IEC IAT 2 Solutions

1.	a) What is opamp? Define the following opamp parameters: (i) Slew Rate (ii) Input Offset Voltage (iii) CMRR	[10]	CO2	L2

(a) Operational Amplifier (Op-Amp)

An **Operational Amplifier (Op-Amp)** is a high-gain, direct-coupled differential amplifier that amplifies the voltage difference between two input terminals. It has two inputs, namely the **inverting input (−)** and the **non-inverting input (+)**, and a single output terminal. Op-amps are designed to provide very large voltage gain, very high input impedance, and very low output impedance.

Op-amps are widely used to perform various linear and non-linear operations such as **amplification, summation, subtraction, differentiation, integration, filtering, oscillation, voltage comparison**, etc. These functions made op-amps popular in analog signal processing, measurement systems, and control circuits.

Op-amps were originally developed to perform mathematical operations in analog computers, hence the name *operational* amplifier.

Characteristics of an ideal Op-Amp
An ideal op-amp has:

- Infinite voltage gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Zero input offset voltage
- Infinite CMRR and Slew Rate

Although practical op-amps deviate from the ideal characteristics, modern IC op-amps like **µA741** approximate these features closely.

(i) Slew Rate

The **Slew Rate (SR)** of an op-amp is defined as the **maximum rate at which the output voltage can change** with respect to time when subjected to a rapidly changing input signal. It represents how fast the op-amp can respond to transient or high-frequency input signals.

$$\text{Slew Rate} = \frac{dV_{out}}{dt}$$

The unit of SR is **V/μs (Volt per microsecond).**

If an input signal demands a faster response than the op-amp's rated slew rate, distortion occurs, particularly in high-frequency applications such as waveform generators and audio amplifiers.

Significance:

- Higher slew rate allows accurate amplification of fast-changing signals.
- Low slew rate causes output waveform distortion (slew-rate limiting).

(ii) Input Offset Voltage

Ideally, when both the inverting and non-inverting terminals are at the same voltage, the output of an op-amp should be zero. However, due to internal transistor mismatches inside the differential amplifier stage, a small imbalance results. **Input Offset Voltage (Vio)** is defined as the **small differential DC voltage required between the two input terminals to make the output voltage exactly zero.**

Typical offset voltages for practical op-amps range from a few microvolts to a few millivolts.

Significance:

- Affects the accuracy in DC amplifier applications.
- Becomes important in instrumentation and sensor signal conditioning circuits.
- Offset voltage can be minimized using offset nulling pins or compensation circuitry in precision applications.

(iii) CMRR (Common Mode Rejection Ratio)

The **Common Mode Rejection Ratio (CMRR)** measures the ability of an op-amp to reject common-mode signals (signals appearing simultaneously and in-phase at both inputs). For an ideal op-amp, common-mode gain is zero, so the output depends only on the difference between the two input signals.

CMRR is defined as the ratio of **Differential gain (Ad)** to **Common-mode gain (Ac)**:

$$\mathrm{CMRR} = \frac{A_d}{A_c}$$

It is often expressed in **decibels (dB)**:

$$\mathrm{CMRR(dB)} = 20\log\left(\frac{A_d}{A_c}\right)$$

Significance:

- Higher CMRR implies better rejection of noise and interference.
- Important in instrumentation amplifiers where both inputs may pick up environmental noise.
- Enhances accuracy in measurement systems and differential sensor interfaces.

Typical CMRR values for general op-amps range from **70 dB to 120 dB**, whereas precision instrumentation op-amps offer even higher values.

2.	a) Explain the working of a single stage astable multivibrator with a new circuit diagram. b) With suitable diagram explain instrumentation and control system.	[6] [4]	CO2 CO4	L2 L2

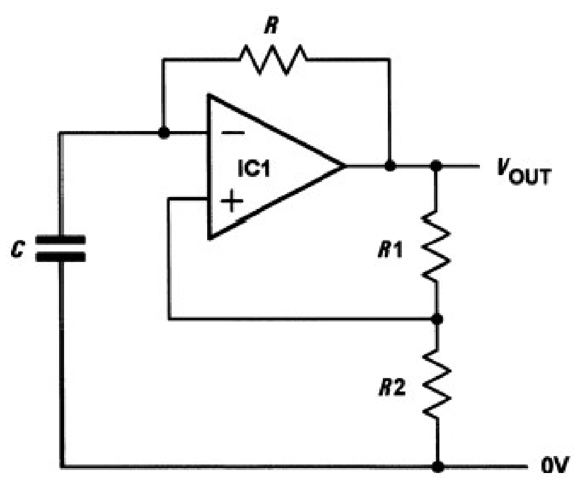


Figure 9.10 Single-stage astable oscillator using an operational amplifier

A simple form of astable oscillator that produces a square wave output can be built using just one operational amplifier, as shown in Fig. 9.10. The circuit employs positive feedback with the output fed back to the non-inverting input via the potential divider formed by $R1$ and $R2$. This circuit can make a very simple square wave source with a frequency that can be made adjustable by replacing R with a variable or preset resistor. Assume that C is initially uncharged and the voltage at the inverting input is slightly less than the voltage at the non-inverting input. The output voltage will rise rapidly to $+V_{CC}$ and the voltage at the inverting input will begin to rise exponentially as capacitor C charges through R. Eventually the voltage at the inverting input will have reached a value that causes the voltage at the inverting input to exceed that present at the non-inverting input. At this point, the output voltage will rapidly fall to $-V_{CC}$. Capacitor C will then start to charge in the other direction and the voltage at the inverting input will begin to fall exponentially. Eventually, the voltage at the inverting input will have reached a value that causes the voltage at the inverting input to be less than that present at the non-inverting input. At this point, the output voltage will rise rapidly to $+V_{CC}$ once again and the cycle will continue indefinitely. The upper threshold voltage (i.e. the maximum positive value for the voltage at the inverting input) will be given by:

$$V_{UT} = V_{CC} \times \left(\frac{R2}{R1+R2} \right)$$

The lower threshold voltage (i.e. the maximum negative value for the voltage at the inverting input) will be given by:

$$V_{LT} = -V_{CC} \times \left(\frac{R2}{R1+R2} \right)$$

Finally, the time for one complete cycle of the output waveform produced by the astable oscillator is given by:

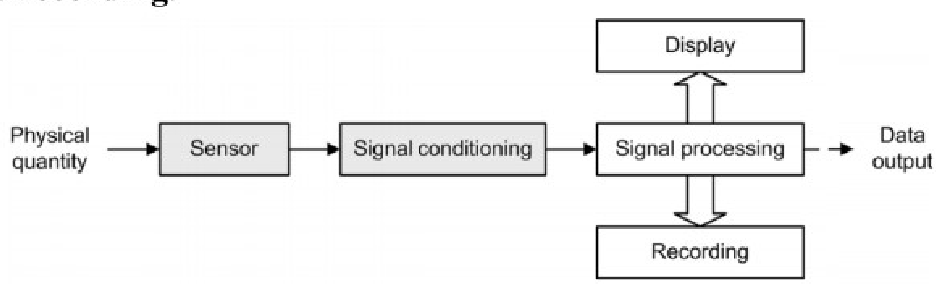
$$T = 2CR \ln\left(1 + 2\left(\frac{R2}{R1}\right)\right)$$

b)

Sensors and interfacing

The physical quantity to be measured (e.g. temperature) acts upon a sensor that produces an electrical output signal.

