Power Amplifiers

Text Book:

[1] Jacob Millman, Cristos C. Halkias, "*Integrated Electronics: Analog and Digital Circuits and Systems*", 34th Reprint 2004, Tata-McGraw-Hill. Chapter: 18

[2] Robert Boylestad and Louis Nashelsky, "*Electronic Devices and Circuit theory*", Fifth Edition, Prentice-hall of India Private Limited 1994. Chapter: 16

[3] Albert Paul Malvino, "*Electronic Principles*", Tata McGraw-Hill, 1999. Chapter: 11

Difference between voltage and power amplifier.

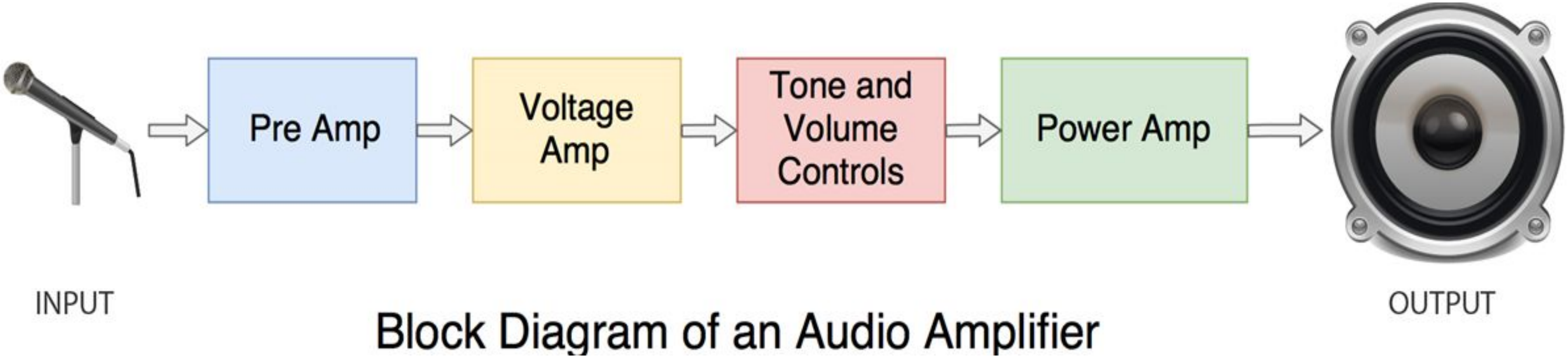
Voltage amplifier

- Voltage amplifier is used to raise voltage level of weak signal.
- No need of heat sink in voltage amplifier.
- Distortion in output will be minimum.
- Size of transistor used is small.
- RC coupling is widely used.
- Used as first stage of amplifier.
- Output impedance is high.

Power amplifier

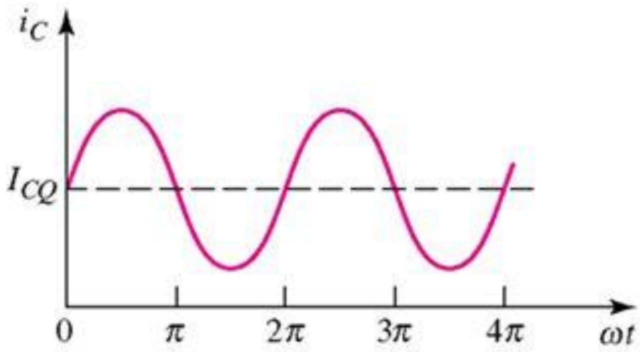
- Power amplifier is used to raise power level of weak signal.
- Heat sink are used in power amplifier.
- Distortion in output will be minimum.
- Size of power transistor is large.
- Transformer coupling is widely used.
- Used as last stage of amplifier.
- Output impedance is low.

POWER AMPLIFIER

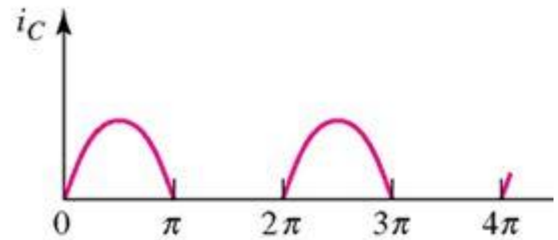


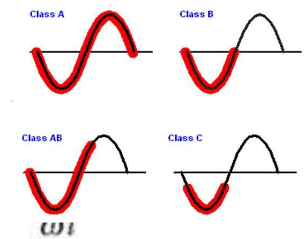
- ✔ A power amplifier is an electronic amplifier designed to increase the magnitude of power of a given input signal.
- ✔ The power of the input signal is increased to a level high enough to drive loads of output devices like speakers, headphones, RF transmitters etc.
- ✔ Unlike voltage/current amplifiers, 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 instead of directly passing the raw audio/RF signal to the power amplifier, it is first pre-amplified using current/voltage amplifiers and is sent as input to the power amp after making necessary modifications.

Power Amplifiers Classification

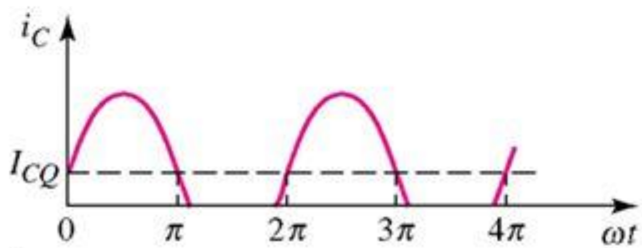


Class A - The transistor conducts during the whole cycle of sinusoidal input signal

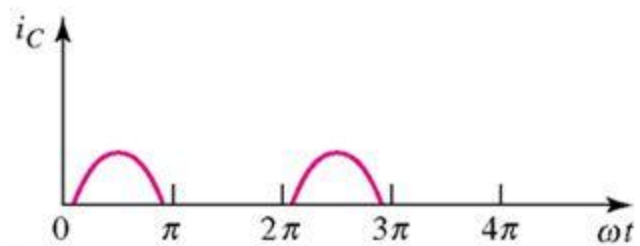




Class B - The transistor conducts during one-half cycle of input signal



Class AB - The transistor conducts for slightly more than half a cycle of input signal

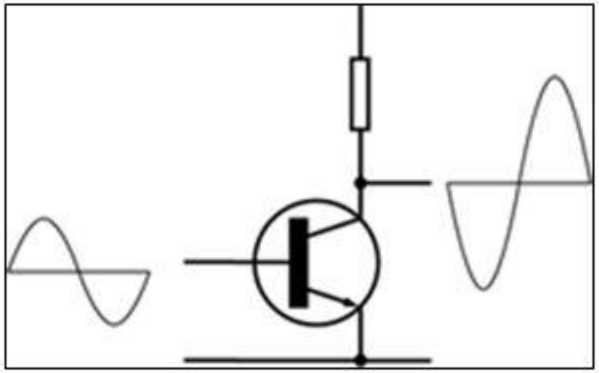


Class C - The transistor conducts for less than half a cycle of input signal

Amplifier classes

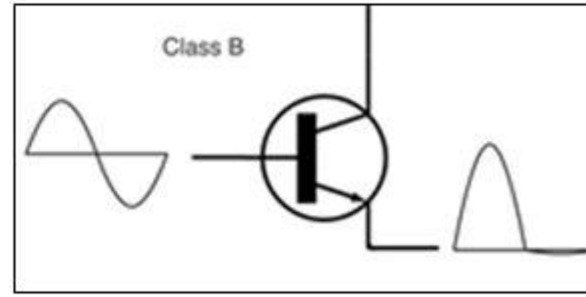
Class A

- *Linear*
- *Bias current*
- *Low efficiency*
- *360 degrees*



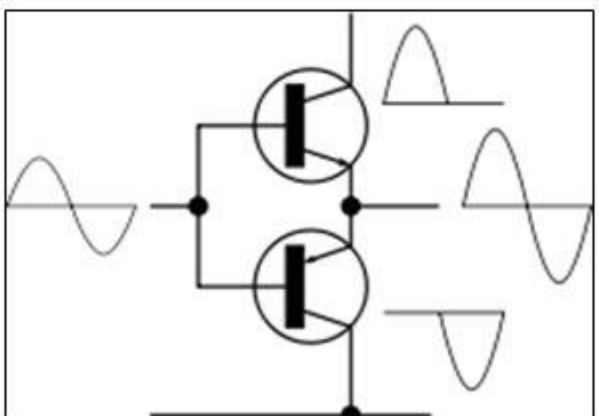
Class B

- *High distortion*
- *Better efficiency*
- *180-360 degrees*



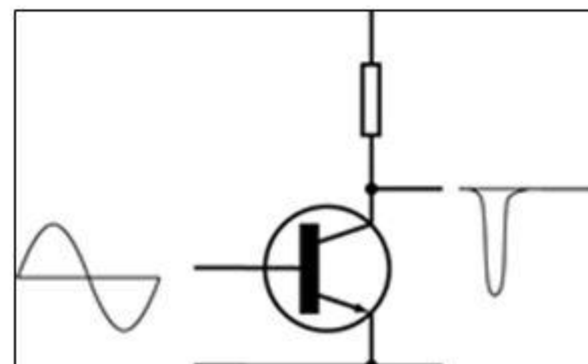
Class AB

- *Linear*
- *Better efficiency*
- *More complex*
- *360 Degrees*



Class C

- *Non-Linear*
- *High efficiency*
- *0-180 degrees*



Amplifier:

An *amplifier* is an electronic device that increases voltage, current or power of a signal.

According to the class of operation, the amplifiers can be classified as:

- Class A, (ii) Class B, (iii) Class AB, and (iv) Class C.

