POWER AMPLIFIER UNIT 2

In small-signal amplifier, the main factors are usually amplification linearity and magnitude of gain. Since signal voltage and current are small in a small signal amplifier, the amount of power handling capacity and power efficiency are of little concern. A voltage amplifier provides voltage amplifier provides voltage amplification primarily to increase the voltage of input signal.

Large-signal or power amplifier, on other hand primarily provide sufficient power to an output load to drive a speaker or other power device, typically few watts to ten of watts.

Power Amplifier: Amplifier ckt used to handle large voltage signal at moderate to high current levels.

The main features of large signal amplifier are the circuit's power efficiency, the max. amount of power that the circuit is capable of handling and the impedance matching to output device.

One method used to categorise amplifiers is by class. Basically, amplifier classes represent the amount the O/P signal varies over one cycle of operation for a full cycle of input signal.

Class A: The O/P signal varies for a full 360° of cycle. This require the Q-point to be biased at a level so that at least half the signal swing of the O/P may vary up and down without going to a high enough voltage to be limited by the supply voltage level or too low to approach the lower supply level, or 0V in this description.

efficiency

represent the amount of ac power delivered from dc source

$$\%\eta = \frac{P_o(ac)}{P_i(dc)} \times 100\%$$

max effi

max. V_{CE} (p-p) $= V_{CC}$

max. I_C (p-p) $= \frac{V_{CC}}{R_C}$

$$\max P_o(ac) = \frac{V_C^2 (rms)}{R_C}$$

$$= \frac{V_C^2 \, rms\,(p)}{R_C}$$

$$= \frac{\left(\frac{V_{CC}}{2\sqrt{2}}\right)^2}{R_C} = \frac{V_{CC}^2}{8R_C}$$

$$\max P_i(dc) = V_{CC} \frac{V_{CC}/R_C}{2}$$

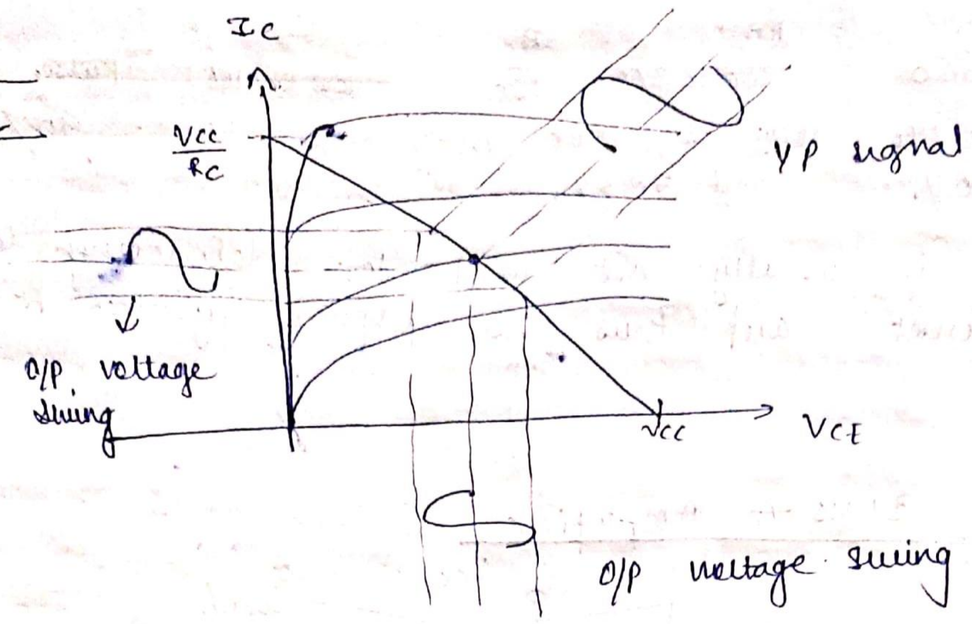
$$= \frac{V_{CC}^2}{2R_C}$$

$$\max \%\eta = \frac{\max P_o(ac)}{\max P_i(dc)} \times 100$$

$$= \frac{V_{CC}^2/8R_C}{V_{CC}^2/2R_C} \times 100$$

$$= 25\%$$

AC opr



Power consideration

$P_i(dc) = V_{CC} I_{CQ}$ —— ①

The power into an amplifier is provided by supply with no I/P signal, the dc current drawn is collector bias current I_{CQ}.

Even with ac signal applied, the average current drawn from supply remains the same

eqn ① represent input power supplied to class A series fed amplifier

Output power

The output voltage & current varying around the bias point provide ac power to the load.

