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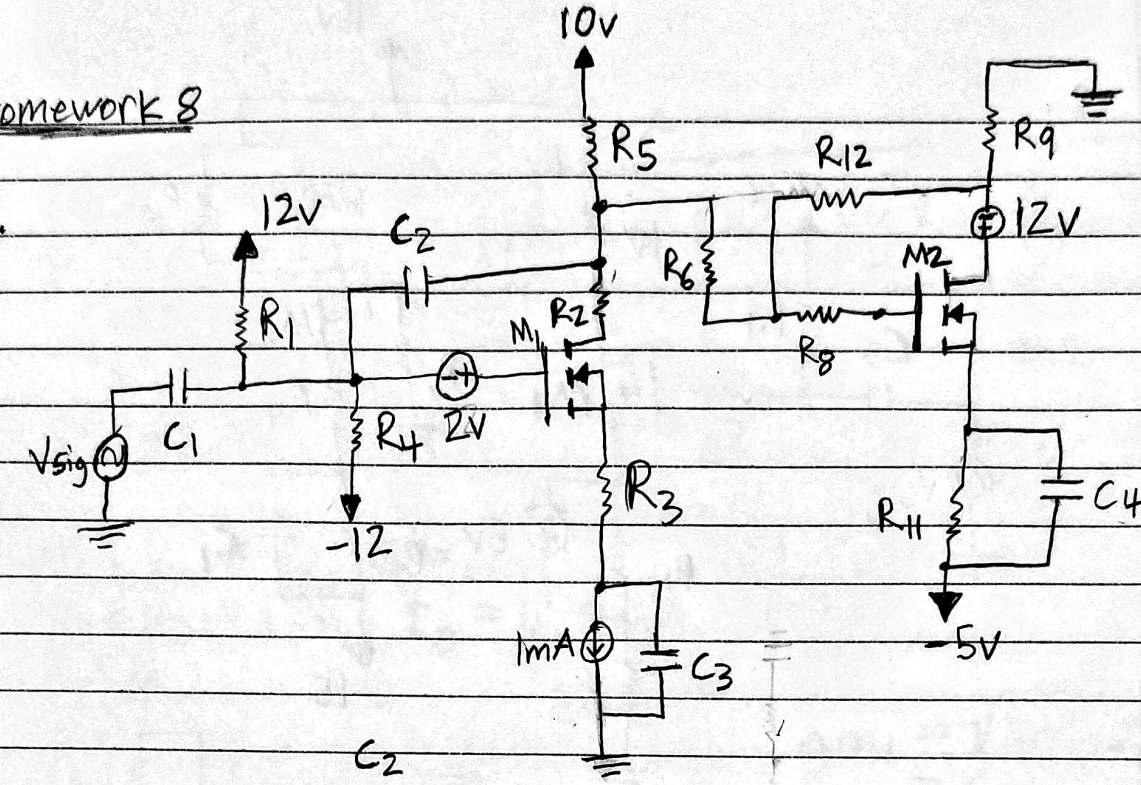
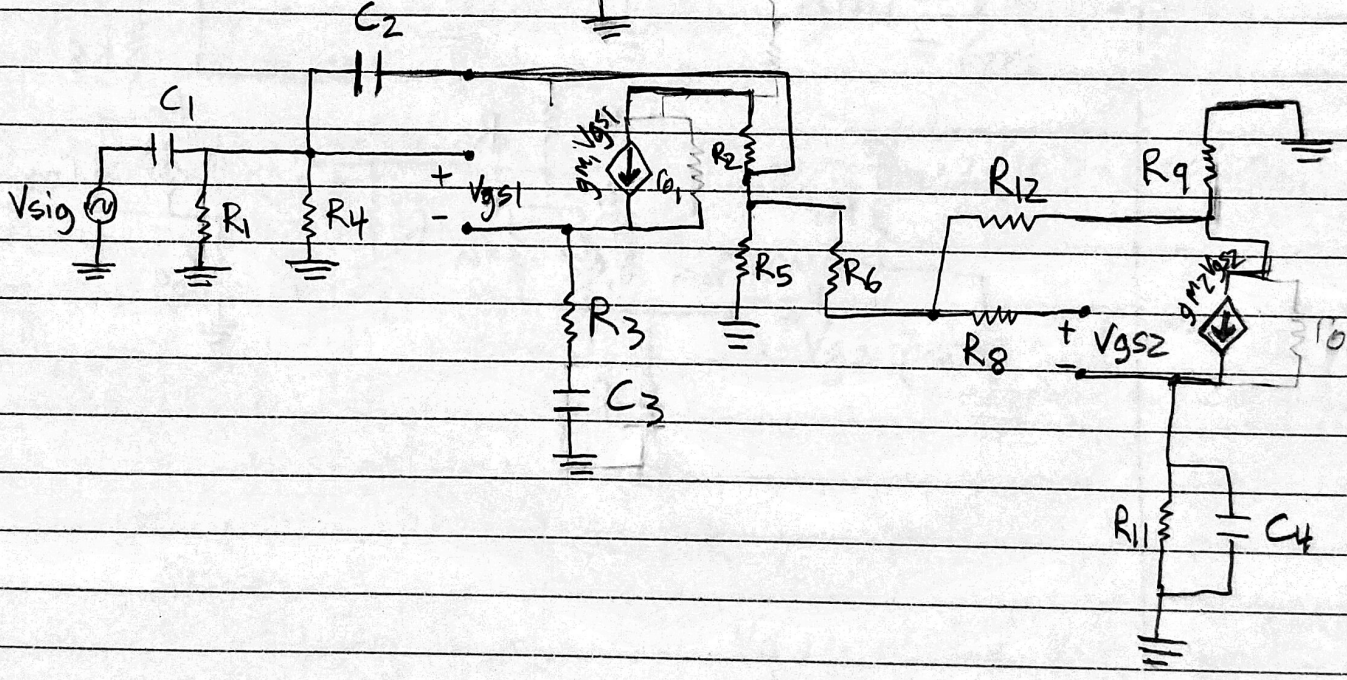
ECE 2280

