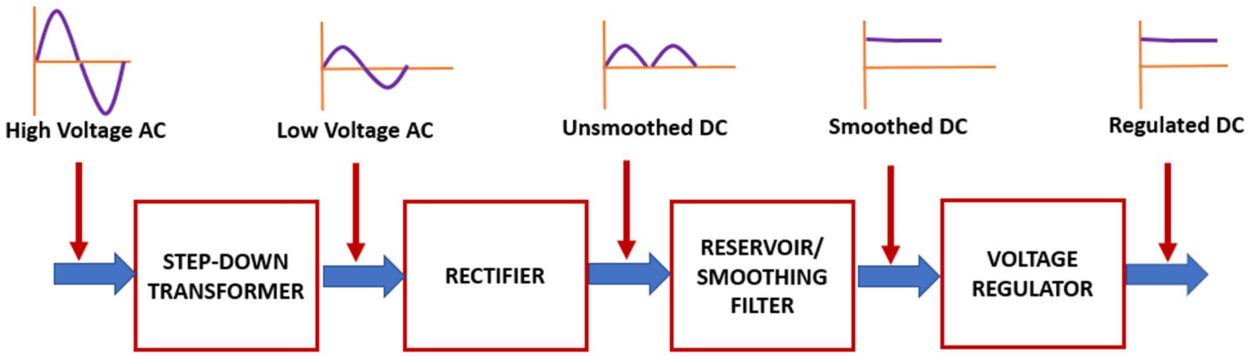
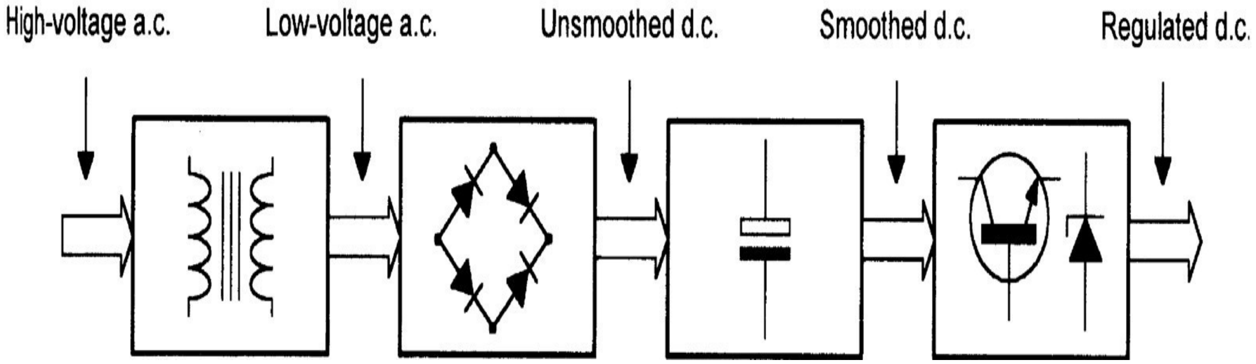
VTU QP Solution (2025-26 Odd)

Module 1

1) a) With a neat block diagram, explain the working of regulated power supply, clearly describing each stage. (8M)

Power supply is a device that supplies electric power to a load. Following is the block diagram of DC power supply.



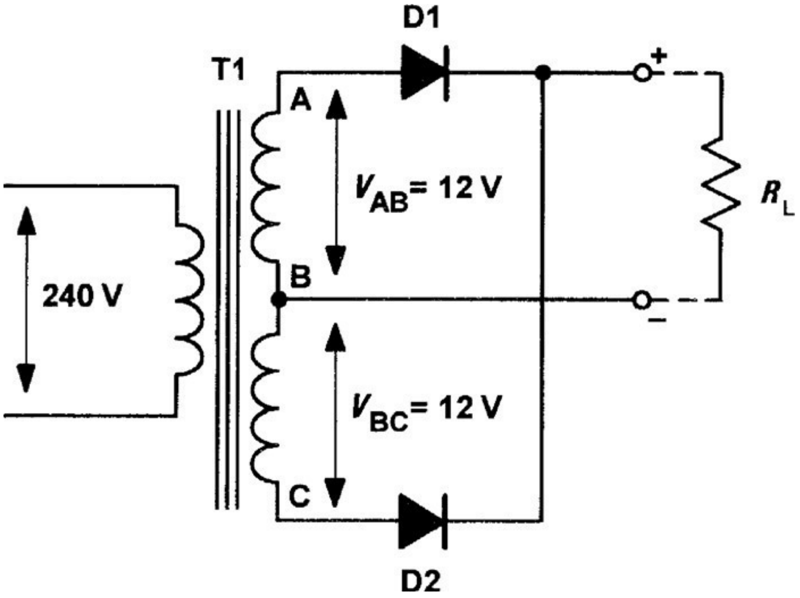


- **Step-Down Transformer** – Steps down the AC main voltage which is usually high (220V) to a lower value (9V, 12V, 15V, 20V, 30V). ***This is achieved by varying the turns ratio on the transformer***.
- **Rectifier –** The AC output from transformer secondary is then rectified using convectional silicon rectifier diodes to produce an ***unsmoothed output (pulsating DC).***

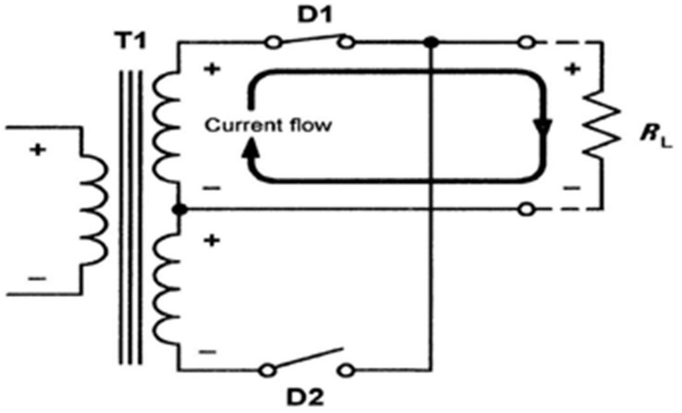
- **Reservoir/Filtering Circuit** – The unsmoothed output from rectifier is smoothened by reservoir/filtering circuit (a ***high value capacitor***). The high value capacitor stores a considerable charge. The capacitor helps smooth out the voltage pulses produced by the rectifier.
- **Voltage Regulator** – A series transistor regulator using a Zener diode as a ***fixed voltage source stabilizes and provides a constant voltage.***

b) With circuit diagram and waveforms, explain the working of Bi-phase full wave rectifier. (6M)

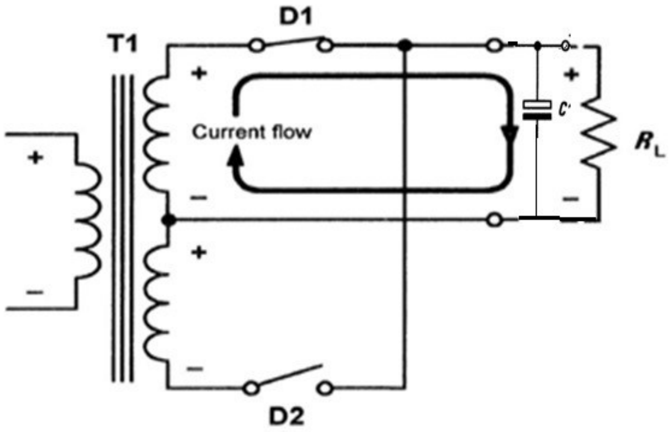
Bi phase Full wave rectifier is a type of full wave rectifier circuit with two diodes and a centre tap transformer and conducts during both the half cycles if the input signal.



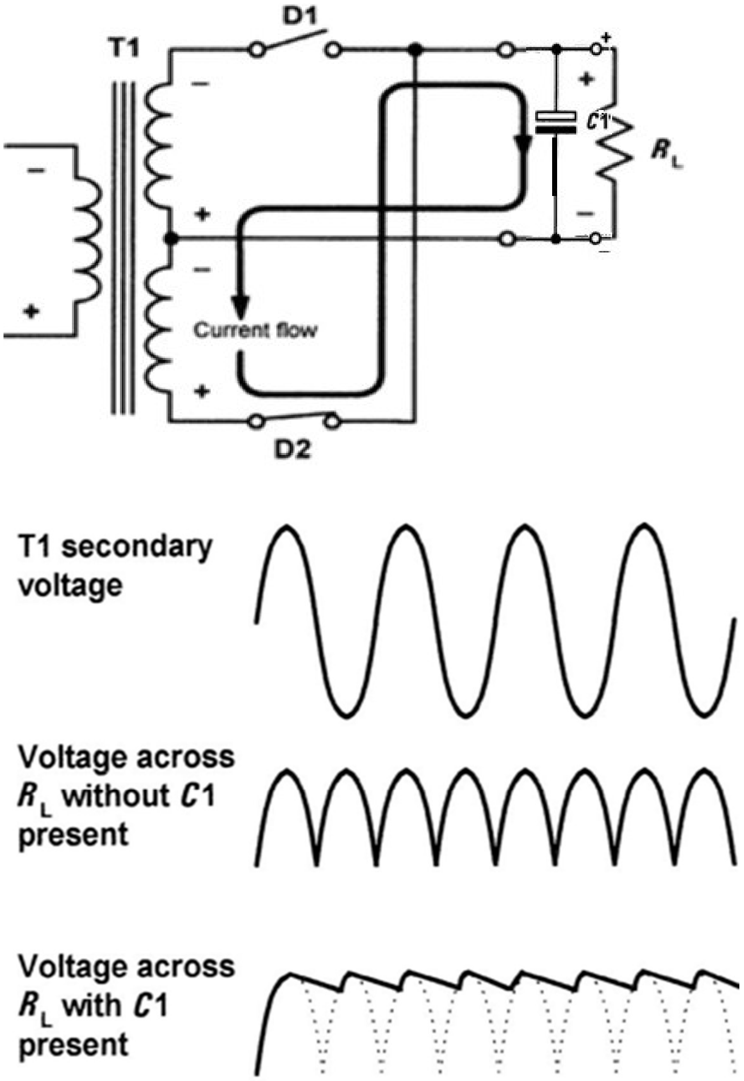
During the positive half cycle, for the segment AB, end A is positive while end B is negative. Hence the diodes D1 are forward biased and can be replaced by closed switch while the diode D2 is reverse biased and can be replaced by open switch.



