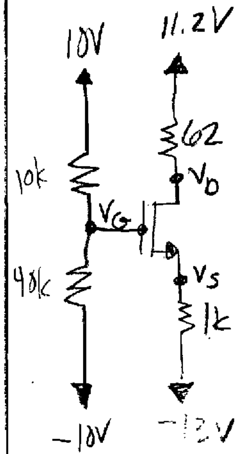
Solution | ECE 2280 | HW#8

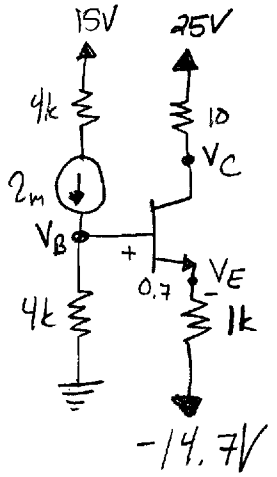
① $r_o = \infty$ $|V_{BE}| = 0.7$ $\beta = 100$

$V_t = 1V$ $k_n' \frac{W}{L} = 10m A/V^2$

$V_{DO} = 0.8V$ $V_{in} = 5 + 1m \sin 20t$

$\beta I_B = \frac{\beta}{\beta+1} I_E = I_C$





$V_B = (2m - I_B)\,4k$

$V_E = (\beta+1) I_B \cdot 1k - 14.7V = V_B - 0.7$

$101k I_B = V_B + 14 = 8 - 4k I_B + 14$

$105k I_B = 22$

$I_B = \frac{22}{105k} = 209.5 \mu A$

$I_C = 100 \cdot I_B = 20.95 mA$

$I_E = \frac{101}{100} I_C = 21.16 mA$

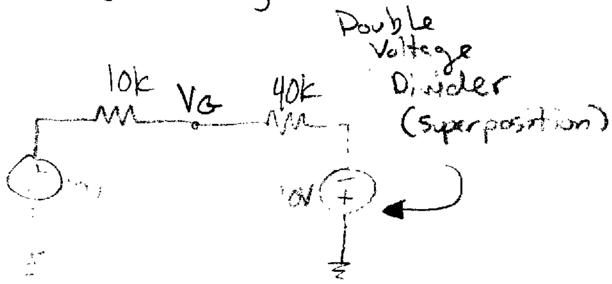
$V_B = (2m - 209.5\mu)\,4k = 7.162 V$

$V_C = 25 - 10(I_C) = 24.8 V$

$V_E = 6.46 V$

$I_G = 0$ $I_D = I_S$

$V_G = \frac{4}{5} 10 + \frac{1}{5}(-10) = 6V$



$V_S = -13V + I_D 1k \Rightarrow I_D = \frac{V_S + 13}{1k}$

$V_D = 11.2V - 62 I_D$

$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2 = 5m A/V^2 (6 - V_S - 1)^2 = 5m (5 - V_S)^2$

$\frac{V_S + 13}{5} = (5 - V_S)^2 = 25 - 10 V_S + V_S^2$

$V_S + 13 = 125 - 50 V_S + 5 V_S^2$

$V_S^2 - \frac{51}{5} V_S + \frac{112}{5} = 0 \Rightarrow V_S = \frac{16}{5}$ or ~~7~~ (Not in Sat.) $\Rightarrow I_D = 16.2mA$ or ~~20mA~~ (Not in Sat.)

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$V_S = 3.2V$ $V_D = 10.2V$ $V_G = 6V$

$I_D = 16.2mA$ $I_S = 16.2mA$ $I_G = 0A$

(a) $I_D = 16.2mA$

$I_S = 16.2mA$

$I_B = 209.5\mu A$

$I_E = 21.16mA$

$I_C = 20.95mA$

(b) $V_G = 6V$

$V_S = 3.2V$

$V_D = 10.2V$

$V_B = 7.16V$

$V_E = 6.46V$

(c) M_1 in Saturation?

$V_{GS} \geq V_t$?

