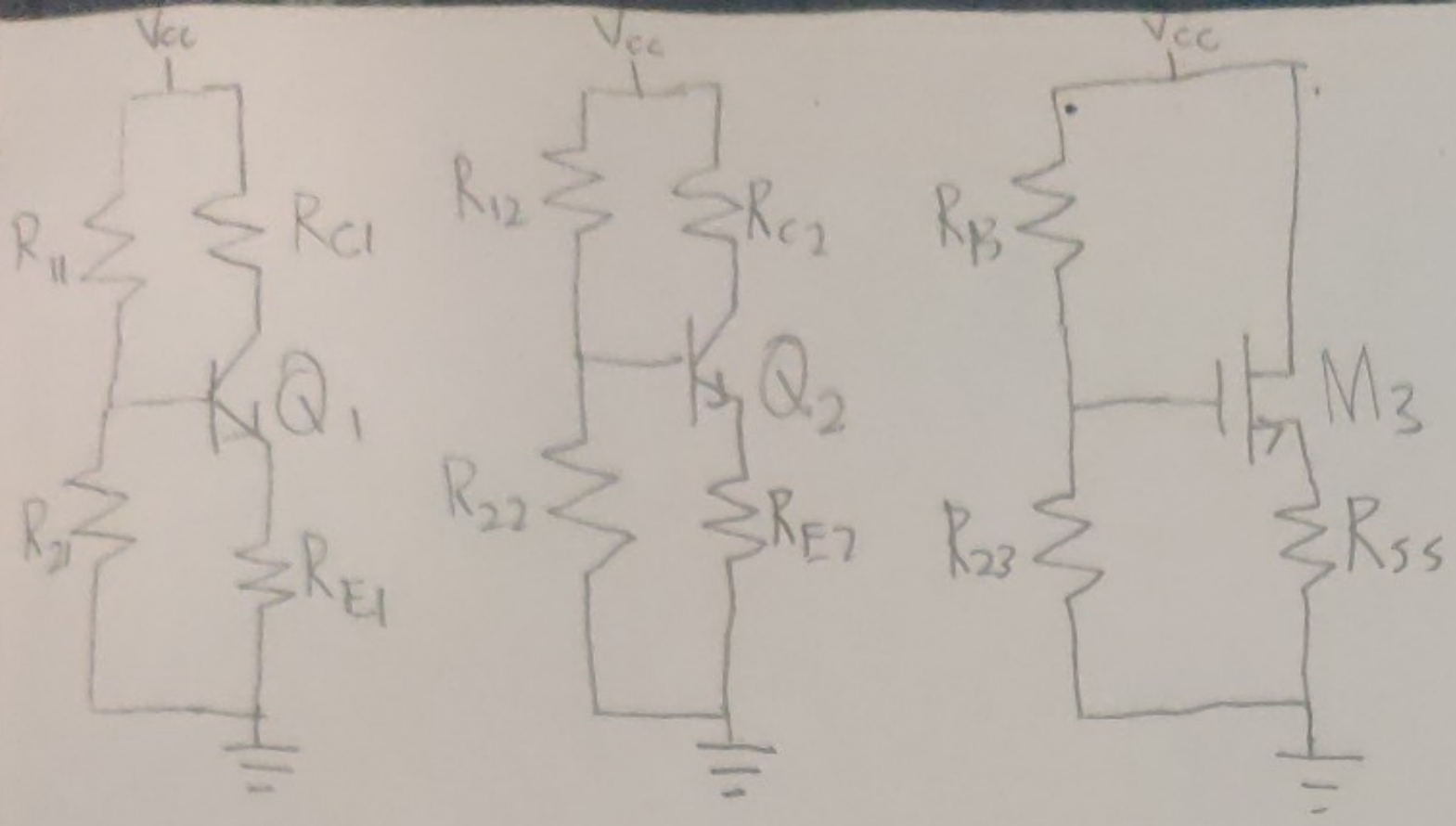
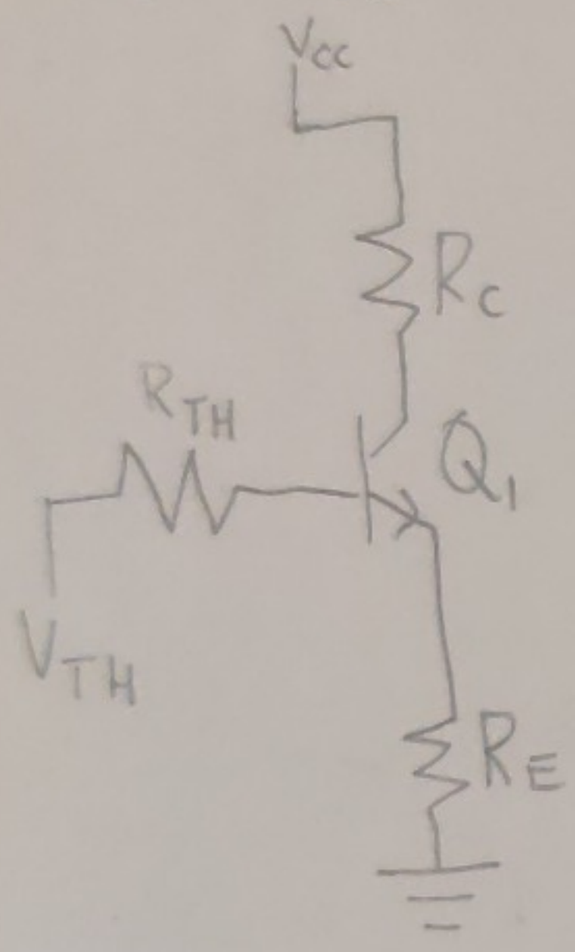


