Microelectronics Circuit Analysis and Design Homework(8th)

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5.24 (a) For the circuit in Figure P5.24, determine V_B and I_E such that $V_B = V_C$. Assume $\beta = 90$.
(b) What value of V_B results in $V_{CE} = 2$V?

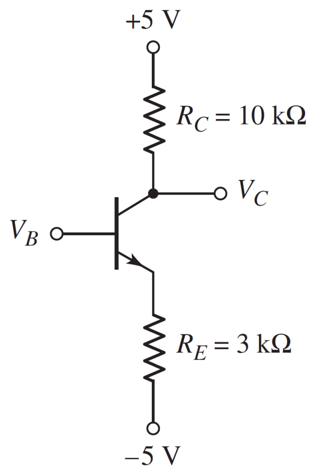

Figure 1: Problem 5.24

Solution:
(a)Assume the BJT works in the forward-active region:

$$\begin{cases} I_C = \dfrac{5 - V_C}{R_C} \\ I_E = \dfrac{V_B - V_{BE(on)-(-5)}}{R_E} \\ I_E = \dfrac{1+\beta}{\beta} I_C \\ V_B = V_C \end{cases} \Rightarrow \begin{cases} V_B = -2.14\text{V} \\ I_E = 0.72\text{mA} \end{cases}$$

(b)Obviously, the BJT work in the active region, so we have equation:

$$\begin{cases} V_C - V_B + V_{BE(on)} = V_{CE} \\ I_C = \dfrac{5 - V_C}{R_C} \\ I_E = \dfrac{V_B - V_{BE(on)-(-5)}}{R_E} \\ I_E = \dfrac{1+\beta}{\beta} I_C \end{cases} \Rightarrow \begin{cases} V_B = -2.44\text{V} \\ I_E = 0.62\text{mA} \end{cases}$$

5.43 The common-emitter current gain of the transistor in Figure P5.43 is $\beta = 80$. Plot the voltage transfer characteristics over the range $0 \leq V_I \leq 5\text{V}$.

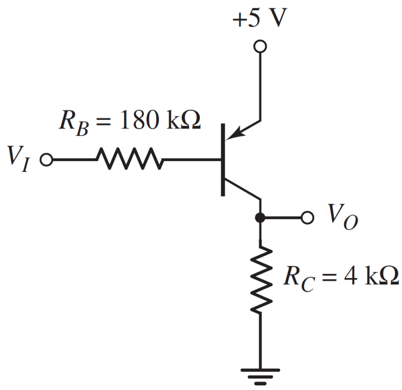

Figure 2: Problem 5.43

Solution:

It's a PNP BJT

case 1: $V_I \in (4.3, 5), V_{EB} < 0.7\text{V}$, the B-E junction isn't conducted, $I_E = 0, V_O = 0$

case 2: When BJT works in saturation region(at sat-point), $V_{EC} = 0.2\text{V}$, $V_O = 4.8\text{V}$, $V_I = 5 - V_{EC(ON)} - \dfrac{V_O}{\beta R_C} R_B = 1.6\text{V}$, so when $V_I < 1.6\text{V}$, $V_O = 4.8\text{V}$

case 3: $V_I \in [1.6, 4.3]$, the BJT works in the active region:

$$\frac{V_O}{R_C} = \beta \frac{5 - V_{BE(ON)} - V_I}{R_B} \Rightarrow V_O = -\frac{16}{9} V_I + \frac{344}{45}$$

5.70 For the circuit in Figure P5.70, let $R_C = 2.2\text{k}\Omega$, $R_E = 2\text{k}\Omega$, $R_1 = 10\text{k}\Omega$, $R_2 = 20\text{k}\Omega$, and $\beta = 60$. (a) Find R_{TH} and V_{TH} for the base circuit. (b) Determine I_{BQ}, I_{CQ}, V_E , and V_C.

