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POWER AMPLIFIERS

Classification of power a mplifiers

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POWER AMPLIFIERS

Required

- To deliver a large current to a small load resistance e.g. a udio speaker; or to deliver a large voltage to a large load resistance e.g. switching power supply;

- To be of low output resistance in order to avoid loss of ga in and to maintain linearity (to minimize harmonic distorti on)

- To deliver power to the load efficiently

POWER TRANSISTORS - BJT

Transistor limitations

1 maximum rated current,

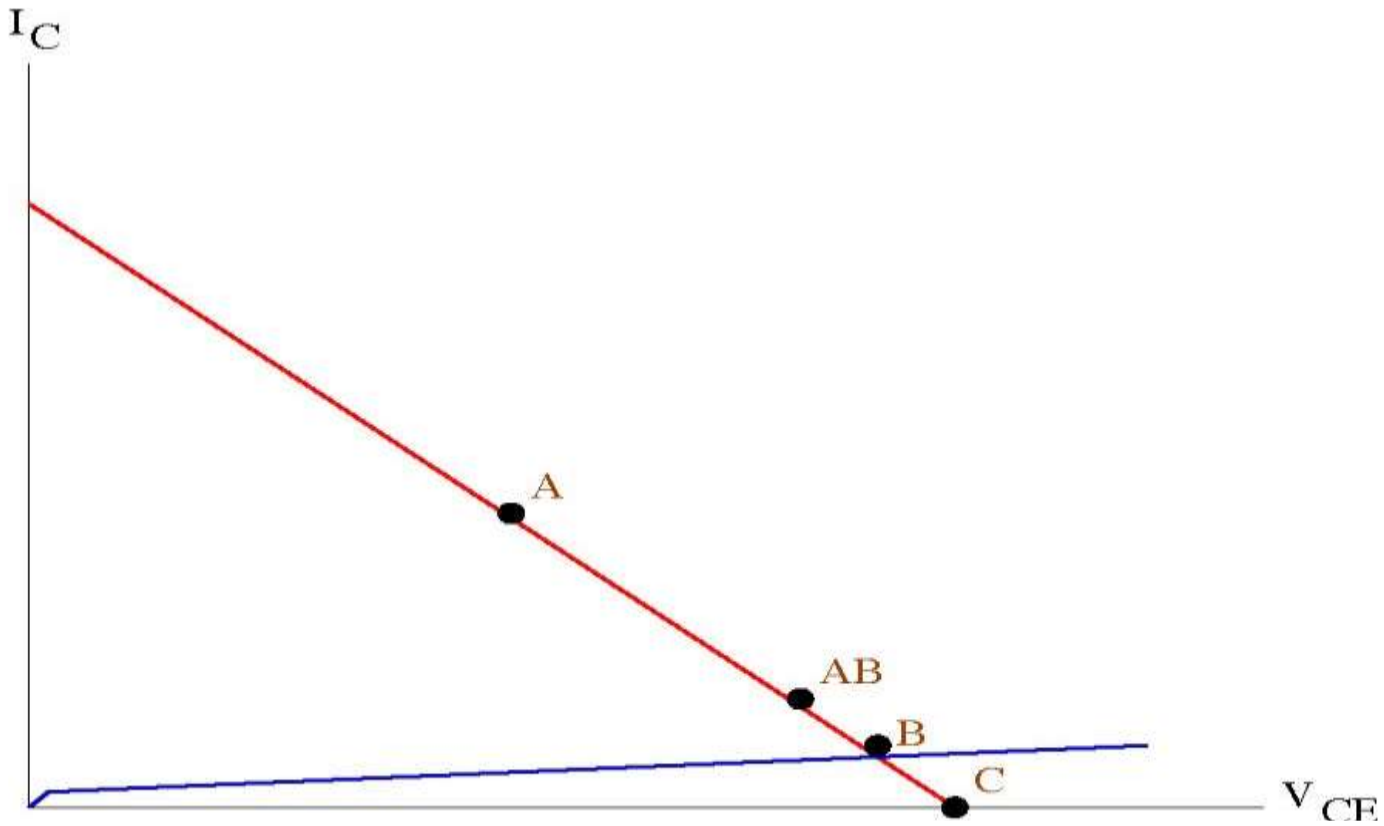
2 maximum rated voltage,

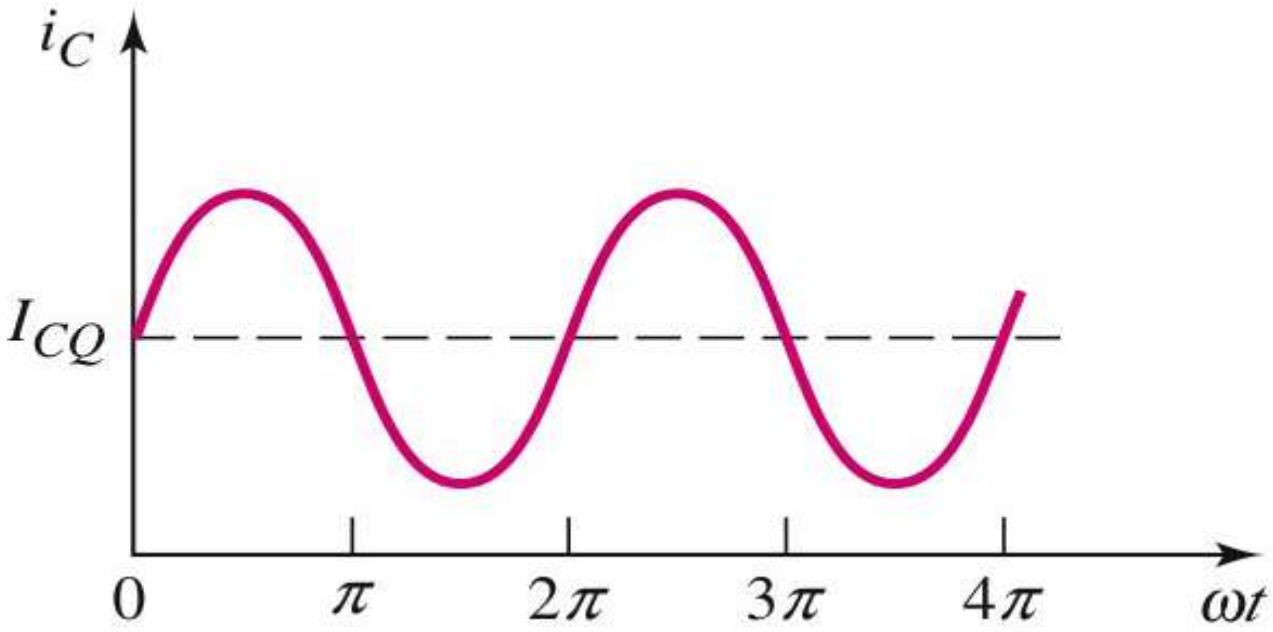
3 maximum rated power, and

4 maximum allowed temperature.

