2007 Fall: Electronic Circuits 2

CHAPTER 14

Output Stages and Power Amplifiers

Introduction

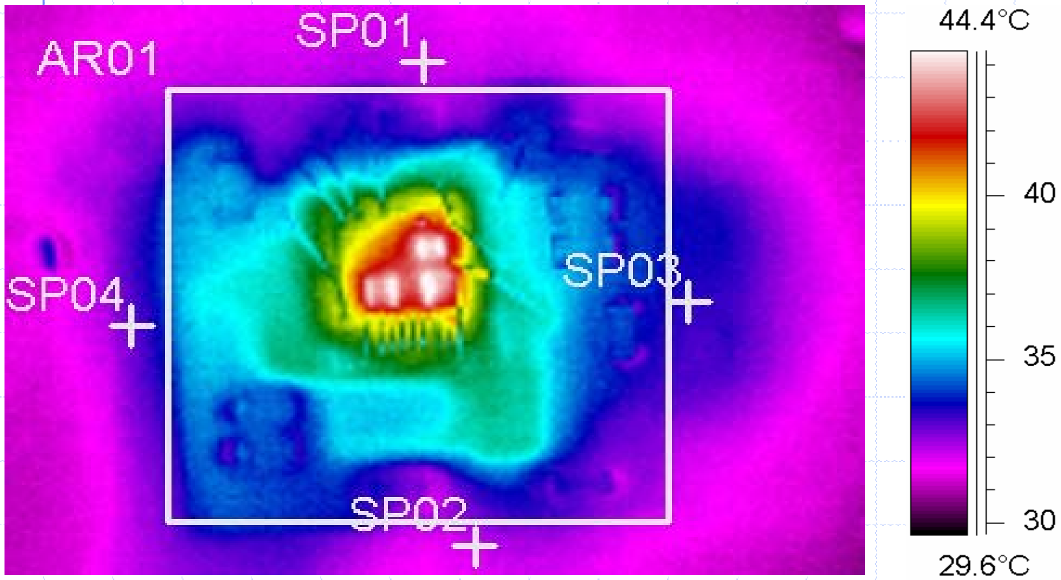
- In this chapter, we will be covering…
  - Classification of Output Stages
  - Class A Output Stage
  - Class B Output Stage
  - Class AB Output Stage
  - Biasing the Class AB Circuit

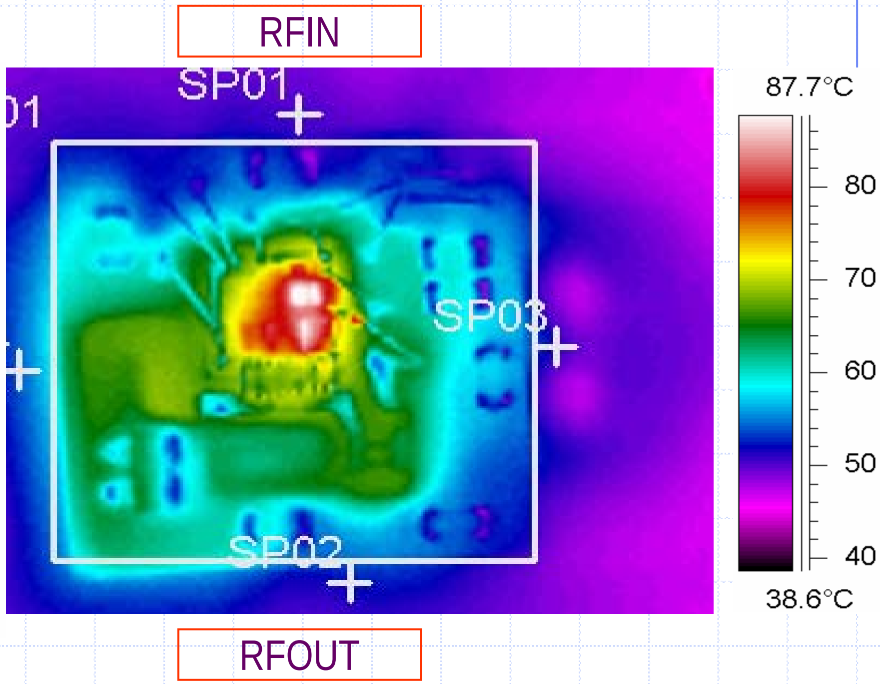
14.1 Classification of Output Stages

- Output stages are classified according to the collector current waveform when an input signal is applied.

