Module 5

Basic Electronic Circuits and Instrumentation

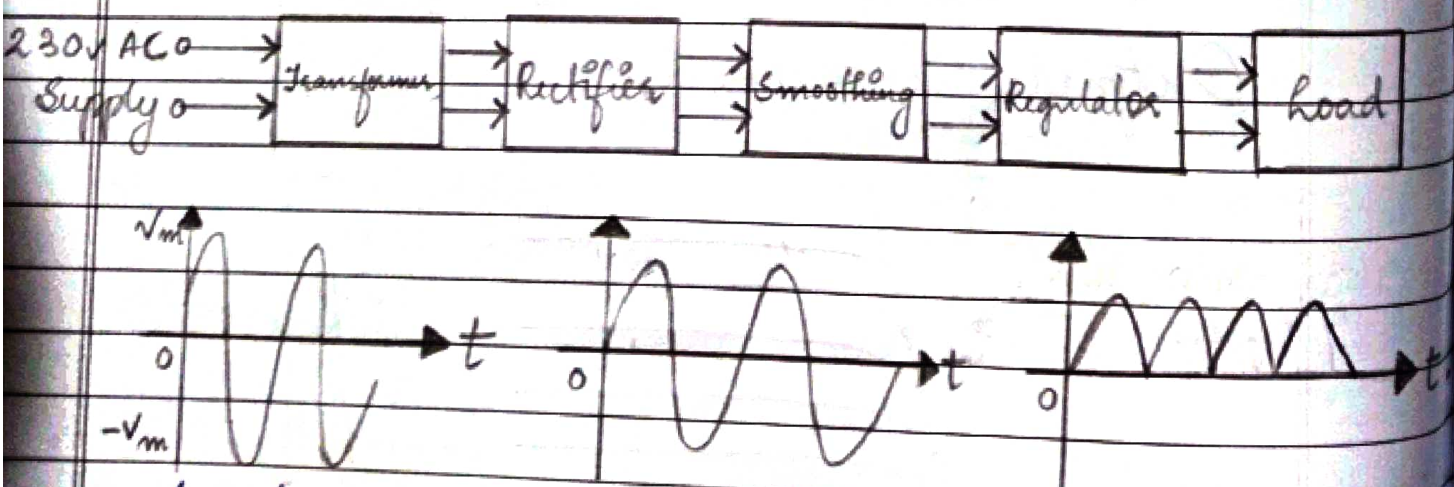
* **Rectifiers :**

A rectifier is an electrical device that converts alternating current, which periodically reverses direction, to direct current, which flows in only one direction. The reverse operation is performed by the inverter. The process is known as rectification.

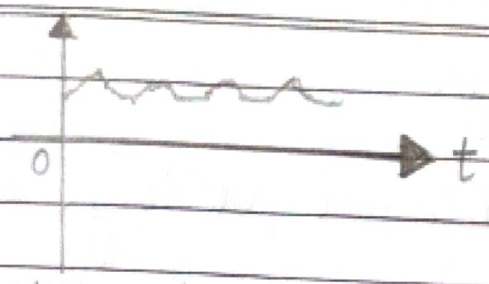
* **Power Supply**

A power supply is an electrical device that supplies electric power to an electrical load.

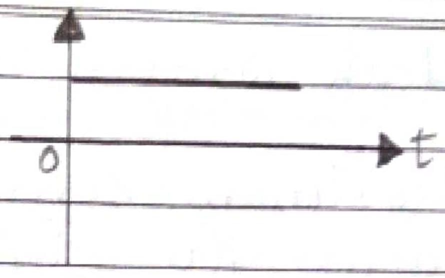
* **Block Diagram of DC Power Supply**



Input Waveform   Transformer output   Rectified Output

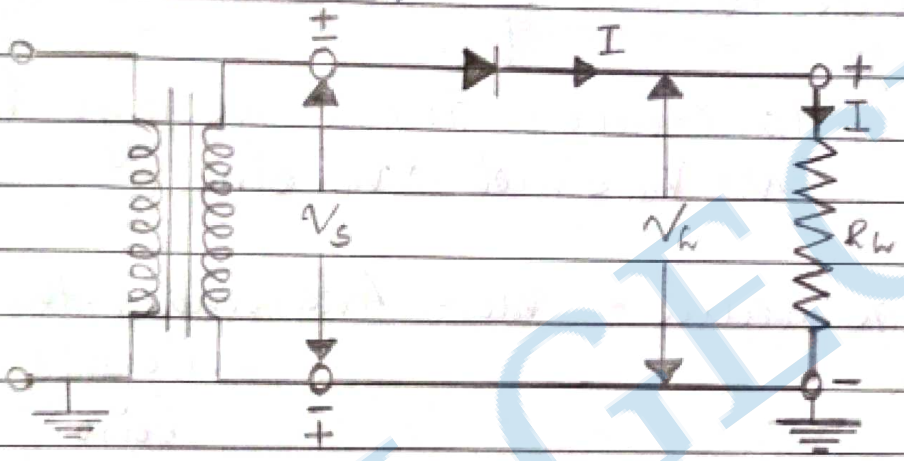


Filtered Output

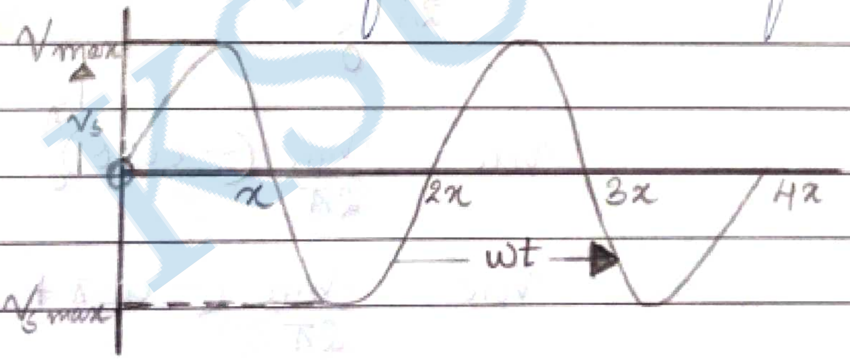


Pure dc output

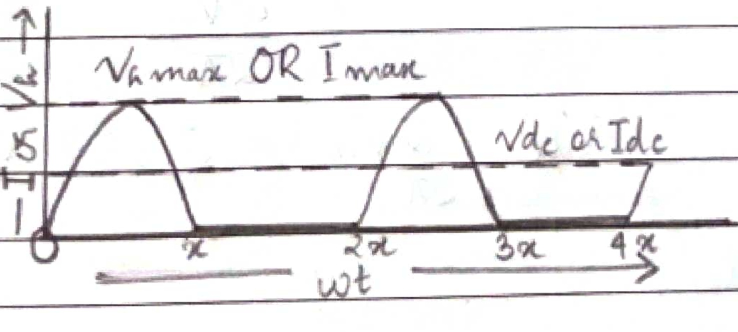
* Half wave Rectifier



Half-Wave Rectifier



Input Voltage Waveform



* **Peak Inverse Voltage**

- Maximum reverse biased voltage appears across the diode.