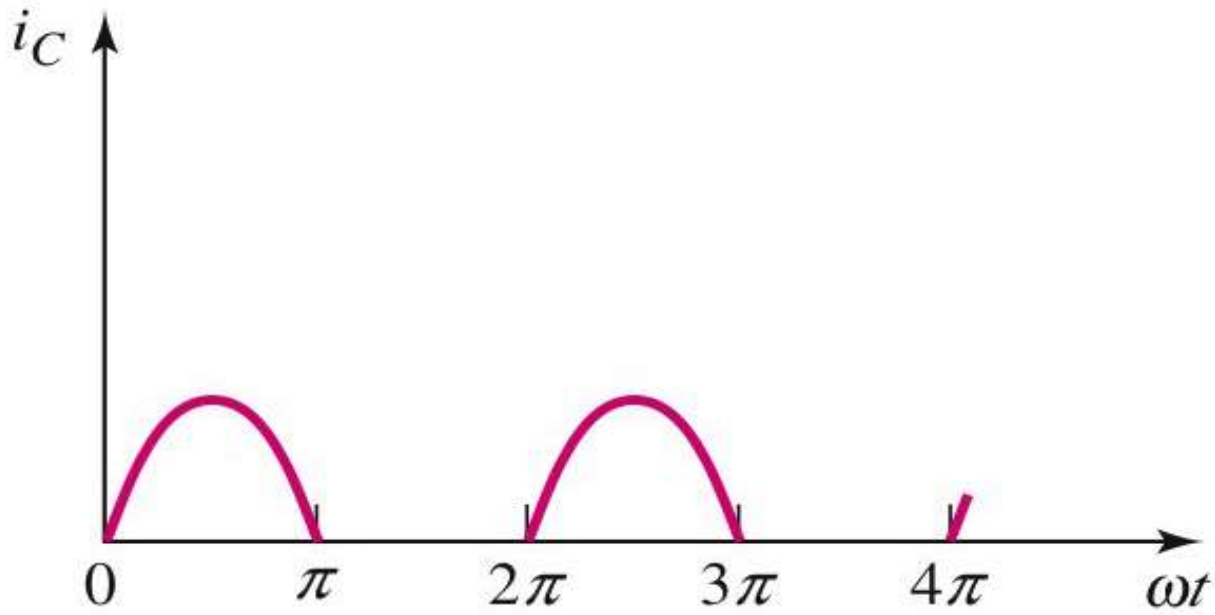
Classes of Amplifiers

They are grouped together based on their Q-points on the DC load line.

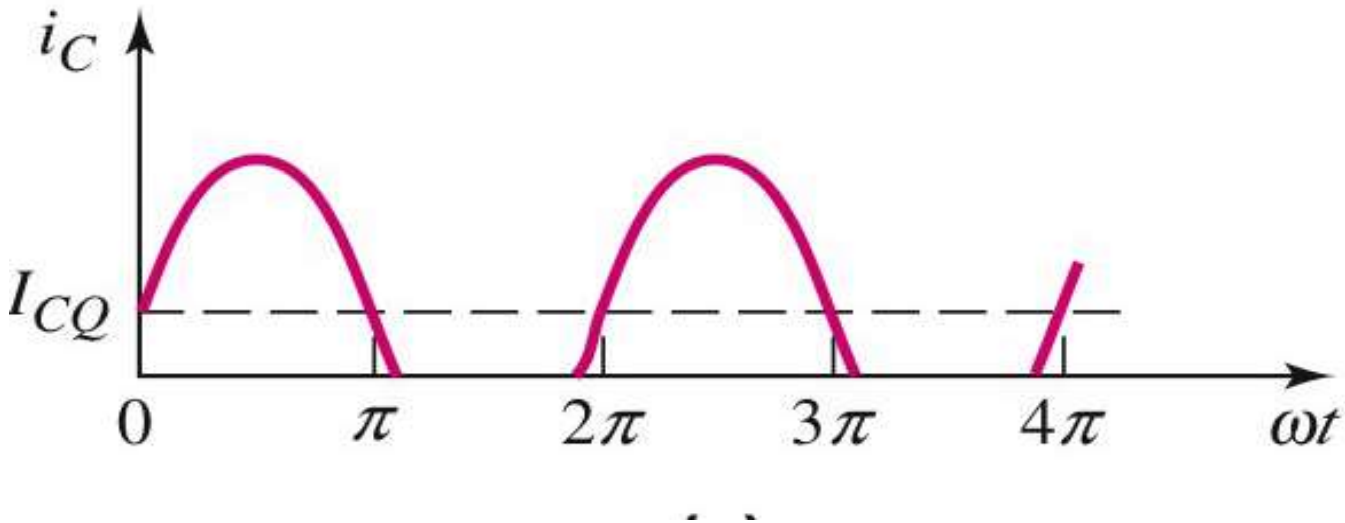




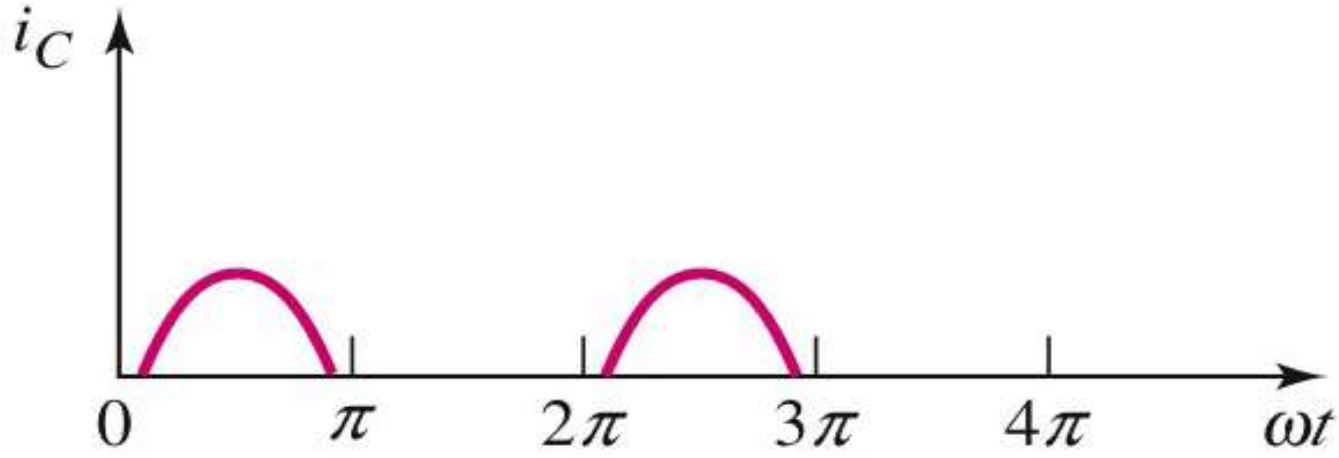
In class-A; the transistor conducts during the whole cycle of sinusoidal input signal



In class-B; the transistor conducts during on e-half cycle of input signal



In class-AB; the transistor conducts for slightly mo re than half a cycle of input signal