- When a sinusoidal input signal is applied,
  - Class A : biased at a current greater than the amplitude of signal current.
  - Class B : biased at zero dc current.
  - Class AB : an intermediate class between A and B.
    biased at a nonzero dc current much smaller than the peak current of the sine-wave signal.

Thermal Issues



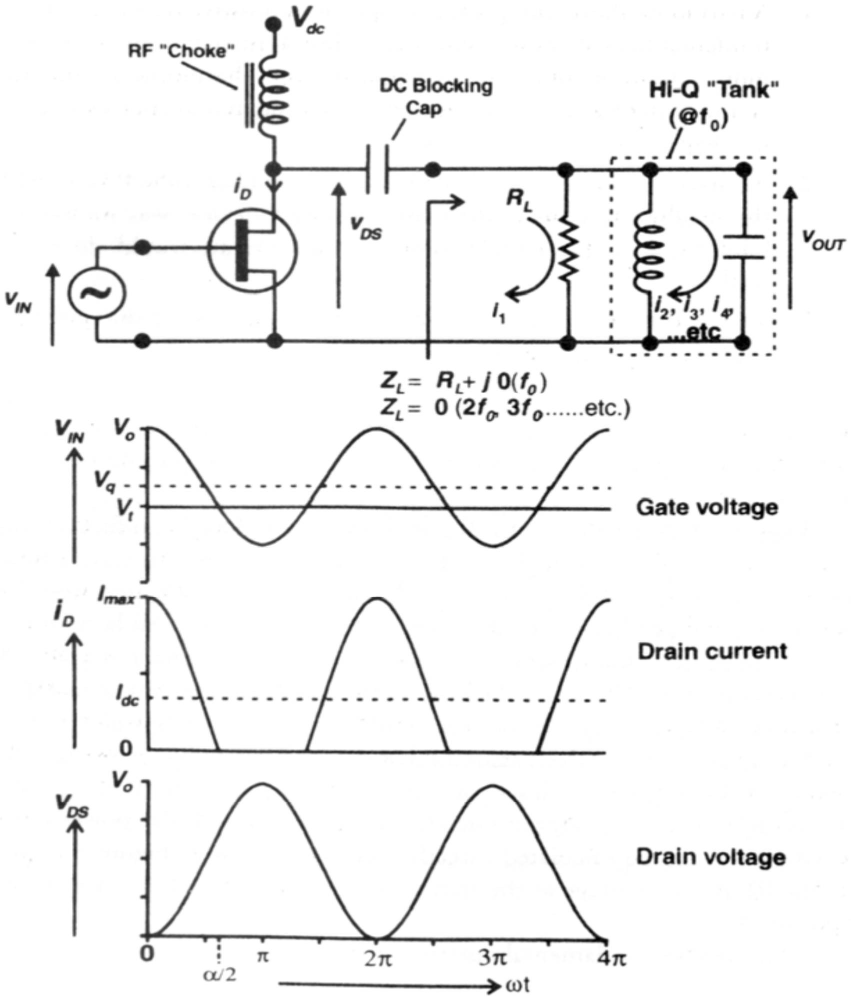


Dissipated Power (W)	T-junction (°C)	T-case (°C)
0.369	45.3	33.4

Dissipated Power (W)	T-junction (°C)	T-case (°C)
1.113	91.9	51.1

- Junction temperature
- Dissipated power = $P_{supply} - P_{output}$ → Need to minimize P_d

