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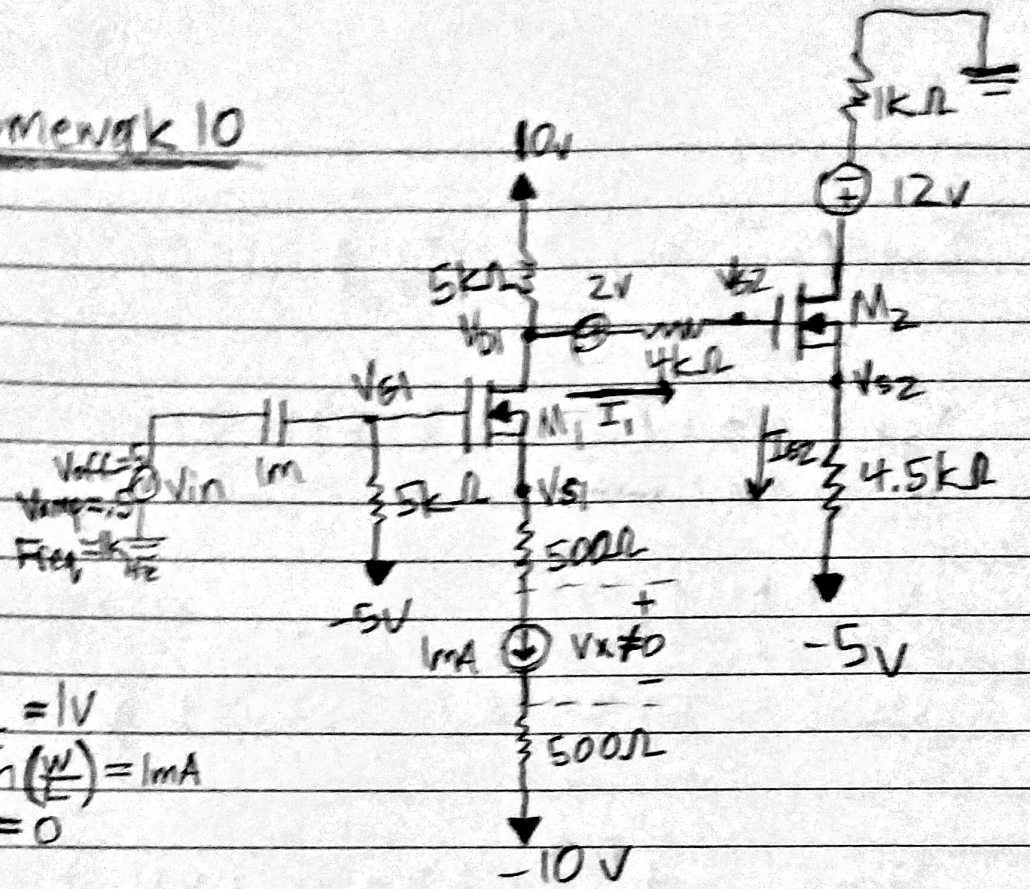
ECE 2280

Homework 10

1.



$V_t = 1V$

$k_n\left(\frac{W}{L}\right) = 1mA$

$\lambda = 0$

$$V_{G1} = -5V$$

$$1mA = \frac{1}{2}(1m)(-5-V_{S1}-1)^2$$

$$V_{S1} = -7.41$$

$$I_1 = 0$$

$$V_{D1} = 10-(1m)(5k) = 5V$$

$$V_{G2} = 10-5+2 = 7V$$

$$I_{S2} = \frac{1}{2}(1m)(7+5-I_{S2}(4.5k)-1)^2$$

$$500I_{S2} = (11-I_{S2}(4.5k))^2$$

$$500I_{S2} = 121-99000I_{S2}+20.25M I_{S2}^2$$

$$0 = 121-99500I_{S2}+20.25M I_{S2}^2$$

$$I_{S2} = \frac{99.5kI_{S2} \pm \sqrt{-99.5k^2-4(20.25M)(121)}}{2(20.25M)}$$

9962.43

$I_{S2} = 2.7mA, \boxed{2mA}$

$V_{S2} = -5v + (2.7mA)(4.5k) = 7.15v$
$V_{D2} = 1k(2.7mA) - 12v = -9.3$

$|V_{DS}| \quad |V_{GS}| - |V_t|$
$16.45 > 7 - 7.15 - 1 \checkmark \quad -.15 > 1 \times$

