Quiescent Operating Point, DC Load Line, AC without Load, and AC with Load Analysis

Source: Electronic Devices: A Design Approach Ali Aminian and Marian Kazimierczuk, 2004

Reference Figure 6-1

Determine Quiescent Point I_{CQ} and V_{CEQ}

$$V_B = V_{CC}\frac{R_2}{R_1+R_2} = 12\frac{5100}{17600+5100} = 2.7\text{ Volts}$$

$$V_E = V_B - V_{BE} = 2.7 - 0.7 = 2\text{ Volts}$$

$$I_E = \frac{V_E}{R_E} = \frac{2}{1000} = 2\text{ mA}$$

$V_{CE} = V_{CC} - I_E(R_C + R_E) = 12 - 2 \text{ x } 10^{-3}$ (2000 + 1000) = 6 Volts

$I_{CEQ} = I_C = I_E = 2$ mA

$V_{CEQ} = V_{CE} = 6$ Volts

DC Load Line

$V_{CE\text{ Cut-off}} = V_{CC} = 12$ Volts

$$I_{C\,Sat} = \frac{V_{CC}}{R_C+R_E} = \frac{12}{2000+1000} = 4\text{ mA}$$

AC Load Line (without Load)

$$I_{o(NL)} = I_{CQ} + \frac{V_{CEQ}}{R'}$$ where $R' = R_C$

$$I_{o(NL)} = 2\text{ x }10^{-3} + \frac{6}{2000} = 5\text{ mA}$$

$$V_{o(NL)} = V_{CEQ} + I_{CQ}\,R'$$ where $R' = R_C$

$$V_{o(NL)} = 6 + 2\text{ x }10^{-3}(2000) = 10\text{ Volts}$$

AC Load Line (with Load)

$$I_{o(WL)} = I_{CQ} + \frac{V_{CEQ}}{R'}$$ where $R' = R_C \parallel R_L$

$$I_{o(WL)} = 2\text{ x }10^{-3} + \frac{6}{1000} = 8\text{ mA}$$

$$V_{o(WL)} = V_{CEQ} + I_{CQ}\,R'$$ where $R' = R_C \parallel R_L$

$$V_{o(WL)} = 6 + 2\text{ x }10^{-3}(1000) = 8\text{ Volts}$$

Discussion

Reference Figure 6.2

The DC Operating Point sets the limits of the output signal swing.

All three load lines (DC, AC without Load, and AC with Load) pass through the operating point.

Note that the operating point is located at I_B = 20 uA. The maximum excursion of i_B is limited to 20 uA below the operating point and 20 uA above the operating point for a total of 40 uA peak-peak, which results in a swing of i_C of 4 mA peak-peak and a corresponding swing of v_{CE} of 8 V peak-peak.

For fine grain values, refer to Figure 6.2. For the AC Load Line without Load, the relative values are i_C 1.9 mA to 2.1 mA (4 mA peak-peak) and v_{CE} 4.2 V below V_{CEQ} (6.0 - 4.2 = 1.8) to 3.8 Volts above V_{CEQ} (6.0 + 3.8) = 9.8 Volts (8 Volts peak-peak).

For the AC Load Line with Load (see Figure 6.8), the same limits apply to i_B, but now due to a change in slope of the AC Load with Load this corresponds to 1.9 and 2.3 mA (4.2 mA peak-peak) change in i_C and a 2.3 and 1.9 V (4.2 peak-peak) in v_{CE}.