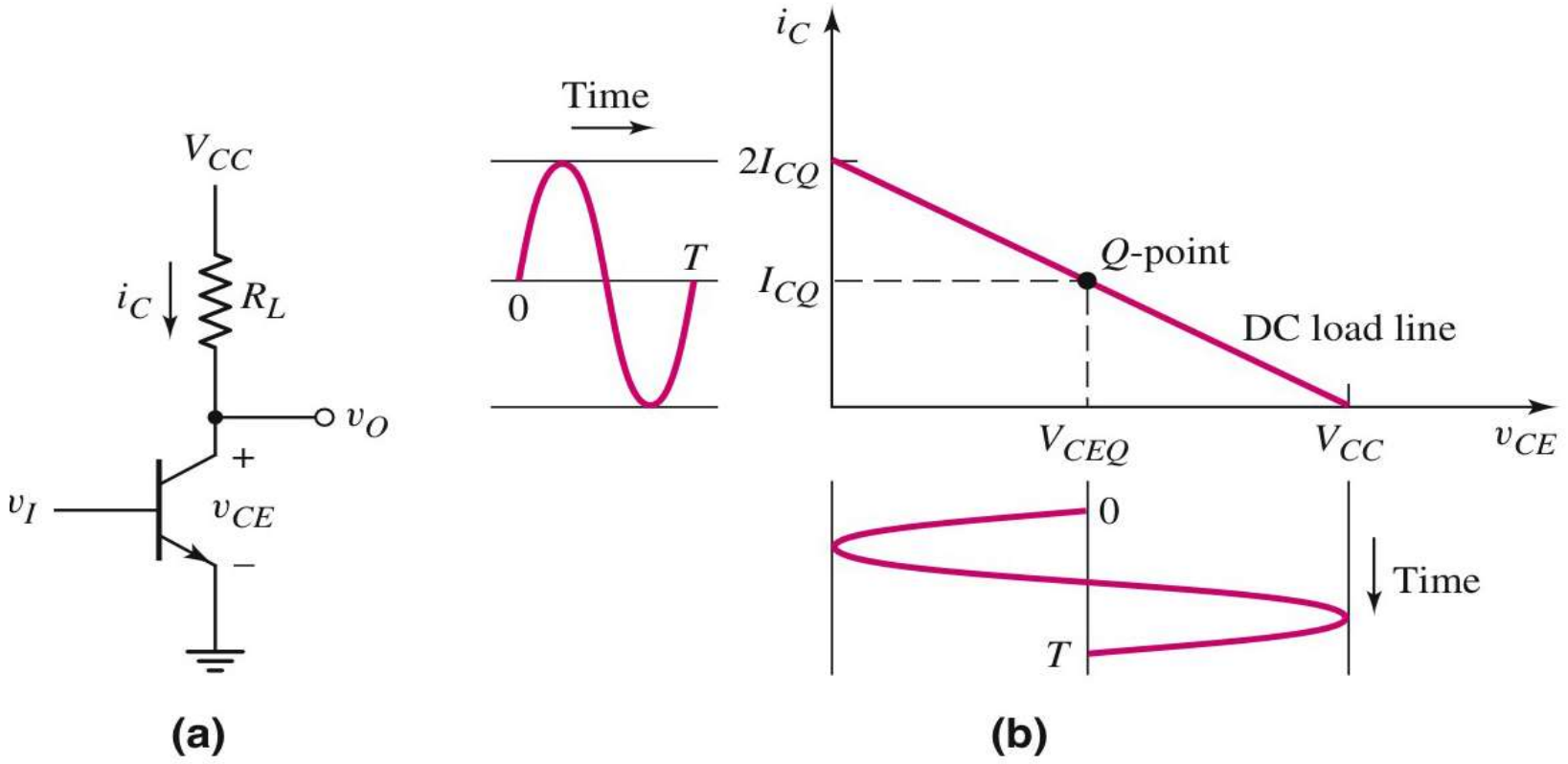


In class-C; the transistor conducts for less t han half a cycle of input signal

Cass–A operation

For maximum swing (+ve and –ve), transistor is biased such that the Q point is at centre of the load line.

The transistor conducts for a full cycle of the input signal



Instantaneous power dissipation in transistor is;

$$P_Q = v_{CE} i_C$$

For sinusoidal input signal;

$$i_C = I_{CQ} + I_p \sin \omega t$$

And;

$$v_{CE} = \frac{V_{CC}}{2} - V_p \sin \omega t$$

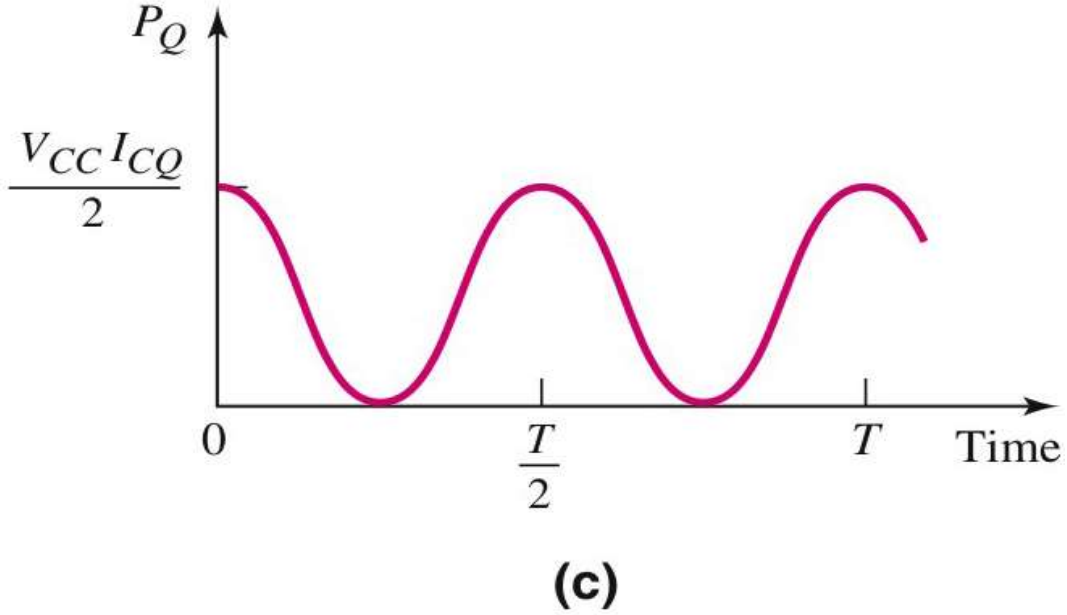
For maximum possible swing;

$$I_p = I_{CQ} \text{ and } V_p = \frac{V_{CC}}{2}$$

Therefore;

$$P_Q = \frac{V_{CC} I_{CQ}}{2}(1 + \sin \omega t)$$

(See graphical re presentation)



(c)

When the input signal = 0, the transistor must be capable of h andling a continuous power of;

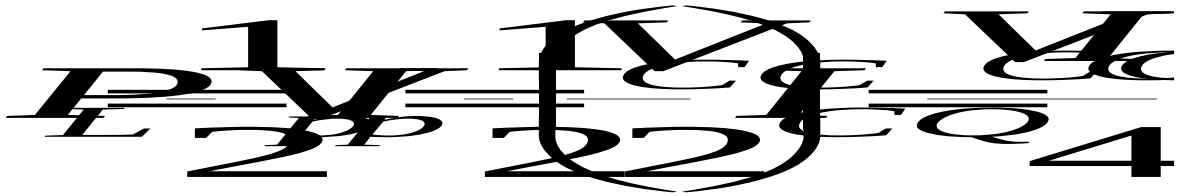
$$\frac{V_{CC} I_{CQ}}{2}$$

Efficiency;

$$\eta = \frac{P_L}{P_S}$$

P_L = average ac power to the load
P_S = average power supplied by the source (V_{CC})

For maximum possible swing;



Power supplied by the source;

Maximum theoretical efficiency of class A a mplifier is therefore 25 %

The efficiency;