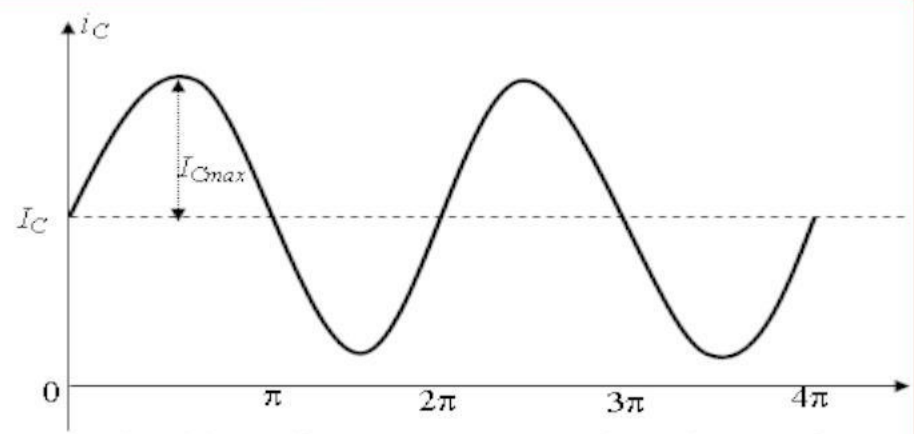


Fig.1(a) Collector current waveform for transistor operating in Class A.

Class A: A *class A* amplifier is one in which the operating point and the input signal are such that the current in the output circuit flows at full times.

The output signal of *class A* amplifiers varies for a full 360° of the cycle.

Class B: A *class B* amplifier is one in which the operating point is at an extreme end of its characteristic, so that the quiescent power is very small. If the signal voltage is sinusoidal, amplification takes place for only one-half a cycle.

A *class B* circuit provides an output signal varying over one-half the input signal cycle, of for 180° of input signal.

Class AB: A *class AB* amplifier is one operating between the two extremes defined for class A and class B. Hence the output signal is zero for part but less than one-half of an input sinusoidal signal.

For class AB operation the output signal swing occurs between 180° and 360° and is neither class A nor class B operation.

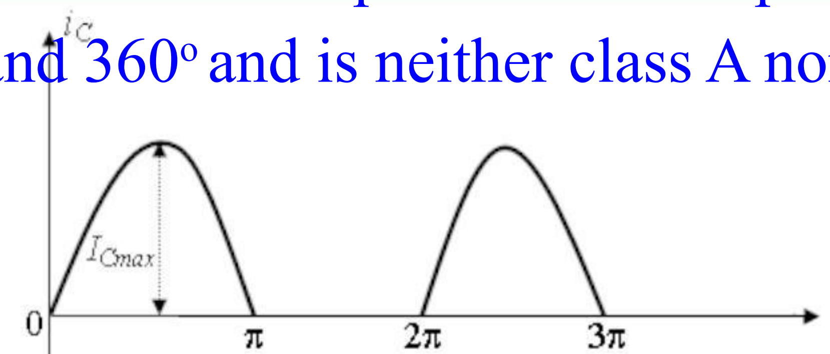


Fig.1(b) Collector current waveform for transistor operating in Class B.

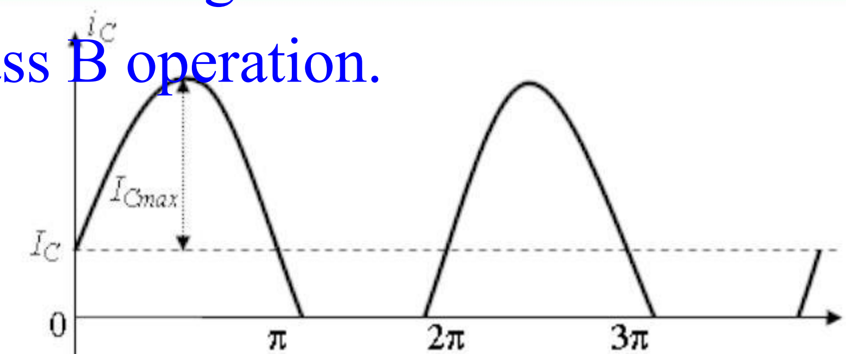


Fig.1(c) Collector current waveform for transistor operating in Class AB.

Class C: A *class C* amplifier is one in which the operating point is chosen so that the output current (or voltage) is zero for more than one-half of the input sinusoidal signal cycle.

The output of a class C amplifier is biased for operation at less than 180^o of the cycle and will operate only with a tuned (resonant) circuit which provides a full cycle of operation for the tuned or resonant frequency.

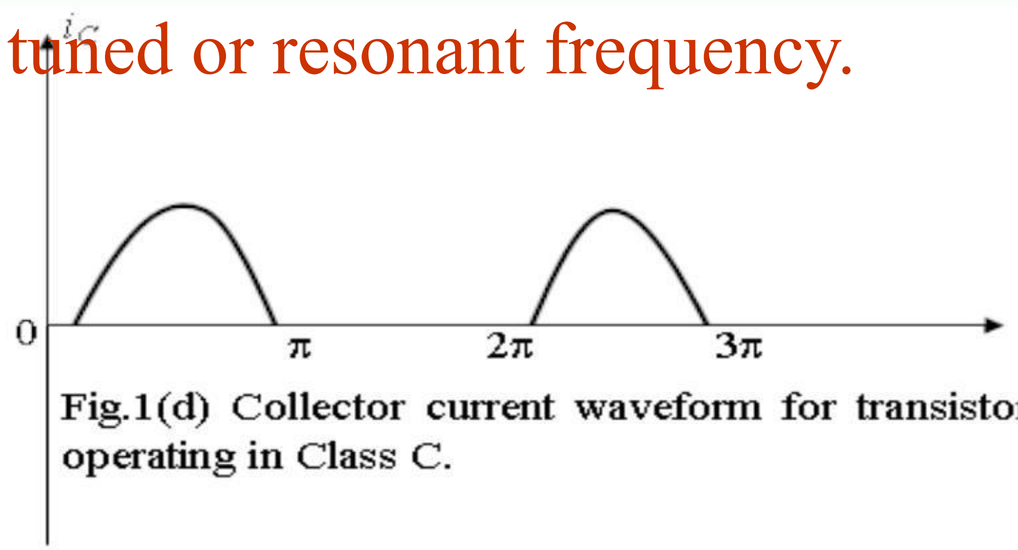
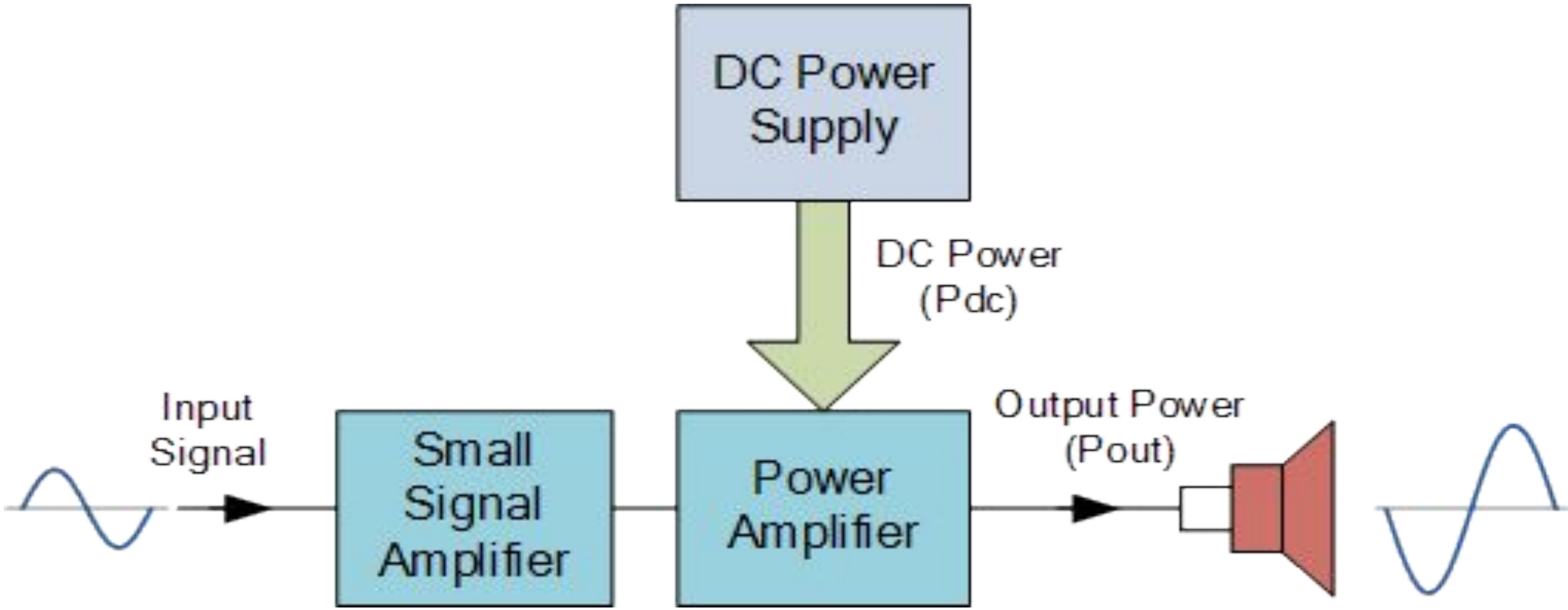


Fig.1(d) Collector current waveform for transistor operating in Class C.

POWER AMPLIFIER EFFICIENCY



$$\eta\% = \frac{P_{OUT}}{P_{DC}} \times 100$$

Where:

- $\eta\%$ – is the efficiency of the amplifier.
- Pout – is the amplifiers output power delivered to the load.
- Pdc – is the DC power taken from the supply.

Series-Fed Class A Amplifier

The fixed-bias circuit connection shown in **Fig. 16.1** can be used to discuss the main features of a class A amplifier.

The beta (β) of power transistor is generally less than 100, the overall amplifier circuit using power transistors being capable of handle large power or current not providing much voltage gain.

DC Bias

The dc bias set by V_{CC} and R_B fixes the dc base-bias current at

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \qquad (16.1)$$

with the collector current then being

$$I_C = \beta I_B \qquad (16.2)$$

with the collector-emitter voltage then

$$V_{CE} = V_{CC} - I_C R_C \qquad (16.3)$$

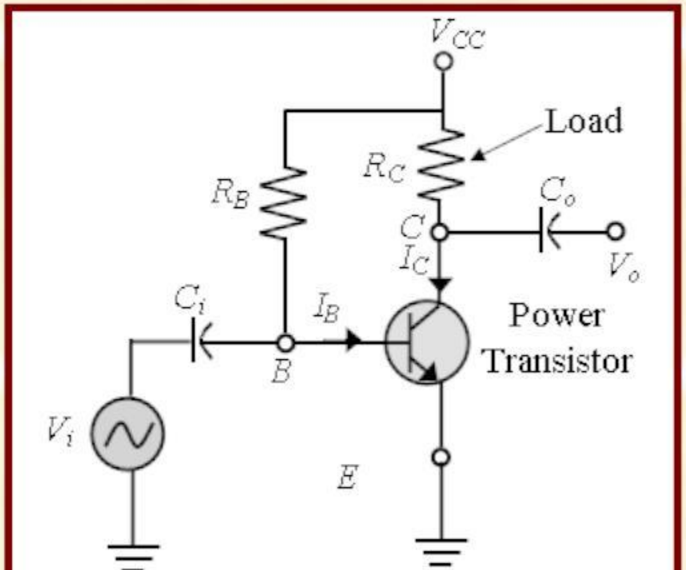


Fig. 16.1 Series-fed Class A large-signal amplifier.