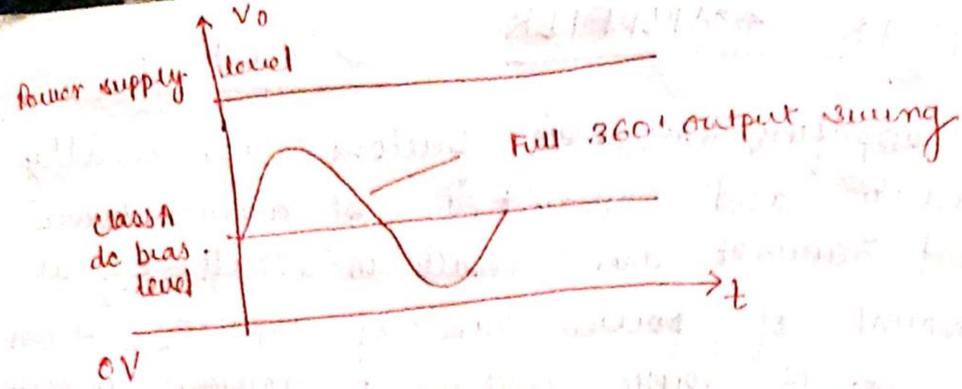
The larger the I/P signal, the larger is the O/P swing, up to maximum set by ckt.

The ac power delivered to load (Rc)

$P_o(ac) = V_{CE}(rms)\ I_c(rms)$

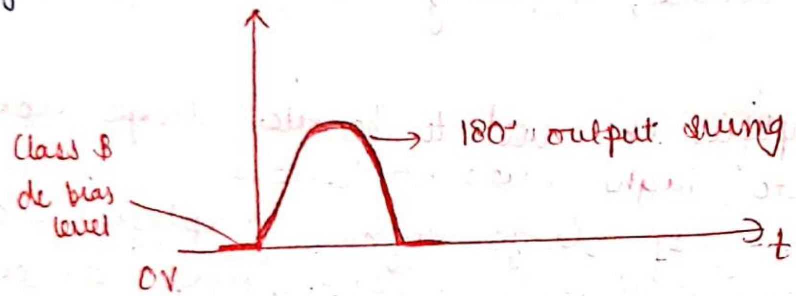
$= I_c^2(rms)\ R_c$

$= \frac{V_c^2(rms)}{R_c}$

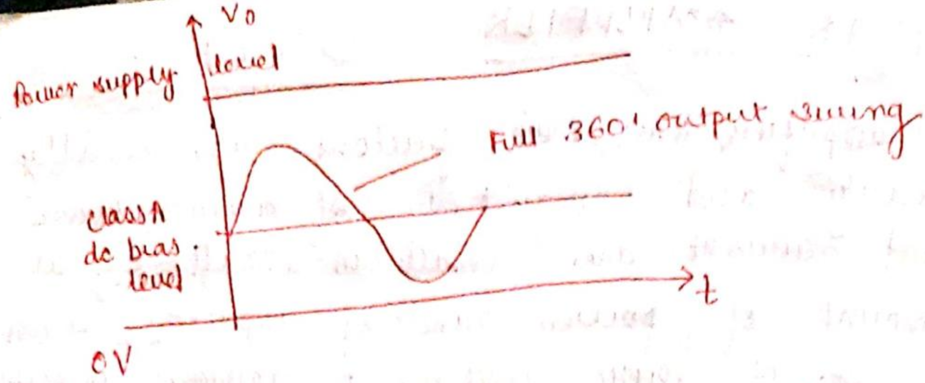


Amplifier operating classes

Class B : A class B ckt provides an O/P signal varying over one-half the input signal cycle, or for 180' of signal.



The dc bias point for class B is therefore at 0V, with the output then varying from this bias point for a half cycle. Obviously, the output is not a faithful reproduction of I/P if only one half cycle is present. Two class B opr — one to provide output on the positive output half cycle and an other to provide ops on the negative output half cycle are necessary. The combined half cycles then provide an output for a full 360° of operation. This type of connection is referred to as push-pull operation. Note that class B ops by itself creates a very distorted output signal since reproduction of input take place for only 180° of output signal swing



