Power Amplifier

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Amplifier

- An amplifier is an electronic device used to increase the magnitude of voltage/current/power of an input signal.
- It takes in a weak electrical signal and reproduces a similar stronger signal at the output by using an external power source.

Amplifier

- Depending on the changes it makes to the input signal, amplifiers are broadly classified into Current, Voltage and Power amplifiers.

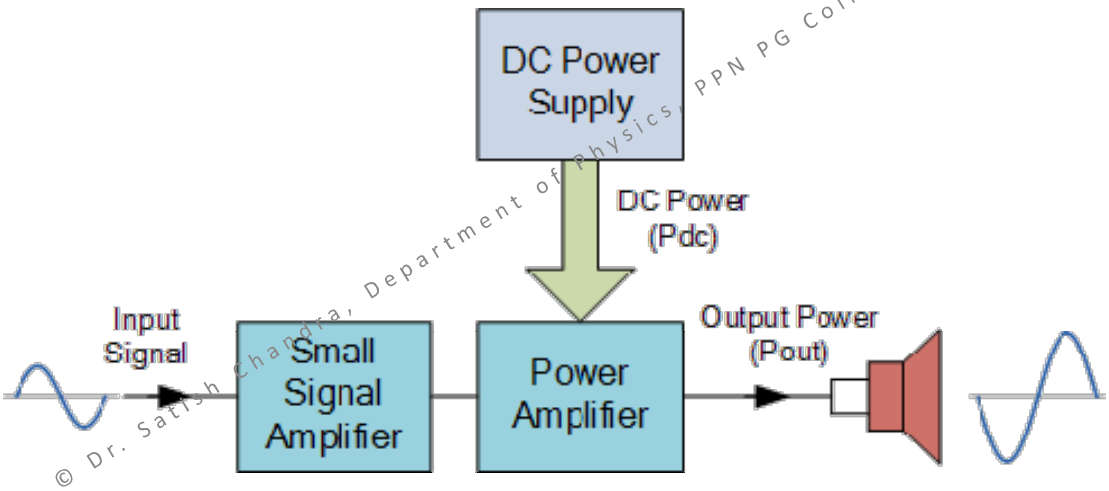
Power Amplifier

- A power amplifier is an electronic amplifier designed to increase the magnitude of power of a given input signal.
- The power of the input signal is increased to a level high enough to drive loads of output devices.
- Like speakers, headphones, RF transmitters etc.

Power Amplifier

- A power amplifier is designed to drive loads directly and is used as a final block in an amplifier chain.
- The input signal to a power amplifier needs to be above a certain threshold. So, it is first pre-amplified using current/voltage amplifiers

Power Amplifier



Power Amplifier Efficiency

- The efficiency of the amplifier in percentage,

$$\eta = \frac{P_{out}}{P_{dc}} \times 100$$

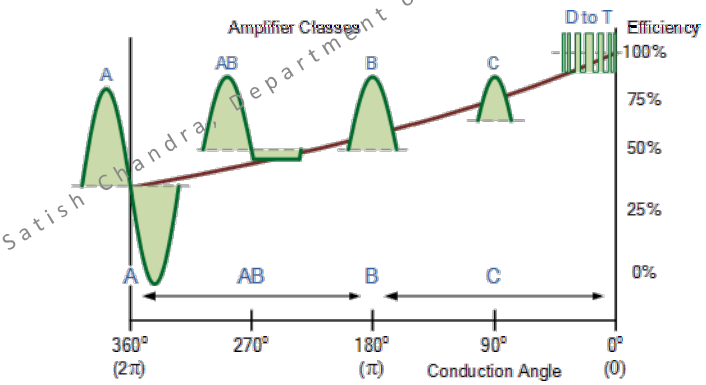
- P_{out} is the amplifier output power delivered to the load and P_{dc} is the DC power taken from the supply.
- It is very important that the amplifiers power supply is well designed to provide the maximum available continuous power to the output signal.

Types of Power Amplifiers

- Audio Power Amplifiers
- Radio Frequency Power Amplifiers
- DC Power Amplifiers

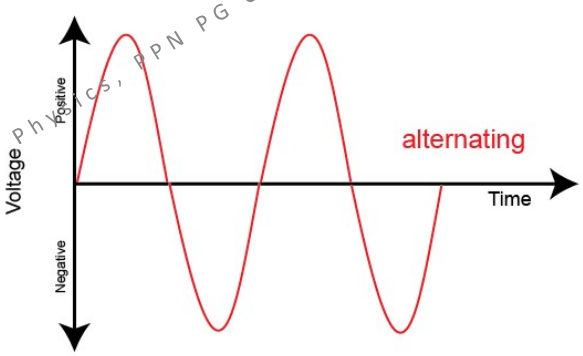
Power Amplifier Classes

- The most commonly used power amplifiers are the ones that are used in audio amplifier circuits and they come under classes A, B, AB or C.

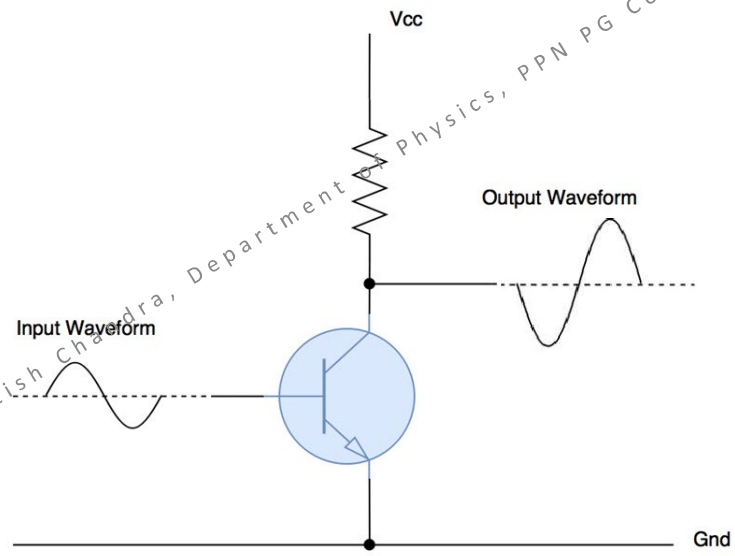


Class A Power Amplifier

- Analog waveforms are made up of positive and negative halves of the waveform.
- In class A amplifiers, the entire input waveform is used in the amplification process.



Class A Power Amplifier



Class A Power Amplifier

- The Class A amplifier is the simplest form of power amplifier that uses a single switching transistor in the standard common emitter circuit configuration to produce an inverted output.
- The transistor is always biased "ON" so that it conducts during one complete cycle of the input signal waveform producing minimum distortion and maximum amplitude of the output signal.