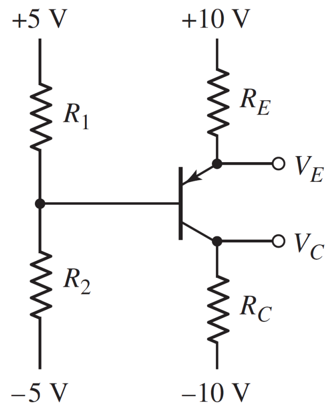

Figure 3: Problem 5.70

Solution:

(a)$V_{TH} = V^- + \frac{R_2}{R_1+R_2}(V^+ - V^-) = \frac{5}{3}\text{V}, R_{TH} = R_1||R_2 = \frac{20}{3}\text{k}\Omega$

(b)Equation is as follow:

$$(1+\beta)I_B R_E + V_{BE(ON)} + I_B R_{TH} + V_{TH} = 10 \Rightarrow I_B = 0.0593\text{mA}$$

$\therefore I_C = \beta I_B = 3.56\text{mA}, V_E = V_S - I_E R_E = 2.76\text{V}, V_C = -10\text{V} + I_C R_C = -2.17\text{V}$

6.8 The parameters of each transistor in the circuits shown in Figure P6.8 are $\beta = 130$, $V_A = 80$V, and $I_{CQ} = 0.2$mA. Determine the output resistance R_o for each circuit.

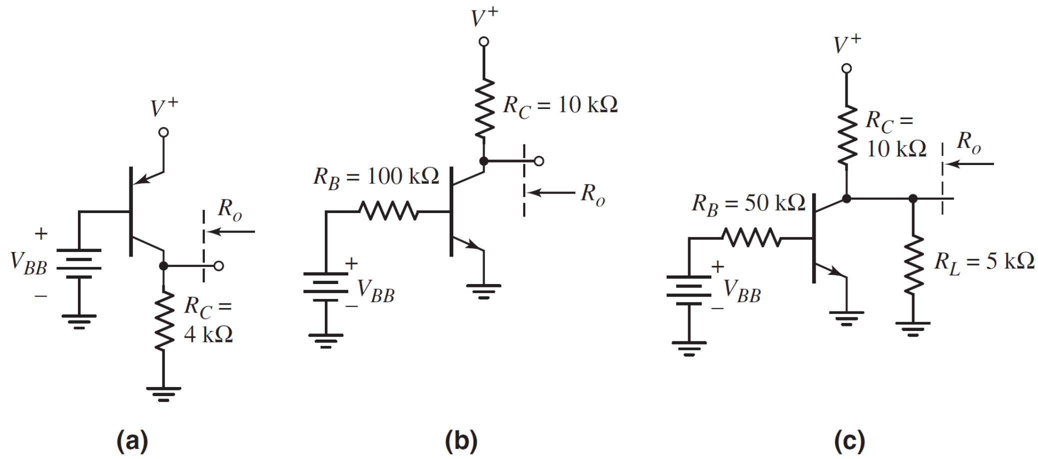

Figure 4: Problem 6.8

Solution:

$r_o = \frac{V_A}{I_{CQ}} = 400\text{k}\Omega$

(a)$R_o = r_o||R_C = 3.96\text{k}\Omega$

(b)$R_o = r_o||R_C = 9.76\text{k}\Omega$

(c)$R_o = r_o||R_L||R_C = 3.31\text{k}\Omega$

6.18 The signal source in Figure P6.18 is $v_s = 5\sin\omega t\,\text{mV}$. The transistor parameters are $\beta = 120$ and $V_A = \infty$. (a) (i) Design the circuit such that $I_{CQ} = 0.25\text{mA}$ and $V_{CEQ} = 3\text{V}$. (ii) Find the small-signal voltage gain $A_v = v_o/v_s$. (iii) Find $v_o(t)$. (b) Repeat part (a) for $R_S = 0$.

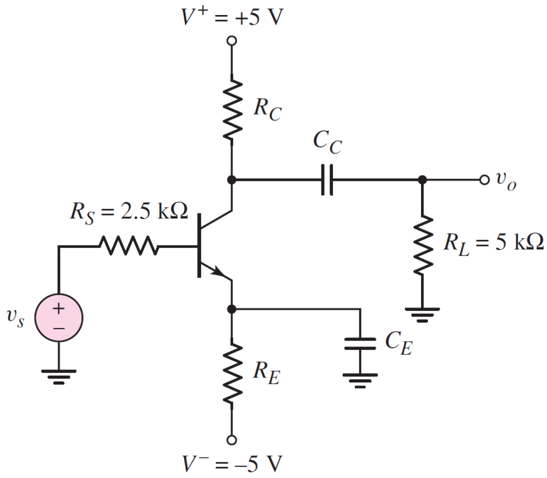

Figure 5: Problem 6.18

Solution:

(a)(i)$I_{BQ} = \dfrac{I_{CQ}}{\beta} = 0.00661\text{mA}$, then because of KVL, we have equation:

$$\begin{cases} I_{BQ}R_S + V_{BEON} + (\beta+1)I_B R_E = 0 - V^- \\ I_C R_C + V_{CEQ} + (\beta+1)I_B = V^+ - V^- \end{cases} \Rightarrow \begin{cases} R_C = 10.9\text{k}\Omega \\ R_E = 17.0\text{k}\Omega \end{cases}$$

(ii)$A_v = \dfrac{-g_m(\dfrac{r_\pi}{R_S + r_\pi}\cdot v_s)(R_L||R_C)}{v_s} = -27.5$

(iii)$v_o(t) = A_v v_s = -0.14\sin\omega t\,\text{V}$

(b)(i)because of KVL, we have equation:

$$\begin{cases} \beta I_{BQ}R_C + VCEQ + (\beta+1)I_B R_E = V^+ - V^- \\ V_{BEON} + (\beta+1)I_B R_E = 0 - V^- \end{cases} \Rightarrow \begin{cases} R_C = 10.8\text{k}\Omega \\ R_E = 17.1\text{k}\Omega \end{cases}$$

(ii)$A_v = \dfrac{-g_m(\cdot v_s)(R_L||R_C)}{v_s} = -32.9$

(iii)$v_o(t) = A_v v_s = -0.16\sin\omega t$V

6.33 For the circuit in Figure P6.15, let $\beta = 100$, $V_A = \infty$, $R_E = 12.9\text{k}\Omega$, and $R_C = 6\text{k}\Omega$. Determine the maximum undistorted swing in the output voltage if the total instantaneous C–E voltage is to remain in the range $1 \le v_{CE} \le 9$V and if the total instantaneous collector current is to remain greater or equal to 50μ A.

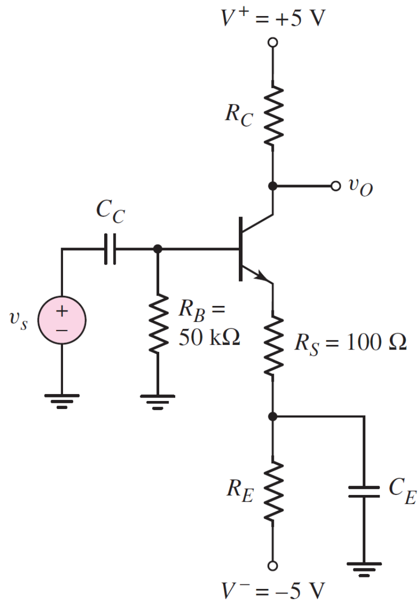

Figure 6: Problem 6.33

Solution:

First, we solve out Q-point:

because of KVL, we have equation:

$$I_B R_B + V_{BE(ON)} + (\beta+1)I_B(R_E+R_S) = 0 - V^- \Rightarrow I_B = 0.00315\text{mA}$$

$\therefore I_C = 0.315\text{mA}, I_E = 0.319\text{mA}, V_{CEQ} = (V^+ - V^-) - I_C R_C - I_E(R_E+R_S) = 3.96\text{V}$

Second, AC circuit Load Line Analysis:

$AC - slope = -\dfrac{1}{R_C||R_S} = -\dfrac{1}{6.1} \Rightarrow 315\mu\text{A} - 50\mu\text{A} = \Delta i_{CE(\max)} = -\dfrac{1}{6.1}\Delta v_{CE(\max)}$

$\Rightarrow \Delta v_{CE(\max)} = 1.62\text{V} \Rightarrow v_{CE(\min)} = 2.34\text{V} > 1\text{V}$

Third, calculate the max undistorted swing:

$V_{pp(\max)} = 2\Delta v_{CE(\max)} = 3.24\text{V}$

6.39 For the circuit in Figure P6.24, the transistor parameters are $\beta = 100$ and $V_A = \infty$. (a) Determine the maximum undistorted swing in the output voltage if the total instantaneous E–C voltage is to remain in the range $1 \leq v_{EC} \leq 9$V. (b) Using the results of part (a), determine the range of collector current.

