Basic Amplifier

We hope that you have gained sufficient knowledge on operating point, its stability and the compensation techniques in the previous chapter. Let us now try to understand the fundamental concepts of a basic amplifier circuit.

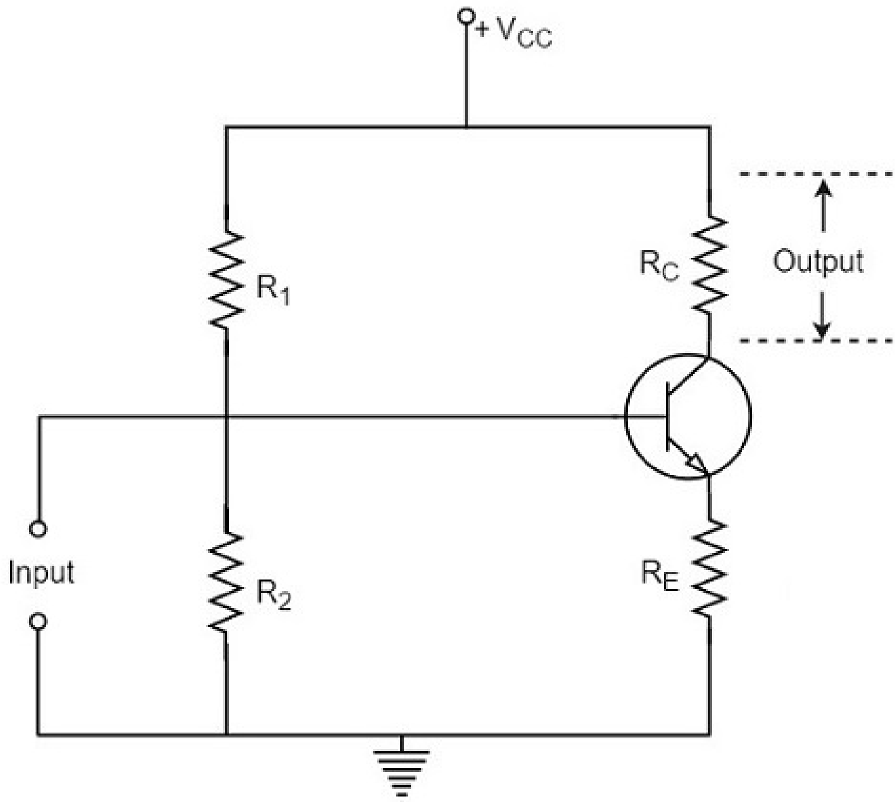
An electronic signal contains some information which cannot be utilized if doesn't have proper strength. The process of increasing the signal strength is called as **Amplification**. Almost all electronic equipment must include some means for amplifying the signals. We find the use of amplifiers in medical devices, scientific equipment, automation, military tools, communication devices, and even in household equipment.

Amplification in practical applications is done using Multi-stage amplifiers. A number of single-stage amplifiers are cascaded to form a Multi-stage amplifier. Let us see how a single-stage amplifier is built, which is the basic for a Multi-stage amplifier.

Single-stage Transistor Amplifier

When only one transistor with associated circuitry is used for amplifying a weak signal, the circuit is known as **single-stage amplifier**.

Analyzing the working of a Single-stage amplifier circuit, makes us easy to understand the formation and working of Multi-stage amplifier circuits. A Single stage transistor amplifier has one transistor, bias circuit and other auxiliary components. The following circuit diagram shows how a single stage transistor amplifier looks like.

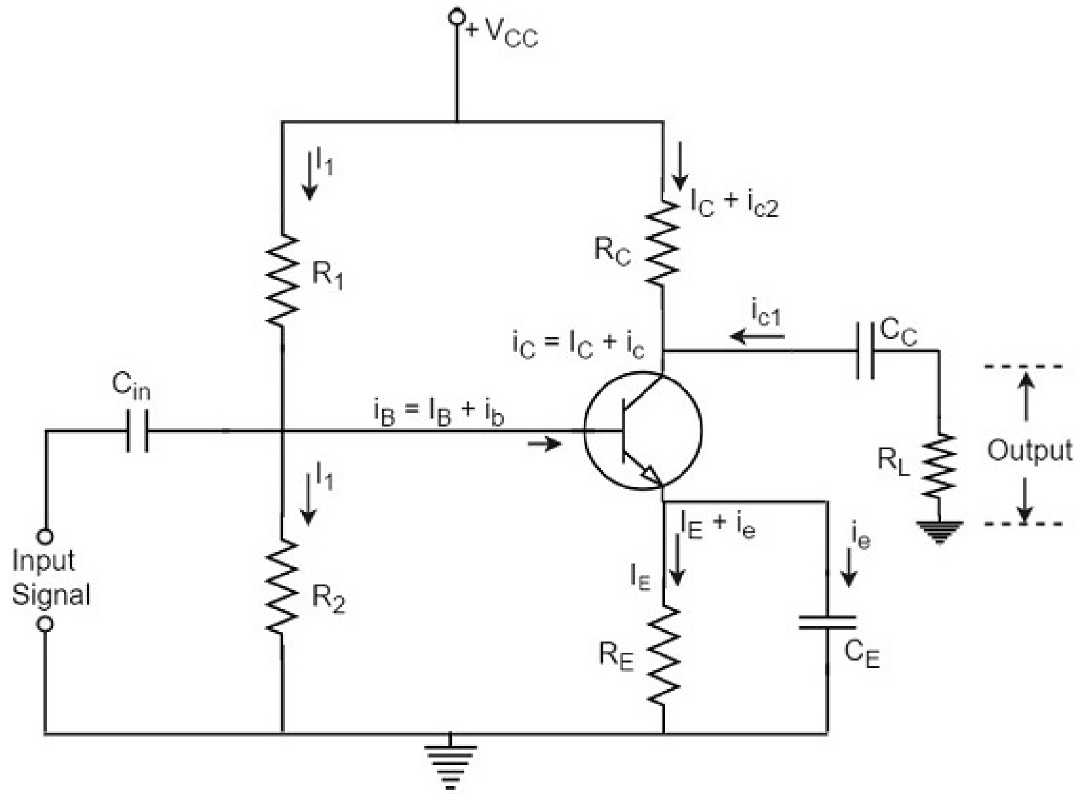


When a weak input signal is given to the base of the transistor as shown in the figure, a small amount of base current flows. Due to the transistor action, a larger current flows in the collector of the transistor. (As the collector current is β times of the base current which means $I_C = \beta I_B$). Now, as the collector current increases, the voltage drop across the resistor R_C also increases, which is collected as the output.

Hence a small input at the base gets amplified as the signal of larger magnitude and strength at the collector output. Hence this transistor acts as an amplifier.

Practical Circuit of a Transistor Amplifier

The circuit of a practical transistor amplifier is as shown below, which represents a voltage divider biasing circuit.



The various prominent circuit elements and their functions are as described below.

Biasing Circuit

The resistors R_1, R_2 and R_E form the biasing and stabilization circuit, which helps in establishing a proper operating point.

Input Capacitor C_{in}

This capacitor couples the input signal to the base of the transistor. The input capacitor C_{in} allows AC signal, but isolates the signal source from R_2. If this capacitor is not present, the input signal gets directly applied, which changes the bias at R_2.

Coupling Capacitor C_C

This capacitor is present at the end of one stage and connects it to the other stage. As it couples two stages it is called as **coupling capacitor**. This capacitor blocks DC of one stage to enter the other but allows AC to pass. Hence it is also called as **blocking capacitor**.

Due to the presence of coupling capacitor C_C, the output across the resistor R_L is free from the collector's DC voltage. If this is not present, the bias conditions of the next stage will be drastically changed due to the shunting effect of R_C, as it would come in parallel to R_2 of the next stage.

Emitter by-pass capacitor C_E

This capacitor is employed in parallel to the emitter resistor R_E. The amplified AC signal is by passed through this. If this is not present, that signal will pass through R_E which produces a voltage drop across R_E that will feedback the input signal reducing the output voltage.

The Load resistor R_L

The resistance R_L connected at the output is known as **Load resistor**. When a number of stages are used, then R_L represents the input resistance of the next stage.

Various Circuit currents

Let us go through various circuit currents in the complete amplifier circuit. These are already mentioned in the above figure.

Base Current

When no signal is applied in the base circuit, DC base current I_B flows due to biasing circuit. When AC signal is applied, AC base current i_b also flows. Therefore, with the application of signal, total base current i_B is given by

$$i_B = I_B + i_b$$

Collector Current

When no signal is applied, a DC collector current I_C flows due to biasing circuit. When AC signal is applied, AC collector current i_c also flows. Therefore, the total collector current i_C is given by

$$i_C = I_C + i_c$$

Where

$I_C = \beta I_B$ = zero signal collecor current

$i_c = \beta i_b$ = collecor current due to signal

Emitter Current

When no signal is applied, a DC emitter current I_E flows. With the application of signal, total emitter current i_E is given by

$$i_E = I_E + i_e$$

It should be remembered that

$$I_E = I_B + I_C$$

$$i_e = i_b + i_c$$

As base current is usually small, it is to be noted that

$$I_E \cong I_C \quad \text{and} \quad i_e \cong i_c$$

These are the important considerations for the practical circuit of transistor amplifier. Now let us know about the classification of Amplifiers.

Amplifiers Classification

An Amplifier circuit is one which strengthens the signal. The amplifier action and the important considerations for the practical circuit of transistor amplifier were also detailed in previous chapters.

Let us now try to understand the classification of amplifiers. Amplifiers are classified according to many considerations.

Based on number of stages

Depending upon the number of stages of Amplification, there are Single-stage amplifiers and Multi-stage amplifiers.

- **Single-stage Amplifiers** − This has only one transistor circuit, which is a singlestage amplification.
- **Multi-stage Amplifiers** − This has multiple transistor circuit, which provides multi-stage amplification.

Based on its output

Depending upon the parameter that is amplified at the output, there are voltage and power amplifiers.