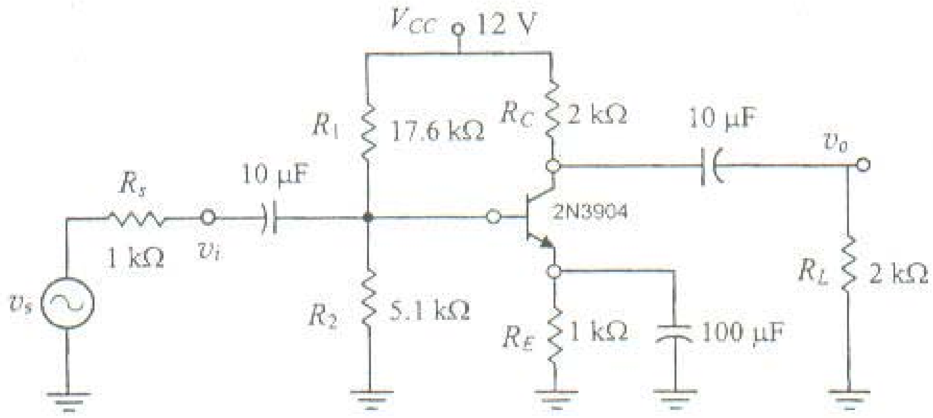

Figure 6-1: A voltage-divider biased common-emitter amplifier

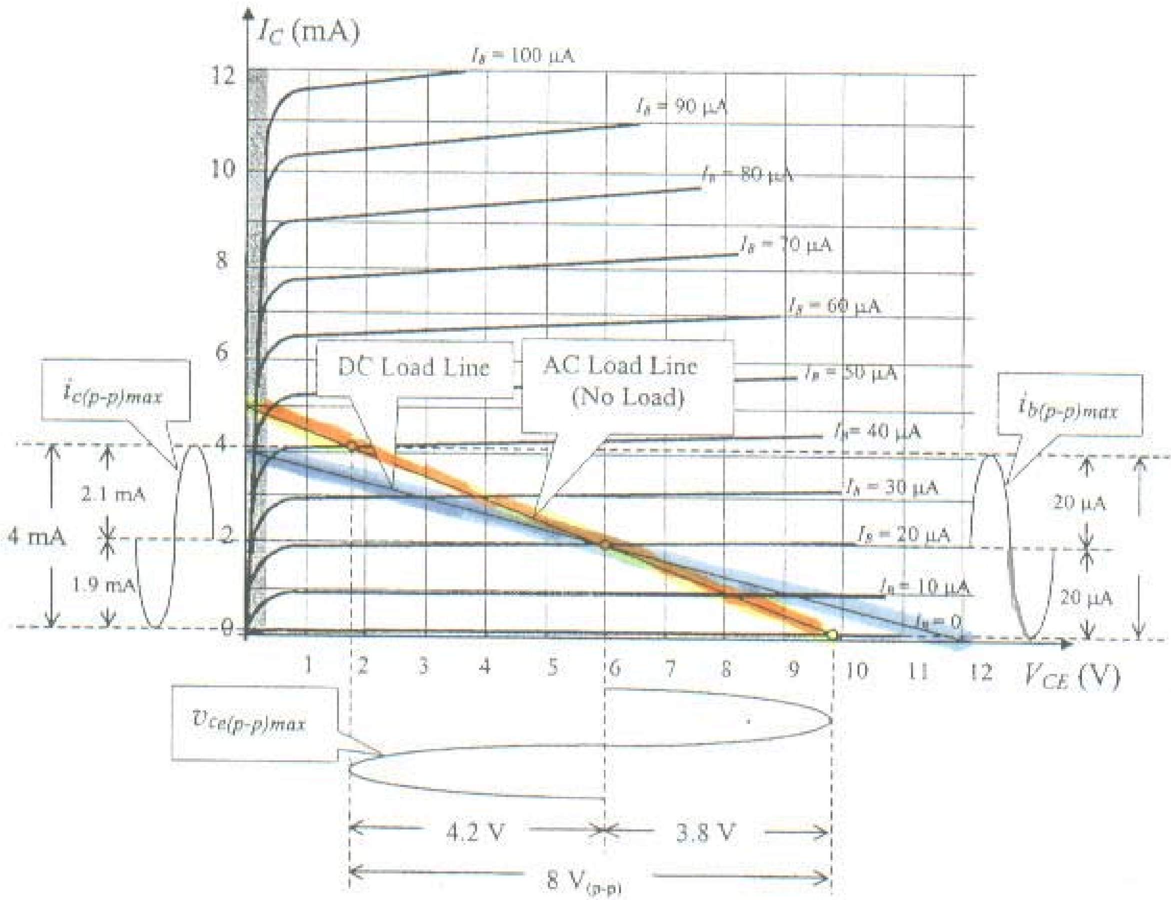

Figure 6-2: DC and AC load lines with the maximum input and output signals