$V_{S2} = -5v + (2mA)(4.5k) = 4V$

$V_{D2} = 1k(-2mA) - 12v = -10$

$-10 - 4 > (7 - 4) - 1$

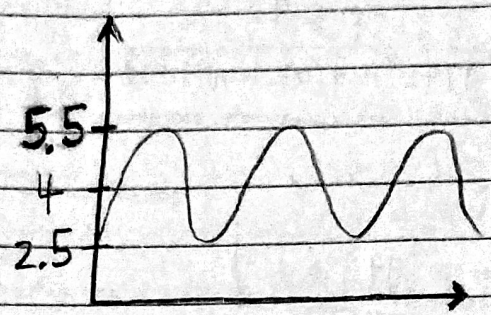
$14 > 2 \checkmark \quad 3 > 1 \checkmark$

Bias point: $V_{GS_1} = 2.41V$
$I_{D_1} = 1mA$

2.

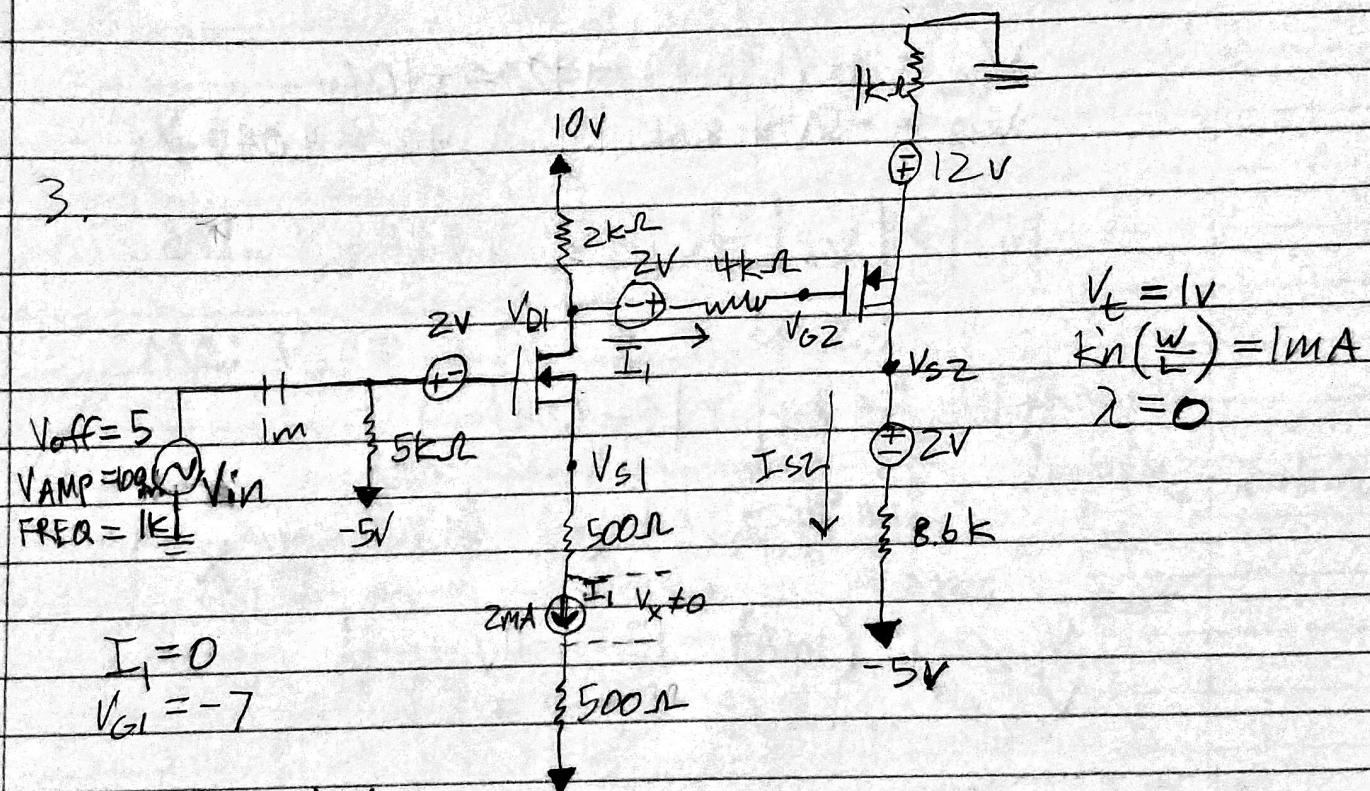
$$\frac{V_{s2}}{V_{in}} = (-3)(.5) = -1.5$$