Further signal conditioning will be required(To remove noise) before the signal will be at an acceptable level and in an acceptable form for signal processing, display and recording.



(a) An instrumentation system

The diagram represents a typical **Instrumentation System** used for measuring physical quantities using sensors, conditioning the signal, processing it, and finally displaying or recording the result.

The system mainly consists of the following blocks:

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1. Physical Quantity

A **physical quantity** is the parameter that needs to be measured from the environment. Examples include:

- Temperature
- Pressure
- Light intensity
- Sound
- Humidity
- Force
- Displacement
- Speed, etc.

This physical quantity itself cannot be directly used by electronic systems, so it must be converted into an electrical signal.

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2. Sensor (Transducer)

A **sensor** or **transducer** converts the physical quantity into an electrical signal.
Example:

- A temperature sensor converts temperature → voltage
- A microphone converts sound → electrical signal

The output signal from the sensor is usually **very weak** and may contain **noise**.

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3. Signal Conditioning

The weak sensor signal is not suitable for direct processing. Therefore, **signal conditioning** is required.

Signal conditioning includes operations like:

- **Amplification** (increase signal strength)
- **Filtering** (remove unwanted noise)
- **Isolation**
- **Linearization**
- **Analog-to-Digital conversion (ADC)** (if needed)

After conditioning, the signal becomes clean and usable for further processing.

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4. Signal Processing

In this block, the conditioned signal is further processed for interpretation and decision-making.

Signal processing may include:

- Analog or digital processing
- Computation
- Conversion
- Scaling
- Correction

Often, a microcontroller, DSP, or computer performs this task.

---

5. Display

The processed signal can then be shown visually through a display device.

Examples:

- Digital meter
- LCD/LED display
- Oscilloscope
- Computer screen

This allows the user to understand the measurement in readable form.

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6. Recording

In some systems, the data must be stored for future analysis.

Recording devices include:

- Data loggers
- Memory units
- Computers
- Storage systems

This is useful in industrial monitoring, research, medical diagnostics, etc.

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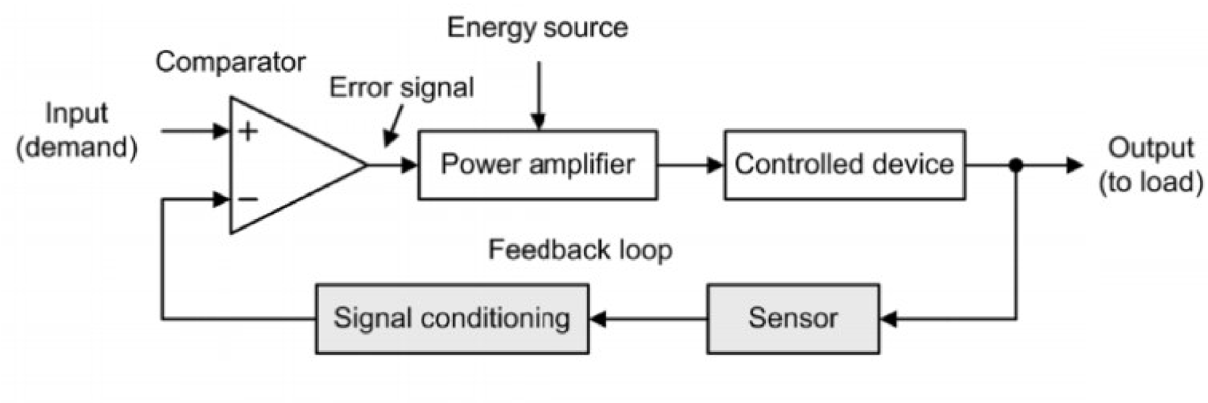
7. Data Output

Finally, the processed information is output for external use or control applications.
This data can be:

- Used by another system
- Sent to a controller
- Transmitted to a network
- Used for automation or feedback control

The arrangement of a control system. This uses negative feedback in order to regulate and stabilize the output.



(b) A control system

Explanation of the Block Diagram of a Control System

The figure represents a **closed-loop control system** that uses **negative feedback** to regulate and stabilize the output. The goal is to make the output follow the input demand as accurately as possible.

Major Blocks and Their Functions

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1. Input (Demand)

- The input represents the **desired output value** or **reference signal**.
- It specifies how the system should behave.
- Example:
  - Desired temperature in an AC system
  - Desired position in a motor control system

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2. Comparator / Error Detector

- The comparator compares the **input (desired)** with the **feedback signal (actual output)**.
- The difference between them is the **error signal**.

Error=Input−Feedback\text{Error} = \text{Input} - \text{Feedback}Error=Input−Feedback

- If error = 0, system output is perfect.

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3. Power Amplifier

- The error signal is usually weak and cannot drive the load directly.
- The power amplifier increases the signal strength.
- It draws power from the energy source and supplies amplified power to the **controlled device (actuator)**.

Example:

- Motor driver in robotics
- Servo amplifier in control systems

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4. Controlled Device (Plant / Actuator)

- This is the part of the system that performs the actual work.
- It receives the amplified error signal and produces the required output.

Examples:

- Electric motor
- Heater
- Valve
- Hydraulic actuator

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5. Output (to Load)

- This is the actual value produced by the system.
- The output should match the input demand as closely as possible.

Example:

- Actual temperature
- Motor speed
- Position of a mechanical arm

Feedback Loop

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6. Sensor

- The sensor measures the actual output.
- Converts physical quantity into an electrical signal suitable for feedback.