for the CE amplifier of Figure 6-1, with no load

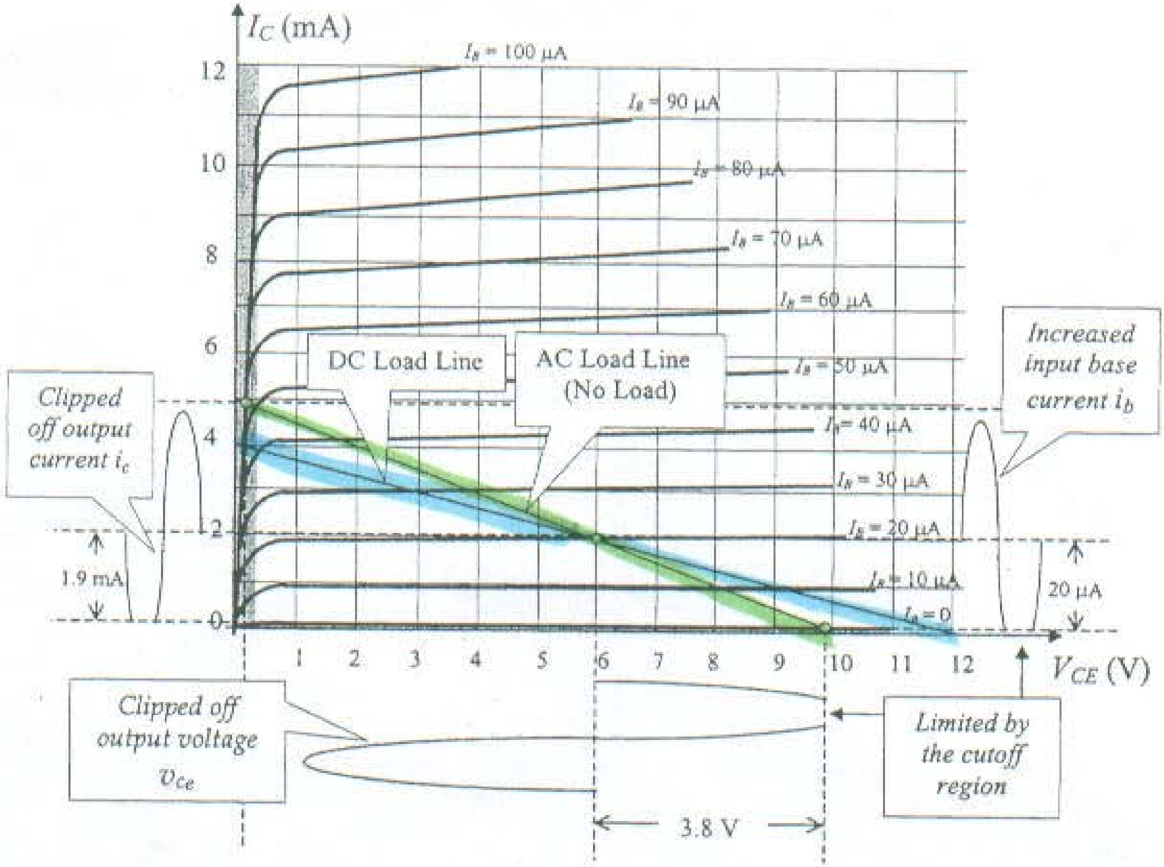

Figure 6-3: Output current and voltage signals with increased input signal i_b for the CE amplifier of Figure 6-1, without load

