Homework Assignment No. 6 - Solutions

14.12

$V_{EQ} = 12\dfrac{62k\Omega}{20k\Omega + 62k\Omega} = 9.07V$ | $R_{EQ} = 20k\Omega \| 62k\Omega = 15.1k\Omega$

$I_B = \dfrac{(12 - 0.7 - 9.07)V}{15.1k\Omega + (75+1)3.9k\Omega} = 7.16\mu A$ | $I_C = 537\ \mu A$ | $V_{EC} = 12 - 3900I_E - 8200I_C = 5.47\ V$

Forward – active region is correct. | $r_\pi = \dfrac{75(0.025V)}{537\mu A} = 3.49k\Omega$

$\mathbf{v_{th}} = \mathbf{v_s}\dfrac{15.1k\Omega}{1k\Omega + 15.1k\Omega} = 0.938\mathbf{v_s}$ | $R_{th} = 1k\Omega \| 15.1k\Omega = 0.938k\Omega$

$R_L = r_o \| 8.2k\Omega \| 100k\Omega \cong 8.2k\Omega \| 100k\Omega = 7.58k\Omega$ | $A_{Vth} = -\dfrac{75(7.58k\Omega)}{0.938k\Omega + 3.49k\Omega} = -128$

$A_V = 0.938A_{Vth} = -120$ | $A_I = -75\dfrac{15.1k\Omega}{15.1k\Omega + 3.49k\Omega} = -60.9$

$R_{IN} = 15.1k\Omega \| 3.49k\Omega = 2.83\ k\Omega$ | $R_{OUT} = r_o \| 8.2k\Omega \cong 8.2k\Omega$

$\mathbf{v_{be}} = 0.938\mathbf{v_s}\dfrac{3.49k\Omega}{0.938k\Omega + 3.49k\Omega} = 0.739\mathbf{v_s}$ | $\mathbf{v_s} = \dfrac{5.00mV}{0.739} = 6.76\ mV$

$A_V \cong -10V_{CC} = -10(12) = -120.$ | Gain is identical to the rule - of - thumb estimate.

14.13

$V_{EQ} = 18\dfrac{500k\Omega}{1.4M\Omega + 500k\Omega} = 4.74V$ | $R_{EQ} = 500k\Omega \| 1.4M\Omega = 368k\Omega$

$4.74 = V_{GS} + 27000I_{DS} = 1 + \sqrt{\dfrac{2I_{DS}}{250x10^{-6}}} + 27000I_{DS} \rightarrow I_{DS} = 104\mu A$

$V_{DS} = 18 - I_{DS}(75k\Omega + 27k\Omega) = 7.39V$ | Saturation region is correct.

$g_m = \sqrt{2\left(250x10^{-6}\right)\left(104x10^{-6}\right)} = 0.228mS$

$\mathbf{v_{th}} = \mathbf{v_s}\dfrac{368k\Omega}{1k\Omega + 368k\Omega} = 0.997\mathbf{v_s}$ | $R_{th} = 1k\Omega \| 368k\Omega = 0.997k\Omega$

$R_L = r_o \| 75k\Omega \| 470k\Omega \cong 75k\Omega \| 470k\Omega = 64.7k\Omega$ | $A_{Vth} = -(0.228mS)(64.7k\Omega) = -14.8$

$A_V = 0.997A_{Vth} = -14.7$ | $A_I = 368k\Omega(-g_m)\dfrac{75k\Omega}{75k\Omega + 470k\Omega} = -11.6$

$R_{IN} = 368\ k\Omega$ | $R_{OUT} = r_o \| 75k\Omega \cong 75k\Omega$

$\mathbf{v_{gs}} = 0.997\mathbf{v_s}$ | $V_{GS} - V_{TN} = \sqrt{\dfrac{2(104\mu A)}{250\mu A / V^2}} = 0.912V$ | $\mathbf{v_s} = 0.2\dfrac{0.912V}{0.997} = 0.183\ V$

$A_V \cong -\dfrac{V_{DD}}{V_{GS} - V_{TN}} = -\dfrac{18}{0.912} = -19.7$ | The rule - of - thumb estimate assumes $V_{R_L} = \dfrac{V_{DD}}{2}$.

We have $V_{R_L} = 104\mu A(75k\Omega) = 7.80V = 0.433V_{DD}$

The estimate also doesn't account for the presence of R_3.

14.15

$V_{GS} = -(11k\Omega)I_{DS} = -(11k\Omega)(20mA)\left(1 - \frac{V_{GS}}{-4}\right)^2 \rightarrow V_{GS} = -3.50V,\ I_{DS} = -\frac{V_{GS}}{11k\Omega} = 318\ \mu A$

$V_{DS} = 20 - I_{DS}(11k\Omega + 39k\Omega) = 4.10V$ | Saturation region is correct.