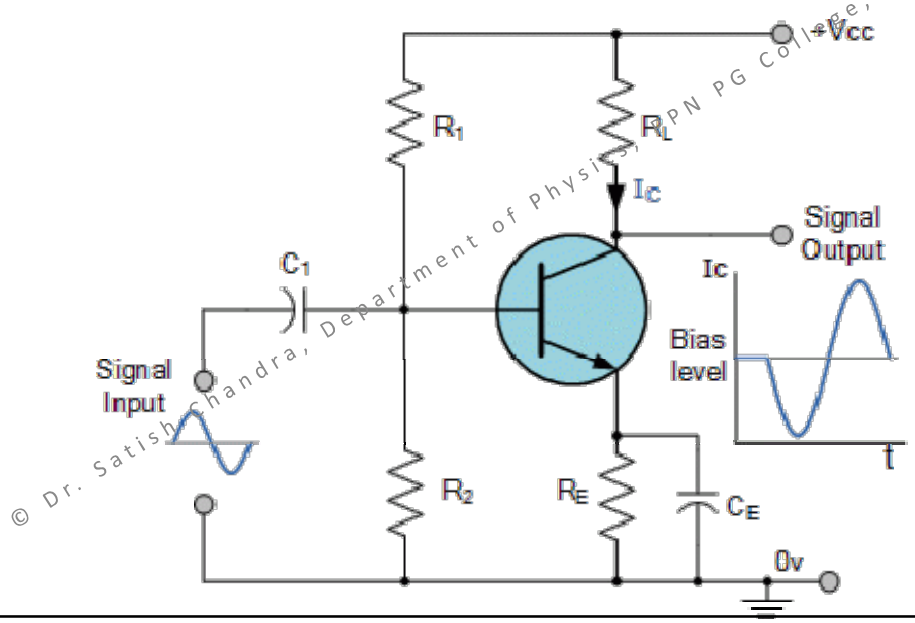
Class A Amplifiers

- 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 never turns "OFF" which is one of its main disadvantages.

Class A Power Amplifier

- Class A power amplifier output stages may use a single power transistor or pairs of transistors connected together to share the high load current.

Single Stage Class A Amplifier Circuit



Single Stage Class A Amplifier Circuit

- This is the simplest type of Class A power amplifier circuit.
- It uses a single-ended transistor for its output stage with the resistive load connected directly to the Collector terminal.
- When the transistor switches “ON” it sinks the output current through the Collector resulting in a voltage drop across the Emitter resistance .

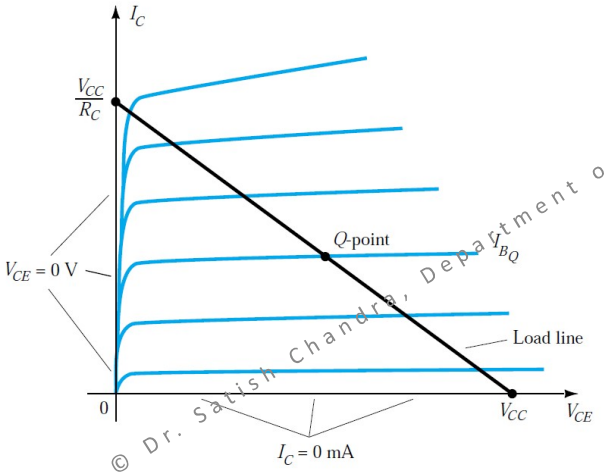
Single Stage Class A Amplifier Circuit

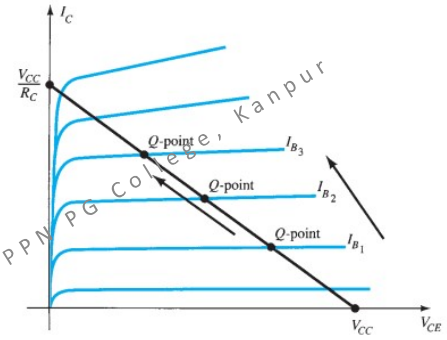
- Throughout the input signal, the transistor remains in forward bias mode.
- In this class, the transistor remains in active mode all the time even if there is no input signal, which leads to excessive heat generation thus causing a reduction in the efficiency.
- The efficiency of class A amplifiers is 25% in normal configuration and 50% in a transformer coupled configuration.

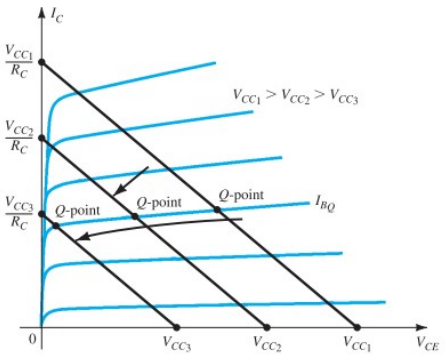
Single Stage Class A Amplifier Circuit

- When the input voltage is applied at the base terminal of the transistor operating in CE mode it leads to variation in base current, this variation in I_B produces similar variation in collector current I_C and the output is taken across the load.
- The applied input signal fluctuates the collector current from max to min which resultantly moves the Q point along the load line.

