CO1

Develop basic single stage amplifiers

Explain transistor biasing and different biasing circuits.

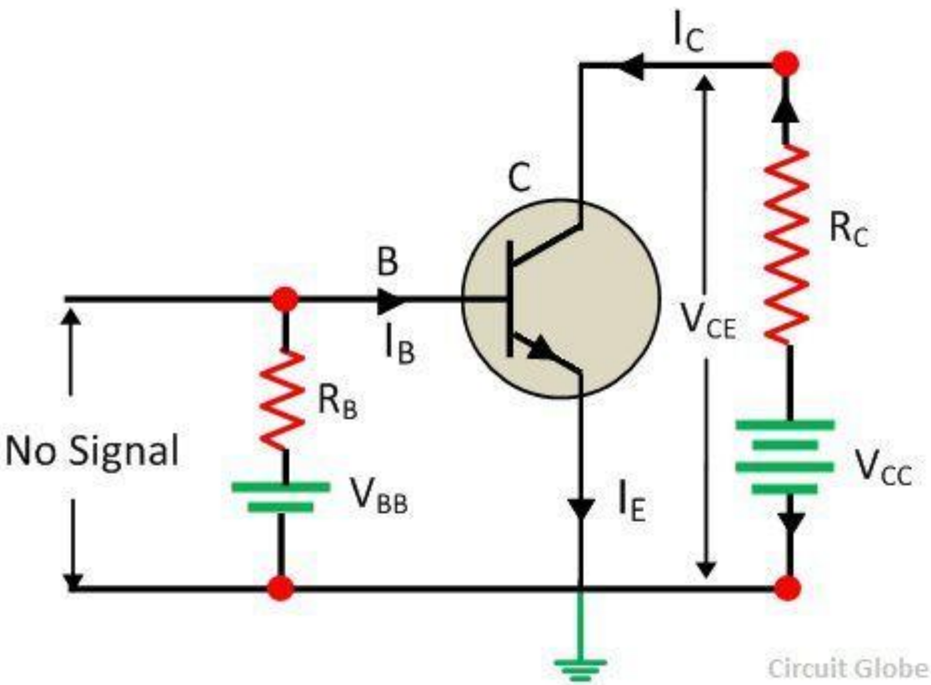
Develop single stage CE amplifier with voltage divider biasing and obtain its parameters

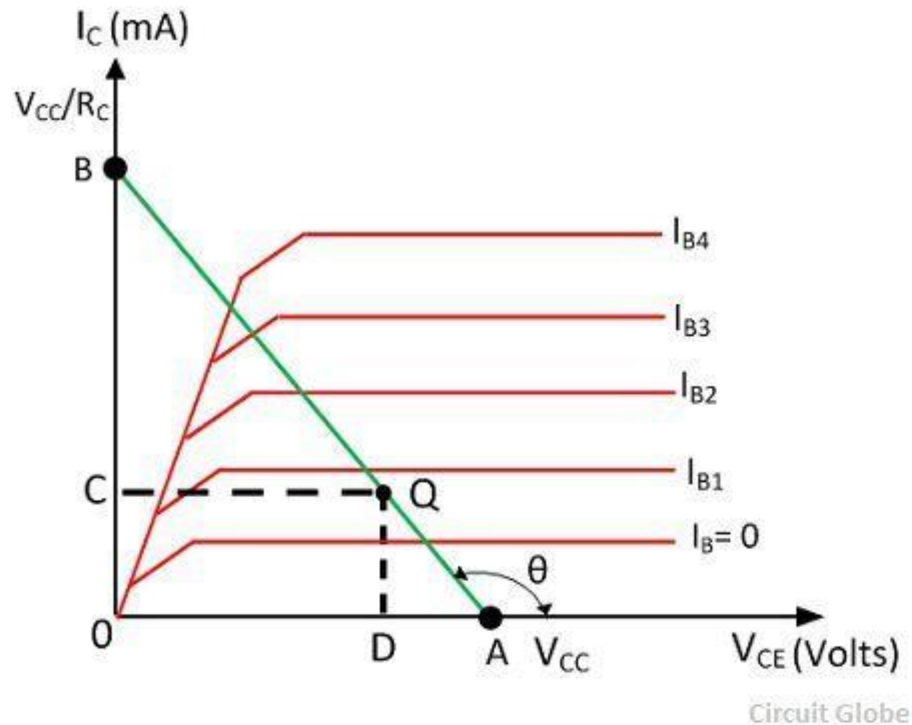
Summarize the features and applications of emitter follower

DC Load Line

- The DC load line represents *the desirable values of the collector current(Ic) and the collector-emitter voltage(Vce)*. It is drawn when no signal is given to the input.
- Consider a CE NPN transistor circuit shown in the figure below where no signal is applied to the input side. For this circuit, *DC condition* will obtain, and the output characteristic of such a circuit is shown in the figure below.

