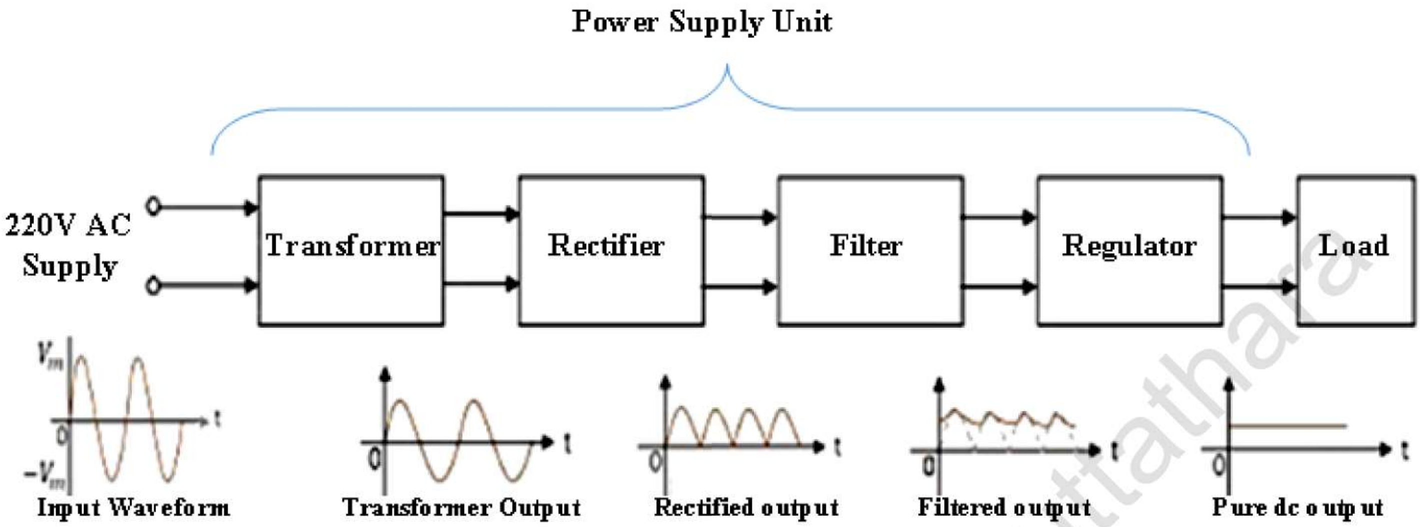
MODULE 5

Block diagram description of a dc power supply

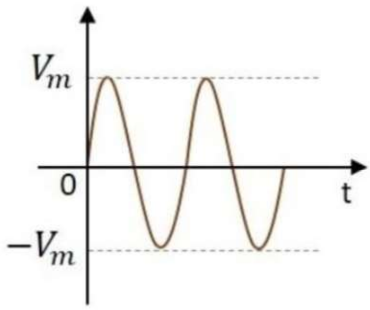


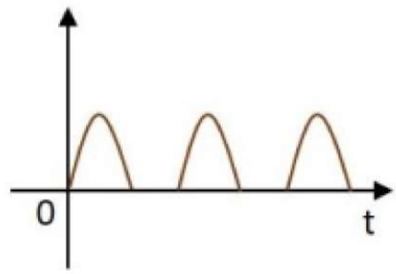
A typical Power supply unit consists of the following.

1. **Step-down Transformer** − It steps down **220v AC power supply** into **an AC of required level**.
2. **Rectifier** – It is circuit that convert the AC input voltage to **pulsating DC voltage**. Output of rectifier is passed through a Filter.
3. **Smoothing/Filter** − **A filtering circuit is used to smoothen** the variations (or ripples component) present in the rectified output. Output of Filter is passed through a Regulator.
4. **Regulator** − A regulator circuit is used to control the unregulated input level to a **desired DC output level**.
5. **Load** − The load is device which uses the pure DC output from the regulated DC output.

Need for Power Supplies: There are many small sections present in the electronic devices such as Computer, Television, Cathode ray Oscilloscope etc. but all of those sections don’t need 220V AC supply which we get. Instead one or more sections may need a 12v DC while some others may need a 30v DC. In order to provide the required dc voltages, the incoming 220v AC supply has to be converted into pure DC for the usage. The Power supply units serve the same purpose.

Rectification





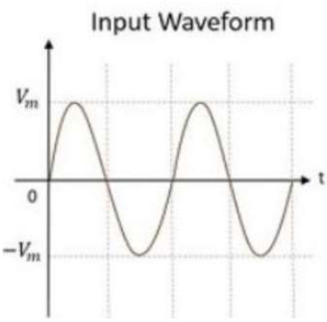
- An alternating current has the property to change its state continuously.
- This is understood by observing the sine wave by which an alternating current is indicated. It raises in its positive direction goes to a peak positive value, reduces from there to normal and again goes to negative portion and reaches the negative peak and again gets back to normal and goes on.
- During its journey in the formation of wave, we can observe that the wave goes in positive and negative directions. Actually, it alters completely and hence the name alternating current.
- But during the process of rectification, this alternating current is changed into direct current DC. The wave which flows in both positive and negative direction till then, will get its direction restricted only to positive direction, when converted to DC. Hence the current is allowed to flow only in positive direction and resisted in negative direction, just as in the figure.

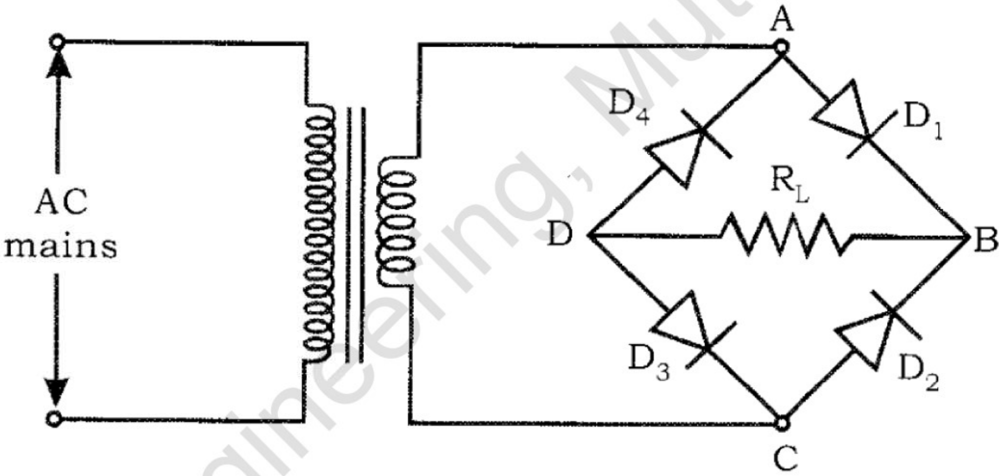
- The circuit which does rectification is called as a Rectifier circuit. A diode is used as a rectifier, to construct a rectifier circuit
- Types of Rectifier circuits

  There are two main types of rectifier circuits, depending upon their output.
  They are
    1) Half-wave Rectifier
    2) Full-wave Rectifier
- A Half-wave rectifier circuit rectifies only positive half cycles of the input supply whereas a Full-wave rectifier circuit rectifies both positive and negative half cycles of the input supply.