Load Line & Q Point



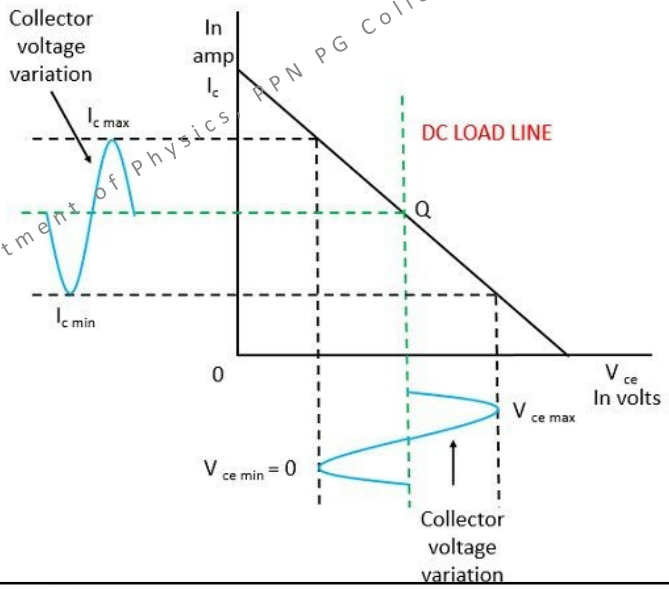




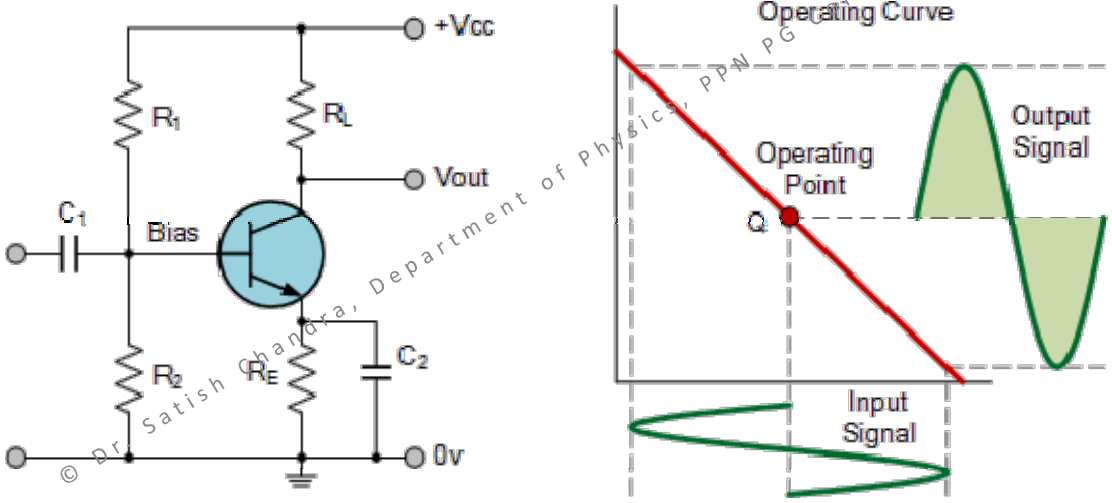
$$V_{CE} = V_{CC} - I_C R_C$$

Class A Amplifier Circuit

- It operates in the linear portion of its characteristic curves, the single output device conducts through a full 360 degrees of the output waveform.

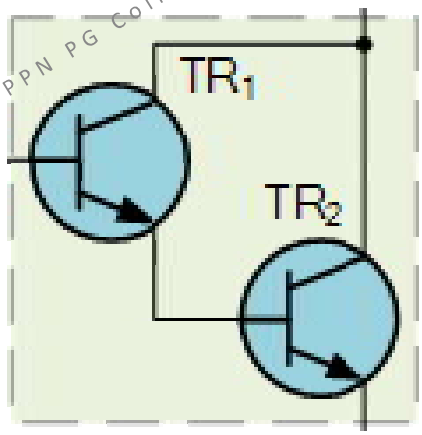


Class A Amplifier Circuit



Darlington Transistor Configurations

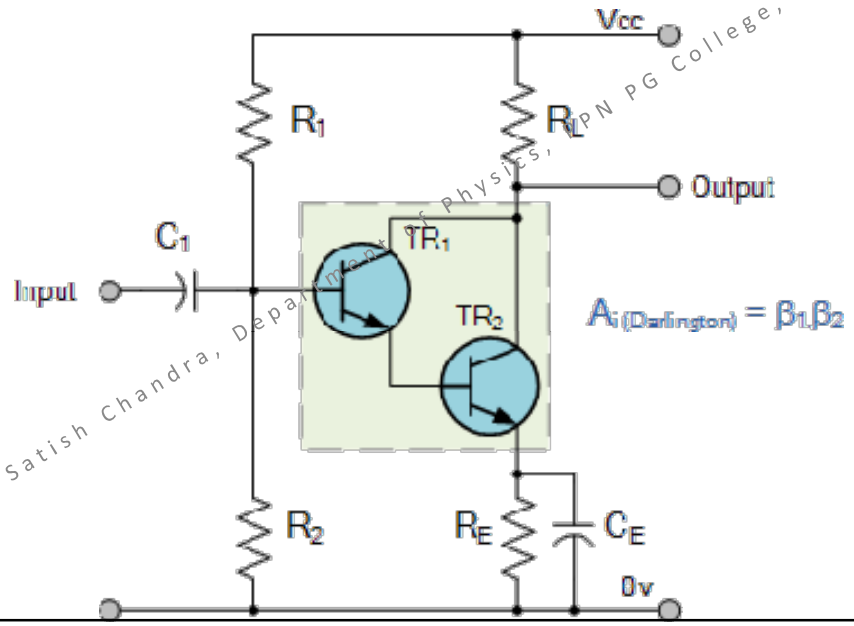
- Another simple way to increase the current handling capacity of the circuit while at the same time obtain a greater power gain is to replace the single output transistor with a **Darlington Transistor Pair**.



Darlington Transistor Configurations

- These types of devices are basically two transistors within a single package, one small **pilot transistor** and another larger **switching transistor**.
- The big advantage of these devices are that the input impedance is suitably large while the output impedance is relatively low, thereby reducing the power loss and therefore the heat within the switching device.

Darlington Transistor Configurations



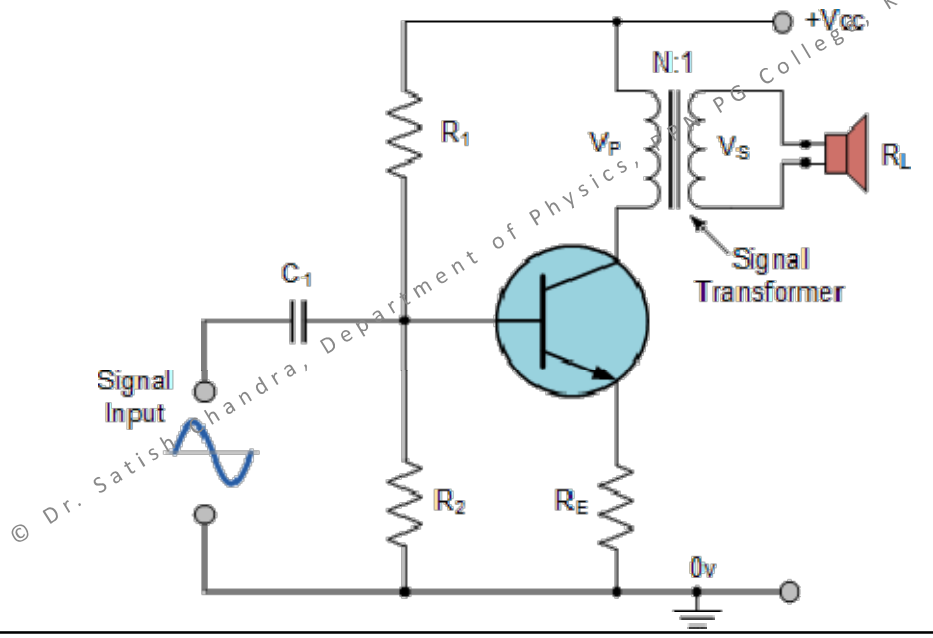
Darlington Transistor Configurations

- The overall current gain β of a Darlington Pair is the product of the two individual gains of the transistors multiplied together.
- A very high β values along with high Collector currents are possible compared to a single transistor circuit.