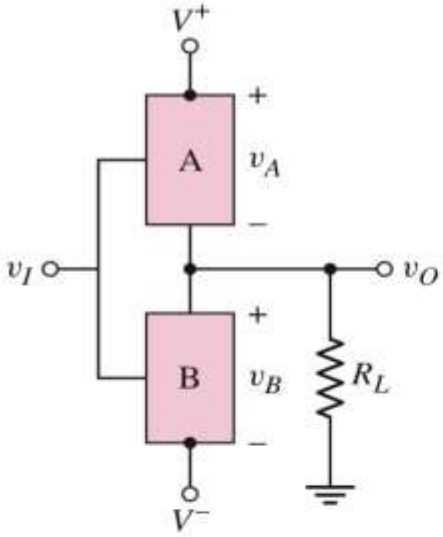
Cass–B operation

Consists of complementary pair electronic devices

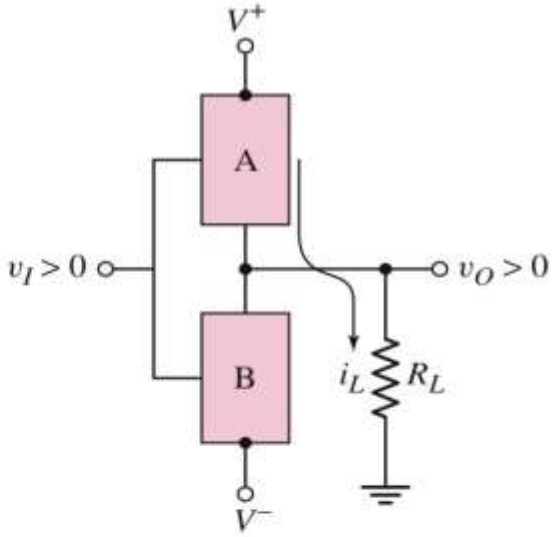
One conducts for one half cycle of the input signal and t he other conducts for another half of the input signal

Both devices are off when the input is zero

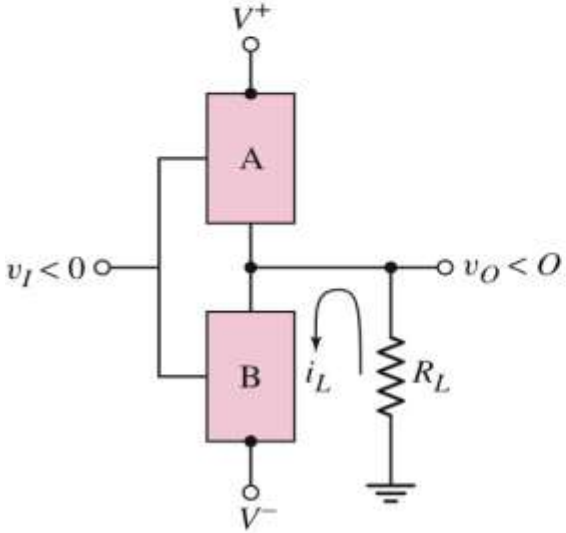
(See Figure)


V^+
A
+
v_A
–
v_I
v_O
+
B
v_B
R_L
–
V^-

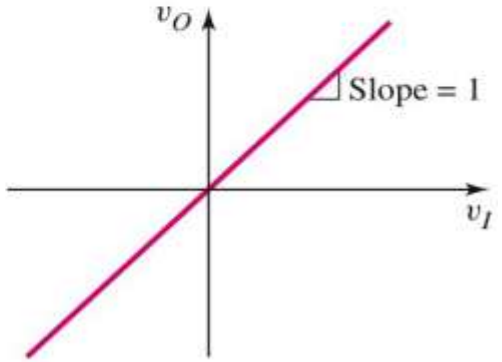
(a)


V^+
A
$v_I > 0$
$v_O > 0$
B
i_L
R_L
V^-

(b)


V^+
A
$v_I < 0$
$v_O < O$
B
i_L
R_L
V^-

(c)


v_O
Slope = 1
v_I

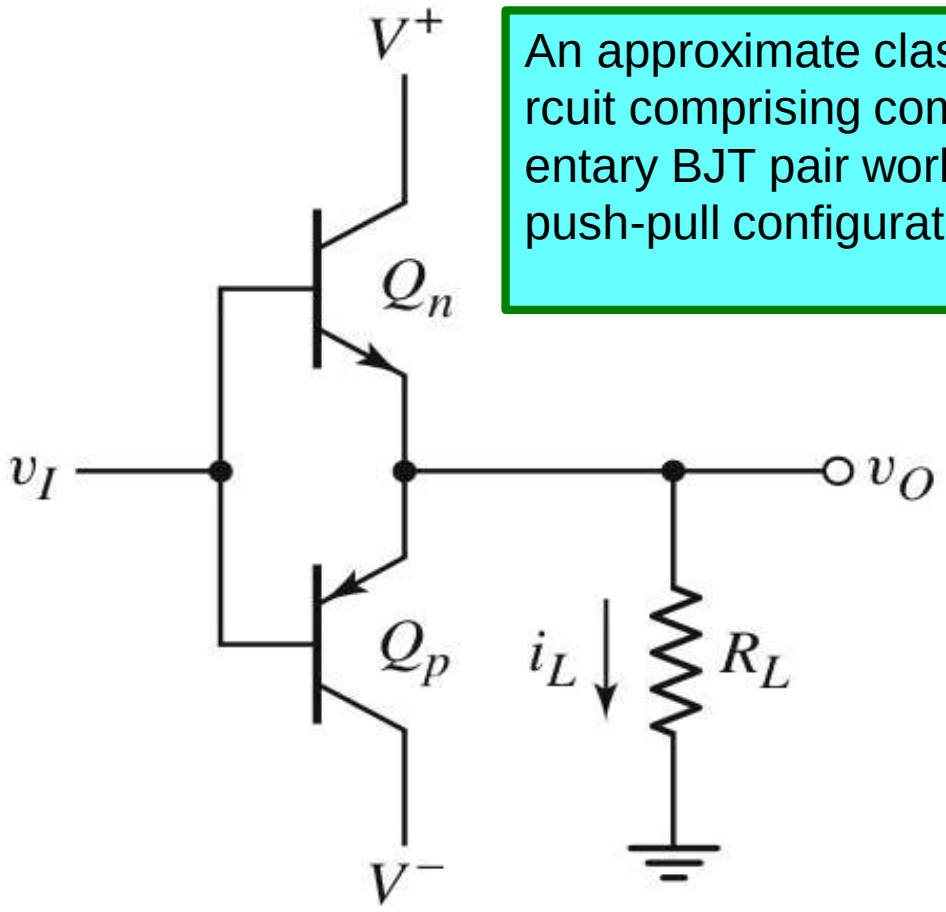
(d)

Complementary push-pull circuit

Assuming ideal transistor;
when $v_I = 0$;
both Q_n & Q_p are off;

when $v_I > 0$;
Q_n conducts & Q_p is off;

when $v_I < 0$;
Q_p conducts & Q_n is off



An approximate class-B circuit comprising complementary BJT pair working in push-pull configuration.