Example:

- Thermistor for temperature
- Encoder for position/speed
- Flow sensor for fluid systems

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7. Signal Conditioning

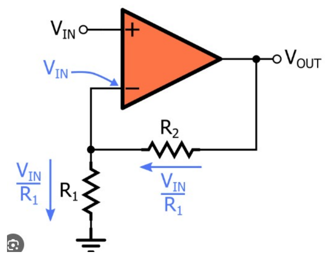
- The sensor signal may be noisy, weak, or non-linear.
- Signal conditioning improves the feedback signal by:
    - Filtering
    - Amplifying

- Linearizing
- ADC conversion (if needed)

After conditioning, the signal is fed back to the comparator.

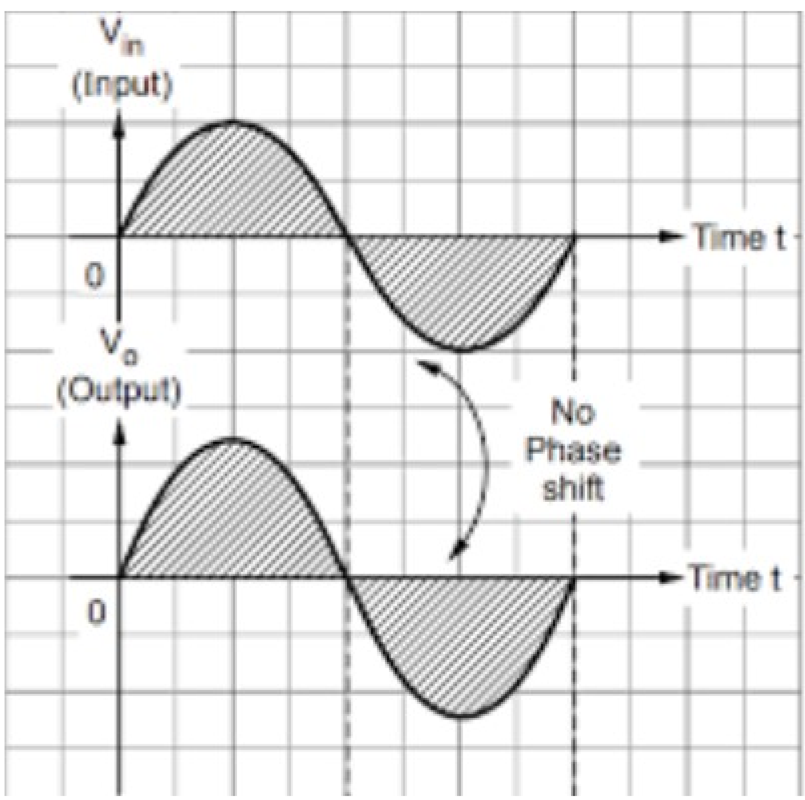
3	Explain the following opamp circuits (i) Non Inverting Amplifier (ii) Integrator	[10]	CO2	L3

Non inverting Amplifier



A non-inverting amplifier is an op-amp configuration in which the input signal is applied to the **non-inverting terminal (+)**, and the inverting terminal (−) is connected to a feedback network.

The output signal is amplified and remains **in phase** with the input.



Gain Derivation with Equation

The feedback network consists of resistors R_f and R_i forming a voltage divider.

Feedback voltage:

$$V_f = V_{out} \cdot \frac{R_i}{R_i + R_f}$$

For an ideal op-amp in closed-loop:

$$V_+ = V_-$$

So at the inverting terminal:

$$V_- = V_f$$

But input is applied to non-inverting terminal:

$$V_+ = V_{in}$$

Therefore:

$$V_{in} = V_{out} \cdot \frac{R_i}{R_i + R_f}$$

Rearranging to find output voltage:

$$V_{out} = V_{in} \left(1 + \frac{R_f}{R_i}\right)$$

Closed-Loop Voltage Gain

$$A_v = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_i}$$

Integrator

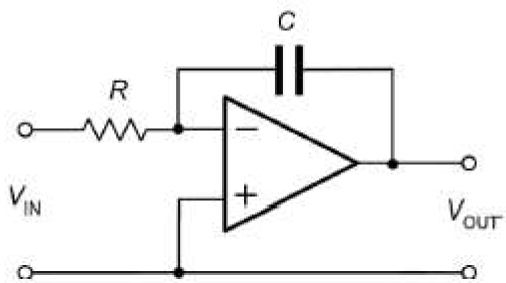


Figure 8.15 An integrator

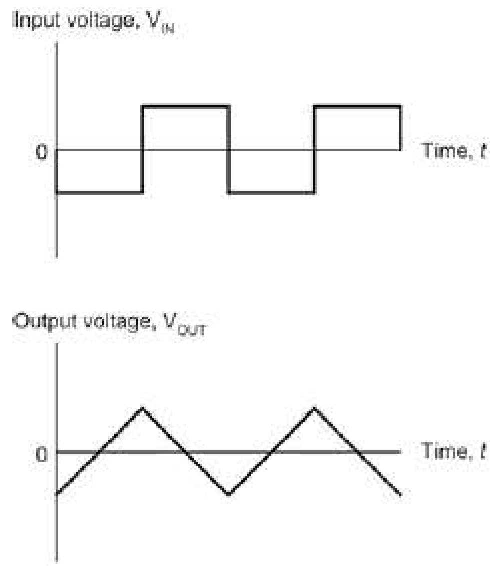


Figure 8.16 Typical input and output waveforms for an integrator

An integrator using an operational amplifier is shown in Fig. 8.15. This circuit provides the opposite function to that of a differentiator (see earlier) in that its output is equivalent to the area under the graph of the input function rather than its rate of change. If the input voltage remains constant (and is other than 0 V) the output voltage will ramp up or down according to the polarity of the input. The longer the input voltage remains
at a particular value the larger the value of output voltage (of either polarity) will be produced. Typical input and output waveforms for an integrator are shown in Fig. 8.16. Notice how the square wave input is converted to a wave that has a triangular shape. Once again, note that the output waveform is inverted.

$$\frac{Vin - 0}{R1} = C1\frac{d(0 - V_{out})}{dt}$$

$$=> \frac{Vin}{R1} = -C1\frac{dV_{out}}{dt}$$

Now, integrating both sides,

$$=> \int_0^t \frac{Vin}{R1} = -\int_0^t C1\frac{dV_{out}}{dt}$$

Or the **ideal output voltage of op-amp integrator is**

$$V_{out} = -\frac{1}{R1C1}\int_0^t Vin\,dt = -\int_0^t Vin\,\frac{dt}{R1\,C1}$$

4	a)	What is embedded system? Compare Embedded System with General Purpose System?	[6]	CO4	L2
	b)	List the advantages of digital communication over analog communication.	[4]	CO3	L2

1.1 WHAT IS AN EMBEDDED SYSTEM?

LO 1 Know what an embedded system is

An embedded system is an electronic/electro-mechanical system designed to perform a specific function and is a combination of both hardware and firmware (software).