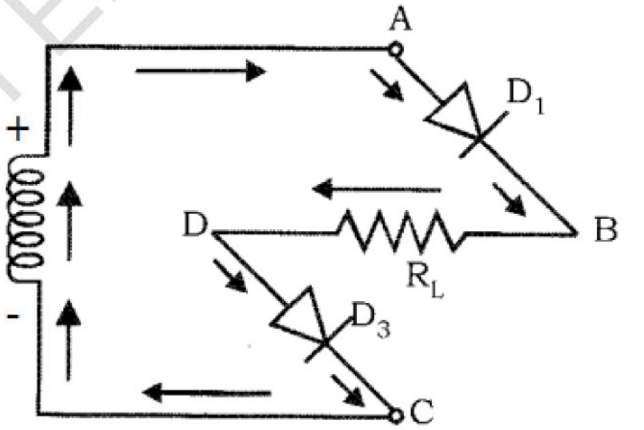
Working of a full wave bridge rectifier

It consists of four diodes D_1, D_2, D_3 and D_4 connected in the form of a bridge ABCD. Two leads A and C of the network are connected to the secondary coil and the other two leads D and B are connected to the load resistor R_L.



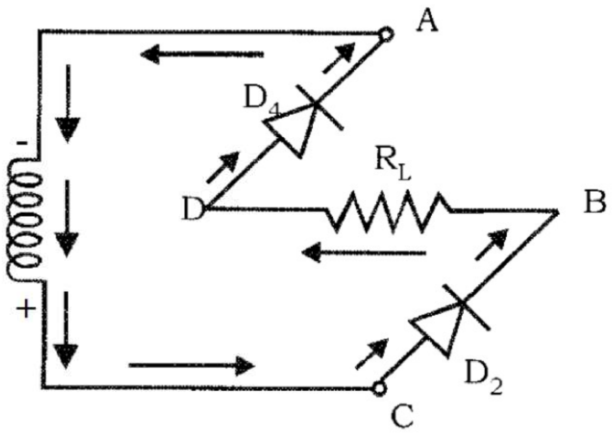


Case I: During the positive half cycle



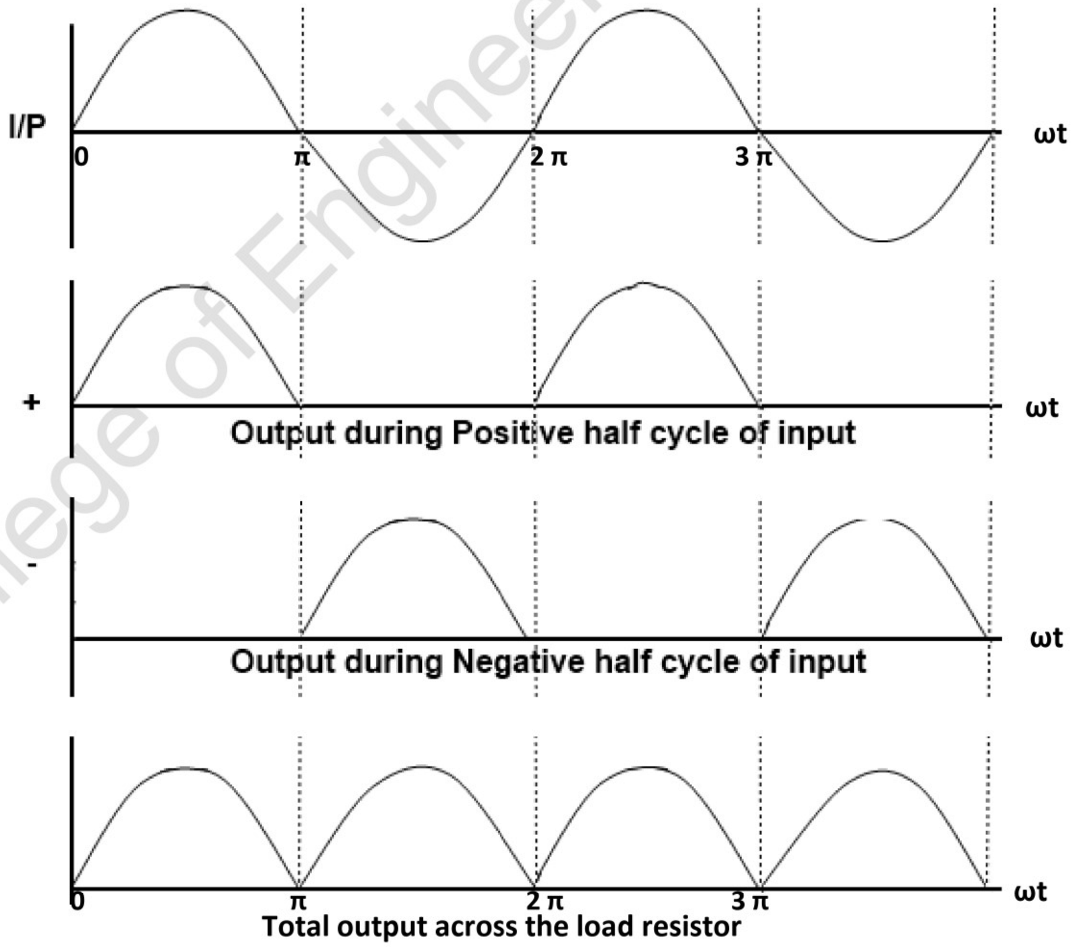
- The terminal **A is positive with respect to C.**
- The diodes **D_1 and D_3 are forward biased.**
- At this instant, the diodes D_2 and D_4 reverse biased.
- The current flows through D_1, R_L and D_3.

Case II: During the negative half cycle



- The terminal **A is negative with respect to C**
- The diodes **D_2 and D_4 are forward biased**.
- At this instant, the diodes D_1 and D_4 are reversed biased.
- The current flows through D_2 R_L and D_4.

- Thus, there is output voltage during both halves of the input cycle. It is also observed that the output across the load resistor is in the same direction for both the half cycles. i.e from right to left in the given circuit diagram.



$\theta = \omega t$

Let $V_{in} = V_m \sin\theta$ be sinusoidal voltage of frequency f (50 Hz) appearing across the secondary coil of the transformer. V_m is the peak amplitude of the input sinusoidal signal.