- **Voltage Amplifiers** − The amplifier circuit that increases the voltage level of the input signal, is called as Voltage amplifier.
- **Power Amplifiers** − The amplifier circuit that increases the power level of the input signal, is called as Power amplifier.

Based on the input signals

Depending upon the magnitude of the input signal applied, they can be categorized as Small signal and large signal amplifiers.

- **Small signal Amplifiers** − When the input signal is so weak so as to produce small fluctuations in the collector current compared to its quiescent value, the amplifier is known as Small signal amplifier.
- **Large signal amplifiers** − When the fluctuations in collector current are large i.e. beyond the linear portion of the characteristics, the amplifier is known as large signal amplifier.

Based on the frequency range

Depending upon the frequency range of the signals being used, there are audio and radio amplifiers.

- **Audio Amplifiers** − The amplifier circuit that amplifies the signals that lie in the audio frequency range i.e. from 20Hz to 20 KHz frequency range, is called as audio amplifier.

- **Power Amplifiers** − The amplifier circuit that amplifies the signals that lie in a very high frequency range, is called as Power amplifier.

Based on Biasing Conditions

Depending upon their mode of operation, there are class A, class B and class C amplifiers.

- **Class A amplifier** − The biasing conditions in class A power amplifier are such that the collector current flows for the entire AC signal applied.
- **Class B amplifier** − The biasing conditions in class B power amplifier are such that the collector current flows for half-cycle of input AC signal applied.
- **Class C amplifier** − The biasing conditions in class C power amplifier are such that the collector current flows for less than half cycle of input AC signal applied.
- **Class AB amplifier** − The class AB power amplifier is one which is created by combining both class A and class B in order to have all the advantages of both the classes and to minimize the problems they have.

Based on the Coupling method

Depending upon the method of coupling one stage to the other, there are RC coupled, Transformer coupled and direct coupled amplifier.

- **RC Coupled amplifier** − A Multi-stage amplifier circuit that is coupled to the next stage using resistor and capacitor (RC) combination can be called as a RC coupled amplifier.
- **Transformer Coupled amplifier** − A Multi-stage amplifier circuit that is coupled to the next stage, with the help of a transformer, can be called as a Transformer coupled amplifier.
- **Direct Coupled amplifier** − A Multi-stage amplifier circuit that is coupled to the next stage directly, can be called as a direct coupled amplifier.

Based on the Transistor Configuration

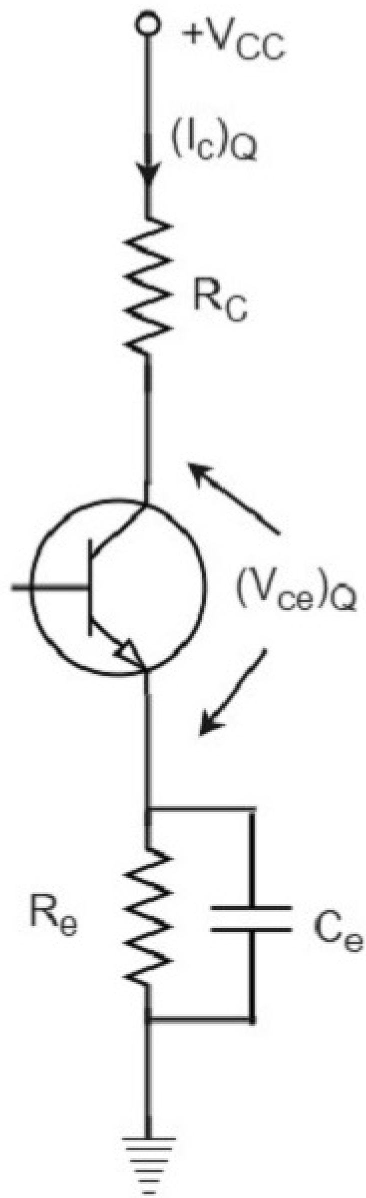
Depending upon the type of transistor configuration, there are CE CB and CC amplifiers.

- **CE amplifier** − The amplifier circuit that is formed using a CE configured transistor combination is called as CE amplifier.
- **CB amplifier** − The amplifier circuit that is formed using a CB configured transistor combination is called as CB amplifier.
- **CC amplifier** − The amplifier circuit that is formed using a CC configured transistor combination is called as CC amplifier.

Class A Power Amplifiers

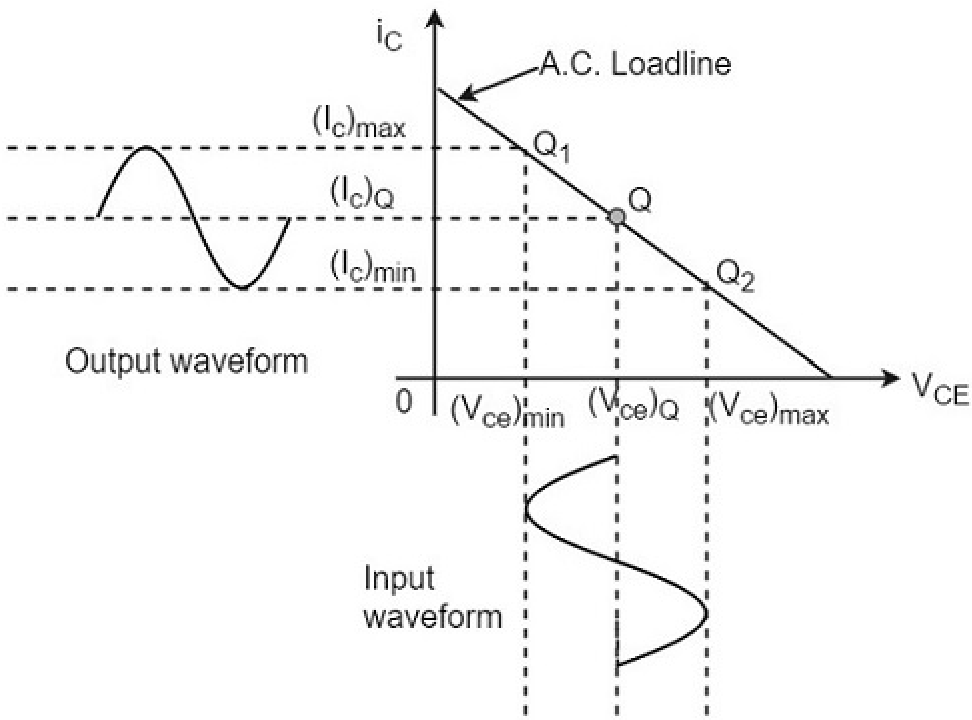
We have already come across the details of transistor biasing, which is very important for the operation of a transistor as an amplifier. Hence to achieve faithful amplification, the biasing of the transistor has to be done such that the amplifier operates over the linear region.

A Class A power amplifier is one in which the output current flows for the entire cycle of the AC input supply. Hence the complete signal present at the input is amplified at the output. The following figure shows the circuit diagram for Class A Power amplifier.



From the above figure, it can be observed that the transformer is present at the collector as a load. The use of transformer permits the impedance matching, resulting in the transference of maximum power to the load e.g. loud speaker.

The operating point of this amplifier is present in the linear region. It is so selected that the current flows for the entire ac input cycle. The below figure explains the selection of operating point.



The output characteristics with operating point Q is shown in the figure above. Here $(I_c)_Q$ and $(V_{ce})_Q$ represent no signal collector current and voltage between collector and emitter respectively. When signal is applied, the Q-point shifts to Q_1 and Q_2. The output current increases to $(I_c)_{max}$ and decreases to $(I_c)_{min}$. Similarly, the collector-emitter voltage increases to $(V_{ce})_{max}$ and decreases to $(V_{ce})_{min}$.

D.C. Power drawn from collector battery V_{cc} is given by

$$P_{in} = voltage \times current = V_{CC}(I_C)_Q$$

This power is used in the following two parts −

- Power dissipated in the collector load as heat is given by

$$P_{RC} = (current)^2 \times resistance = (I_C)_Q^2 R_C$$

- Power given to transistor is given by

$$P_{tr} = P_{in} - P_{RC} = V_{CC} - (I_C)_Q^2 R_C$$

When signal is applied, the power given to transistor is used in the following two parts −

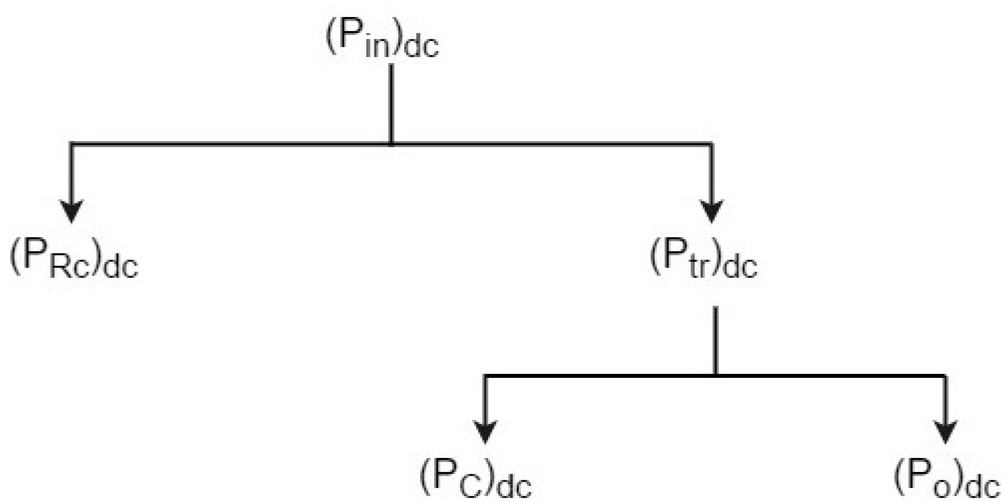
- A.C. Power developed across load resistors RC which constitutes the a.c. power output.

$$(P_O)_{ac} = I^2 R_C = \frac{V^2}{R_C} = \left(\frac{V_m}{\sqrt{2}}\right)^2 \frac{1}{R_C} = \frac{V_m^2}{2R_C}$$

  Where **I** is the R.M.S. value of a.c. output current through load, **V** is the R.M.S. value of a.c. voltage, and $\mathbf{V_m}$ is the maximum value of V.