To appreciate the importance of the dc bias the operation of the power amplifier, consider the collector characteristic shown in **Fig. 16.3**.

A dc load line is drawn using the values of V_{CC} and R_C.

The intersection of the dc bias value of I_B with the dc load line then determines the operating point (*Q*-point) for the circuit.

The quiescent-point values are those calculated using Eqs. (16.1) through (16.3).

If the dc bias collector current is set at one-half the possible signal swing (between 0 and V_{CC}/R_C) the largest collector current swing will be possible.

Additionally, if the quiescent collector-emitter voltage is set at one-half the supply voltage, the largest voltage swing (between 0 and V_{CC}) will be possible.

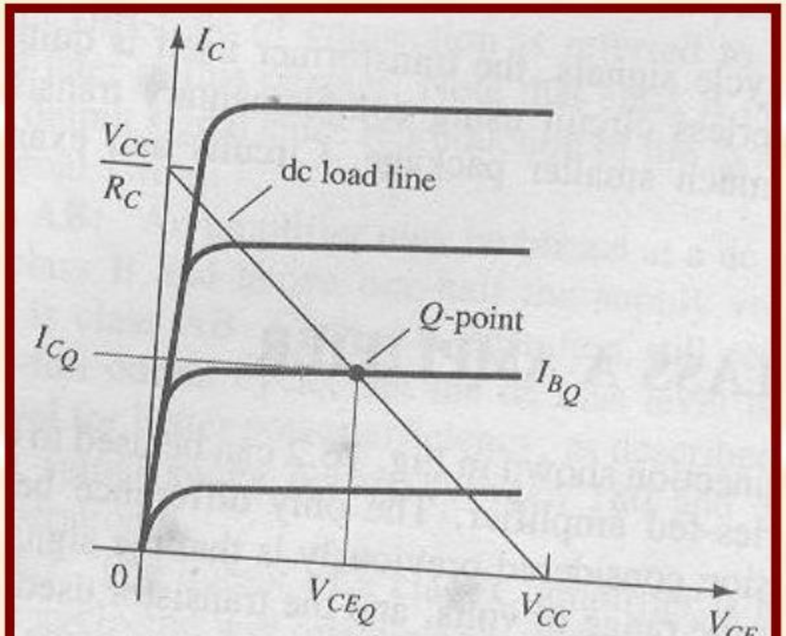


Figure 16.3 Transistor characteristic showing load line and *Q*- point.

AC Operation

When an input ac signal is applied to the amplifier of Fig. 16.1, the output will vary from its dc bias operating voltage and current.

A small input signal, as shown in **Fig. 16.4(a)**, will cause the base current to vary above and below the dc bias point, which will then cause the collector current (output) to vary from the dc bias point set as well as the collector-emitter voltage to vary around its dc bias value.

Power Considerations

The input power with no input signal drawn from the supply is

$$P_i(\text{dc}) = V_{CC} I_{CQ} \qquad (16.4)$$

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

So P_i(dc) represent the input power.

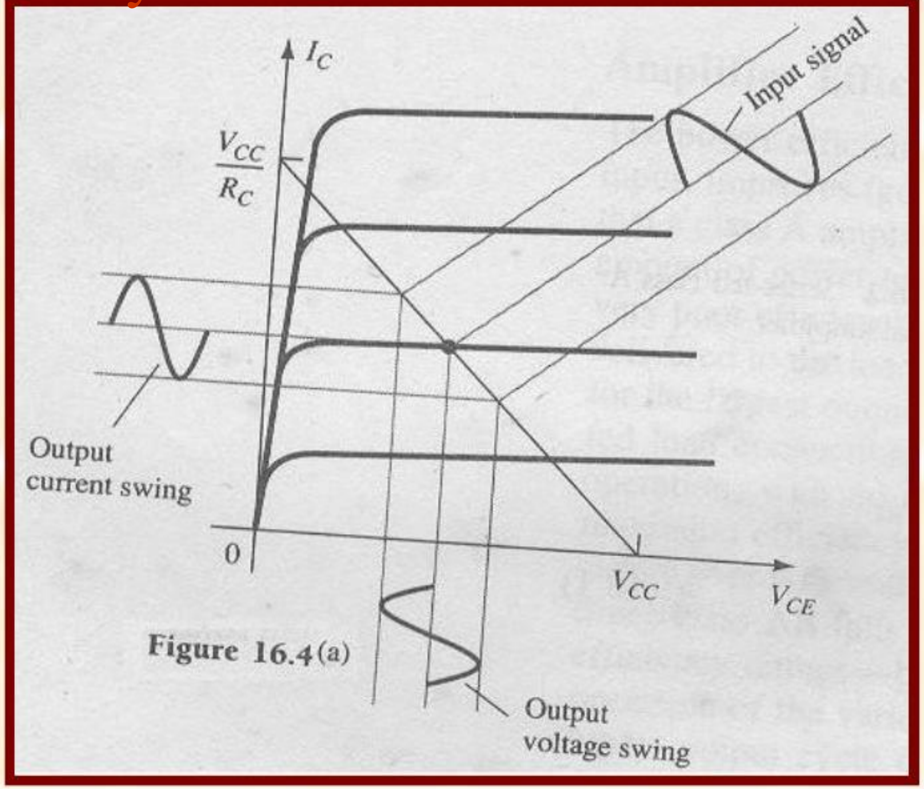


Figure 16.4(a)

Output Power

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

The ac power is delivered to the load R_C, in the circuit of Fig. 16.1 is given by

Using rms value :

$$P_o(\text{ac}) = V_{CE}(\text{rms}) I_C(\text{rms}) \quad (16.5a)$$

$$P_o(\text{ac}) = I_C^2(\text{rms}) R_C \quad (16.5b)$$

$$P_o(\text{ac}) = \frac{V_{CE}^2(\text{rms})}{R_C} \quad (16.5c)$$

Using peak value :

$$P_o(\text{ac}) = \frac{V_{CE}(\text{p}) I_C(\text{p})}{2} \quad (16.5a)$$

$$P_o(\text{ac}) = \frac{I_C^2(\text{p}) R_C}{2} \quad (16.5b)$$

$$P_o(\text{ac}) = \frac{V_{CE}^2(\text{p})}{2R_C} \quad (16.5c)$$

Using peak - to - peak value :

$$P_o(\text{ac}) = \frac{V_{CE}(\text{p - p})\, I_C(\text{p - p})}{8} \qquad (16.5a)$$

$$P_o(\text{ac}) = \frac{I_C^2(\text{p - p})\, R_C}{8} \qquad (16.5b)$$

$$P_o(\text{ac}) = \frac{V_{CE}^2(\text{p - p})}{8R_C} \qquad (16.5c)$$

Efficiency

The efficiency of an amplifier represents the amount of ac power delivered (transferred) from the dc source.

The efficiency of the amplifier is calculated using

$$\%\eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% \quad (16.8a)$$

$$\%\eta = \frac{V_{CE}^2(\text{p - p})}{8R_C \times V_{CC} I_{CQ}} \times 100\% \qquad (16.8b)$$

Maximum Efficiency

For the class A series amplifier the maximum efficiency can be determined using the maximum voltage and current swings.

For the voltage swing it is

$$\text{Maximum } V_{CE}(\text{p}-\text{p}) = V_{CC}$$

$$\text{Maximum } I_C(\text{p}-\text{p}) = \frac{V_{CC}}{R_C}$$

Using the maximum voltage swing in Eq. (16.7c) yields

$$\text{Maximum } P_o(\text{ac}) = \frac{V_{CC}^2}{8R_C}$$

The maximum power input can be calculated using the dc bias current set to half the maximum value.

Thus

$$\text{Maximum } P_i(\text{dc}) = V_{CC}\frac{V_{CC}/2}{R_C} = \frac{V_{CC}^2}{2R_C}$$

We can then use Eq. (16.8) to calculate the maximum efficiency:

$$\text{maximum } \%\eta = \frac{\text{maximum} P_o(\text{ac})}{\text{maximum} P_i(\text{dc})} \times 100\% = \frac{V_{CC}^2}{8R_C} \times \frac{2R_C}{V_{CC}^2} \times 100\%$$

$$= \frac{2}{8} \times 100\% = 25\%$$

The maximum efficiency of a class A amplifier is thus seen to be 25%.

A form of class A amplifier having maximum efficiency of 50% uses a transformer to couple the output signal to the load as shown in **Fig. 16.6**.