- Half wave rectifiers, PIV = V_m.

* **Average Values of Voltage & Current**

- Let instantaneous input voltage be $v = V_m \sin\omega t = V_m \sin\theta$

- Average value = V_{dc} = $\frac{\text{Area under the wave in one cycle}}{\text{base}}$

$$V_{dc} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta \, d\theta$$

$$V_{dc} = \frac{V_m}{2\pi}(-\cos\theta)_0^{\pi}$$

$$V_{dc} = \frac{V_m}{2\pi}(-\cos\pi + \cos 0)$$

$$= \frac{V_m}{2\pi}(1+1)$$

$$= \frac{2V_m}{2\pi}$$

$$V_{dc} = \frac{2V_m}{2\pi} = \frac{0.637\ V_m}{2} = 0.316\,V_m$$

Similarly,

$$I_{dc} = \frac{2I_m}{2\pi} = \frac{0.637\ I_m}{2} = 0.316\,I_m$$

papergrid

Date: / /

- $I_m = \frac{V_m}{R_L}$

* RMS Values of Voltage & Current

$$\text{RMS value} = \sqrt{\frac{1}{2\pi}\int_0^{\pi}(I_m \sin\omega t)^2 d(\omega t) + \frac{1}{2\pi}\int_0^{2\pi} 0\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi} \sin^2\omega t\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi} 2\sin^2\omega t\, d(\omega t)}$$

$$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1-\cos(2\omega t)\, d(\omega t)}$$

$$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1\, d\omega t - \int_0^{\pi}\cos(2\omega t)\, d\omega t}$$

$$= \frac{I_m}{2}\sqrt{\frac{1}{\pi}[\pi - 0]}$$

$$= \frac{I_m}{2} = 0.5 I_m$$

||ly $V_{rms} = V_m/2$

* Ripple Factor (γ)

- Ratio of rms value of ac component of load current to the average value of load current.

$$\text{Ripple factor} = \frac{\text{r.m.s value of a.c. component}}{\text{value of d.c. component}}$$

$$= \frac{I_{ac}}{I_{dc}}$$

By definition, the effective or r.m.s value of total load current is given by:

Or $$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

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

Dividing throughout by I_{dc}, we get

$$\frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

But I_{ac}/I_{dc} is the ripple factor

$\therefore$ $$\text{Ripple factor} = \frac{1}{I_{dc}}\sqrt{I_{rms}^2 - I_{dc}^2}$$

$$= \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$I_{rms} = \frac{I_m}{2}, \quad I_{dc} = \frac{I_m}{\pi}$$

$$\text{Ripple factor} = \sqrt{\left(\frac{I_m \times \pi}{I_m \times 2}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{4} - 1}$$

$$= \sqrt{\frac{\pi^2 - 4}{4}} = \frac{\sqrt{\pi^2 - 4}}{2}$$

$$= \frac{\sqrt{9.8596 - 4}}{2} = \frac{2.42}{2} = 1.21$$

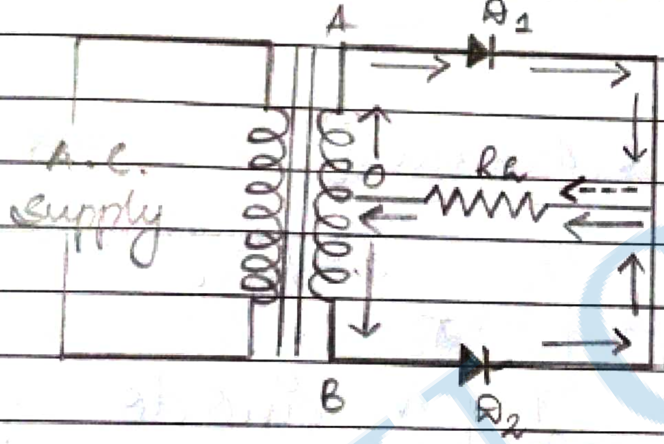
papergrid
Date: / /

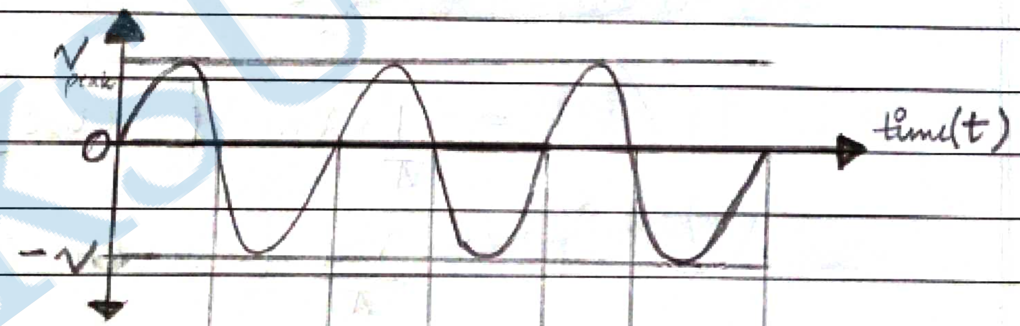
* ## Voltage regulation

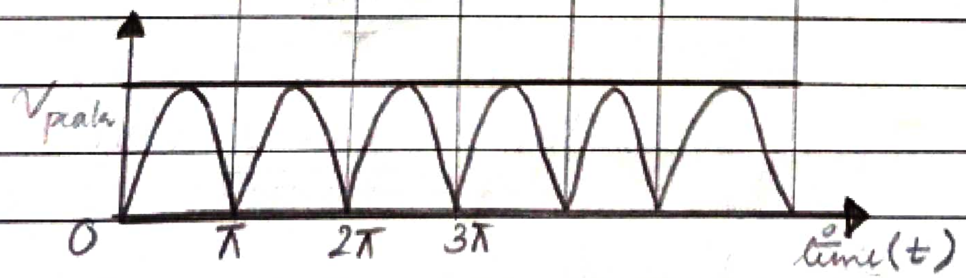
Measure of variation of dc output voltage as a function of dc current.

$$\% \text{ regulation} = \frac{(V_{no\,load} - V_{full\,load}) \times 100}{V_{full\,load}}$$

