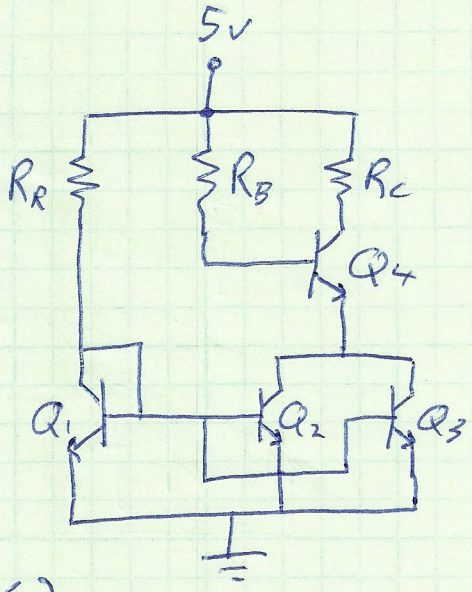
Question 1



$I_{C4} = 2mA \rightarrow I_{C2} = I_{C3} = 1mA$

$I_{C1} = 1mA$

$R_R = \frac{5 - 0.7}{1mA} = \underline{4.3k\Omega}$

Q_1 is always in active mode

Q_2 and Q_3 active if $V_{CE2} = V_{CE3} > V_{D0}$

Choose $V_{CE2} = V_{CE3} = 1V$ (for example)

$V_{E4} = 1V$

$5 - R_B I_{B4} - 0.7 - 1 = 0$

$R_B I_{B4} = 3.3V$

$I_{B4} = \frac{2mA}{\beta} = 20\mu A$

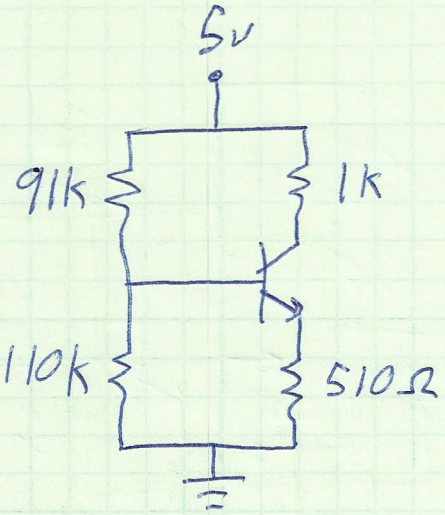
$R_B = \frac{3.3V}{20\mu A} = \underline{165k\Omega}$

$5 - R_C I_{C4} - V_{CE4} - 1 = 0$

$5 - R_C \cdot 2mA - 2 - 1 = 0$

$R_C = \frac{2V}{2mA} = \underline{1k\Omega}$

Question 2



a) $V_{BB} = 5v \cdot \frac{110k}{91k+110k} = 2.74v$

$R_B = 91k \,||\, 110k = 50k\Omega$

$V_{BB} - I_B R_B - 0.7 - (\beta+1) I_B \cdot 510 = 0$

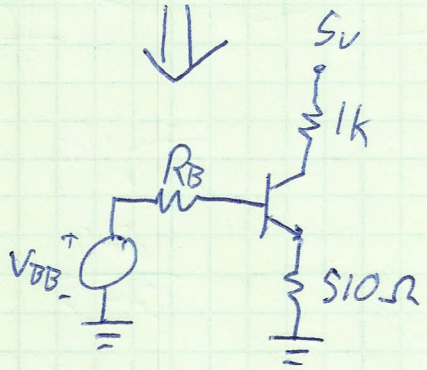
$2.74 - 0.7 - I_B(50k + 51.5k) = 0$

$I_B = 20\mu A$

$I_C = \beta I_B = \underline{2mA}$

$V_{CE} = 5v - 2mA(1k + 510\Omega)$

$V_{CE} = \underline{2v}$



b) The circuit is stable with respect to typical variations in V_{BE} which are about 0.1v because $V_E = 1v \gg 0.1v$

c) The circuit is not stable with respect to variations in β because this stability condition requires that $R_B \ll (1+\beta_{min}) R_E$. However, in this circuit $R_B = 50k\Omega$ and $(1+\beta) R_E = 51.5k\Omega$, so the stability condition is not satisfied.

