UNIT V

POWER AMPLIFIERS AND DC CONVERTERS

Power amplifiers- class A-Class B-Class AB-Class C-Power MOSFET-Temperature Effect- Class AB Power amplifier using MOSFET –DC/DC convertors – Buck, Boost, Buck-Boost analysis and design

BJT SMALL SIGNAL MODEL

1. CE, CB and CC Amplifiers:

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier. At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased.

Let us consider the common emitter amplifier circuit using voltage divider bias.

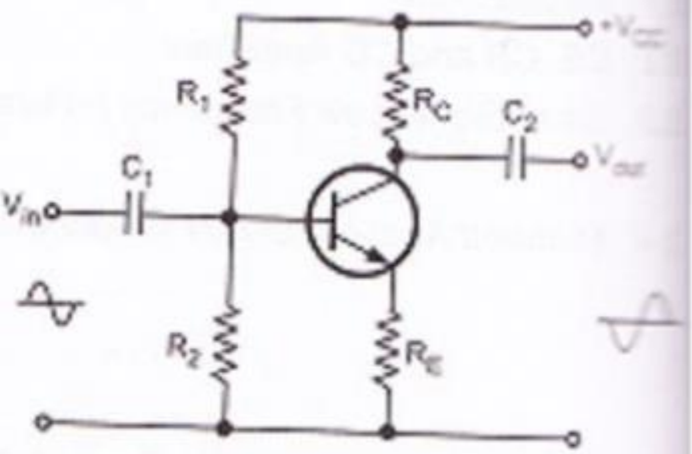


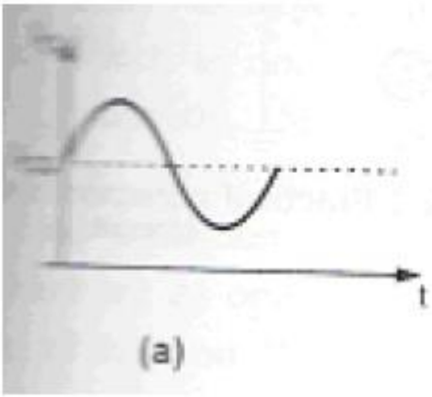
Fig. Common emitter amplifier

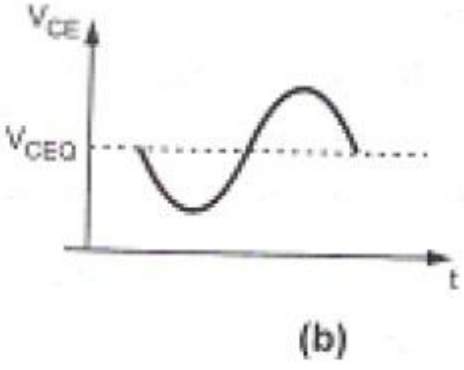
In the absence of input signal, only D.C. voltage is present in the circuit. It is known as zero signal or no signal condition or quiescent condition. D.C. collector-emitter voltage VCE, D.C. collector current IC and base current IB is the quiescent operating point for the amplifier. Due to this base current varies sinusoidaly as shown in the below figure.

Fig. IBQ is quiescent DC base current

If the transistor is biased to operate in active region, output is linearly proportional to the input.

The collector current is β times larger than the input base current in CE configuration. The collector current will also vary sinusoidally about its quiescent value ICQ. The output voltage will also vary sinusoidally as shown in the below figure.





Variations in the collector current and voltage between collector and emitter due to change in base current are shown graphically with the help of load line in the above figure.

2. Common Emitter Amplifier Circuit:

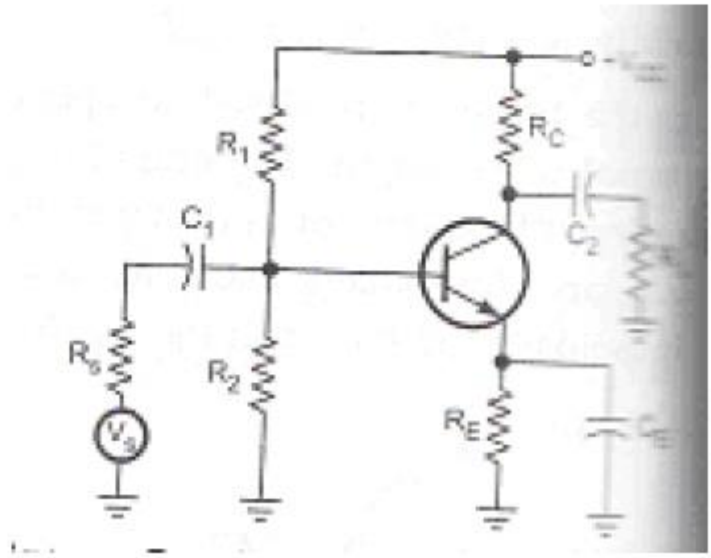


Fig. Practical common-emitter amplifier circuit

From above circuit, it consists of different circuit components. The functions of these components are as follows:

1. Biasing Circuit:

Resistors R1, R2 and RE forms the voltage divider biasing circuit for CE amplifier and it sets the proper operating point for CE amplifier.