$2.8V \geq 1V$ yes ☑

$V_{DS} - V_{GS} \geq -V_t$?

$7V - 2.8V \geq -1V$?

$4.2V \geq -1V$ yes ☑

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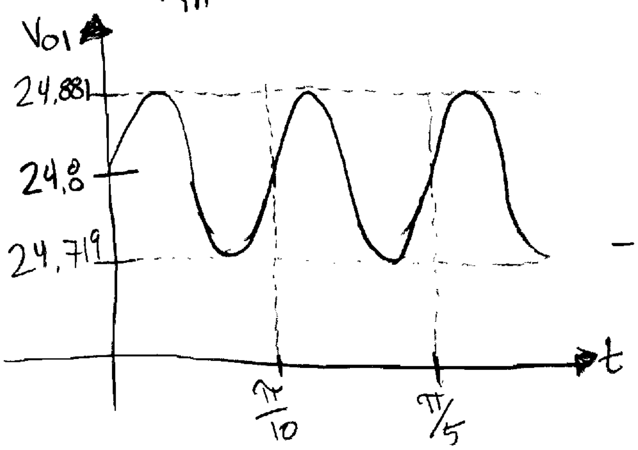
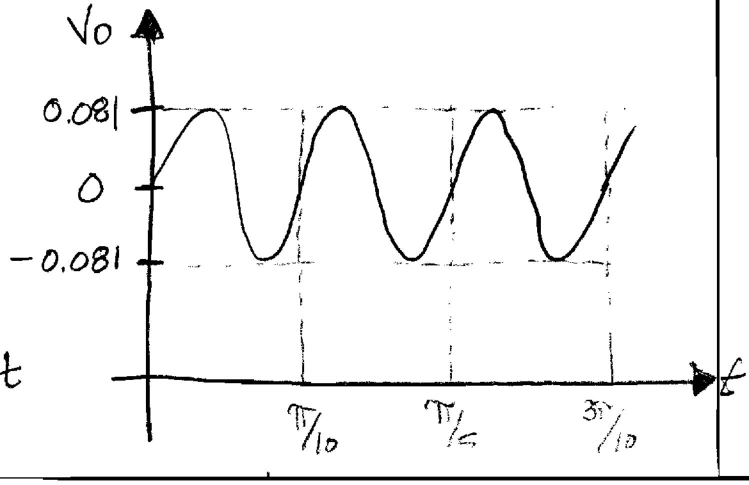
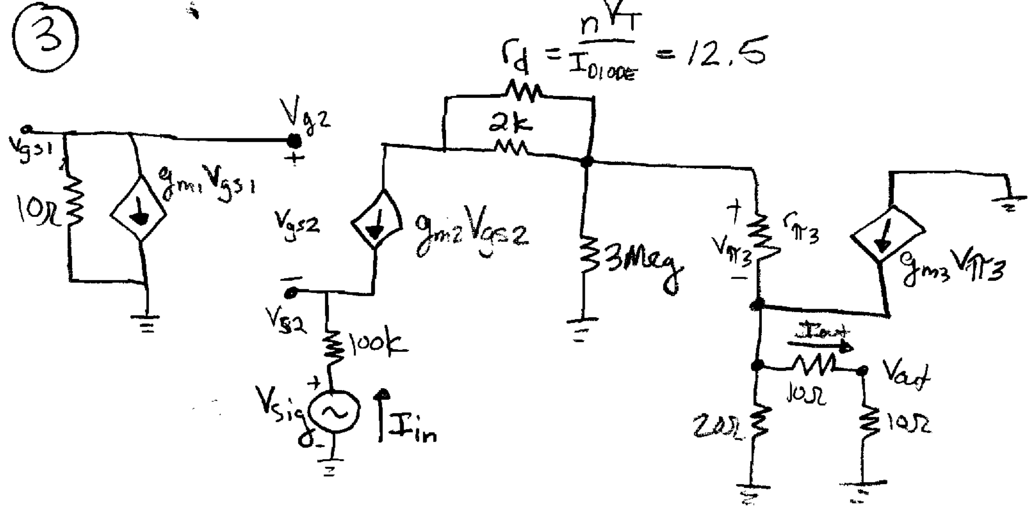
② $V_o / V_{in} = 81 V/V$