1. **Peak Inverse Voltage** (PIV) (implies maximum voltage) across the non-conducting diode **= V_m**
2. **Average values of Output voltage and current** is given by

$$\text{Average or DC value of the output voltage, } V_{dc} = \frac{\text{Area under the curve over a half cycle}}{\text{Base (half cycle)}}$$

$$= \frac{\int_0^\pi V_{in}\, d\theta}{\pi}$$

$$= \frac{\int_0^\pi V_m \sin\theta\, d\theta}{\pi}$$

$$= \frac{V_m}{\pi}\int_0^\pi \sin\theta\, d\theta \qquad \text{Since } \int_0^\pi \sin\theta\, d\theta = [-\cos\theta]_0^\pi = 2$$

$$\boxed{V_{dc} = \frac{2V_m}{\pi}}$$

Similarly,

$$\boxed{I_{dc} = \frac{2I_m}{\pi}}$$

3. **RMS value of Output voltage and current**

$$I_{rms} = \sqrt{\frac{\int_0^{2\pi} i_L^2 d\theta}{2\pi}} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I_m^2 \sin^2\theta d\theta}$$

On solving,

$$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}} \quad \& \quad \textit{Similarly,} \quad \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

4. **Ripple Factor**

$$Ripple\ Factor = \frac{rms\ value\ of\ ac\ component\ present\ in\ the\ output}{dc\ component}$$

Since the power dissipated in the load resistance defines the rms value of current and total power is the sum of the power dissipated by the direct and alternating components, we have

$$I_{rms}^2 R_L = I_{dc}^2 R_L + I_{ac}^2 R_L$$

$$I_{ac}^2 = I_{rms}^2 - I_{dc}^2$$

$$\boxed{\text{Ripple factor, } \gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}}$$

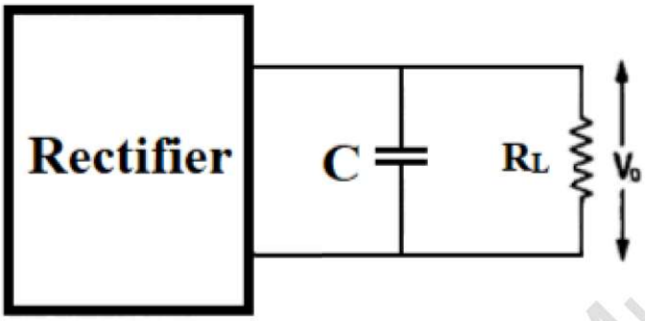
$$= \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1}$$

On solving,

$$\boxed{\gamma = 0.482}$$

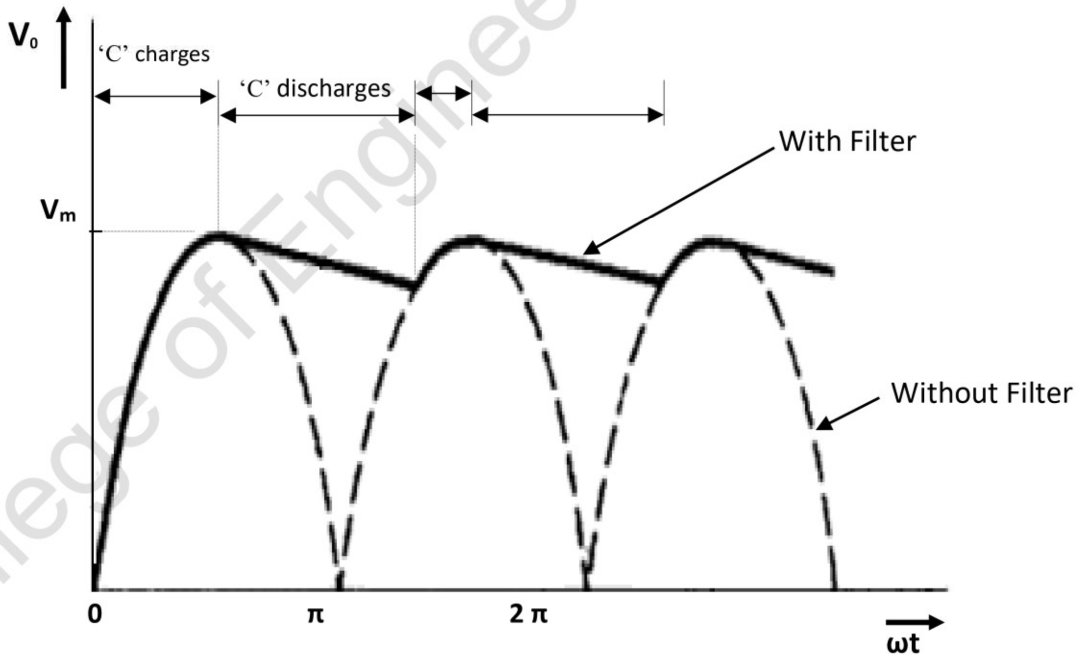
Capacitor filter

- This is the simplest and cheapest filter
- The output of a rectifier is pulsating in nature and contains considerable ripple in addition to the dc component. A filter is therefore introduced after rectifier in a power supply to remove the ac components or ripples without affecting the dc voltage.
- If (voltage applied across the capacitor) ≥ (voltage present in the capacitor), Then Capacitor charges. Else Capacitor discharges



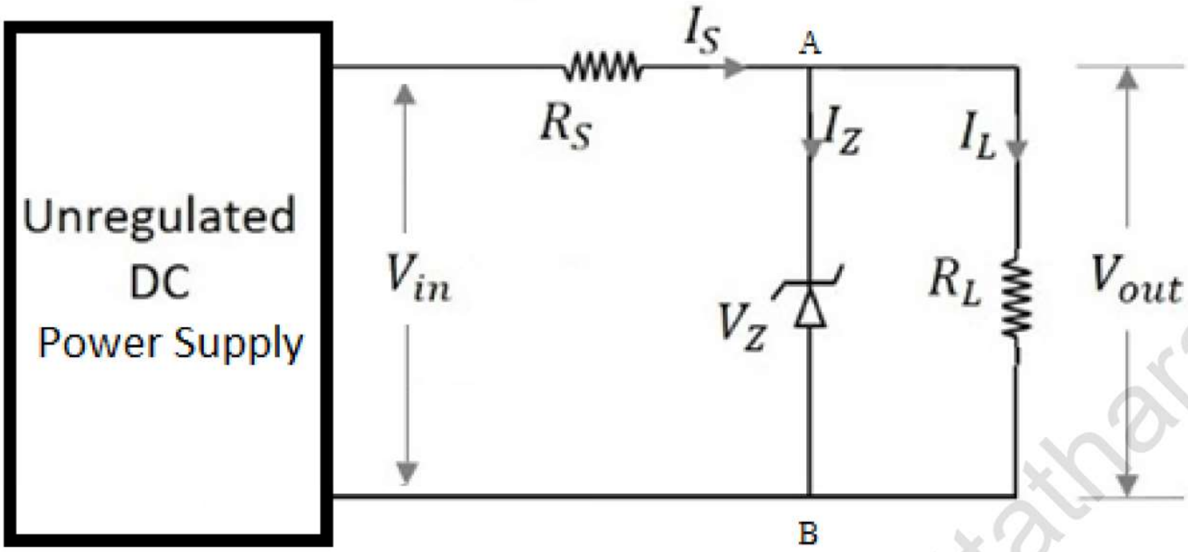
Circuit diagram: Rectifier with Capacitor Filter

- Connect **a large value capacitor C in shunt with the load resistor** R_L, as shown in Figure.
- **When the rectifier output voltage is increasing, the capacitor charges to the peak voltage V_m.**
- **After the positive peak is passed, the rectifier output voltage falls which permits the capacitor to discharge through resistor R_L.** This is shown in Figure.