The DC load line curve of the circuit is shown in the figure below





- By applying Kirchhoff's voltage law(KVL) to the collector circuit, we get,

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

$$V_{CE} = V_{CC} - I_C R_C \ldots .equ(1)$$

The above equation shows that the V_{CC} and R_C are the constant value, and it is the first-degree equation which is represented by the straight line on the output characteristic. This load line is known as a DC load line. The *input characteristic(Ib)* is used to determine the locus of V_{CE} and I_C point for the given value of R_C. The end point of the line are located as:

- **1.** The collector-emitter voltage V_{CE} is maximum when the collector current $I_C = 0$ then from the equation (1) we get,

$$V_{CE} = V_{CC} - 0 \times R_C$$

$$V_{CE} = V_{CC}$$

2. The collector current I_C becomes maximum when the collector-emitter voltage $V_{CE} = 0$ then from the equation (1) we get.

$$0 = V_{CC} - I_C R_C$$

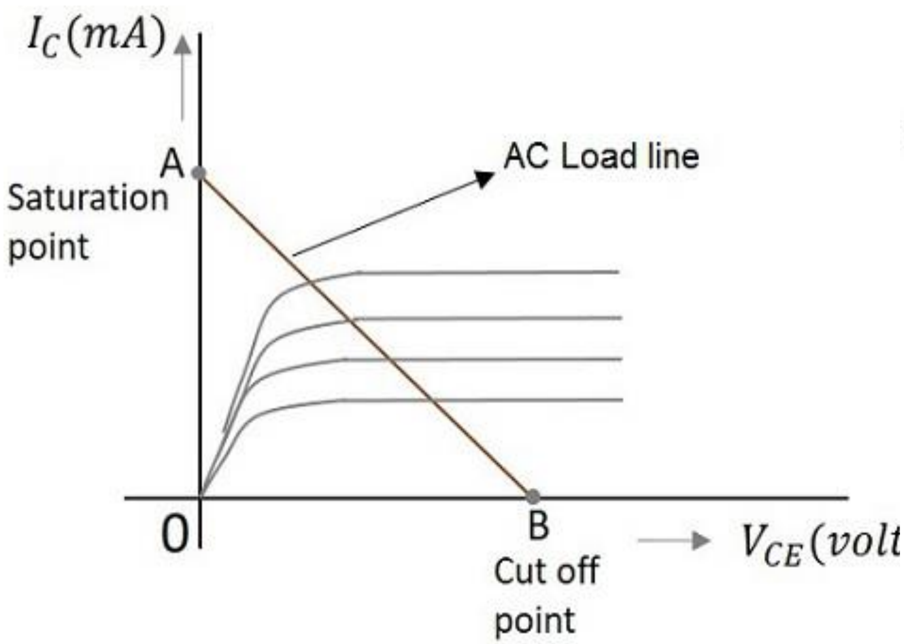
$$I_C = \frac{V_{CC}}{R_C}$$

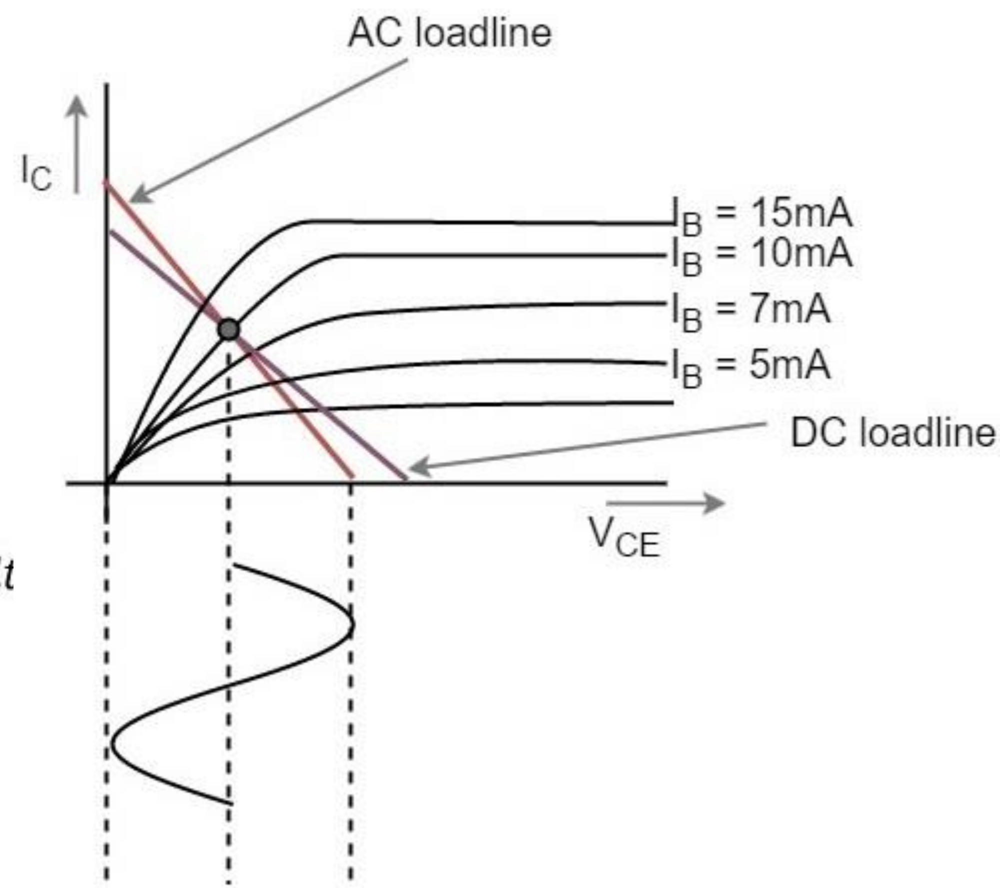
This gives the second point on the collector current axis as shown in the figure above. By adding the points A and B, the DC load line is drawn. With the help of load line, any value of collector current can be determined.

AC Load Line

- The DC load line discussed previously, analyzes the variation of collector currents and voltages, when no AC voltage is applied.
- Whereas the AC load line gives the peak-to-peak voltage, or the maximum possible output swing for a given amplifier.

When AC and DC Load lines are represented in a graph, it can be understood that they are not identical. Both of these lines intersect at the **Q-point** or **quiescent point**. The endpoints of AC load line are saturation and cut off points. This is understood from the figure below





Operating Point

- When a line is drawn joining the saturation and cut off points, such a line can be called as **Load line**. This line, when drawn over the output characteristic curve, makes contact at a point called as **Operating point**.
- This operating point is also called as **quiescent point** or simply **Q-point**.
- There can be many such intersecting points, but the Q-point is selected in such a way that irrespective of AC signal swing, the transistor remains in the active region.