Conduction Angle Dependence under Harmonic Short Termination



- Harmonic short termination
  - No harmonic voltage
  - Load resistance

① $$R_{opt} = \frac{V_{DC}}{I_1}$$

② $$R_{opt,class-A} = R_{opt,class-B}$$

③ $$R_{opt,class-AB} < R_{opt,class-A}$$

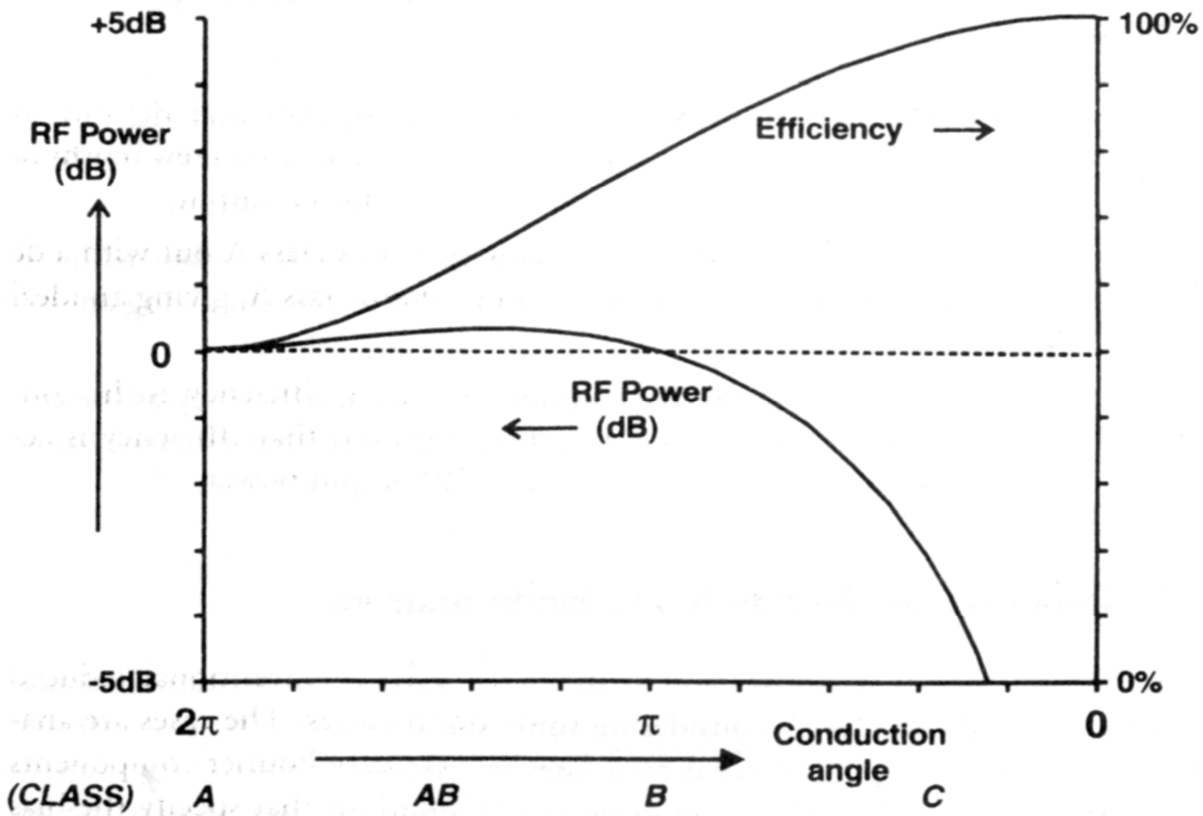
R_L determines voltage swing