During the positive half cycle, for the segment AB, end A is positive while end B is negative, while for the segment BC, B is positive and C is negative. Hence the diodes D1 are forward biased and can be replaced by closed switch while the diode D2 is reverse biased and can be replaced by open switch. The capacitor thus gets charges to its peak input voltage during the positive half cycle. The capacitor is chosen such that it has a small charging time and large discharge time.

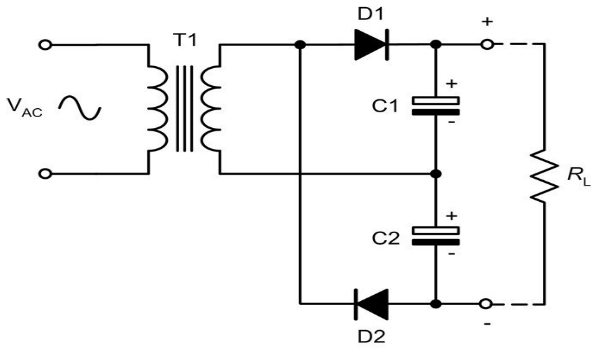


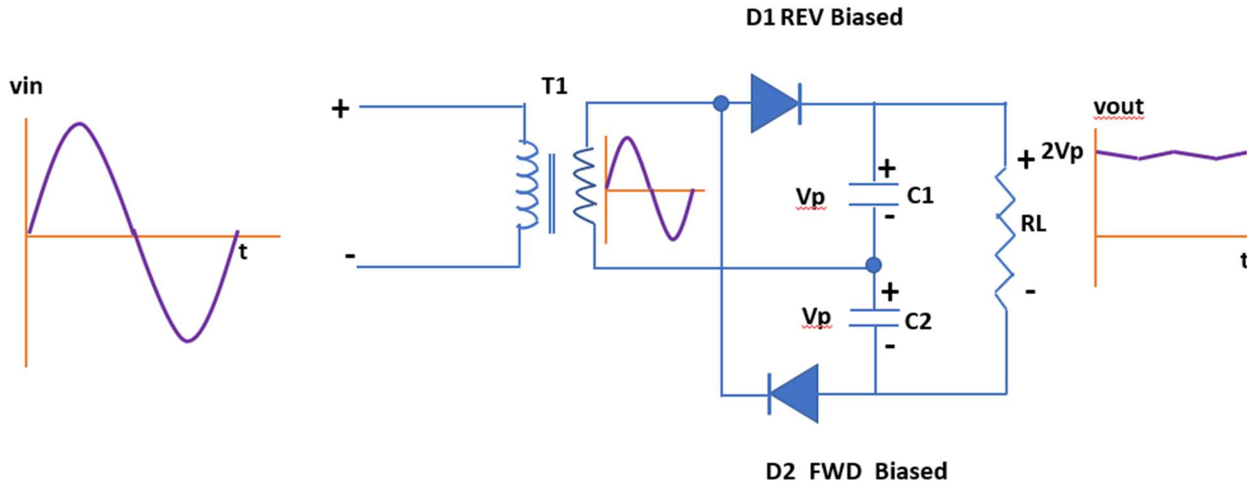
As the input voltage reduces during the negative half cycle, for a fraction of time both the diodes are reverse biased and the capacitor starts discharging through the load. As the input voltage further reduces, for the segment AB, end A is negative while end B is positive while for the segment BC, B is negative and C is positive. Hence the diodes D1 are reverse biased and can be replaced by open switch while the diode D2 is forward biased and can be replaced by closed switch and the capacitor again gets charged to its peak input value and the cycle repeats.



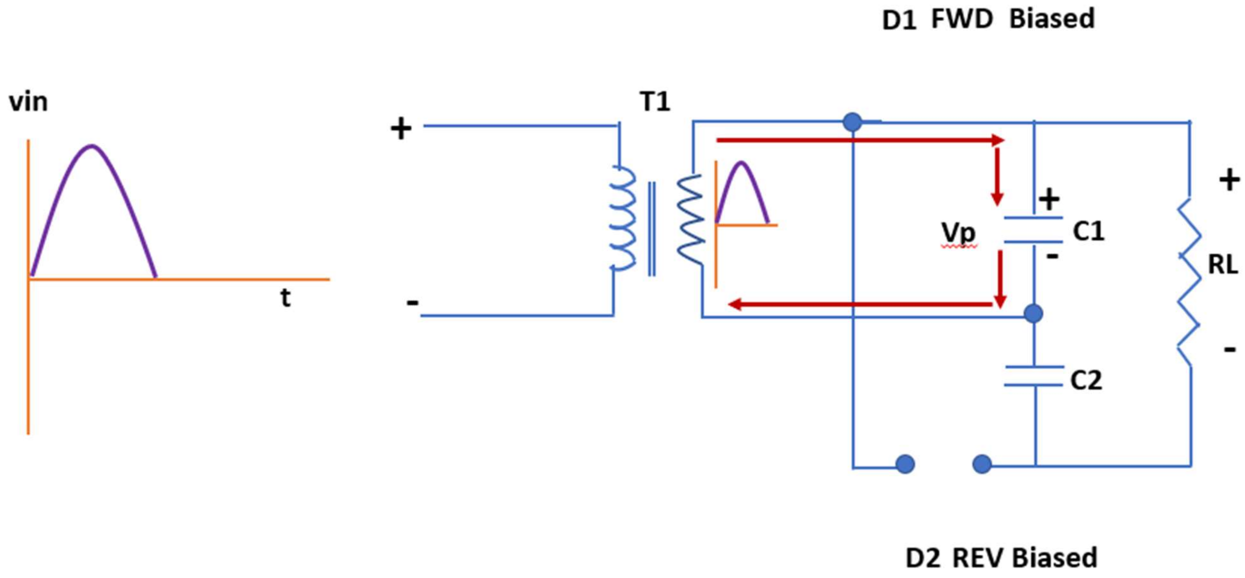
c) With a neat circuit diagram brief out the operation of voltage doubler. (6M)

Voltage Doubler is a circuit in which the output voltage is double the input voltage.

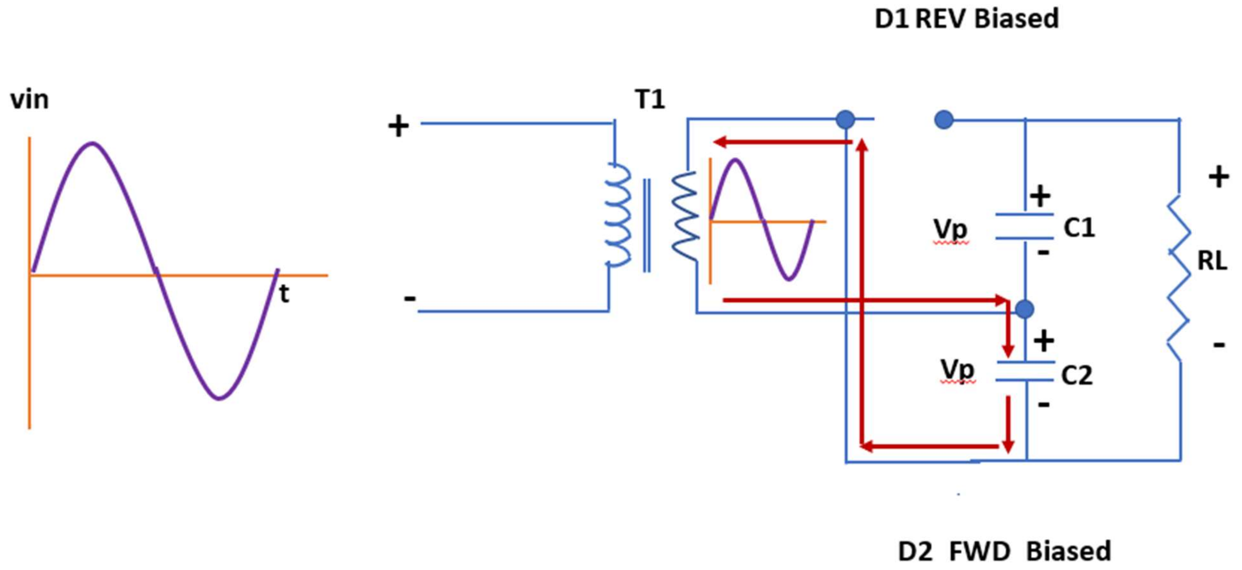




During the positive half cycle, diode D1 is forward biased and D2 is reverse biased and capacitor, C1 will charge to positive peak of secondary



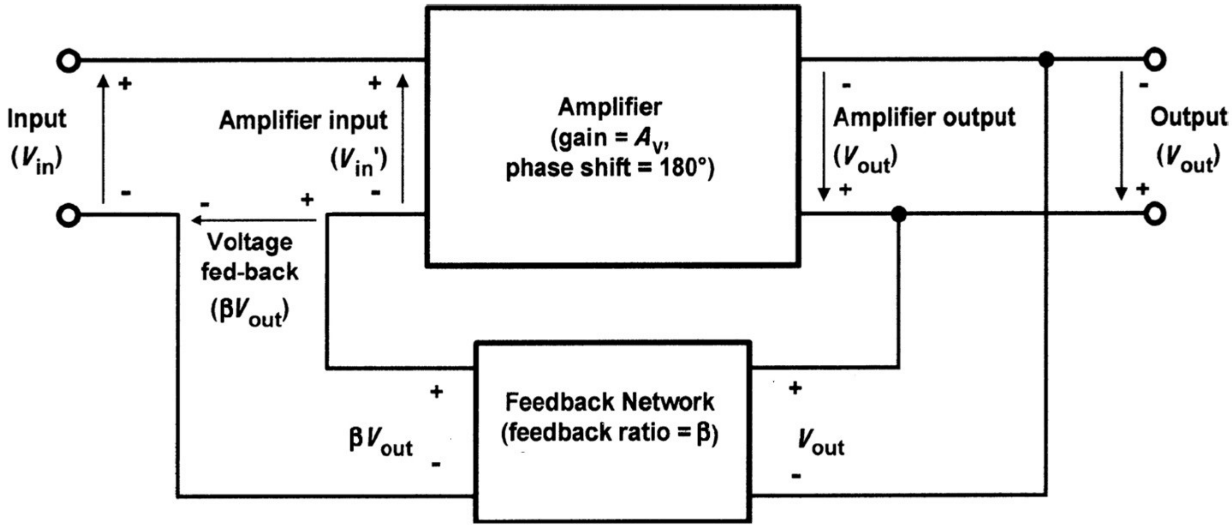
During the negative half cycle, diode D1 is reverse biased and D2 is forward biased and capacitor, C2 will charge to negative peak of secondary voltage.