- **To reduce the ripple in the rectified output, we should allow the capacitor to discharge slowly**.
- **Time constant = R_LC**
- Time constant implies the charging and the discharging rate of the Capacitor.
- The smaller the Resistance or the Capacitance, the smaller the Time Constant, the faster the charging and the discharging rate of the Capacitor, and vice versa.
- This means that value **of R_L should be as large as possible** so as **to reduce the ripples** and therefore capacitor filters are suitable for load current applications.

Working of simple Zener voltage regulator



- A zener diode can be used as a voltage regulator the Zener diode operates in the breakdown region maintains constant voltage across the load.
- The circuit consists of a current limiting resistor (R_s) and zener diode in parallel with the load resistance (R_L).
- **The Zener diode is selected in such a way that its breakdown voltage is equal to the desired regulating output.**
- If the input voltage is less than the Zener voltage, the diode does not conduct.
- **For proper operation, the voltage of an unregulated power supply must be greater than the zener voltage.**
- From circuit diagram,

  Using Kirchhoff current law at node A

  $$I_s = I_z + I_L \qquad \rightarrow eq\_1$$

  Using Kirchhoff voltage law

  $$V_{in} - I_s R_s - V_z = 0$$

  $$\Rightarrow V_z = V_{in} - I_s R_s \qquad \rightarrow eq\_2$$

- Once Zener breakdown occurs, **the voltage across the device remains constant** with rapid rise in current.

  $$\Rightarrow V_{out} = V_z = \text{constant}$$

  $$V_{out} = V_{in} - I_s R_s = \text{constant} \qquad \rightarrow eq\_3$$

- In the regulator circuit, any increase in input voltage beyond the designed level causes corresponding increase in current, I_s through the circuit.

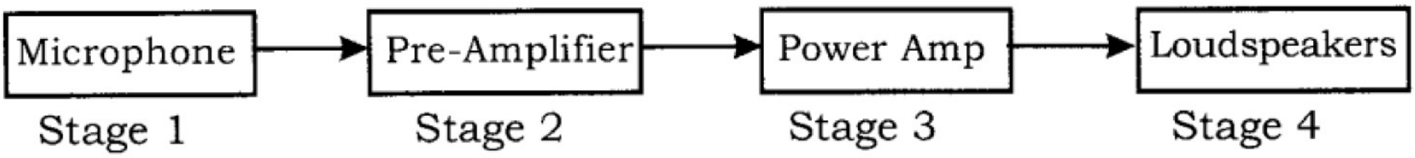
  As V_{in} increases, I_S increases, $I_S R_S$ increases => Keeping V_{out} = constant= $I_L R_L$
- Assume R_L = constant for a device

  $\Rightarrow$ I_L = constant
- Since this voltage ensures breakdown operation of Zener diode, the increase in input current I_S is fully reflected across zener.

  As I_S increases, (we know that $I_S = I_Z + I_L$), I_Z increases which will make I_L constant
- Therefore, load current I_L remains almost constant. So, variation in the load voltage is regulated by Zener diode.

Block diagram of Public Address system

- A "Public Address" system is anything that amplifies sound so more people can hear it.
- A simple public address system (or PA system) is shown in the following block diagram.



Stage 1: Microphone (Transducer)

- ✓ The microphone converts sound waves into electrical signals that can be processed by the rest of the system.
- ✓ It is important that the microphone **creates a faithful reproduction of the sound wave as an electrical signal.**

Stage 2: Pre-Amplifier

- ✓ It is basically a voltage amplifier.
- ✓ **Its purpose is to take the small electrical signals from the microphone and increase the amplitude of the signal voltage.**

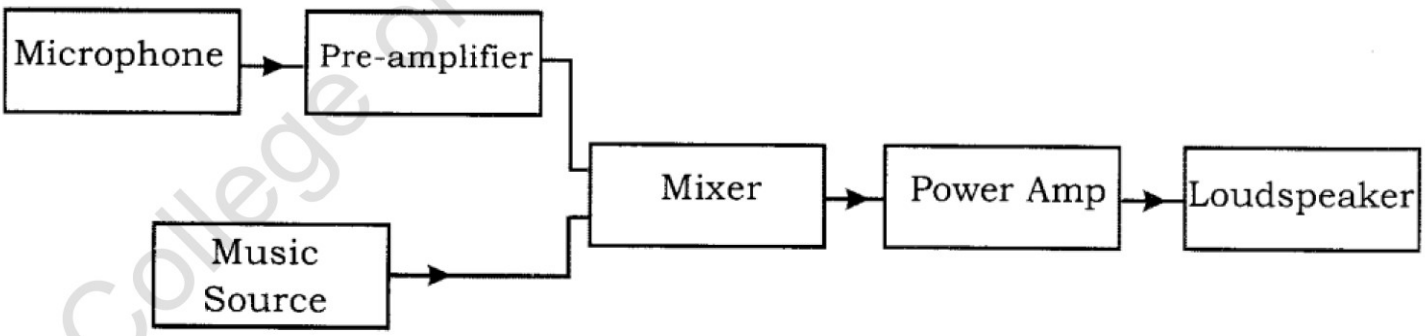
Stage 3: Power Amplifier

- ✓ The power amplifier **takes this enlarged voltage signal, and boosts the current so that it is strong enough to drive the, loudspeaker.**

Stage 4: Loud Speaker

- ✓ The loudspeaker is the final part of the system where the electrical signal is transformed back into a sound wave.