2. Input Capacitor C1:

C1 couples the signal to base of the transistor. It blocks any D.C. component present in the signal and passes only A.C. signal for amplification.

3. Emitter Bypass Capacitor CE:

CE is connected in parallel with emitter resistance RE to provide a low reactance path to the amplified A.C. This will reduce the output voltage and reducing the gain value.

4. Output Coupling Capacitor C2:

C2 couples the output of the amplifier to the load or to the next stage of the amplifier. It blocks D.C. and passes only A.C. part of the amplified signal.

Need for C1, C2, and CE:

The impedance of the capacitor is given by,

XC = 1/ (2∏fc)

Phase reversal:

The phase relationship between the input and output voltages can be determined by considering the effect of positive and negative half cycle separately. The collector current is β times the base current, so the collector current will also increases. This increases the voltage drop across RC.

VC = VCC - ICRC

Increase in IC results in a drop in collector voltage VC, as VCC is constant. Vi increases in a positive direction, Vo goes in negative direction and negative half cycle of output voltage can be obtained for positive half cycle at the input.

In negative half cycle of input, A.C. and D.C. voltage will oppose each other. This will reduce the base current. Accordingly collector current and drop across RC both will reduce and it increases the output voltage. So positive half cycle at the output for negative half cycle at the input can be obtained. So there is a phase shift of 180º between input and output voltages for a common emitter amplifier.

3. Common Collector Amplifier Circuit:

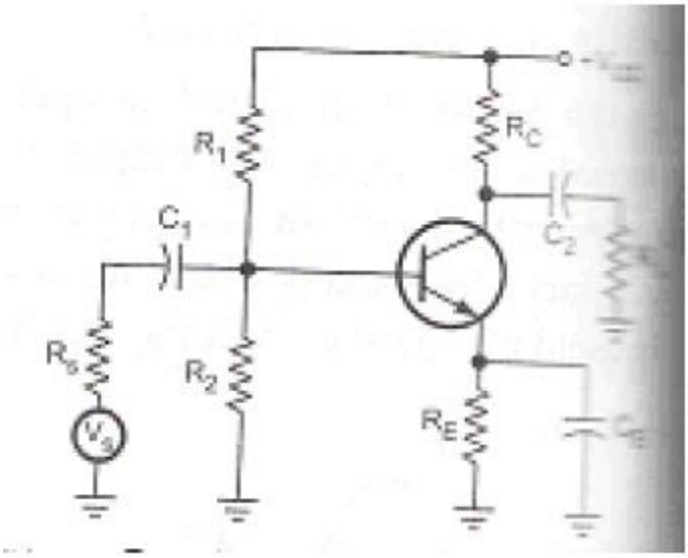


Fig. Practical common-emitter amplifier circuit

From above circuit, D.C. biasing is provided by R1, R2 and RE. The load resistance is capacitor coupled to the emitter terminal of the transistor. When a signal is applied to base of the transistor, VB is increased and decreased as the signal goes positive and negative respectively.

From figure, VE = VB - VBE

Consider VBE is constant, so the variation in VB appears at emitter and emitter voltage VE will vary same as base voltage VB. In common collector circuit, emitter terminal follows the signal voltage applied to the base. It is also known as emitter follower.

4. Common Base Amplifier Circuit:

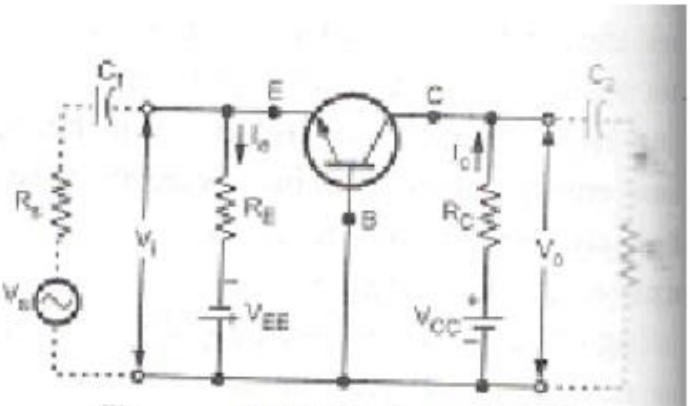


Fig. Common base circuit

From above circuit, the signal source is coupled to the emitter of the transistor through C1. The load resistance RL is coupled to the collector of the transistor through C2. The positive going pulse of input source increases the emitter voltage. As base voltage is constant, forward bias of emitter-base junction reduces. This reduces Ib, Ic and drop across Rc.