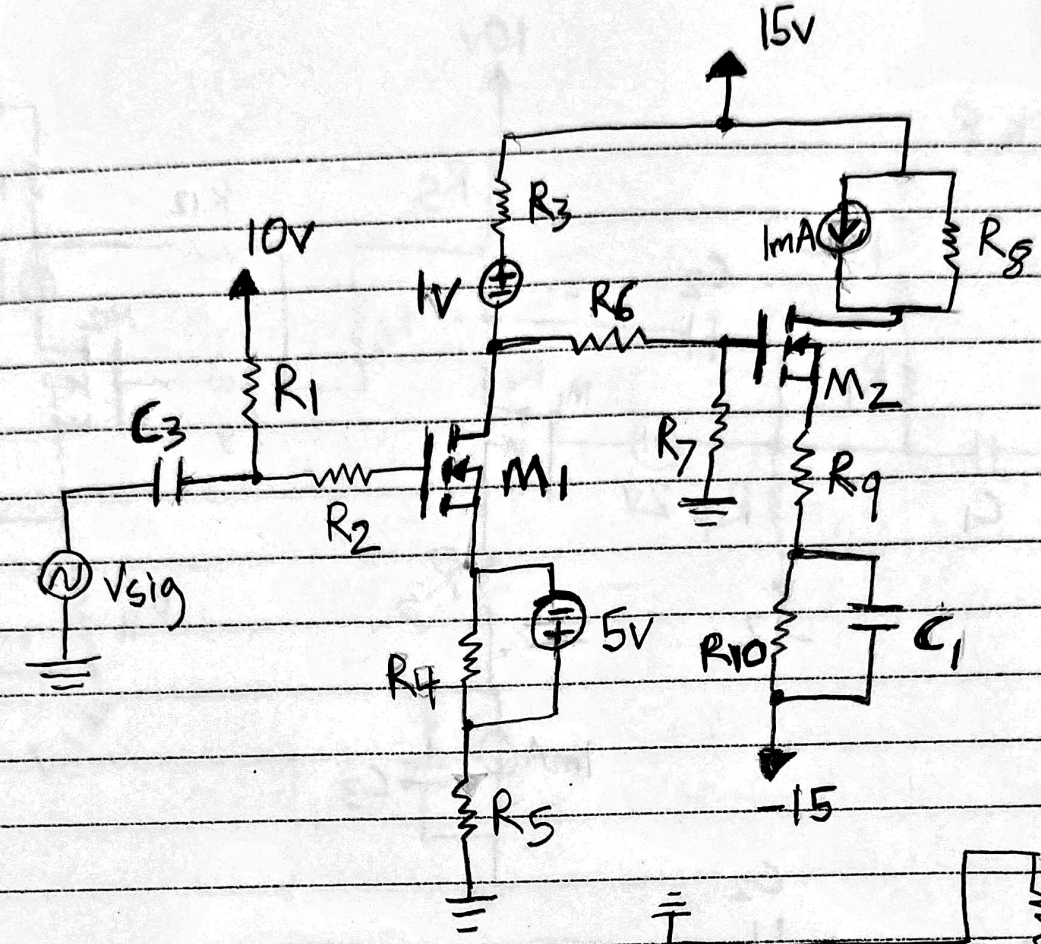
Homework 8

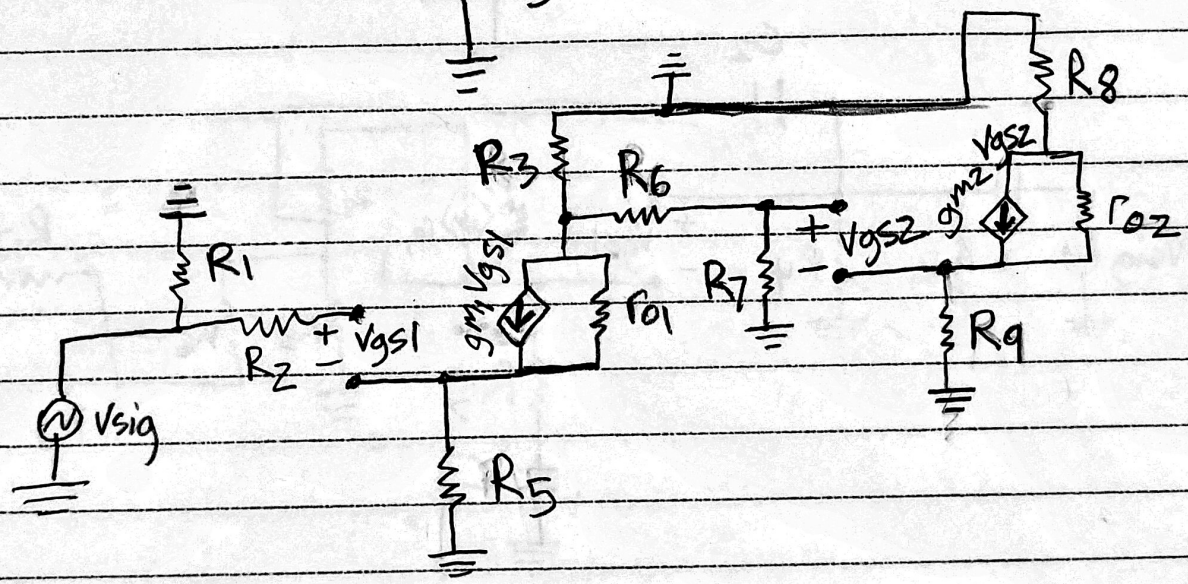
1.



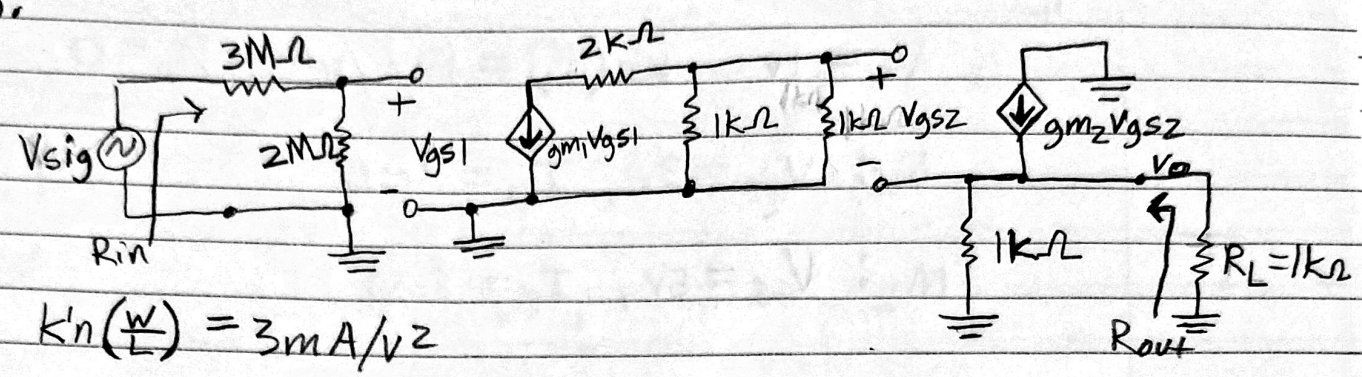


2.


15V
10V
1V
1mA
R_3
R_8
R_6
M_2
R_1
C_3
M_1
R_7
R_9
R_2
V_{sig}
5V
R_{10}
C_1
R_4
-15
R_5


R_8
R_3
R_6
V_{gs2}
g_{m2}
r_{o2}
R_1
$+ V_{gs2} -$
$g_{m1}V_{gs1}$
r_{o1}
R_7
R_9
$+ V_{gs1} -$
R_2
V_{sig}
R_5

3.