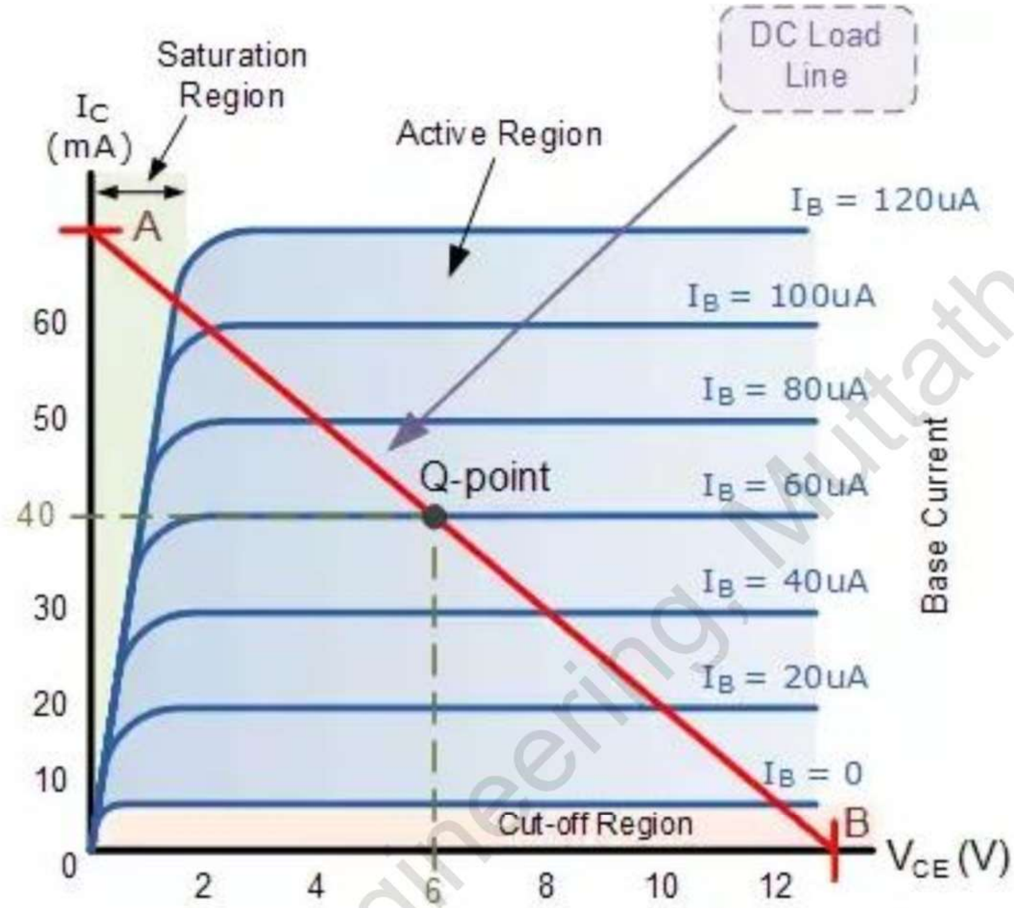
- If the system has carried out its function correctly, the emerging sound wave will be an undistorted but amplified version of the original.
- A more sophisticated PA system would allow a number of inputs to be connected
- For eg., a band would have several microphone inputs and guitar pick-up inputs. These inputs would need to be faded in or out individually.
- Consider the following block diagram



- It can be noticed that there are two additions to the simple PA system. The first is a music source and the second is a mixer.
- **Mixer:** Its function is to add together electrical signals from microphones or pick-ups from electric guitars or sound tracks from a CD player.
- Most music sources produce a much larger signal than a microphone and do not need a pre-amplifier.
- **In a real system, each microphone would have its own pre-amplifier.**
- **Clipping:** If we try to amplify the signal too much the system will not be able to provide the voltage required. This results in distortion of the output signal, called **clipping distortion.**

Why bias a transistor?

DC biasing is a static operation. It deals with setting a fixed (steady) level of current with a desired fixed voltage drop across the device. For eg, consider Common-Emitter Configuration. The purpose of dc biasing of a transistor is to obtain certain dc collector current I_C at a certain dc collector voltage V_{CE}.



These values of I_C and V_{CE} define the point, at which the transistor operates. This point is known as operating point (or quiescent point or Q-point).

Modes of Operation of transistor is changed by changing the operating point

E-B Junction	C-B Junction	Region of Operation	Application
Forward Biased	Forward Biased	**Saturation region**	ON Switch
Forward Biased	***Reverse Biased***	***Forward Active region (or simply "Active region")***	***Amplifiers***
Reverse Biased	Reverse Biased	**Cut-off region**	OFF Switch

Methods of Transistor Biasing

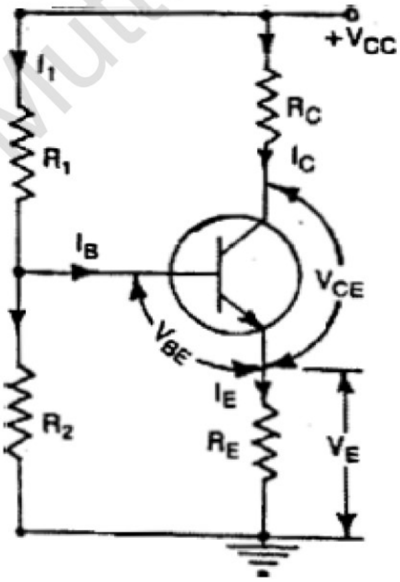
The following are the most commonly used biasing arrangements employing single supply source

(i) Base resistor biasing
(iii) Emitter resistor biasing
(ii) Feedback resistor biasing
(iv) Voltage divider biasing.
Out of the above said methods, the most common and popular method is voltage divider biasing.

Concept of voltage divider biasing

- In this biasing circuit as shown the figure, **two resistors R_1 and R_2 are connected across the supply voltage V_{cc}** and thus it **provides the necessary biasing.**
- A resistor connected in the emitter circuit **R_E provides stability.**
- If R_E is not present, the transistor may get damaged due to thermal runaway.
- If R_E is present, voltage drop across R_E increases with increase in current due to excess power dissipation.
- This voltage drop is in a direction to reverse bias the base-emitter junction of the transistor.
- Now, base current **I_B** is reduced, which in turn reduces the collector current **I_C**.
  - ⇨ Corresponding reduction in power at collector junction => thus stabilizes both I_B and I_C.
- Since the resistors R_1 and R_2 form the voltage divider hence the name voltage divider biasing.
- The voltage drop across R_2 forward bias the base emitter junction and causes the base current.
- Hence, collector current flows which sets up the zero signal conditions. This is the most widely used method of providing biasing and stabilisation to transistor since the operating point in this case, can be made almost independent of β.

Circuit Analysis of voltage divider biasing



Let current I_1 flows through resistors R_1
current I_2 flows through resistors R_2
By Kirchhoff's current law, $I_1 = I_2 + I_B$

Since base current I_B is very small, it can be neglected

$$I_1 \cong I_2$$

Voltage across resistor R_2 is given by $(using\ voltage\ division\ rule)$

$$V_2 = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC}$$

Writing loop equation in base emitter circuit, we get
$V_2 = V_{BE} + V_E$

$V_2 = V_{BE} + I_E R_E$ (since $V_E = I_E R_E$)

$I_E = \dfrac{V_2 - V_{BE}}{R_E} \cong I_C$ ($I_E = I_C + I_B$ and I_B is very small)

In all practical circuits $V_2 >> V_{BE}$, therefore, V_{BE} is neglected.

$$I_C = \frac{V_2}{R_E}$$

Applying Kirchhoff's voltage law to the output (collector) side, we get,

$V_{CC} = I_C R_C + V_{CE} + I_E R_E$

$V_{CC} = I_C R_C + V_{CE} + I_C R_E$ (since $I_E \cong I_C$)