Since the output is taken from C1 and C2 connected in series the resulting output voltage is twice that produced by one diode alone.

2)a) Derive the expression for gain of the amplifier with negative feedback. Explain how feedback improves performance.

- Negative feedback used to precisely control the gain, reduce distortion and improve bandwidth by reducing the overall gain of the circuit.
- The gain can be reduced to a manageable value by feeding back a small proportion of the output.
- The amount of feedback determines the overall (or closed-loop) gain.



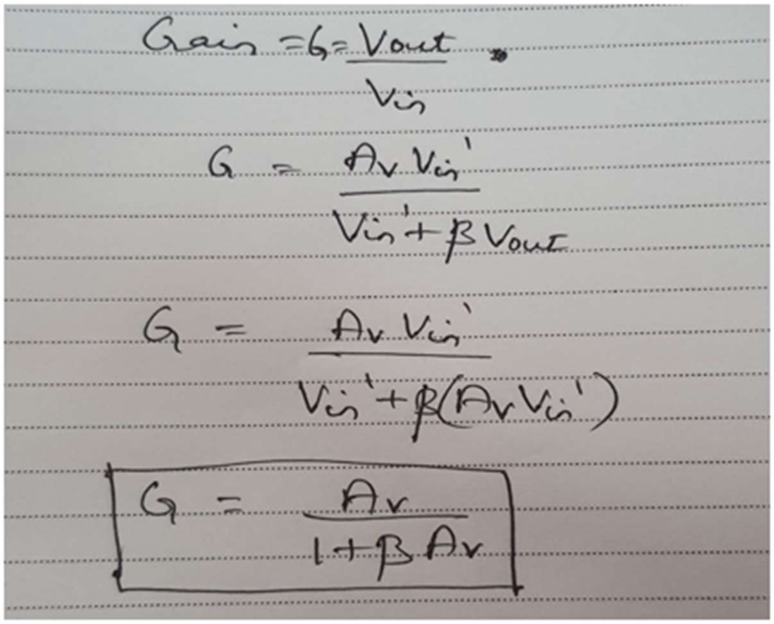
Applying KVL,

$$V_{in} = V_{in}' + \beta V_{out}$$

$$V_{in}' = V_{in} - \beta V_{out}$$

This indicates that the amplifier's input voltage has been reduced by taking negative feedback.

$$V_{out} = A_v \times V_{in}$$



$$\text{Gain} = G = \frac{V_{out}}{V_{in}}$$

$$G = \frac{A_v V_{in}'}{V_{in}' + \beta V_{out}}$$

$$G = \frac{A_v V_{in}'}{V_{in}' + \beta(A_v V_{in}')}$$

$$\boxed{G = \frac{A_v}{1+\beta A_v}}$$

Hence overall gain with negative feedback is less than the gain without feedback.

If Av is very large then, G = 1/β.

b) Write short notes on any four types of amplifiers with its frequency response curves.

Audio frequency amplifiers

- Operate in the band of frequencies that is normally associated with audio signals (e.g. ***20 Hz to 20 kHz***).

Radio Frequency amplifiers

- Operate in the band of frequencies that is normally associated with radio(100kHz-1GHz).

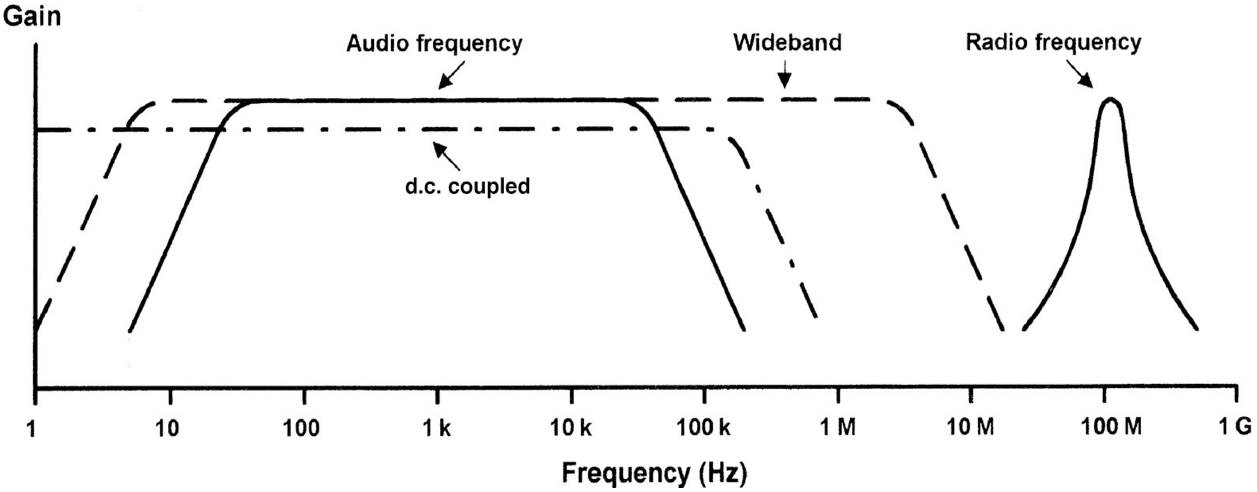
Small signal amplifier

- Designed to cater for low-level signals (normally ***less than 1 V*** and often much smaller).

- Specially designed to combat the effects of noise.

Low noise amplifiers

- Designed so that they contribute negligible noise (signal disturbance) to the signal being amplified.
- Designed for use with very small signal levels (usually less than 10 mV) or so).



c) An amplifier produces an output voltage of 5 V for an input of 85 mV. If the input and output currents in this condition are, respectively, 5 mA and 200 mA, determine the: (4M)

(a) voltage gain
(b) current gain
(c) power gain.

$V_i = 85mV$,

$V_{out} = 5V$,

$I_{in} = 5mA$,

$I_{out} = 200mA$

a) Voltage gain = Av = $V_{out}/V_{in} = 5/(85 \times 10^{-3}) = 58.82$
b) Current gain = Ai = Iout/Iin = $(200*10^{-3}) / (5*10^{-3}) = 50$
c) Power gain = Ap = Av * Ai = 58.82 * 50 = 2941.176

Module-2

Q.3a) With a neat diagram, derive the expression for over all gain of a positive feedback amplifier. Explain the conditions for sustained oscillations.

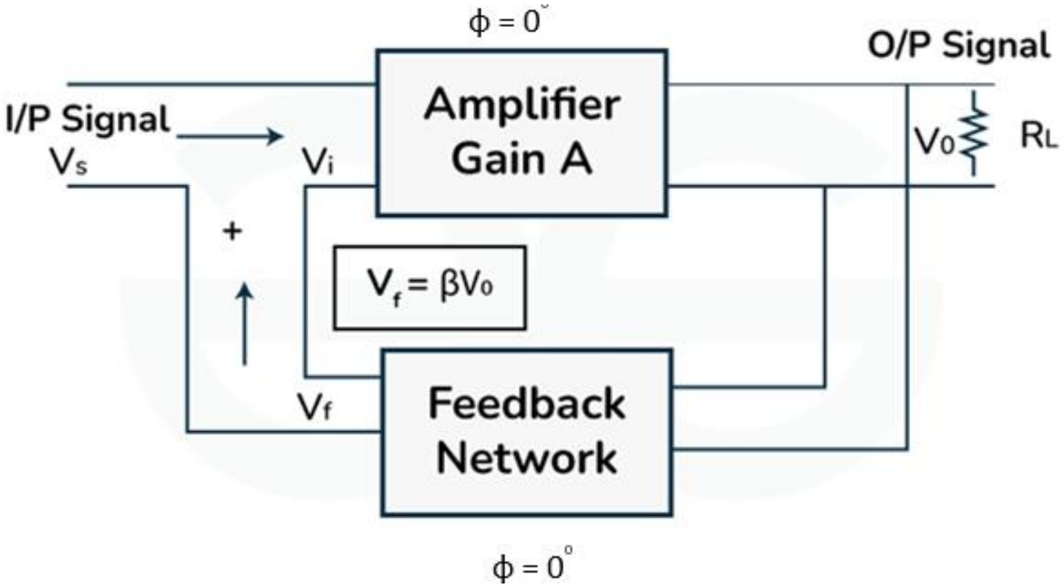


Fig. Block diagram of Positive feedback Amplifier

The process by which some part or fraction of output is combined with the input is known as feedback. If the feedback voltage V_f is inphase with the input signal Vs is called positive feedback, then the net effect of feedback will increase the input signal given to the basic amplifier.

$V_i = V_s + V_f$

The gain of amplifier with positive feedback is

$$A_f = \frac{V_o}{V_s} \qquad \begin{bmatrix} V_i = V_s + V_f \\ V_s = V_i - V_f \end{bmatrix}$$

$$A_f = \frac{V_o}{V_i - V_f}$$

$$A_f = \frac{1}{\frac{V_i}{V_o} - \frac{V_f}{V_o}}$$

$$A_f = \frac{1}{\frac{1}{A} - \beta}$$

$$\boxed{A_f = \frac{A}{1 - A\beta}} \qquad A_f << A$$

Conditions for Sustained Oscillations (Barkhausen Criterion)
For a positive feedback amplifier to act as an oscillator (produce sustained oscillations without an external input), it must satisfy the Barkhausen Criterion:

1. Loop Gain Unity: The product of the amplifier gain ‘A’ and the feedback gain ‘β’ must be unity, i.e., $|A \beta| = 1$.
2. Zero Phase Shift: The total phase shift around the loop must be 0^0 or 360^0.

Q.3b) Explain the operations of three stage ladder RC network oscillator with neat circuit diagram.