Every embedded system is unique, and the hardware as well as the firmware is highly specialised to the application domain. Embedded systems are becoming an inevitable part of any product or equipment in all fields including household appliances, telecommunications, medical equipment, industrial control, consumer products, etc.

General Purpose Computing System	Embedded System
A system which is a combination of a generic hardware and a General Purpose Operating System for executing a variety of applications	A system which is a combination of special purpose hardware and embedded OS for executing a specific set of applications

(*Contd.*)

*The illustration given here is based on the processor details available till Dec 2015. Since processor technology is undergoing rapid changes, the processor names mentioned here may not be relevant in future.

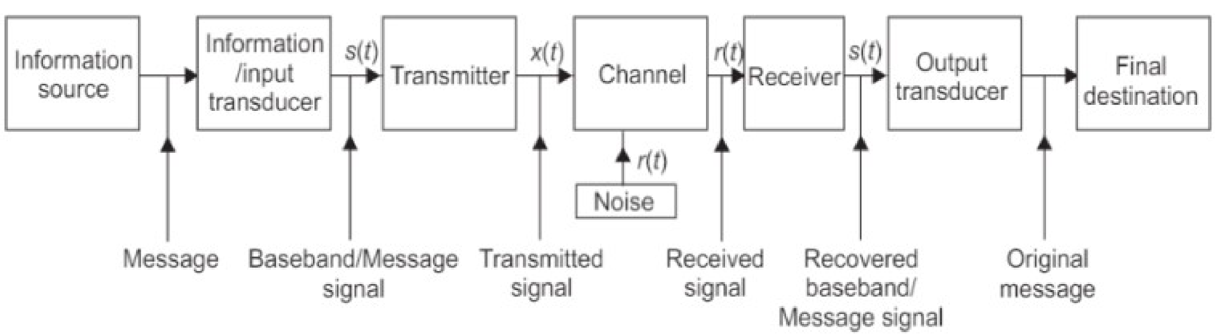
General Purpose Computing System	Embedded System
Contains a General Purpose Operating System (GPOS)	May or may not contain an operating system for functioning
Applications are alterable (programmable) by the user (It is possible for the end user to re-install the operating system, and also add or remove user applications)	The firmware of the embedded system is pre-programmed and it is non-alterable by the end-user (There may be exceptions for systems supporting OS kernel image flashing through special hardware settings)
Performance is the key deciding factor in the selection of the system. Always, 'Faster is Better'	Application-specific requirements (like performance, power requirements, memory usage, etc.) are the key deciding factors
Less/not at all tailored towards reduced operating power requirements, options for different levels of power management.	Highly tailored to take advantage of the power saving modes supported by the hardware and the operating system
Response requirements are not time-critical	For certain category of embedded systems like mission critical systems, the response time requirement is highly critical
Need not be deterministic in execution behaviour	Execution behaviour is deterministic for certain types of embedded systems like 'Hard Real Time' systems

vantages of Digital Communication over Analog Communication

Parameter	Digital Communication	Analog Communication
Nature of Signal	Uses **discrete** signals (0s and 1s)	Uses **continuous** signals
Noise Immunity	Highly **resistant to noise** due to threshold detection	Highly **susceptible to noise and interference**
Error Detection & Correction	Supports **error detection and correction** (CRC, Hamming, Reed–Solomon)	No inherent error detection or correction
Signal Regeneration	Signals can be **perfectly regenerated** using repeaters	Signals get **amplified with noise**, distortion accumulates
Quality over Distance	Signal quality remains **nearly constant** over long distances	Signal quality **degrades continuously** with distance
Bandwidth Utilization	**Efficient bandwidth usage** with compression and coding	Inefficient bandwidth utilization
Flexibility	Easily supports **multiplexing, compression, encryption**	Limited flexibility
Storage & Processing	Easy to **store, process, and manipulate** using computers	Difficult to store and process
Security	High security using **encryption techniques**	Low security; easy to intercept
Compatibility with Computers	Fully **compatible with digital systems**	Not directly compatible
System Reliability	High reliability and stability	Lower reliability
Hardware Implementation	Implemented using **LSI/VLSI, DSP, microprocessors**	Implemented using analog components
Maintenance & Calibration	Requires **less maintenance**	Requires frequent calibration
Signal Distortion	Less distortion due to digital regeneration	More distortion
Cost (Long Term)	Lower cost for large-scale systems	Higher cost over long distances

5	Explain the communication system with a neat block diagram.	[10]	CO3	L2

General form of a Basic Communication System



Basic Communication System – Block Diagram Explanation

A communication system transfers information from one point (source) to another (destination) through a medium (channel). The given block diagram shows the general form of such a system.

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1. Information Source

- Generates the original message that needs to be communicated.
- Message may be **text, speech, image, video, data**, etc.
- Examples:
  - Human voice (speech communication)
  - Data from computer (digital communication)

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2. Input Transducer

- Converts the physical message into an **electrical signal**.
- This electrical signal is known as the **baseband message**.

Examples:

- Microphone: sound → electrical signal
- Camera: image → electrical video signal
- Keyboard: keystrokes → binary data

Resulting signal is **s(t)**.

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3. Transmitter

- Processes the baseband signal to make it suitable for transmission.
- Major functions:
  - Modulation (AM, FM, PM, digital modulation)
  - Encoding and compression
  - Filtering
  - Amplification

After processing, transmitted signal becomes **x(t)**.

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4. Channel

- The medium through which the signal travels.
- Examples:
  - Free space
  - Optical fiber
  - Coaxial cable
  - Twisted pair cable
  - Water/air medium (for acoustic waves)

The channel introduces **noise** and **distortions**.

Noise is represented as **n(t)**.

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5. Receiver

- Performs the **reverse operations** of the transmitter.
- Major functions:
  - Demodulation
  - Decoding/decompression
  - Filtering
  - Amplification

The output becomes recovered baseband signal **s(t)**.

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6. Output Transducer

- Converts the electrical signal back to physical form to reproduce the message.