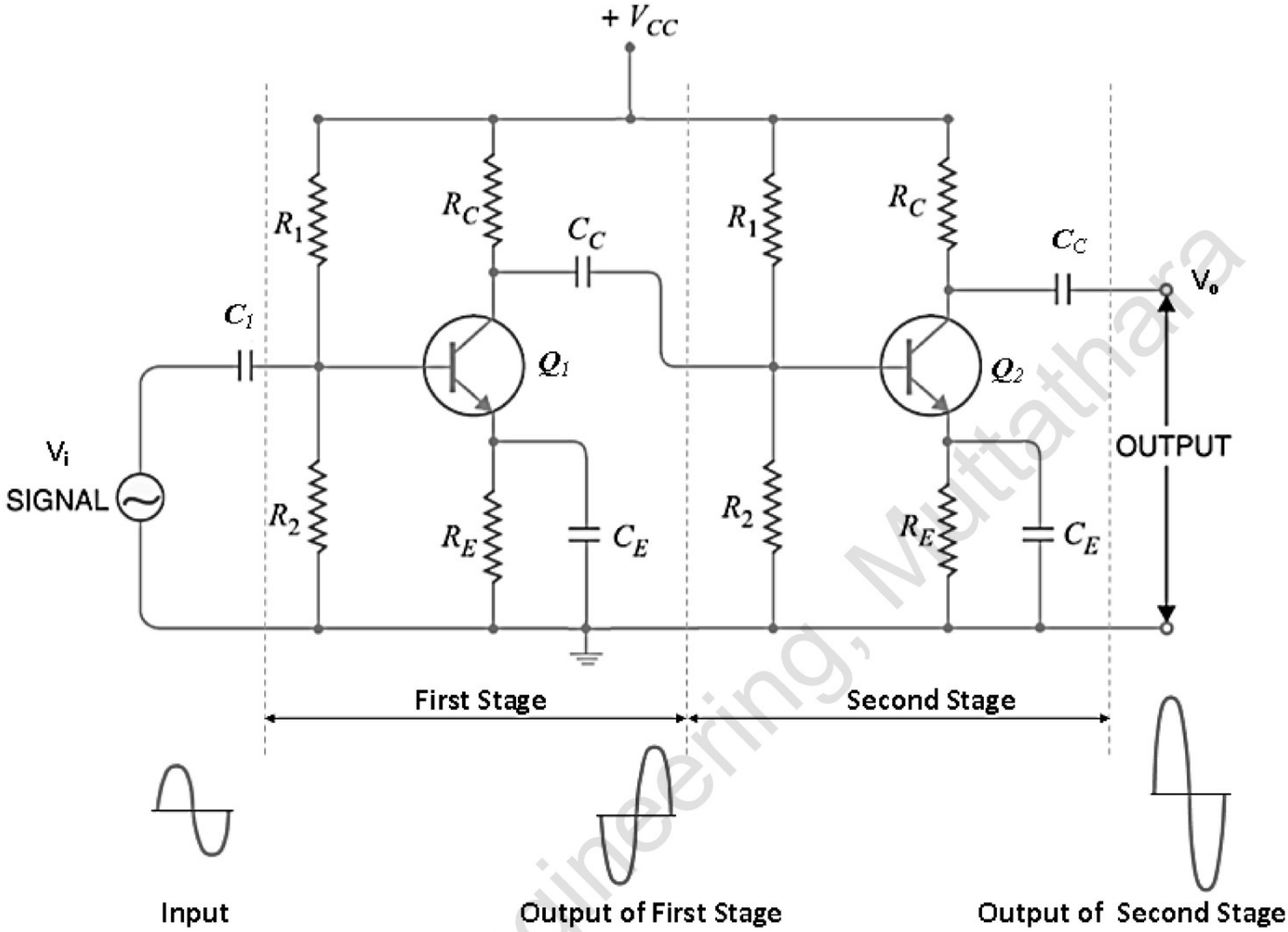
Taking V_{CE} to L.H.S, and rest terms to R.H.S, we get

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

This is the most widely used method of providing biasing and stabilisation to transistor since the operating point in this case, can be made almost independent of β.

Circuit diagram and working of common emitter (RC coupled) amplifier with its frequency response

The circuit consists of two single-stage common-emitter transistor amplifier



The function of each component in the circuit is explained below

1) **Transistor:** Q_1: Transistor of 1st stage ; Q_2: Transistor of 2 stage
2) **Capacitor:**
   a) Input Coupling capacitor C_1
      - ✓ Used to couple the input signal to the base of Q_1.
      - ✓ Block dc only (This ensure that biasing of transistor is not affected)

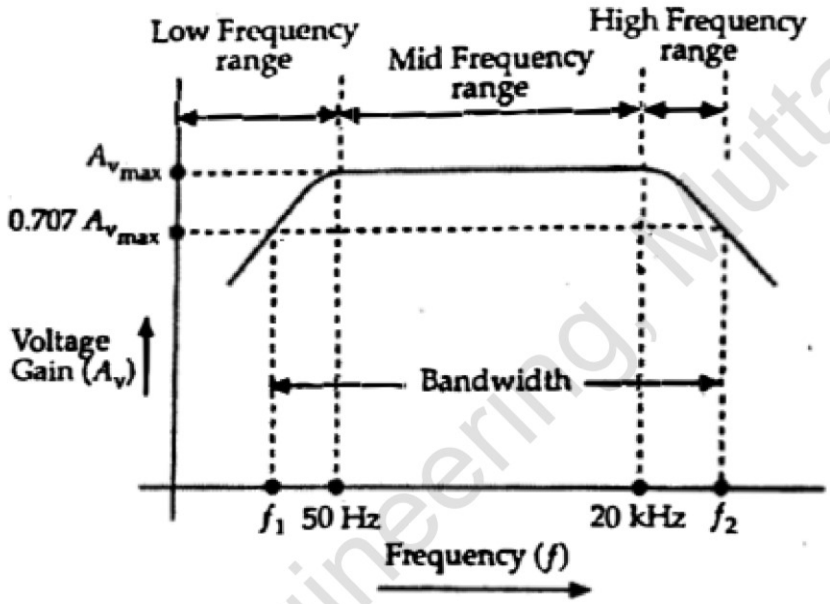
   b) Collector Coupling capacitor, C_C
      - ✓ Used to couple various stages (when cascaded)
      - ✓ Block dc only (This ensure that biasing of transistor is not affected)

   c) Emitter by-pass capacitor, C_E to eliminate feedback
      - ✓ Bypass only ac signal to ground. Thus, dc component pass through R_E.
      - ✓ This ensure that biasing and stability of transistor is not affected.
      - ✓ Without it, the voltage gain of each stage would be lost.
3) **Resistor**
   a) R_1 and R_2 : Voltage divider bias to give a suitable forward bias at base-emitter junction.
   b) R_C : Collector resistor which decides the operating (Q) point.
   c) R_E : Emitter resistor to improve thermal stabilization

Operation :

- When an ac signal is applied to the input of the first stage, it is amplified with a phase reversal by transistor Q_1 and appears across the Collector Resistor R_C.
- This amplified signal is given to the input of the second stage through a coupling capacitor Cc.
- The second stage further amplifies the signal. The amplified output appears across Rc, in the collector of Q_2 with further phase reversal.
- The output signal of a two stage R-C coupled amplifier is the twice-amplified replica of the input signal.
- It is in phase with input signal because it has been reversed twice.
- The total gain is less than the product of the gains of individual stages.