$Q_1 = Q_2$



$$R_{TH1} = R_{11} \| R_{21}$$

$$V_{TH1} = V_{CC} \frac{R_{21}}{R_{11}+R_{21}}$$

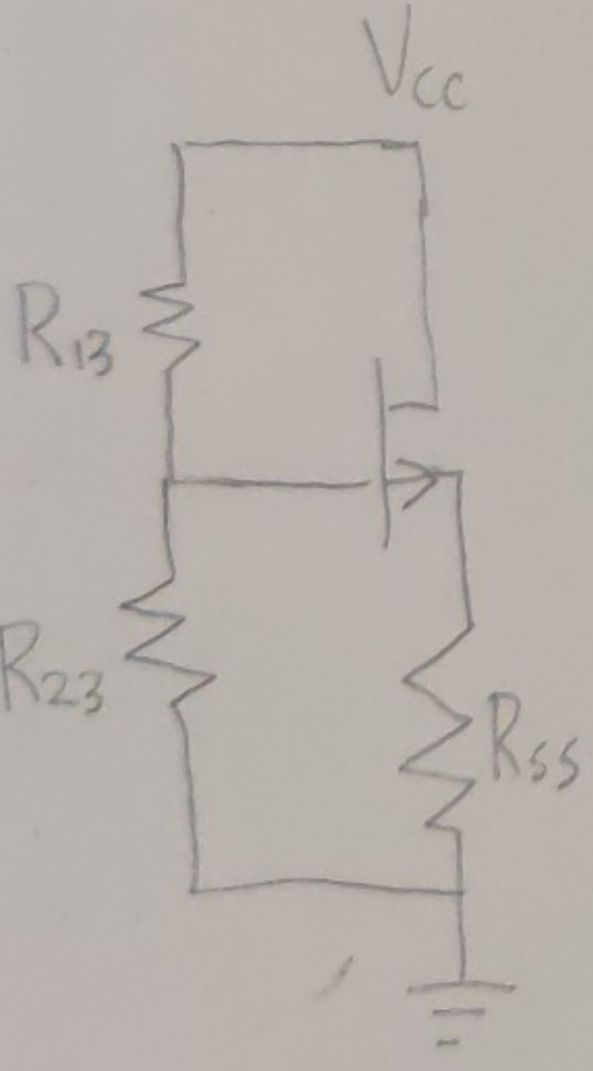
$$V_{B1} = V_{TH1} - I_{B1} R_{TH1}$$
$$V_{C1} = V_{CC} - I_{C1} R_{C1}$$
$$V_{E1} = I_E R_E$$

$$V_{TH1} = I_{B1} R_{TH1} + V_{BE} + (1+\beta) I_{B1} R_{E1}$$

$$V_{TH1} - V_{BE} = I_{B1}(R_{TH1} + (1+\beta) R_{E1})$$

$$I_{B1} = \frac{V_{TH1} - V_{BE}}{R_{TH1} + (1+\beta) R_{E1}}$$

$$I_{E1} = (1+\beta) I_{B1}$$
$$I_{C1} = \beta I_{B1}$$
$$I_{B1} = \frac{V_{TH1} - V_{BE}}{R_{TH1} + (1+\beta) R_{E1}}$$