$g_m = \frac{2}{|-4|}\sqrt{20mA(318\mu A)} = 1.26mS$ | $\mathbf{v}_{th} = \mathbf{v}_s \frac{1M\Omega}{0.5k\Omega + 1M\Omega} = 1.00\mathbf{v}_s$

$R_{th} = 0.5k\Omega \| 1M\Omega = 0.500k\Omega$ | $R_L = 39k\Omega \| 500k\Omega = 36.2k\Omega$

$A_V = A_{Vth} = -\frac{1.26mS(36.2k\Omega)}{1 + 1.26mS(11k\Omega)} = -3.07$ | $R_{IN} = 1.00\ M\Omega$ | $R_{OUT} = 39k\Omega$

$A_I = -R_G \frac{g_m}{1 + g_m R_L} = -(10^6)\frac{1.26mS}{1 + 1.26mS(11k\Omega)} = -84.8$

$\mathbf{v}_{th} = 1.00\mathbf{v}_s$ | $V_{GS} - V_P = -3.5 - (-4) = 0.500V$ | $\mathbf{v}_s = 0.2(0.5)[1 + 1.26mS(11k\Omega)] = 1.49\ V$

14.21

$V_{EQ} = 18\frac{51k\Omega}{51k\Omega + 100k\Omega} = 6.08V$ | $R_{EQ} = 51k\Omega \| 100k\Omega = 33.8k\Omega$

$I_B = \frac{(6.08 - 0.7 + 18)V}{33.8k\Omega + (126)(4.7k\Omega)} = 37.3\mu A$ | $I_C = 4.67\ mA$ | $V_{CE} = 36 - 2000I_C - 4700I_E = 4.54\ V$

Forward - active region is correct. | $r_\pi = \frac{125(0.025V)}{4.67mA} = 669\Omega$ | $r_o = \frac{(50 + 4.54)V}{4.67mA} = 11.7k\Omega$

$\mathbf{v}_{th} = \mathbf{v}_s \frac{33.8\Omega}{500\Omega + 33.8k\Omega} = 0.985\mathbf{v}_s$ | $R_{th} = 33.8k\Omega \| 500\Omega = 493\Omega$

$R_L = 24k\Omega \| 4.7k\Omega \| 11.7k\Omega = 2.94k\Omega$ | $A_{Vth} = -\frac{126(2.94k\Omega)}{0.493k\Omega + 0.669k\Omega + 126(2.94k\Omega)} = 0.997$

$A_V = 0.985A_{Vth} = 0.982$ | $R_{IN} = 33.8k\Omega \| [0.669k\Omega + 126(2.94k\Omega)] = 31.0\ k\Omega$

$A_I = A_V \frac{R_S + R_{IN}}{R_3} = 0.982\frac{0.5k\Omega + 31.0k\Omega}{24.0k\Omega} = 1.29$ | $R_{OUT} = \frac{493\Omega + 669\Omega}{126} \| 2.94k\Omega = 9.19\ \Omega$

$\mathbf{v}_{be} = 0.982\mathbf{v}_s \frac{0.669k\Omega}{0.493k\Omega + 0.669k\Omega + 126(2.94k\Omega)} = 0.00177\mathbf{v}_s$ | $\mathbf{v}_s = \frac{5.00mV}{0.00177} = 2.83\ V$

14.23

$V_{GS} = 5V$ | $I_{DS} = \frac{4x10^{-4}}{2}(5-1)^2 = 3.2mA$ | $V_{DS} = 5 - (-5) = 10V$ - Saturation region operation is correct. | $g_m = \sqrt{2(4x10^{-4})(3.2mA)[1 + 0.02(10)]} = 1.75mS$

$r_o = \frac{\frac{1}{0.02} + 10}{3.2mA} = 18.8k\Omega$ – Cannot neglect! | $R_L = 18.8k\Omega \| 100k\Omega = 15.8k\Omega$

$A_V = \frac{10^6}{10^6 + 10^4}\frac{1.75mS(15.8k\Omega)}{1 + 1.75mS(15.8k\Omega)} = 0.956$ | $A_I = 10^6\frac{1.75mS(15.8k\Omega)}{1 + 1.75mS(15.8k\Omega)}\frac{1}{10^5} = 9.56$

$R_{IN} = R_G = 1\ M\Omega$ | $R_{OUT} = \frac{1}{g_m} \| r_o = 555\ \Omega$

$\mathbf{v}_{gs} = \mathbf{v}_s \frac{10^6}{10^6 + 10^4}\frac{1}{1 + 1.75mS(15.8k\Omega)} = 0.0346\mathbf{v}_s$ | $\mathbf{v}_s \le \frac{0.2(5-1)}{0.0346} = 23.2\ V$ But, v_{DS} must exceed $v_{GS} - V_{TN} \equiv V_{GS} - V_{TN} = 4V$ for saturation.

$V_{DS} = 10 - \mathbf{v}_o = 10 - 0.956\mathbf{v}_s \ge 4 \rightarrow \mathbf{v}_s \le 6.28\ V$ – Limited by the Q - point voltages

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