FREQUENCY RESPONSE OF R-C COUPLED AMPLIFIER



- It is evident from the graph that the voltage gain drops off at low frequencies (i.e.,frequencies below 50 Hz) and at high frequencies (i.e., frequencies above 20 kHz), while it remains constant in the mid-frequency range (i.e., 50 Hz to20 kHz).

Reactance of capacitor, $X_c = \frac{1}{2\pi f C}$

1) **At low frequencies (i.e., below 50 Hz)**
   - At low frequencies, Capacitor offers a **high reactance** (or high impedance).
     - ✓ **Coupling capacitors Cc can't effectively couple** the signal from one stage to the next stage.
     - ✓ In addition to this, the **emitter bypass capacitor** C_E **can't effectively bypass ac signal** to ground
   - As a result of these two factors, the voltage gain drops off at low frequencies.
2) **At high frequencies (i.e., above 20 kHz)**
   - At high frequencies, Capacitor offers a **low reactance** (or low impedance).
     - ✓ **Coupling capacitor Cc acts as a short circuit**. Thus, allows dc to pass through it. As a result of this, the loading effect of the next stage increases, which reduces the voltage gain.
     - ✓ **Short circuiting effects of (internal) junction capacitor of the transistor**, mainly collector to base and base to emitter junction capacitances.
   - As a result of these two factors, the voltage gain drops off at high frequencies.
3) **At mid frequencies (i.e., 50 Hz to 20 kHz)**
   - The effect of coupling capacitor is such that it maintains a constant voltage gain.

- Thus, as the frequency increases, the **reactance of coupling capacitor Cc decreases**, which tends to **increase the gain.**
- However, at the same time, **due to low capacitive reactance**, there will **be higher loading effect** and **gain will be reduced.**
- These two factors cancel each other. Thus, a constant voltage gain is maintained throughout in the mid-frequency range.

- **Bandwidth of an Amplifier**

➢ The limit is set at those frequencies at which the **voltage gain reduces to 70.7% of the maximum** voltage gain Av_{max}

➢ These frequencies are known as **cut-off frequencies** of the amplifier and are marked as f_1 and f_2, as shown in Fig.

➢ The frequency f_1 is the lower cut-off frequency and the frequency f_2 is the upper cut-off frequency.

➢ The difference of the two frequencies is called the bandwidth of the amplifier.

Bandwidth = $(f_2 - f_1)$ Hz

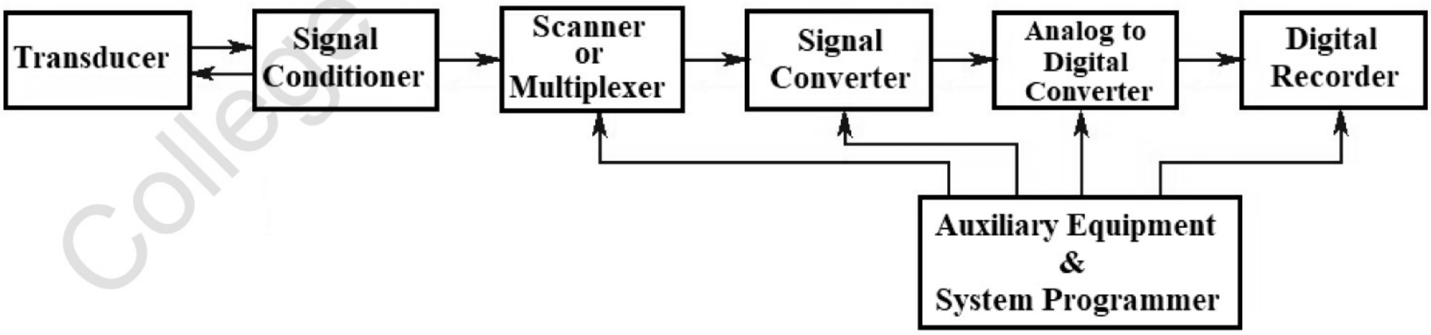
Advantages of R-C coupled amplifier

1. It requires cheap components like resistors and capacitors. Hence, it is small, light and inexpensive.
2. It has a wide frequency response. The gain is constant over the audio frequency range which is the region of most importance for speech, music, etc.
3. It provides less frequency distortion.
4. Its overall amplification is higher than that of the other couplings.

Disadvantages of R-C coupled amplifier

1. The overall gain of the amplifier is comparatively small because of the loading effect of successive stages.
2. R-C coupled amplifiers have tendency to become noisy with age, especially in moist climates.
3. The impedance matching is poor as the output impedance of R-C coupled amplifier is several hundred ohms, whereas that of a speaker is only a few ohms. Hence small amount of power will be transferred to the speaker.

Block diagram of an electronic instrumentation system



Transducer is a device that converts variations in a physical quantity, such as pressure or brightness, into an electrical signal, or vice versa. All the physical input parameters such as temperature, pressure, displacement, velocity, acceleration, **pressure or brightness** ,etc will be converted into its proportionate electrical signal.

Signal Conditioning Unit: This working of this unit is exactly the same as that of a signal processing unit in an analog instrumentation system. It includes all the balancing circuits and calibrating elements along with it.

Scanner/Multiplexer: Multiple analog signals are received by this device and are sequentially provided on to a measuring instrument.

Signal Converter: It is used to convert an analog signal to a form that is acceptable by the analog to digital converter.