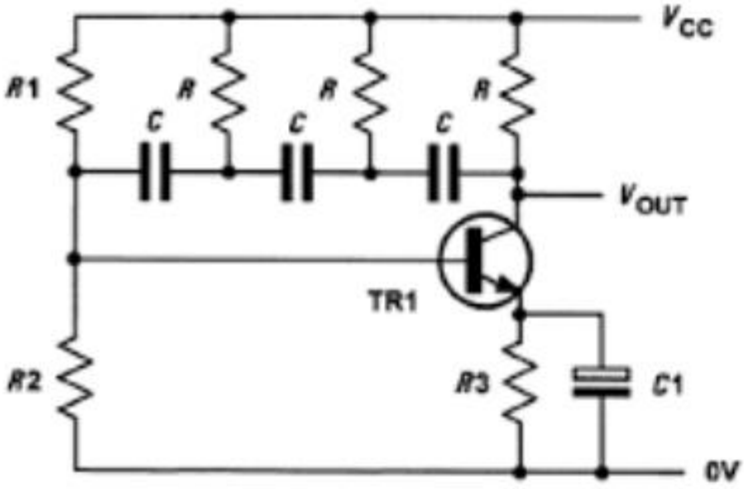


Fig. Sine wave oscillator based on a three-stage C–R ladder network

A three-stage ladder RC network oscillator, commonly known as an RC Phase Shift Oscillator, is a linear electronic circuit that produces a sinusoidal output. The circuit consists of an amplifying stage typically a Common-Emitter transistor and a feedback stage containing the three RC ladder sections as shown in Fig below. TR1 operates as a conventional common-emitter (CE) amplifier stage with R1 and R2 providing base bias potential and R3 and C1 providing emitter stabilization.

To satisfy the Barkhausen criterion for sustained oscillations, the total phase shift around the closed loop must be 360° (or 0°) and the loop gain must be at least unity. The CE amplifier provides an initial 180° phase shift, while each of the three identical RC stages in the "ladder" is designed to provide a 60° phase shift at a specific frequency, totalling an additional 180°. When the circuit is powered, internal thermal noise or small voltage fluctuations are amplified and fed through this frequency-selective network, only the frequency

$$f_o = \frac{1}{2\pi RC\sqrt{6}}$$

returns to the input exactly in-phase (360° total shift) to be reinforced. Because the RC ladder network attenuates the signal by a factor of 1/29, the amplifier must have a voltage gain of at least 29 to overcome these losses and maintain a stable output.

Q.3c) In wein bridge oscillator, C_1=C_2=125nF, determine the frequency of oscillation, When R_1=R_2=5KΩ.

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

if R_1=R_2=R and C_1=C_2 = C then,

$$f = \frac{1}{2\pi RC} = f = \frac{1}{2\pi \text{ x 5x10\textasciicircum 3x125x10\textasciicircum -9}} = 254.64 \text{ Hz}$$

Q.4a) Define the following with respect to operational amplifiers and provide their typical values. i. Open loop voltage gain ii. Input offset voltage iii. Slew rate iv. Full power bandwidth

i. Open loop Voltage gain: The open-loop voltage gain of an operational amplifier is defined as the ratio of output voltage to input voltage measured with no feedback applied. Aol =V_0/V_i.

Typical value of open loop gain is 10^5 for IC741.

ii. Input offset voltage: The ideal op-amp produces zero volts out for zero volts difference is applied to its inputs. In practice, due to imperfect internal balance, there may be some small voltage present at the output. The voltage that must be applied differentially to the operational amplifier input in order to make the output voltage exactly zero is known as the input offset voltage.

Typical values of input offset voltage range from 1 mV to 15 mV

iii. Slew rate: The slew rate of an operational amplifier is the rate of change of output voltage with time in response to a rectangular step input voltage is applied.

Slew rate = $\Delta V_0/\Delta t$

where,

ΔV_0 is the change in output voltage (in volts) and Δt is the corresponding interval of time (in seconds).

Slew rate is measured in V/s (or V/μs) and typical values range from 0.2 V/μs to over 20 V/μs.

Full power bandwidth: Full power bandwidth is the maximum frequency at which an operational amplifier can produce its maximum rated output voltage swing without significant distortion.

Typical value is 2MHz.

Q.4b) Explain the operation of op-Amp integrator and differentiator with circuit diagrams and output waveforms.

* Integrator:

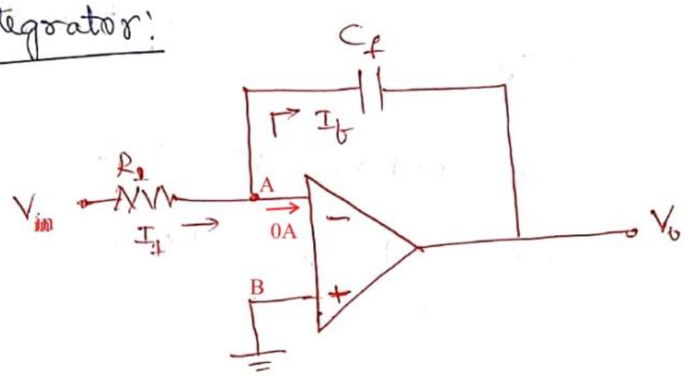


Fig. Integrator

An integrator is a circuit in which the output voltage is proportional to the integral of the input voltage.

Opamp integrator circuit is shown in above figure.

The node B is grounded. the node A is also at the ground potential, from the concept of virtual ground. i.e., $V_A = V_B = 0V$.

As the input current of opamp is zero, the entire current I_1 flowing through R_f; also flows throug C_f, as shown in above figure.

The current I_1 through R_1 is given by

$$I_1 = \frac{V_{in} - V_A}{R_1} = \frac{V_{in}}{R_1} \longrightarrow ①$$

The current through capacitor C_f is given by

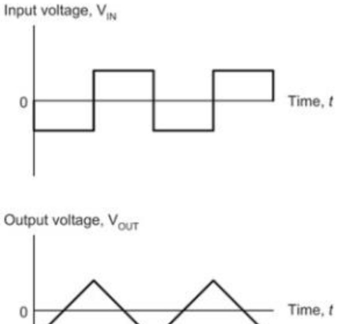
$$I_f = C_f \frac{d(V_A - V_0)}{dt} = -C_f \frac{dV_0}{dt} \longrightarrow ②$$

Now applying the KCL at node A of integrator circuit,

$I_f = I_1$

Therefore equating equations 1 and 2, we get

$$\frac{V_{in}}{R_1} = -C_f \frac{dV_0}{dt}$$



Typical input and output wavefor
for an integrator

Integrating on both sides,

$$\int_0^t \frac{V_{in}}{R_1} \, dt = -C_f \int_0^t \frac{dV_0}{dt} \, dt$$

$$\int_0^t \frac{V_{in}}{R_1} \, dt = -C_f V_0$$

$$\therefore V_0 = \frac{-1}{R_1 C_f} \int_0^t V_{in} \, dt.$$

Thus V_0 is scaled version of the integral of V_{in}.

* Differentiator:

A differentiator is circuit in which the output voltage is proportional to the time derivative of input voltage

The opamp-differentiator circuit is shown in the figure.

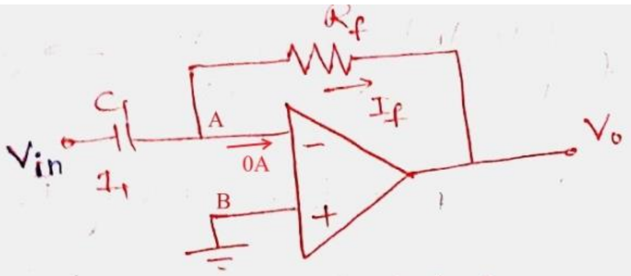


Fig: Differentiator

The node B is grounded. The node A is also at ground potential according to the concept of virtual ground.

∴ $V_A = V_B = 0V$.

As the input current of opamp is zero, entire current I_1 flows through the resistance R_f.

The current I_1 through the capacitor C_1 is given by,

$$I_1 = C_1 \frac{d(V_{in} - V_A)}{dt} = C_1 \frac{dV_{in}}{dt} \rightarrow ① \quad \Big| \because V_A = 0V$$

The current through R_f is given by.

$$I_f = \frac{V_A - V_0}{R_f} = \frac{-V_0}{R_f} \longrightarrow ② \quad \Big| \because V_A = 0V$$

Now applying the KCL at node A of differentiator circuit,

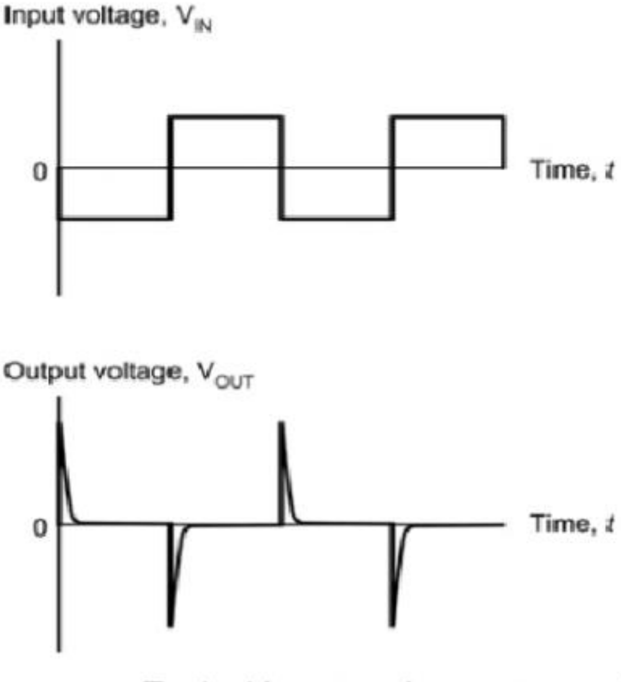
$I_f = I_1$

therefore equating equations 1 and 2, we get,

$$-\frac{V_0}{R_f} = C_1 \frac{dV_{in}}{dt}.$$

$$V_0 = -R_f C_1 \frac{dV_{in}}{dt}.$$

Thus V_0, is a scaled version of differentiation of V_{in}.