Examples:

- Loudspeaker: electrical signal → sound
- Monitor: video signal → image
- Printer: data → printed text

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7. Final Destination

- The location/person/system that receives the actual information.
- Examples:
  - Human listener (in audio communication)
  - Computer (for data communication)
  - Display screen (for video communication)

6	a) Explain the different analog modulation techniques with neat waveforms.	[6]	CO3	L2
	b) Write short notes on (i) Sensors (ii) Actuators	[4]	CO4	L2

1. Amplitude Modulation

❑**Amplitude modulation (AM)** -modulation technique in which instantaneous amplitude of the carrier signal is varied in accordar with the instantaneous amplitude of the analog modulating signal be transmitted

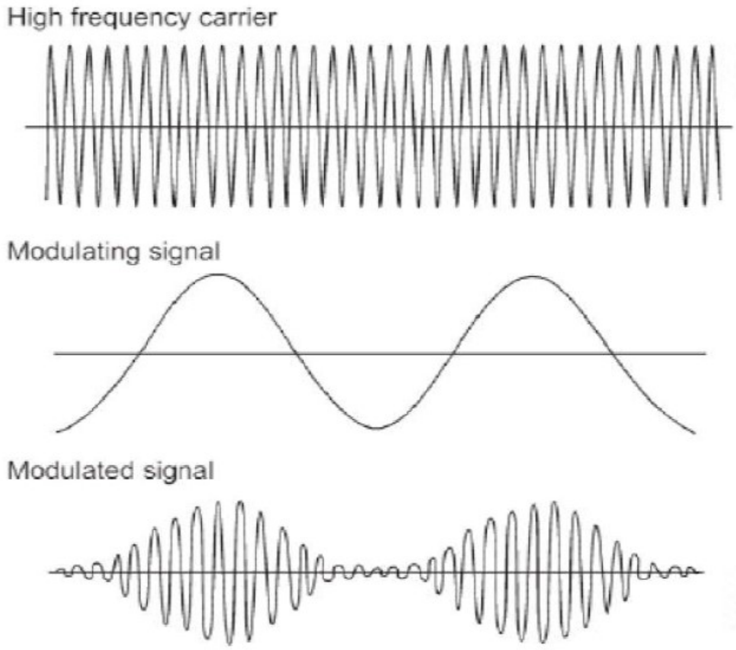
❑Modulating signal - an analog baseband signal which is random.

❑Carrier signal- a sinusoidal wave with high frequency

Variations in amplitude of carrier signal represent the information

Modulation Index $\mu = A_m/A_c$

Equation of AM Wave



$$c(t) = Ac\cos(\omega_c t + \theta_c)$$

$$x(t) = Am\cos(\omega_m t + \theta_m)$$

$$s(t) = A\cos\omega_c t$$

$$A \propto (A_c + x(t))$$

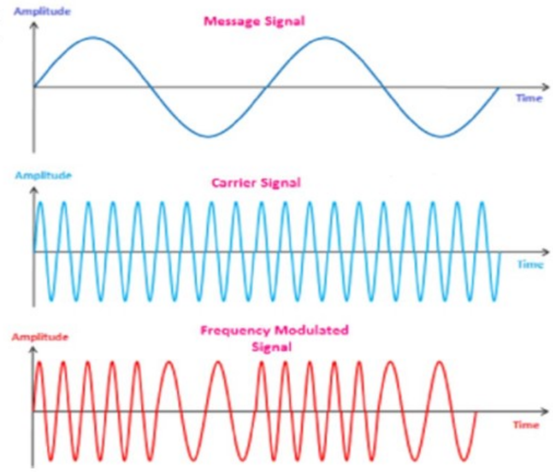
2. Frequency Modulation

- Process of changing the frequency of the carrier signal in accordance with the instantaneous value of the modulating voltage while keeping the amplitude and phase of the carrier constant.
- The original frequency of the carrier signal is called the **centre or resting frequency denoted as f_c.**
- Frequency deviation (Δf) -The amount by which the frequency of the carrier wave changes or shifts above or below the resting frequency.
- $$\Delta f \propto m(t)$$

Frequency Modulation

- The total variation of frequency of FM wave from the lowest to highest is termed as carrier swing (CS)
- CS=2× Δf
- Modulation Index
- $\mu_f = \frac{Frequency\ deviation}{Modulating\ frequency} = \frac{\Delta f}{fm}$
- FM Demo:

  https://youtu.be/4SOGF4AUIY



As the instantaneous frequency is given by

$$\omega_i = \omega_c + K_f \cdot x(t)$$

Where, K_f is a proportionality constant and is known as the frequency sensitivity of the modulator.

$$\phi_i = \int \left[\omega_c + K_f \cdot x(t)\right] dt$$

$$\phi_i = \omega_c t + K_f \int x(t) \cdot dt$$

$$\phi_i = \int \omega_i \cdot dt$$

According to the definition of FM, the expression for frequency modulated signal will be

$$s(t) = A_c \cdot \cos\phi_i$$

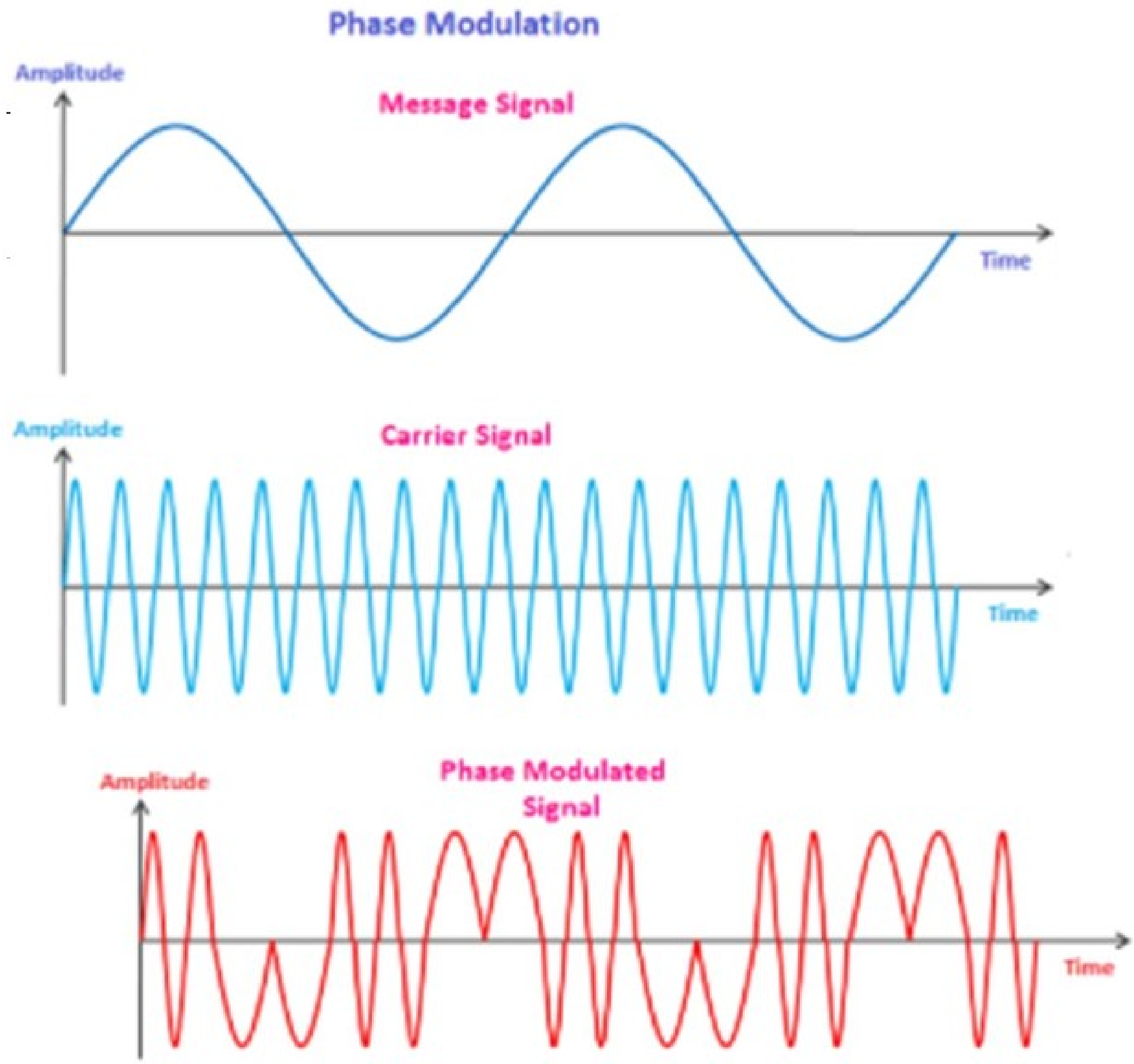
$$s(t) = A_c \cdot \cos\left[\omega_c t + K_f \cdot \int x(t) \cdot dt\right]$$