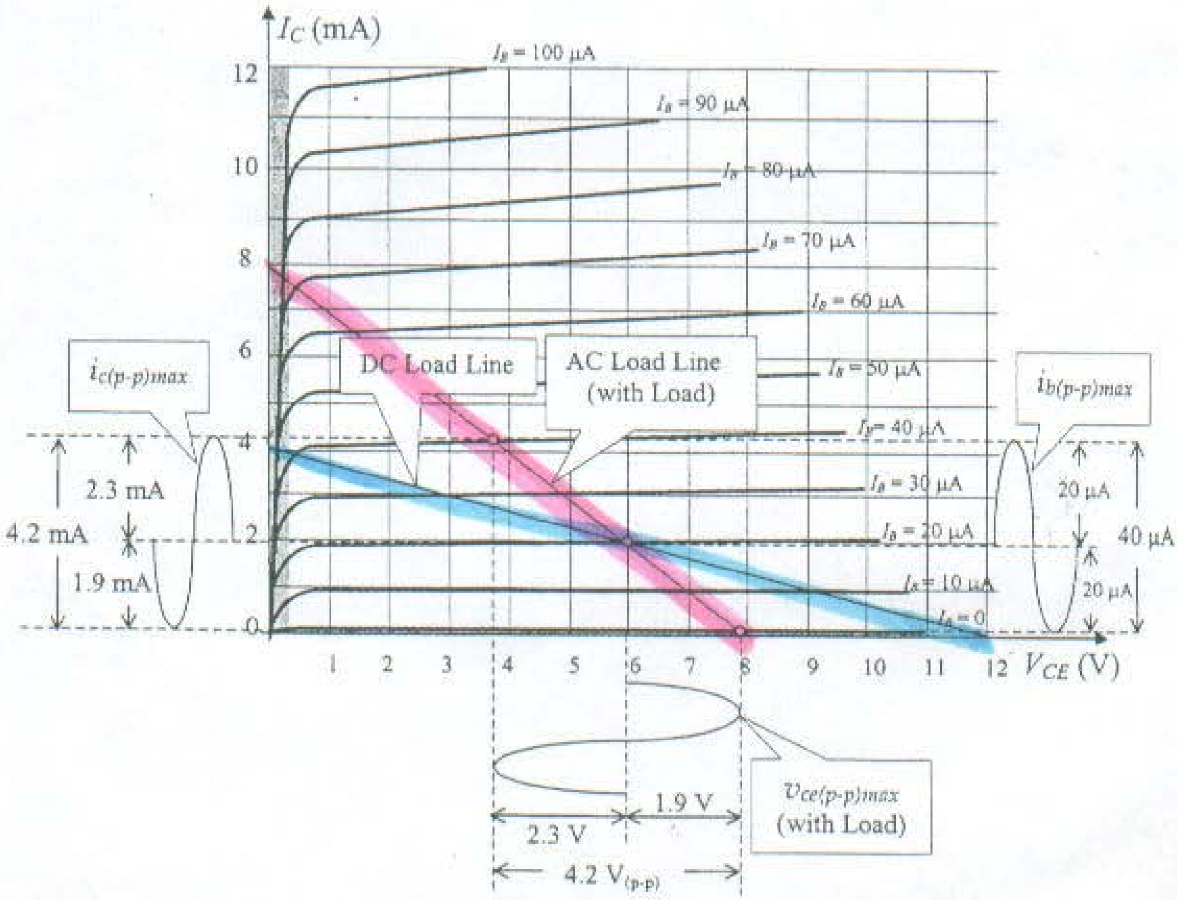

Figure 6-8: Maximum output current and voltage signals for the CE amplifier of Figure 6-1, with load