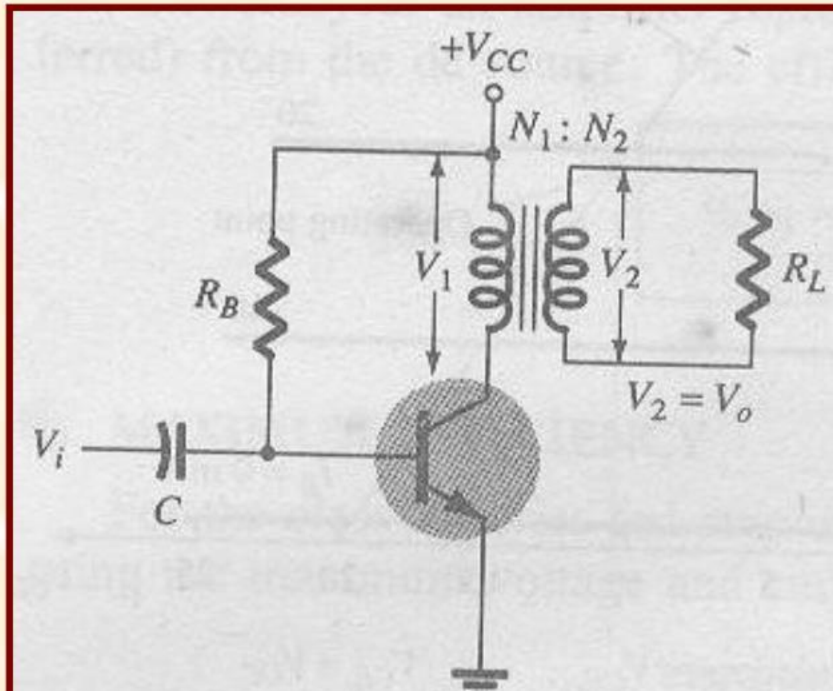
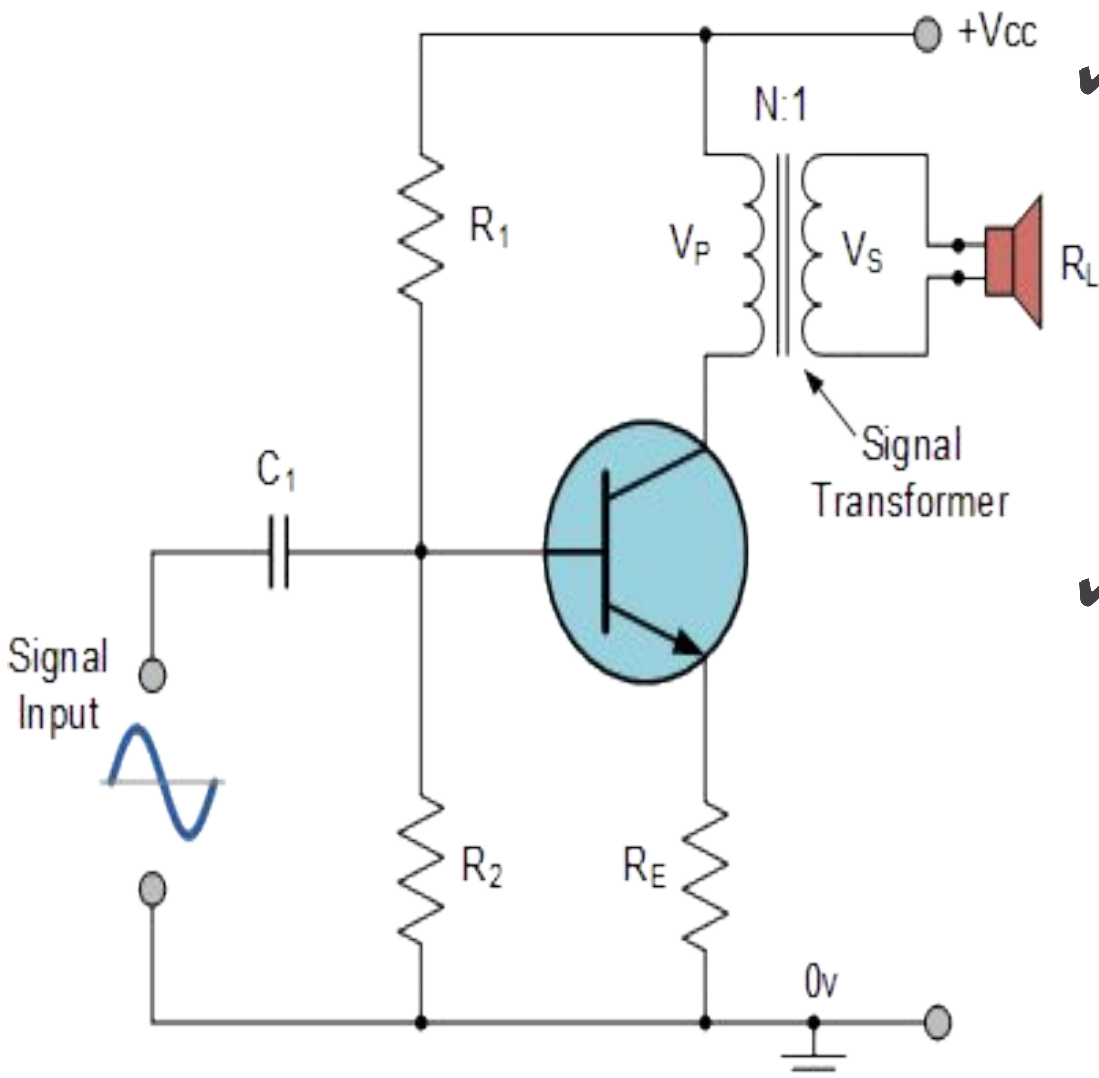
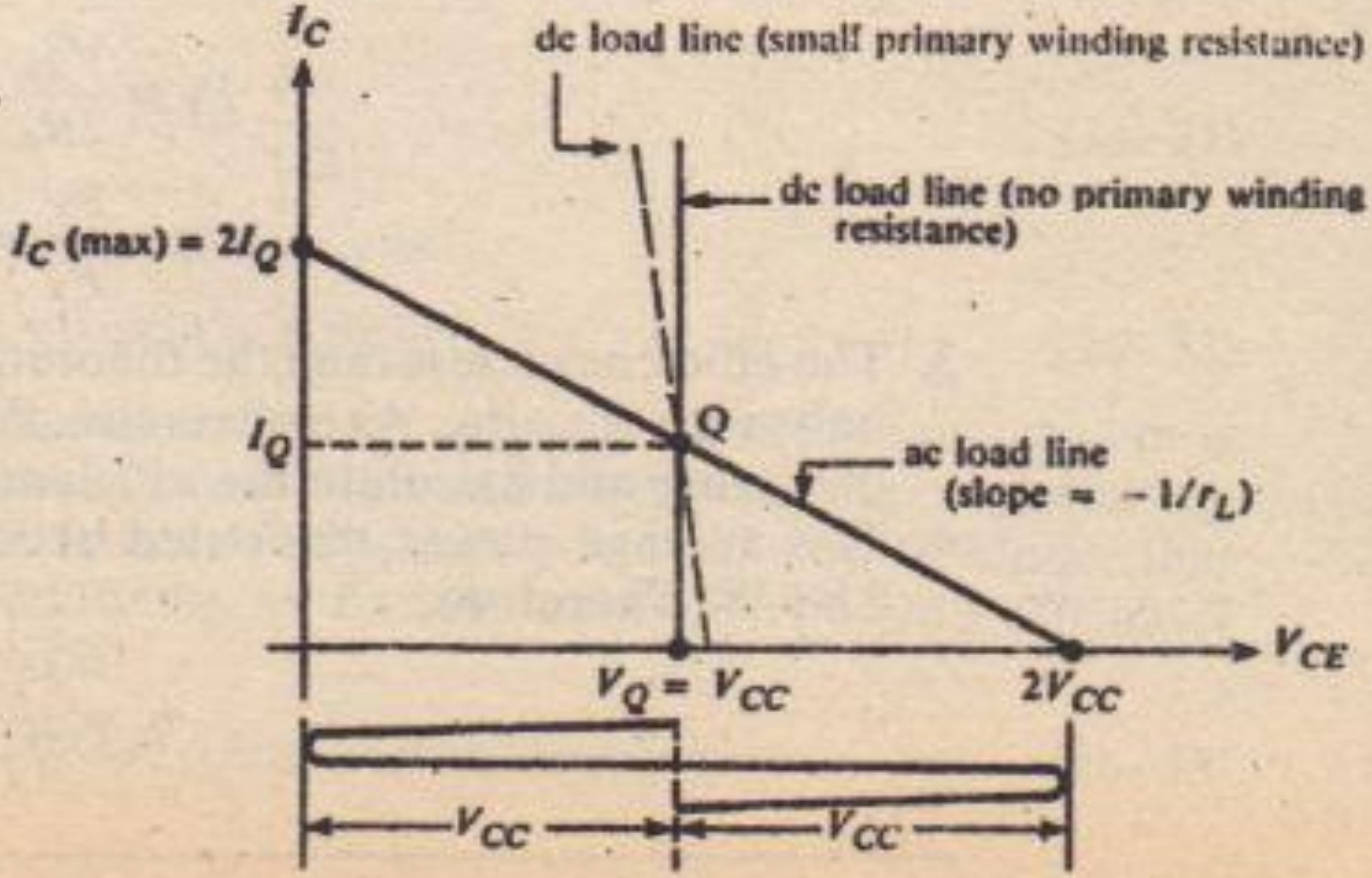


Figure 16.6 (a) Transformer-coupled audio power amplifier.

TRANSFORMER COUPLED CLASS A POWER AMPLIFIER



- ✔ As the Collector current, Ic 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 2Vcc giving a maximum collector current of twice Ic when the Collector voltage is at its minimum.



I_C
dc load line (small primary winding resistance)
dc load line (no primary winding resistance)
I_C (max) = $2I_Q$
Q
I_Q
ac load line
(slope = $-1/r_L$)
V_{CE}
$V_Q = V_{CC}$
$2V_{CC}$
V_{CC}
V_{CC}

EFFICIENCY OF TRANSFORMER COUPLED CLASS A PA

The r.m.s. Collector voltage is given as:

$$V_{CE} = \frac{V_{C(max)} - V_{C(min)}}{2\sqrt{2}} = \frac{2V_{CC} - 0}{2\sqrt{2}}$$

The r.m.s. Collector current is given as:

$$I_{CE} = \frac{I_{C(max)} - I_{C(min)}}{2\sqrt{2}} = \frac{2I_C - 0}{2\sqrt{2}}$$

The r.m.s. Power delivered to the load (Pac) is therefore given as:

$$P_{ac} = V_{CE} \times I_{CE} = \frac{2V_{CC}}{2\sqrt{2}} \times \frac{2I_C}{2\sqrt{2}} = \frac{2V_{CC}\,2I_C}{8}$$

EFFICIENCY OF TRANSFORMER COUPLED CLASS A PA

The average power drawn from the supply (Pdc) is given by:

$$P_{dc} = V_{CC} \times I_{C}$$

and therefore the efficiency of a Transformer-coupled Class A amplifier is given as:

$$\eta_{(max)} = \frac{P_{ac}}{P_{dc}} = \frac{2V_{CC}\,2I_{C}}{8V_{CC}I_{C}} \times 100\%$$

Maximum theoretical efficiency of Transformer coupled class A amplifier is therefore 50%

Example 16.1 Calculate the (i) base current, collector current and collector to emitter voltage for the operating (or Q) point (ii) input power, output power, and efficiency of the amplifier circuit in the following figure for an input voltage in a base current of 10 mA peak.