$k'_n\left(\frac{W}{L}\right) = 3mA/V^2$

M_1: $V_{GS} = 4V$, $I_D = 6mA$
M_2: $V_{GS} = 5.3V$, $I_D = 16.7mA$
$\lambda = 0$

$g_{m1} = \sqrt{3m \cdot 2(6m)}$
$= 6m$

$g_{m2} = \sqrt{3m \cdot 2(16.7m)} = 10m$

a) $R_{in} = 5M\Omega$

b) $R_{out} = 1k\Omega \,||\, \frac{1}{g_{m2}}$
$= 91\Omega$

c)

$V_o = \frac{g_{m2} V_{GS2} (1k\Omega)}{2k} \cdot 1k$

$V_{gs2} = V_{g2} - V_{s2}$

$V_{s2} = V_o$

$V_{g2} = \frac{-g_{m1} V_{gs1} (1k)}{2k} (1k)$

$V_{gs1} = V_{g1} - V_{s1}$

$V_{s1} = 0$

$V_{g1} = \frac{2M(V_{sig})}{5M}$

$V_{g2} = \frac{(-6m)\left(\frac{2M(V_{sig})}{5M}\right)(1M)}{2k}$

$V_{gs2} = -1.2\, V_{sig} - V_o$

$V_o = \frac{(10m)(-1.2\, V_{sig} - V_o)(1M)}{2k}$

$V_o = \frac{-12k\, V_{sig} - 10k V_o}{2k}$

$V_o = 6\, V_{sig} - 5\, V_o$

$6V_o = -6V_{sig}$

$-V_o = V_{sig}$

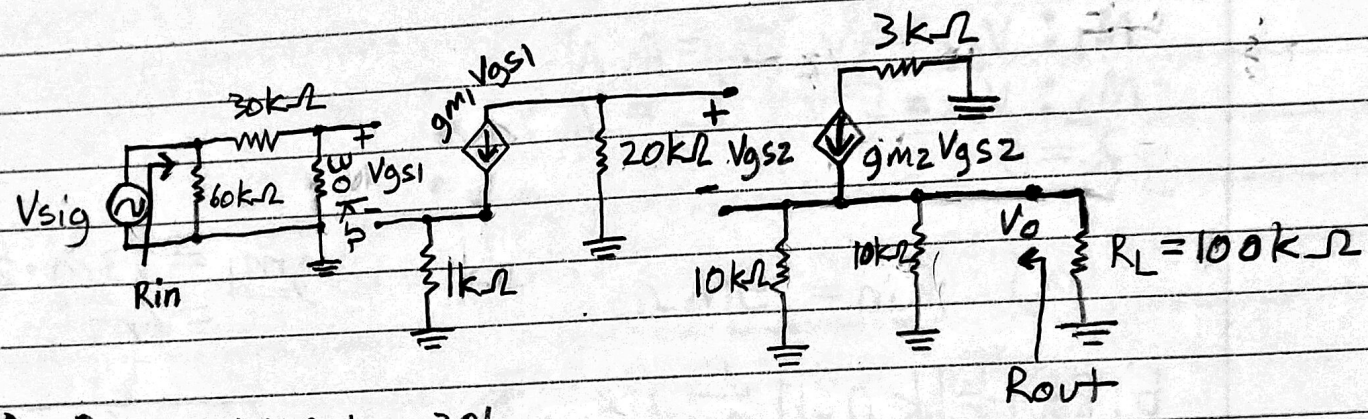
$\frac{-V_o}{V_{sig}} = 1$ $\quad \boxed{\frac{V_o}{V_{sig}} = -1}$

4.