(3)



$V_{gs1} = -g_{m1}V_{gs1}\cdot 10\Omega$

$(1+10g_{m1})V_{gs1} = 0$

$V_{gs1} = 0$ since $1+10g_{m1} \neq 0$

which means $V_{gs2} = -V_{s2}$

$g_{m2} = \sqrt{2\frac{K_n'W}{L}I_D} = 6.32\,mA/V^2$

$g_{m1} = ?$

$r_d \| 2k = 12.4\Omega$

a) $r_d = \frac{nV_T}{I_{DIODE}} = 12.5\Omega$ $\quad$ $g_{m2} = 6.32\,mA/V^2$

$r_{\pi 3} = \frac{V_T}{I_B} = (\beta+1)\frac{V_T}{I_E}$ $\quad$ $g_{m3} = \frac{I_C}{V_T} = \frac{\frac{\beta}{\beta+1}I_E}{V_T}$

$r_{\pi 3} = 631.25$ $\quad$ $g_{m3} = 158.4\,mA/V^2$

b) $R_{in} = 200k \| 200k + \frac{1}{g_{m2}} = 100.2k\Omega = R_{in}$

c) $R_{out} = 10\Omega \left\| \left(10 + 20 \left\| \left(\frac{631 + 3Meg}{101}\right)\right)\right.$

$R_{out} = 7.5\Omega$

d) MidBand Gain? V_o/V_{sig}

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(3d cont')...

$$V_{s2} = V_{sig} \cdot \frac{1}{g_{m2}} \cdot \frac{1}{R_{in}} \qquad V_{gs2} = -V_{s2}$$

$$\frac{V_{gs2}}{V_{sig}} = -\frac{1}{g_{m2}} \cdot \frac{1}{R_{in}}$$

$$I = -g_{m2} V_{gs2} \left(12.5 \| 2k + 3Meg \| (631.25 + (101)(10))\right)$$

$$= -g_{m2} V_{gs2} (1652) \Rightarrow \frac{I}{V_{gs2}} = -g_{m2}(1652)$$

$$I_2 = I \cdot \frac{3Meg}{3Meg + 631.25 + 10 \cdot 101} \approx 0.999 I$$

$$\frac{I_2}{I} = 0.999$$

$$\frac{I_{out}}{I_2} = \frac{20 \cdot (101)}{(20+10+10)(101)} = \frac{1}{2}$$

$$\frac{V_{out}}{I_{out}} = 10\Omega$$

$$\frac{V_{out}}{V_{sig}} = \frac{V_{gs2}}{V_{sig}} \cdot \frac{I}{V_{gs2}} \cdot \frac{I_2}{I} \cdot \frac{I_{out}}{I_2} \cdot \frac{V_{out}}{I_{out}} = \left(-\frac{1}{g_{m2}} \cdot \frac{1}{R_{in}}\right)\left(-g_{m2}(1652)\right)\frac{0.999}{2}$$

$$\boxed{\frac{V_{out}}{V_{sig}} = 8.24\,mV/V}$$

$$\frac{I_{out}}{I_{in}} = \frac{V_{out}}{V_{sig}} \cdot \frac{I_{out}}{V_{out}} \cdot \frac{V_{sig}}{I_{in}} = \frac{R_{in}}{10\Omega} \cdot 8.24\frac{mV}{V}$$

