Amplifier
Lecture 8

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Definition of Amplifier:

An amplifier is an electronic device that can increase the power of a signal. An amplifier is a two port electrical network that produces a signal at the output port that is the replica of the signal applied to the input port. It increases the amplitude of the signal applied to the input terminal producing a proportionally greater amplitude signal at the output. The amount of amplification provide by an amplifier is measured by its gain. The amplifier is a circuit that has a power gain greater than one. Amplifiers can be described according to their properties of input and output and how can these two are related. All amplifiers have a gain, the multiplication factor that relates the magnitude of some properties of output signal to the input signal.

In many cases the property of output varies is dependent on the same property of input, making the gain unitless. Most amplifier are designed to be linear, it means it provides constant gain for any normal input level and output signal. In some cases variable gain is useful. Certain signal processes linear applications use exponential gain amplifiers. Every amplifier device include at least one active device i.e. transistor or tube.

R-C Coupled Amplifier:

In a two stage R-C coupled amplifier shows combination of only resistance and capacitance, output of first stage appear across the collector resistance R_C. This output coupled to the base of next stage through the coupling capacitor C_C.

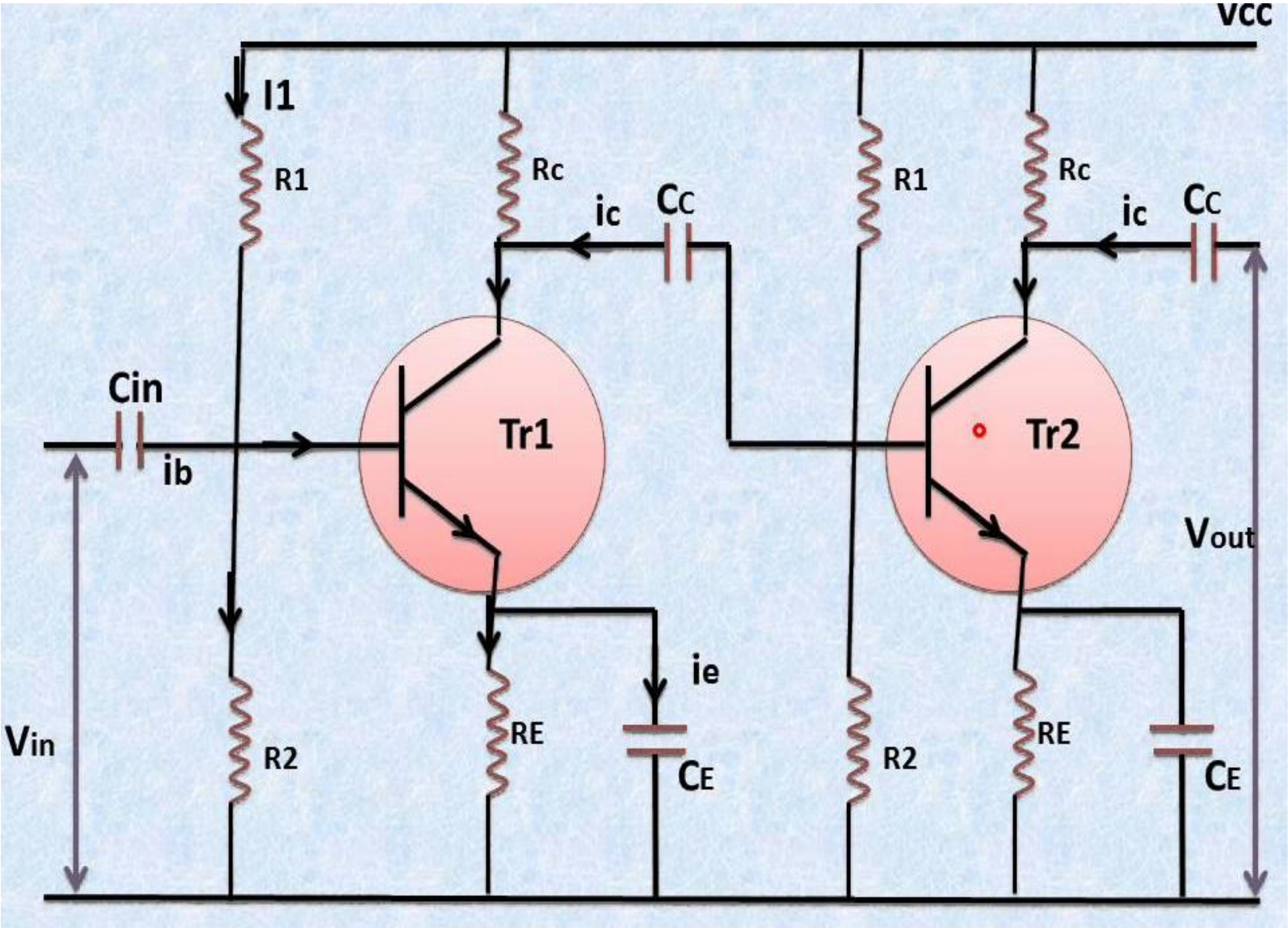

Fig 1: R-C coupled Amplifier

The coupling capacitor C_C couples the output signal of the first stage to the input of second stage. It blocks the DC voltage at output of first stage from appearing at input of second stage, but allows the AC component only. The $Q - point$ is determine by supply voltage V_{CC} together with resistance $R_1, R_2, R_C\ and\ R_E$. The bypass capacitor CE has a small reactance at lowest signal frequency. The voltage gain is

$$A_V = \frac{V_2}{V_1} = |A_V| < \theta \rightarrow (i)$$

The variation of magnitude and phase angle of gain of an amplifier with frequency is referred to frequency response characteristic of amplifier.