$V_t = 1v \quad kn\left(\frac{W}{L}\right) = 1mA/V^2 \quad \lambda = 0$

M_1: $V_{GS} = 3v$, $I_D = 2mA$

M_2: $V_{GS} = 5v$, $I_D = 8mA$



a) $R_{in} = 60k \| 60k = 30k$

b) $R_{out} = 10k \| 10k \| \frac{1}{gm_2}$

$= 5k \| \frac{1}{gm_2}$

$= 238\Omega$

$gm_2 = 1mA(5v - 1v)$

$= 4mA$

c) $V_o = \frac{gm_2 V_{gs2}(5k)}{105k}(100k) = 19V_{gs2}$

$V_{gs2} = V_{g_2} - V_{s_2}$

$V_{s2} = V_o \quad V_{s2} = \frac{gm_2 V_{gs2}(100k)}{105k}(5k) = 19V_{gs2}$

$V_{g_2} = -gm_1 V_{gs1}(20k)$

$= -V_{gs1}(40)$

$gm_1 = 1mA(3v - 1v)$

$= 2mA$

$$V_{gs1} = V_{g1} - V_{s1}$$

$$V_{s1} = g_{m1} V_{gs1} (1k) = 2V_{gs1}$$

$$V_{g1} = \frac{V_{sig}(30k)}{60k} = \frac{V_{sig}}{2}$$

$$V_{gs1} = \frac{V_{sig}}{2} - 2V_{gs1}$$

$$3V_{gs1} = \frac{V_{sig}}{2}$$

$$V_{gs1} = \frac{V_{sig}}{2}$$

$$V_{gs2} = \left(-\frac{V_{sig}}{2}\right) 40 - 19V_{gs2}$$

$$20V_{gs2} = -20V_{sig}$$

$$V_{gs2} = -V_{sig}$$

$$V_o = 19(-V_{sig})$$

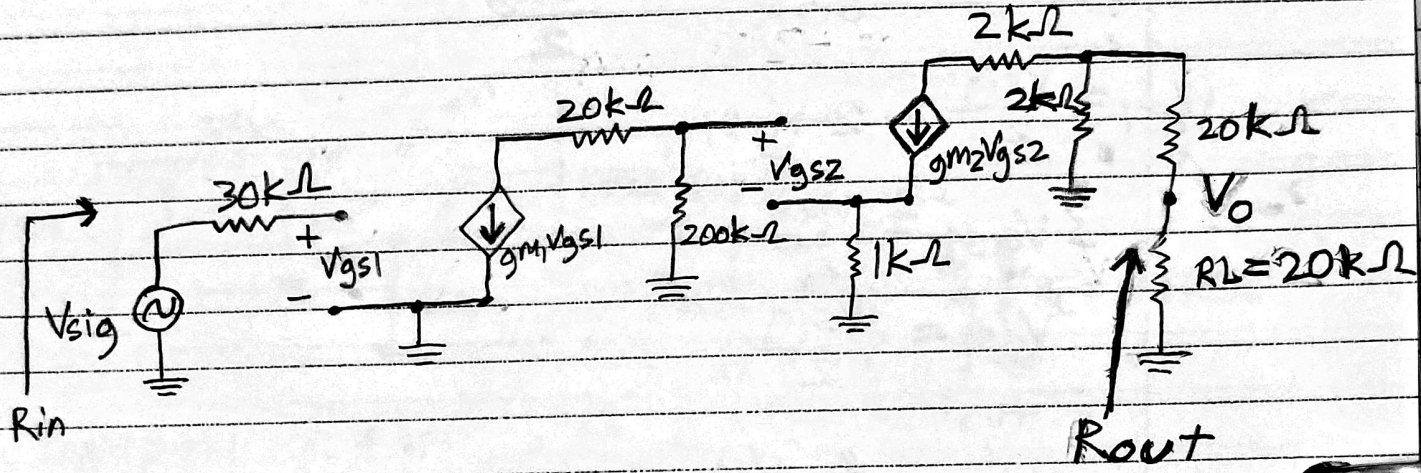
$$\frac{V_o}{V_{sig}} = -6.35V$$

5.