* ## Full Wave Rectifier





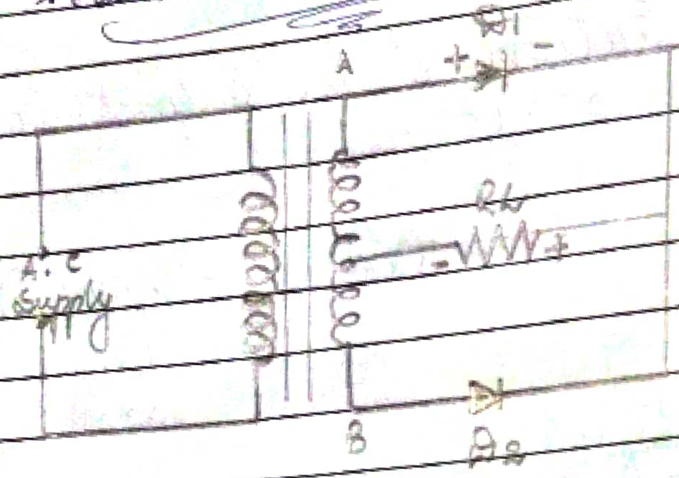


Average value

$V_{avg} = \frac{\text{Area under the wave for one cycle}}{\text{base}}$

Date: / /

* Peak Inverse Voltage



Applying KVL

$-V_m - V_m - V_D = 0$

$V_D = 2V_m$

$PIV = 2V_m$

* Average value

$$V_{avg} = V_{dc} = \frac{\text{Area under the wave in one cycle}}{\text{base}}$$

$$= \frac{1}{\pi}\int_0^{\pi} V_m \sin\theta \, d\theta \quad \{v = V_m \sin\theta\}$$

$$= \frac{1}{\pi} \times V_m \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{V_m}{\pi}\left[-\cos\pi + \cos 0\right]$$

$$= \frac{2V_m}{\pi}$$

$$V_{dc} = 0.637 V_m$$

∴ Similarly,

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

$$= 0.637 I_m$$

papergrid

Date: / /

* RMS value of voltage & current

$$\text{RMS value} = \sqrt{\frac{1}{\pi}\int_0^{\pi}(I_m \sin \omega t)^2 d\omega t + \frac{1}{\pi}\int_{\pi}^{2\pi} 0 \, d\omega t}$$

$$= \sqrt{\frac{I_m^2}{\pi}\int_0^{\pi} \sin^2\omega t \, d(\omega t)}$$

$$= I_m \sqrt{\frac{1}{2\pi}\int_0^{\pi} 2\sin^2\omega t \, d(\omega t)}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1-\cos(2\omega t) \, d(\omega t)}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\int_0^{\pi} 1 \, d\omega t - \int_0^{\pi}\cos(2\omega t) d\omega t}$$

$$= \frac{I_m}{\sqrt{2}}\sqrt{\frac{1}{\pi} \times [\pi - 0]}$$

$$= \frac{I_m}{\sqrt{2}}$$

Similarly,

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

* Ripple factor

$$R.F = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

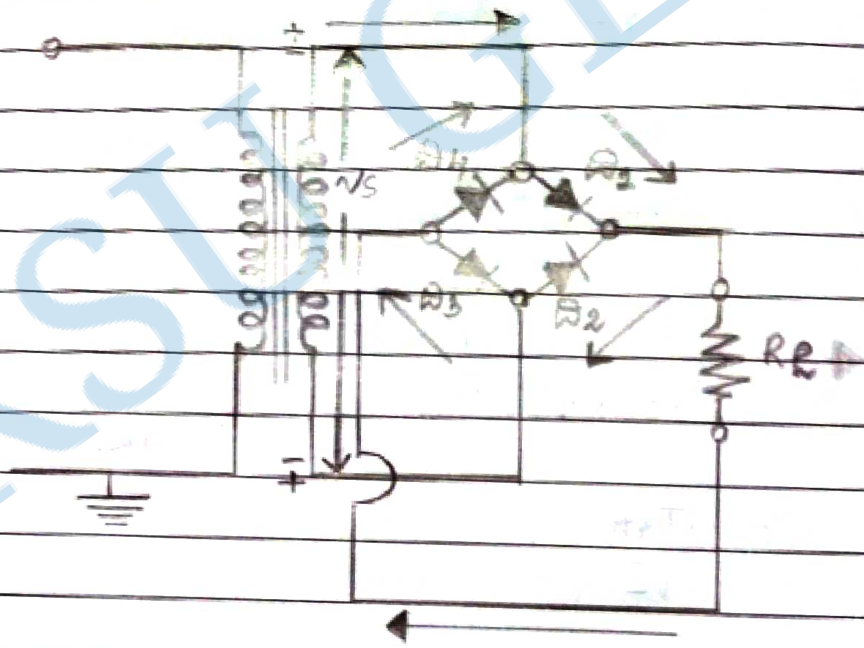
$$= \sqrt{\left(\frac{I_m}{\sqrt{2}} \times \frac{\pi}{2I_m}\right)^2 - 1}$$

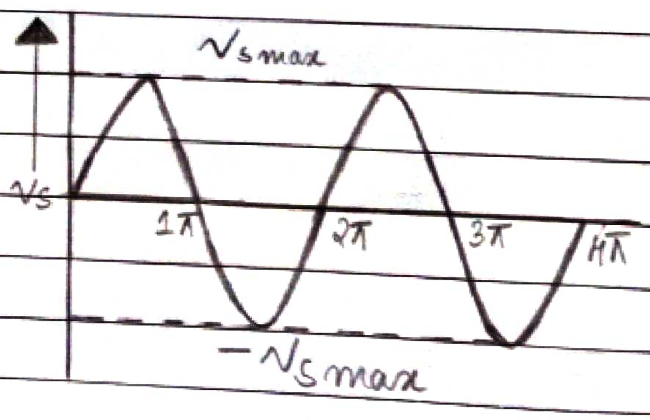
$$= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2 - 8}{8}} = \frac{1.363}{2\sqrt{2}}$$