$$V_{s2\,total} = 4 \pm -1.5$$



yes

3.



$V_t = 1V$

$k_n\left(\frac{W}{L}\right) = 1mA$

$\lambda = 0$

$I_1 = 0$

$V_{G1} = -7$

$$2mA = \frac{1}{2}(1mA)(-7 - V_{s1} - 1)^2 - 15V$$

$$4 = (-8 - V_{s1})^2$$

$$-10V = V_{s1}$$

$$V_{G2} = 10 - 2k(2m) + 2 = 8V$$

$$I_{s2} = \frac{1}{2}(1m)(8 + 5 - (I_{s2})(8.6k) - 2 - 1)^2$$

$$2k I_{S2} = (10 - I_{S2}(8.6k))^2$$

$$2k I_{S2} = 100 - 172k I_{S2} + 73.96M I_{S2}^2$$

$$0 = 100 - 174k I_{S2} + 73.9M I_{S2}^2$$

$$I_{S2} = \frac{174k \pm \sqrt{174k^2 - 4(73.9M)(100)}}{2(73.9M)} \qquad 26305.9$$

$$= 1.4mA \quad = \boxed{999\mu A}$$

$$V_{D2} = 1k(1.4mA) - 12 = -10.6V$$
$$V_{S2} = -5v + 8.6k(1.4mA) + 2 = 9.04V$$

$$|V_{DS}| > |V_{GS}| - |V_t|$$

$$|-10.6 - 9.04| > |8 - 9.04| - 1$$

$$19.64 > .04 \checkmark \qquad -1.04 < 1 \times$$

$$V_{D2} = 1k(1mA) - 12 = -11V$$
$$V_{S2} = -5v + 8.6k(1mA) + 2 = 5.6V$$

$$|-11 - 5.6| > |8 - 5.6| - 1 \qquad 2.4 > 1$$

$$16.6 > 1.4 \checkmark \qquad \checkmark$$

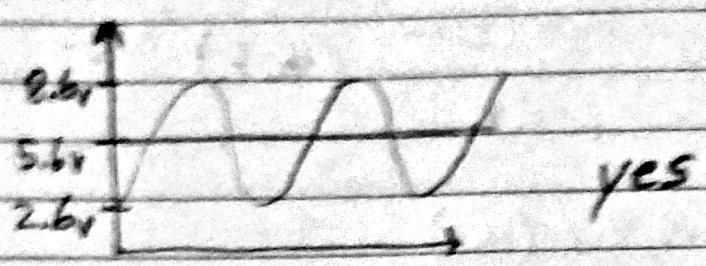
Bias Point:

$$V_{GS1} = 3V$$
$$I_{D1} = 2mA$$

4.