$$V_2 \rightarrow output\ voltage, V_1 \rightarrow input\ voltage$$

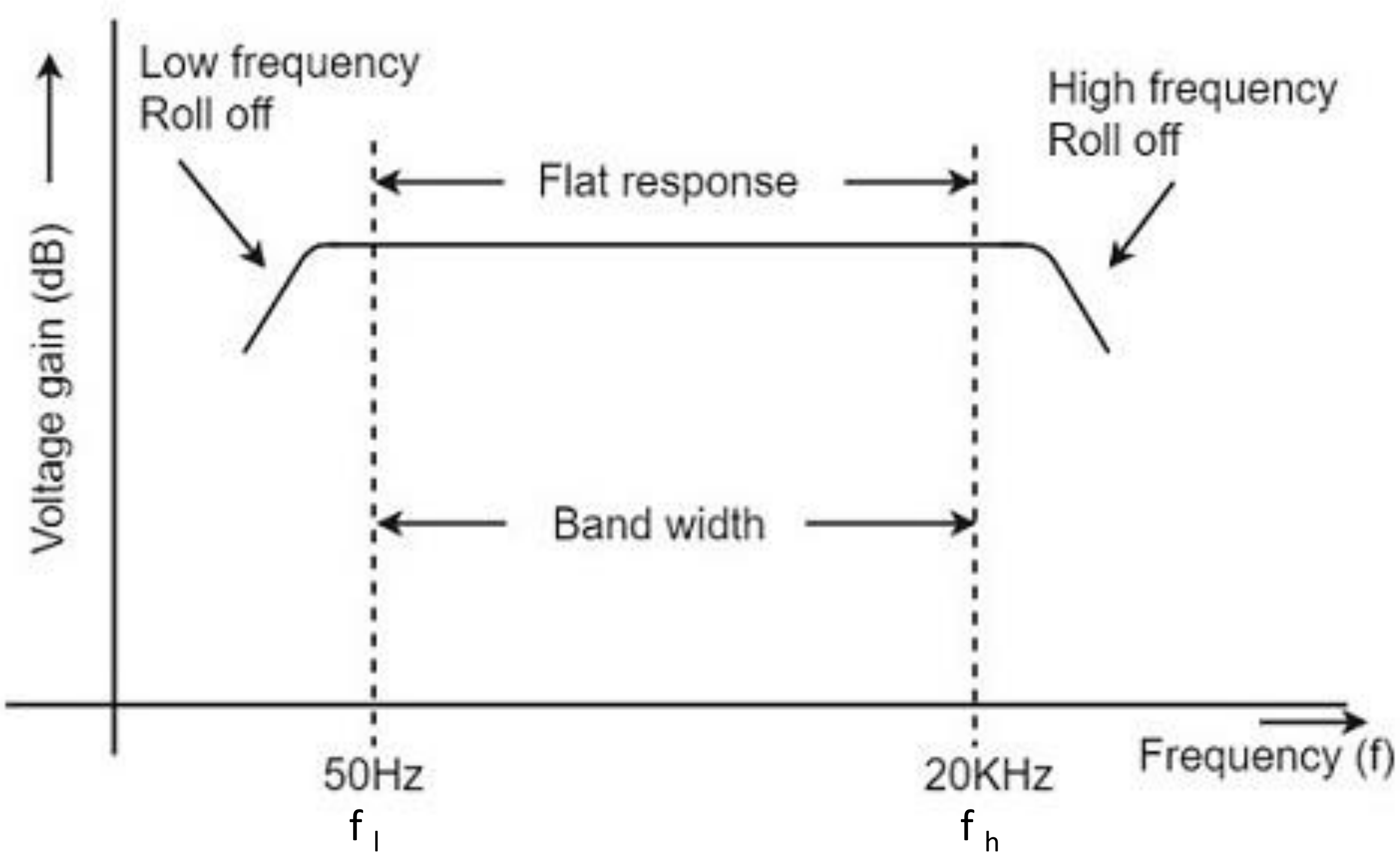

Fig 2 : Frequency Response Curve

$Response\ characteristic\ has\ three\ regions\ -$

$Mid\ frequency\ range$ where voltage gain $|A_V|$ is approximately constant and phase angle $(\theta)\ is\ 180^0$. The voltage gain of the capacitors is maintained constant in this range of frequency. If the frequency increases the reactance of the capacitor C_C decreases which tends to increase the gain. But this lower capacitance reactive increases loading effect of the next stage by which there is a reduction in gain. Due to this factors the gain is maintained constant.

$Low\ frequency$ range where gain $|A_V|$ decreases and phase angle increases over 180^0, below mid frequency. The capacitive reactance is inversely proportional to the frequency.

At low frequency the reactance is quite high. The reactance of the input capacitor and the coupling capacitor are so high that only small part of signal is allowed. The reactance of emitter bypass capacitor C_E is also very high at low frequency. Hence it can not shunt the emitter resistance effectively. With all these factors the voltage gain rolls off at low frequency.

$High\ frequency\ range$ where gain $|A_V|$ falls off and phase angle decreases below 180^0 with increasing frequency above mid frequency. Again considering the same point the capacitive reactance is low at high frequency. So a capacitor behaves as a short circuit at high frequency. As a result of this the loading effect of the next stage increases, which reduces the voltage gain.

Along with this as the capacitance of emitter decreases , it increases the base current of the transistor due to which the current gain reduces. Hence the voltage gain rolls off at high frequency.

Here the capacitive reactance is inversely proportional to frequency.

$$X_C = \frac{1}{2\pi f C}$$

The important parameter in frequency response of an amplifier are half power frequency where power gain of amplifier drops to half of mid frequency power gain. Obviouly the voltage gain at half power frequency is $\frac{1}{\sqrt{2}}$ or .707 times the mid frequency voltage gain.

Let f_l is in the low frequency range where $|A_V| = \frac{|A_{vm}|}{\sqrt{2}}$ is defined as lower half power frequency. Similarly f_h in the high frequency range is upper half power frequency. The phase angle (θ) is at 225^0 at lower half power frequency f_l and 135^0 at upper power frequency f_h. The range of frequency between f_l and f_h is called band width(BW) of the amplifier.