Need for stabilization of operating point

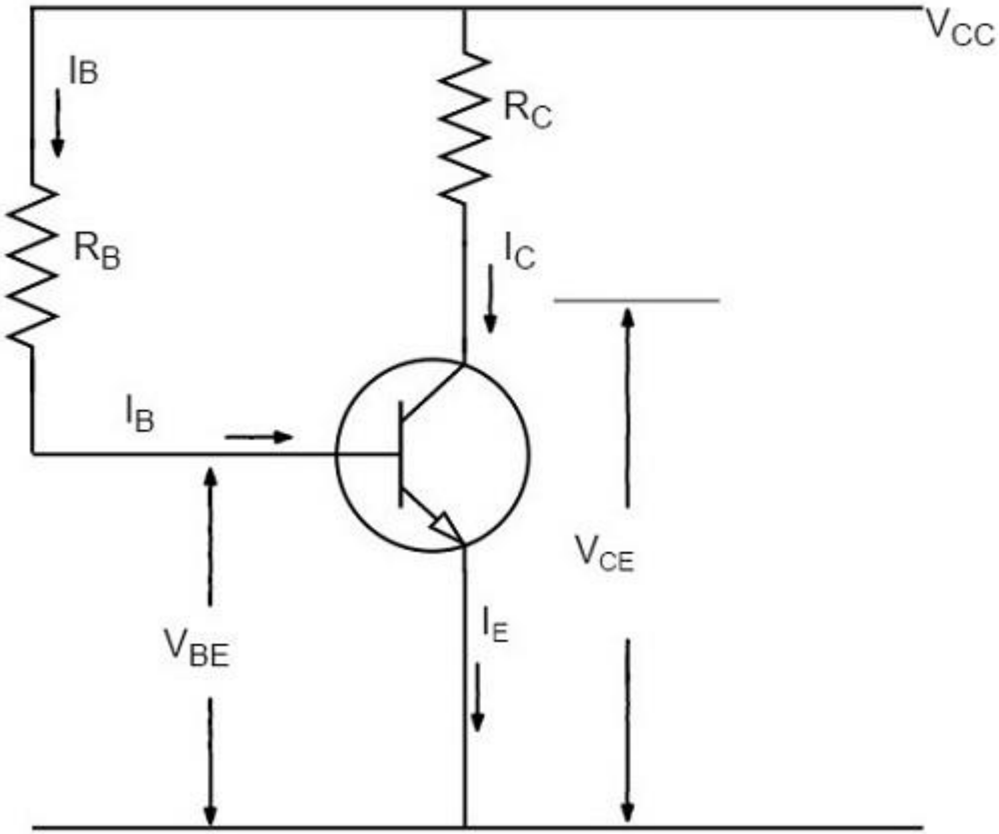
- *The maintaining of the operating point, unaffected by temperature variations or the alterations in transistor parameters*.
- To make Ic independent of temperature, beta, Vbe and to get faithful amplification stabilization is important factor. Due to which Q point remains in the middle of the load line.
- **Need for Stabilization**
- 1)Temperature Dependence of Collector Current Ic:
  - Since, $I_c = \beta I_b + (1+\beta) I_{co}$
    - Reverse saturation current: Ico doubles for every 10 degree rise in temperature.
    - Transistor Current Gain β, increases linearly with rise in temperature.
  - Base Emitter Voltage Vbe, decreases by 2.5mV per dergee rise in temperature.
- Any or all of the above factors can cause a shift in the Q-point with rise in temperature.

- <u>2)Individual Variations:-</u>
- The value of Vbe & β are not exactly same for any two transistors even when they are of same type. Thus, replacing any transistor or replicating a circuit might not give same results.
- <u>3)Thermal Runaway:-</u>
- It is the self destruction of a non stabilized transistor.
- Temp rise -> β rise -> Ic rise -> further temp rise
- and the cycle goes on & on finally transistor will burn.
- *<u>Therefore, stabilization of Q-point is necessary.</u>*

List different transistor biasing

- **The five common biasing circuits:**
- Fixed bias.
- Collector-to-base bias or collector feedback bias
- Fixed bias with emitter resistor.
- Voltage divider bias or potential divider.
- Emitter bias.

Illustrate the behaviour of common emitter configuration with fixed bias

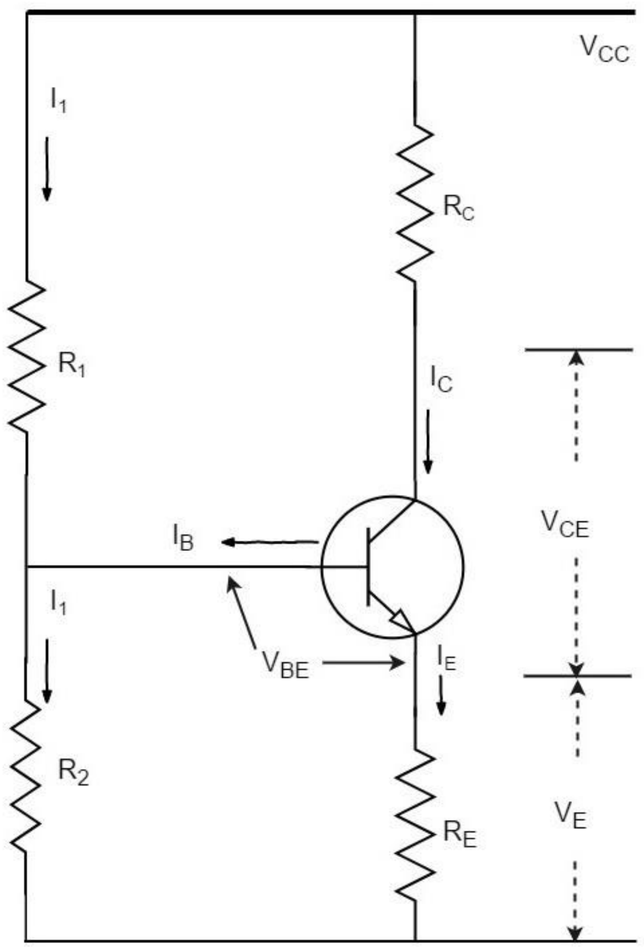


FIXED BIASING

- In this method, *a resistor R_B of high resistance is connected in base*, as the name implies. The required zero signal base current is provided by V_{CC} which flows through R_B. *The base emitter junction is forward biased*, as base is positive with respect to emitter.
- The required value of zero signal base current and hence the collector current (as $I_C = \beta I_B$) can be made to flow by selecting the proper value of base resistor RB. Hence the value of R_B is to be known. The figure shows how a base resistor method of biasing circuit looks like.