$$\frac{V_{s2}}{V_{in}} = (-30)(.1) = -3V$$

$$V_{S2_{total}} = 5.6 \pm -3V$$



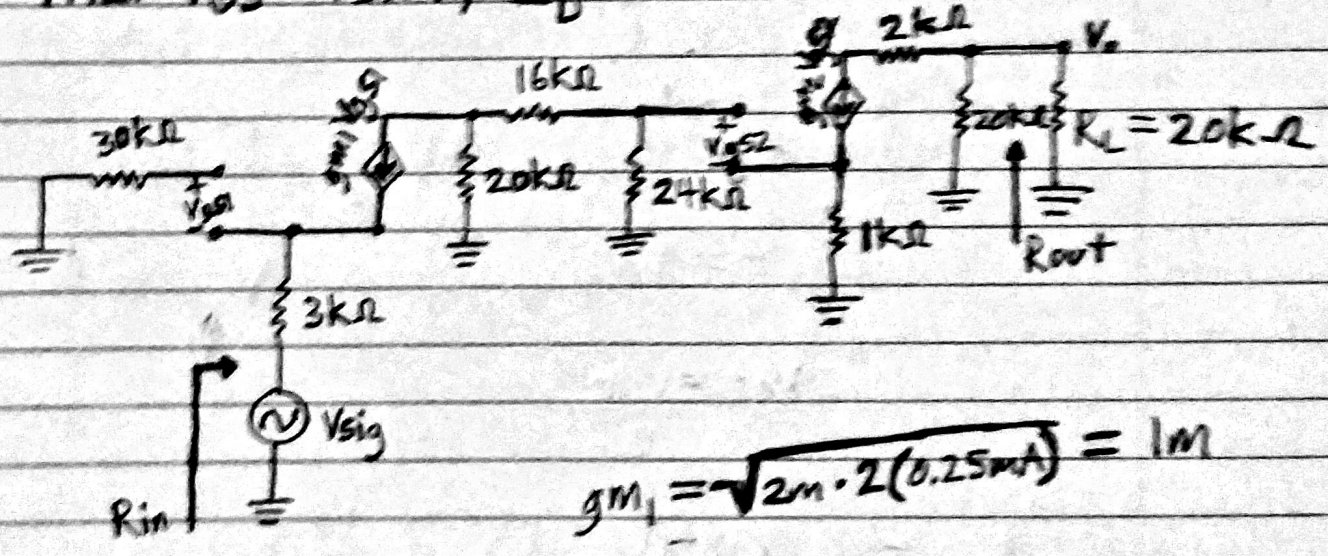
yes

5.