Typical input and output waveforms for a differentiator

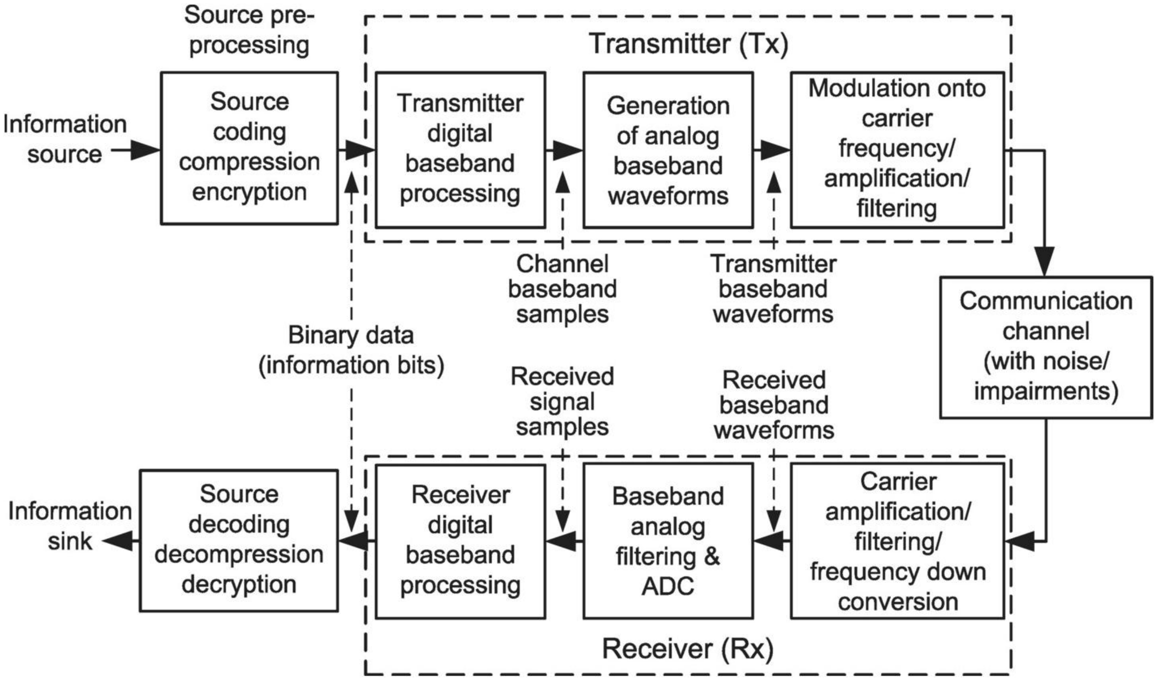
Q.4c) An operational amplifier with negative feedback produces an output voltage of 3V when supplied with an input of 450uV. Determine the value of closed loop voltage gain and express the answer in decibels.

Closed loop voltage gain = V_o/V_i = 3/(450 x 10^-6) = 6666.667

Closed loop voltage gain in decibels = 20log(V_o/V_i) = 20 log(6666.667) = 76.48 dB.

Q.5 (a) Block Diagram of Communication System and Explanation

A communication system is a system used to transfer information from one place to another with minimum distortion and maximum efficiency. The basic elements of a communication system are information source, input transducer, transmitter, communication channel, receiver, output transducer and destination.



The information source generates the message to be transmitted. The message may be in the form of voice, music, video or digital data. This original signal is usually a low-frequency signal called the baseband signal. Since the message is generally in physical form, it is first converted into an electrical signal by the input transducer. For example, a microphone converts sound waves into electrical signals and a camera converts light into electrical signals.

The electrical signal from the transducer is then applied to the transmitter. The transmitter performs several important functions such as amplification, modulation, frequency translation and power amplification. Since low-frequency signals cannot travel long distances efficiently, the transmitter modulates the baseband signal with a high-frequency carrier signal. This process enables long-distance transmission.

The modulated signal is then sent through the communication channel. The channel is the medium through which the signal travels from transmitter to receiver. It may be free space, coaxial cable or optical fiber. During transmission, the signal may suffer attenuation and distortion. In addition to this, unwanted disturbances called noise may get added to the signal.

Noise is any unwanted electrical disturbance that interferes with the desired signal. It may distort the amplitude, frequency or phase of the signal and reduces the quality of communication. The signal along with noise reaches the receiver.

The receiver performs the reverse operations of the transmitter. It first amplifies the weak received signal, then demodulates it to recover the original baseband signal. Filtering is also done to remove unwanted noise components. After processing, the recovered signal is given to the output transducer.

The output transducer converts the electrical signal back into physical form. For example, a speaker converts electrical signals into sound waves. Finally, the message reaches the destination, which is the intended user of the information.

Q.5 (b) Noise and Radio Wave Propagation

Noise is defined as any unwanted signal that interferes with the desired message signal and reduces the quality of communication. It affects the signal-to-noise ratio (SNR) and degrades system performance. Noise can be broadly classified into external noise and internal noise.

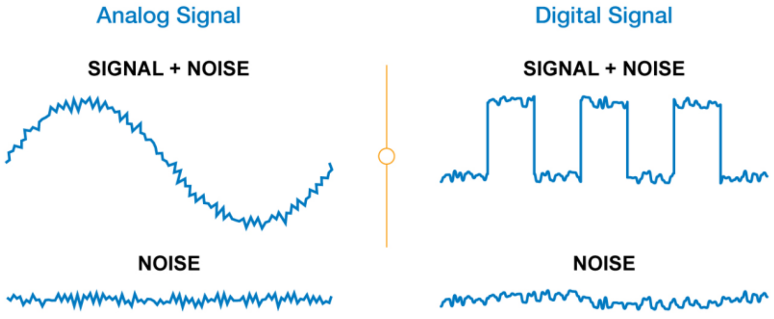


FIGURE 1. Noise in Analog and Digital Signals

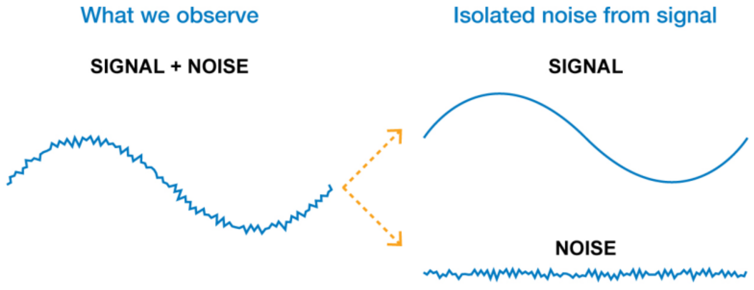
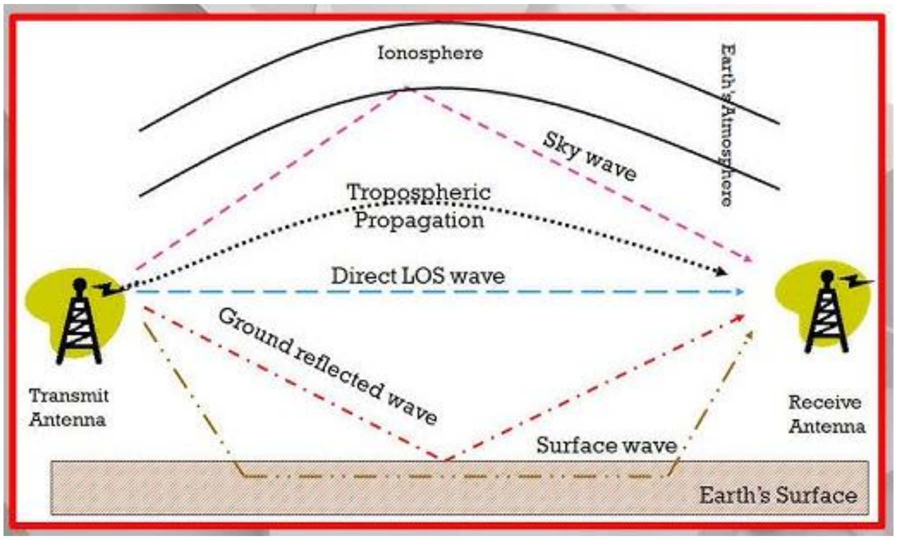


FIGURE 2. Isolated Noise from Signal

External noise originates outside the communication system. Atmospheric noise is caused by lightning and thunderstorms. Extraterrestrial noise is produced by the sun and other cosmic sources. Man-made noise is generated by electrical machines, switching circuits and industrial equipment. Internal noise is generated within electronic components of the system. Thermal noise is caused by random motion of electrons in conductors. Shot noise occurs in semiconductor devices due to random movement of charge carriers. Flicker noise is a low-frequency noise observed in electronic devices.



Radio wave propagation refers to the way in which radio waves travel from transmitter to receiver. Depending on frequency and atmospheric conditions, radio waves propagate in different modes. Ground wave propagation occurs when radio waves travel along the surface of the earth. It is mainly used for frequencies below 2 MHz and is commonly used in AM broadcasting. Sky wave propagation occurs when radio waves are reflected back to the earth by the ionosphere. It is used for long-distance communication and operates in the frequency range of 2 MHz to 30 MHz. Space wave propagation occurs when radio waves travel directly from transmitter to receiver in a line-of-sight path. It is used for frequencies above 30 MHz and is commonly used in FM and television transmission.

Thus, a communication system enables efficient transmission of information, but its performance is affected by noise and the mode of radio wave propagation.

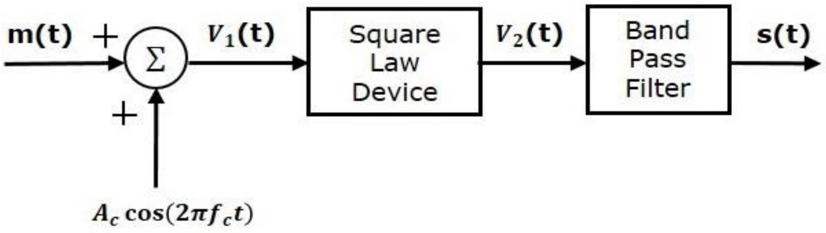
Q.6 (a) Advantages of Digital Communication and Generation of AM

Digital communication has several advantages over analog communication. In digital communication, the information signal is converted into binary form consisting of 0s and 1s before transmission. One of the main advantages is high noise immunity. Since digital signals use discrete levels, the effect of noise can be reduced using regenerative repeaters. Another advantage is that error detection and correction techniques can be easily applied, which improves reliability. Digital communication also provides better security because encryption techniques can be implemented effectively. It allows easy storage and processing using computers and digital systems. Furthermore, digital signals can be multiplexed efficiently and transmitted over long distances with less distortion.

Amplitude Modulation (AM) is a modulation technique in which the amplitude of a high-frequency carrier signal is varied in accordance with the instantaneous amplitude of the message signal, while the frequency and phase of the carrier remain constant. Let the carrier signal be represented as

Vc = Ac sin(ωc t)
and the message signal be represented as
Vm = Am sin(ωm t).