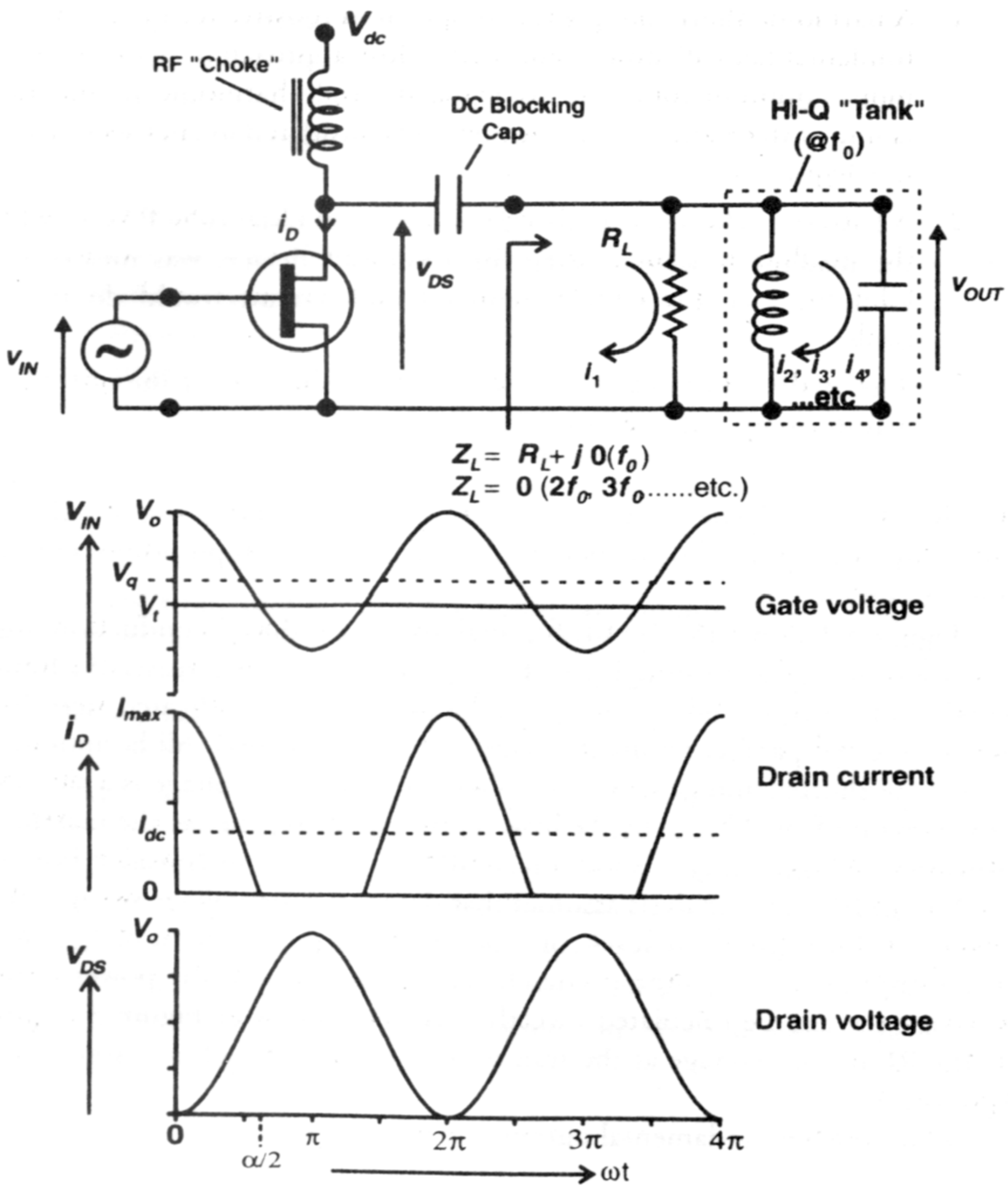
Class and Efficiency

- Output Efficiency (Drain/Collector Efficiency)

$$\eta \triangleq \frac{P_1}{P_{dc}}$$

- η ↑ rapidly as class-C





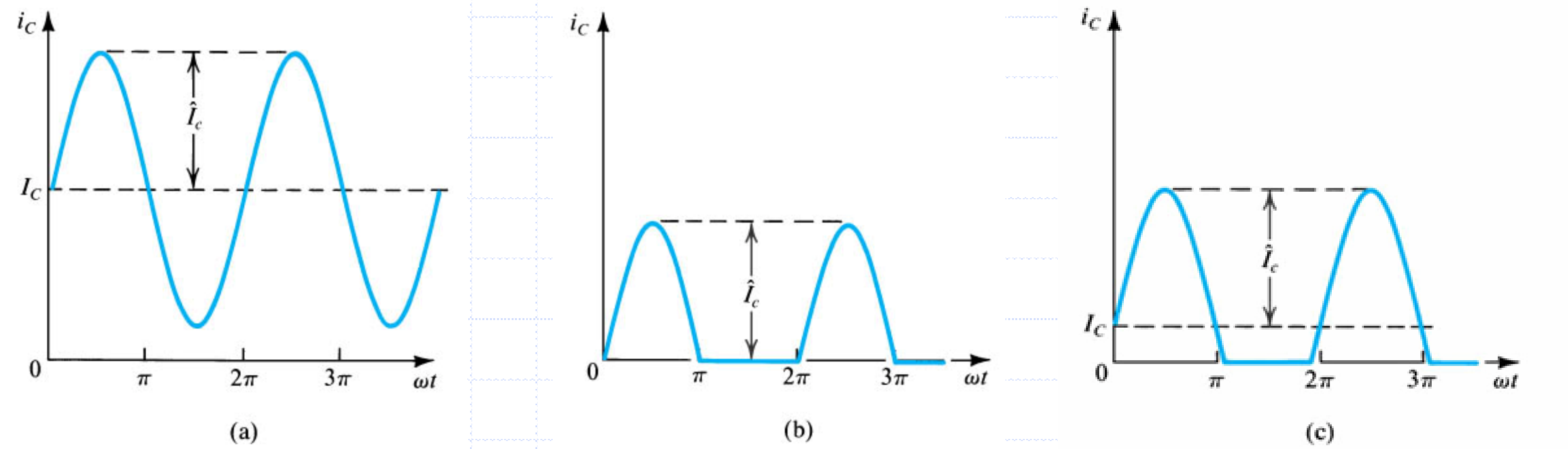
Ideal Case

- All harmonics short-circuited → No distortion
- R_L determines voltage swing
- R_L also determines DC power consumption