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

M1: $V_{GS} = 1.5v$, $I_D = 0.25mA$

M2: $V_{GS} = 13.5v$, $I_D = 156.25mA$



$$gm_1 = \sqrt{2n \cdot 2(0.25mA)} = 1m$$

$$R_{in} = 3k + \frac{1}{gm_1} = 4k\Omega$$

$$R_{out} = 20k\Omega$$

$$V_o = \frac{-g_{m_2} V_{gs2} (20k\Omega)}{40k\Omega} (20k\Omega)$$

$$V_{gs2} = V_{g_2} - V_{s2}$$

$$V_{g2} = \frac{-g_{m1} V_{gs1} (20k\Omega)}{60k\Omega} (40k)$$

$$V_{s2} = g_{m_2} V_{gs2} (1k\Omega)$$

$$V_{gs1} = V_{g_1} - V_{s1}$$

$$V_{s1} = g_{m_1} V_{gs1} (1k\Omega) - V_{sig}$$

$$V_{g1} = 0$$

$$g_{m_2} = \sqrt{2m \cdot 2(156.25m)} = 25m$$

$$V_{gs1} = -1m\, V_{gs1} (1k) + V_{sig}$$

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

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

$$V_{g2} = \frac{-1m \left(\frac{V_{sig}}{2}\right) (20k)}{60k} (40k)$$

$$V_{g2} = -V_{sig}\, 6.66$$

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

$V_{gs2} = -V_{sig}\, 6.66 - 25 V_{gs2}$

$V_{gs2} = -.2664 V_{sig}$

$$V_o = \frac{-25m(-.2664 V_{sig})(20k\Omega)}{40k\Omega} 20k\Omega$$

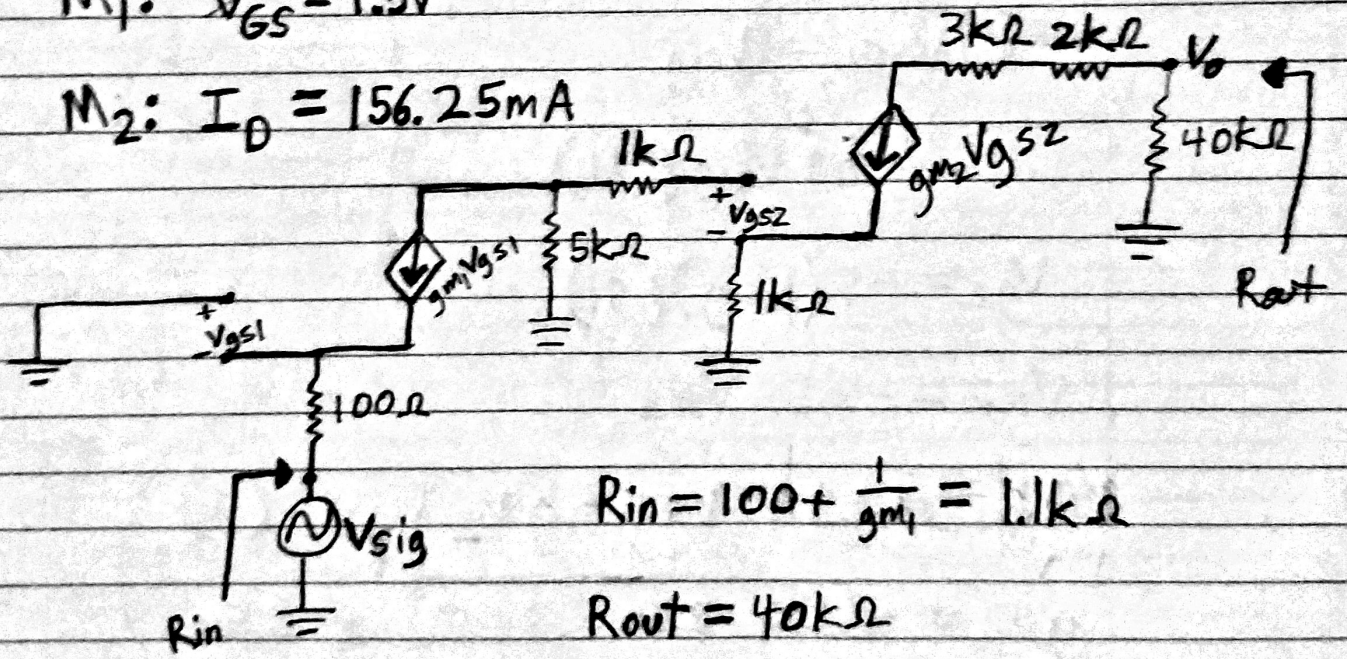
$$\frac{V_o}{V_{sig}} = -19.2\ V/V$$

6.