When modulation takes place, the amplitude of the carrier changes according to the message signal and the resulting AM wave is given by
V = Ac [1 + m sin(ωm t)] sin(ωc t),
where m is the modulation index and is defined as m = Am / Ac.



The modulation index determines the quality of modulation. If m is less than 1, the system is said to be under-modulated. If m is equal to 1, it is 100 percent modulation and provides maximum output without distortion. If m is greater than 1, over-modulation occurs and distortion appears in the output waveform. Thus, AM enables transmission of low-frequency signals over long distances by using a high-frequency carrier.

Q.6 (b) Explain ASK, FSK and PSK Modulation Schemes

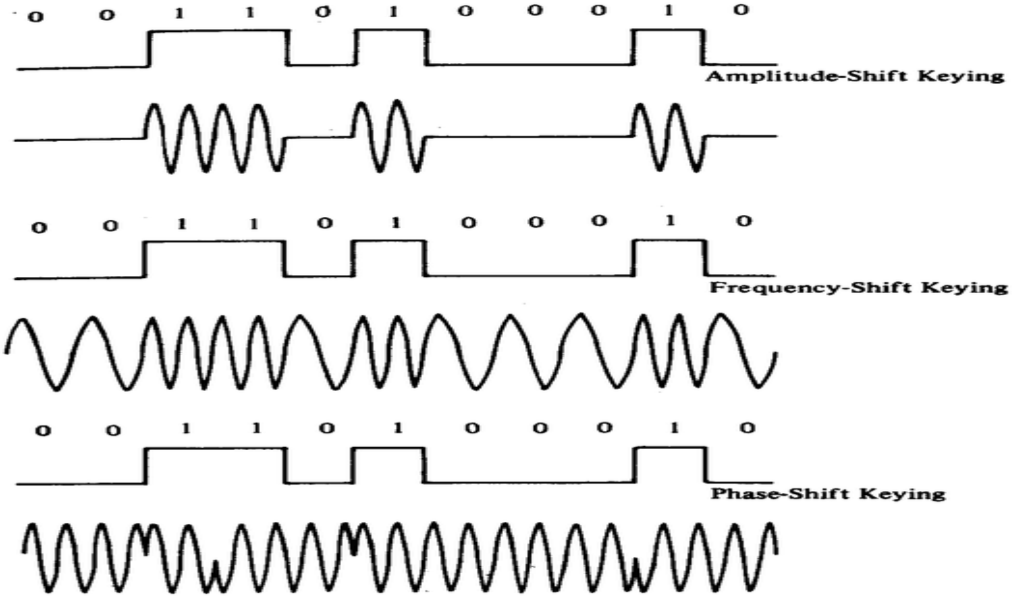
In digital communication, digital data can be transmitted using different modulation techniques such as Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

In Amplitude Shift Keying (ASK), the amplitude of the carrier signal is varied according to the binary data, while the frequency and phase remain constant. When binary 1 is transmitted, the carrier has high amplitude, and when binary 0 is transmitted, the carrier amplitude becomes zero or low. ASK is simple to implement but is more susceptible to noise because noise mainly affects amplitude.

In Frequency Shift Keying (FSK), the frequency of the carrier signal is varied according to the binary data, while amplitude remains constant. For binary 1, one frequency (f1) is transmitted, and for binary 0, another frequency (f2) is transmitted. FSK provides better noise immunity than ASK because information is carried in frequency variation rather than amplitude.

In Phase Shift Keying (PSK), the phase of the carrier signal is varied according to the binary data while amplitude and frequency remain constant. In Binary Phase Shift Keying (BPSK), the phase of the carrier changes by 180 degrees between binary 0 and binary 1. PSK provides better performance in the presence of noise and is widely used in modern digital communication systems.

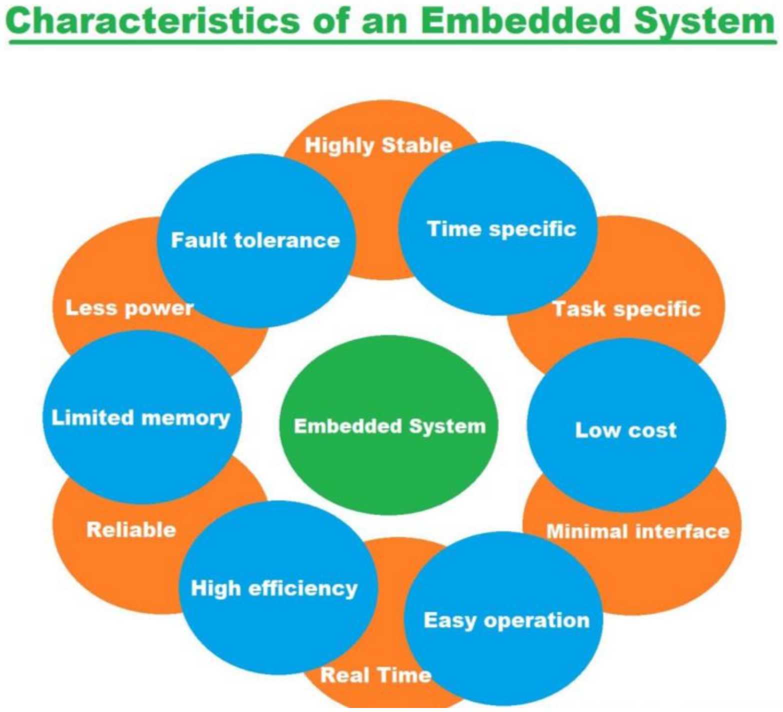
Thus, ASK, FSK and PSK are important digital modulation techniques used for transmitting binary data efficiently over communication channels.



Q.7 (a) Define Embedded Systems, Key Characteristics and Applications

An embedded system is a microcontroller or microprocessor-based system designed to perform a specific and dedicated function within a larger system. Unlike general-purpose computers, embedded systems are built for a particular task and are optimized for performance, size, cost, and power consumption. They are usually a combination of hardware and software designed to work together efficiently for real-time applications.

One of the main characteristics of an embedded system is that it is application specific, meaning it performs only a predefined task. It is often designed to operate in real-time, where it must respond to inputs within a fixed time limit. Embedded systems are typically compact in size and consume low power, making them suitable for portable and battery-operated devices. They are highly reliable and stable since they are used in critical applications such as medical and automotive systems. They usually have limited memory and processing capability because they are optimized for a particular function rather than multiple tasks.



Embedded systems are widely used in various application areas. In automotive systems, they are used in engine control units, airbag systems and anti-lock braking systems. In consumer electronics, they are used in washing machines, microwave ovens, televisions and mobile phones. In industrial automation, they are used for process control and monitoring. In medical equipment, embedded systems are used in ECG machines, infusion pumps and patient monitoring systems. They are also used in robotics, aerospace systems and smart home devices. Thus, embedded systems play an important role in modern technology.

Q.7 (b) Purpose of Embedded Systems and Difference Between Embedded Systems and General-Purpose Computing Systems

The main purpose of an embedded system is to control, monitor and automate specific operations within a larger system. Embedded systems improve efficiency, accuracy and reliability of devices. They are designed to perform real-time data processing and control operations with minimal human intervention. They help in reducing system size, cost and power consumption while increasing performance. In many applications, embedded systems ensure safety and stability by continuously monitoring system parameters and taking corrective actions when necessary.

Embedded systems differ significantly from general-purpose computing systems. An embedded system is designed for a single dedicated task, whereas a general-purpose system such as a personal computer is designed to perform multiple tasks. Embedded systems usually operate in real-time environments, but general-purpose systems do not necessarily require real-time operation. Embedded systems have limited memory and processing power, while general-purpose systems have large memory and powerful processors. The software in an embedded system is usually fixed and stored in ROM or flash memory, whereas in a general-purpose system, users can install and modify software freely. Therefore, embedded systems are optimized for specific applications, while general-purpose systems are flexible and multifunctional.

Q.8 (a) Role of Memory, Sensors, Actuators and Display Devices in Embedded Systems

In an embedded system, memory plays a crucial role in storing program instructions and data. It is used to store the operating program, intermediate results and configuration data. There are different types of memory used in embedded systems. ROM is used to store permanent programs and firmware. RAM is used for temporary data storage during program execution. Flash memory is used for reprogrammable storage of application software. The proper selection of memory ensures efficient and reliable operation of the system.

Sensors are important components of embedded systems as they convert physical quantities into electrical signals. Physical parameters such as temperature, pressure, light, humidity and motion are sensed by sensors and converted into electrical signals that can be processed by the microcontroller. For example, a temperature sensor converts temperature variations into corresponding voltage changes.

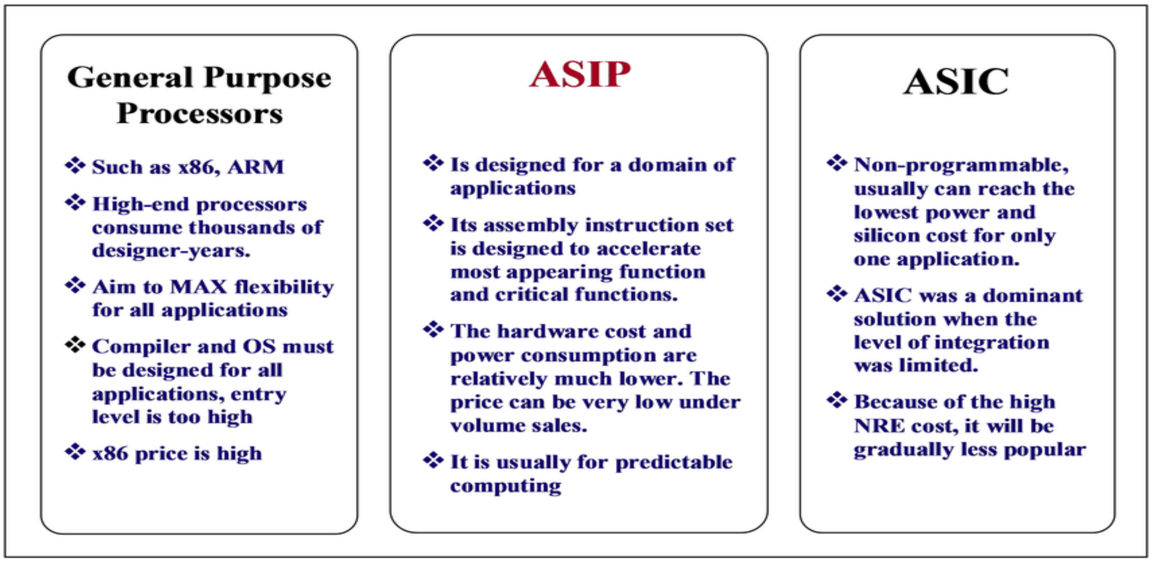
Actuators perform the opposite function of sensors. They convert electrical signals from the controller into physical action. Examples of actuators include motors, relays, solenoids and buzzers. For instance, in a temperature control system, when the temperature exceeds a set limit, the microcontroller sends a signal to the actuator to turn on a cooling fan.

