EEE 51 Assignment 1 Answer Key

2nd Semester SY 2018-2019

BJT DC Biasing

(a) Finding V_{BE}, I_C, and V_{OUT}

$$I_C = I_S e^{\frac{V_{BE}}{V_T}} \tag{1}$$

$$I_B = \frac{I_C}{\beta} \tag{2}$$

KVL at $135k\Omega$ to GND loop,

$$10 - I_B R_1 - V_{BE} = 0 \tag{3}$$

Substituting (1) and (2) to (3) will give

$$10 - V_{BE} - \frac{I_s}{\beta} e^{\frac{V_{BE}}{V_T}} R_1 = 0 \tag{4}$$

Plugging in the given values will give

$$10 - V_{BE} - 1.125 \ \ x10^{-10} \ \ e^{\frac{V_{BE}}{26mV}} = 0$$

Solving the equation will give the value of V_{BE} which then allows for computing the value of I_C and V_{OUT}

$$\boxed{V_{BE} = 0.654V}$$

$$I_C = 100 \ \ x10^{-15} \ \ e^{\frac{0.651V}{26mV}}$$

$$\boxed{I_C = 8.39mA}$$

$$\boxed{V_{OUT} = 10 - 8.39mA(800\Omega) = 3.28V}$$

(b) Suppose RE is 200 and R2 is finite but has an unknown value

(i) Find I_C by KVL at 10V→R_C→V_{OUT}

$$I_C = \frac{10 - V_{OUT}}{R_C}$$

$$\boxed{I_C = 6.25mA}$$

(ii) Since V_A approaches infinity, base-emitter voltage can be computed using

$$I_C = I_s \ \ e^{\frac{V_{BE}}{V_T}}$$

$$\boxed{V_{BE} = 0.646V}$$

Using the computed V_{BE}, the value of I_B can be computed

$$I_B = \frac{I_C}{\beta}$$

$$\boxed{I_B = 52.08\mu A}$$

(iii) The voltage across R_2 can be computed using KVL

$$V_2 = V_{BE} + (I_C + I_B)R_E$$
$$\boxed{V_2 = 1.91V}$$

(iv) Using node-voltage equations at node V_2, the equation below can be generated

$$\frac{10 - V_2}{R_1} = \frac{V_2}{R2} + I_B$$

Rearranging then substituting the calculated values from i, ii, and iii

$$R_2 = \frac{V_2}{\frac{10-V_2}{R_1} - I_B} = \frac{1.91}{\frac{10-1.91}{135k\Omega} - 52.08\mu A}$$

$$\boxed{R_2 = 243.44k\Omega}$$

MOSFET DC Biasing

(a) From the KVL loop on the input side of M_1, V_{GS} should be solved:

$$V_{BIAS} - V_{GS} - V_{R_S} - V_{SS} = 0$$
$$V_{GS} = V_{BIAS} - V_{R_S} - V_{SS}$$
$$V_{GS} = 0.65V - 0.65V - (-0.8V)$$
$$\boxed{V_{GS} = 0.8V}$$

(b)

$$I_D = k(V_{GS} - V_{TH})^2 \rightarrow \textit{Saturation}$$
$$I_D = 2k\left[(V_{GS} - V_{TH})V_{DS} - \frac{V_{DS}^2}{2}\right] \rightarrow \textit{Linear}$$

Assumptions: Since V_{DS} is not given and cannot be solved as of this moment which is a present factor in linear mode equation, we first assume saturation mode.

$$I_D = k(V_{GS} - V_{TH})^2$$
$$I_D = 100\mu A/V^2(0.8V - 0.2V)^2$$
$$\boxed{I_D = 36\mu A}$$

(c) The KVL branch from V_{DD} to V_{SS} passing through the V_{DS} of $M1$ is

$$V_{DD} - (I_D + I_L)R_D - V_{DS} - V_{R_S} - V_{SS} = 0$$
$$V_{DS} = V_{DD} - (I_D + I_L)R_D - V_{R_S} - V_{SS}$$
$$= 0.8V - (36\mu A + 20\mu A)5k\Omega - 0.65V - (-0.8V)$$
$$\boxed{V_{DS} = 0.67V}$$

(d) The conditions for saturation and linear are as follows:

$$V_{DS} > V_{GS} - V_{TH} \rightarrow \textit{Saturation}$$
$$V_{DS} < V_{GS} - V_{TH} \rightarrow \textit{Linear}$$

Since the values for V_{GS} and V_{DS} are already obtained and verifying the assumption from (b),

$$V_{DS} > V_{GS} - V_{TH}$$
$$0.67V > 0.8V - 0.2V$$
$$\boxed{0.67V > 0.6V}$$

Therefore, $M1$ is indeed in saturation mode.

(e) From the KVL loop at the output side of M_1, V_O could be obtained:

$$V_O - V_{DS} - V_{R_S} - V_{SS} = 0$$
$$V_O = V_{DS} + V_{R_S} + V_{SS}$$
$$= 0.67V + 0.65V - 0.8V$$
$$\boxed{V_O = 0.52V}$$

(f)

$$R_S = \frac{V_{R_S}}{I_D}$$
$$= \frac{0.65V}{36\mu A}$$
$$\boxed{R_S = 18.06k\Omega}$$

$$R_L = \frac{V_O}{I_L}$$
$$= \frac{0.52V}{20\mu A}$$
$$\boxed{R_L = 26k\Omega}$$