- The D.C. power dissipated by the transistor (collector region) in the form of heat, i.e., $(P_C)_{dc}$

We have represented the whole power flow in the following diagram.



This class A power amplifier can amplify small signals with least distortion and the output will be an exact replica of the input with increased strength.

Let us now try to draw some expressions to represent efficiencies.

Overall Efficiency

The overall efficiency of the amplifier circuit is given by

$$(\eta)_{overall} = \frac{a.c\, power\, delivered\, to\, the\, load}{total\, power\, delivered\, by\, d.c\, supply}$$

$$= \frac{(P_O)_{ac}}{(P_{in})_{dc}}$$

Collector Efficiency

The collector efficiency of the transistor is defined as

$$(\eta)_{collector} = \frac{average\ a.c\ power\ output}{average\ d.c\ power\ input\ to\ transistor}$$

$$= \frac{(P_O)_{ac}}{(P_{tr})_{dc}}$$

Expression for overall efficiency

$$(P_O)_{ac} = V_{rms} \times I_{rms}$$

$$= \frac{1}{\sqrt{2}}\left[\frac{(V_{ce})_{max} - (V_{ce})_{min}}{2}\right] \times \frac{1}{\sqrt{2}}\left[\frac{(I_C)_{max} - (I_C)_{min}}{2}\right]$$

$$= \frac{[(V_{ce})_{max} - (V_{ce})_{min}] \times [(I_C)_{max} - (I_C)_{min}]}{8}$$

Therefore

$$(\eta)_{overall} = \frac{[(V_{ce})_{max} - (V_{ce})_{min}] \times [(I_C)_{max} - (I_C)_{min}]}{8 \times V_{CC}(I_C)_Q}$$

Advantages of Class A Amplifiers

The advantages of Class A power amplifier are as follows −

- The current flows for complete input cycle
- It can amplify small signals
- The output is same as input
- No distortion is present

Disadvantages of Class A Amplifiers

The advantages of Class A power amplifier are as follows −

- Low power output
- Low collector efficiency

Class AB and Class C Power Amplifiers

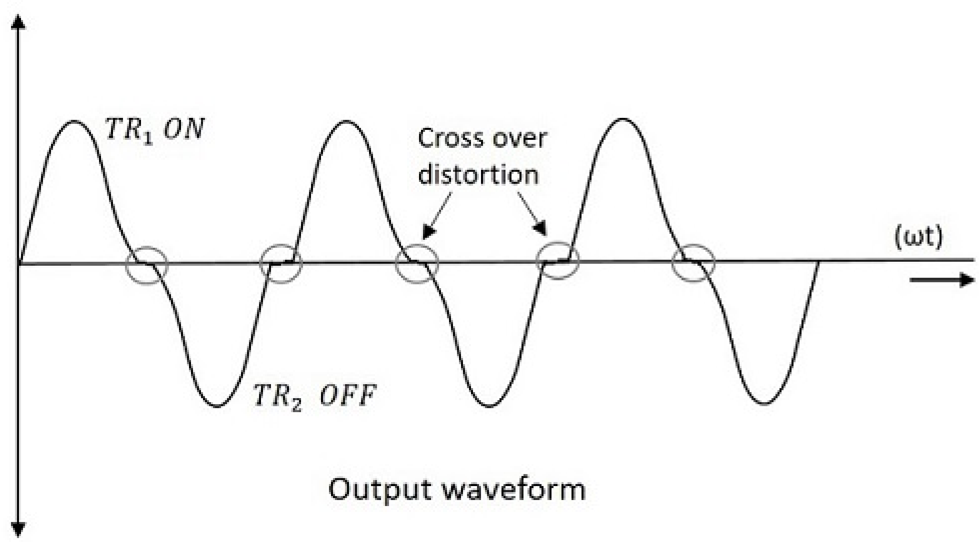
The class A and class B amplifier so far discussed has got few limitations. Let us now try to combine these two to get a new circuit which would have all the advantages of both class A and class B amplifier without their inefficiencies. Before that, let us also go through another important problem, called as **Cross over distortion**, the output of class B encounters with.

Cross-over Distortion

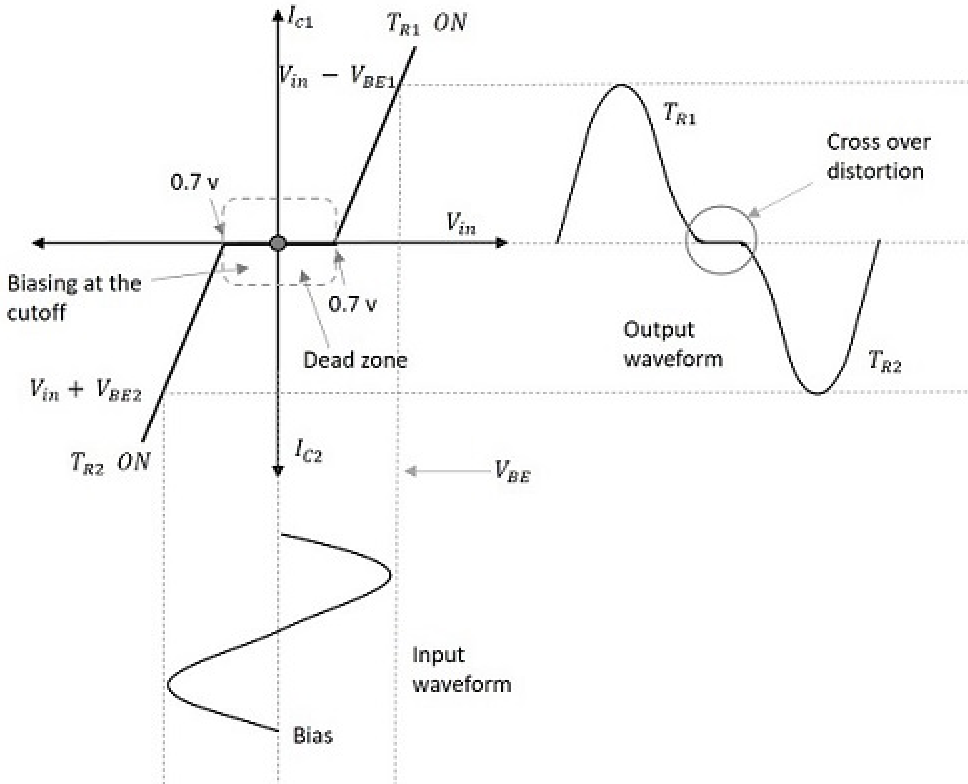
In the push-pull configuration, the two identical transistors get into conduction, one after the other and the output produced will be the combination of both.

When the signal changes or crosses over from one transistor to the other at the zero voltage point, it produces an amount of distortion to the output wave shape. For a transistor in order to conduct, the base emitter junction should cross 0.7v, the cut off voltage. The time taken for a transistor to get ON from OFF or to get OFF from ON state is called the **transition period**.

At the zero voltage point, the transition period of switching over the transistors from one to the other, has its effect which leads to the instances where both the transistors are OFF at a time. Such instances can be called as **Flat spot** or **Dead band** on the output wave shape.



The above figure clearly shows the cross over distortion which is prominent in the output waveform. This is the main disadvantage. This cross over distortion effect also reduces the overall peak to peak value of the output waveform which in turn reduces the maximum power output. This can be more clearly understood through the non-linear characteristic of the waveform as shown below.



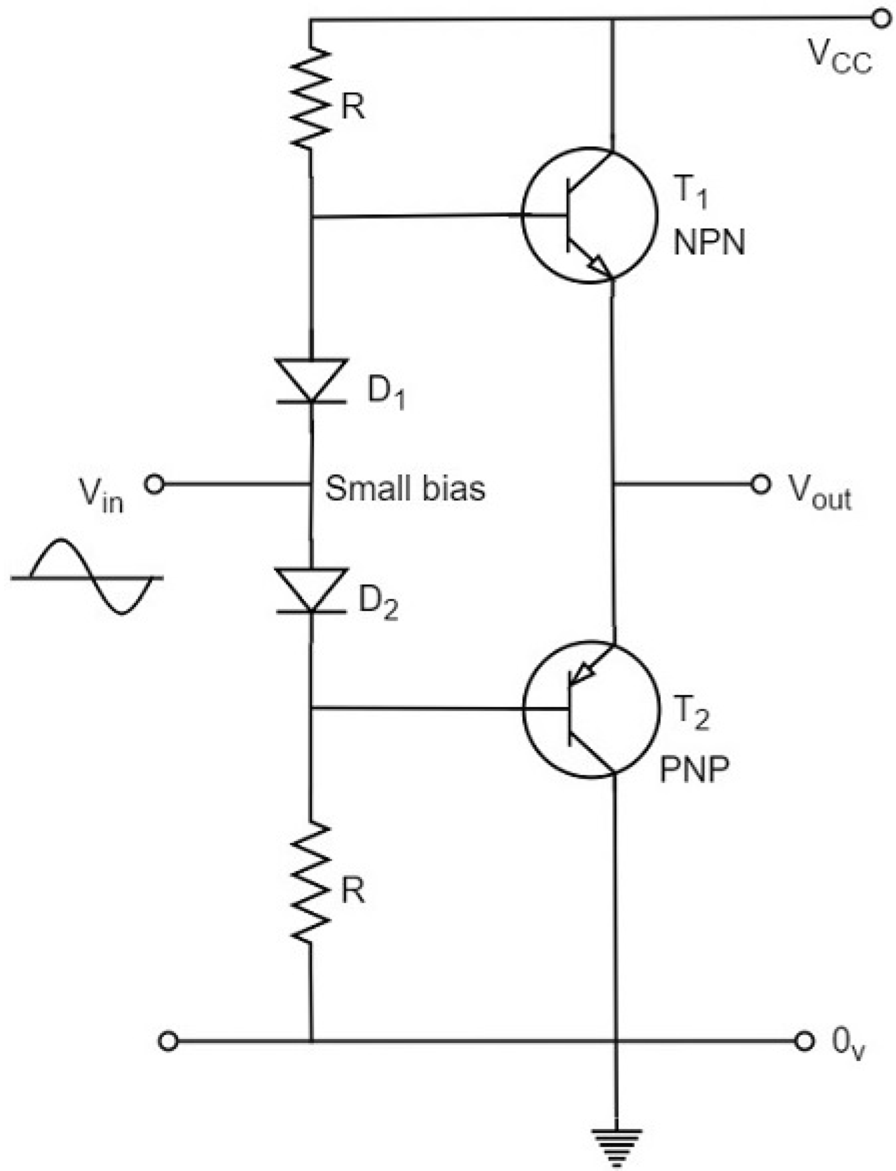
It is understood that this cross-over distortion is less pronounced for large input signals, where as it causes severe disturbance for small input signals. This cross over distortion can be eliminated if the conduction of the amplifier is more than one half cycle, so that both the transistors won't be OFF at the same time.