Display devices are used to provide visual output to the user. LEDs are simple display devices used as status indicators to show ON or OFF conditions. A 7-segment display is commonly used to display numeric digits from 0 to 9. It consists of seven segments arranged in the form of the number 8, and by turning ON or OFF specific segments, different numbers can be displayed. These components together enable the embedded system to interact with the external environment effectively.

Q.8 (b) Compare RISC and CISC Architectures and GPP and ASIP Processors

RISC (Reduced Instruction Set Computer) and CISC (Complex Instruction Set Computer) are two types of processor architectures. In RISC architecture, the instruction set is small and simple. Each instruction performs a single operation and is usually executed in one clock cycle. RISC uses fixed-length instructions and has a large number of registers. This results in faster execution and simpler hardware design. In contrast, CISC architecture has a large and complex instruction set. Each instruction can perform multiple operations. The instructions are usually of variable length and may take multiple clock cycles to execute. CISC reduces the number of instructions per program but increases hardware complexity.

GPP (General Purpose Processor) and ASIP (Application Specific Instruction Processor) differ based on application focus. A GPP is designed to perform a wide range of applications and is used in personal computers and laptops. It offers flexibility and supports multiple software applications. However, it generally consumes more power. An ASIP is designed for a specific application and is optimized for that particular task. It provides better performance and lower power consumption for dedicated applications. ASIPs are commonly used in embedded systems where efficiency and specialization are important. Thus, RISC and CISC differ in instruction design philosophy, while GPP and ASIP differ in application specialization.



General Purpose Processors

- Such as x86, ARM
- High-end processors consume thousands of designer-years.
- Aim to MAX flexibility for all applications
- Compiler and OS must be designed for all applications, entry level is too high
- x86 price is high

ASIP

- Is designed for a domain of applications
- Its assembly instruction set is designed to accelerate most appearing function and critical functions.
- The hardware cost and power consumption are relatively much lower. The price can be very low under volume sales.
- It is usually for predictable computing

ASIC

- Non-programmable, usually can reach the lowest power and silicon cost for only one application.
- ASIC was a dominant solution when the level of integration was limited.
- Because of the high NRE cost, it will be gradually less popular

CISC	RISC
It has a microprogramming unit.	It has a hard-wired unit of programming.
The instruction set has various different instructions that can be used for complex operations.	The instruction set is reduced, and most of these instructions are very primitive.
Performance is optimized with emphasis on hardware.	Performance is optimized which emphasis on software
Only single register set	Multiple register sets are present
They are mostly less or not pipelined	This type of processors are highly pipelined
Execution time is very high	Execution time is very less
Code expansion is not a problem.	Code expansion may create a problem.
Decoding of instructions is complex.	The decoding of instructions is simple.
It requires external memory for calculations	It doesn’t require external memory for calculations
Examples of CISC processors are the System/360, VAX, AMD, and Intel x86 CPUs.	Common RISC microprocessors are ARC, Alpha, ARC, ARM, AVR, PA-RISC, and SPARC.
Instructions can take several clock cycles	Single-cycle for each instruction
More efficient use of RAM than RISC	Heavy use of RAM (can cause bottlenecks if RAM is limited)
Simple, standardized instructions	Complex and variable-length instructions
A small number of fixed-length instructions	A large number of instructions
Limited addressing modes	Compound addressing modes
Important applications are Security systems, Home automation.	Important applications are : Smartphones, PDAs.
Varying formats (16-64 bits for each instruction).	fixed (32-bit) format
Unified cache for instructions and data.	Separate data and instruction cache.

Module 5

Q.9

a. Explain 1’s Complement and 2’s Complement methods with two examples each.

Digital computers operate using the binary number system (0 and 1). However, real-world arithmetic requires negative numbers also (e.g., −5, −10). Since hardware circuits (ALU) can easily perform addition but not direct subtraction, computers use complement methods to represent negative numbers.

Using complements:
$A - B \Rightarrow A + (\text{complement of } B)$

Two complement systems are used:

1. 1’s Complement
2. 2’s Complement

1’s Complement Method

The 1’s complement of a binary number is obtained by changing all 0s to 1s and all 1s to 0s (bit inversion).
$0 \leftrightarrow 1$

Example:
$1010 \rightarrow 0101$

It is used to represent negative binary numbers.

Subtraction using 1’s Complement

To perform: $A - B$

Steps:

1. Convert A and B into binary
2. Find 1’s complement of B
3. Add it to A
4. If carry occurs → add carry to LSB (End-around carry)
5. If no carry → result is negative; take 1’s complement and add minus sign

Example 1: 9−5

Convert to 4-bit binary:
$(9)_{10} = (1001)_2$, $(5)_{10} = (0101)_2$

Step 1: 1’s complement of 5

$0101 \rightarrow 1010$

Step 2: Add

```
  1001
+ 1010
--------
1 0011
```

Carry generated.

Step 3: End-around carry

```
0011
+   1
------
0100
```

$(0100)_2$

Answer = +4

Example 2: 5−9

$(5)_{10}=(0101)_2$, $(9)_{10}=(1001)_2$

Step 1: 1’s complement of 9

1001→0110

Step 2: Add

```
  0101
+ 0110
--------
  1011
```

No carry → negative result.

Step 3: Take 1’s complement

1011→0100, Answer= −4

Disadvantage of 1’s Complement

It produces two representations of zero:
+0=0000   −0=1111

This confuses the processor and complicates hardware design.

3. 2’s Complement Method

The 2’s complement of a binary number is obtained by:
2’s complement=1’s complement+1

This is the standard representation used in all modern computers, CPUs, and microprocessors.

Subtraction using 2’s Complement

To compute:
$A-B$

Steps:

1. Convert A and B into binary
2. Find 2’s complement of B
3. Add with A
4. If carry occurs → ignore carry → positive result
5. If no carry → take 2’s complement of result → negative answer

Example 1: $9-5$

$(9)_{10}=(1001)_2$, $(5)_{10}=(0101)_2$

Step 1: 2’s complement of 5

1’s complement:
$0101 \rightarrow 1010$

Add 1:
$1010+1=1011$

Step 2: Add

```
  1001
+ 1011
--------
1 0100
```

Ignore carry.
$(0100)_2$

Answer = +4

Example 2: $5-9$

$(5)_{10}= (0101)_2$, $(9)_{10}=(1001)_2$

Step 1: 2’s complement of 9

1’s complement:
$1001 \rightarrow 0110$

Add 1:
$0110+1=0111$

Step 2: Add

```
  0101
+ 0111
--------
 1100
```

No carry → negative result.

Step 3: Take 2’s complement

1’s complement:
1100→0011

Add 1:
0011+1=0100, Answer= −4

Comparison of 1’s and 2’s Complement

Feature	1’s Complement	2’s Complement
Operation	Bit inversion	Bit inversion + 1
Zero representation	Two zeros	One zero
Carry handling	End-around carry	Carry ignored
Hardware complexity	More	Less
Used in modern computers	No	Yes

Complement methods allow computers to perform subtraction using only binary addition circuits. Although 1’s complement is conceptually simple, it suffers from double-zero representation and extra carry handling. Therefore, modern processors and ALUs use 2’s complement representation because it simplifies hardware design, eliminates negative zero, and enables fast arithmetic operations.

9.b)

(i) Convert $(100101)_2$ → Decimal and Octal

Binary to Decimal:

$100101_2 = 1\cdot2^5 + 0\cdot2^4 + 0\cdot2^3 + 1\cdot2^2 + 0\cdot2^1 + 1\cdot2^0 = 32 + 4 + 1 = 37_{10}$

Binary to Octal: Group into 3 bits from right → 100 101

$100_2 = 4$, $101_2 = 5$ → $(100101)_2 = 45_8$

(ii) Convert $(782F)_{16}$ → Binary and Decimal

Hex to Binary (each hex digit = 4 bits):

7=0111, 8=1000, 2=0010, F=1111 → $0111\ 1000\ 0010\ 1111_2$

Hex to Decimal:

7·16^3 + 8·16^2 + 2·16^1 + 15·16^0 = 7·4096 + 8·256 + 2·16 + 15 = 28672 + 2048 + 32 + 15 = 30767_{10}

(iii) Convert $(59.2589)_{10}$ → Binary and Octal

Integer part (59) to Binary using division by 2: $59_{10} = 111011_2$

Fractional part (0.2589) to Binary using multiplication by 2 (approx): ≈ $.0100001_2$

Result ≈ 111011.0100001_2

Integer part (59) to Octal using division by 8: $59_{10} = 73_8$

Fractional part (0.2589) to Octal using multiplication by 8 (approx): ≈ $.2044_8$

Result ≈ 73.2044_8

Final Answers

$(100101)_2 = 37_{10} = 45_8$

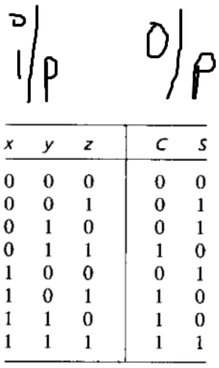
$(782F)_{16} = 0111100000101111_2 = 30767_{10}$

$(59.2589)_{10} \approx 111011.0100001_2$ and ≈ 73.2044

Q.10

a. Explain full adder circuit with its truth table and write expressions for sum and carry.

A full-adder is a combinational circuit that forms the arithmetic sum of three input bits. It consists of three inputs and two outputs. Two of the input variables, denoted by x and y, represent the two significant bits to be added. The third input, z, represents the carry from the previous lower significant position. Two outputs are necessary because the arithmetic sum of three binary digits ranges in value from 0 to 3, and binary 2 or 3 needs two digits. The two outputs are designated by the symbols S for sum and C for carry. The binary variable S gives the value of the least significant bit of the sum. The binary variable C gives the output carry. The truth table of the full-adder is



I/P			O/P	
x	y	z	C	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

The eight rows under the input variables designate all possible combinations of 1's and 0's that these variables may have. The 1's and 0's for the output variables are determined from the arithmetic sum of the input bits. When all input bits are 0's, the output is 0. The S output is equal to 1 when only one input is equal to 1 or when all three inputs are equal to 1. The C output has a carry of 1 if two or three inputs are equal to 1.