Amplifier operating classes

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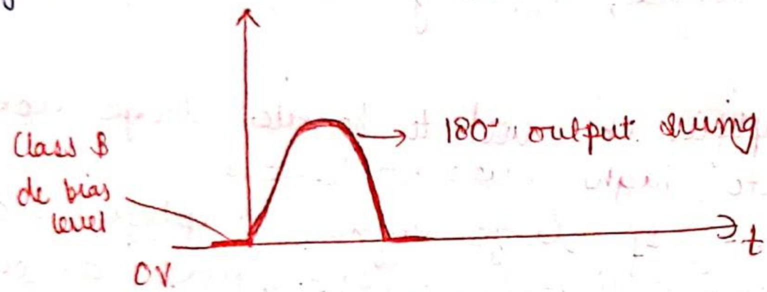


The dc bias point for class B is therefore at OV, with the output then varying from this bias point for a half cycle. Obviously, the output is not a faithful reproduction of I/P if only one half cycle is present. Two class B opr — one to provide output on the positive output half cycle and an other to provide ops on the negative output half cycle are necessary. The combined half cycles then provide an output for a full 360° of operation. This type of connection is referred to as push-pull operation. Note that class B opr by itself creates a very distorted output signal since reproduction of input take place for only 180° of output signal swing

Power Amplifier vs Voltage Amplifier

Amplifiers are devices used in electronics, to improve or multiply the strength of a signal. Depending on the requirements amplifiers are used to increase the voltage of the signal or the current of the signal or the power of the signal. Generally amplifiers are 3 port devices, with an input port, an output port and a power supply port. Generic operation of an amplifier is to produce a strengthened version of the input signal at the output, consuming the power from the power supply. The ratio between the output signal and the input signal of a property such as voltage, current or power is referred to as Gain. For example, ratio between output voltage and the input voltage is the Voltage gain of the amplifier $GAIN_{voltage} = V_{out} / V_{in}$, and similarly $GAIN_{power} = P_{out} / P_{in}$. For linear operation of an amplifier, as required in most cases, the gain values have to be constant in the region of operation

Voltage Amplifier

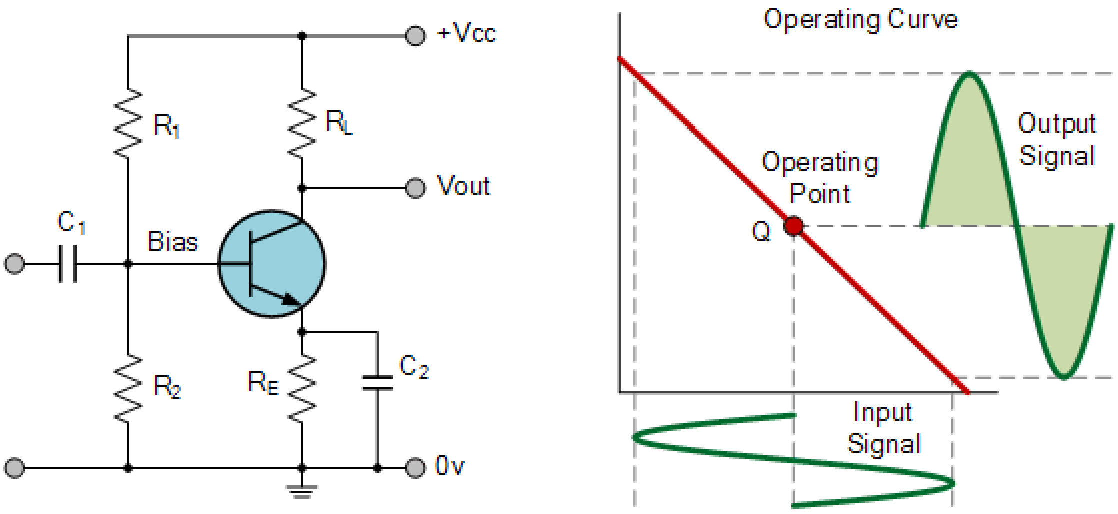
Voltage amplifiers are devices that amplify the input voltage, if possible with minimal current at the output. Technically, an amplifier with high voltage gain is a voltage amplifier, but it may or may not have a low current gain. The power gain of an amplifier is also low due to these properties. Transistors, and op amps, given proper biasing and other conditions, act as basic voltage amplifiers. The main application of voltage amplifiers is to strengthen the signal to make it less affected by noise and attenuation. When transmitted signals lose its strength and get deformed, an amplification of the voltage at the transmitter will minimize the effect and receiver will be able to capture and interpret the signal with reasonable accuracy.

Ideal voltage amplifiers have infinite input impedance and zero output impedance. In practice, an amplifier with high input impedance relative to the output impedance is considered as a good voltage amplifier.