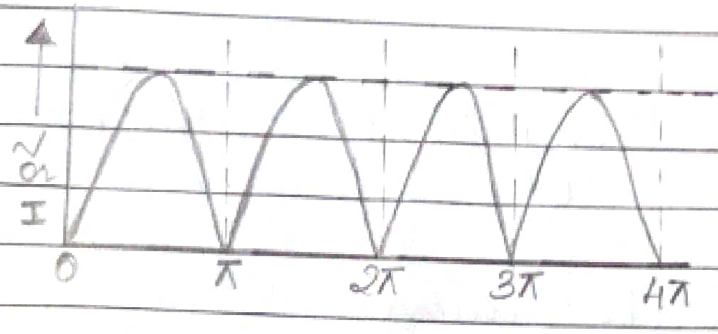
$$= \underline{\underline{0.482}}$$

★ **Bridge Rectifiers**

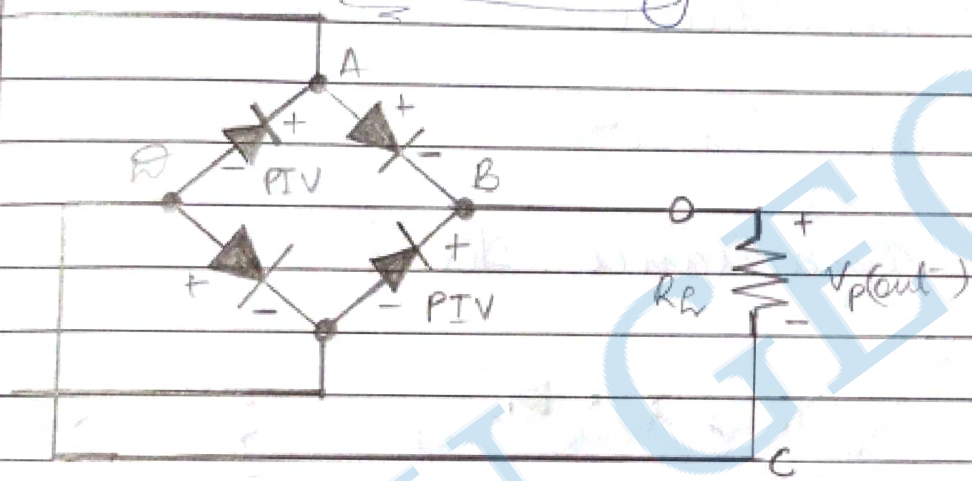


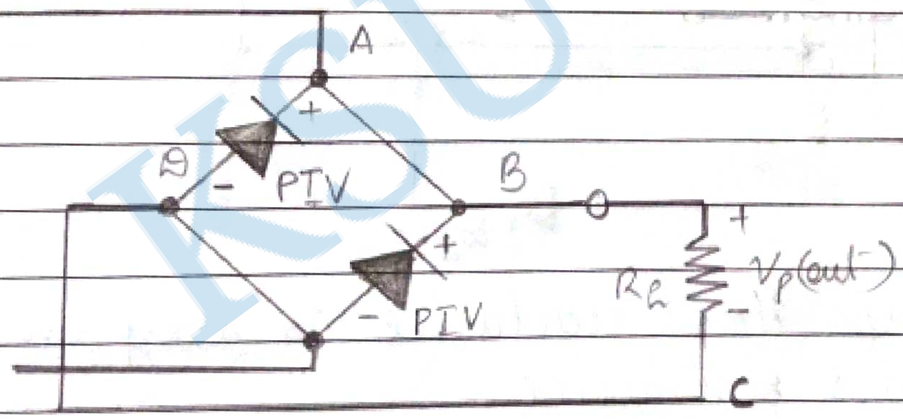


Date: / /



★ Peak Inverse Voltage





- Applying KVL

$V_d - V_p = 0$

$V_d = V_p$

$V_{dm} = V_{pm}$

$PIV = V_{pm}$

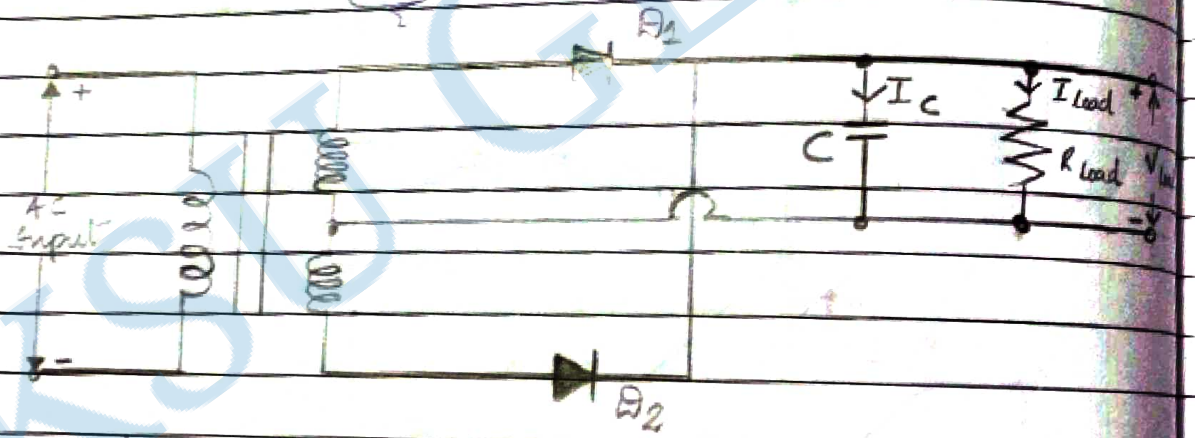
papergrid

Date: / /

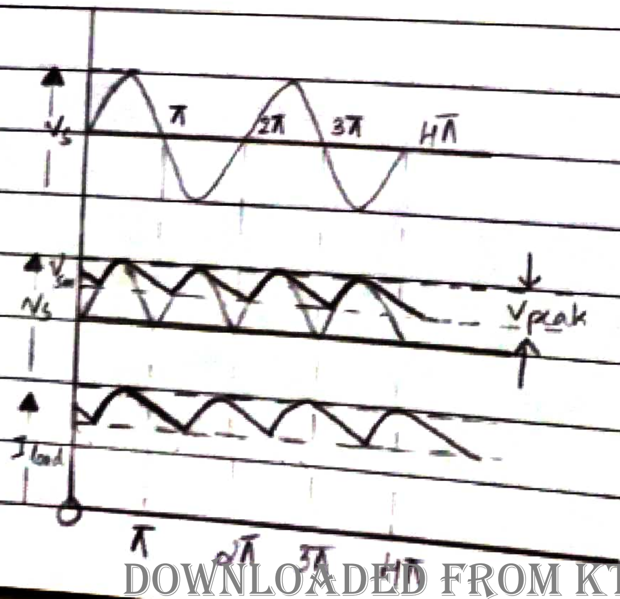
* Filters

- Presents of AC component is the cause of fluctuation - ripple
- A circuit which removes the ripple from the output without affecting DC value
- Shunt capacitance
- Series inductance