- Let I_C be the required zero signal collector current. Therefore,
- $I_B = I_C / \beta$
- Considering the closed circuit from V_{CC}, base, emitter and ground, while applying the Kirchhoff's voltage law, we get,
- $V_{CC} = I_B R_B + V_{BE}$
- Or
- $I_B R_B = V_{CC} - V_{BE}$
  Therefore
- $R_B = V_{CC} - V_{BE} / I_B$
- *V_{CC} is a fixed known quantity and I_B is chosen at some suitable value. As R_B can be found directly, this method is called as **fixed bias method**.*
- Stability factor
- Stability factor, $S=\beta+1$
- Thus the stability factor in a fixed bias is $(\beta+1)$ which means that I_C changes $(\beta+1)$ times as much as any change in I_{CO}.
- So it is highly unstable.

Voltage Divider or Potential Divider or Universal Bias Method



- Among all the methods of providing biasing and stabilization, the **voltage divider bias method** is the most prominent one.
- Here, two resistors R_1 and R_2 are employed, which are connected to V_{CC} and provide biasing. The resistor R_E employed in the emitter provides stabilization.
- *The name voltage divider comes from the voltage divider formed by R_1 and R_2. The voltage drop across R_2 forward biases the base-emitter junction.*
- This causes the base current and hence collector current flow in the zero signal conditions. The figure shows the circuit of voltage divider bias method.

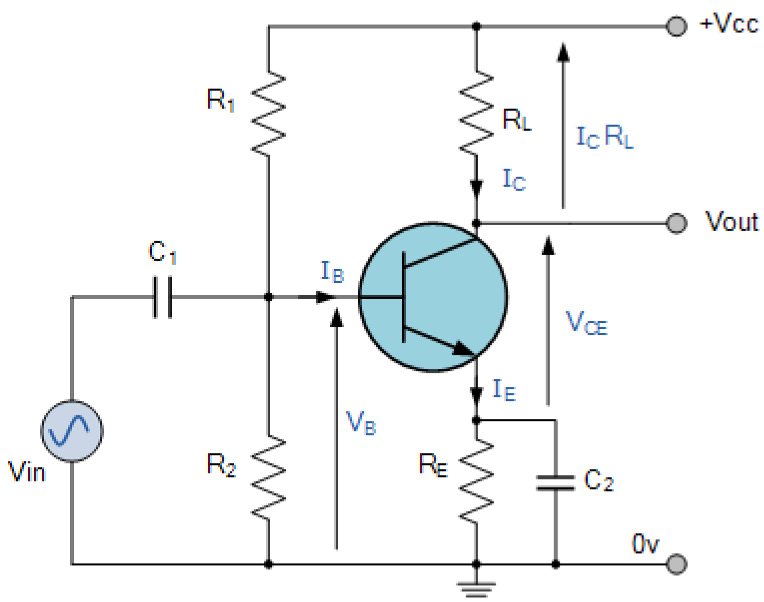
- Suppose that the current flowing through resistance R_1 is I_1. As base current I_B is very small, therefore, it can be assumed with reasonable accuracy that current flowing through R_2 is also I_1.
- Now let us try to derive the expressions for collector current(Ic) and collector voltage(Vce).

- From the circuit, it is evident that,
- $I_1 = V_{CC}/(R1+R2)$
- Therefore, the voltage across resistance R_2 is
- $V2= V_{CC}/(R1+R2)R2$
- Applying Kirchhoff's voltage law to the base circuit,
- $V2= V_{BE} +V_E$
- $V2= V_{BE} + I_E RE$
- $I_E =V2- V_{BE/} RE$
- Since $I_E \approx I_C$,
- $I_C =V2- V_{BE} /RE$

From the above expression, it is evident that I_C doesn't depend upon β. V_{BE} is very small that I_C doesn't get affected by V_{BE} at all. Thus I_C in this circuit is almost independent of transistor parameters and hence good stabilization is achieved.