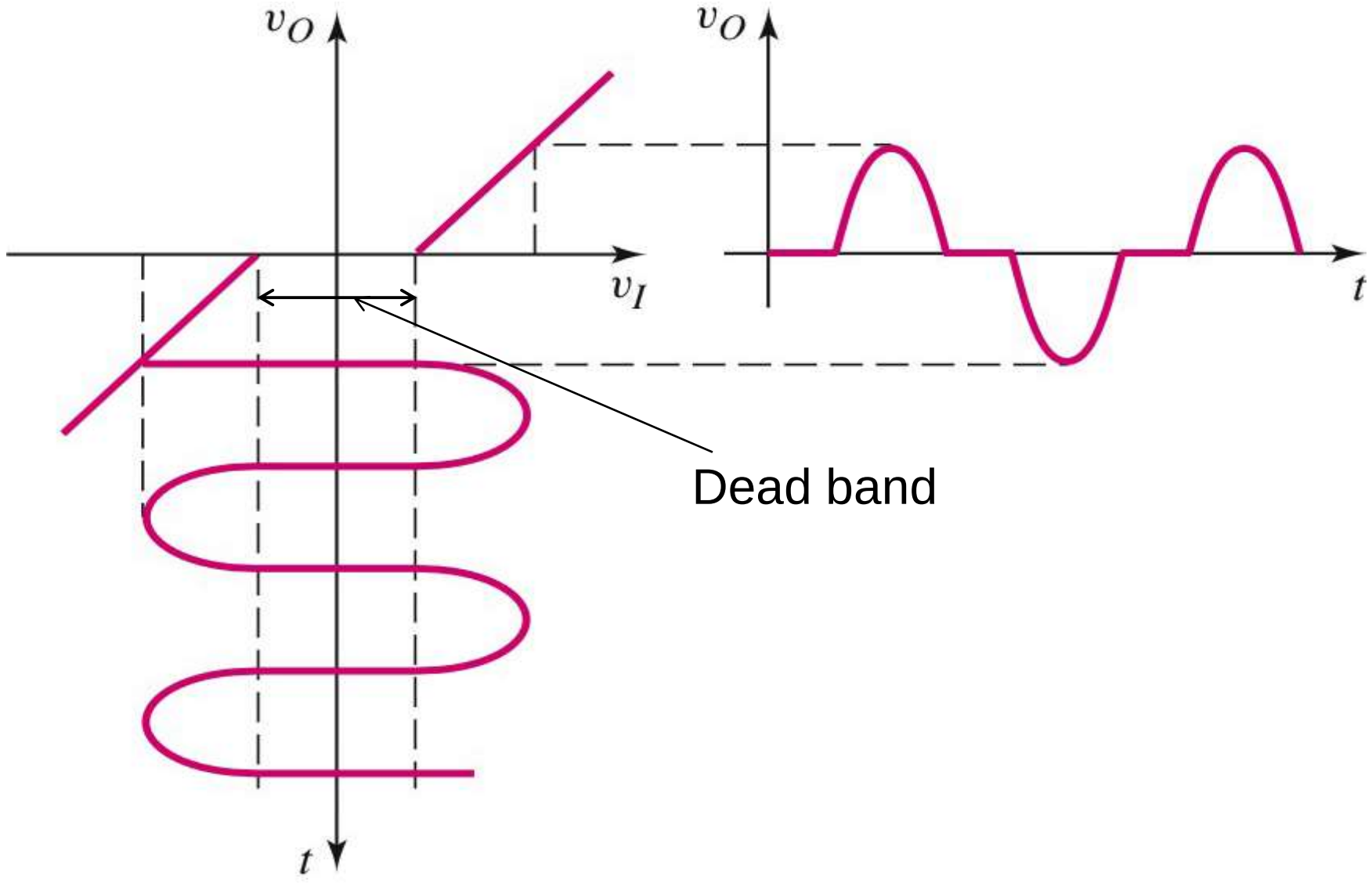
Assuming cut-in voltage of transistor is 0.6 V, v_O = 0 for a range 0.6 V < v_I < 0.6 V.

The transfer characteristic becomes non-linear (See Figu re)

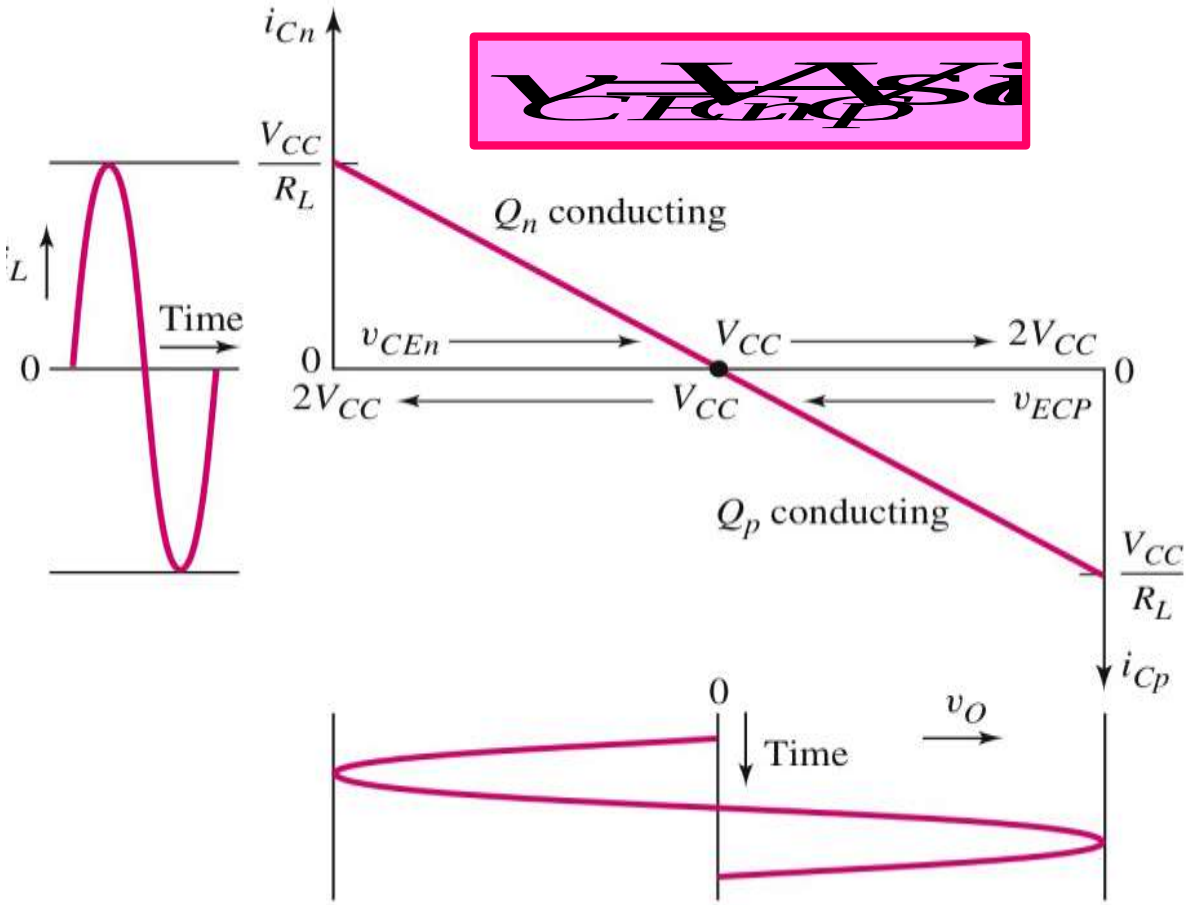
The range where both transistors are simultaneously off k nown as the *dead band*