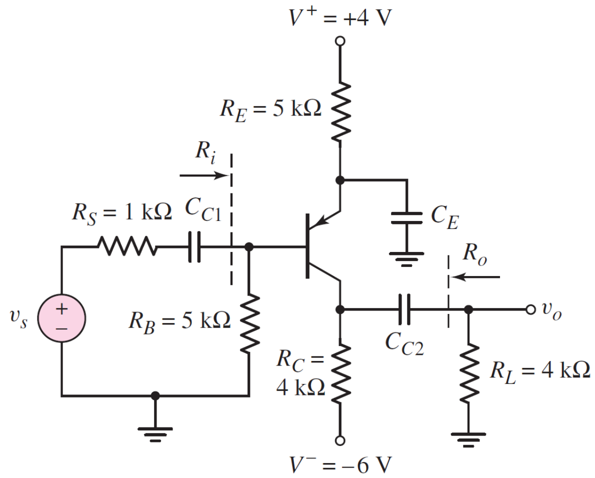

Figure 7: Problem 6.39

Solution:

(a)First, find Q-point:

$$(\beta+1)I_{BQ}R_E + VBE(ON) + I_{BQ}R_B = V^+ \Rightarrow I_{BQ} = 0.00647\text{mA}$$

$\therefore I_{CQ} = 0.647\text{mA}, V_{ECQ} = (V^+ - V^-) - (\beta+1)R_E - I_{CQ}R_C = 4.18\text{V}$

Second, AC circuit Load Line Analysis:

$AC - slope = -\dfrac{1}{R_C||R_L} = -\dfrac{1}{2\text{k}\Omega} \Rightarrow 0.647\text{mA} = \Delta i_{CE(\max)} = -\dfrac{1}{2\text{k}\Omega}\Delta v_{CE(\max)}$

$\Rightarrow \Delta v_{CE(\max)} = 1.294\text{V} \Rightarrow v_{CE(\min)} = V_{CEQ} - \Delta v_{CE(\max)} > 1\text{V}$

Third, calculate the max undistorted swing:

$V_{pp(\max)} = 2\Delta v_{CE(\max)} = 2.59\text{V}$

(b)the answer is obviously: $i_C \in (0, 1.294]$mA

6.65 Consider the circuit shown in Figure P6.69. The transistor has parameters $\beta = 120$ and $V_A = \infty$. (a) Determine the quiescent V_{CEQ}. (b) Determine the small-signal voltage gain $A_v = v_o/v_s$.

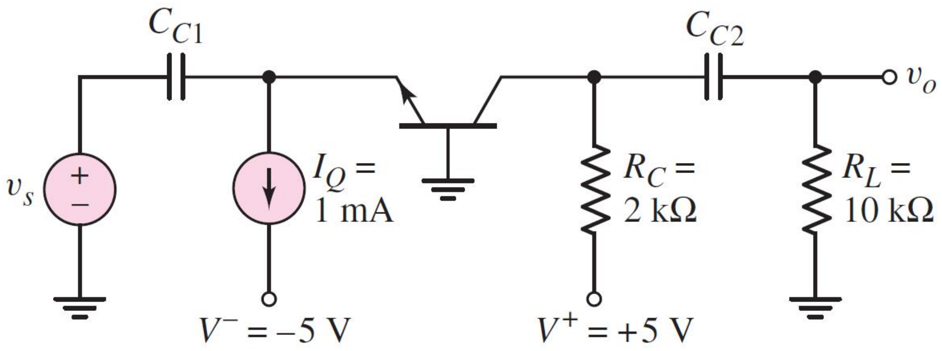

Figure 8: Problem 6.65

Solution:

(a)Because of KCL, we have equation:

$$\begin{cases} I_{BQ} + \beta I_{BQ} = I_Q \\ \beta I_B R_C + V_{CEQ} = V^+ - (-V_{BE(ON)}) \end{cases} \Rightarrow \begin{cases} I_{BQ} = 0.0083\text{mA} \\ V_{CEQ} = 3.72\text{V} \end{cases}$$

(b)$A_v = \dfrac{-g_m V_\pi (R_C||R_L)}{v_s} = g_m(R_C||R_L) = 63.6$