Transformer-coupled Amplifier Circuit

- A transformer connected directly in the Collector circuit to form a circuit called a **Transformer Coupled Amplifier**.
- The transformer improves the efficiency of the amplifier by matching the impedance of the load with that of the amplifiers output using the turns ratio (N_S/N_P) of the.

Transformer-coupled Amplifier Circuit



Transformer-coupled Amplifier Circuit

- As the Collector current, I_c is reduced to below the quiescent Q-point set up by the base bias voltage, due to variations in the base current, the magnetic flux in the transformer core collapses causing an induced *emf* in the transformer primary windings.
- This causes an instantaneous collector voltage to rise to a value of twice the supply voltage $2V_{cc}$ giving a maximum collector current of twice I_c when the Collector voltage is at its minimum.

Class A Power Amplifier

- **Advantages**:
  - It provides distortionless amplification.
  - Small signal can be amplified.

Class A Power Amplifier

- **Disadvantages**:
  - Collector efficiency is low.
  - Output power is low.
  - Due to excessive heat generation, heat sinks are needed which makes them costly and bulky.

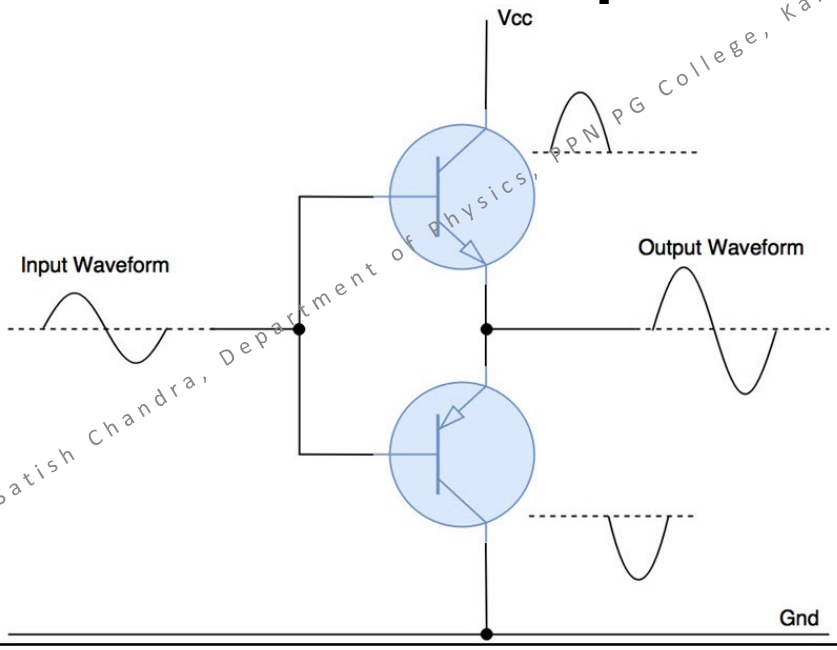
Class B Power Amplifier

- Class B power amplifiers are designed to reduce the efficiency and heating problems present in the class A amplifiers.
- Instead of a single transistor to amplify the entire waveform, this class of amplifiers use two complementary transistors.

Class B Power Amplifier

- One transistor amplifies positive half of the waveform and the other amplifies negative half of the waveform.
- So each active device conducts for one half (180°) of the waveform and two of them when combined amplify the entire signal.

Class B Power Amplifier



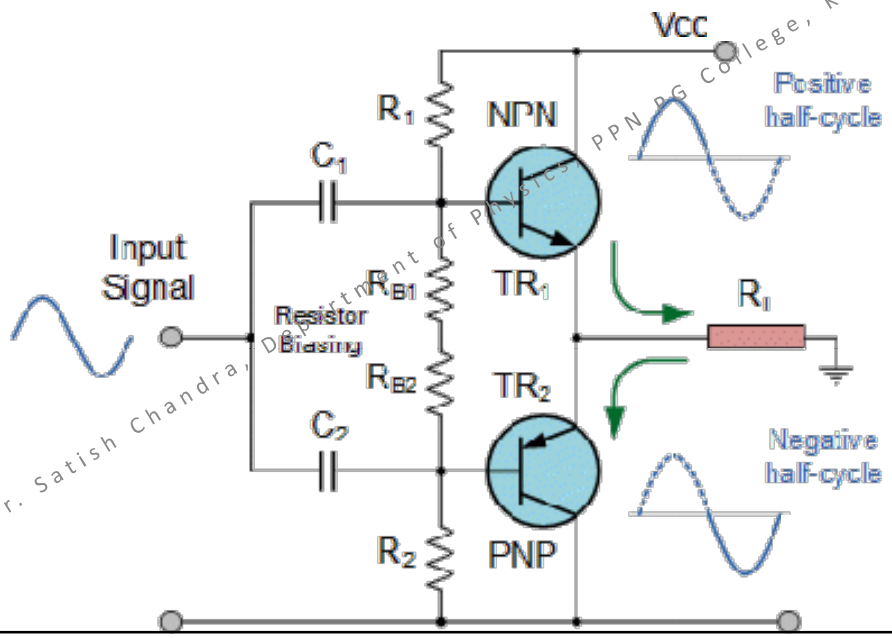
Class B Power Amplifier

- 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.
- The transistor conducts only half of the time, either on positive or negative half cycle of the input signal.

Class B Power Amplifier

- A Class B Amplifier is also known as a **push-pull amplifier**.
- Push-pull amplifiers use two "complementary" or matching transistors, one being an NPN-type and the other being a PNP-type.
- Both power transistors receive the same input signal together that is equal in magnitude, but in opposite phase to each other.

