Transistor as Amplifier

What is Amplifier:

Amplification is a process of increasing the signal strength by increasing the amplitude of a given signal with out changing its characteristics. The input signal may be a current signal, voltage signal or a power signal; amplifier will amplify the signal without changing its characteristics. Applications of amplifier are of wide range, they are mainly used in communications, controllers, audio and video instruments etc.

Using the Transistor as Amplifier:

Transistor can be used as two types

- Switch
- Amplifier

Here we will concentrate how transistor is used as amplifier. Transistor will get completely on at saturation region and completely get off at cutoff region. If transistor wants to works as an amplifier we should make the transistor to work in active region which lies between the saturation and cutoff region. We will discuss more about this topic in later session.

Transistor can be used as amplifier in the following three configurations.

1. Common Base configuration (CB): in the CB configuration we will connect base of the transistor to ground, which has very low input impedance which will give very low output impedance with very low amplification. Gain for this configuration will be very low.
2. Common Collector configuration (CC): in this configuration collector is connected to ground, we have low output impedance for high input impedance and gain for this configuration is very good when compared to CB configuration.
3. Common Emitter configuration (CE): in this configuration emitter is connected to ground and we will have input impedance will be high, output impedance will be medium and gain will be high.

Note: Most of amplification circuits uses CE configuration because it has high gain and high input impedance.

Parameters to Choose an Amplifier:

We need to consider the following specifications before choosing the transistor amplifier. The specifications are input impedance, efficiency, bandwidth, gain, slew rate, linearity, stability, etc.

Input impedance: The voltage source which is connected to the impedance, which is connected to the input, is called input impedance. In the transistor amplifier the input impedance should be high because it will stop the loading of the circuit. For example if the we give 10V signal with 1k ohm source impedance to the 1M input ohm which is connected to the input of the transistor or other electronic peripheral then the input impedance will be

- Input impedence = 10V *(1M/1M+1k) = 9.9v

- If we decrease the impedance to 10K = 10V*(10K/10K+1K) = 9.09V

- If we decrease the impedance to 5K = 10V*(1K/1K+1K) = 5V

So from above circuit if decrease the input impedance the voltage will also get decreased and the gain of the circuit will be decreased. Input impedance should be 10 times higher than the source impedance for good amplification.

Efficiency: The efficiency is nothing but how much input power is effectively used to get the output of the amplifier. In other words efficiency is nothing but how much power is drawn for the power source and how much power is efficiently used to get output by the amplifier.

Efficiency (ζ) = (Pout/Ps)*100

where Pout is power of output and Ps is power drawn from power source.

Bandwidth: The frequency range where amplifier can do good amplification of the signal is called bandwidth of that amplifier. The bandwidth of the frequency is calculated in signal by based on the half power points i.e. the points where the output power becomes half the peak output power in the frequency vs output graph.
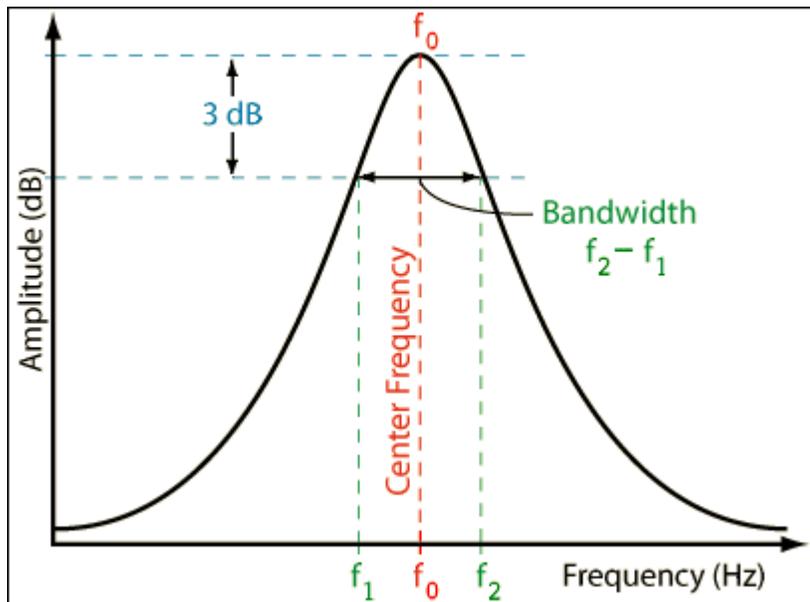
Gain: The gain of the amplifier is measured by calculating the ratio between the output power to the input power. Usually gain is calculated in decibels. Gain of a amplifier can be calculated in voltage and also in current terms also.