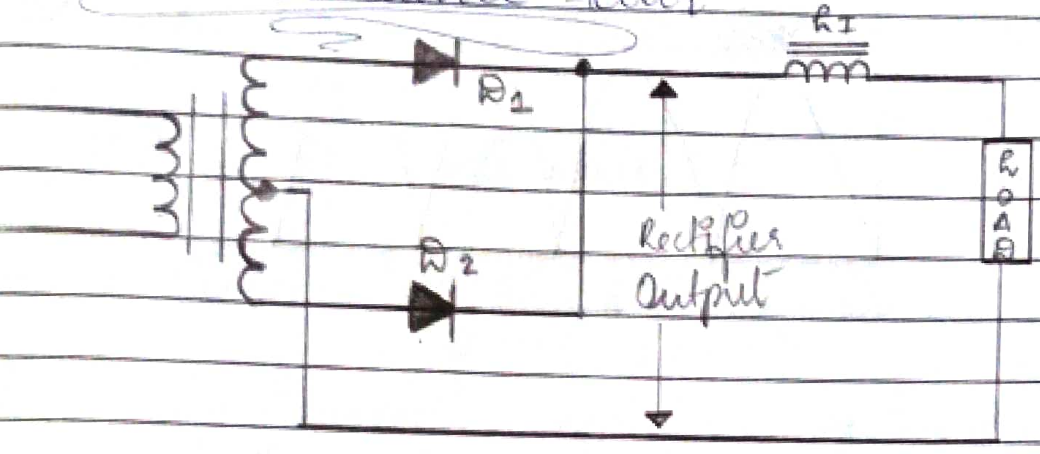
* Shunt Capacitance Filter

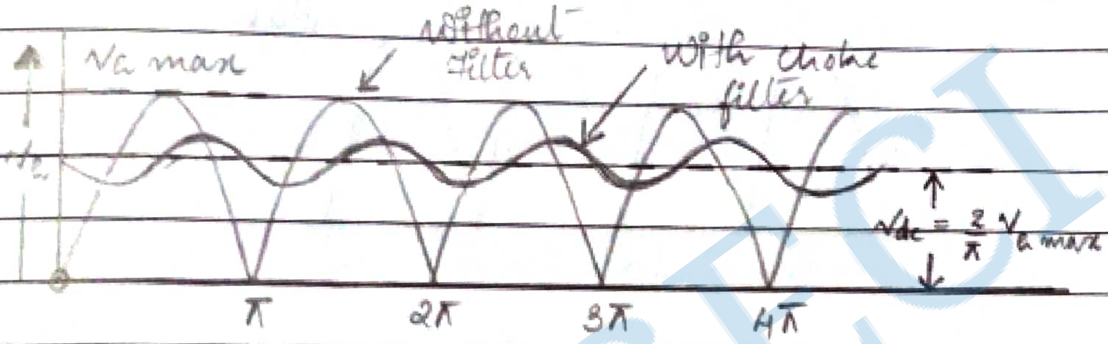


- Shunt capacitor reactance is very small than load resistance.

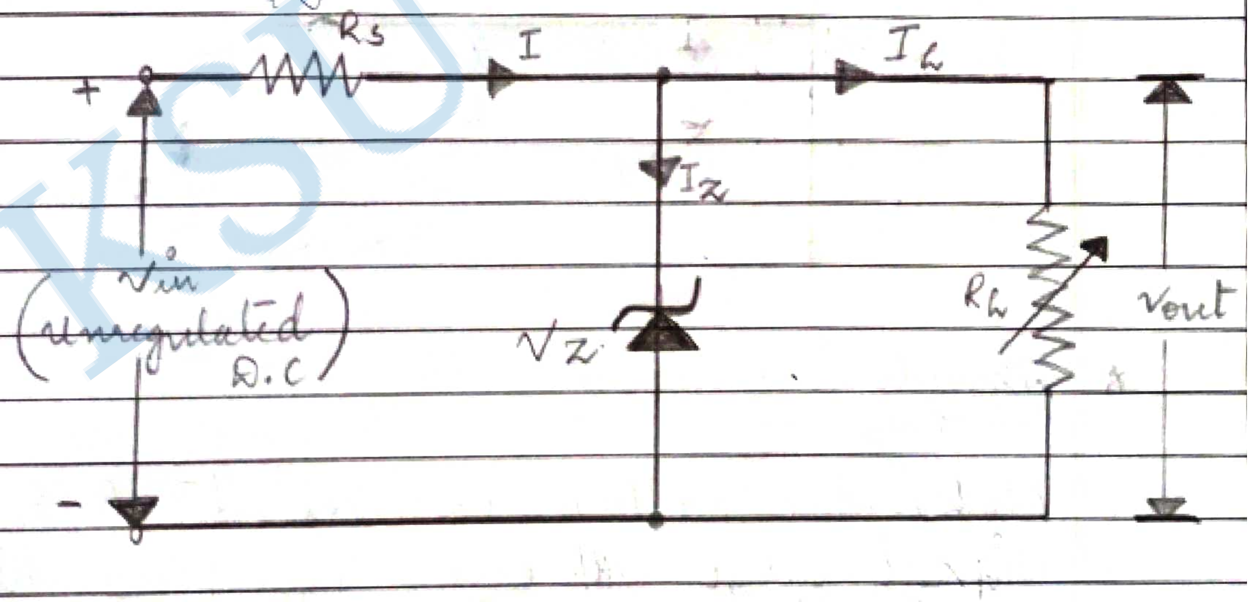


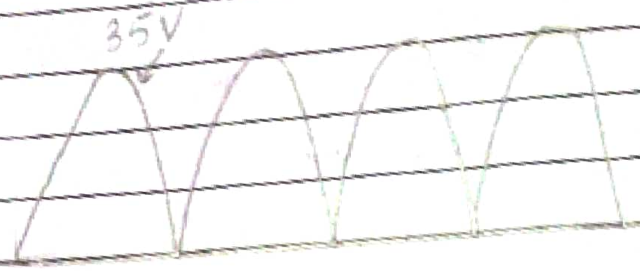
★ Series Inductance Filter

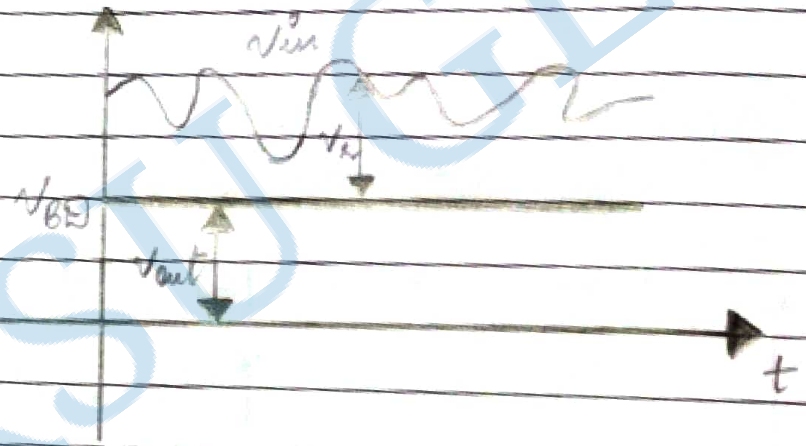




★ Zener Voltage Regulator

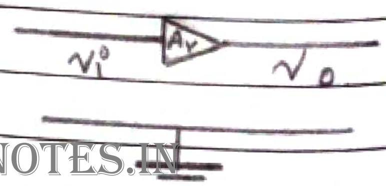


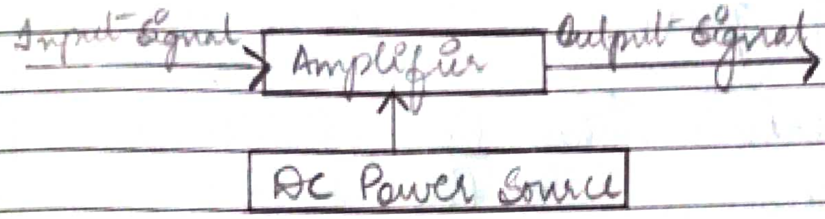




★ Amplifiers

- Make the voltage or current of input signal large without changing the shape of signal.
- Output signal must be an exact replica of input signal.
- Earth point





★ Characteristics of amplifiers

- **Input resistance** : Effective resistance appears across input terminals.