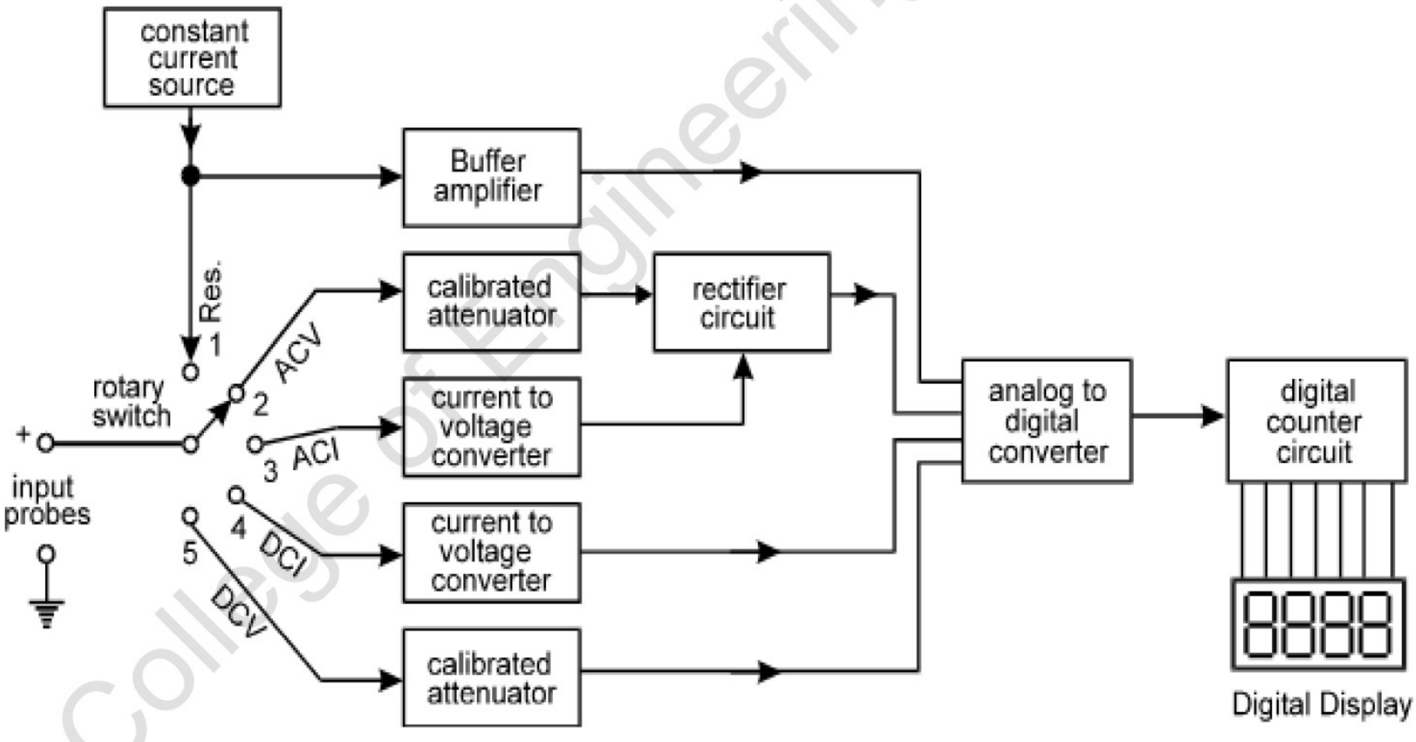
Analog to (A-D) Digital Converter: The analog signal is converted into its proportional digital signal. The output of an A-D converter is given to a digital display.

Auxiliary Equipment: All the system programming and digital data processing functions are carried out by this unit. The auxiliary equipment may be a single computer or may be a collection of individual instruments. Some of its basic functions include linearizing and limit comparison.

Digital Recorder: The readout or display devices may be in analog or digital format. It is mostly a CRO or a computer.
The main advantages of these devices are high accuracy, high speed, and elimination of human operational errors.

Working principle of operation of digital multimeter

Digital multimeter (DMM) is basically a digital voltmeter and may be used for the measurement of voltage, current (dc or ac) and its resistance. All quantities other than dc voltage are first converted into and equivalent dc voltage by some device.



Res: Resistance; ACV: AC voltage; ACI:AC current; DCI: DC current; DCV: DC voltage

To measure resistance:
Connect an unknown resistor across its input probes. Keep rotary switch in the position-1 (refer block diagram above). The proportional current flows through the resistor, from constant current source. According to Ohm's law voltage is produced across it. This voltage is directly proportional to its resistance. This voltage is buffered and fed to A-D converter, to get digital display in Ohms.

To measure AC voltage

Connect an unknown AC voltage across the input probes. Keep rotary switch in position-2. The voltage is attenuated, if it is above the selected range and then rectified to convert it into proportional DC voltage. It is then fed to A-D converter to get the digital display in Volts.

To measure AC current

Current is indirectly measured by converting it into proportional voltage. Connect an unknown AC current across input probes. Keep the switch in position-3. The current is converted into voltage proportionally with the help of I-V converter and then rectified. Now the voltage in terms of AC current is fed to A-D converter to get digital display in Amperes.

To measure DC current

The DC current is also measured indirectly. Connect an unknown DC current across input probes. Keep the switch in position-4. The current is converted into voltage proportionally with the help of I-V converter. Now the voltage in terms of DC current is fed to A-D converter to get the digital display in Amperes.

To measure DC voltage

Connect an unknown DC voltage across input probes. Keep the switch in position-5. The voltage is attenuated, if it is above the selected range and then directly fed to A-D converter to get the digital display in Volts.

Comparison between digital and analog meters

Digital meter	Analog meter
No error in the reading	Wrong scale may be used or might be read incorrectly
Digital display	Indication by pointer on a calibrated scale
Highest resolution and accuracy	Inferior resolution and accuracy
Indicates a negative quantity when the polarity is reversed	Pointer attempts to deflect to the left of zero when the polarity is reversed
Not damaged by rough treatment	Can damage if dropped from some medium levels
Display takes few seconds	Pointer responds more quickly

Questions (Module 5)

PART A

Each question carries 4 marks.

1. **Draw the block diagram of regulated power supply.**
2. **Explain the working of a full wave bridge rectifier**
3. **Explain the working of simple Zener voltage regulator.**
4. **Draw the block diagram of Public Address system.**
5. **Draw the frequency response characteristics of an RC coupled amplifier and state the reasons for the reduction of gain at lower and higher frequencies.**
6. Explain the Concept of voltage divider biasing.
7. What is the need of voltage divider biasing in an RC coupled amplifier?
8. Define operating point in the context of a BJT amplifier.
9. Why is it required to have a voltage amplifier (pre-amplifier) in a public address system?
10. Why is it required to have a power amplifier in a public address system?
11. **Draw the block diagram of an electronic instrumentation system.**
12. What is a transducer?
13. **Draw the block diagram of digital multimeter.**
14. List the comparison between digital and analog meters.
15. **Define peak inverse voltage (PIV).**

PART B

Each question carries 10 marks.

16. **Draw and Explain the block diagram of regulated power supply.**
17. **Explain the working of a full wave bridge rectifier with neat diagram.**
18. Explain the capacitor filter with neat diagram.
19. **Explain the working of simple Zener voltage regulator with neat diagram.**
20. **Draw and Explain the block diagram of Public Address system**
21. Explain the working of common emitter (RC coupled) amplifier with its frequency response
22. **Draw the circuit and explain the working of RC coupled common emitter amplifier. Plot its frequency response showing the cut off frequencies.**
23. **a) With a neat circuit diagram, explain the working of an RC coupled amplifier.**
    b) Draw the frequency response characteristics of an RC coupled amplifier and state the reasons for the reduction of gain at lower and higher frequencies.
24. **Discuss the need for biasing in amplifiers. Explain the functions of each component in RC coupled amplifier with relevant waveform**
25. **Draw and explain the block diagram of an electronic instrumentation system.**
26. **Explain the working principle of operation of digital multimeter with neat block diagram.**