Class B Puss Pull Amplifier



Class B Power Amplifier

- Then the conduction angle for this type of amplifier circuit is only 180^o or 50% of the input signal.
- This pushing and pulling effect of the alternating half cycles by the transistors gives this type of circuit its "push-pull" name.
- But are more generally known as the **Class B Amplifier**

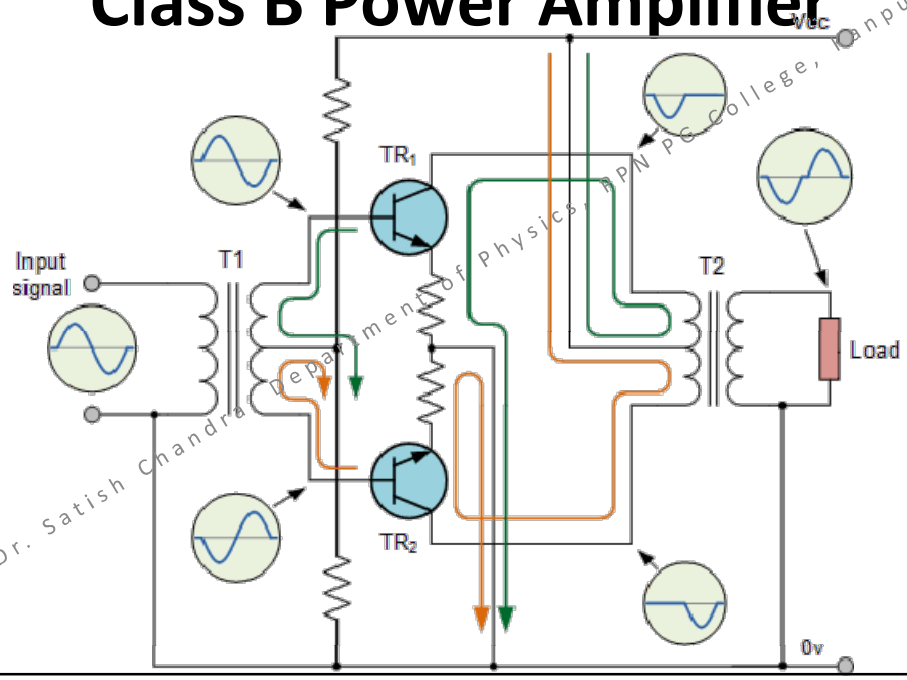
Class B Power Amplifier

- A **Class B** standard circuit that uses a balanced center-tapped input transformer, which splits the incoming waveform signal into two equal halves and which are 180^o out of phase with each other.
- Another center-tapped transformer on the output is used to recombined the two signals providing the increased power to the load.

Class B Power Amplifier

- The transistors used for this type of transformer push-pull amplifier circuit are both NPN transistors with their emitter terminals connected together.

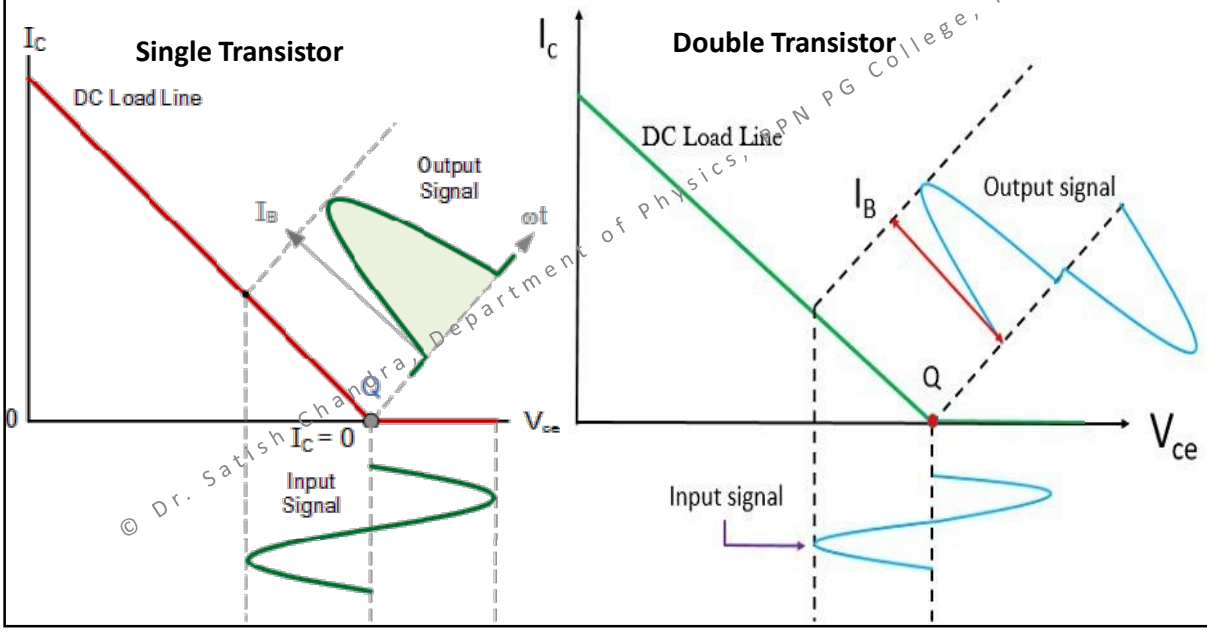
Class B Power Amplifier



Class B Power Amplifier

- **Class B Amplifier** operation has zero DC bias as the transistors are biased at the cut-off, so each transistor only conducts when the input signal is greater than the Base-emitter voltage.
- Therefore, at zero input there is zero output and no power is being consumed.
- This then means that the actual Q-point of a Class B amplifier is on the V_{CE} axis of the load line.

Class B Power Amplifier



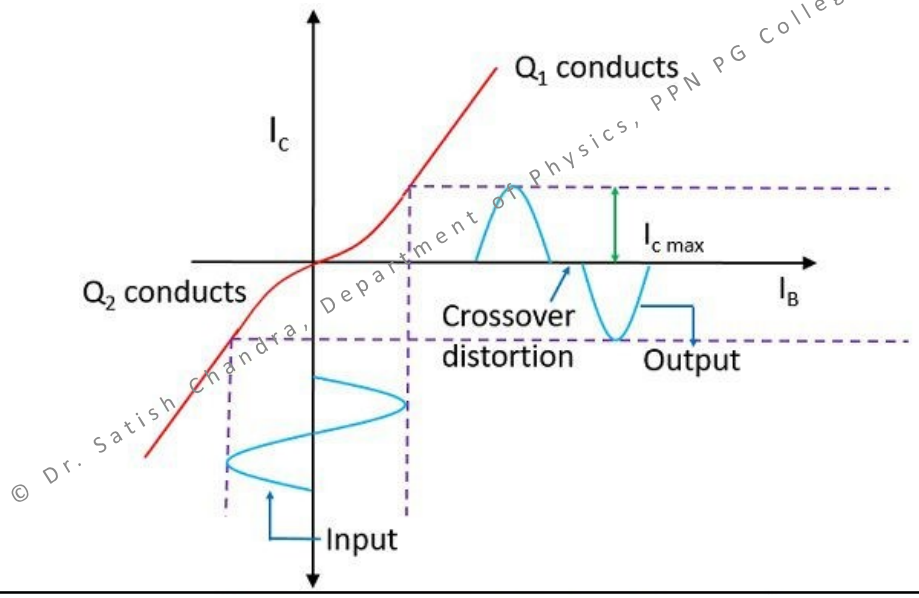
Class B Power Amplifier

- The **Class B Amplifier** has the big advantage over their Class A amplifier in that no current flows through the transistors with no input signal.
- Therefore, no power is dissipated in the output transistors or transformer when there is no signal present unlike Class A amplifier stages, that require significant base bias thereby dissipating lots of heat – even with no input signal present.