14.1 Classification of Output Stages

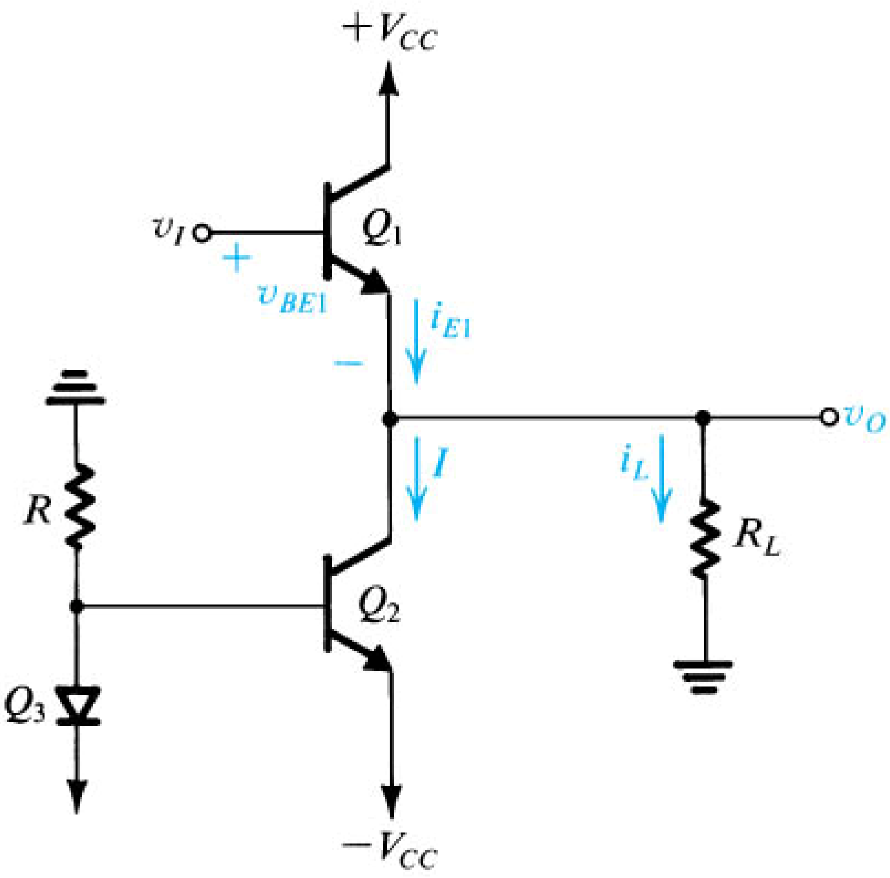
- Collector current waveforms for transistors operating in