$$I_D = K_n (V_{GS} - V_{TN})^2$$

$$V_{GS} = V_G - V_S$$

$$= V_{CC} \frac{R_{23}}{R_B + R_{23}} - I_D R_{SS}$$

$$V_G = V_{CC} \frac{R_{23}}{R_{B3} + R_{23}}$$
$$V_D = V_{CC}$$
$$V_S = I_D R_{SS}$$

$$I_D = K_n (V_G - I_D R_{SS} - V_{TN})^2$$

$$= K_n (V_G^2 - V_G I_D R_{SS} - V_G V_{TN} - I_D R_{SS} V_G + I_D^2 R_{SS}^2 + V_{TN} I_D R_{SS} - V_{TN} V_G + V_{TN} I_D R_{SS} + V_{TN}^2)$$

$$= K_n (I_D^2 R_{SS}^2 + 2 I_D (V_{TN} R_{SS} - V_G R_{SS}) + V_{TN}^2 + V_G^2 - 2 V_G V_{TN})$$

$$0 = K_n R_{SS}^2 I_D^2 + K_n (2 V_{TN} R_{SS} - 2 V_G R_{SS} - 1) I_D + K_n V_{TN}^2 + V_G^2 K_n - 2 V_G V_{TN} K_n$$

$$I_D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$a = K_n R_{SS}^2 \qquad c = K_n (V_{TN}^2 + V_G^2 - 2 V_G V_{TN})$$
$$b = K_n (2 V_{TN} R_{SS} - 2 V_G R_{SS} - 1)$$

$$r_{\pi 1} = \frac{V_T}{I_{B1}} = \frac{26m}{58.835N} = 457.465\Omega$$

$$g_{m1} = \frac{I_{C1}}{V_T} = \frac{8.525m}{26m} = 327.845m$$

$$r_{O1} = \frac{V_A}{I_{C1}} = \frac{65}{8.525m} = 7.624k\Omega$$

$$r_{\pi 2} = \frac{V_T}{I_{B2}} = \frac{26m}{13.634N} = 1.907k\Omega$$

$$g_{m2} = \frac{I_{C2}}{V_T} = \frac{2.045m}{26m} = 78.654m$$

$$r_{O2} = \frac{V_A}{I_{C2}} = \frac{65}{2.045m} = 31.785k\Omega$$

$$g_{m3} = 2\sqrt{K_n I_D} = 1.924m = 2\sqrt{5m \times 185.095N}$$

$$r_{O3} = \frac{1}{\lambda I_D} = \frac{1}{0.01 \times 185.095N} = 540.263k\Omega$$

$R_{11} = 1.k\Omega$ $R_{21} = 501\Omega$ $R_{C1} = 1k\Omega$ $R_{E1} = 500\Omega$

$R_{12} = 6k\Omega$ $R_{22} = 8k\Omega$ $R_{C2} = 2k\Omega$ $R_{E2} = 3.8k\Omega$

$R_{13} = 1k\Omega$ $R_{23} = 6.5k\Omega$ $R_{SS} = 80k\Omega$

$V_O = 15$

$V_G = 15 \times \frac{6.5k}{1k+6.5k} = 13$

$$V_{TH1} = 15\frac{501}{1k+501} = 5.01V$$

$$R_{TH1} = \left(\frac{1}{1k} + \frac{1}{501}\right)^{-1} = 333.78\Omega$$

$$I_{B1} = \frac{5.01 - 0.7}{333.78 + (1+150)500} = 56.835NA$$

$$I_{C1} = 150 \times 56.835N = 8.525mA$$

$$V_{TH2} = 15\frac{8k}{6k+8k} = 8.57V$$

$$R_{TH2} = \left(\frac{1}{6k} + \frac{1}{8k}\right)^{-1} = 3.429k\Omega$$

$$I_{B2} = \frac{8.57 - 0.7}{3.429k + (1+150)3.8k} = 13.634NA$$

$$I_{C1} = 150 \times 13.634N = 2.045mA$$

$a = 5m \times 80k^2 = 32M$

$b = 5m(-2 \times 80k \times 2 - 13 \times 80k \times 2 - 1) = -12.001k$

$c = 5m((-2)^2 + 13^2 - 2 \times 13 \times -2) = 1.125$

$$I_D = \frac{--12k \pm \sqrt{(-12)^2 - 4 \times 32M \times 1.125}}{2(32M)}$$

$= 189.936NA, 185.095NA$

$V_{S1} = 189.936N \times 80k = 15.195\ V$

$V_{S2} = 185.095N \times 80k = 14.808\ V$

$V_{DS1} = 15 - 15.195 = -0.195\ V$

$V_{DS2} = 15 - 14.805 = 0.192\ V$

$V_{DS1} < V_{TN}$ so, $I_D = 195.095NA$

$V_{GS1} = 13 - 15.195 = -2.195V$

$V_{GS2} = 13 - 14.805 = -1.805V$