Class B Power Amplifier

- So the overall conversion efficiency (η) of the amplifier is greater than Class A amplifier with efficiencies reaching as high as 70%.
- But, because of superposition of two halves of the waveform, there exists a small distortion at the crossover region.

Crossover Distortion



Class B Power Amplifier

- Working of class B leads to **crossover distortion** because as we know the voltage of 0.7 Volt is required by the transistor to start its conduction so transistor will not be active below 0.7 Volt.
- This means that the portion of the wave will not get reproduced at the output leading to distorted output.
- This zero crossing distortion is called ***crossover distortion***.

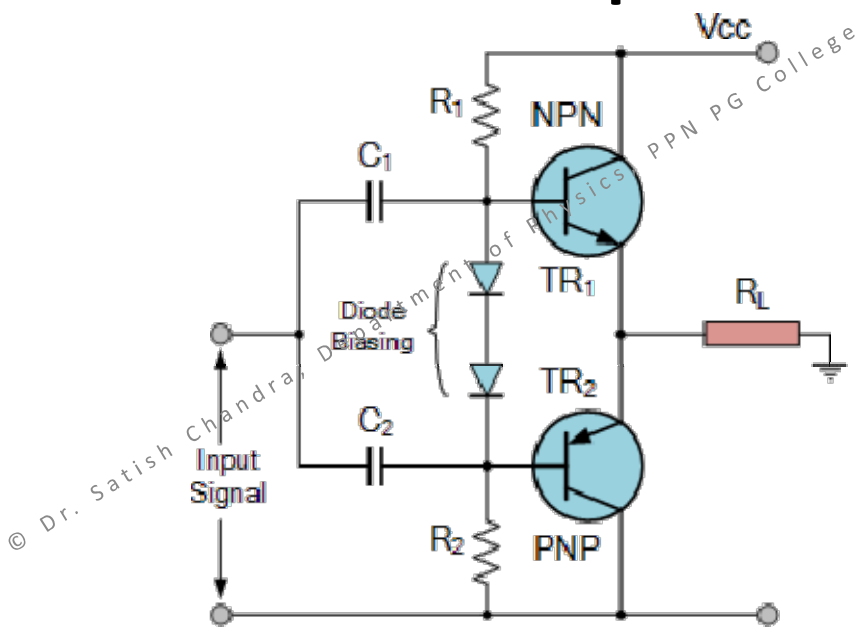
Class B Power Amplifier

- **Advantages**:
  - It is more efficient as compared to the class A power amplifier.
  - Even harmonics are avoided because of the push-pull mechanism.
- **Disadvantages**:
  - It leads to crossover distortion.
  - The cost and size are increased because of coupling transformers.

Class AB Amplifier

- A simple way to eliminate crossover distortion in a Class B amplifier is to add two small voltage sources to the circuit to bias both the transistors at a point slightly above their cut-off point.
- This then would give us what is commonly called an **Class AB Amplifier** circuit.
- However, it is impractical to add additional voltage sources to the amplifier circuit so PN-junctions are used to provide the additional bias in the form of silicon diodes.

Class AB Amplifier



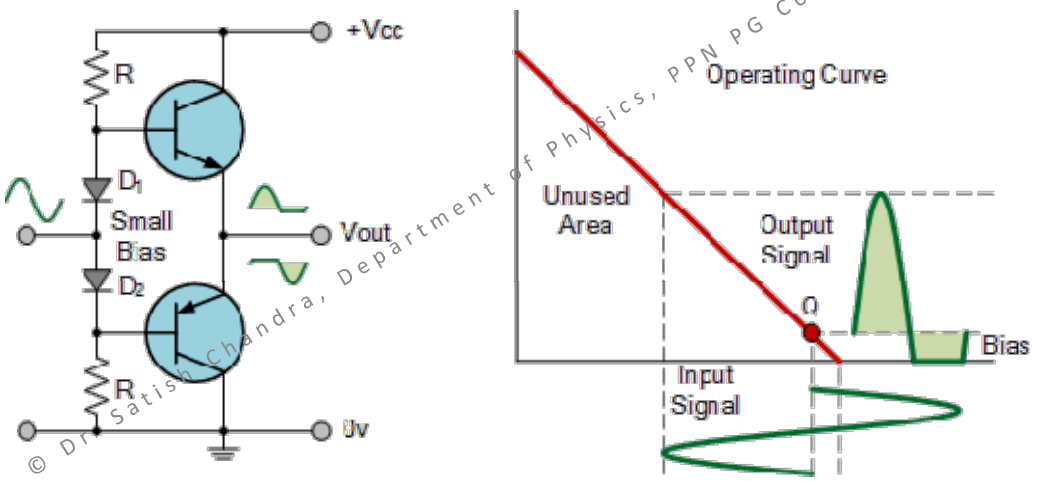
Class AB Amplifier

- A small constant current flows through the series circuit of R_1-D_1-D_2-R_2, producing voltage drops which are symmetrical either side of the input. With no input signal voltage applied, the point between the two diodes is zero volts.
- As current flows through the chain, there is a forward bias voltage drop of approx. 0.7V across the diodes which is applied to the base-emitter junctions of the switching transistors.

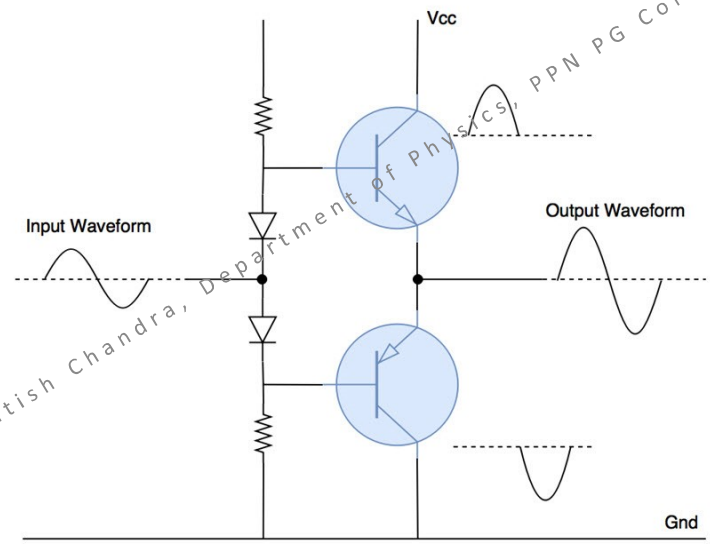
Class AB Amplifier

- Therefore the voltage drop across the diodes, biases the base of transistor TR1 to about 0.7 volts, and the base of transistor TR2 to about –0.7 volts.
- Thus the two silicon diodes provide a constant voltage drop of approximately 1.4 volts between the two bases biasing them above cut-off.

