Common Emitter Amplifier Circuit

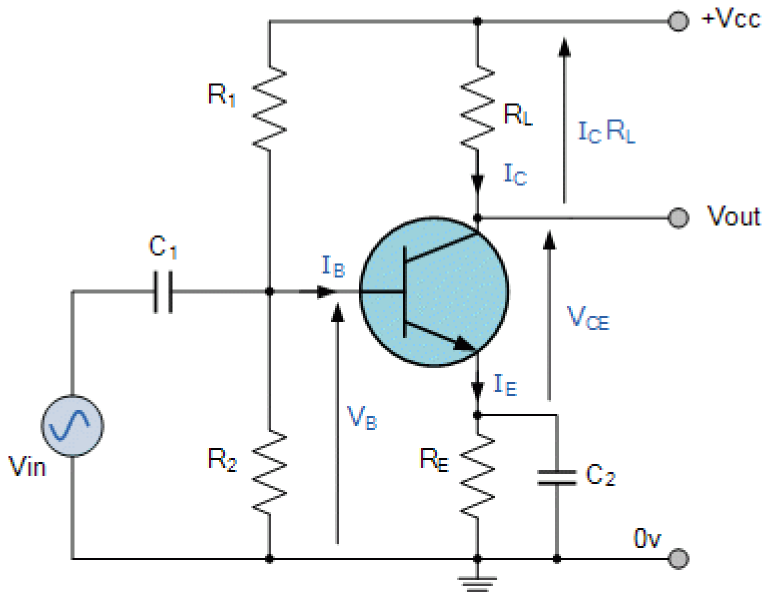

Figure 2.2.1 Practical common-emitter amplifier circuit

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From above circuit, it consists of different circuit components. The functions of these components in figure 2.2.1 are as follows:

1. Biasing Circuit:

Resistors R_1, R_2 and R_E forms the voltage divider biasing circuit for CE amplifier and it sets the proper operating point for CE amplifier.

2. Input Capacitor C_1:

C_1 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 C_E:

C_E is connected in parallel with emitter resistance R_E 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 C_2:

C_2 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 C_1, C_2, and C_E:

The impedance of the capacitor is given by,

$$X_C = 1/(2\prod f_c)$$

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 R_C.

$$V_C = V_{CC} - I_C R_C$$

Increase in I_C results in a drop in collector voltage V_C, as V_{CC} is constant. V_i increases in a positive direction, V_o 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 R_C 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 180^o between input and output voltages for a common emitter amplifier.

Common Emitter Voltage Gain

The Voltage Gain of the common emitter amplifier is equal to the ratio of the change in the input voltage to the change in the amplifiers output voltage. Then ΔV_L is Vout and ΔV_B is Vin. But voltage gain is also equal to the ratio of the signal resistance in the Collector to the signal resistance in the Emitter and is given as:

$$\text{Voltage Gain} = \frac{Vout}{Vin} = \frac{\Delta V_L}{\Delta V_B} = -\frac{R_L}{R_E}$$

Common Emitter Amplifier analysis

The first step in AC analysis of Common Emitter amplifier circuit is to draw the AC equivalent circuit by reducing all DC sources to zero and shorting all the capacitors. The below figure2.2.2 shows the AC equivalent circuit.

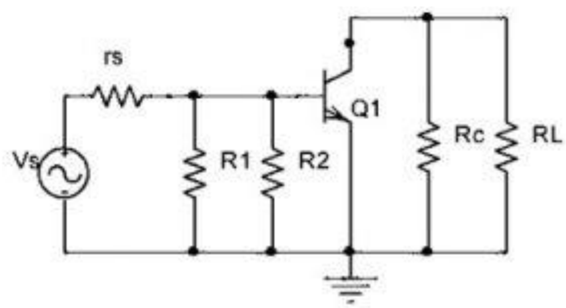

Figure 2.2.2 AC Equivalent Circuit for CE Amplifier

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The next step in the AC analysis is to draw an h-parameter circuit by replacing the transistor in the AC equivalent circuit with its h-parameter model. The below figure 2.2.3 shows the h-parameter equivalent circuit for the CE circuit.