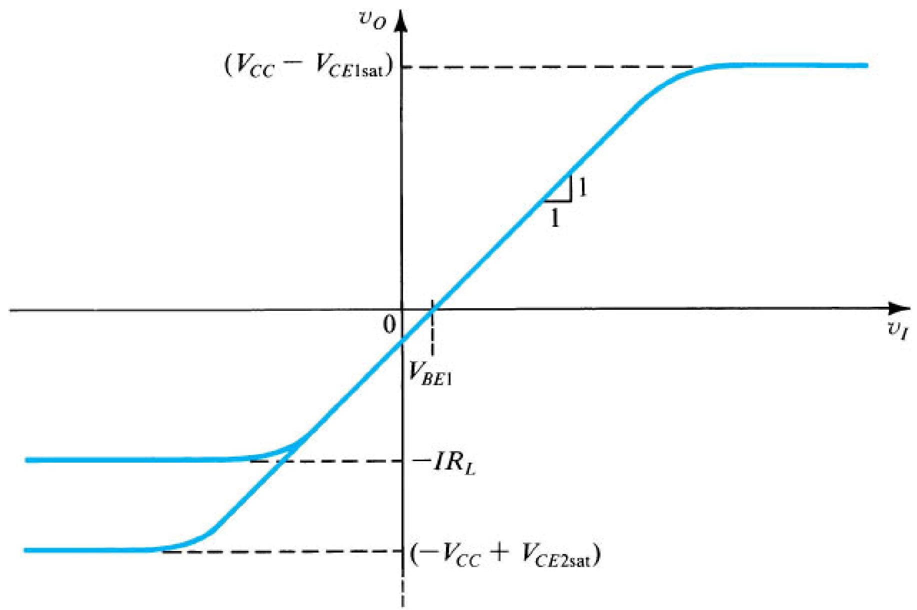
(a) class A (b) class B (c) class AB



14.2.1 Transfer Characteristic

- The emitter follower – the most popular class A ckt.





14.2.1 Transfer Characteristic (cont.)

- The bias current must be greater than the largest negative load current.
- The transfer characteristic is

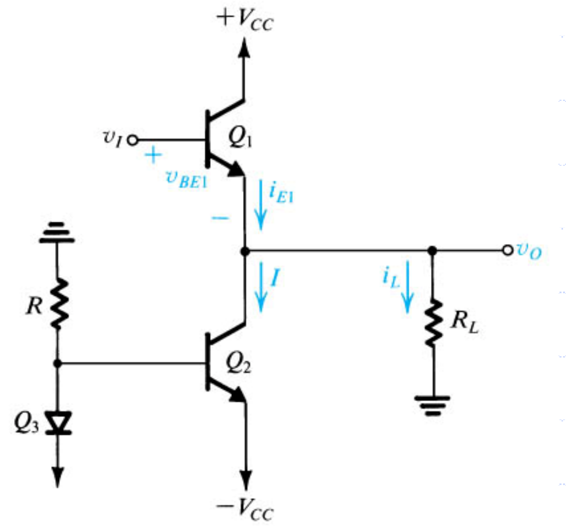
$$v_o = v_I - v_{BE1}$$

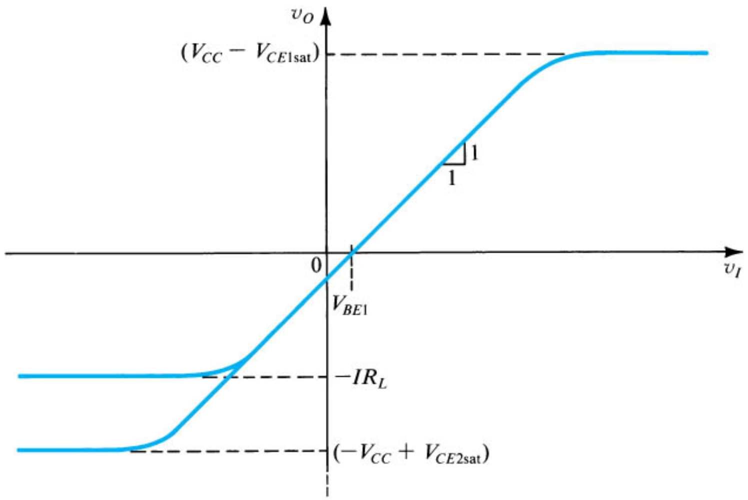
- The positive limit of the linear region is given by