This idea leads to the invention of class AB amplifier, which is the combination of both class A and class B amplifiers, as discussed below.

Class AB Power Amplifier

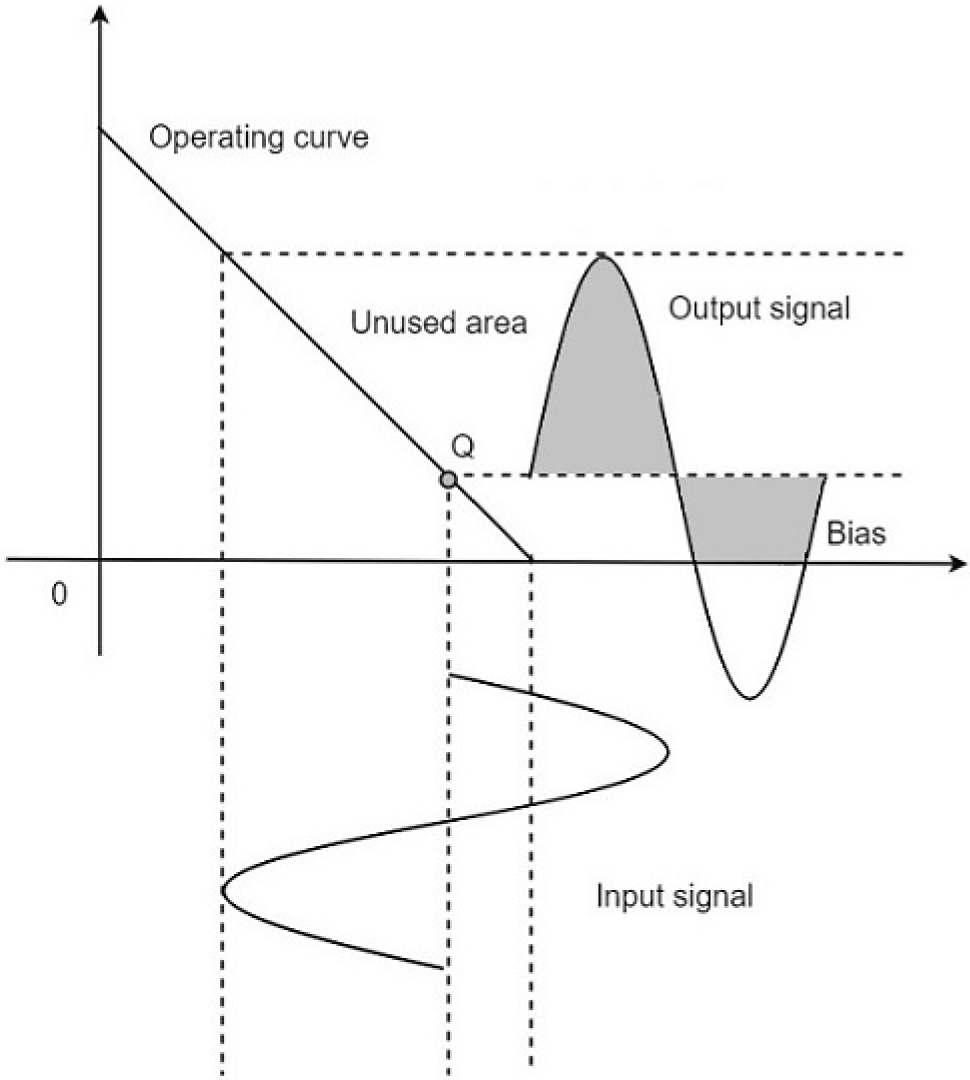
As the name implies, class AB is a combination of class A and class B type of amplifiers. As class A has the problem of low efficiency and class B has distortion problem, this class AB is emerged to eliminate these two problems, by utilizing the advantages of both the classes.

The cross over distortion is the problem that occurs when both the transistors are OFF at the same instant, during the transition period. In order to eliminate this, the condition has to be chosen for more than one half cycle. Hence, the other transistor gets into conduction, before the operating transistor switches to cut off state. This is achieved only by using class AB configuration, as shown in the following circuit diagram.



Therefore, in class AB amplifier design, each of the push-pull transistors is conducting for slightly more than the half cycle of conduction in class B, but much less than the full cycle of conduction of class A.

The conduction angle of class AB amplifier is somewhere between 180^o to 360^o depending upon the operating point selected. This is understood with the help of below figure.



The small bias voltage given using diodes D_1 and D_2, as shown in the above figure, helps the operating point to be above the cutoff point. Hence the output waveform of class AB results as seen in the above figure. The crossover distortion created by class B is overcome by this class AB, as well the inefficiencies of class A and B don't affect the circuit.

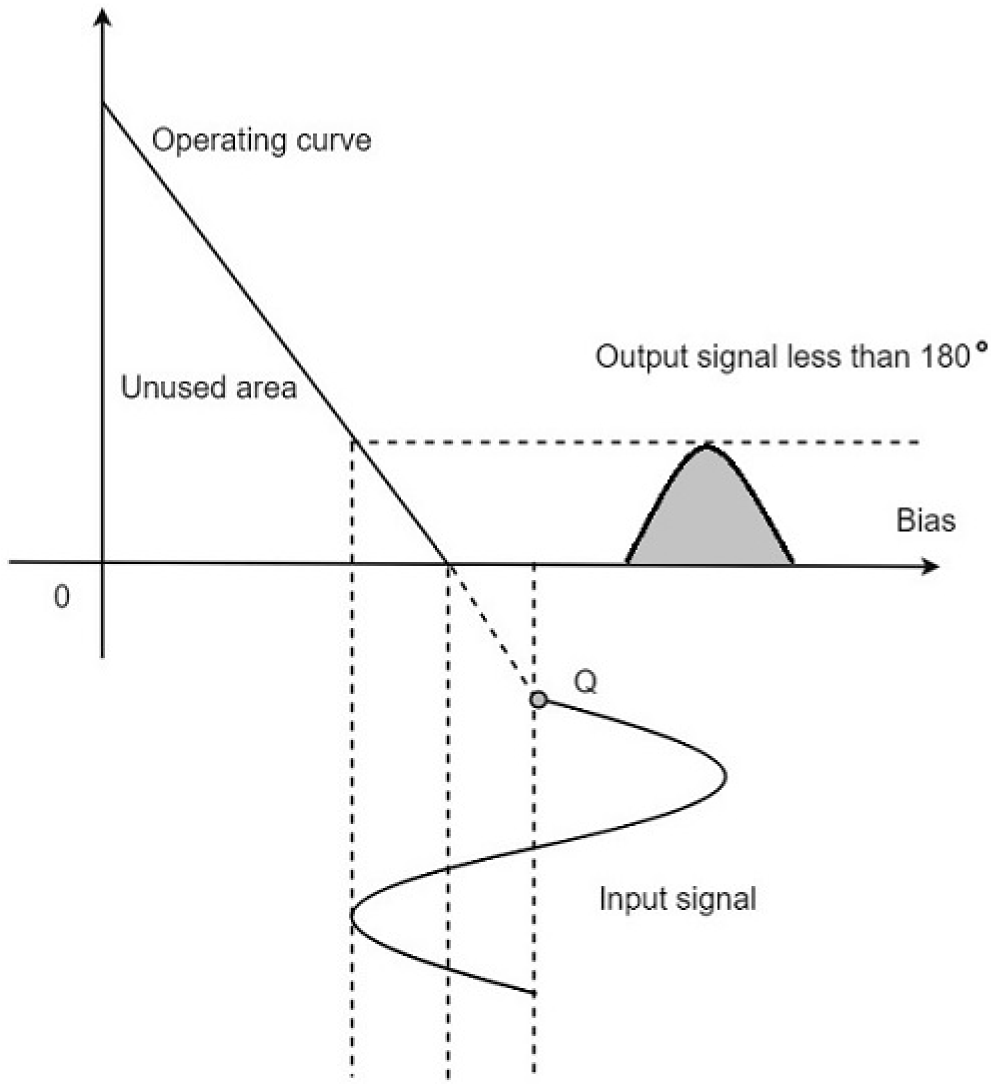
So, the class AB is a good compromise between class A and class B in terms of efficiency and linearity having the efficiency reaching about 50% to 60%. The class A, B and AB amplifiers are called as **linear amplifiers** because the output signal amplitude and phase are linearly related to the input signal amplitude and phase.

Class C Power Amplifier

When the collector current flows for less than half cycle of the input signal, the power amplifier is known as **class C power amplifier**.

The efficiency of class C amplifier is high while linearity is poor. The conduction angle for class C is less than 180^o. It is generally around 90^o, which means the transistor remains idle for more than half of the input signal. So, the output current will be delivered for less time compared to the application of input signal.

The following figure shows the operating point and output of a class C amplifier.



This kind of biasing gives a much improved efficiency of around 80% to the amplifier, but introduces heavy distortion in the output signal. Using the class C amplifier, the pulses produced at its output can be converted to complete sine wave of a particular frequency by using LC circuits in its collector circuit.