Frequency deviation $f_d = |K_f . x(t)|$

Phase Modulation

❑Process in which the instantaneous phase of the carrier signal is varied in accordance with the instantaneous amplitude of the modulating signal

❑The modulating signal is mapped to the carrier signal in the form of variations in the instantaneous phase of the carrier



7	a) With a neat circuit diagram explain the working of a RC ladder Network Oscillator. b) Explain the classification of embedded system based on complexity and performance.	[5] [5]	CO2 CO4	L2 L2

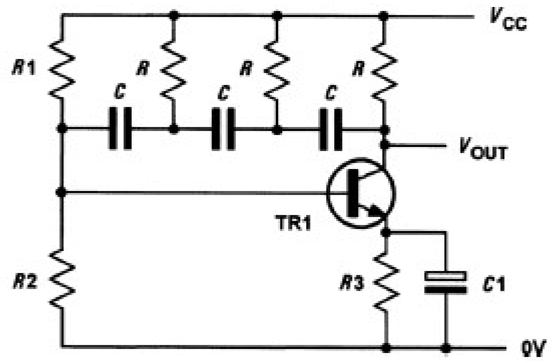


Figure 9.2 Sine wave oscillator based on a three-stage *C–R* ladder network

Ladder network oscillator

A simple phase-shift oscillator based on a three-stage *C–R* ladder network is shown in Fig. 9.2. TR1 operates as a conventional common-emitter amplifier stage with *R*1 and *R*2 providing base bias potential and *R*3 and *C*1 providing emitter stabilization.

The total phase shift provided by the *C–R* ladder network (connected between collector and base) is 180° at the frequency of oscillation. The transistor provides the other 180° phase shift in order to realize an overall phase shift of 360° or 0° (note that these are the same).

The frequency of oscillation of the circuit shown in Fig. 9.2 is given by:

$$f = \frac{1}{2\pi \times \sqrt{6}CR}$$

The loss associated with the ladder network is 29, thus the amplifier must provide a gain of *at least* 29 in order for the circuit to oscillate. In practice this is easily achieved with a single transistor.

b)

1.4 CLASSIFICATION OF EMBEDDED SYSTEMS

LO 4 Classify embedded systems based on performance, complexity and the era in which they evolved

It is possible to have a multitude of classifications for embedded systems, based on different criteria. Some of the criteria used in the classification of embedded systems are as follows:

(1) Based on generation
(2) Complexity and performance requirements
(3) Based on deterministic behaviour
(4) Based on triggering.

The classification based on deterministic system behaviour is applicable for 'Real Time' systems. The application/task execution behaviour for an embedded system can be either deterministic or non- deterministic. Based on the execution behaviour, Real Time embedded systems are classified into *Hard* and *Soft*. We will discuss about hard and soft real time systems in a later chapter. Embedded Systems which are 'Reactive' in nature (Like process control systems in industrial control applications) can be classified based on the trigger. Reactive systems can be either *event triggered* or *time triggered*.

1.4.1 Classification Based on Generation

This classification is based on the order in which the embedded processing systems evolved from the first version to where they are today. As per this criterion, embedded systems can be classified into the following:

1.4.1.1 First Generation The early embedded systems were built around 8bit microprocessors like 8085 and Z80, and 4bit microcontrollers. Simple in hardware circuits with firmware developed in Assembly code. Digital telephone keypads, stepper motor control units etc. are examples of this.

1.4.1.2 Second Generation These are embedded systems built around 16bit microprocessors and 8 or 16 bit microcontrollers, following the first generation embedded systems. The instruction set for the second generation processors/controllers were much more complex and powerful than the first generation processors/controllers. Some of the second generation embedded systems contained embedded operating systems for their operation. Data Acquisition Systems, SCADA systems, etc. are examples of second generation embedded systems.

1.4.1.3 Third Generation With advances in processor technology, embedded system developers started making use of powerful 32bit processors and 16bit microcontrollers for their design. A new concept of application and domain specific processors/controllers like Digital Signal Processors (DSP) and Application Specific Integrated Circuits (ASICs) came into the picture. The instruction set of processors became more complex and powerful and the concept of instruction pipelining also evolved. The processor market was flooded with different types of processors from different vendors. Processors like Intel Pentium, Motorola 68K, etc. gained attention in high performance embedded requirements. Dedicated embedded real time and general purpose operating systems entered into the embedded market. Embedded systems spread its ground to areas like robotics, media, industrial process control, networking, etc.

1.4.1.4 Fourth Generation The advent of System on Chips (SoC), reconfigurable processors and multicore processors are bringing high performance, tight integration and miniaturisation into the embedded device market. The SoC technique implements a total system on a chip by integrating different functionalities with a processor core on an integrated circuit. We will discuss about SoCs in a later chapter. The fourth generation embedded systems are making use of high performance real time embedded operating systems for their functioning. Smart phone devices, mobile internet devices (MIDs), etc. are examples of fourth generation embedded systems.