$V_t = 1V$, $k_n\left(\frac{W}{L}\right) = 2mA/V^2$, $\lambda = 0$

M_1: $V_{GS} = 1.5V$, $I_D = 0.25mA$

M_2: $V_{GS} = 13.5V$, $I_D = 156.25mA$



a) $R_{in} = 0$

b) $R_{out} = 20k + 2k$
$= 22k\Omega$

$g_{m2} = \sqrt{2mA(2)(156.25mA)}$
$= 25m$

c) $V_o = \frac{-g_{m2} V_{gs2} (2k)}{40k} (20k) = -25 V_{gs2}$

$V_{gs2} = V_{g2} - V_{s2}$

$g_{m1} = \sqrt{2mA(2)(0.25m)}$
$= 1m$

$V_o = V_{s2} = g_{m2} V_{gs2} (1k) = 25 V_{gs2}$

$V_{g2} = -g_{m1} V_{gs1} (200k)$
$= -200 V_{gs1}$

$V_{gs1} = V_{g1} - V_{s1}$

$V_{s1} = 0$ $\quad V_{gs1} = V_{sig}$
$V_{g1} = V_{sig}$

$V_{g2} = -200 V_{sig}$

$V_{s2} = 25 V_{gs2}$

$V_{gs2} = -200 V_{sig} - 25 V_{gs2}$

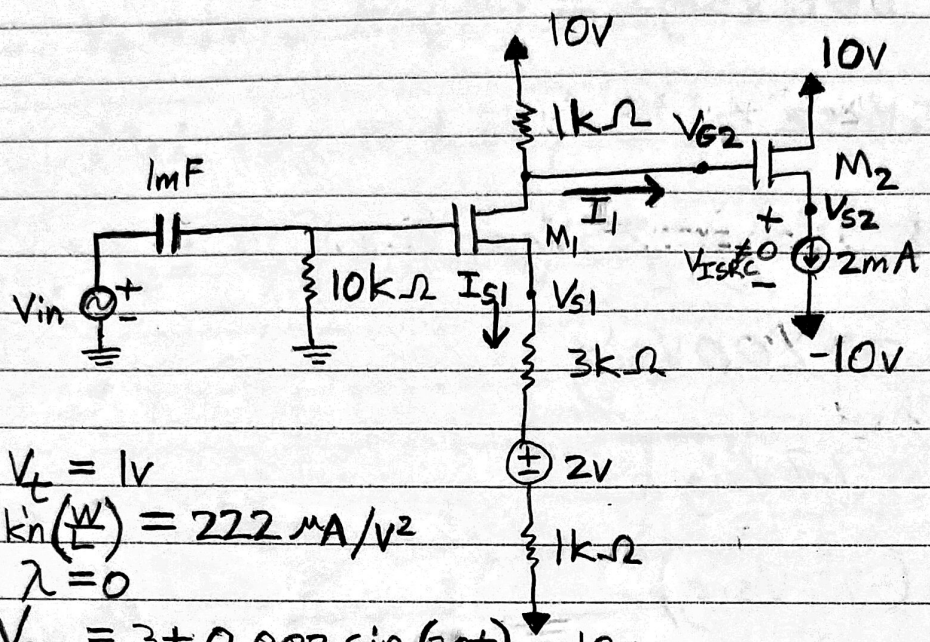
$26 V_{gs2} = -200 V_{sig}$

$V_{gs2} = -7.7 V_{sig}$

$V_o = -25(-7.7 V_{sig})$

$V_o = 183 V$

6.



$V_t = 1V$

$k_n\left(\frac{W}{L}\right) = 222\,\mu A/V^2$

$\lambda = 0$

$V_{IN} = 3 + 0.002\sin(20t)$ -10V

$I_1 = 0 \qquad V_{G2} = 9$

$$2mA = \frac{1}{2}(222\mu)(9 - (-10 + V_{S_2}) - 1)^2$$

$$V_{S_2} = 3.755$$

$V_{G1} = 0$

$$I_{S1} = \frac{1}{2}(222\mu)(0 - (-10 + 1kI_{S1} + 2 + 3kI_{S1}) - 1)^2$$

$$9009I_{S1} = (7 - 4kI_{S1})^2$$

$$9009I_{S1} = 49 - 28kI_{S1} - 28kI_{S1} + 16MI_{S1}^2$$

$$0 = 16MI_{S1}^2 - 65009I_{S1} + 49$$

$$I_{S1} = \frac{65009 \pm \sqrt{-65009^2 - 4(16M)(49)}}{2(16M)} = 3mA, \boxed{1mA}$$

(33017.7)

For 3mA:

$V_{D_1} = 10 - 1k(3mA) = 7v$

$V_{S_1} = -10 + (1k)3mA + 2 + (3k)3mA = 4v$

$V_{DS_1} \quad V_{GS_1} \quad V_t$

$7 - 4 > (0 - 4) - 1$

$3 > -5$ ✓

$V_{GS} \quad V_t$

$-4 > -1$ X

For (1mA):

$V_{D1} = 10 - 1k(1mA) = 9v$

$V_{S1} = -10 + 1k(1mA) + 2 + 3k(1mA) = \boxed{-4v}$

$V_{DS1} > V_{GS1} - V_t$

$9 + 4 > 4 - 1$ ✓

$V_{GS1} \quad V_t$

$4 > -1$ ✓

$V_{S2Max} = 4(2mA) + 3.755 = 3.763$

$V_{S2Min} = 3.755 - 4(2mA) = 3.747$

$V_{DS2} > V_{GS2} - V_t$

$10 - 14.755 > (19 - 14.755) - 1$ ✓

$V_{GS_2} > V_t$

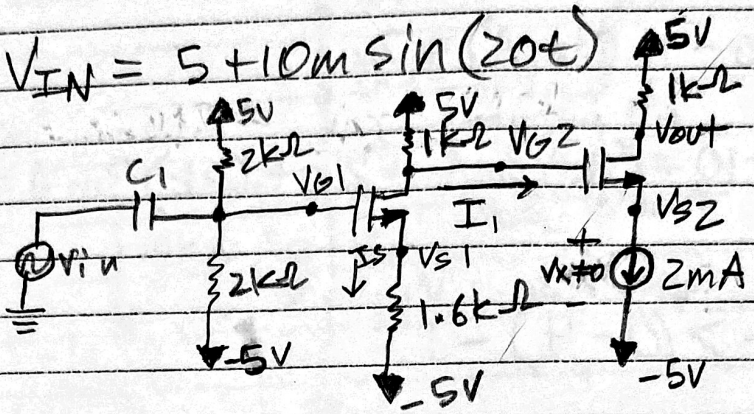
$-5.2457 > -1$ ✓

$V_{S2}total = 3.75 - 8m\sin(20t)$

7.