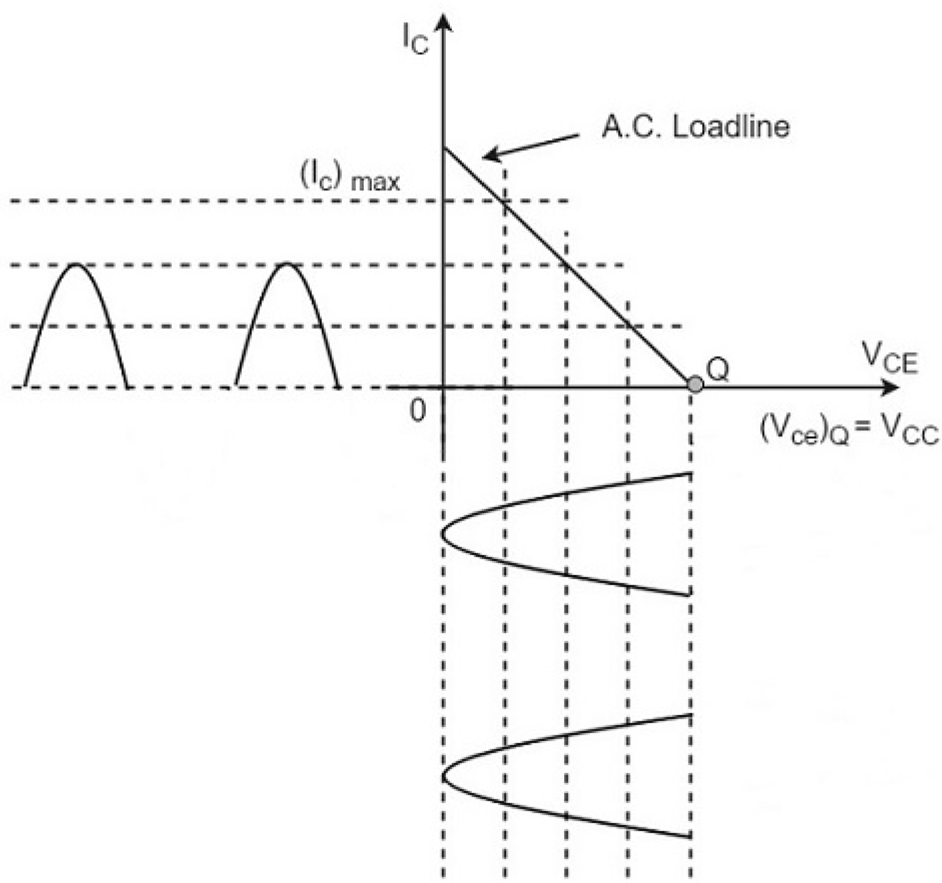
Class B Power Amplifier

When the collector current flows only during the positive half cycle of the input signal, the power amplifier is known as **class B power amplifier**.

Class B Operation

The biasing of the transistor in class B operation is in such a way that at zero signal condition, there will be no collector current. The **operating point** is selected to be at collector cut off voltage. So, when the signal is applied, **only the positive half cycle** is amplified at the output.

The figure below shows the input and output waveforms during class B operation.



When the signal is applied, the circuit is forward biased for the positive half cycle of the input and hence the collector current flows. But during the negative half cycle of the input, the circuit is reverse biased and the collector current will be absent. Hence **only the positive half cycle** is amplified at the output.

As the negative half cycle is completely absent, the signal distortion will be high. Also, when the applied signal increases, the power dissipation will be more. But when compared to class A power amplifier, the output efficiency is increased.

Well, in order to minimize the disadvantages and achieve low distortion, high efficiency and high output power, the push-pull configuration is used in this class B amplifier.

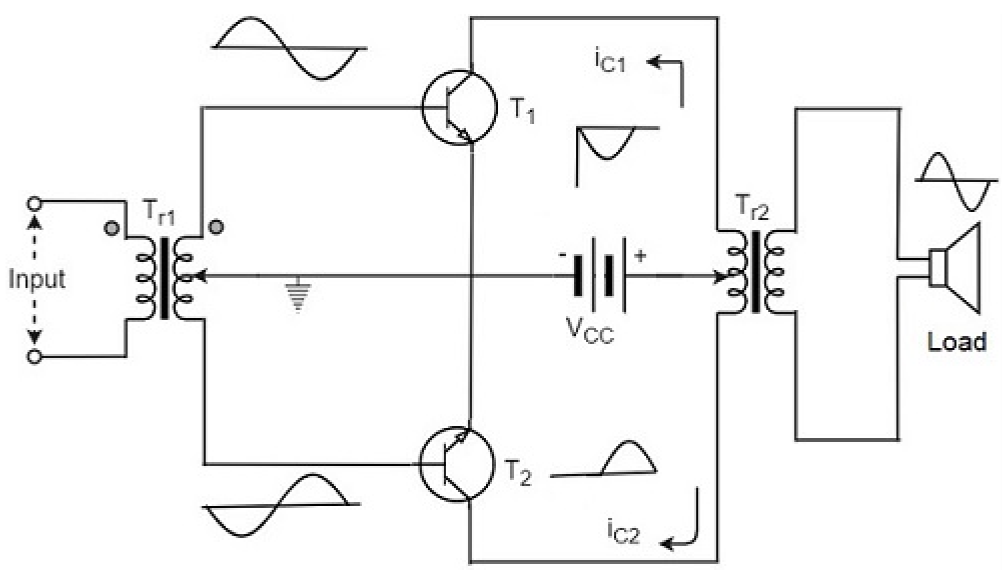
Class B Push-Pull Amplifier

Though the efficiency of class B power amplifier is higher than class A, as only one half cycle of the input is used, the distortion is high. Also, the input power is not completely utilized. In order to compensate these problems, the push-pull configuration is introduced in class B amplifier.

Construction

The circuit of a push-pull class B power amplifier consists of two identical transistors T_1 and T_2 whose bases are connected to the secondary of the center-tapped input transformer T_{r1}. The emitters are shorted and the collectors are given the V_{CC} supply through the primary of the output transformer T_{r2}.

The circuit arrangement of class B push-pull amplifier, is same as that of class A push-pull amplifier except that the transistors are biased at cut off, instead of using the biasing resistors. The figure below gives the detailing of the construction of a push-pull class B power amplifier.

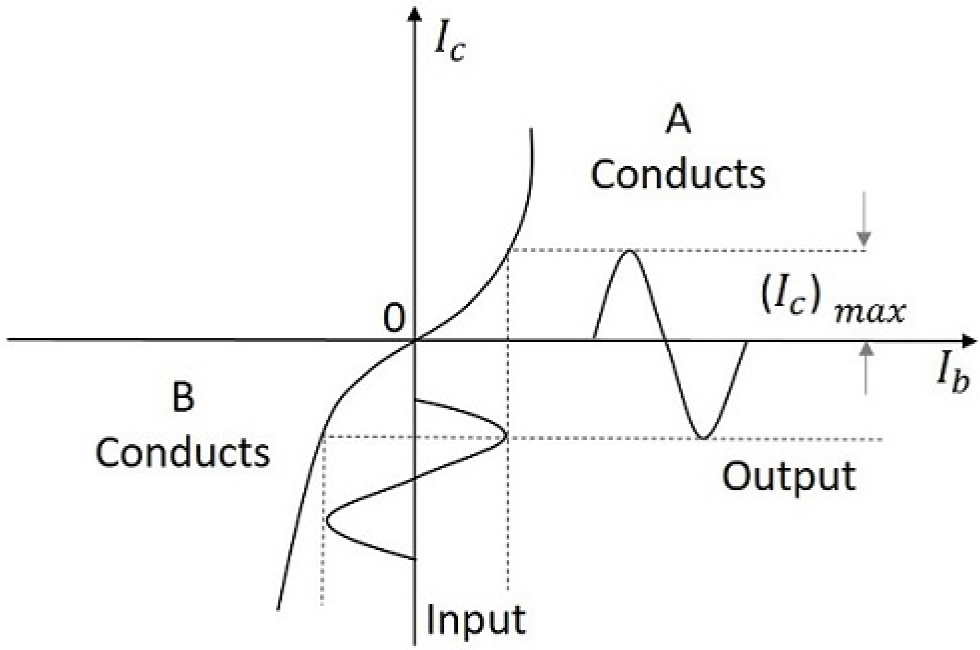


The circuit operation of class B push pull amplifier is detailed below.

Operation

The circuit of class B push-pull amplifier shown in the above figure clears that both the transformers are center-tapped. When no signal is applied at the input, the transistors T_1 and T_2 are in cut off condition and hence no collector currents flow. As no current is drawn from V_{CC}, no power is wasted.

When input signal is given, it is applied to the input transformer T_{r1} which splits the signal into two signals that are 180^o out of phase with each other. These two signals are given to the two identical transistors T_1 and T_2. For the positive half cycle, the base of the transistor T_1 becomes positive and collector current flows. At the same time, the transistor T_2 has negative half cycle, which throws the transistor T_2 into cutoff condition and hence no collector current flows. The waveform is produced as shown in the following figure.



For the next half cycle, the transistor T_1 gets into cut off condition and the transistor T_2 gets into conduction, to contribute the output. Hence for both the cycles, each transistor conducts alternately. The output transformer T_{r3} serves to join the two currents producing an almost undistorted output waveform.

Power Efficiency of Class B Push-Pull Amplifier

The current in each transistor is the average value of half sine loop.

For half sine loop, I_{dc} is given by

$$I_{dc} = \frac{(I_C)_{max}}{\pi}$$

Therefore,

$$(p_{in})_{dc} = 2 \times \left[\frac{(I_C)_{max}}{\pi} \times V_{CC}\right]$$

Here factor 2 is introduced as there are two transistors in push-pull amplifier.