Question 3

a) D_1 and D_3 ON

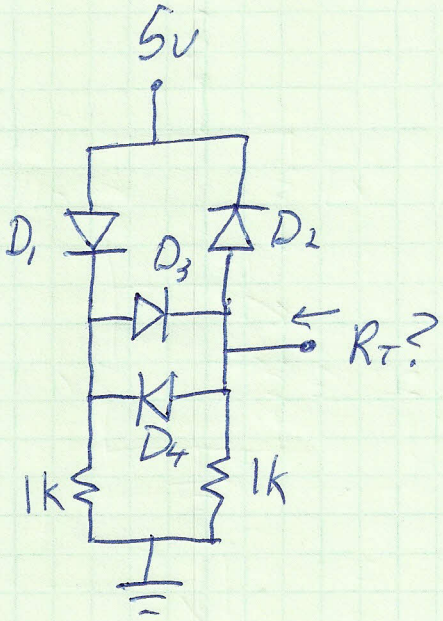
D_2 and D_4 OFF

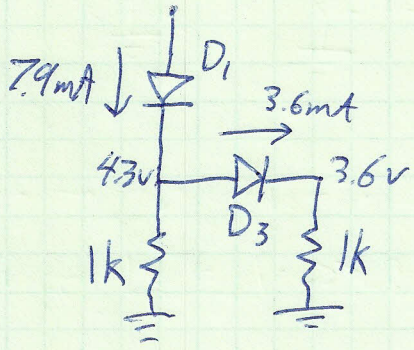
$$r_{d_1} = \frac{nV_T}{I_D} = \frac{2 \times 26mV}{7.9mA} = 6.6\,\Omega$$

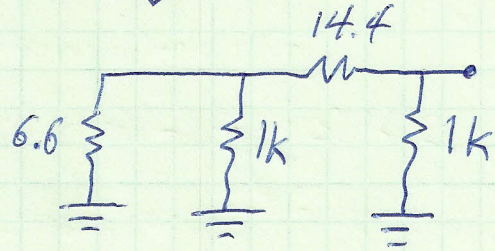
$$r_{d_3} = \frac{nV_T}{I_D} = \frac{2 \times 26mV}{3.6mA} = 14.4\,\Omega$$

$$R_T = (1k \| 6.6 + 14.4) \| 1k$$

b) $R_T = 20.5\,\Omega$

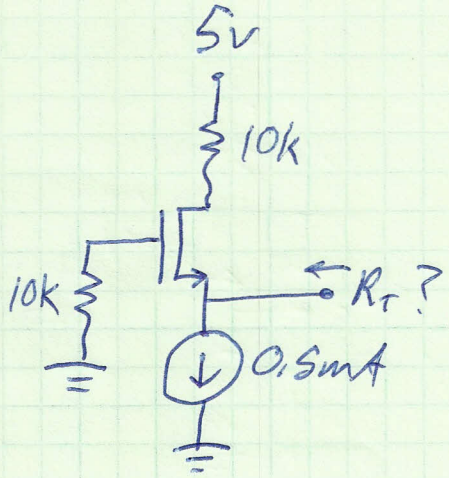






small signal circuit

Question 4



a) $I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{gs}-V_T)^2$

$0.5 = 0.5(V_{gs}-V_T)^2$

$V_{gs} - V_T = 1$

$V_{gs} = 2v \rightarrow V_s = -2v$

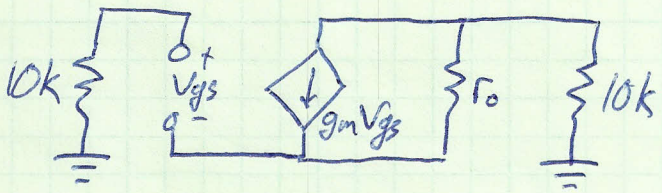
$5v - 10k \times 0.5mA - V_{DS} - (-2v) = 0$

$V_{DS} = 2v > V_{gs} - V_T \rightarrow$ saturation mode

$g_m = \frac{2I_D}{V_{GS}-V_T} = 1mA/V = 10^{-3}\frac{1}{\Omega}$

$r_o = \frac{V_A + V_{DS}}{I_D} = \frac{102v}{0.5mA} = 204k\Omega$

b)



small signal circuit

c) attach test source to transistor source terminal

$V_{gs} = -V_x$

$V_x - r_o(i_x - g_m V_x) - 10k\, i_x = 0$

$V_x - 204k\, i_x + 204 V_x - 10k\, i_x = 0$

$205 V_x = 214k\, i_x$

$R_T = \frac{214k}{205} \simeq 1k\Omega$