$V_t = 1V \quad k'n\left(\frac{W}{L}\right) = 1mA/V^2 \quad \lambda = 0$

$V_{IN} = 5 + 10m\sin(20t)$



$+5V/V$

$V_{G1} = 0$

$$I_S = \frac{1}{2}(1mA)(0-(-5+1.6k(I_S))-1)^2$$

$$2kI_S = 5 - 1.6k(I_S) - 1$$

$$2kI_S = (4 - 1.6k(I_S))^2$$

$$2kI_S = 16 - 6400(I_S) - 6400(I_S) + 2.56MI_S^2$$

$$0 = 16 - 14800I_S + 2.56MI_S^2$$

$$I_S = \frac{14800 \pm \sqrt{-14800^2 - 4(2.56M)(16)}}{2(2.56M)}$$

7429.7

$= 4.3mA, \boxed{1.4mA}$

For 4.3mA:

$V_{D1} = 5v - 1k(4.3mA) = 700mV$

$V_{S1} = -5v + 1.6k(4.3mA) = 1.88v$

$1.18 > .88$ ✓

$-1.88 > 1$ X

For 1.4mA:

$V_{D1} = 5 - 1k(1.4mA) = 3.6V$

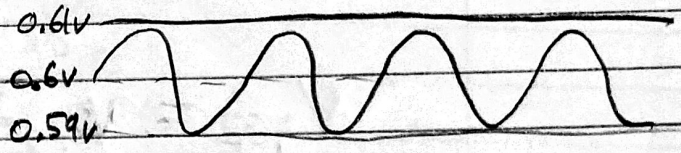
$V_{S1} = -5 + 1.6k(1.4mA) = -2.76$

$V_{SZ_{min}} = -5(2mA) + 0.6V = 0.59v$

$V_{SZ_{max}} = 0.6V + 5(2mA) = 0.61$

$3.6 + 2.76 > 2.76 - 1$ ✓

$2.76 > 1$ ✓

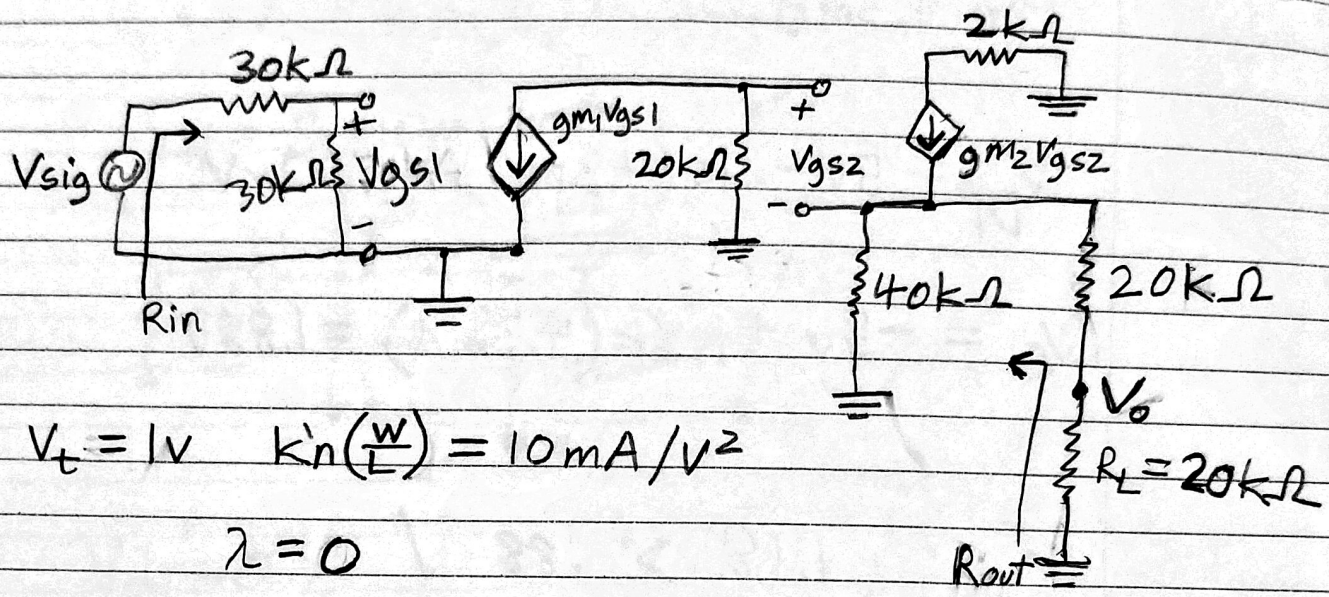


$V_{GZ} = 5 - 1k(1.4mA) = 3.6v$

$2mA = \frac{1}{2}(1mA)(3.6 - V_{SZ} - 1)^2$

$V_{SZ} = 0.6V$

8.