- Applying Kirchhoff's voltage law to the collector(output) side,
- $V_{CC}=I_C R_C+V_{CE}+I_E R_E$
- Since $I_E \cong I_C$
- $=I_C RC+V_{CE}+I_C R_E$
- $=I_C(R_C+R_E)+V_{CE}$
- Therefore,
- $V_{CE}=V_{CC}-I_C(R_C+R_E)$
- R_E provides excellent stabilization in this circuit.
- $V_2= V_{BE}+I_C R_E$
- *Suppose there is a rise in temperature, then the collector current I_C decreases, which causes the voltage drop across R_E to increase. As the voltage drop across R_2 is V_2, which is independent of I_C, the value of V_{BE} decreases. The reduced value of I_B tends to restore I_C to the original value.*
- Stability Factor, S=1
- This is the smallest possible value of S and leads to the maximum possible thermal stability.

Develop a single stage CE amplifier with voltage divider biasing



- *The small signal amplifier is to amplify all of the input signal with the minimum amount of distortion possible to the output signal*, in other words, *the output signal must be an exact reproduction of the input signal but only bigger signal(amplified)*.
- To obtain low distortion when used as an amplifier the operating point or quiescent point(Q point) needs to be correctly selected. This is in fact the DC operating point of the amplifier and its position may be established at any point along the load line by a suitable biasing arrangement.
- *The best position for this Q-point is as close to the center position of the load line*
- The single stage common emitter amplifier circuit shown above uses what is commonly called "Voltage Divider Biasing". *This type of biasing arrangement uses two resistors as a potential divider network across the supply with their center point supplying the required Base bias voltage to the transistor.* Voltage divider biasing is commonly used in the design of bipolar transistor amplifier circuits.

$$V_B = \frac{V_{CC} R_2}{R_1 + R_2}$$

- This method of biasing the transistor, greatly reduces the effects of varying beta,β by holding the base bias at a constant steady voltage level allowing for best stability.
- The quiescent Base voltage, Vb is determined by the *potential divider network formed by the two resistors, R1, R2 and the power supply voltage Vcc* as shown with the current flowing through both resistors.

- **Then the total resistance will be equal to R_1+R_2 giving the current as i = Vcc /R_{1+} R_2.**

- The voltage level generated at the junction of resistors R1 and R2 holds the Base voltage Vb constant at a value below the supply voltage.
- *The potential divider network used in the common emitter amplifier circuit divides the supply voltage in proportion to the resistance.*

Single Stage CE Amplifier Parameters

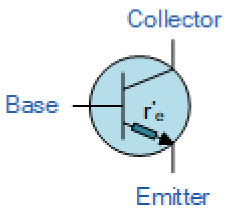
Voltage Gain(Av)

- The **Voltage Gain** of the common emitter amplifier is equal to *the ratio of the change in output voltage to the change in the input voltage*. Then ΔV_L is V_{out} and ΔV_B is V_{in}. 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:

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

- However, BJT’s have a small internal resistance built into their Emitter region called r’e. The transistors semiconductor material offers an internal resistance to the flow of current through it and is generally represented by a small resistor symbol shown inside the main transistor symbol.
- Transistor data sheets tell us that for a small signal bipolar transistors this internal resistance is the r’e $=25mV/I_E$ (25mV being the internal volt drop across the Emitter junction layer).
- This internal Emitter leg resistance, r’e will be in series with the external Emitter resistor, R_E,
- Then the equation for the transistors actual gain will be modified to include this internal resistance

$$\text{Voltage Gain} = -\frac{R_L}{(R_E + r'_e)}$$



Current gain:-

- The **Current Gain** of the common emitter amplifier is equal to the ratio of the change in output current to the change in the input current.

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

- A transistors β, sometimes referred to as h_{FE} on datasheets, defines the transistors forward current gain in the common emitter configuration.
- Beta is an electrical parameter built into the transistor during manufacture. Beta (h_{FE}) has no units as it is a fixed ratio of the two currents, Ic and Ib so a small change in the Base current will cause a large change in the Collector current.