Class AB Amplifier



Class AB Amplifier



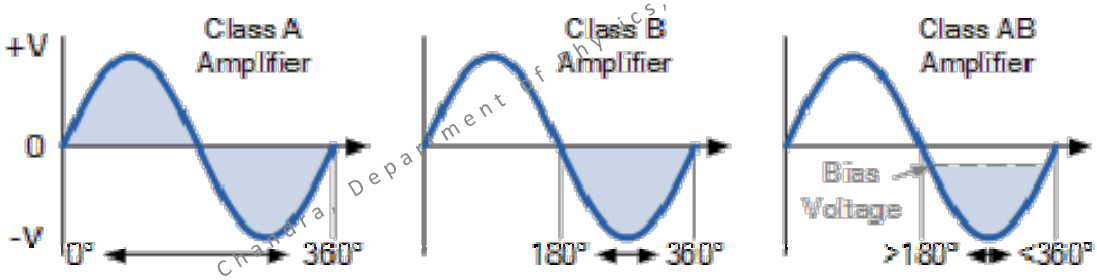
Class AB Amplifier

- 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%.

Comparison of the Different Amplifier Classes

- **Class A: –** The amplifiers single output transistor conducts for the full 360° of the cycle of the input waveform.
- **Class B: –** The amplifiers two output transistors only conduct for one-half, that is, 180° of the input waveform.
- **Class AB: –** The amplifiers two output transistors conduct somewhere between 180° and 360° of the input waveform.

Comparison of the Different Amplifier Classes

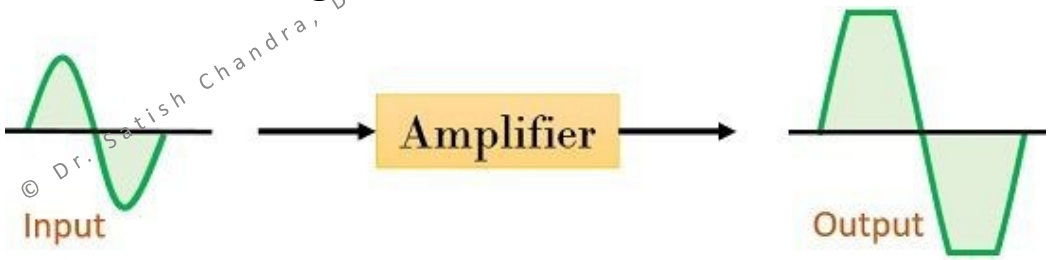


Distortion

- Distortion can be defined as the **changes that occur in output from input** during operation..
- It is always suggested to have a **distortionless** output.
- Distortion in Amplifier basically implies the **variation in the waveform received at the output** with respect to the applied input.
- The **unwanted alterations** generated during amplification is known as distortion.

Distortion

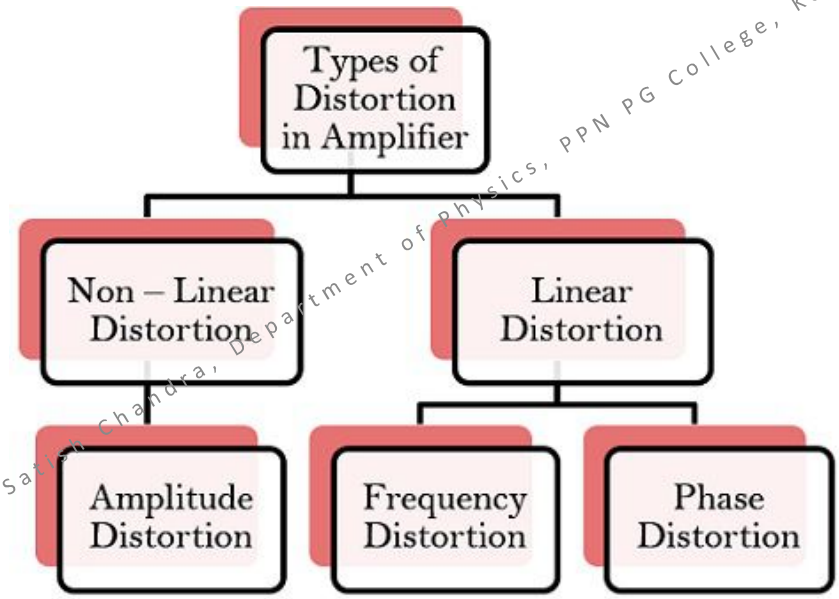
- A pure signal always has a single frequency component where voltage varies positive and negative by an equal amount.
- If this variation is less than full 360^{o} cycle, then it is said that the signal is distorted.



Reasons for signal distortion

- Due to incorrect biasing when the signal is not amplified for the entire cycle of the input signal then distortion occurs.
- It also occurs in the case when the applied input signal is very large.
- Distortion in amplifier sometimes results when the amplification is not linear over the complete frequency range.

Types of Distortion in Amplifier

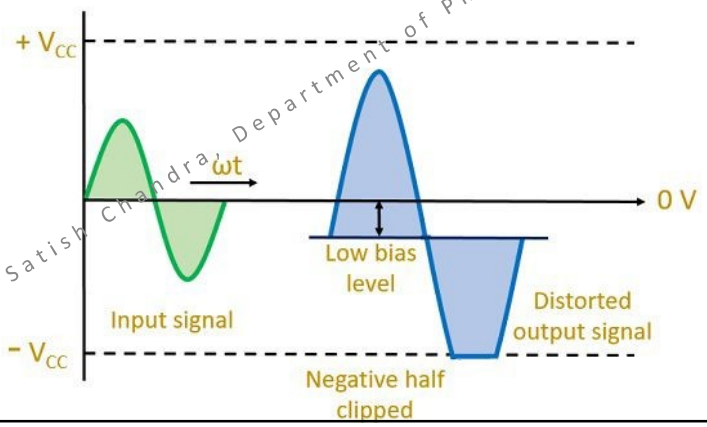


Amplitude Distortion

- Distortion occurs due to **attenuation in the peak value** of the waveform.
- The shift in "Q point" and amplification for less than 360^o of the input signal leads to amplitude distortion.
- It occurs mainly due to **incorrect biasing and clipping**.