$I_{out}/I_{in} = 82.6\ A/A$

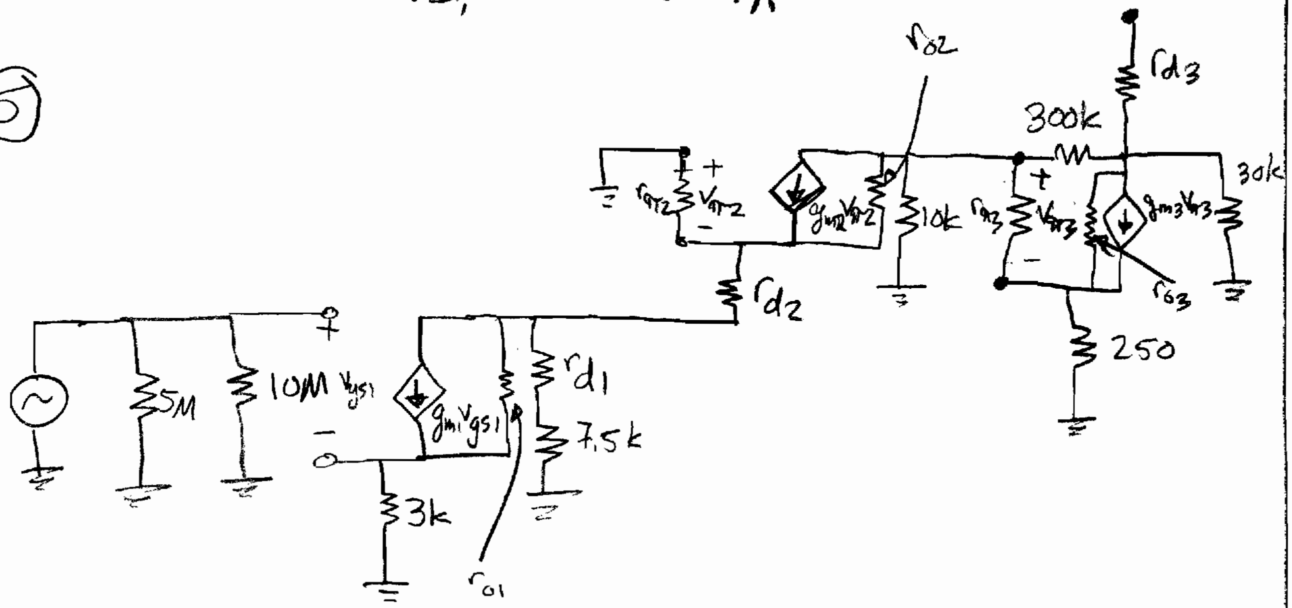
(4) a)

This is a horrible voltage amplifier because $V_o/V_i = 8.24\ mV/V$.

b)

This is a good current amplifier because $I_o/I_i = 82.6\ A/A$

(5)



(6) $\frac{V_{o1}}{V_4} = 83\frac{V}{V}$ $\frac{V_{o2}}{V_{o1}} = 1\frac{V}{V}$

$$\frac{V_o}{V_{sig}} = \frac{V_4}{V_{sig}} \cdot \frac{V_{o1}}{V_4} \cdot \frac{V_{o2}}{V_{o1}} \cdot \frac{V_o}{V_{o2}} = 83\frac{V}{V}$$

$V_{sig} = 100\,mVAC$

$V_o = 8.3\,VAC$

This is 42% of the voltage suplies available. (20V) This no longer qualifies as a "small-signal" and there will be significant distortion in the amplifier.

NOT A LINEAR AMPLIFIER

(7)

$C_3' = 1\,mF$

$R_{th3} = 10k\Omega \,||\, \frac{1}{g_{m1}} = 10k \,||\, \frac{1}{5m} = 196.07\,\Omega$

$f_L' = \frac{2\pi}{R_{th3} C_3} = 3.2 \times 10^{-5}\ Hz$

$C_4 = 1\mu F$

$R_{th} = R_L + R_1 \,||\, \left(\frac{r_{\pi 1}}{\beta+1} + \frac{R_Z}{\beta+1}\right) = 1k + 1k \,||\, \left(\frac{200 + 100k}{101}\right) \approx 1.5k\Omega$

$f_L'' = \frac{2\pi}{R_{th4} C_4} \cong 4200\ Hz$ or $4.2\ kHz$

$$f_L = f_L'' = 4.2\ kHz$$