- **Output resistance** : Effective resistance appears across output terminals.

- **Voltage gain** : $A_v = V_o / V_i$

$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{input voltage}}$$

$$A_v = \frac{V_o}{V_i}$$

- **Current gain** :

$$A_i = \frac{I_o}{I_i}$$

- **Power gain** :

$$A_p = \frac{P_o}{P_i}$$

★ Decibels

papergrid

Date: / /

- unit of gain
- No of bels = $\log_{10} \frac{P_o}{P_i}$
- No of Decibels = $10^{\log_{10}\left(\frac{P_o}{P_i}\right)}$

★ Decibel power gain

$$A_p(dB) = 10 \log_{10} \frac{P_o}{P_i}$$

★ Decibel voltage gain

$$A_v(dB) = 20 \log_{10} \frac{V_o}{V_i}$$

★ Decibel current gain

$$A_i(dB) = 20 \log_{10} \frac{I_o}{I_i}$$

★ Ideal Amplifier

- The amplifiers gain, (A) should remain constant for varying values of input signal.
- Gain is not ~~be~~ affected by frequency. Signals of all freqhencies shuls be amplified by exactly the same amount.
- The amplifiers gain must add noise to the output signal. It should remove any noise that ~~is~~ already exists in

papergrid

Date: / /

the input signal.

- The amplifiers gain should not be affected by changes in temperature giving good temperature stability.

- The gain of the amplifier must remain stable over long period of time.

* Classification of amplifiers

- Based on inputs

-) Small signal amplifiers

These are designed to amplify very small signal voltage levels of only a few micro-volts (uV) from sensors or audio signals.

-) Large signal amplifiers (audio power amplifiers or power switching amplifiers).

Large signal amplifiers are designed to amplify large input voltage signals or switch heavy load currents as you would find driving loudspeakers.

- Based on biasing condition

-) Class A
-) Class B

Date: / /

- Class AB
- Class C.

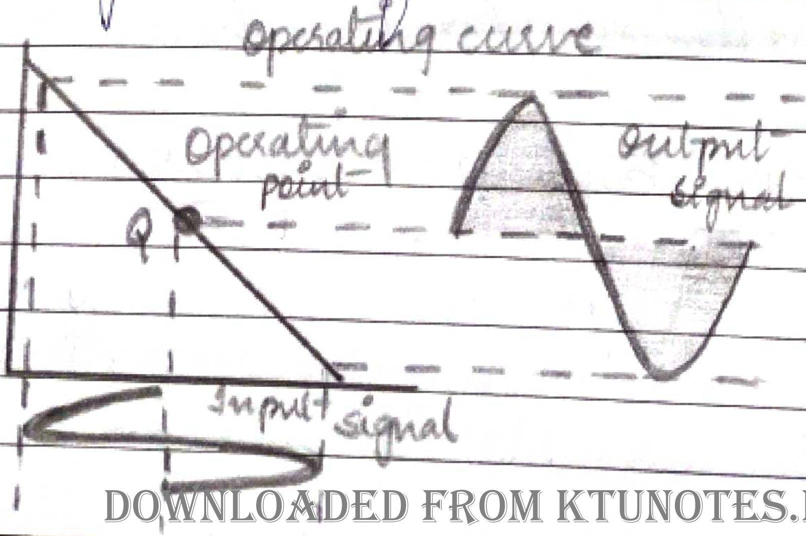
- Class A

- The most commonly used type of power amplifier configuration is the class A amplifier.

- The class A amplifier is the simplest form of power amplifier that uses a single switching transistor in the standard common emitter circuit configuration as seen previously to produce an inverted output.

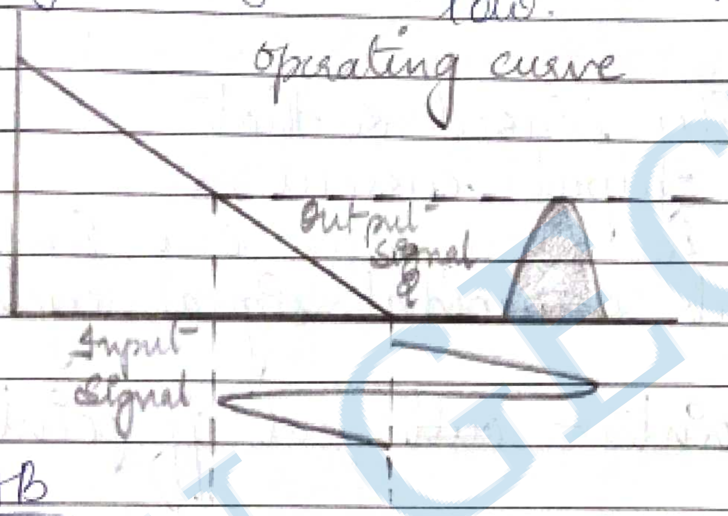
- The transistor is always biased "ON" so that it conducts during one complete cycle of the input signal waveform producing minimum distortion and maximum amplitude of the output signal.

- Operates over a linear portion of characteristics - Q point at the centre of linear portion of characteristics.



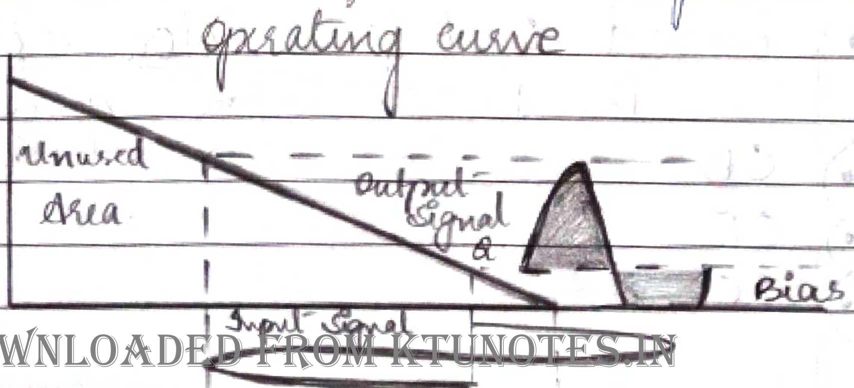
Class B

- Q point is in cut off region.
- Output current is only for half cycle.
- Efficiency is high - power dissipation is low.