R.M.S. value of collector current = $(I_C)_{max}/\sqrt{2}$

R.M.S. value of output voltage = $V_{CC}/\sqrt{2}$

Under ideal conditions of maximum power

Therefore,

$$(P_O)_{ac} = \frac{(I_C)_{max}}{\sqrt{2}} \times \frac{V_{CC}}{\sqrt{2}} = \frac{(I_C)_{max} \times V_{CC}}{2}$$

Now overall maximum efficiency

$$\eta_{overall} = \frac{(P_O)_{ac}}{(P_{in})_{dc}}$$

$$= \frac{(I_C)_{max} \times V_{CC}}{2} \times \frac{\pi}{2(I_C)_{max} \times V_{CC}}$$

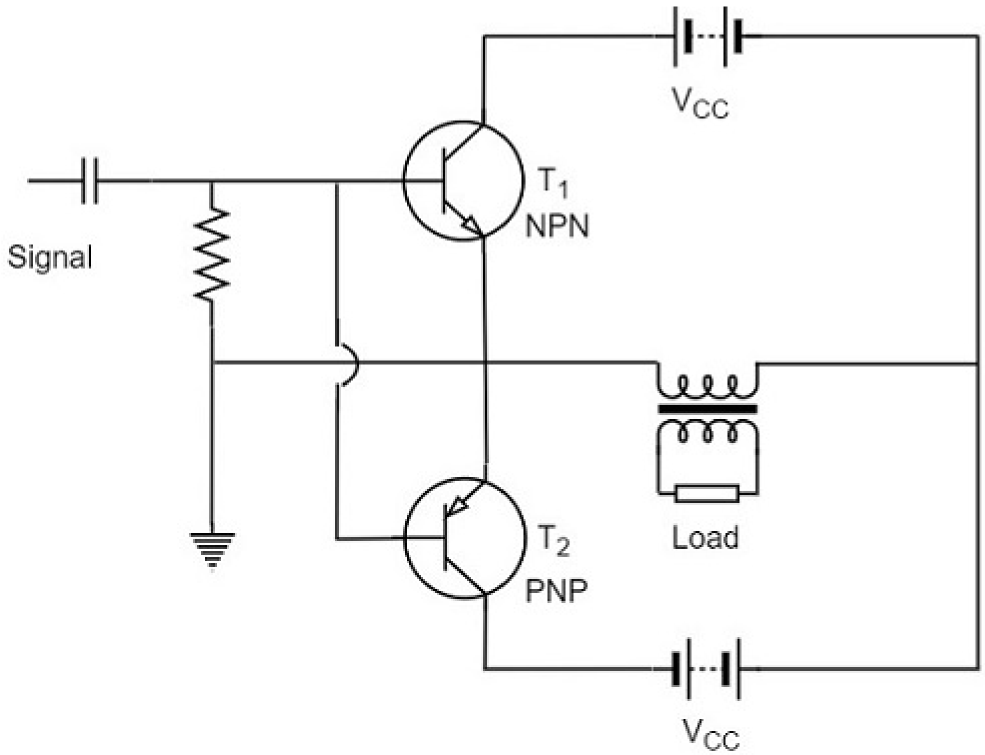
$$= \frac{\pi}{4} = 0.785 = 78.5\%$$

The collector efficiency would be the same.

Hence the class B push-pull amplifier improves the efficiency than the class A push-pull amplifier.

Complementary Symmetry Push-Pull Class B Amplifier

The push pull amplifier which was just discussed improves efficiency but the usage of center-tapped transformers makes the circuit bulky, heavy and costly. To make the circuit simple and to improve the efficiency, the transistors used can be complemented, as shown in the following circuit diagram.



The above circuit employs a NPN transistor and a PNP transistor connected in push pull configuration. When the input signal is applied, during the positive half cycle of the input signal, the NPN transistor conducts and the PNP transistor cuts off. During the negative half cycle, the NPN transistor cuts off and the PNP transistor conducts.

In this way, the NPN transistor amplifies during positive half cycle of the input, while PNP transistor amplifies during negative half cycle of the input. As the transistors are both complement to each other, yet act symmetrically while being connected in push pull configuration of class B, this circuit is termed as **Complementary symmetry push pull class B amplifier**.

Advantages

The advantages of Complementary symmetry push pull class B amplifier are as follows.

- As there is no need of center tapped transformers, the weight and cost are reduced.
- Equal and opposite input signal voltages are not required.

Disadvantages

The disadvantages of Complementary symmetry push pull class B amplifier are as follows.

- It is difficult to get a pair of transistors (NPN and PNP) that have similar characteristics.
- We require both positive and negative supply voltages.

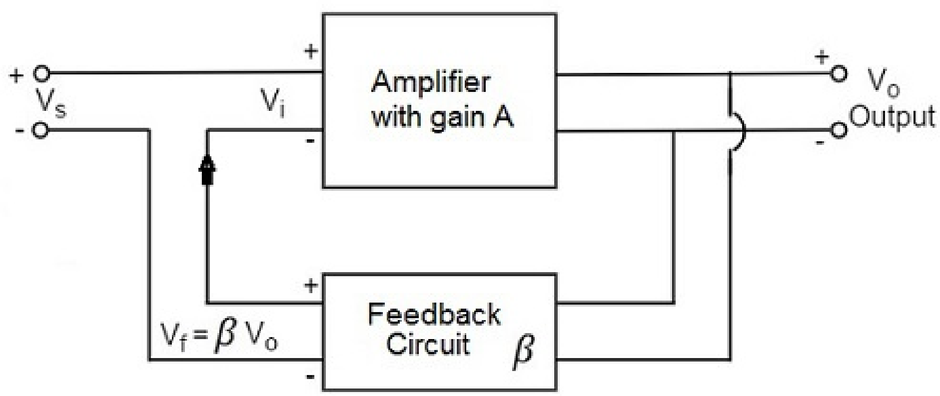
Amplifiers Feedback

An amplifier circuit simply increases the signal strength. But while amplifying, it just increases the strength of its input signal whether it contains information or some noise along with information. This noise or some disturbance is introduced in the amplifiers because of their strong tendency to introduce **hum** due to sudden temperature changes or stray electric and magnetic fields. Therefore, every high gain amplifier tends to give noise along with signal in its output, which is very undesirable.

The noise level in the amplifier circuits can be considerably reduced by using **negative feedback** done by injecting a fraction of output in phase opposition to the input signal.

Principle of Feedback Amplifier

A feedback amplifier generally consists of two parts. They are the **amplifier** and the **feedback circuit**. The feedback circuit usually consists of resistors. The concept of feedback amplifier can be understood from the following figure.



From the above figure, the gain of the amplifier is represented as A. the gain of the amplifier is the ratio of output voltage V_o to the input voltage V_i. the feedback network extracts a voltage $V_f = \beta V_o$ from the output V_o of the amplifier.

This voltage is added for positive feedback and subtracted for negative feedback, from the signal voltage V_s. Now,

$$V_i = V_s + V_f = V_s + \beta V_o$$

$$V_i = V_s - V_f = V_s - \beta V_o$$

The quantity $\beta = V_f/V_o$ is called as feedback ratio or feedback fraction.

Let us consider the case of negative feedback. The output V_o must be equal to the input voltage (V_s - βV_o) multiplied by the gain A of the amplifier.

Hence,

$$(V_s - \beta V_o)A = V_o$$

Or

$$AV_s - A\beta V_o = V_o$$

Or

$$AV_s = V_o(1 + A\beta)$$

Therefore,

$$\frac{V_o}{V_s} = \frac{A}{1 + A\beta}$$

Let A_f be the overall gain (gain with the feedback) of the amplifier. This is defined as the ratio of output voltage V_o to the applied signal voltage V_s, i.e.,

$$A_f = \frac{Output\ voltage}{Input\ signal\ voltage} = \frac{V_o}{V_s}$$

So, from the above two equations, we can understand that,

The equation of gain of the feedback amplifier, with negative feedback is given by

$$A_f = \frac{A}{1 + A\beta}$$

The equation of gain of the feedback amplifier, with positive feedback is given by

$$A_f = \frac{A}{1 - A\beta}$$

These are the standard equations to calculate the gain of feedback amplifiers.

Types of Feedbacks

The process of injecting a fraction of output energy of some device back to the input is known as **Feedback**. It has been found that feedback is very useful in reducing noise and making the amplifier operation stable.

Depending upon whether the feedback signal **aids** or **opposes** the input signal, there are two types of feedbacks used.

Positive Feedback

The feedback in which the feedback energy i.e., either voltage or current is in phase with the input signal and thus aids it is called as **Positive feedback**.

Both the input signal and feedback signal introduces a phase shift of 180^o thus making a 360^o resultant phase shift around the loop, to be finally in phase with the input signal.

Though the positive feedback **increases the gain** of the amplifier, it has the disadvantages such as

- Increasing distortion
- Instability

It is because of these disadvantages the positive feedback is not recommended for the amplifiers. If the positive feedback is sufficiently large, it leads to oscillations, by which oscillator circuits are formed. This concept will be discussed in OSCILLATORS tutorial.

Negative Feedback

The feedback in which the feedback energy i.e., either voltage or current is out of phase with the input and thus opposes it, is called as **negative feedback**.

In negative feedback, the amplifier introduces a phase shift of 180^o into the circuit while the feedback network is so designed that it produces no phase shift or zero phase shift. Thus the resultant feedback voltage V_f is 180^o out of phase with the input signal V_{in}.

Though the **gain** of negative feedback amplifier is **reduced**, there are many advantages of negative feedback such as

- Stability of gain is improved
- Reduction in distortion
- Reduction in noise
- Increase in input impedance
- Decrease in output impedance
- Increase in the range of uniform application

It is because of these advantages negative feedback is frequently employed in amplifiers.

Amplifiers Negative Feedback

Negative feedback in an amplifier is the method of feeding a portion of the amplified output to the input but in opposite phase. The phase opposition occurs as the amplifier provides 180^o phase shift whereas the feedback network doesn't.

While the output energy is being applied to the input, for the voltage energy to be taken as feedback, the output is taken in shunt connection and for the current energy to be taken as feedback, the output is taken in series connection.

There are two main types of negative feedback circuits. They are −

- Negative Voltage Feedback
- Negative Current Feedback

Negative Voltage Feedback

In this method, the voltage feedback to the input of amplifier is proportional to the output voltage. This is further classified into two types −

- Voltage-series feedback
- Voltage-shunt feedback

Negative Current Feedback

In this method, the voltage feedback to the input of amplifier is proportional to the output current. This is further classified into two types.