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

M_1: $V_{GS} = 1.5V$

M_2: $I_D = 156.25mA$



$R_{in} = 100 + \frac{1}{gm_1} = 1.1k\Omega$

$R_{out} = 40k\Omega$

$gm_1 = 2mA\,(1.5-1) = 1m$

$V_o = -g_{m2} V_{gs2} (5k)$

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

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

$V_{g2} = -g_{m1} V_{gs1} (5k)$

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

$V_{s1} = g_{m1} V_{gs1} (100) - V_{sig}$

$V_{g1} = 0$

$V_{s1} = 100m\, V_{gs1} - V_{sig}$

$V_{gs1} = -100m\, V_{gs1} + V_{sig}$

$1.1 V_{gs1} = V_{sig}$

$V_{gs1} = V_{sig}(.91)$

$V_{g2} = -5(V_{sig})(.91)$

$V_{g2} = -4.55\, V_{sig}$

$V_{gs2} = -4.55 V_{sig} - g_{m2} V_{gs2} (1k)$

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

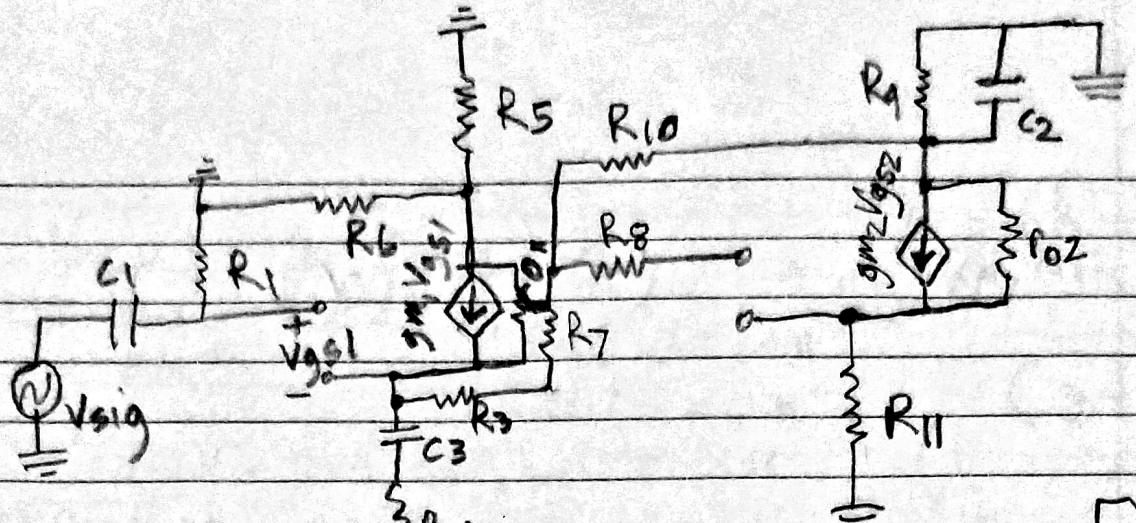
$V_{gs2} = -4.55 V_{sig} - 25\, V_{gs2}$