Power Amplifiers

Power amplifiers are devices to amplify the input power, if possible with minimal change in the output voltage with respect to the input voltage. That is, power amplifiers have a high power gain, but the output voltage may or may not change. The amplifier efficiency of power amplifiers is always lower than 100%. Therefore, high heat dissipation is observed at power amplification stages. Power amplifiers are used in devices which require a large power across the loads. In multi stage amplifiers, power amplification is made in the final stages of amplification. Audio amplifiers and RF amplifiers use power amplifiers at the final stage to deliver sufficient power the load. Servo motor controllers also use power amplifiers to drive the motors. Power amplifiers are classified into several classes depending on the fraction of the input signal used in amplification. Classes A, B, AB and C are used in analog circuits, while classes D and E are used in switching circuits

Class A Amplifier



Class A Amplifiers are the most common type of amplifier topology as they use just one output switching transistor (Bipolar, FET, IGBT, etc) within their amplifier design. This single output transistor is biased around the Q-point within the middle of its load line and so is never driven into its cut-off or saturation regions thus allowing it to conduct current over the full 360 degrees of the input cycle. Then the output transistor of a class-A topology never turns “OFF” which is one of its main disadvantages.

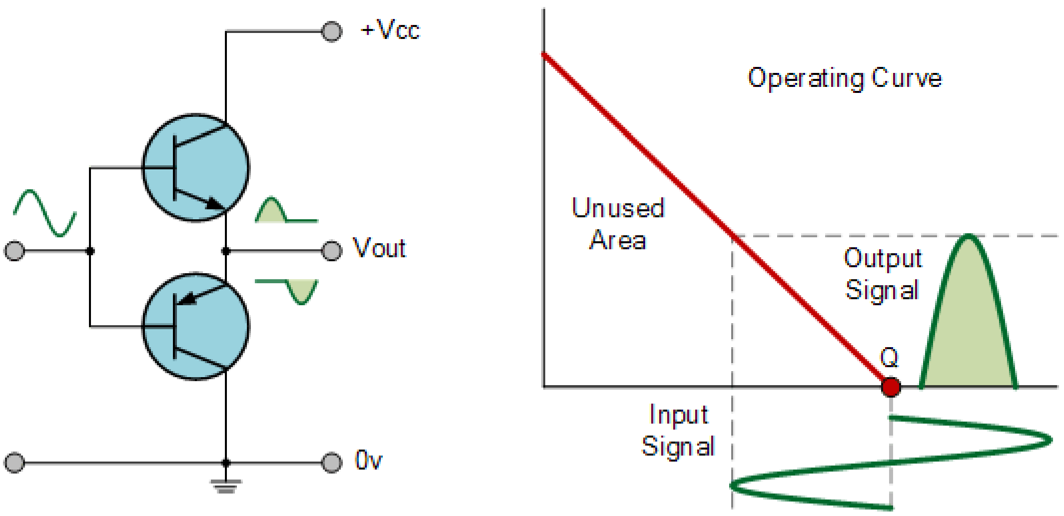
Class “A” amplifiers are considered the best class of amplifier design due mainly to their excellent linearity, high gain and low signal distortion levels when designed correctly. Although seldom used in high power amplifier applications due to thermal power supply considerations, class-A amplifiers are probably the best sounding of all the amplifier classes mentioned here and as such are used in high-fidelity audio amplifier designs.

Class B Amplifier

Class B amplifiers were invented as a solution to the efficiency and heating problems associated with the previous class A amplifier. The basic class B amplifier uses two complimentary transistors either bipolar of FET for each half of the waveform with its output stage configured in a "push-pull" type arrangement, so that each transistor device amplifies only half of the output waveform.

In the class B amplifier, there is no DC base bias current as its quiescent current is zero, so that the dc power is small and therefore its efficiency is much higher than that of the class A amplifier. However, the price paid for the improvement in the efficiency is in the linearity of the switching device.

PUSH- PULL CONFIGURATION



When the input signal goes positive, the positive biased transistor conducts while the negative transistor is switched "OFF". Likewise, when the input signal goes negative, the positive transistor switches "OFF" while the negative biased transistor turns "ON" and conducts the negative portion of the signal. Thus the transistor conducts only half of the time, either on positive or negative half cycle of the input signal.

Then we can see that each transistor device of the class B amplifier only conducts through one half or 180 degrees of the output waveform in strict time alternation, but as the output stage has devices for both halves of the signal waveform the two halves are combined together to produce the full linear output waveform.