Vo = VCC - ICRC

Reduction in IC results in an increase in Vo. Positive going input produces positive going output and vice versa. So there is no phase shift between input and output in common base amplifier.

General shape of frequency response of amplifiers:

An audio frequency amplifier which operates over audio frequency range extending from 20 Hz to 20 kHz. Audio frequency amplifiers are used in radio receivers, large public meeting and various announcements to be made for the passengers on railway platforms. Over the range of frequencies at which it is to be used an amplifier should ideally provide the same amplification for all frequencies. The degree to which this is done is usually indicated by the curve known as frequency response curve of the amplifier.

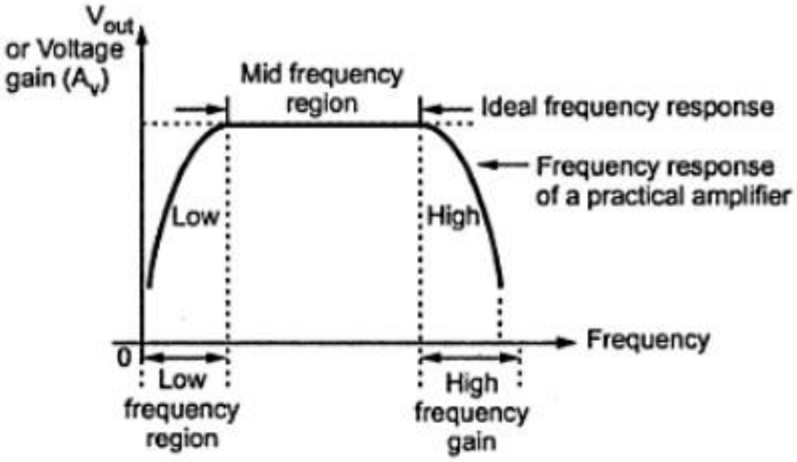


Fig. **A typical frequency response of an amplifier**

To plot this curve, input voltage to the amplifier is kept constant and frequency of input signal is continuously varied. The output voltage at each frequency of input signal is noted and the gain of the amplifier is calculated. For an audio frequency amplifier, the frequency range is quite large from 20 Hz to 20 kHz. In this frequency response, the gain of the amplifier remains constant in mid-frequency while the gain varies with frequency in low and high frequency regions of the curve. Only at low and high frequency ends, gain deviates from ideal characteristics. The decrease in voltage gain with frequency is called roll-off.

1. Definition of cut-off frequencies and bandwidth:

The range of frequencies can be specified over which the gain does not deviate more than 70.7% of the maximum gain at some reference mid-frequency.

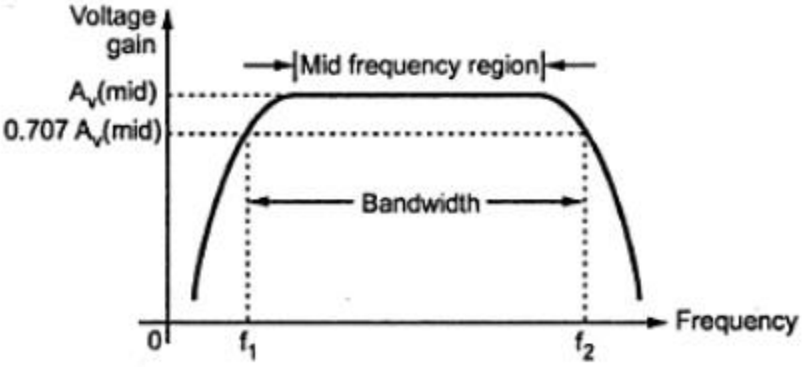


Fig. Frequency response, half power frequencies and bandwidth of an RC coupled amplifier

From above figure, the frequencies f1 & f2 are called lower cut-off and upper cut-off frequencies.

Bandwidth of the amplifier is defined as the difference between f2 & f1.

Bandwidth of the amplifier = f2 - f1

The frequency f2 lies in high frequency region while frequency f1 lies in low frequency region. These two frequencies are also called as half-power frequencies since gain or output voltage drops to 70.7% of maximum value and this represents a power level of one half the power at the reference frequency in mid-frequency region.