$V_t = 1V \quad k'_n\left(\frac{W}{L}\right) = 10mA/V^2$

$\lambda = 0$

M_1: $V_{GS} = 9V$, $I_D = 3.2A$

M_2: $V_{GS} = 1.18V$, $I_D = 162\mu A$

$g_{m2} = \sqrt{10mA \cdot 2(162\mu A)}$
$= 1.8m$

$R_{in} = 60k\Omega$

$R_{out} = 20k\Omega + 40k \,||\, \frac{1}{g_{m2}}$
$= 20,548\Omega$

$g_{m1} = \sqrt{10mA \cdot 2(3.2A)}$
$= 25.3m$

$V_o = \frac{g_{m2} V_{gs2} (40k)}{80k\Omega} (20k) = 18\, V_{gs2}$

$V_{gs2} = V_{g2} - V_{s2}$

$V_{g2} = -g_{m1} V_{gs1} (20k) = -5060\, V_{gs1}$

$V_{s2} = \frac{g_{m2} V_{gs2} (40k)}{80k\Omega} (40k) = 36\, V_{gs2}$

$$V_{gs1} = V_{g1} - V_{s1}$$

$$V_{g1} = \frac{V_{sig}(30k)}{60k}$$

$$V_{s1} = 0$$

$$V_{gs1} = \frac{V_{sig}}{2}$$

$$V_{g2} = \frac{-5060\, V_{sig}}{2} = -2530 V_{sig}$$

$$V_{gs2} = -2530 V_{sig} - 36\, V_{gs2}$$

$$-5059 V_{gs2} = -36\, V_{sig}$$

$$V_{gs2} = 7.1m V_{sig}$$

$$\frac{V_o}{V_{sig}} = -1231$$

9.

$V_t = 2V$, $\lambda = 0$, $k'_n\left(\frac{W}{L}\right) = 1mA/V^2$

$V_{IN} = 5 + 1m\sin(\omega t)$

$10mA = \frac{1}{2}(1mA)(0 - V_S - 2)^2$

$V_S = -6.47V$

$V_D = 5V$

$V_{S\,max} = 2(10mA) - 6.47 = -6.45$

$V_{S\,min} = -2(10mA) - 6.47 = -6.49$

$V_{DS} \quad V_{GS} - V_t$

$5 + 6.47 > 0 - (-6.47) - 2$ ✓

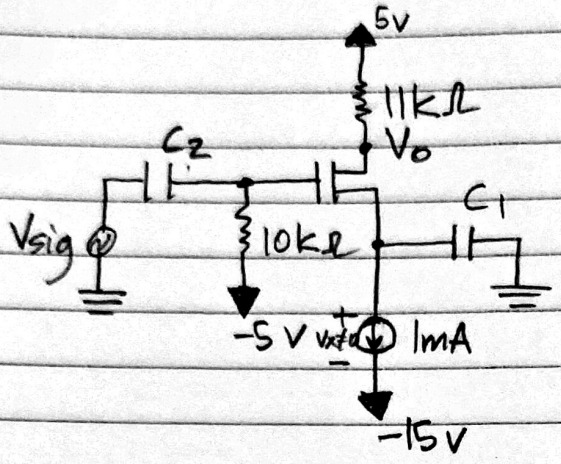
$V_{GS} \quad V_t$

$0 + 6.47 > 2$ ✓

Because the current source is 10mA and not 1mA.

Also the capacitor could cause the difference, also outside of operating region

10.



$V_t = 2V, \quad \lambda = 0$

$k_n\left(\frac{W}{L}\right) = 2mA/V^2$

$V_{IN} = 5 + 50m \sin(\omega t)$

It is outside of the operating region

$V_G = -5V$

$1mA = \frac{1}{2}(2mA)(-5 - V_S - 2)^2$

$V_S = -8V$

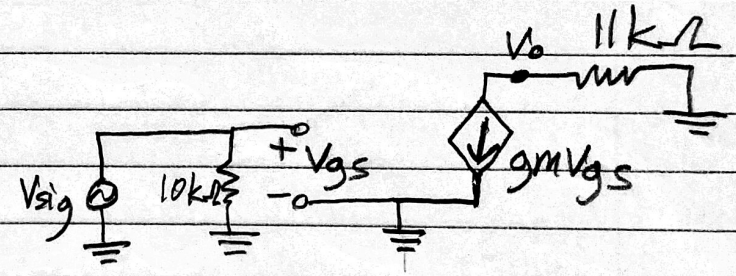
$V_D = 5 - 11k(1mA) = -6V$

$V_{DS} \quad V_{GS} - V_t$

$14 \geq 3 - 2$ ✓

$V_{GS} > V_t$

$3 > 2$ ✓



$R_{in} = 10k\Omega$

$R_{out} = 11k\Omega$

$V_o = -g_m V_{gs}(11k\Omega)$

$V_{gs} = V_{sig} - 0$

$g_m = 2mA(3-2) = 2mA$

$\frac{V_o}{V_{sig}} = -22$