Class AB

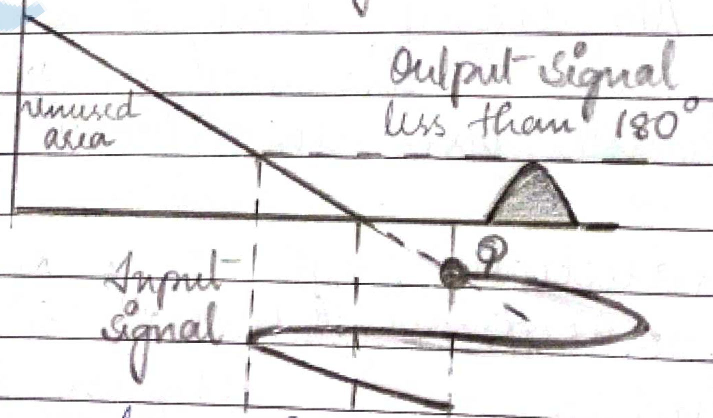
- Combination of the "class A" and the "class B" type amplifiers.
- The AB classification of amplifier is currently one of the most common used types of audio power amplifier design.
- Conduction angle of a class AB amplifier is somewhere between 180° and 360° depending upon the chosen bias point.



Class C

- Current flow as plu pulses.
- The greatest efficiency but the poorest linearity.
- Heavily biased so that the output current is zero for more than one half cycle of an input sinusoidal signal cycle.
- Q point – ~~cutt~~ cut off point
- Conduction angle for the transistor is significantly less than 180 degrees.

Operating curve



- **Based on transistor configuration**
  - CB
  - CE
  - CC

papergrid

Date: / /

- Based on coupling

i) Resistance - Capacitance coupling

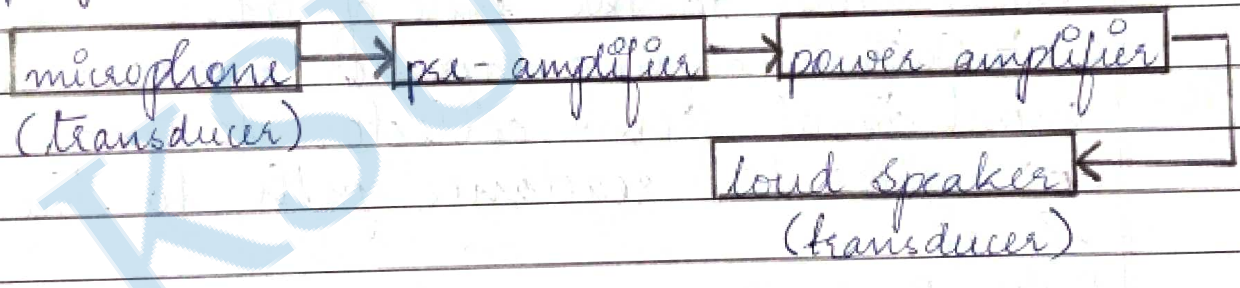
Individual stages of the amplifier are connected together using a resistor-capacitor combination.

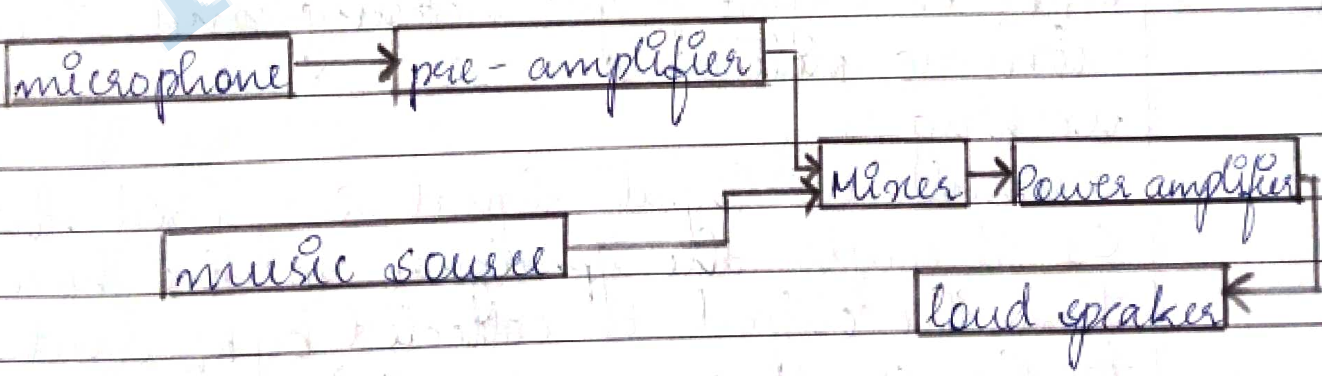
ii) Transformer coupling - impedance matching

iii) Direct coupling

* Public Address System

System that amplifies sound, so more people can hear it.



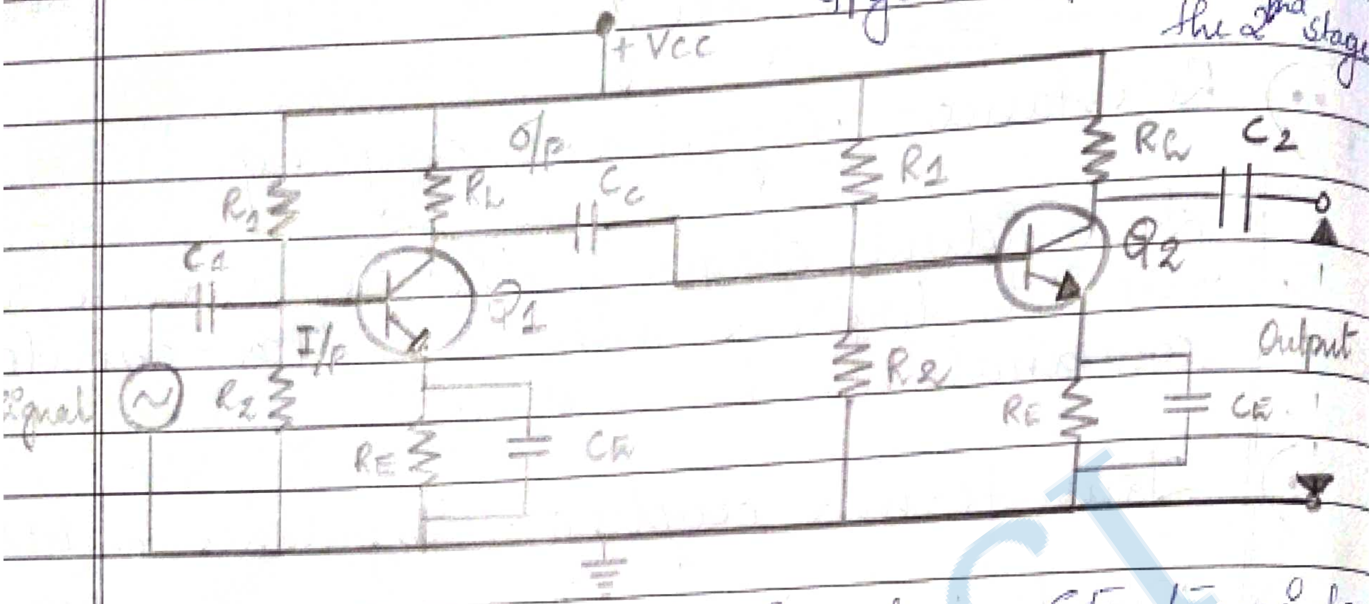


* RC Coupled Transistor Amplifiers

papergrid

Date: / /

Q_1 gives $180°$ phase shift to the 2^{nd} stage



Construction: 2 single stage CE transistor amplifier.