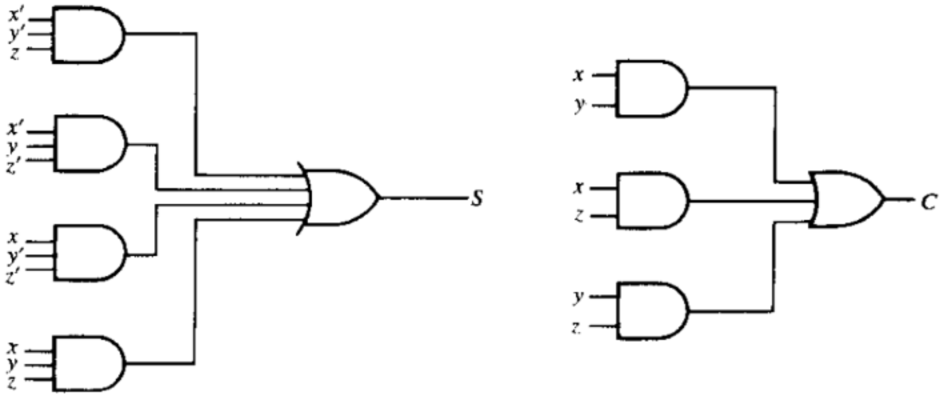
The input and output bits of the combinational circuit have different interpretations at various stages of the problem. Physically, the binary signals of the input wires are considered binary digits added arithmetically to form a two-digit sum at the output wires. On the other hand, the same binary values are considered variables of Boolean functions when expressed in the truth table or when the circuit is implemented with logic gates. It is important to realize that two different interpretations are given to the values of the bits encountered in this circuit.

The input-output logical relationship of the full-adder circuit may be expressed in two Boolean functions, one for each output variable. Requires a unique map for its simplification. Each map must have eight squares, since each output is a function of three input variables. The maps of Fig. 4-3 are used for simplifying the two output functions. The 1's in the squares for the maps of S and C are determined directly from the truth table. The squares with 1's for the S output do not combine in adjacent squares to give a simplified expression in sum of products. The C output can be simplified to a six-literal expression. The logic diagram for the full-adder implemented in sum of products is shown in Fig. 4-4. This implementation uses the following Boolean expressions:

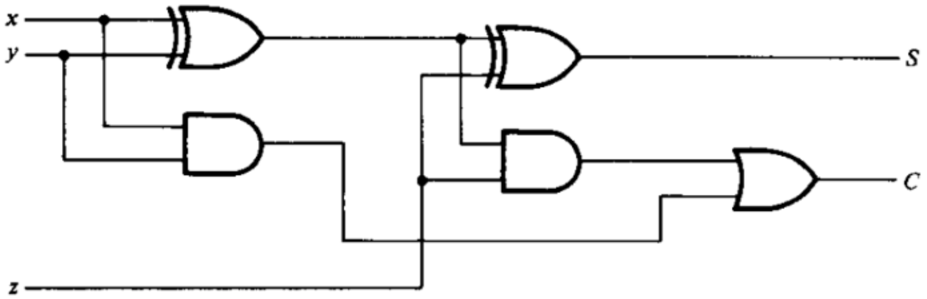
$$S = x'y'z + x'yz' + xy'z' + xyz$$

$$C = xy + xz + yz$$

Other configurations for a full-adder may be developed. The product of sums implementation requires the same number of gates as in Fig. 4-4, with the number of AND and OR gates interchanged. A full-adder can be implemented with two half-adders and one OR gate.



Implementation of a full-adder in sum of products



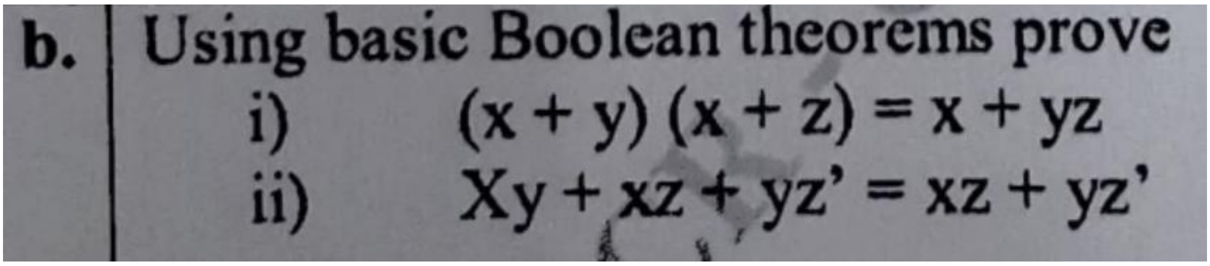
Implementation of a full-adder with two half-adders and an OR gate

$$\begin{aligned} S &= z \oplus (x \oplus y) \\ &= z'(xy' + x'y) + z(xy' + x'y)' \\ &= z'(xy' + x'y) + z(xy + x'y') \\ &= xy'z' + x'yz' + xyz + x'y'z \end{aligned}$$

and the carry output is

$$C = z(xy' + x'y) + xy = xy'z + x'yz + xy$$

b.



b. Using basic Boolean theorems prove

i) (x + y) (x + z) = x + yz

ii) Xy + xz + yz’ = xz + yz’

(i) Prove

$$(x+y)(x+z) = x + yz$$

Step 1: Apply Distributive Law

$$(x+y)(x+z)$$

$$= x(x+z) + y(x+z)$$

$$= xx + xz + xy + yz$$

Step 2: Idempotent Law

$$xx = x$$

$$= x + xz + xy + yz$$

Step 3: Absorption Law

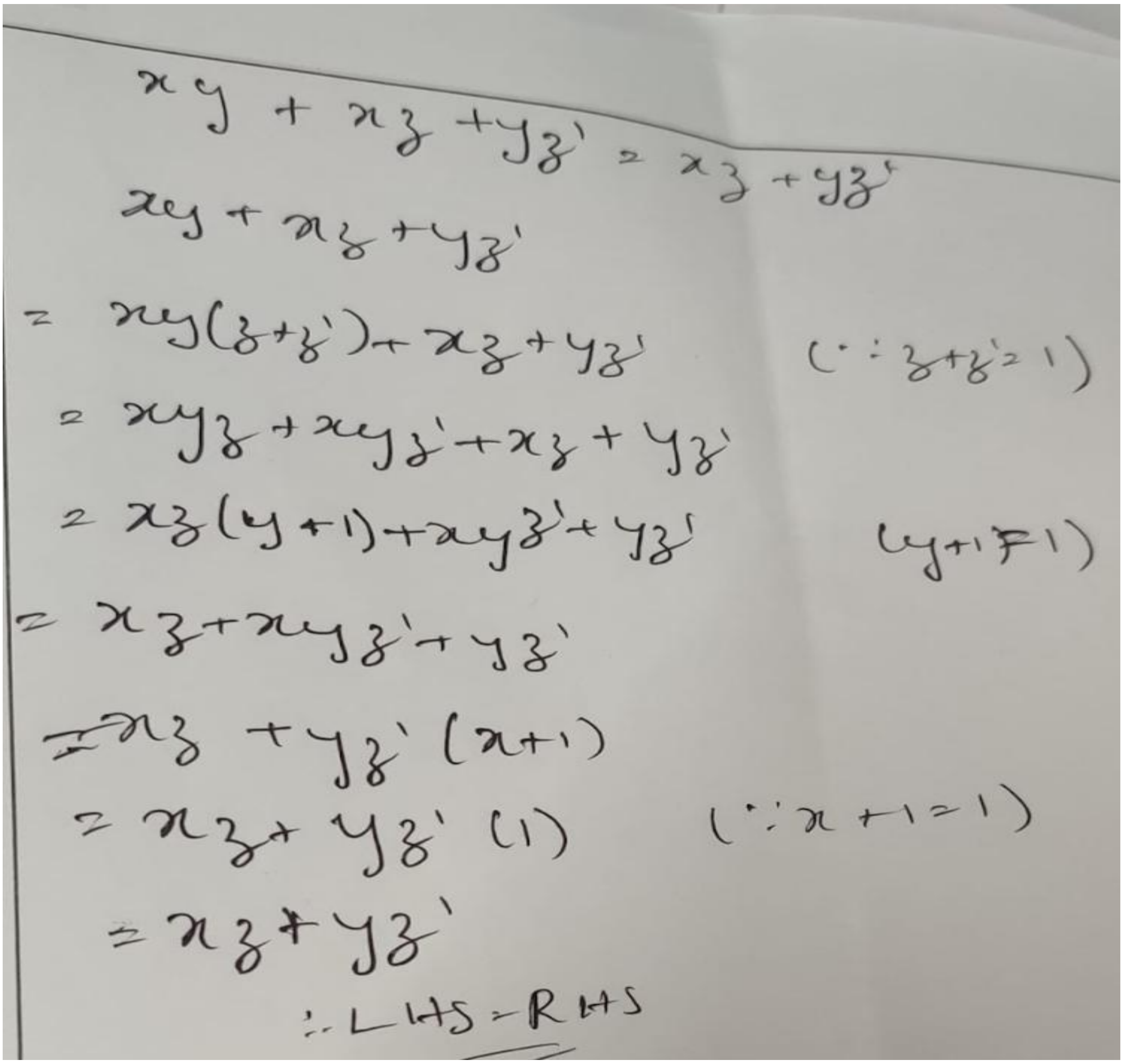
$$x + xz = x$$

$$x + xy = x$$

So,

$$= x + yz$$

$$\boxed{(x+y)(x+z) = x + yz}$$



$$xy + xz + yz' = xz + yz'$$

$$xy + xz + yz'$$

$$= xy(z+z') + xz + yz' \qquad (\because z+z'=1)$$

$$= xyz + xyz' + xz + yz'$$

$$= xz(y+1) + xyz' + yz' \qquad (y+1=1)$$

$$= xz + xyz' + yz'$$

$$= xz + yz'(x+1)$$

$$= xz + yz'(1) \qquad (\because x+1=1)$$

$$= xz + yz'$$

$\therefore$ LHS = RHS