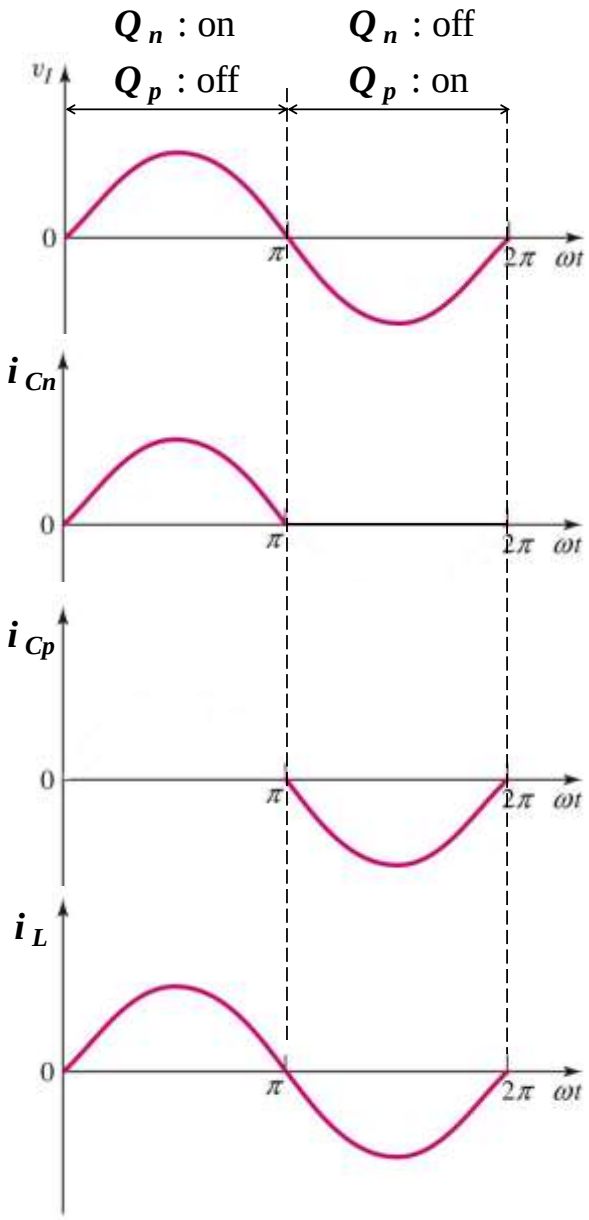
The output will be distorted – **crossover distortion** (See Figure)

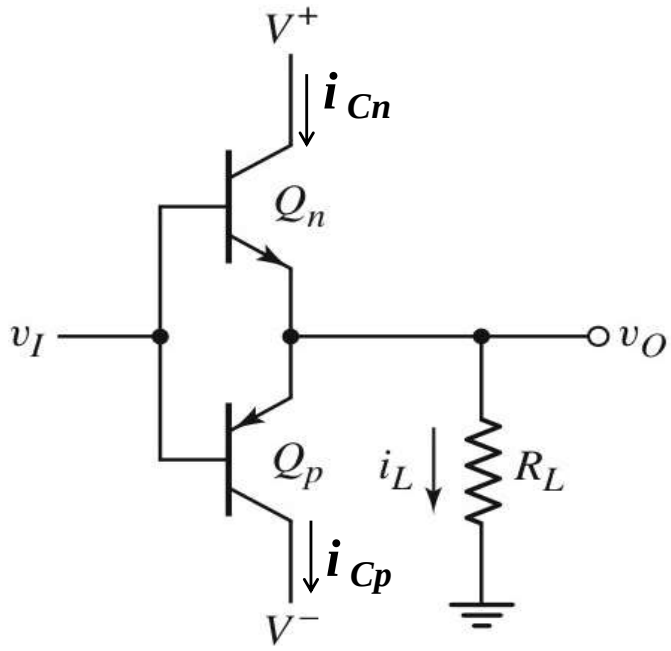
Crossover distortion can be eliminated by biasing the tran sistor with small quiescent current – class-AB


v_O
v_I
t
v_O
t
Dead band

Theoretical maximum efficiency of class-B amplifiers




Q_n : on
Q_p : off
Q_n : off
Q_p : on
v_I
i_{Cn}
i_{Cp}
i_L
0
π
2π
ωt


V^+
i_{Cn}
Q_n
v_I
v_O
Q_p
i_L
R_L
i_{Cp}
V^-

$$v_O = V_p \sin \omega t$$

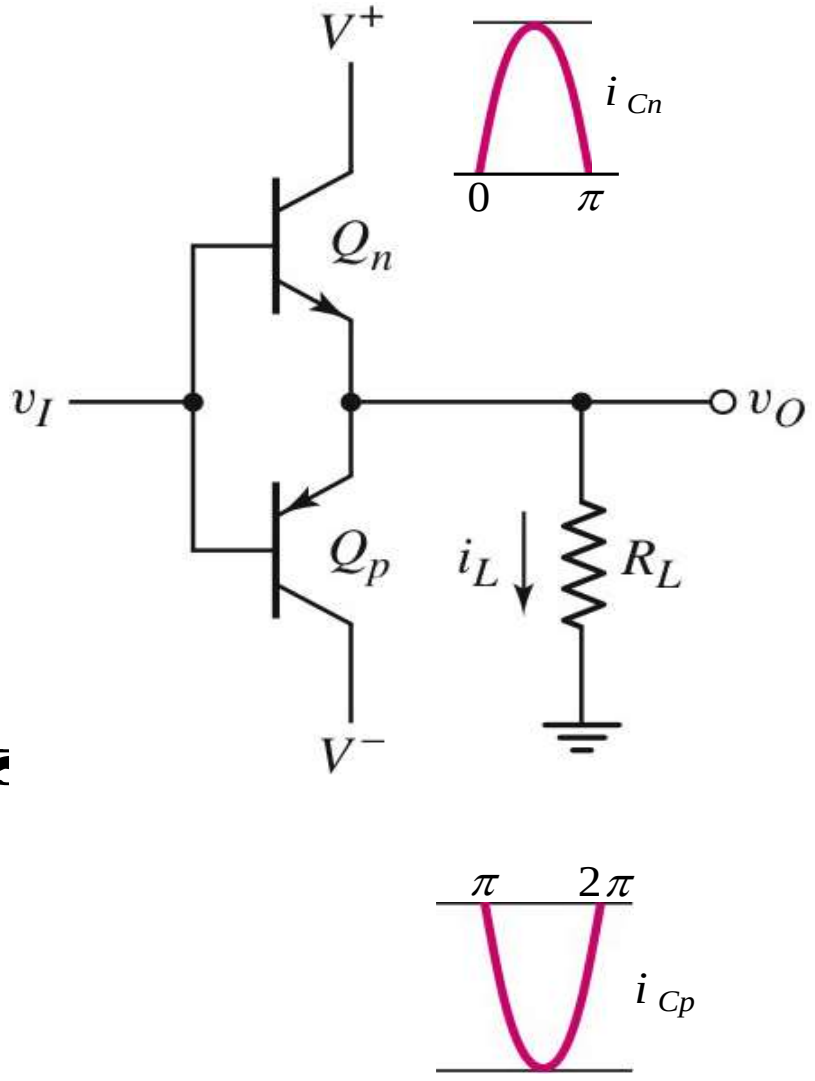
Maximum possible value of V_p is V_{CC}.