$$v_{O\max} = V_{CC} - V_{CE1sat}$$

- In the negative direction, the limit of the linear region is

$$v_{O\min} = -IR_L \quad or \quad -V_{CC} + V_{CE2sat}$$

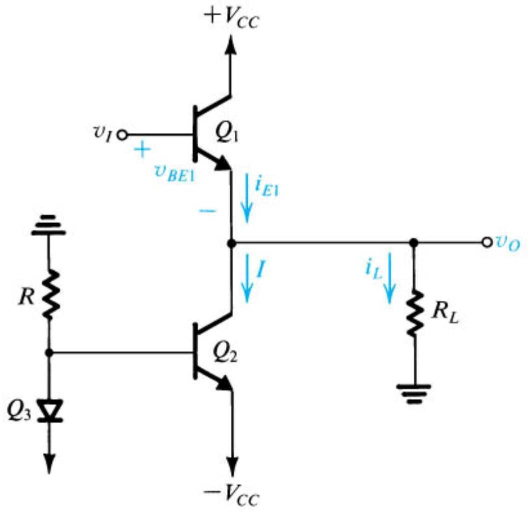


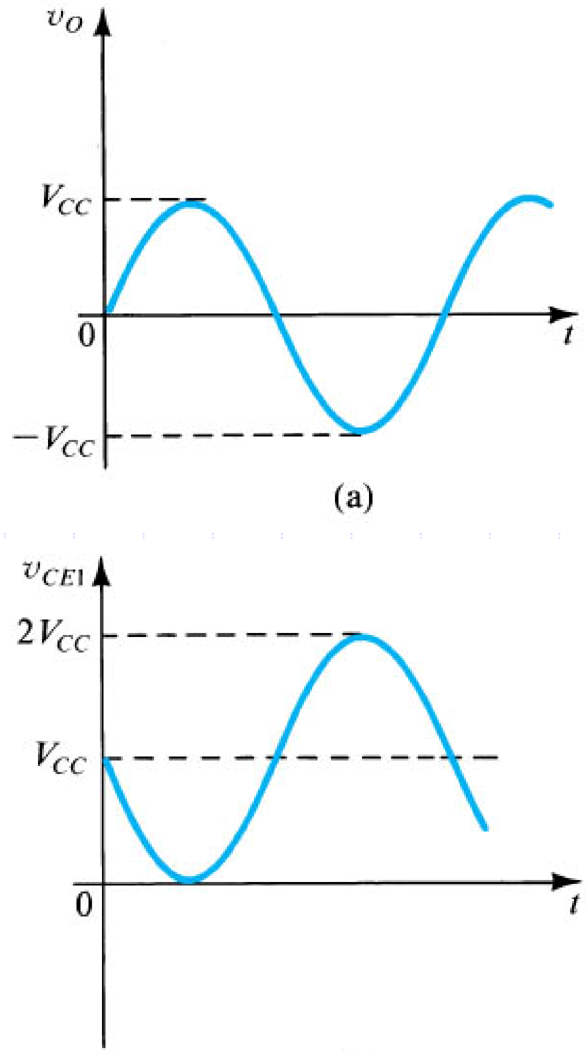


14.2.2 Signal Waveforms

- For sine-wave input, neglecting V_{CEsat}, the output voltage can swing from $-V_{CC}$ to $+V_{CC}$ with the quiescent value being zero.

- Since $v_{CE1} = V_{CC} - v_o$,



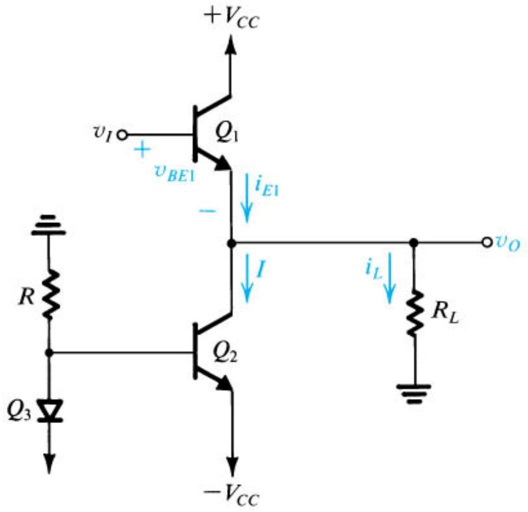


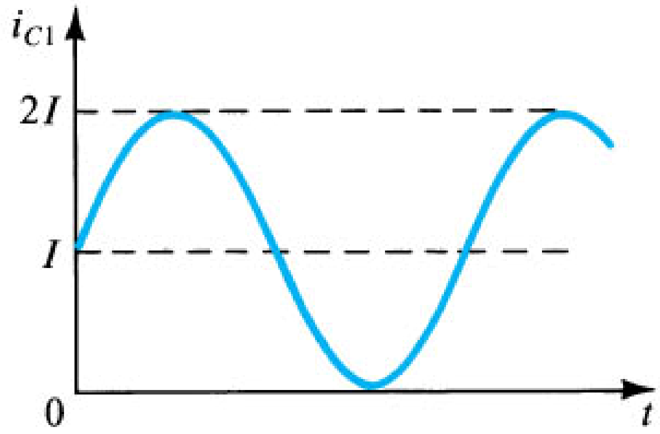
(a)

(b)