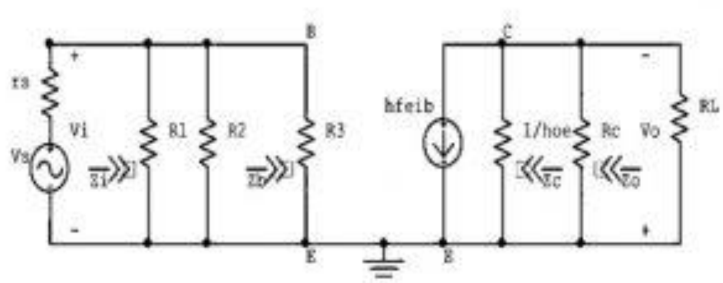

Figure 2.2.3 h-Parameter Equivalent Circuit for Common Emitter Amplifier

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The typical CE circuit performance is summarised below:

Device input impedance, Zb = hie

Circuit input impedance, Zi = R1 || R2 || Zb

Device output impedance, Zc= 1/hoe

Circuit output impedance, Zo = RC || ZC ≈ RC

Circuit voltage gain, Av = -hfe/hie*(Rc|| RL)

Circuit current gain, AI = hfe. RC. Rb/ (Rc+RL) (Rc+hie)

Circuit power gain, Ap = Av * Ai

CE Amplifier Frequency Response

The voltage gain of a CE amplifier varies with signal frequency. It is because the reactance of the capacitors in the circuit changes with signal frequency and hence affects the output voltage. The curve drawn between voltage gain and the signal frequency of an amplifier is known as frequency response. The below figure shows the frequency response of a typical CE amplifier.

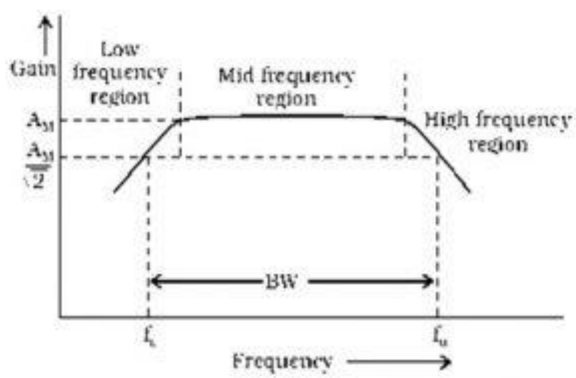

Figure 2.2.4 Frequency Response

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From the above figure 2.2.4, we observe that the voltage gain drops off at low (< FL) and high (> FH) frequencies, whereas it is constant over the mid-frequency range (FL to FH).

At Low Frequencies (< FL)

The reactance of coupling capacitor C2 is relatively high and hence very small part of the signal will pass from the amplifier stage to the load. Moreover, CE cannot shunt the RE effectively because of its large reactance at low frequencies. These two factors cause a drops off of voltage gain at low frequencies.

At High Frequencies (> FH)

The reactance of coupling capacitor C2 is very small and it behaves as a short circuit. This increases the loading effect of the amplifier stage and serves to reduce the voltage gain. Moreover, at high frequencies, the capacitive reactance of base-emitters junction is low which increases the base current. This frequency reduces the current amplification factor β. Due to these two reasons, the voltage gain drops off at a high frequency.

At Mid Frequencies (FL to FH)

The voltage gain of the amplifier is constant. The effect of the coupling capacitor C2 in this frequency range is such as to maintain a constant voltage gain. Thus, as the frequency increases in this range, the reactance of CC decreases, which tends to increase the gain.

However, at the same time, lower reactance means higher almost cancel each other, resulting in a uniform fair at mid-frequency.

We can observe the frequency response of any amplifier circuit is the difference in its performance through changes within the input signal's frequency because it shows the frequency bands where the output remains fairly stable. The circuit bandwidth can be defined as the frequency range either small or big among fH & fL. So from this, we can decide the voltage gain for any sinusoidal input in a given range of frequency. The frequency response of a logarithmic presentation is the Bode diagram. Most of the audio amplifiers have a flat frequency response that ranges from 20 Hz – 20 kHz. For an audio amplifier, the frequency range is known as Bandwidth. Frequency points like fL & fH are related to the lower corner & the upper corner of the amplifier which are the gain falls of the circuits at high as well as low frequencies.