$$V_p \le V_{CC}$$

$$i_{Cn} = \frac{V_p}{R_L} \sin \omega t \quad \text{for } 0 < \omega t < \pi$$

and

$$i_{Cp} = \frac{V_p}{R_L} \sin \omega t \quad \text{for } \pi < \omega t < 2\pi$$



The instantaneous power in Q_n is;

$$P_{Qn} = V_{CE} i_L$$

$$= (V_{CC} - V_p \sin \omega t)\left(\frac{V_p}{R_L} \sin \omega t\right) \qquad \text{for } 0 < \omega t < \pi$$

and

$$P_{Qn} = 0 \qquad \text{for } \pi < \omega t < 2\pi$$

The average power in Q_n is;

$$P_{Qn} = \frac{V_{CC} V_p}{\pi R_L} - \frac{V_p^2}{4 R_L}$$

$$P_{Qn} = P_Q \qquad \text{(symmetry)}$$

Differentiating for maximum P_{Qn} with respect to V_p gives us;

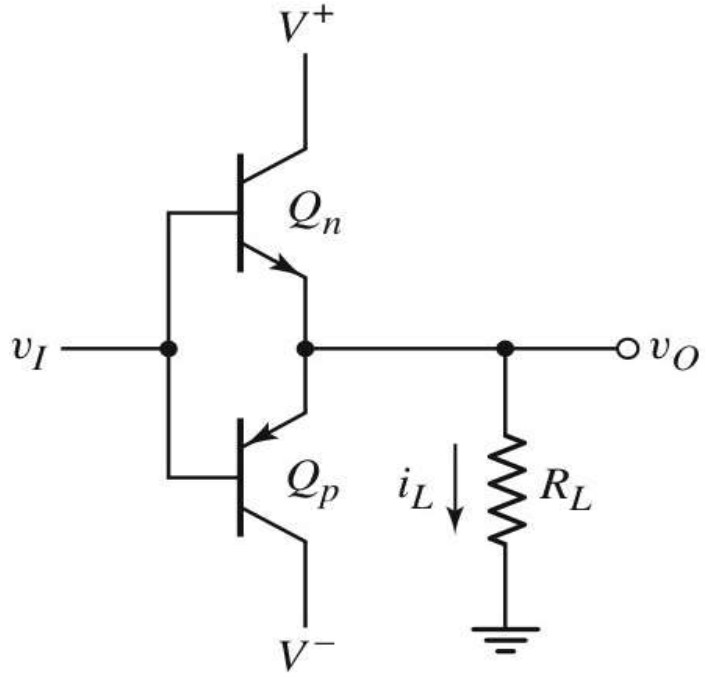
$$P_{Qn(max)} = \frac{V_{CC}^2}{\pi^2 R_L} \qquad \left(\text{when } V_p = \frac{2V_{CC}}{\pi} \right)$$

Since each power source supplies half sinewave of current, the average value is;

$$I_S = \frac{V_p}{\pi R_L}$$

The total power supplied by the two sources is;

$$P_S = 2V_{CC}\left(\frac{V_p}{R_L}\right)$$



The power delivered to the load is;

$$P_L = \frac{V_{o(rms)}^2}{R_L} = \frac{\left(V_p/\sqrt{2}\right)^2}{R_L} = \frac{V_p^2}{2R_L}$$

The efficiency is;

$$\eta = \frac{P_L}{P_S} = \frac{\pi V_p}{4V_{CC}}$$

Maximum efficiency occures when $V_p = V_{CC}$

Under this condition;

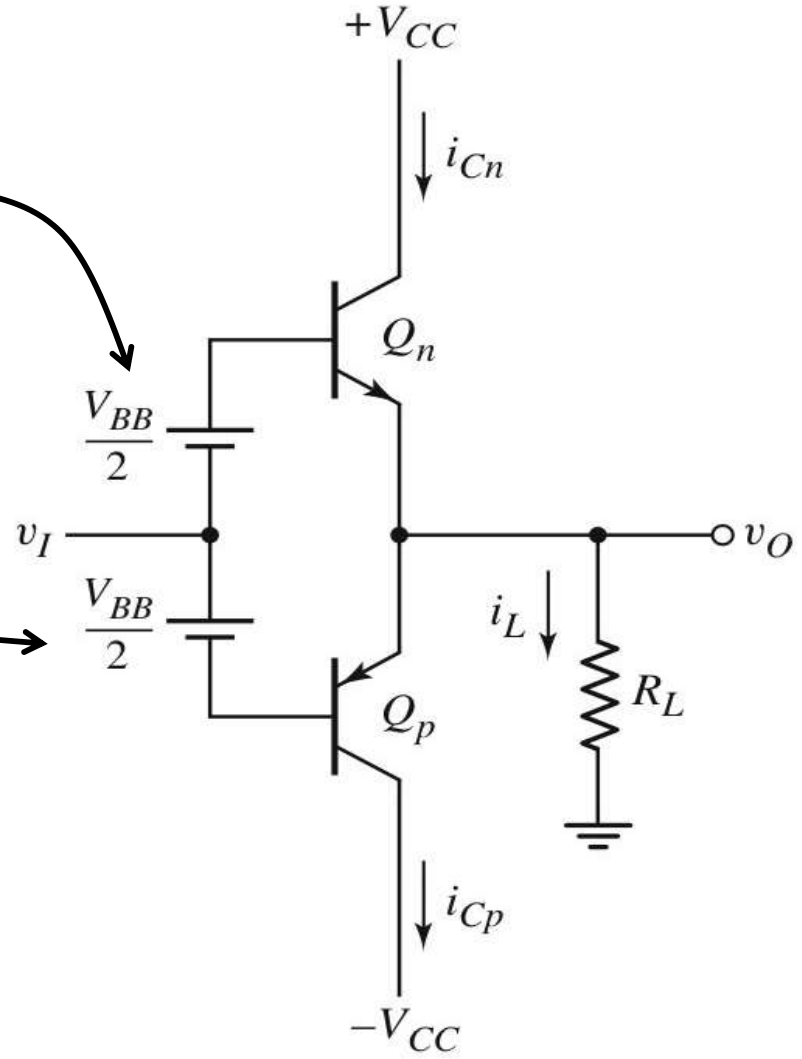
$$\eta = \frac{\pi}{4} = 0.78$$

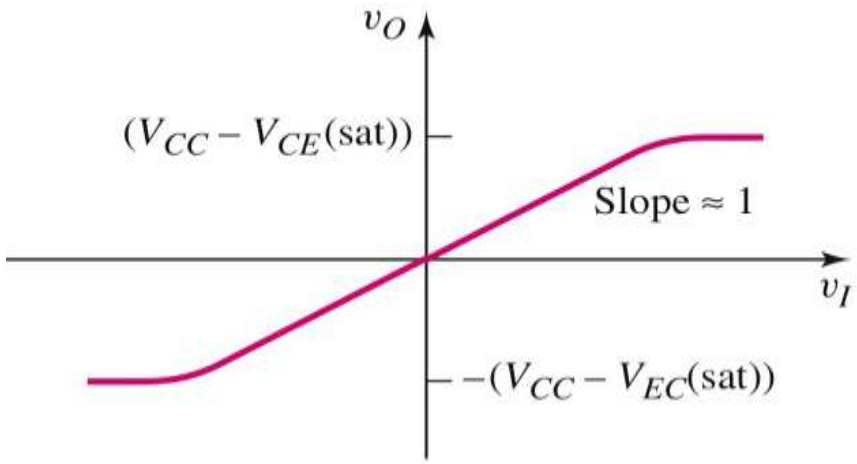
Maximum theoretical efficiency of class B amplifier is therefore 78.5%