$$BW = f_h - f_l \rightarrow (ii)$$

The mid frequency range extend approximately over the frequency range $10f_l$ to $0.1f_h$ over this range $|A_V|$ does not fall below 99.5% of maximum value of A_{vm}. In mid frequency range coupling capacitor C_C has a negligible resistance

$$Output\ voltage\ V_2 = -h_{fe} i_b R_C \rightarrow (v)$$

$$Input\ Voltage\ V_1 = h_{ie} i_b + R_C \ \rightarrow (vi)$$

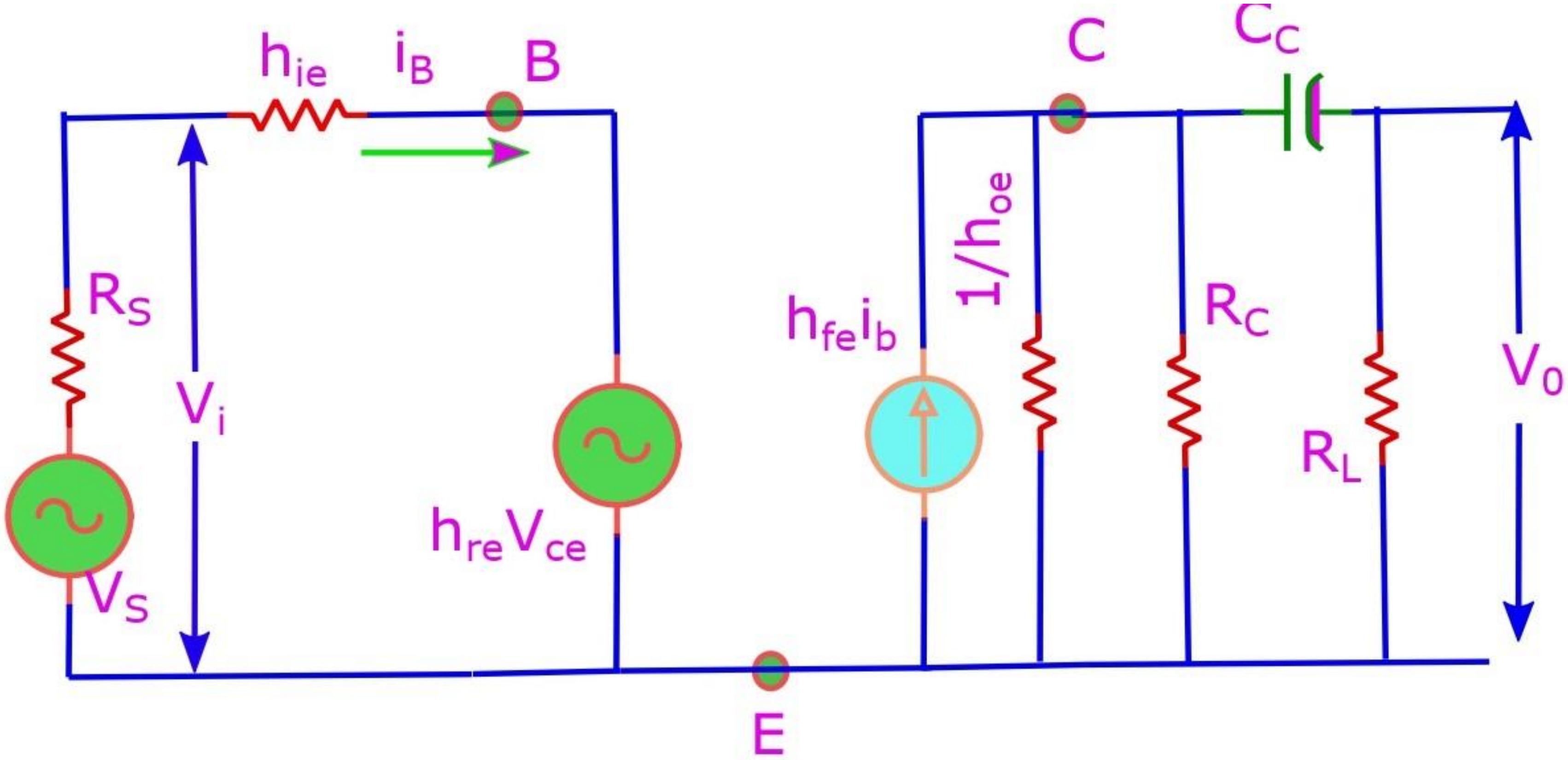

Fig 3: Equivalent Circuit

$$|A_V| = \frac{V_2}{V_1} =-= \frac{h_{fe}R_C}{h_{ie} + R_C} = \frac{h_{fe}}{1 + \frac{h_{ie}}{R_C}} \rightarrow (vii)$$