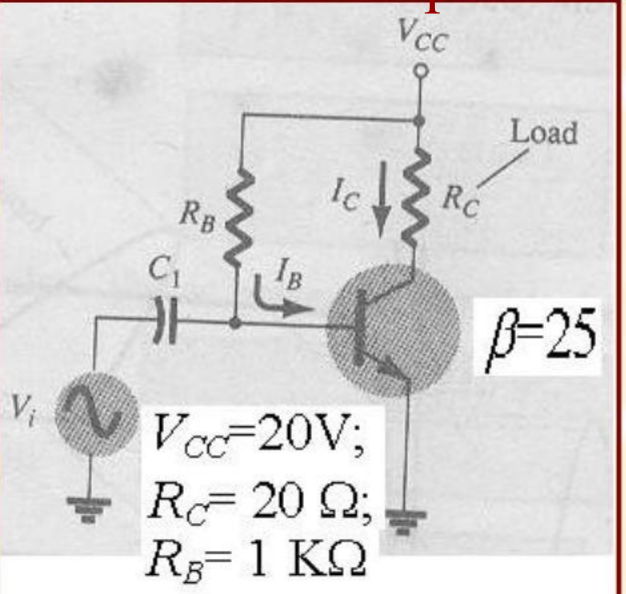


Fig. 16.5(a)

Solution:

(i) the *Q*-point can be determined by DC analysis as:

$$I_{B_Q} = \frac{V_{CC} - 0.7\text{V}}{R_B} = \frac{20\text{V} - 0.7\text{V}}{1\text{K}\Omega} = 19.3 \text{ mA}$$

$$I_C = \beta I_B = 25(19.3\text{mA}) = 0.48 \text{ A}$$

$$V_{CE_Q} = 20\text{V} - (0.48\text{A})(20\Omega) = 10.4\text{V}$$

(ii) When the input ac base current increases from its dc bias level, the collector current rises by

$$I_C(\text{p}) = \beta I_B(\text{p}) = 25(10\text{mA}) = 250\ \text{mA peak}$$

$$P_o(\text{ac}) = \frac{I_C^2(\text{p})}{2} R_o = \frac{(250\times 10^{-3})^2}{2} 20 = 0.625\text{W}$$

$$P_i(\text{dc}) = V_{CC} I_{CQ} = (20\text{V})(0.48\text{A}) = 9.6\text{W}$$

$$\%\eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\% = \frac{0.625\text{W}}{9.6\text{W}} = 6.5\%$$

Class B Amplifier

Class B operation is provided when the dc bias transistor biased just off, the transistor turning on when the ac signal is applied.

This is essentially no bias and the transistor conducts current for only one-half of the signal cycle.

To obtain output for the full cycle of signal, it is necessary to use two transistors and have each conduct on opposite half-cycles, the combined operation providing a full cycle of output signal.

Since one part of the circuit pushes the signal high during one-half cycle and the other part pulls the signal low during the other half-cycle, the circuit is referred to as a push-pull circuit.

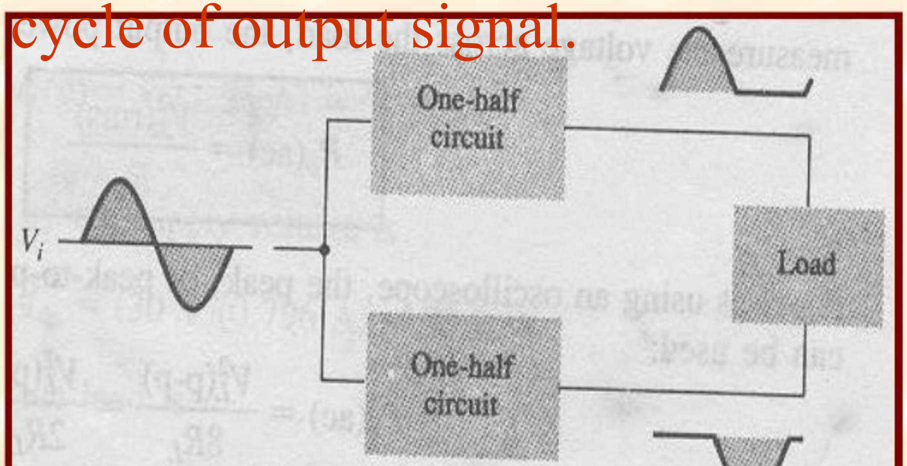


Figure 16.12 Block representation of push-pull operation.

Figure 16.12 shows a diagram for push-pull operation.

The arrangement of a push-pull circuit is shown in **Fig. 18-8**. When the signal on transistor Q_1 is positive, the signal on Q_2 is negative by an equal amount.

During the first half-cycle of operation, transistor Q_1 is driven into conduction, whereas transistor Q_2 is driven off. The current i_1 through the transformer results in the first half-cycle of signal to the load.

During the second half-cycle of operation, transistor Q_2 is driven into conduction, whereas transistor Q_1 is driven off. The current i_2 through the transformer results in the second half-cycle of signal to the load.

The overall signal developed across the load then varies over the full cycle of signal operation.

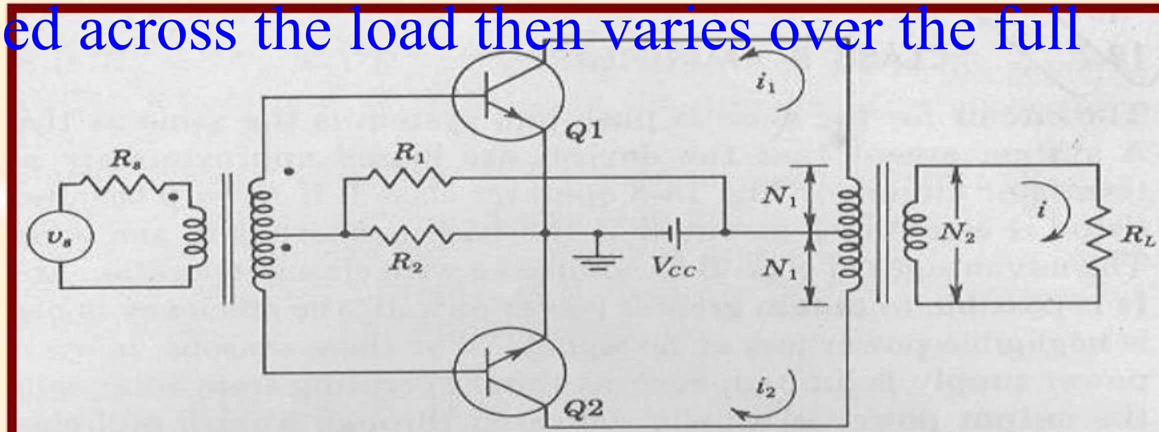


Fig. 18-8 Two transistors in a push-pull arrangement.

Consider an input signal (base current) of the form $i_{b1} = I_{bm} \cos\omega t$ applied to Q_1.

The output current of this transistor is given by Eq. (18.33):

$$i_{1C} = I_{C} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + \ldots\ldots\ldots\ldots \quad (18.33)$$

The corresponding input signal to Q_2 is

$$i_{B2} = -i_{b1} = I_{bm} \cos(\omega t + \pi)$$

The output current of this transistor is obtained by replacing ωt by $\omega t + \pi$ in the expression for i_{b1}. That is,

$$i_2 = i_1 \ cos\ (\omega t + \pi) \quad (18.34)$$

Hence,

$$i_{2C} = I_C + B_0 + B_1 \cos(\omega t + \pi) + B_2 \cos 2(\omega t + \pi) + B_3 \cos 3(\omega t + \pi) + \ldots\ldots\ldots\ldots$$

which is

$$i_{2C} = I_C + B_0 - B_1 \cos\omega t + B_2 \cos 2\omega t - B_3 \cos 3\omega t + \ldots\ldots\ldots\ldots \quad (18.35)$$

The total output current is then proportional to the difference between the collector current in the two resistors. That is,

$$i = k(i_1 - i_2) = 2k(B_1 \cos\omega t + B_3 \cos 3\omega t + \ldots\ldots\ldots\ldots) \quad (18.36)$$

This expression shows that a push-pull circuit will balance out all even harmonics in the output and will leave the third-harmonic term is the principle source of distortion.

This conclusion was reached on the assumption that the two transistors are identical. If their characteristics differ appreciably, the appearance of even harmonics must be expected.

The fact that the output current contains no even-harmonic.

Advantages of Push-Pull System

1) Push-pull circuit give more output per active device: Because no even harmonics are present in the output of a push-pull amplifier, such a circuit will give more output per active device for a given amount of distortion. For the same reason, a push-pull arrangement may be used to obtain less distortion for a given power output per transistor.

2) **Eliminates any tendency toward core saturation and nonlinear distortion of transformer:** The dc components of the collector current oppose each other magnetically in the transformer core. This eliminates any tendency toward core saturation and consequent nonlinear distortion that might arise from the curvature of the transformer-magnetizing curve.

3) Ripple voltage will not appear in the load: The effects of ripple voltages that may be contained in the power supply because of inadequate filtering will be balance out. This cancellation results because the currents produced by this ripple voltage are in oppose

Class B amplifier operation

The transistor circuit of Fig. 18-8 operates class B if $R_2=0$ because a silicon transistor is essentially at cutoff if the base is shorted to the emitter.

Advantages of Class B as compared with class A operation

2. It is possible to obtain greater power output,
3. The efficiency is higher, and
4. There is negligible power loss at no signal.