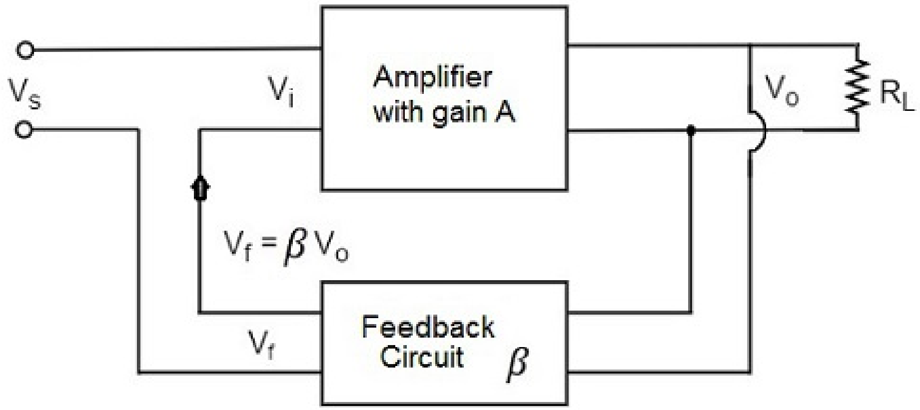
- Current-series feedback
- Current-shunt feedback

Let us have a brief idea on all of them.

Voltage-Series Feedback

In the voltage series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **shunt-driven series-fed** feedback, i.e., a parallel-series circuit.

The following figure shows the block diagram of voltage series feedback, by which it is evident that the feedback circuit is placed in shunt with the output but in series with the input.

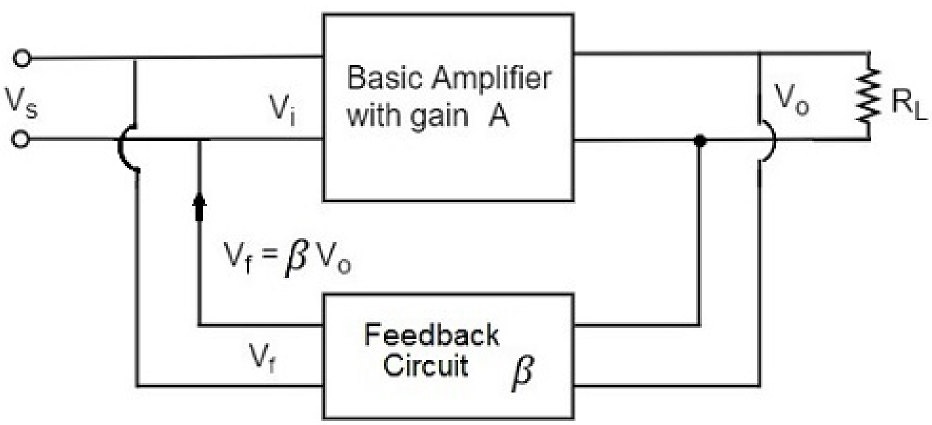


As the feedback circuit is connected in shunt with the output, the output impedance is decreased and due to the series connection with the input, the input impedance is increased.

Voltage-Shunt Feedback

In the voltage shunt feedback circuit, a fraction of the output voltage is applied in parallel with the input voltage through the feedback network. This is also known as **shunt-driven shunt-fed** feedback i.e., a parallel-parallel proto type.

The below figure shows the block diagram of voltage shunt feedback, by which it is evident that the feedback circuit is placed in shunt with the output and also with the input.

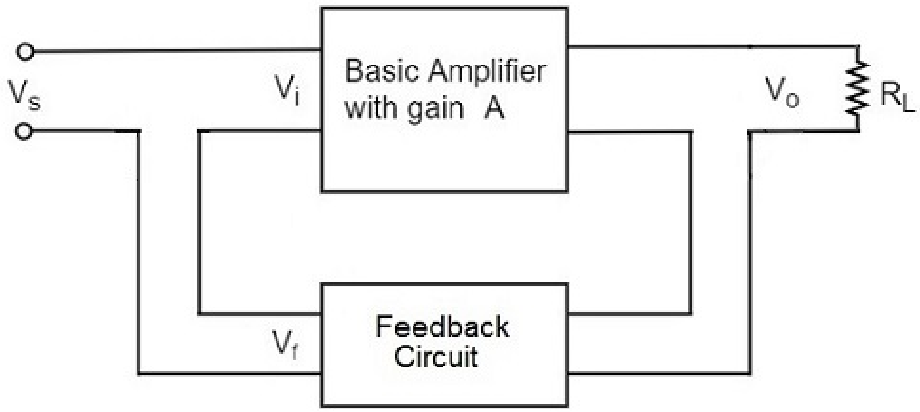


As the feedback circuit is connected in shunt with the output and the input as well, both the output impedance and the input impedance are decreased.

Current-Series Feedback

In the current series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **series-driven series-fed** feedback i.e., a series-series circuit.

The following figure shows the block diagram of current series feedback, by which it is evident that the feedback circuit is placed in series with the output and also with the input.

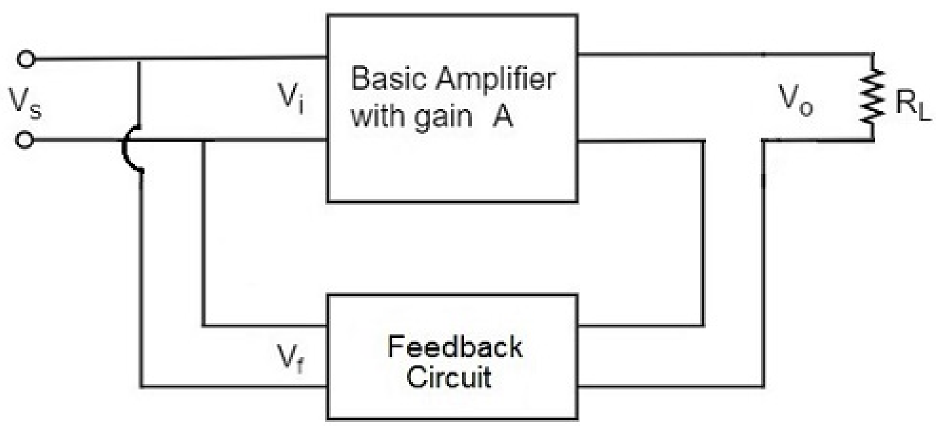


As the feedback circuit is connected in series with the output and the input as well, both the output impedance and the input impedance are increased.

Current-Shunt Feedback

In the current shunt feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **series-driven shunt-fed** feedback i.e., a series-parallel circuit.

The below figure shows the block diagram of current shunt feedback, by which it is evident that the feedback circuit is placed in series with the output but in parallel with the input.



As the feedback circuit is connected in series with the output, the output impedance is increased and due to the parallel connection with the input, the input impedance is decreased.

Let us now tabulate the amplifier characteristics that get affected by different types of negative feedbacks.

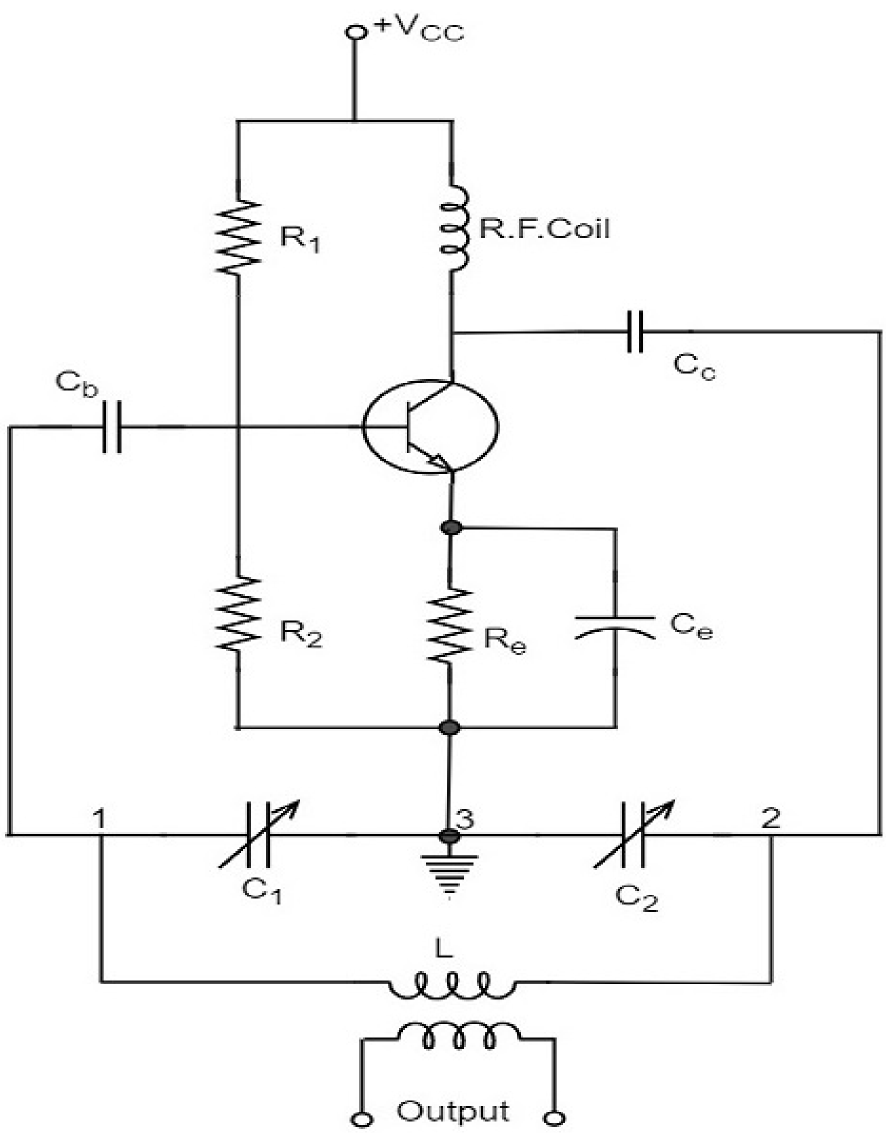
Characteristics	Types of Feedback			
	Voltage-Series	**Voltage-Shunt**	**Current-Series**	**Current-Shunt**
Voltage Gain	Decreases	Decreases	Decreases	Decreases
Bandwidth	Increases	Increases	Increases	Increases
Input resistance	Increases	Decreases	Increases	Decreases
Output resistance	Decreases	Decreases	Increases	Increases
Harmonic distortion	Decreases	Decreases	Decreases	Decreases
Noise	Decreases	Decreases	Decreases	Decreases

Colpitts Oscillator

A Colpitts oscillator looks just like the Hartley oscillator but the inductors and capacitors are replaced with each other in the tank circuit. The constructional details and operation of a colpitts oscillator are as discussed below.