The phase angle between voltage gain is 180^0. $|A_{vm}|$ is independent of frequency and rises with R_C approaching h_{fe} as $R_C \rightarrow \propto$. In mid frequency range the reactance of coupling capacitor C_C must be included. The shunt capacitor to be considered as open circuit.

$$V_2 = -h_{ie}i_2 = -\frac{h_{ie}h_{fe}i_bZ_L}{h_{ie} - \frac{j}{\omega C}}$$

$$V_1 = h_{ie}i_b$$

$$|A_{vl}| = \frac{V_2}{V_1} = -\frac{h_{fe} Z_L}{h_{ie} - \frac{j}{\omega C}} = -\frac{h_{fe} R_C}{h_{ie} + R_C - \frac{j}{\omega C}} \rightarrow (viii)$$

$$|A_{vl}| = \frac{h_{fe} R_C}{\sqrt{(h_{ie} + R_C\ )^2 + \frac{1}{\omega^2 C^2}}} \rightarrow (ix)$$

Therefore

$$A_{vl} = \frac{A_{vm}}{1 - \frac{j}{[2\pi f C(h_{ie} + R_C)]}} \rightarrow (x)$$

Again we know that

$$f_l = \frac{1}{2\pi C(h_{ie} + R_C)} \rightarrow (xi)$$

Therefore

$$A_{vl} = \frac{A_{vm}}{1 - j\left(\frac{f_l}{f}\right)} \rightarrow (xii)$$

$$|A_{vl}| = \frac{|A_{vm}|}{\sqrt{1 + \left(\frac{f_l}{f}\right)^2}} \rightarrow (xiii)$$

Phase Angle

$$\theta_l = 180^0 + tan^{-1}\left(\frac{f_l}{f}\right) \rightarrow (xiv)$$

$$\theta_l = 180^0 + 45^0 = 225^0$$

At high frequency reactance of coupling capacitor is negligible, but reactance of shunt capacitance assume more important.

$$V_2 = -h_{fe} i_b Z_L$$

$$V_1 = h_{ie} i_b$$

$$A_{vh} = \frac{V_2}{V_1} = -\frac{h_{fe} i_b Z_L}{h_{ie} i_b} = -\frac{h_{fe} Z_L}{h_{ie}} \rightarrow (xv)$$

$$A_{vh} = -\frac{h_{fe} R_C}{h_{ie} + R_C + j\omega C_S h_{ie} R_C} \rightarrow (xvi)$$

$$|A_{vh}| = \frac{h_{fe}R_C}{\sqrt{(h_{ie} + R_C)^2 + (\omega C_S h_{ie} R_C)^2}} \rightarrow (xvii)$$

$$A_{vh} = \frac{A_{vm}}{1 + \frac{j\omega C_S h_{ie} R_C}{(h_{ie} + R_C)}} \rightarrow (xviii)$$

$$A_{vh} = \frac{A_{vm}}{1 + j\left(\frac{f}{f_h}\right)} \rightarrow (xix)$$

$$|A_{vh}| = \frac{|A_{vm}|}{1 + \left(\frac{f}{f_h}\right)^2} \rightarrow (xx)$$

$$\theta_h = 180^0 - tan^{-1}\left(\frac{f}{f_h}\right) \rightarrow (xvii)$$

$$\theta_h = 180^0 - 45^0 = 135^0$$

Advantage:

The frequency response of RC coupled amplifier provided constant gain over a wide frequency range, hence most suitable for audio frequency range.

The circuit is simple and has lower cost because it employes resistors and capacitors which are cheap

It becomes more compact with the upgrading technology

Disadvantage:

The voltage and power gain are low because of effective load resistance.

They become noisy with age

Due to poor impedance matching power transfer is low

Application:

They have excellent audio fedility over a wide range frequency

They are widely used as voltage amplifier

Due to poor impedance matching RC coupling is rarely used in the final stage.