Disadvantages of Class B as compared with class A operation

2. The harmonic distortion is higher,
3. Self-bias cannot be used, and
4. The supply voltage must have

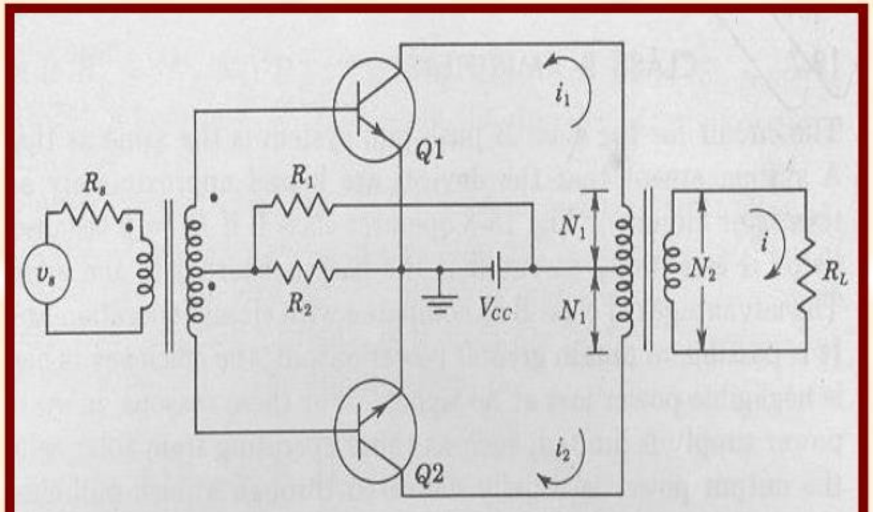


Fig. 18-8 Two transistors in a push-pull arrangement.

The graphical construction from which to determine the output current and voltage waveshapes for a single transistor operating as a class B stage is indicated in **Fig. 18-9**.

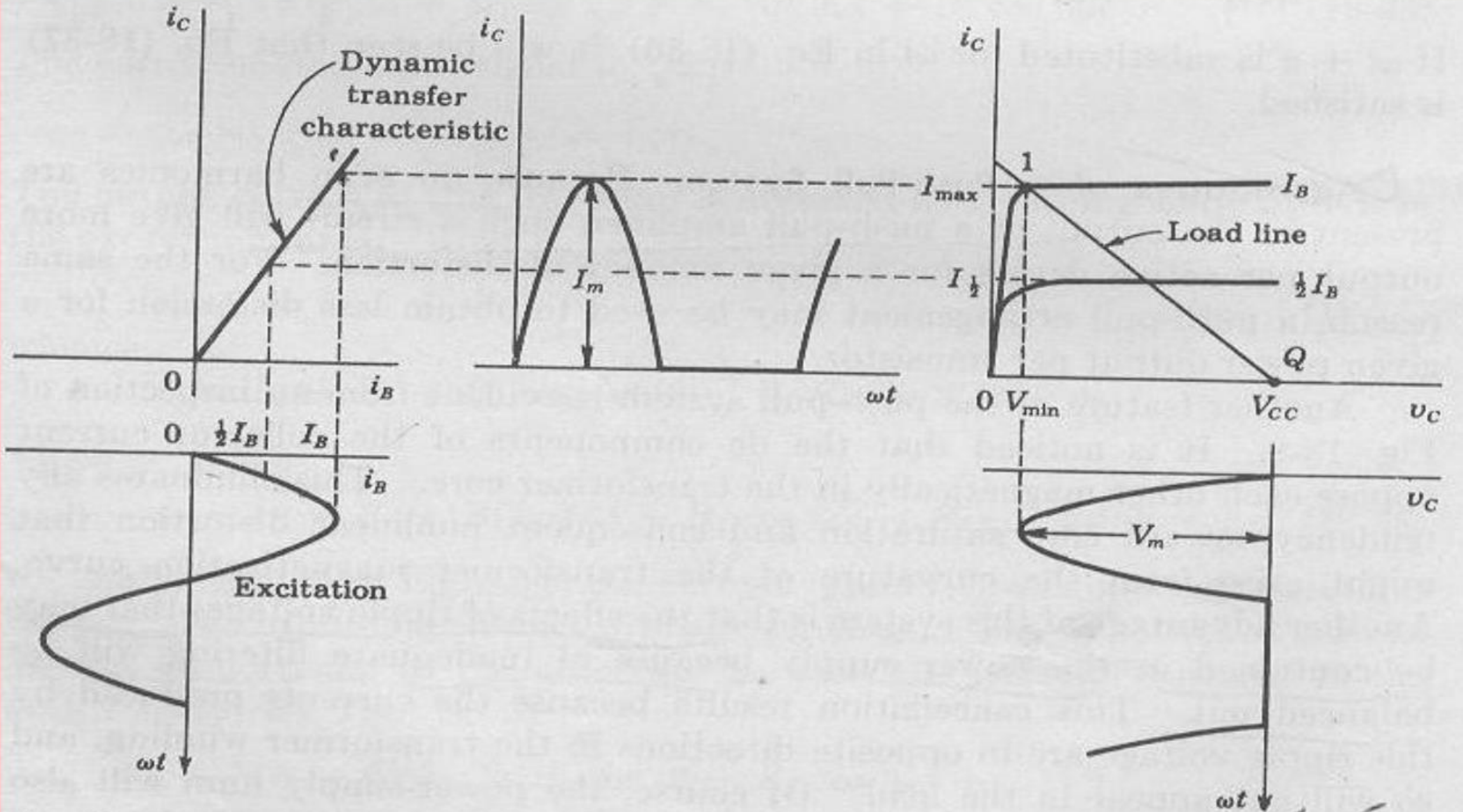


Fig. 18-9 Graphical construction for determining the output waveforms of a single class B transistor stage.

Input power: The power supplied to the load by an amplifier is drawn from the power supply which provides the input or dc power.

The amount of this power can be calculated using

$$P_i(\text{dc}) = V_{CC} I_{dc} \quad (16.17)$$

In class B operation the current drawn from a single power supply has the same form of a full-wave rectified signal. So,

$$I_{dc} = \frac{2}{\pi} I(\text{p}) \quad (16.18) \text{ and } P_i(\text{dc}) = V_{CC} \frac{2}{\pi} I(\text{p}) \quad (16.19)$$

Output Power: The output across the load is given by

$$P_o(\text{ac}) = \frac{V_L^2(\text{rms})}{R_L} \quad (16.20)$$

$$P_o(\text{ac}) = \frac{V_L^2(\text{p})}{2R_L} = \frac{V_L^2(\text{p-p})}{8R_L} \quad (16.21)$$

Efficiency: The efficiency of the class B amplifier can be calculated using the basic equation

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

$$\%\eta = \frac{V_L^2(\text{p})}{2R_L} \frac{\pi}{2V_{CC} I(\text{p})} \times 100\%$$

$$\text{using, } I(\text{p}) = \frac{V_L(\text{p})}{R_L}$$

$$\%\eta = \frac{V_L^2(\text{p})}{2R_L} \frac{\pi R_L}{2V_{CC} V_L(\text{p})} \times 100\%$$

$$\%\eta = \frac{\pi}{4} \frac{V_L(\text{p})}{V_{CC}} \times 100\% \quad (16.22)$$

Maximum Efficiency: Equation (16.22) shows that the larger the peak voltage, the higher the circuit efficiency, up to a maximum value when the , this maximum efficiency then being

$$\text{Maximum, } I(\text{p}) = \frac{V_{CC}}{R_L} \qquad \text{Maximum, } I_{dc} = \frac{2}{\pi}\frac{V_{CC}}{R_L}$$

$$\text{Maximum, } P_i(\text{dc}) = V_{CC}\left(\frac{2}{\pi}\frac{V_{CC}}{R_L}\right) = \frac{2V_{CC}^2}{\pi R_L} \qquad \text{Maximum, } P_o(\text{ac}) = \frac{V_{CC}^2}{2R_L}$$

$$\text{Maximum, } \%\eta = \frac{V_{CC}^2}{2R_L} \times \frac{\pi R_L}{2V_{CC}^2} = \frac{\pi}{4} \times 100\% = 78.5\%$$

Maximum theoretical efficiency of class B amplifier is therefore 78.5%

Crossover distortion

The distortion caused by the nonlinear transistor input characteristic is indicated in **Fig. 18-12**. The i_B -v_B curve for each transistor is drawn, and the construction used to obtain the output current (assumed proportional to the base current) is shown.

In the region of small currents (for $v_B < V_\gamma$), the output is much smaller than it would be if the response were linear. This effect is called *crossover distortion*.

In order to overcome the problem of crossover distortion, the transistor must operate in a class AB mode.

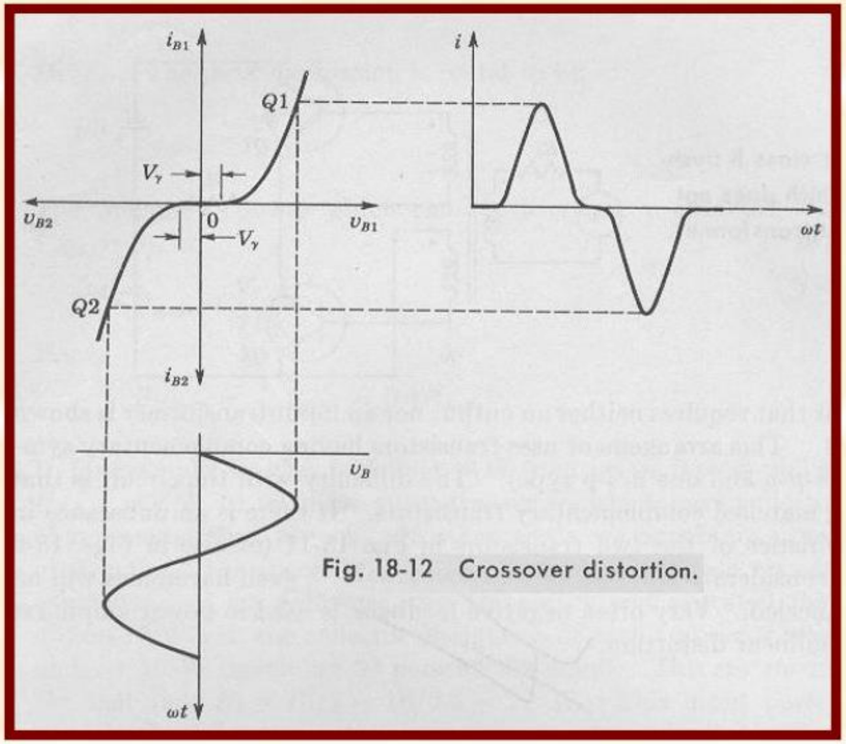


Fig. 18-12 Crossover distortion.