$V_{gs2} = -.175 V_{sig}$

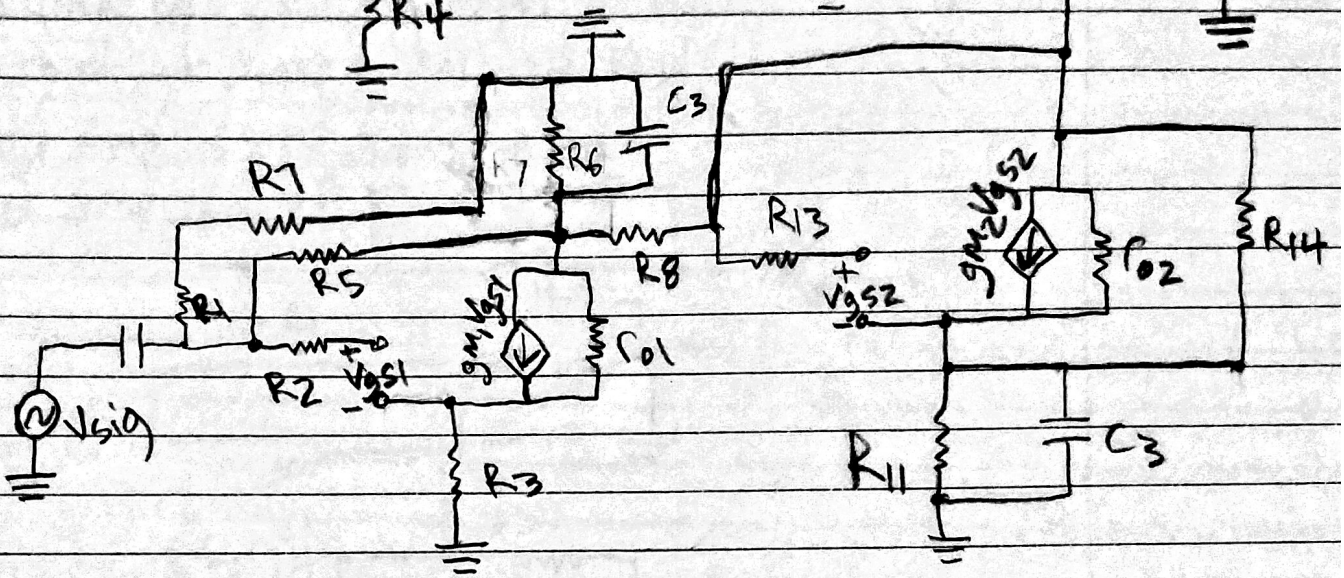
$V_o = 21.875 V_{sig}$

$V_o = -175\ V/V$

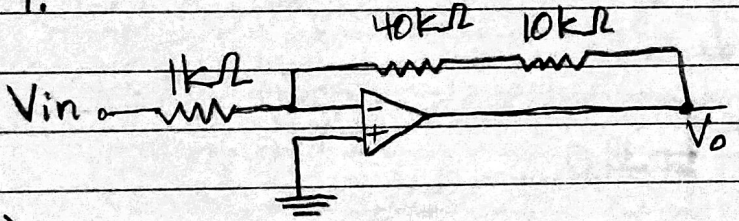
7.



8.



9.



a) $\frac{V_o}{V_{in}} = \frac{50k\Omega}{1k\Omega} = -50\ V/V$

b) $f_c = \frac{5T}{50+1} = \frac{1.5M}{51} = 29,411.76$

$f_{max} = \frac{.7}{1A} \cdot \frac{1}{2\pi(5)} = 22,281.69$

c) $f_c = \frac{75M}{51} = 1,470,588.235$

$f_{max} = \frac{15}{1A} \cdot \frac{1}{2\pi(5)} = 477464.83$

larger

d)

$V_{o_{total}} = 51(7m) \mp 50(.1)$

max = 5.357

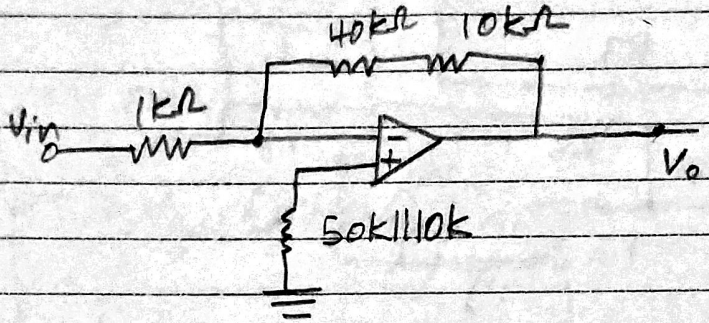
e) min = −4.643

i) Highest Av, so Amp 6484

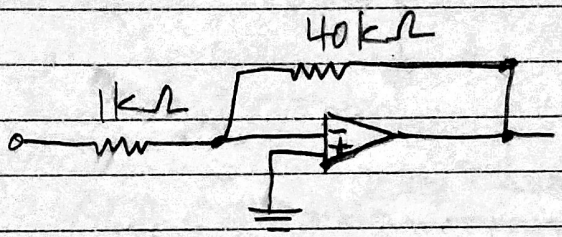
ii) Highest input offset, so Amp 6484

iii) Highest slew rate & Gain-Bandwidth, so Amp 6154

f)



10.



a) $\frac{V_o}{V_{in}} = \frac{40k}{1k} = -40$

b) $f_c = \frac{1M}{41} = 24,390.24$

$f_{max} = \frac{0.5}{1M} \cdot \frac{1}{2\pi(4)} = \boxed{19,894.37}$

c) $f_c = \frac{1.5M}{1M} \cdot \frac{1}{2\pi(4)} = 5.97 \cdot 10^{10}$

$f_{max} = \frac{.1}{1M} \cdot \frac{1}{2\pi(4)} = 3,978.87$ lower

d) $V_{o\,total} = 41(7m) \mp 40(.1)$

Max = 4.287

Min = -3.713

e)

i) Amp 6380

ii) Amp 6570

iii) Amp 6230

f)