Solutions to Selected Problems (Problem Set 2)

Chapter 7: 7.30, 7.32, 7.34, 7.35, 7.44

7.30

Refer to Fig. P7.30

(a) For v_I sufficiently low so that Q_1 is cut off:

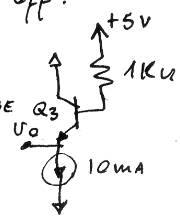
$V_{BE}|_{Q_3} = 0.7 + V_T \ln \frac{10}{1}$

$= 0.76V$

$V_{OH} = v_O = 5 - \frac{10}{101} \times 1 - V_{BE}$

$= 5 - \frac{10}{101} - 0.76$

$= \underline{4.14V}$

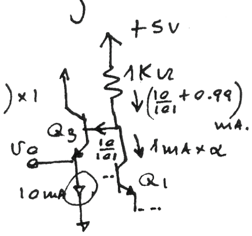


(b) For v_I sufficiently high so that Q_1 is conducting all the current I:

$V_{BE}|_{Q_3} = 0.76V$

$V_{OL} = v_O = 5 - \left(\frac{10}{101} + 0.99\right) \times 1 - 0.76$

$= \underline{3.15V}$



(c) $i_{E1} = I / (1 + e^{(v_{B2} - v_{B1})/V_T})$

$= I/100$

$e^{(3.64 - v_I)/V_T} = 99$

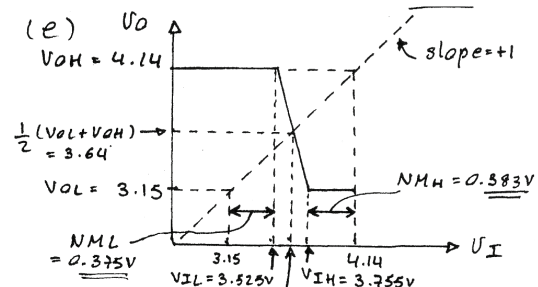
$v_I = 3.64 - V_T \ln 99 = \underline{3.525}\,V = V_{IL}$

(d) $i_{E1} = 0.99I = \dfrac{I}{1 + e^{(3.64 - V_{IH})/V_T}}$

$1 + e^{(3.64 - V_{IH})/V_T} = 1.01$

$V_{IH} = 3.64 + V_T \ln 100 = \underline{3.755V}$

(e)



Midpoint: $(V_{IL} + V_{IH})/2 = 3.64V$ CONT.

Since the mid-point of the output voltage swing is equal to 3.64V, the output voltage swing is centred on the mid-point of the input range; an ideal choice for it equalizes the noise margins.

7.32

$R_{id} \geq 10K\Omega$; $A_d = 200\ V/V$;

$\beta \geq 100$; $V_{CC} = 10V$

$R_{id} = 10^4 = 2r_\pi = 2 \times \frac{100}{g_m}$

$\Rightarrow g_m = 20\ mA/V$

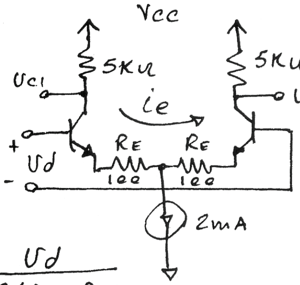
Thus each device is operating at $0.5mA$ and $I = \underline{1mA}$

Voltage gain $= g_m . R_C$

$200 = 20 R_C$

$\Rightarrow R_C = \underline{10K\Omega}$

7.34



$r_e = \frac{V_T}{I_E} = \frac{25m}{1m} = 25\Omega$

(a) $i_e = \frac{v_d}{2(r_e + R_E)} = \frac{0.1\text{ V}}{2(25+100)\Omega} = \underline{0.4\text{mA}}$

(b) $i_{E1} = 1 + 0.4 = \underline{1.4}\text{ mA}$

$i_{E2} = 1 - 0.4 = \underline{0.6\text{mA}}$

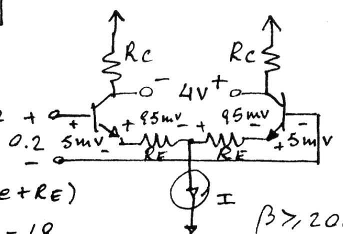
(c) $v_{c1} = -i_e R_c \simeq -0.4 \times 5 = \underline{-2V}$

$v_{c2} = \underline{+2V}$

(d) $v_{od} = 4V$

$A_d = v_{od}/v_{id} = \frac{4}{0.1} = \underline{40}\text{ V/V}$

7.35



$\frac{2R_c}{2(r_e + R_E)} \simeq \frac{4}{0.2}$

$R_c = 20(r_e + R_E)$

$\frac{R_E}{r_e} = \frac{95}{5} = 19$

$\beta \geq 200$

$R_{in} \geq 80K$

$R_{in} = 2(\beta+1)(r_e + R_E)$

$= 2 \times 201 \times 20 r_e = 80K\Omega$

$\Rightarrow r_e \simeq \frac{80000}{8000} = 10\Omega$

Thus each device is operating at a current of $\frac{25mV}{10\Omega} = 2.5mA$

$\Rightarrow I = \underline{5mA}$

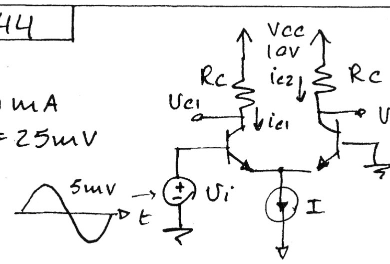
$R_E = 19 \times 10 = \underline{190\Omega}$

$R_c = 20 \times 200 = \underline{4K\Omega}$

7.44

I in mA

$V_T = 25mV$



$i_{c1} = \frac{I}{2} + \left(\frac{I/2}{V_T}\right)\left(\frac{5}{2}\right) \sin\omega t$

$i_{c2} = \frac{I}{2} - \left(\frac{I/2}{V_T}\right)\left(\frac{5}{2}\right) \sin\omega t$

$v_{c1} = V_{cc} - \frac{I}{2} R_c - \frac{I/2}{V_T} R_c \frac{5}{2} \sin\omega t$

$v_{c2} = V_{cc} - \frac{I}{2} R_c + \frac{I/2}{V_T} R_c \frac{5}{2} \sin\omega t$

$V_{c1}, V_{c2} \geq 0$

$\Rightarrow 10 - 5I - 0.5I = 0$

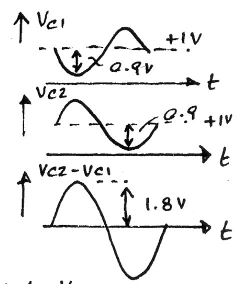
$I = \underline{1.8\text{mA}}$

$V_{c1} = V_{c2} = 1V$

$A_d = \frac{20K\Omega}{2r_e}$, where

$r_e = \frac{25}{0.9} = 27.8\Omega$

Thus, $A_d = \underline{360}\text{V/V}$



$v_{c2} - v_{c1} = \underline{1.8 \sin\omega t}$, V