(16.10) Calculate (i) the input power, (ii) the output power, (iii) the power handled by each transistor, and (iv) the efficiency for an input of 12 V (rms) of a push-pull Class-B amplifier circuit having biasing voltage, V_{CC} = 25 V and load resistance, R_L = 4 Ω.

Solution: Given, V_i(rms)=12V, **V_{CC} = 25 V, load resistance, R_L = 4 Ω.**

$$V_i(p) = \sqrt{2}\,V_i(rms) = \sqrt{2}\times 12\text{V} \approx 17\text{V}$$

Since, the operating point is selected in cutoff region, thus
$V_i(p)=V_L(p)=17$V

$$I_L(p) = \frac{V_L(p)}{R_L} = \frac{17\text{V}}{4\Omega} = 4.25\text{A}$$

$$I_{dc} = \frac{2}{\pi} I_L(p) = \frac{2}{\pi}\times 4.25\text{ A} = 2.71\text{A}$$

$$P_i\,(\text{dc}) = V_{CC} I_{dc} = 25\text{V}\times 4.25\text{A} = 67.75\text{W}$$

$$P_o(\text{ac}) = \frac{V_L^2(p)}{2R_L} = \frac{(17\text{V})^2}{2\times 4\Omega} = 36.125\text{W}$$

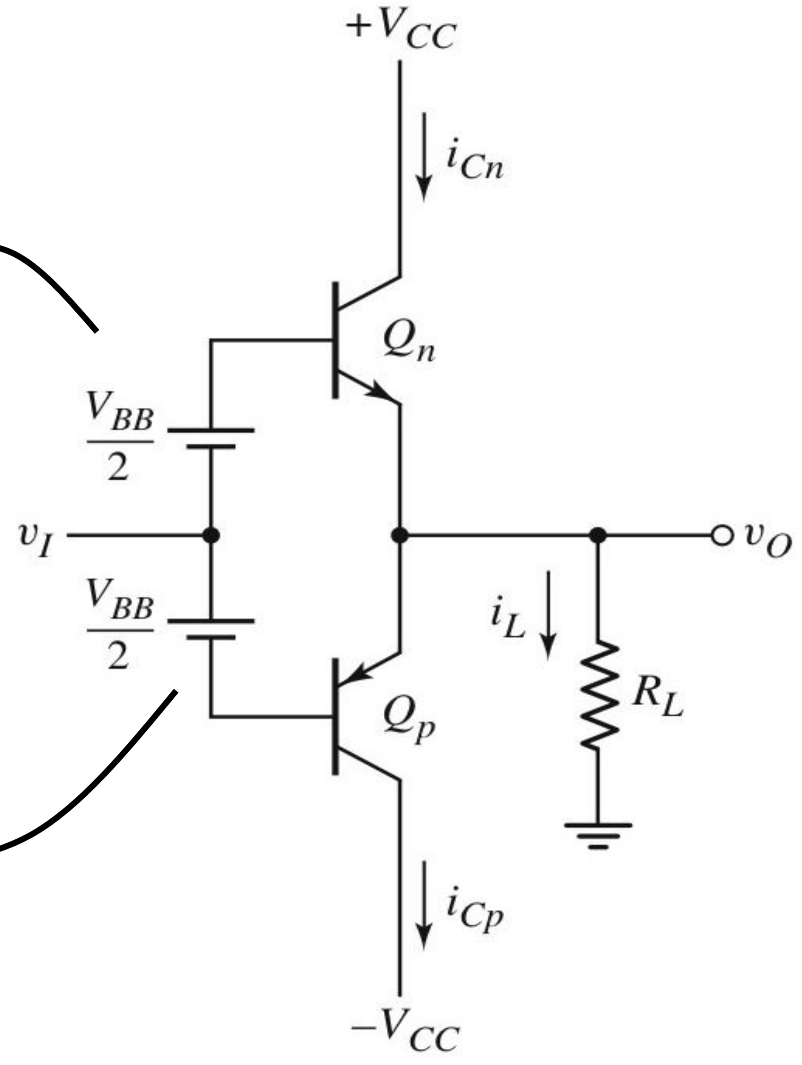
Power dissipated by each output transistor is:

$$P_Q = \frac{P_{2Q}}{2} = \frac{P_i - P_o}{2} = \frac{67.75 - 36.125}{2} = 15.8 \text{ W}$$

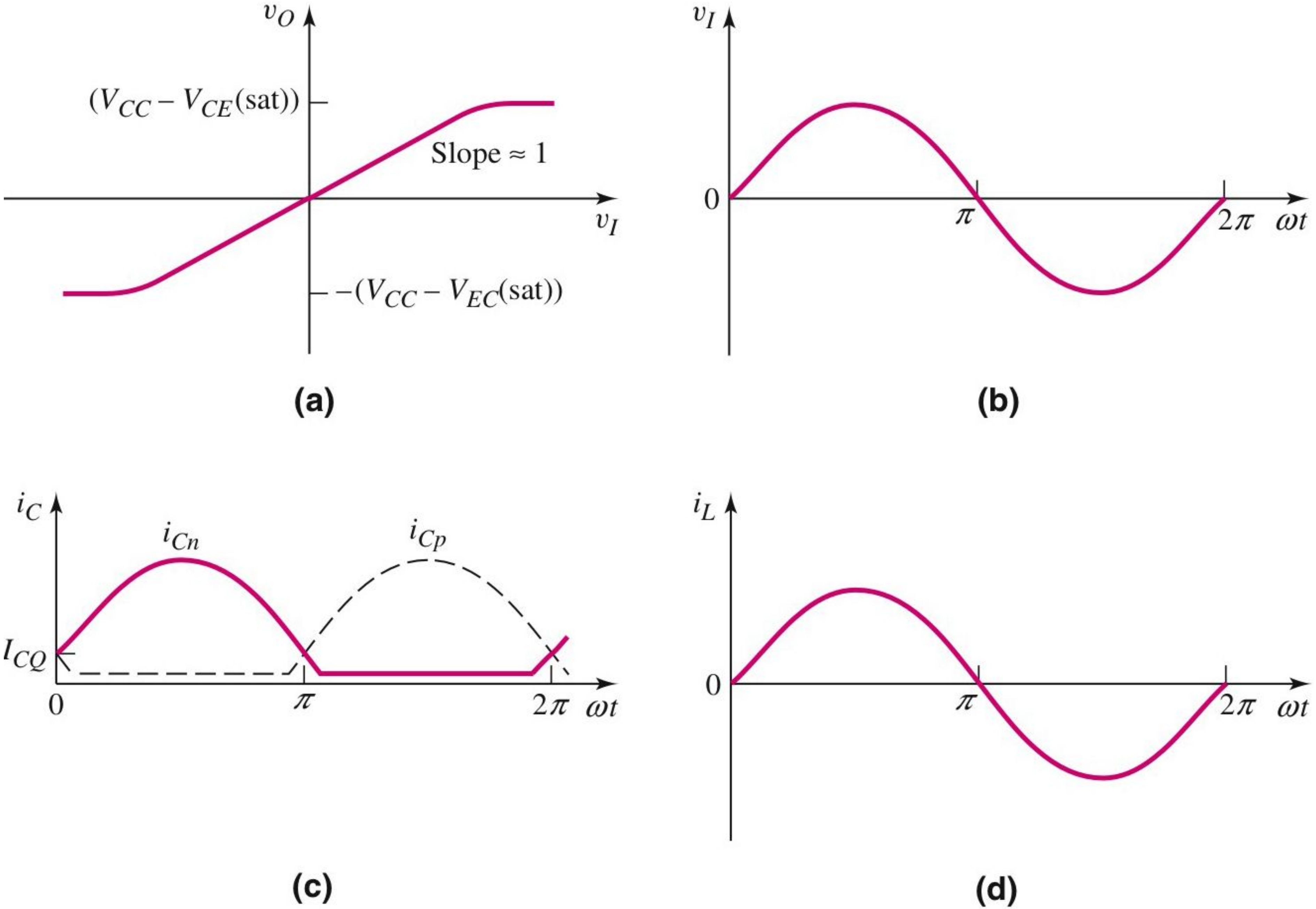
$$\text{Efficiency, } \%\eta = \frac{P_o}{P_i}\times 100\% = \frac{36.125}{67.75}\times 100\% = 53.3\%$$