Cass–AB operation

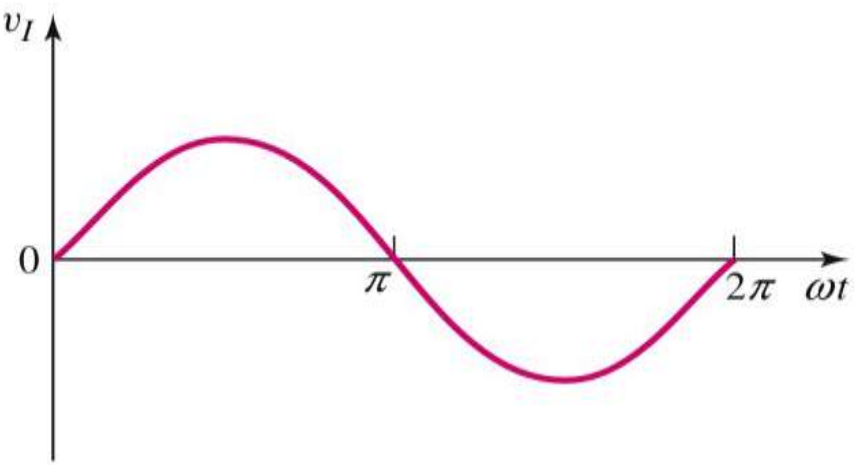
Small quiescent bias on each output transistor to eliminate c rossover distortion

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

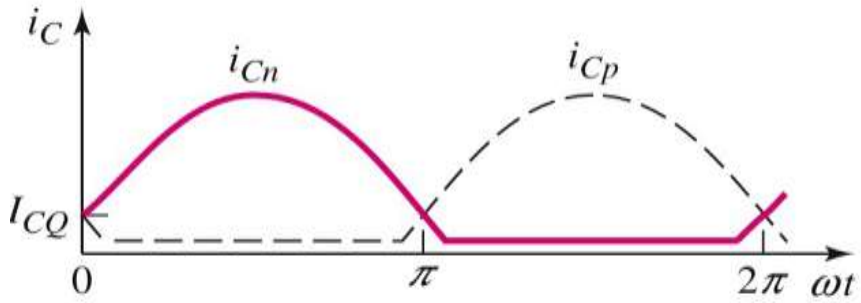



v_O
$(V_{CC} - V_{CE}(\text{sat}))$
Slope ≈ 1
v_I
$-(V_{CC} - V_{EC}(\text{sat}))$

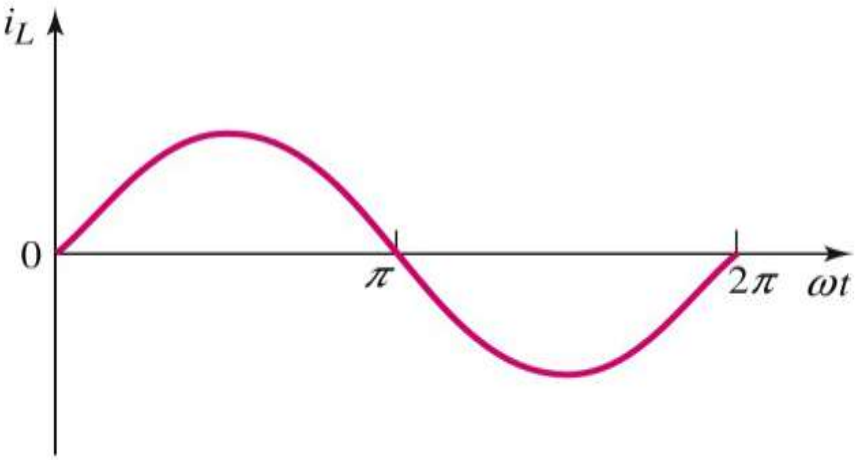
(a)


v_I
0
π
2π
ωt

(b)


i_C
i_{Cn}
i_{Cp}
I_{CQ}
0
π
2π
ωt

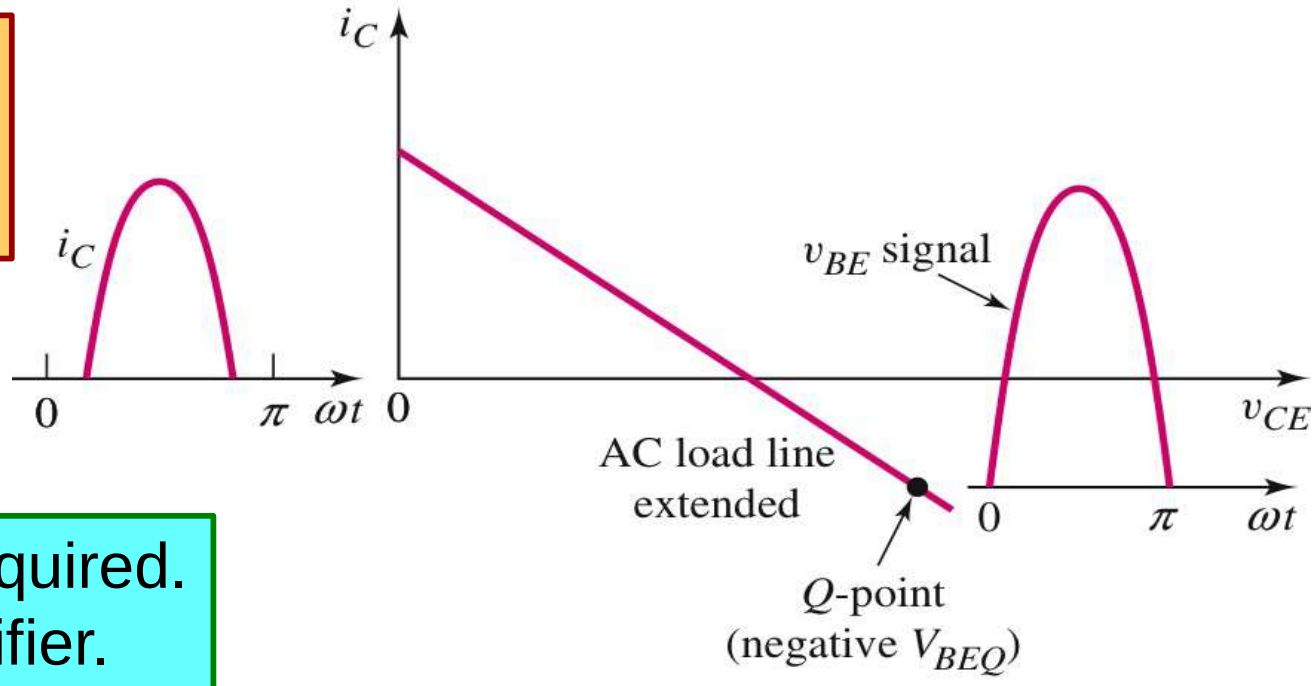
(c)


i_L
0
π
2π
ωt

(d)

Cass–C operation

Transistor conducts f or less than half a cy cle 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.