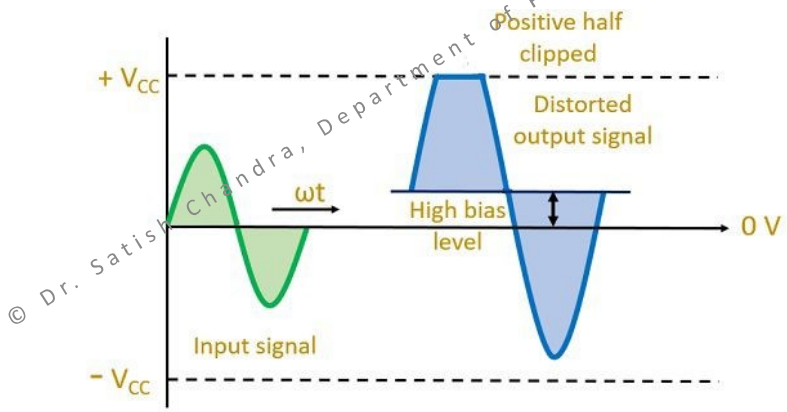
Amplitude Distortion

- Suppose insufficient biasing is provided, the Q point will lie near the lower half of the load line. In such condition, **negative half** of input is **clipped**



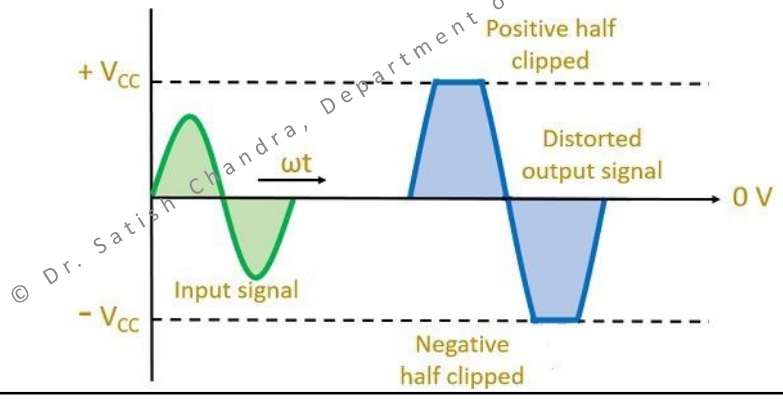
Amplitude Distortion

- Suppose an extra bias potential is provided, the "Q point" will now be at the upper half of the load line. This condition gives an output that is **cut-off at positive half** of the waveform.

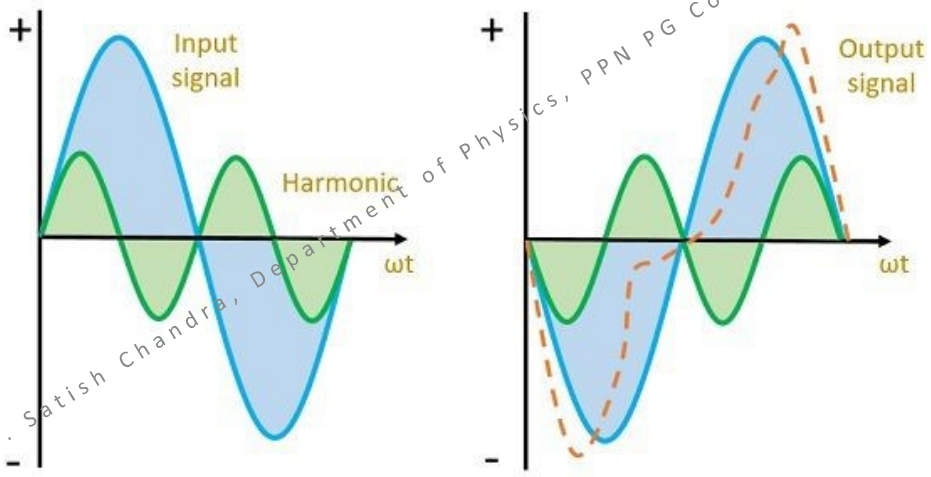


Amplitude Distortion

- When large input signal is amplified by the gain of the amplifier, both **positive and negative half** of the waveform gets **clipped.** This is also known as **clipping distortion**.



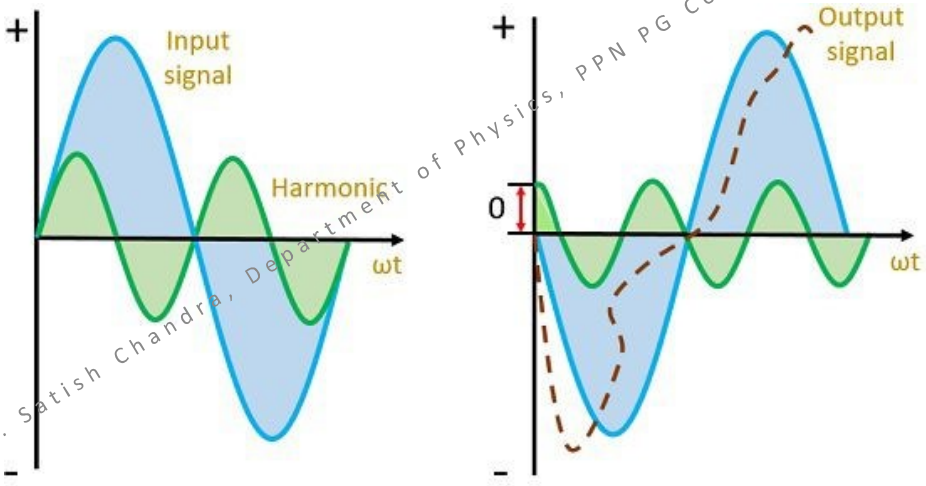
Frequency Distortion



Frequency Distortion

- The input consists of fundamental frequency along with harmonics.
- The combination of the two on amplification will give a distorted signal at the output.
- It occurs either due to the presence of reactive elements or by the electrode capacitances of the amplifier circuits.

Phase Distortion



Phase Distortion

- Phase Distortion in the amplifier is also known as **delay distortion**.
- Whenever there is a time delay between input and occurrence of the signal at the output. It is said to be phase distorted signal.
- It occurs mainly due to electrical reactance.
- A signal consists of different frequency components. So, when different frequency suffers different phase shift, phase distortion takes place.