Class–AB operation

Small quiescent bias on each output transistor to eliminate crossover distortion

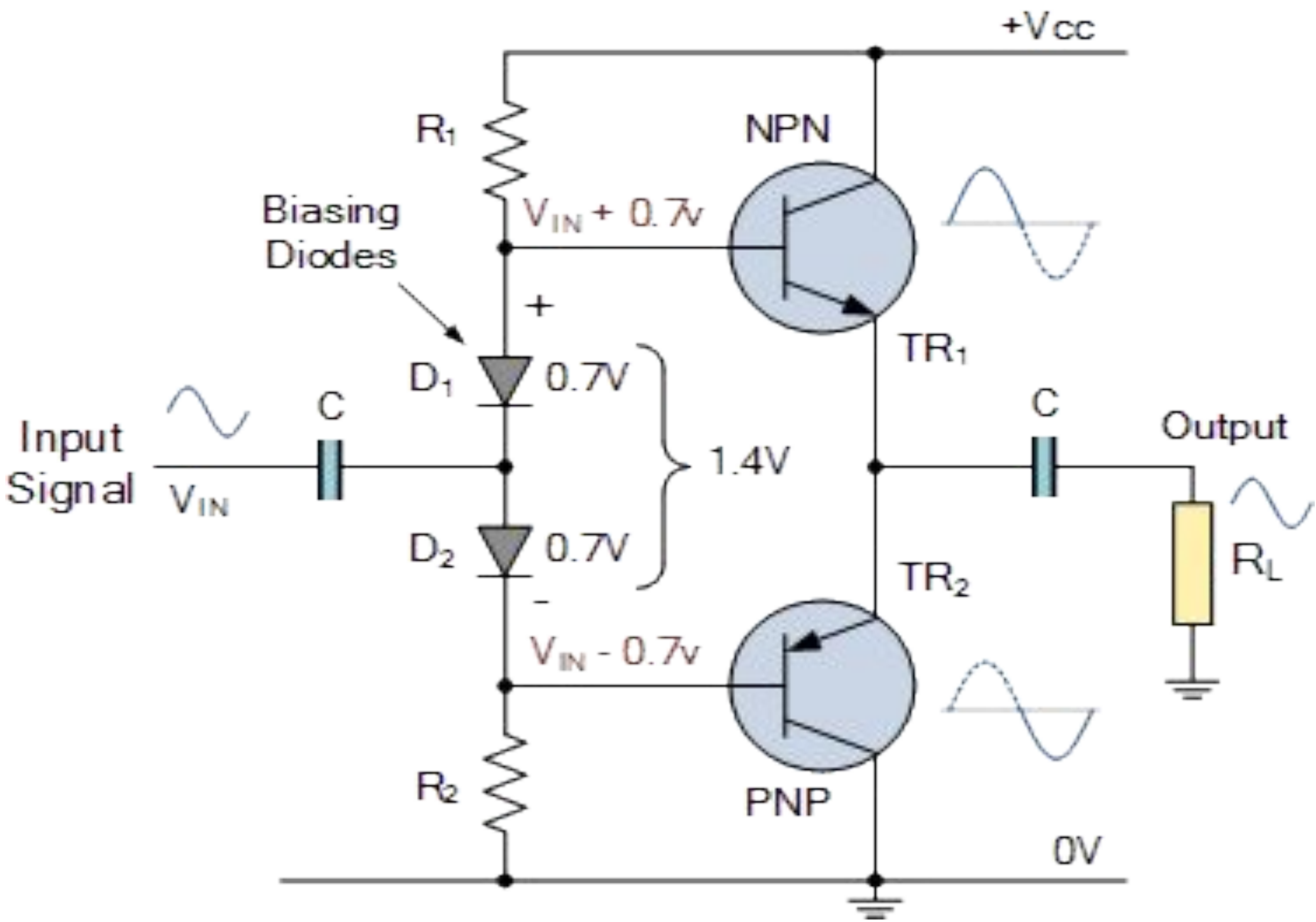


Small I_{CQ} flows through each transistor in the absent of input signal



v_O
$(V_{CC} - V_{CE}(\text{sat}))$
Slope ≈ 1
v_I
$-(V_{CC} - V_{EC}(\text{sat}))$
(a)
v_I
0
π
2π
ωt
(b)
i_C
i_{Cn}
i_{Cp}
I_{CQ}
0
π
2π
ωt
(c)
i_L
0
π
2π
ωt
(d)

Class AB Output stage with Diode Biasing



Class AB Output stage with Diode Biasing

- While the use of biasing resistors may not solve the temperature problem, one way to compensate for any temperature related variation in the base-emitter voltage, (V_{BE}) is to use a pair of normal forward biased diodes within the amplifiers biasing arrangement as shown.
- A small constant current flows through the series circuit of R1-D1-D2-R2, 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 approximately 0.7V across the diodes which is applied to the base-emitter junctions of the switching transistors.
- 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 Output stage with Diode Biasing

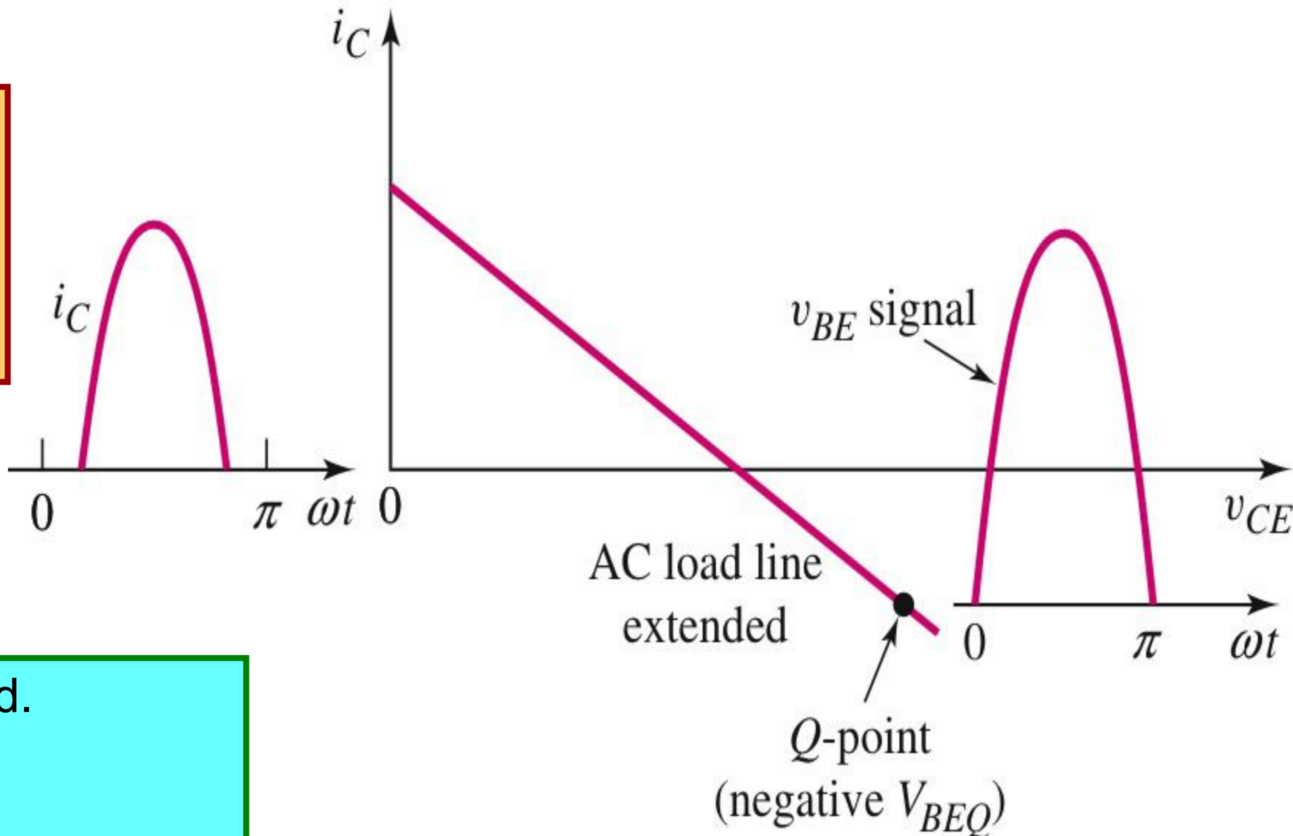
- As the temperature of the circuit rises, so too does that of the diodes as they are located next to the transistors. The voltage across the PN junction of the diode thus decreases diverting some of the transistors base current stabilising the transistors collector current.
- If the electrical characteristics of the diodes are closely matched to that of the transistors base-emitter junction, the current flowing in the diodes and the current in the transistors will be the same creating what is called a current mirror. The effect of this current mirror compensates for variations in temperature producing the required Class AB operation thereby eliminating any crossover distortion.

Class AB Output stage with Diode Biasing

- In practice, diode biasing is easily accomplished in modern day integrated circuit amplifiers as both the diode and switching transistor are fabricated onto the same chip, such as in the popular LM386 audio power amplifier IC. This means that they both have identical characteristics curves over a wide temperature change providing thermal stabilisation of the quiescent current.
- The biasing of a Class AB amplifier output stage is generally adjusted to suit a particular amplifier application. The amplifiers quiescent current is adjusted to zero to minimise power consumption, as in Class B operation, or adjusted for a very small quiescent current to flow that minimises crossover distortion producing a true Class AB amplifier operation.

Class – C Operation

Transistor conducts for less than half a cycle of input signal



- Tuned circuit is required.
- Used for RF amplifier.
- Efficiency > 78.5%

B – E junction is reverse-biased to obtain Q-point beyond cut-off.

Class C Operation

With class B, we need to use a push-pull arrangement. That's why almost all class B amplifiers are push-pull amplifiers.

With class C, we need to use a resonant circuit for the load. This is why almost all class C amplifiers are tuned amplifiers.

With class C operation, the collector current flows for less than half a cycle.

A parallel resonant circuit can filter the pulses of collector current and produce a pure sine wave of output voltage.

The main application for class C is with tuned RF amplifiers.

The maximum efficiency of a tuned class C amplifier is 100 percent.

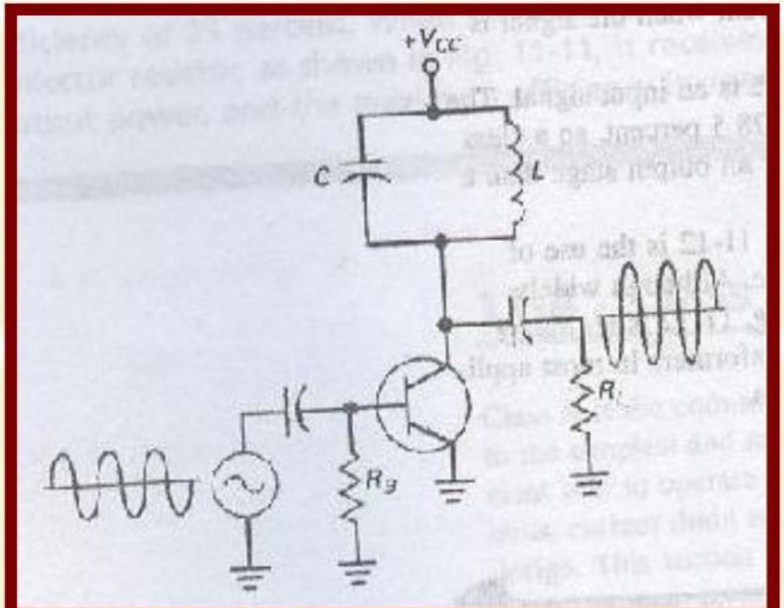
Figure 11-13a shows a tuned RF amplifier.

The ac input voltage drives the base, and an amplified output voltage appears at the collector.

The amplified and inverted signal is then capacitively coupled to the load resistance.

Because of the parallel resonant circuit, the output voltage is maximum at the resonant frequency, given by:

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (11.14)$$



On either side of the resonant frequency f_r, the voltage gain drops as shown in Fig. 11-13b.

For this reason, a tuned class C amplifier is always intended to amplify a narrow band of frequencies.

This makes it ideal for amplifying radio and television signals because each station or channel is assigned a narrow band of frequencies on both sides of a center frequency.