This push-pull design of amplifier is obviously more efficient than Class A, at about 50%, but the problem with the class B amplifier design is that it can create distortion at the zero-crossing point of the waveform due to the transistors dead band of input base voltages from -0.7V to +0.7.

This means that the the part of the waveform which falls within this 0.7 volt window will not be reproduced accurately making the class B amplifier unsuitable for precision audio amplifier applications.

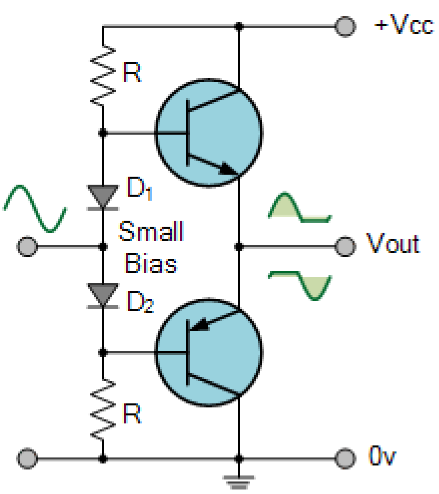
To overcome this zero-crossing distortion (also known as Crossover Distortion) class AB amplifiers were developed.

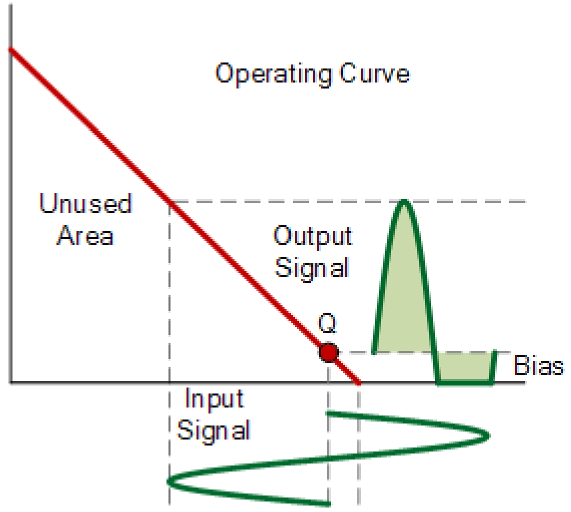
Class AB Amplifier

As its name suggests, the **Class AB Amplifier** is a combination of the “Class A” and the “Class B” type amplifiers we have looked at above. The AB classification of amplifier is currently one of the most common used types of audio power amplifier design. The class AB amplifier is a variation of a class B amplifier as described above, except that both devices are allowed to conduct at the same time around the waveforms crossover point eliminating the crossover distortion problems of the previous class B amplifier.

The two transistors have a very small bias voltage, typically at 5 to 10% of the quiescent current to bias the transistors just above its cut-off point. Then the conducting device, either bipolar of FET, will be “ON” for more than one half cycle, but much less than one full cycle of the input signal. Therefore, in a 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.

In other words, the conduction angle of a class AB amplifier is somewhere between 180^o and 360^o depending upon the chosen bias point as shown.





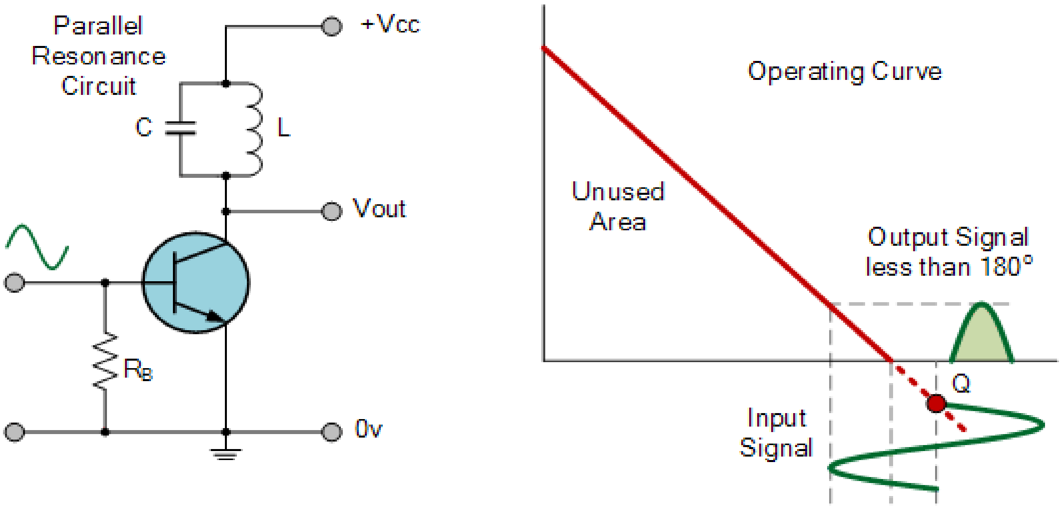
The advantage of this small bias voltage, provided by series diodes or resistors, is that the crossover distortion created by the class B amplifier characteristics is overcome, without the inefficiencies of the class A amplifier design. So the class AB amplifier is a good compromise between class A and class B in terms of efficiency and linearity, with conversion efficiencies reaching about 50% to 60%.