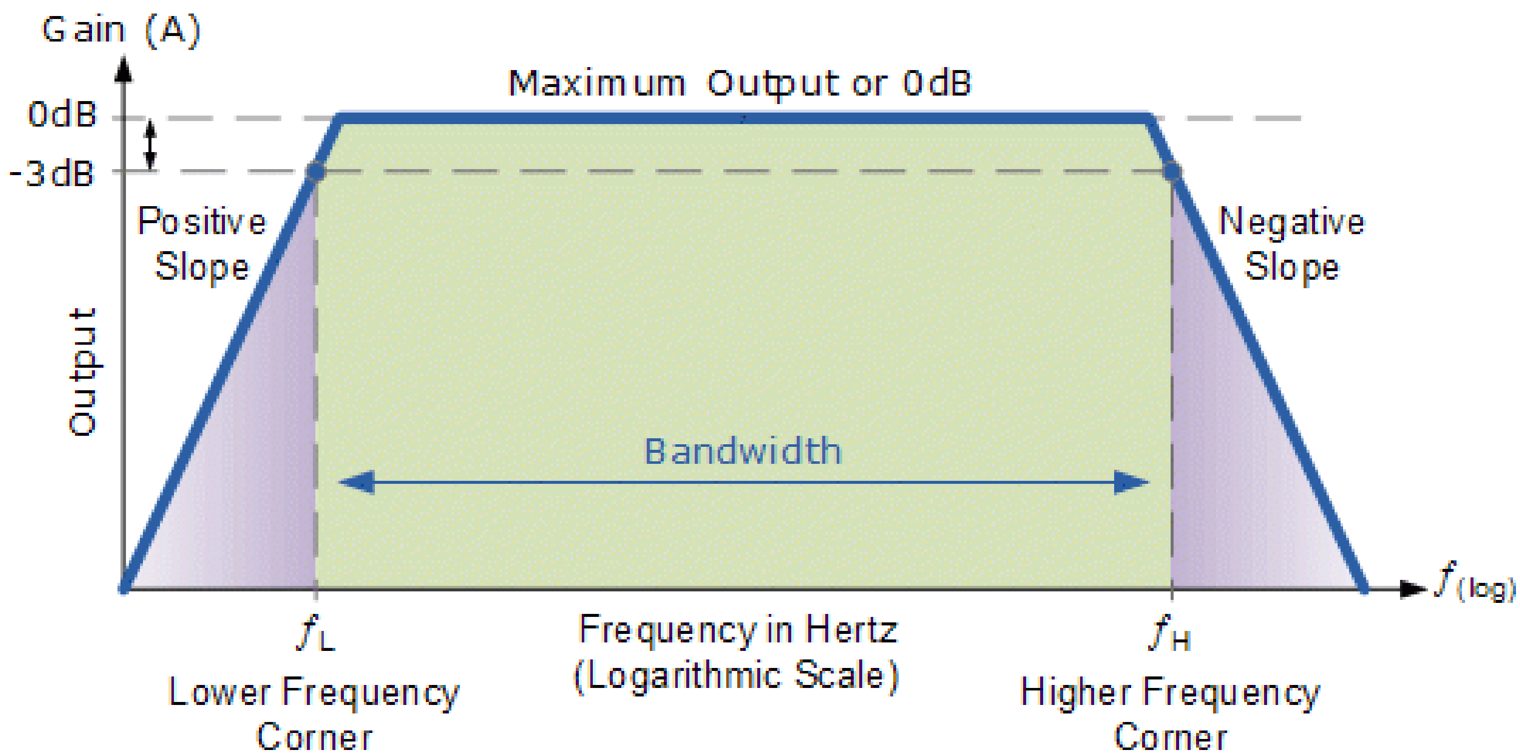
Input Resistance(R_i)

- It is the ratio of input voltage to the input current.
- $R_i = V_i/I_i = V_b / I_b$
- The base voltage is, $V_b = I_e.R_e$ and I_e approx equal to I_c
- And $Ib = Ic/\beta$
- Now substituting, $Ri = Ie.Re/(Ic/\beta) = \beta Re$
- $Ri = \beta .Re$ is the input resistance.

Output Resistance(Ro)

- It is the ratio of output voltage to the input voltage.   Ro=Rc
- Power Gain:-
- It is the ratio of output power to the input power.

Frequency Response & Bandwidth of an Amplifier



Frequency versus Gain plotted on graph is called frequency response. Frequency is plotted on x-axis and Gain plotted on y-axis.