Construction

Let us first take a look at the circuit diagram of a Colpitts oscillator.



The resistors R_1, R_2 and R_e provide necessary bias condition for the circuit. The capacitor C_e provides a.c. ground thereby providing any signal degeneration. This also provides temperature stabilization.

The capacitors C_c and C_b are employed to block d.c. and to provide an a.c. path. The radio frequency choke (R.F.C) offers very high impedance to high frequency currents which means it shorts for d.c. and opens for a.c. Hence it provides d.c. load for collector and keeps a.c. currents out of d.c. supply source.

Tank Circuit

The frequency determining network is a parallel resonant circuit which consists of variable capacitors C_1 and C_2 along with an inductor L. The junction of C_1 and C_2 are earthed. The capacitor C_1 has its one end connected to base via C_c and the other to emitter via C_e. the voltage developed across C_1 provides the regenerative feedback required for the sustained oscillations.

Operation

When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across C_1 which are applied to the base emitter junction and appear in the amplified form in the collector circuit and supply losses to the tank circuit.

If terminal 1 is at positive potential with respect to terminal 3 at any instant, then terminal 2 will be at negative potential with respect to 3 at that instant because terminal 3 is grounded. Therefore, points 1 and 2 are out of phase by 180^o.

As the CE configured transistor provides 180^o phase shift, it makes 360^o phase shift between the input and output voltages. Hence, feedback is properly phased to produce continuous Undamped oscillations. When the **loop gain |βA| of the amplifier is greater than one, oscillations are sustained** in the circuit.

Frequency

The equation for **frequency of Colpitts oscillator** is given as

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

C_T is the total capacitance of C_1 and C_2 connected in series.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$C_T = \frac{C_1 \times C_2}{C_1 + C_2}$$

Advantages

The advantages of Colpitts oscillator are as follows −

- Colpitts oscillator can generate sinusoidal signals of very high frequencies.
- It can withstand high and low temperatures.

- The frequency stability is high.
- Frequency can be varied by using both the variable capacitors.
- Less number of components are sufficient.
- The amplitude of the output remains constant over a fixed frequency range.

The Colpitts oscillator is designed to eliminate the disadvantages of Hartley oscillator and is known to have no specific disadvantages. Hence there are many applications of a colpitts oscillator.

Applications

The applications of Colpitts oscillator are as follows −

- Colpitts oscillator can be used as High frequency sinewave generator.
- This can be used as a temperature sensor with some associated circuitry.
- Mostly used as a local oscillator in radio receivers.
- It is also used as R.F. Oscillator.
- It is also used in Mobile applications.
- It has got many other commercial applications.

Hartley Oscillator

A very popular **local oscillator** circuit that is mostly used in **radio receivers** is the **Hartley Oscillator** circuit. The constructional details and operation of a Hartley oscillator are as discussed below.

Construction

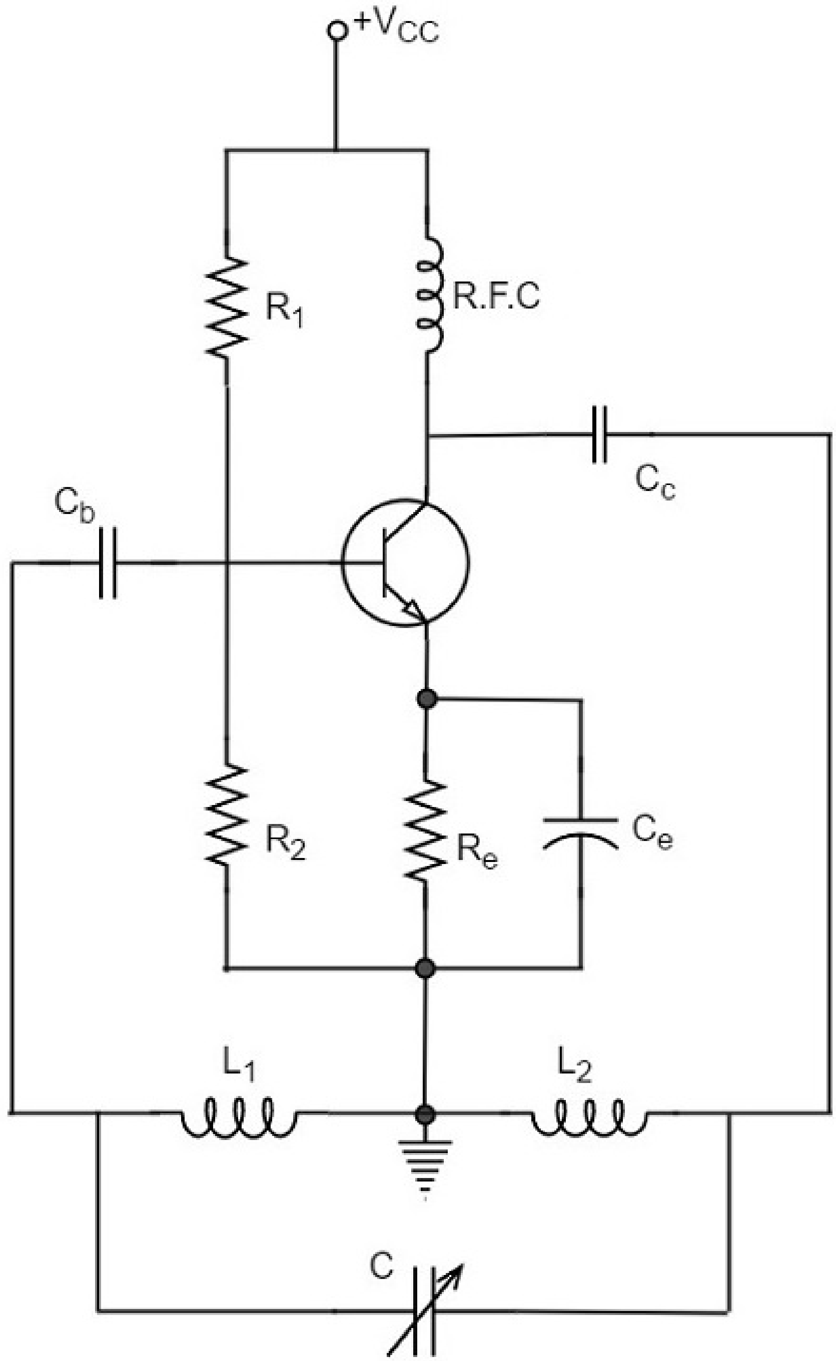
In the circuit diagram of a Hartley oscillator shown below, the resistors R_1, R_2 and R_e provide necessary bias condition for the circuit. The capacitor C_e provides a.c. ground thereby providing any signal degeneration. This also provides temperature stabilization.

The capacitors C_c and C_b are employed to block d.c. and to provide an a.c. path. The radio frequency choke (R.F.C) offers very high impedance to high frequency currents which means it shorts for d.c. and opens for a.c. Hence it provides d.c. load for collector and keeps a.c. currents out of d.c. supply source

Tank Circuit

The frequency determining network is a parallel resonant circuit which consists of the inductors L_1 and L_2 along with a variable capacitor C. The junction of L_1 and L_2 are earthed. The coil L_1 has its one end connected to base via C_c and the other to emitter via C_e. So, L_2 is in the output circuit. Both the coils L_1 and L_2 are inductively coupled and together form an **Auto-transformer**.

The following circuit diagram shows the arrangement of a Hartley oscillator. The tank circuit is **shunt fed** in this circuit. It can also be a **series-fed**.



Operation

When the collector supply is given, a transient current is produced in the oscillatory or tank circuit. The oscillatory current in the tank circuit produces a.c. voltage across L_1.

The **auto-transformer** made by the inductive coupling of L_1 and L_2 helps in determining the frequency and establishes the feedback. As the CE configured transistor provides 180^o phase shift, another 180^o phase shift is provided by the transformer, which makes 360^o phase shift between the input and output voltages.

This makes the feedback positive which is essential for the condition of oscillations. When the **loop gain |βA| of the amplifier is greater than one**, oscillations are sustained in the circuit.

Frequency

The equation for **frequency of Hartley oscillator** is given as

$$f = \frac{1}{2\pi\sqrt{L_T C}}$$

$$L_T = L_1 + L_2 + 2M$$

Here, $\mathbf{L_T}$ is the total cumulatively coupled inductance; $\mathbf{L_1}$ and $\mathbf{L_2}$ represent inductances of 1^{st} and 2^{nd} coils; and **M** represents mutual inductance.

Mutual inductance is calculated when two windings are considered.

Advantages

The advantages of Hartley oscillator are

- Instead of using a large transformer, a single coil can be used as an auto-transformer.
- Frequency can be varied by employing either a variable capacitor or a variable inductor.
- Less number of components are sufficient.
- The amplitude of the output remains constant over a fixed frequency range.

Disadvantages

The disadvantages of Hartley oscillator are

- It cannot be a low frequency oscillator.
- Harmonic distortions are present.

Applications

The applications of Hartley oscillator are

- It is used to produce a sinewave of desired frequency.
- Mostly used as a local oscillator in radio receivers.
- It is also used as R.F. Oscillator.