Low frequency analysis of amplifier to obtain lower cut-off frequency:

Decibel Unit:

The decibel is a logarithmic measurement of the ratio of one power to another or one voltage to another. Voltage gain of the amplifier is represented in decibels (dBs). It is given by,

Voltage gain in dB = 20 log Av

Power gain in decibels is given by,

Power gain in dB = 10 log Ap

Where Av is greater than one, gain is positive and when Av is less than one, gain is negative. The positive and negative gain indicates that the amplification and attenuation respectively. Usually the maximum gain is called mid frequency range gain is assigned a 0 db value. Any value of gain below mid frequency range can be referred as 0 db and expressed as a negative db value.

Example:

Assume that mid frequency gain of a certain amplifier is 100. Then, Voltage gain = 20 log 100 = 40 db

At f1 and f2 Av = 100/√2 = 70.7

Voltage gain at f1 = Voltage gain at f2 = 20 log 70.7 = 37 db

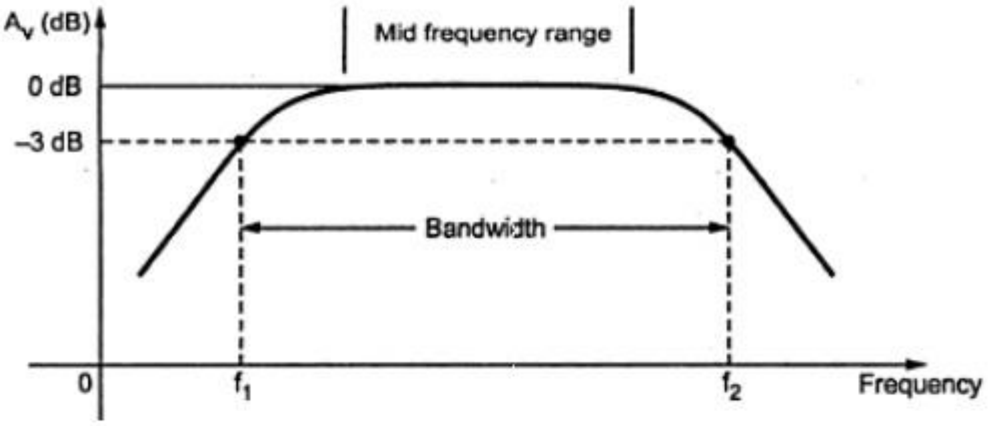


Fig. Normalized voltage gain vs frequency

From above figure, it shows that the voltage gain at f1 and f2 is less than 3db of the maximum voltage gain. Due to this the frequencies f1 and f2 are also called as 3 db frequencies. At f1 & f2 power gain drops by 3 db. For all frequencies within the bandwidth, amplifier power gain is at least half of the maximum power gain. This bandwidth is also referred to as 3 db bandwidth.

- **Significance of octaves and decades:**

The octaves and decades are the measures of change in frequency. A ten times change in frequency is called a decade. Otherwise, an octave corresponds to a doubling or halving of the frequency.

Example:

An increase in frequency from 100 Hz to 200 Hz is an octave.

A decrease in frequency from 100 kHz to 50 kHz is also an octave.