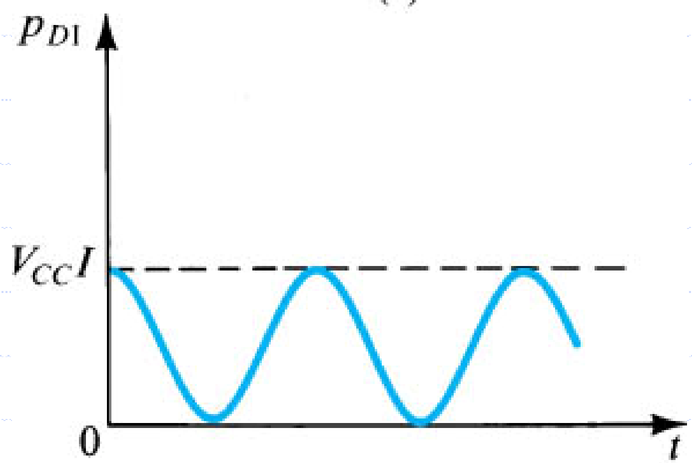
14.2.2 Signal Waveforms (cont.)

- Assuming that the bias current is selected to allow a maximum negative load current of V_{cc}/R_L,
- The instantaneous power dissipation in Q1, $p_{D1}=v_{CE1} \cdot i_{C1}$





(c)



(d)

14.2.3 Power Dissipation

- The maximum instantaneous power dissipation in Q_1
  $= V_{CC} \cdot I$
  = The quiescent power dissipation in Q_1.
  - The emitter follower transistor dissipates the largest amount of power when $v_o=0$: The transistor Q_1 must be able to withstand a continuous power dissipation of $V_{CC} \cdot I$.
  - The power dissipation in Q_1 depends on the value of R_L: When $R_L=0$, a very large current may flow through Q_1: short circuit protection is needed.

- The maximum instantaneous power dissipation in Q_2
  $=2 \cdot V_{CC} \cdot I$

14.2.4 Power-Conversion Efficiency

- Power-Conversion Efficiency of an output stage is defined as

$$\eta = \frac{Load\ \ power(P_L)}{Supply\ \ power(P_S)}$$

  - For the emitter follower, the average load power will be

$$P_L = \frac{(\hat{V}_o/\sqrt{2})^2}{R_L} = \frac{1}{2}\frac{\hat{V}_o^{\ 2}}{R_L}$$

  - The average (positive + negative) supply power is,

$$P_S = 2V_{CC}I$$

  - Thus, the PCE is,

$$\eta = \frac{1}{4}\frac{\hat{V}_o^{\ 2}}{IR_L V_{CC}} = \frac{1}{4}\frac{\hat{V}_o}{IR_L}\frac{\hat{V}_o}{V_{CC}}$$

14.2.4 Power-Conversion Efficiency (cont.)

- The maximum efficiency is 25%, obtained when

$$\hat{V}_o = V_{CC} = IR_L$$

- Because 25% is a rather low figure, the class A output stage is rarely used in high-power applications (>1W).

- In practice the output voltage swing is limited to lower values to avoid transistors saturation and associated nonlinear distortion. Thus the efficiency achieved is usually in the 10% to 20% range.

14.3 Class B Output Stage

- The class B output stage consists of a complementary pare of transistors connected in such a way that both cannot conduct simultaneously.

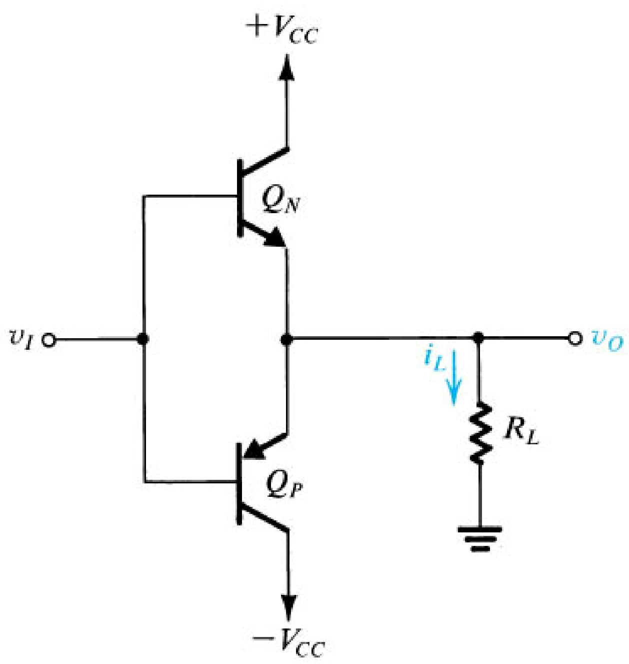


Figure 14.5 A class B output stage.