- GAIN in power G = 10 log (Pout/Pin)

- GAIN in voltage G = 20 log (Vout/Vin)

- GAIN in current G= 20 log (Iout/Iin)

Higher gain circuits will be high sensitive and give good output even when small input is given.

Stability: The ability of amplifier to avoid self oscillations. Because of these oscillations the signal might be overlapped or get masked the useful signal. Stability can be reached by adding zonal network at the output which will produce negative feedback.

Skew Rate: The skew rate is defined as the rate of amplifier will give the output in response to the input signal. If the slew rate is high we can say the amplifier is fast. The slew rate is represented V/μs and equation is SR=(dVo/dt) .

Linearity: If the input of the amplifier is increased the output of the amplifier should also increased linearly this effect is called linearity. This effect will be 100% achieved by ideal amplifier, when we take practical case the amplifier will produce linear output for its input up to certain limit, after that if input frequency is increased the output gain will be decreased due to internal parasitic capacitance of the signal. This non linearity can be reduced by negative feed back.

Noise: Noise is defined as the unwanted frequencies in the signal due to the component interface, external interferences, component failures, same frequency signals in the same circuit, etc.

Now we will concentrate on how transistor will work in active region and Common emitter RC coupled amplifier.
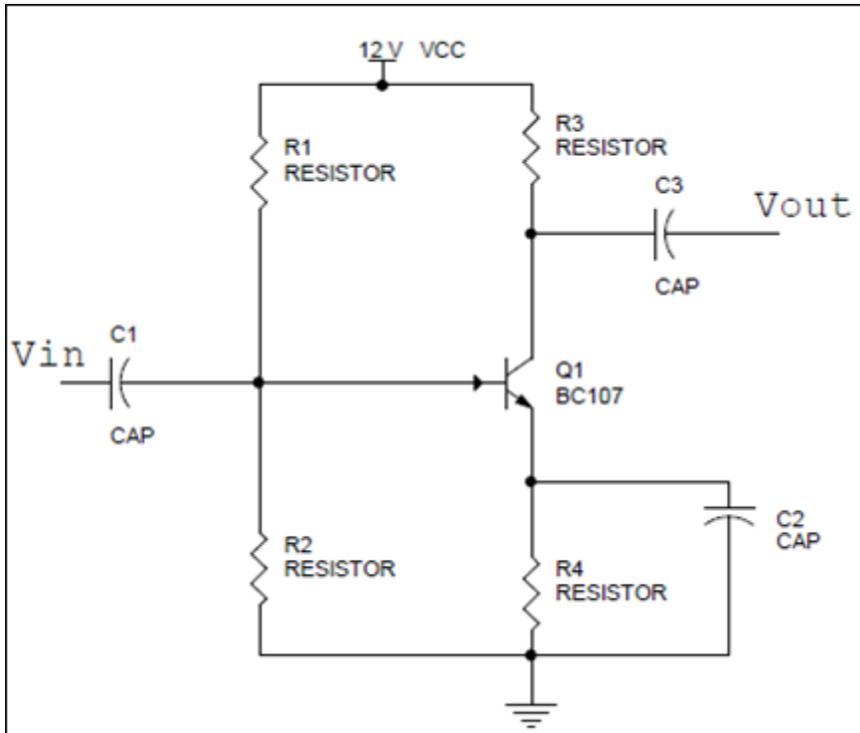
Transistor:

Transistor is an electronic device which is mainly used for switching and amplification purpose. Transistor are of two types PNP and NPN, in PNP holes are majority carriers and in NPN electrons are the minority carriers. NPN transistors are faster than PNP because mobility of the electrons is faster than holes.