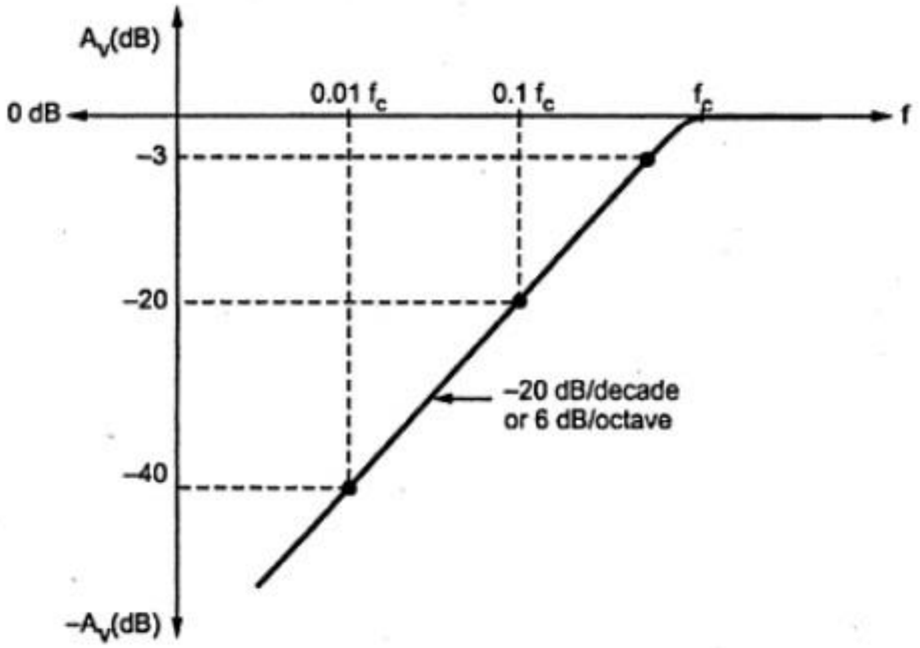


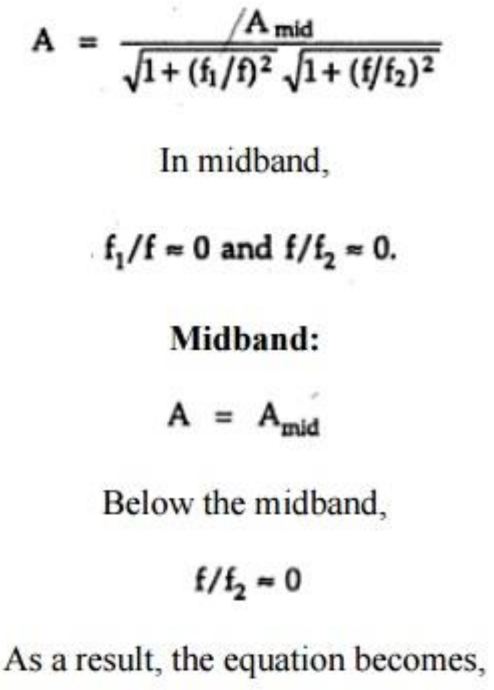
Fig. Frequency response showing significance of decade and octave

At lower and higher frequencies the decrease in the gain of amplifiers is often indicated in terms of db/decades or db/octaves. If the attenuation in gain is 20 db for each decade, then it is indicated by line having slope of 20 db/decade. A rate of -20 db/decade is approximately equivalent to - 6db/octave. A rate of -40 db/decade is approximately equivalent to -12db/octave.

- **Midband gain:**

It is defined as the band of frequencies between 10 f1 and 0.1 f2. It is denoted as midband gain or Amid.

The voltage gain of the amplifier outside the midband is approximately given as,



$$A = \frac{A_{mid}}{\sqrt{1+(f_1/f)^2}\,\sqrt{1+(f/f_2)^2}}$$

In midband,

$$f_1/f \approx 0 \text{ and } f/f_2 \approx 0.$$

Midband:

$$A = A_{mid}$$

Below the midband,

$$f/f_2 \approx 0$$

As a result, the equation becomes,

Below midband:

$$A = \frac{A_{mid}}{\sqrt{1 + (f_1/f)^2}}$$

Above midband,

$$f_1/f \approx 0.$$

As a result, the equation becomes,

Above midband:

$$A = \frac{A_{mid}}{\sqrt{1 + (f/f_2)^2}}$$

- **Problem:**

For an amplifier, midband gain = 100 and lower cutoff frequency is 1 kHz. Find the gain of an amplifier at frequency 20 Hz.

Solution:

Below midband:

$$A = \frac{A_{mid}}{\sqrt{1 + (f_1/f)^2}}$$

$$A = \frac{100}{\sqrt{1 + \left(\frac{1000}{20}\right)^2}} = 2$$

Effect of various capacitors on frequency response:

- **Effect of coupling capacitors:**

The reactance of the capacitor is Xc = 1/2∏fc

At medium and high frequencies, the factor f makes Xc very small, so that all coupling capacitors behave as short circuits. At low frequencies, Xcincreases. This increase in Xc drops the signal voltage across the capacitor and reduces the circuit gain. As signal frequencies decrease, capacitor reactance increase and gain continues to fall, reducing the output voltage.

- **Effect of Bypass capacitors:**

At lower frequencies, bypass capacitor CE is not a short. So emitter is not at ac ground. Xc in parallel with RE creates an impedance. The signal voltage drops across this impedance reducing the circuit gain.

- **Effect of internal transistor capacitances:**

At high frequencies, coupling and bypass capacitors act as short circuit and do not affect the amplifier frequency response. At high frequencies, internal capacitances, commonly known as junction capacitances. The following figure shows the junction capacitances for both BJT and FET. Incase of BJT, Cbe is the base emitter junction capacitance and Cbc is the base collector junction capacitance. Incase of FET, Cgs is the internal capacitance between gate and source and Cgd is the internal capacitance between gate and drain.

(a) BJT

(b) JFET

Fig. Internal transistor capacitances