1.4.1.5 What Next? The processor and embedded market is highly dynamic and demanding. So 'what will be the next smart move in the next embedded generation?' Let's wait and see.

1.4.2 Classification Based on Complexity and Performance

This classification is based on the complexity and system performance requirements. According to this classification, embedded systems can be grouped into the following:

1.4.2.1 Small-Scale Embedded Systems Embedded systems which are simple in application needs and where the performance requirements are not time critical fall under this category. An electronic toy is a typical example of a small-scale embedded system. Small-scale embedded systems are usually built around low performance and low cost 8 or 16 bit microprocessors/microcontrollers. A small-scale embedded system may or may not contain an operating system for its functioning.

1.4.2.2 Medium-Scale Embedded Systems Embedded systems which are slightly complex in hardware and firmware (software) requirements fall under this category. Medium-scale embedded systems are usually built around medium performance, low cost 16 or 32 bit microprocessors/microcontrollers or digital signal processors. They usually contain an embedded operating system (either general purpose or real time operating system) for functioning.

1.4.2.3 Large-Scale Embedded Systems/Complex Systems Embedded systems which involve highly complex hardware and firmware requirements fall under this category. They are employed in mission critical applications demanding high performance. Such systems are commonly built around high performance 32 or 64 bit RISC processors/controllers or Reconfigurable System on Chip (RSoC) or multi-core processors and programmable logic devices. They may contain multiple processors/controllers and co-units/hardware accelerators for offloading the processing requirements from the main processor of the system. Decoding/ encoding of media, cryptographic function implementation, etc. are examples for processing requirements which can be implemented using a co-processor/hardware accelerator. Complex embedded systems usually contain a high performance Real Time Operating System (RTOS) for task scheduling, prioritisation, and management.

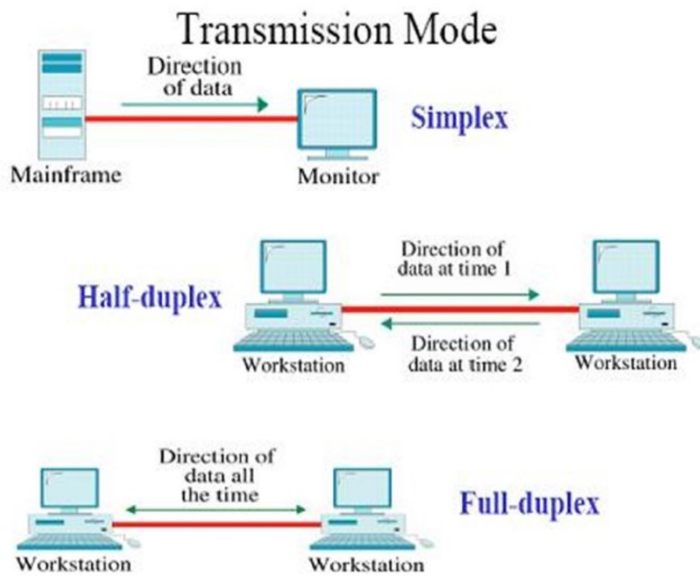
8.	a) Discuss the types of Communication system.	[5]	CO3	L2
	b) Explain the concept of Radio wave propagation with a neat diagram.	[5]	CO3	L2

TYPES OF COMMUNICATION SYSTEMS

One may categorize communication systems based on their physical infrastructure and the specifications of the signals they transmit.

- **Communication Systems based on Physical Infrastructure**
  - **1. Line Communication Systems AND Radio communication system**
    - **Radio broadcast – Purely radio communication**
    - **Landline Telephony- Purely Line communication**
  - ***2. SIMPLEX AND DUPLEX***
- **Communication systems based on Signal specifications**
  - **Analog/ Digital Communication systems**
  - **Baseband/ Carrier Communication systems**

1.Communication Systems based on Physical Infrastructure



TYPES OF COMMUNICATION SYSTEMS

Communication systems can be classified based on two major aspects:

1. **Physical Infrastructure** (how the signals physically travel)
2. **Signal Specifications** (type and nature of signals being transmitted)

A. Classification Based on Physical Infrastructure

This classification focuses on the **medium or path** used to transfer information.

Two main types:

---

1. Line Communication Systems

In line communication, communication takes place through **physical wired media**.

Examples of line media:

- Twisted pair cables
- Coaxial cables
- Optical fibers
- Telephone lines

Examples:

(a) Landline Telephony

- Uses copper telephone lines
- Completely wired
- Two-way communication (duplex)

(b) Cable Television

- Uses coaxial cable
- Signal distribution over a physical network

---

2. Radio Communication Systems

Here the communication uses **wireless radio waves** as the medium.

Examples:

(a) Radio Broadcasting

- Purely wireless
- Transmitter → Antenna → Free space → Receiver
- Typically **simplex** (one-way)

(b) Satellite Communication

- Uses microwave links to/from satellites
- Example: GPS, DTH, VSAT

(c) Mobile Communication

- Uses cellular radio networks
- Example: GSM, LTE, 5G

Simplex and Duplex (Direction of Information Flow)

Directionality differentiates communication further:

Type	Meaning	Example
Simplex	one-way only	Radio/TV broadcasting
Half-duplex	two-way but not simultaneous	Walkie-talkie
Full-duplex	two-way simultaneous	Mobile phone, landline phone

---

B. Classification Based on Signal Specifications

This classification is based on the **form, frequency, and characteristics of the signal** being transmitted.

Two important categories:

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1. Analog and Digital Communication Systems

(a) Analog Communication

- Signal varies continuously with time and amplitude
- Examples: AM, FM, TV broadcasting, Voice radio

Characteristics:

- Sensitive to noise
- Requires modulation techniques for long distance

(b) Digital Communication

- Signal is discrete (binary 0 and 1)
- Examples: Computer networks, Mobile data, Digital TV, Internet

Advantages:

- Less noise
- Data compression possible
- Encryption/security possible
- Easier error detection and correction

---

2. Baseband and Carrier Communication Systems

(a) Baseband Communication

- No modulation
- Message transmitted directly as low-frequency signal
- Example: Ethernet (wired LAN), audio signals

Limitation:

- Suitable only for short distances

(b) Carrier Communication

- Message modulates a high-frequency carrier signal
- Used for long-distance and wireless communication

Types of modulation techniques:

- AM (Amplitude Modulation)

- FM (Frequency Modulation)
- PM (Phase Modulation)
- Digital modulations (ASK, FSK, PSK, QAM)