We all know that transistor works in three regions

1. **Cut-Off Region:** In the cut-off region transistor will be get off and in saturation region transistor will get on. This regions are mainly used in switching conditions.
2. **Active Region:** In the active region transistor will be on. The collector to emitter voltage (Vce) will be in between cut-off and saturation regions. Transistor can amplify the small changes in voltage at base which is given to the collector. Transistor requires only 0.7V to work completely in saturation mode.
   o 0.2<Vce<Vcc where Vcc is the power supply
3. **Saturation Region:** In the active region collector current (Ic) is proportional to the base current (Ib) by a constant multiplier called β if we denoted the above sentence in equation that will be Ic= βIb. By this we can easily use transistor as a linear amplifier in active region.

Common Emitter RC Coupled Amplifier: Common emitter RC coupled amplifier is basic and simple amplifier. The circuit of RC coupled amplifier is shown below.

The capacitor C1 is a filter which is used to block the Dc voltage and allow only the variations in the voltage to the transistor. The Resistor R1, R2 is used as biasing network which will keep the transistor in active region. If we don't use the biasing the voltage from capacitor is directly given to the transistor. We all know that transistor will get on for 0.7v. Normally we will give more voltage to the transistor (> 0.7v), with this voltage transistor will easily go to the saturation mode and act as a closed loop circuit. Proper biasing network will keep the transistor in active region.

Resistors R3 and R4 is used to drop the voltage of Vcc. R3 is the collector resistor and R4 is the emitter resistor which is selected in such a way that both should drop the Vcc voltage by 50%. R3 should drop around 40% and remaining 10% is dropped by R4. The capacitor c2 and R4 will make negative feedback which makes the circuit stable.

Design of RC coupled amplifier:

The design of a single stage RC coupled amplifier is shown below.

The nominal vale of collector current Ic and hfe can be obtained from the datasheet of the transistor.

Design of Re and Ce:

- Let voltage across Re: $V_{Re} = 10\%V_{cc}$ ………..(1)
- Voltage across Rc: $V_{Rc} = 40\%\ V_{cc}$. …………..(2)

The remaining 50% will drop across the collector-emitter .

From (1) and (2) $R_c = 0.4 (V_{cc}/I_c)$ and Re = 01(V_{cc}/I_c).

Design of R1 and R2:

Basecurrent$I_b = I_c/hfe.$
Let$I_c \approx I_e$.
Let   current   through   R1; $IR1 =$ 10$I_b.$
Also voltage across R2: V$R2$ must be equal to V$_{be}$ + V$_{Re}$. From this VR2 can be found.
There fore V$R1$ = V$_{cc}$-V$R2$. Since VR1 ,VR2 and IR1 are found we can find R1 and R2 using the following equations.
R1 = V$R1$/I$R1$ and R2 = V$R2$/I$R1$.

Finding Ce: Impedance of emitter by-pass capacitor should be one by tenth of Re.

i.e. XCe = 1/10 (Re)

Also XCe = 1/2∏FCe

F can be selected to be 100Hz. From this Ce can be found.

Finding Cin: Impedance of the input capacitor(Cin) should be one by tenth of the transistors input impedance (Rin).

i.e. XCin = 1/10 (Rin)

Rin = R1 parallel R2 parallel (1 + (hfe *re))*

re = 25mV/Ie.

Xcin = 1/2∏FCin.

From this Cin can be found.

Finding Cout: Impedance of the output capacitor (Cout) must be one by tenth of the circuit's output resistance (Rout).

i.e, XCout = 1/10 (Rout).

Rout = Rc.

X$Cout$ = 1/ 2∏FC$out.$

From this Cout can be found.

Setting the gain: Introducing a suitable load resistor RL across the transistor's collector and ground will set the gain.

Expression for the voltage gain (Av) of a common emitter transistor amplifier is as follows.

Av = -(rc/re)

re = 25mV/Ie

and rc = Rc parallel RL

From this RL can be found.