Class C Amplifier

The **Class C Amplifier** design has the greatest efficiency but the poorest linearity of the classes of amplifiers mentioned here. The previous classes, A, B and AB are considered linear amplifiers, as the output signals amplitude and phase are linearly related to the input signals amplitude and phase.

However, the class C amplifier is heavily biased so that the output current is zero for more than one half of an input sinusoidal signal cycle with the transistor idling at its cut-off point. In other words, the conduction angle for the transistor is significantly less than 180 degrees, and is generally around the 90 degrees area.

While this form of transistor biasing gives a much improved efficiency of around 80% to the amplifier, it introduces a very heavy distortion of the output signal. Therefore, class C amplifiers are not suitable for use as audio amplifiers.



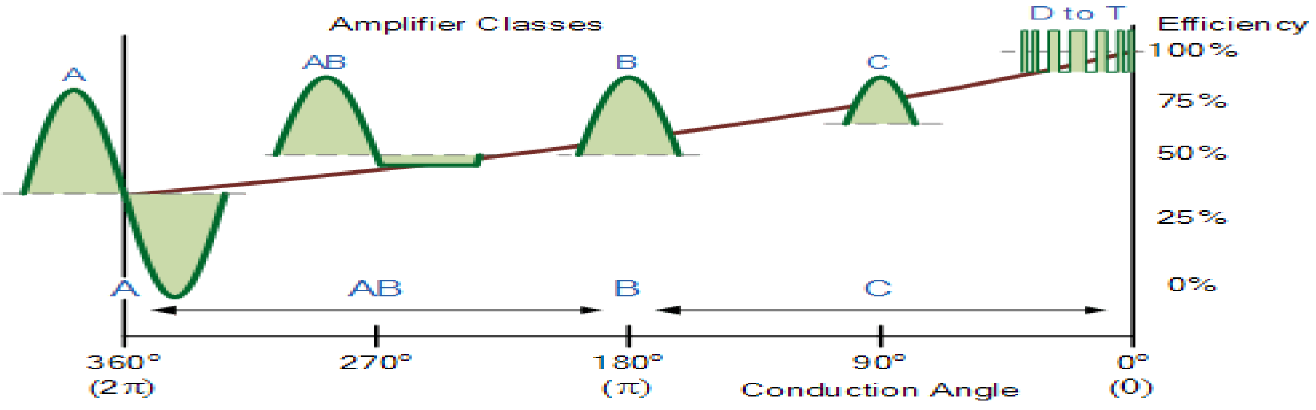
Due to its heavy audio distortion, class C amplifiers are commonly used in high frequency sine wave oscillators and certain types of radio frequency amplifiers, where the pulses of current produced at the amplifiers output can be converted to complete sine waves of a particular frequency by the use of LC resonant circuits in its collector circuit.

Amplifier Classes Summary

Then we have seen that the quiescent DC operating point (Q-point) of an amplifier determines the amplifier classification. By setting the position of the Q-point at half way on the load line of the amplifiers characteristics curve, the amplifier will operate as a class A amplifier. By moving the Q-point lower down the load line changes the amplifier into a class AB, B or C amplifier.

Then the class of operation of the amplifier with regards to its DC operating point can be given as:

Amplifier Classes and Efficiency



Concept of thermal runaway and protection

A thermal runaway refers to the overheating of a technical apparatus due to a self-reinforcing process that generates heat. This damage usually causes the destruction of the apparatus and often leads to a fire or explosion.Thermal runaway is where the biasing and operating point is such that the temperature causes the gain to increase, which causes the temperature to increase, which causes the gain to increase, in a vicious circle, leading to destruction of the BJT. Proper biasing and gain management can prevent this from occurring.