Specification:

CE amplifier : invert amplifier

C_c (coupling capacitor): connects 1^{st} and 2^{nd} stage.

C_1 : input coupling capacitor used to couple input signal to the base of Q_1.

C_2 : Output coupling capacitor used to couple ouput signal from collector to load.

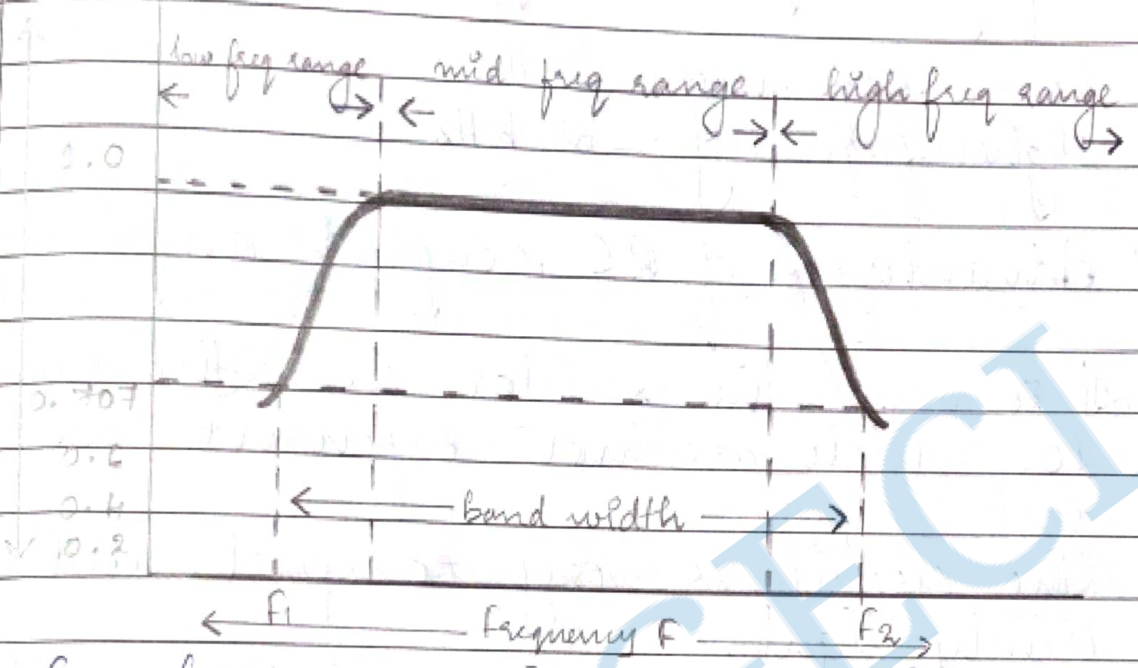
C_E : gives low reactance path to the emitter signal.

R_1, R_2, R_E : give proper biasing and stablization to network.

Working:

When an input signal is passed through C_1 it couples the i/p signal to the base Q_1. Then the output is collected by R_C and given to the coupling capacitor (C_c). This is then converted to the input signal of the 2^{nd} stage. Hence the ~~ouptput~~ output recieved at R_C is passed through the C_2, which couples the o/p from collector to the load.

Frequency Response of RC coupled amplifier



Low frequency region : low gain
* C_c in series ; impedence is considered
* $$X_C = \frac{1}{\omega C}$$
  $$= \frac{1}{2\pi f C} \qquad \{\omega = 2\pi F\}$$
* As F increases gain increases.

High Frequency Region : high gain
* Impedence low
* Capacitor acts as a short circuit
* Output voltage ↓ses gain ↑ses

* Cut off frequency is used to choose the band width.

Lower frequency : F_1
Higher frequency : F_2

* band width : $f_2 - f_1$

* half power point = $\frac{1}{\sqrt{2}}$ = 3dB point

  Lower frequency = 50 Hz
  Higher frequency = 20 KHz

Advantages of RC coupled amplifier

*
* It used the resistor and the capacitor which are not expensive so the cost is low.
* The circuit is very compact and extremly light.
* The frequency responce of RC coupled amplifier is excellent.
* It offers a constant gain over a wide frequency band.

Disadvantages of RC coupled amplifier

* It has low voltage and power gain.
* It is unsuitable for low frequency application.
* It has poor impedence matching because its output impedence is several times larger than the device, at its end terminals.
* It has the tendency to become noisy with times.
* It has narrow bandwidth.

papergrid

Date: / /

Transistor Biasing

- DC biasing is a static operation.
- Bias establishes the DC operating point for proper operation of an amplifier.

Modes	EBJ	CBJ	Applications
Cutoff	Reverse	Reverse	Switching applications in digital circuits
Saturation	Forward	Forward	
Active	Forward	Reverse	Amplifier
Reverse active	Reverse	Forward	Performance degradation.

Voltage Divider Biasing

- The operating point Q is independent of beta - good stabilization.
- Beta depends on doping concentration.

Electronic Instrumentation System

* **Measurement**

  The process of determining the amount, degree or capacity by comparison with the accepted standards of the system units being used.

* **Electronic Instrument**

  It is a device for determining the value or magnitude of a quantity or variable such as voltage, current or resistance.

papergrid

Date: / /

Performance Parameters

Accuracy

It is the degree of closeness with which the instrument reading approaches the true value of the quantity to be measured.

Precision

It is a measure of consistency or repeatability of measurement. This means when a quantity is measured repeatedly, the instrument should give the same value i.e, successive readings do not differ.

Resolution

The smallest change in a measurement variable to which an instrument will respond.

Sensitivity

It is the ratio of change in the output (response) of the instrument to a change of input or measured variable.

Expected Value

It is the desired value of measured quantity or the most probable value that is expected to obtain.

Error

It is the derivation of the true value from the desired value.

Electronic Instrumentation System