Gain = Vo/Vi

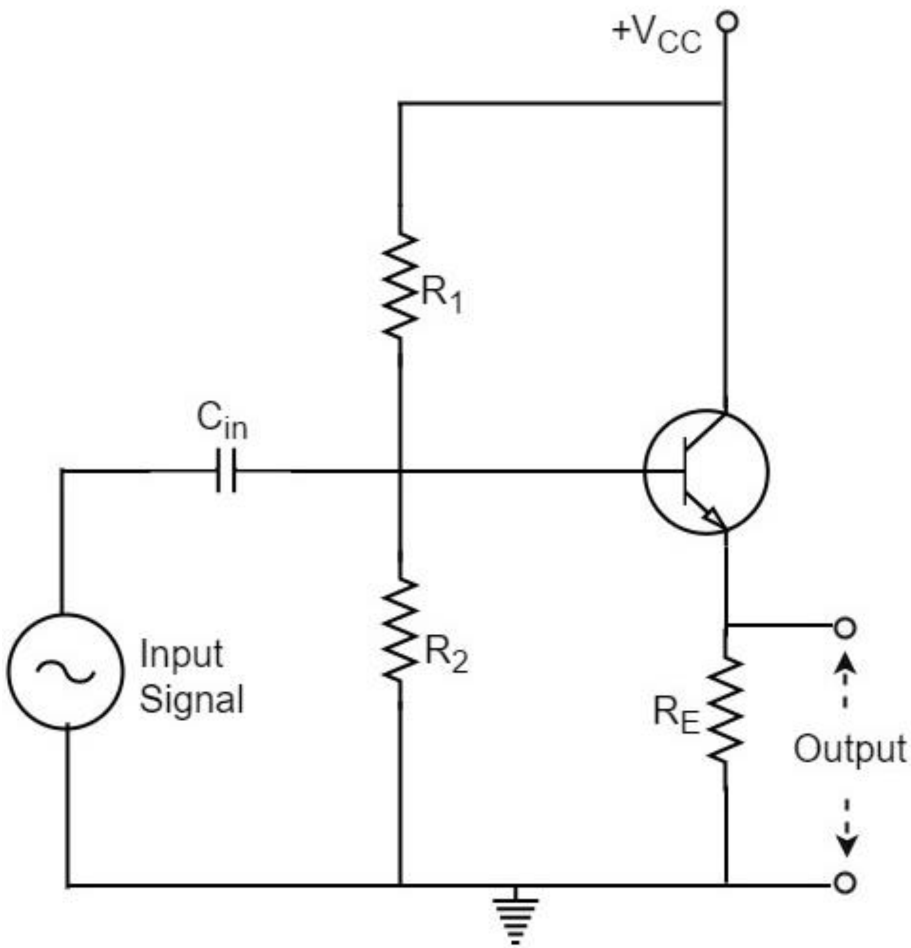
Bandwidth:- $\text{Bandwidth, (BW)} = f_H - f_L$

It is the range of frequencies over which gain constant. f_L is the lower cut off frequency and f_H is the upper cut off frequency.

The decibel, (dB) which is 1/10th of a bel (B), is a common non-linear unit for measuring gain and is defined as **$20\log_{10}(A)$** where **A is the decimal gain**, being plotted on the y-axis. Zero decibels, (0dB) corresponds to a magnitude function of unity giving the maximum output. In other words, 0dB occurs when Vout = Vin as there is no attenuation at this frequency level and is given as:

Emitter Follower

Emitter follower is a case of negative current feedback circuit. This is mostly used as a last stage amplifier in signal generator circuits.



Construction & Operation

- The constructional details of an emitter follower circuit are nearly similar to a normal amplifier. The main difference is that the **load R_L is absent** at the collector terminal, but present at the emitter terminal of the circuit. Thus *the output is taken from the emitter terminal instead of collector terminal.*
- The biasing is provided by potential divider method.
- The input signal voltage applied between base and emitter, develops an output voltage V_o across R_E, which is in the emitter section. Therefore,
  - **$Vo=I_ER_E$**

- The whole of this output current is applied to the input through feedback. Hence, $V_f = V_o$
- As the output voltage developed across R_L is proportional to the emitter current, this emitter follower circuit is a current feedback circuit. Hence, $\beta = V_f/V_o = 1$
- It is also noted that the input signal voltage to the transistor (= V_i) is equal to the difference of V_s and V_o i.e., $V_i = V_s - V_o$
-

Hence the feedback is negative.

Features

- It has high input impedance
- It has low output impedance
- It is ideal circuit for impedance matching
- No voltage gain. In fact, the voltage gain is nearly 1.
- Relatively high current gain and power gain.
- Input and output ac voltages are in phase.
- It is used as a buffer amplifier.