Advantages:

- Long distance possible
- Multiplexing possible (more users)
- Better signal-to-noise ratio
- Less interference

Different modes of propagation of electromagnetic waves

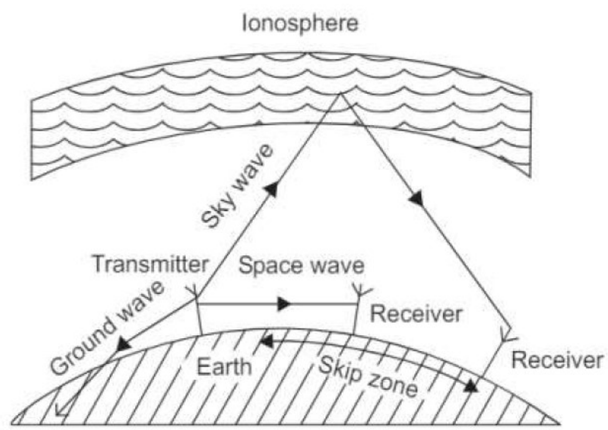

Fig. 1.28

Ground wave propagation

- **Radio waves are guided by the earth** and **move along its curved surface** from the transmitter to the receiver.
- As waves move around ground they are **strongly influenced** by the **electrical properties of the ground.**
- **As high frequency waves are strongly absorbed by ground. Ground wave propagation is useful only at only LOW frequencies.**
- Below 500 kHz, ground waves can be used for communication within distances of about 1500 km from the transmitter.
- **AM radio broadcast** in the medium frequency band cover local areas and take place primarily by the **ground wave**.
- Ground wave transmission is very reliable whatever the atmospheric conditions be.

Space or tropospheric wave propagation

- **Radio wave transmitted from an antenna**, travels in a **straight line** directly reaches the receiving antenna
- In space wave or line of sight propagation, radio waves move in the earth's troposphere within about 15 km over the surface of the earth.
- **The space wave is made up of two components:**

(a) a *direct or line-of- sight wave* from the transmitting *to* the receiving antenna and

(b) the *ground-reflected* wave traversing form the transmitting antenna to ground and reflected to the receiving antenna

- **Television frequencies in the range 100-220 MHz are transmitted through this mode.**

Sky wave propagation

ıdio waves transmitted from the transmitting antenna reach the receiving antenna ːer reflection from the ionosphere, i.e. the ionized layers lying in the earth's upper nosphere.

ıort wave transmission around the globe is possible through sky wave via successive lections at the ionosphere and the earth's surface.

ıosphere - The ionized *region* of the earth's upper atmosphere extending from about 40 ı to the height of a few earth radii above the earth.
ıe ionosphere is made up of electrons, and positive and negative ions in the ckground of neutral particles of the atmosphere.

e propagation of radio wave through the ionosphere is affected by the electrons and ions the ionosphere. The effect of the electrons on the propagation is much greater than that of ː ions since the electronic mass is much less than the ionic mass.

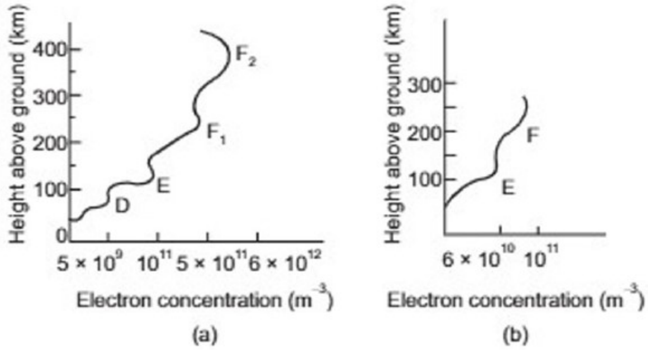

Fig. 1.11 Schematic illustration of the height distribution of the electron concentration of different ionospheric layers during (*a*) day and (*b*) night

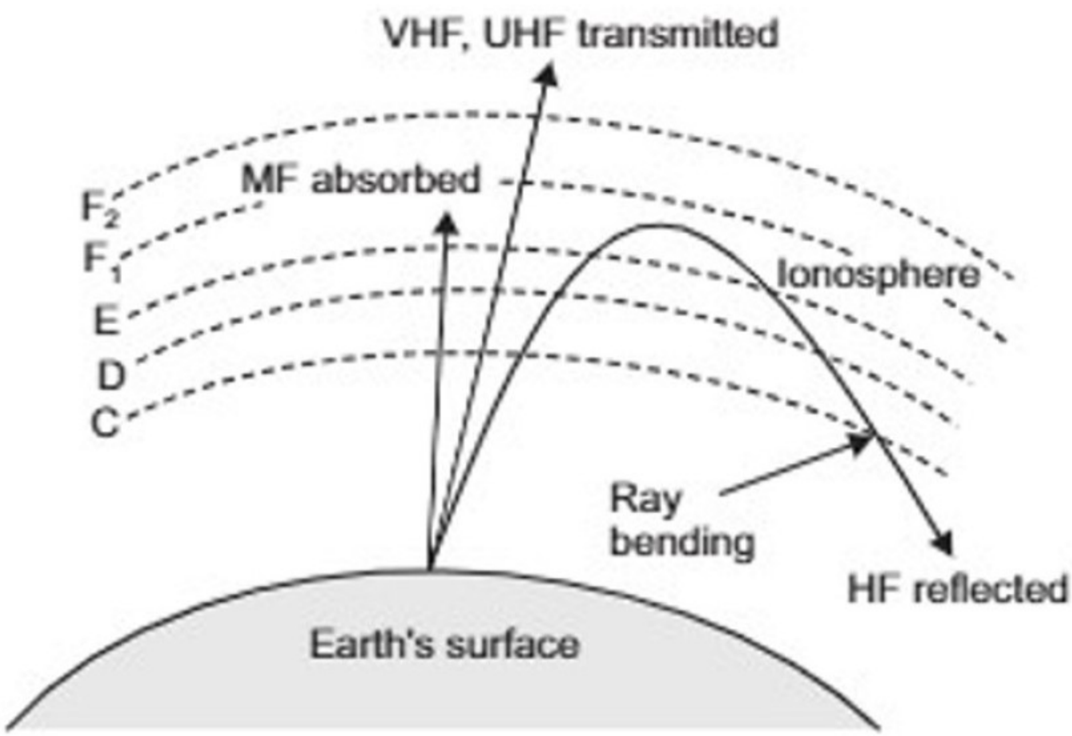

Fig. 1.12 Effect of ionosphere on different e.m. waves