These frequency points are also known as decibel points. So the BW can be defined as

$$\mathbf{BW = f_H – f_L}$$

The dB (decibel) is 1/10th of a B (bel), is a familiar non-linear unit to measure gain & is defined like 20log10(A). Here ‘A’ is the decimal gain which is plotted over the y-axis.The maximum output can be obtained through the zero decibels which communicate toward a magnitude function of unity otherwise it occurs once Vout = Vin when there is no reduction at this frequency level, so

$$\mathbf{V_{OUT}/V_{IN} = 1,}$$

$$\mathbf{so\ 20log(1) = 0dB}$$

We can notice from the above graph, the output at the two cut-off frequency points will decrease from 0dB to -3dB & continues to drop at a fixed rate. This reduction within gain is known commonly as the roll-off section of the frequency response curve. In all basic filter and amplifier circuits, this roll-off rate can be defined as 20dB/decade, which is equal to a 6dB/octave rate. So, the order of the circuit is multiplied with these values.

These -3dB cut-off frequency points will describe the frequency where the o/p gain can be decreased to 70 % of its utmost value. After that, we can properly say that the frequency point is also the frequency at which the gain of the system has reduced to 0.7 of its utmost value.

Common Emitter Transistor Amplifier

The circuit diagram of the common emitter transistor amplifier has a common configuration and it is a standard format of transistor circuit whereas voltage gain is desired. The common emitter amplifier is also converted as an inverting amplifier. The different types of configurations in transistor amplifiers are common base and the common collector transistor and the figure are shown in the following circuits.

Common Emitter Transistor Amplifier

Characteristics of Common Emitter Amplifier

The voltage gain of a common emitter amplifier is medium

The power gain is high in the common emitter amplifier

There is a phase relationship of 180 degrees in input and output

In the common emitter amplifier, the input and output resistors are medium. The characteristics graph between the bias and the gain is shown in figure 2.2.5 below.

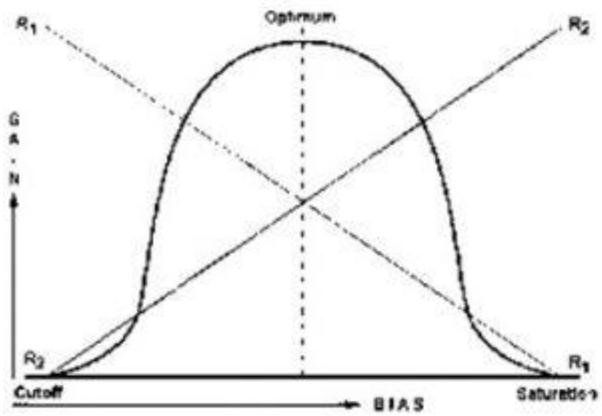

Figure 2.2.5 Characteristics Transistor Bias Voltage

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The Vcc (supply voltage) will determine the utmost Ic (collector current) once the transistor is activated. The Ib (base current) for the transistor can be found from the Ic (collector current) & the DC current gain β (Beta) of the transistor.

VB = VCC R2/R1+R2

Sometimes, 'β' is referred to as 'hFE' which is the forward current gain of the transistor within the CE configuration. Beta (β) is a fixed ratio of the two currents like Ic and Ib, so it doesn't contain units. So a small change within the base current will make a huge change within the collector current.

The same type of transistors as well as their part number will contain huge changes within their 'β' values. For instance, the NPN transistor like BC107 includes a Beta value (DC current gain in between 110 – 450 based on the datasheet. So one transistor may include a 110 Beta value whereas another may include of 450 Beta value, however, both the transistors are NPN BC107 transistors because Beta is a feature of the structure of the transistor but not of its function.

When the base or emitter junction of the transistor is connected forward bias, then the emitter voltage 'Ve' will be a single junction where voltage drop is dissimilar to the voltage of the Base terminal. The emitter current (Ie) is nothing but the voltage across the emitter resistor. This can be calculated simply through Ohm's Law. The 'Ic' (collector current) can be approximated, as it is approximately a similar value to the emitter current.

Input and Output Impedance of Common Emitter Amplifier

In any electronic circuit design, impedance levels are one of the main attributes that need to consider. The value of input impedance is normally in the region of 1kΩ, while this can differ significantly based on the conditions as well as values of the circuit. The less input impedance will result from the truth that the input is given across the two terminals of the transistor-like base & emitter because there is a forward-biased junction.

Also, the o/p impedance is comparatively high because it varies significantly again on the values of selected electronic component values & allowed current levels. The o/p impedance is a minimum of 10kΩ otherwise possibly high. But if the current drain permits high levels of current to be drawn, then the o/p impedance will be decreased significantly. The impedance or resistance level comes from the truth that the output is used from the collector terminal because there is a reverse-biased junction.