidth of NRZ
- **Self-clocking:** Better clock recovery
- **Power requirement:** Higher than NRZ
- **Error detection:** No inherent capability

### Waveform Comparison:

Binary Data:    1    0    1    1    0    0    1

Polar NRZ:

\ / \ / \ /      \ / \ / \ / \ / \ /

[illegible]

### Mnemonic

“HZRT” - Half bit active + Zero Return in RZ, full Time in NRZ

Question 5(b) OR [4 marks]

Explain delta modulation in brief.

## Solution

### Delta Modulation (DM):

**Definition:**

- Simplest form of differential encoding
- Encodes only the sign of difference between current and previous sample
- Single bit per sample for transmission (1 or 0)

**Block Diagram:**

		+{-}{-}{-}{-}{-}{-}+		Encoded}
Input	+{-}{-}{-}{-}+			Bitstream}
Signal	{-}{-}{-}{-} +/{-} {-}{-}{-}{-}	C	{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}{-}	
	+{-}{-}{-}{-}+		}	
	\^{	+{-}{-}{-}{-}{-}{-}+}		
		v		
	+{-}{-}{-}{-}+	+{-}{-}{-}{-}+}		
		{-}{-}{-}{-}{-} +/{-} }		

+{-}{-}{-}+      +{-}{-}{-}{-}+  
Integrator      Step Size

#### Working principle:

1. Compare input signal with predicted value (from integrator)
2. If input > predicted: Output = 1, increase predicted value
3. If input < predicted: Output = 0, decrease predicted value
4. Step size determines how much predicted value changes

#### Advantages:

- **Simple implementation:** Minimal hardware
- **Low bit rate:** 1 bit per sample
- **Robust:** Relatively immune to channel noise

#### Limitations:

- **Slope overload:** Cannot track rapid signal changes
- **Granular noise:** Oscillations around steady signals
- **Limited resolution:** Quality depends on step size and sampling rate

#### Waveforms:

Original:            /{///}

Reconstructed: /{///}  
(Staircase approximation)

Binary output: 1101001011

#### Mnemonic

“1BSG” - 1 Bit per Sample, Slope overload and Granular noise limitations

### Question 5(c) OR [7 marks]

Explain PCM-TDM system.

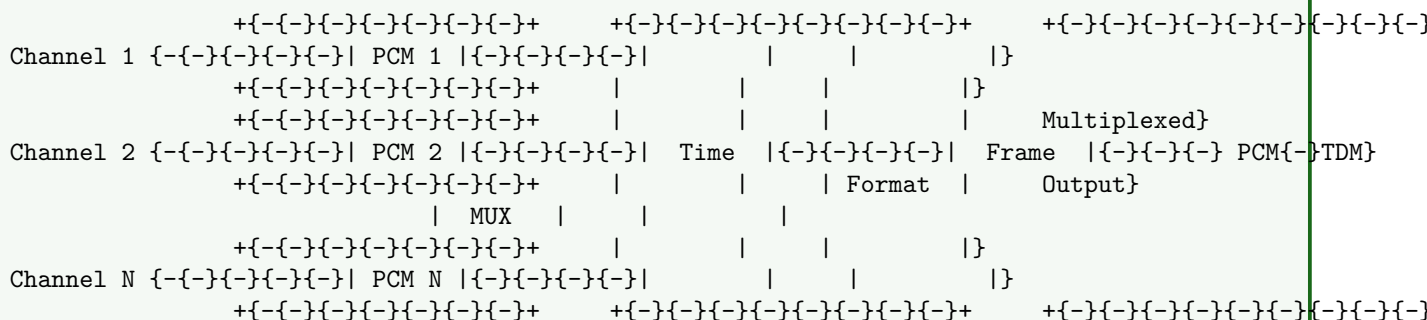
#### Solution

#### PCM-TDM System:

##### Definition:

- Combined system using Pulse Code Modulation (PCM) with Time Division Multiplexing (TDM)
- Multiple analog channels converted to digital PCM, then multiplexed in time

##### Block Diagram:



#### PCM Process for Each Channel:

1. **Sampling:** Each channel sampled at  $f_s \geq 2f_{max}$
1. **Quantization:** Samples assigned to discrete levels
2. **Encoding:** Quantized values converted to binary code

#### TDM Frame Structure:

- Frame consists of one sample from each channel
- Frame includes synchronization bits/word
- Frame rate equals sampling rate ( $f_s$ )
- Bit rate =  $f_s \times N \times n$  ( $N = \text{channels}$ ,

$n = \text{bits/sample}$ )

