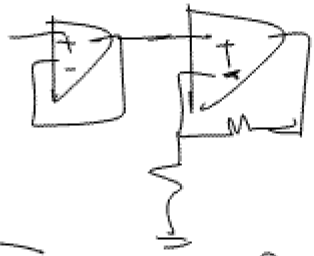
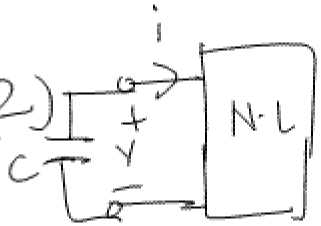
FINAL REVIEW SESSION

Final → 4 problems ⇒ (1) op-amps [negative feedback + cascade ← most likely (2 op-amps only)]

↓



(2)



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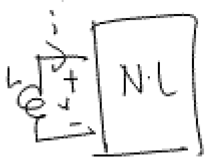


[NO FLIP-FLOP]

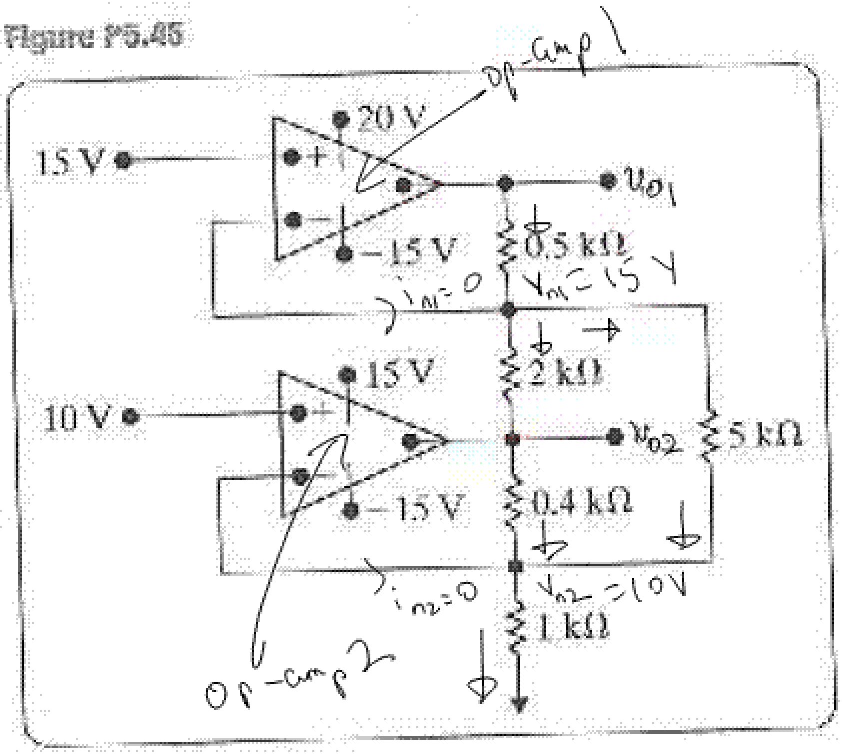
(3) Diode problem (SIMPLE) - (≤ 3 diodes)

(4) Nmos [No pmos] [VERY SIMPLE]

Eg 1: Op-amps Cascade (N&R P. 5.45)

5.45 **P** The two op amps in the circuit in Fig. P5.45 are ideal. Calculate v_{o1} and v_{o2}.

Figure P5.45



Assume op-amp 1 does not rail: $V_{n1} = V_{p1} = 15\ V$

Assume op-amp 2 does not rail; $V_{n2} = V_{p2} = 10\ V$

Also: $i_{n1} = i_{n2} = 0\ A$

KCL @ V_{n1}: $$\frac{V_{o1} - V_{n1}}{0.5k} = \frac{V_{n1} - V_{n2}}{5k} + \frac{V_{n1} - V_{o2}}{2k} \text{ — ①}$$

KCL @ V_{n2}: $$\frac{V_{o2} - V_{n2}}{0.4k} + \frac{V_{n1} - V_{n2}}{5k} = \frac{V_{n2}}{1k}$$

$$\Rightarrow \frac{V_{o2} - 10V}{0.4k} + \frac{15 - 10}{5k} = \frac{10}{1k}$$

$$\Rightarrow \quad \frac{V_{o2}-10}{0.4k} + 1\ mA = 10\ mA$$

$$\Rightarrow \quad V_{o2}-10 = (9\ mA)(0.4\ k)$$

$$\Rightarrow \quad \boxed{V_{o2} = 13.6\ V}$$

Substituting V_{o2} in ①:

$$\frac{V_{o1}-15}{0.5k} = \frac{15-10}{5k} + \frac{15-13.6}{2k}$$

$$\Rightarrow \quad \frac{V_{o1}-15}{0.5k} = 1\ mA + 0.7\ mA$$

$$\Rightarrow \quad V_{o1} = (0.5V + 0.35V) + 15V$$

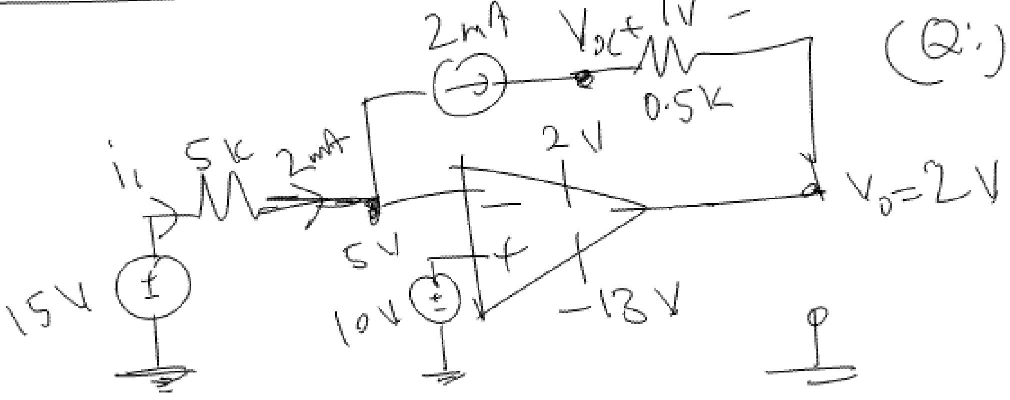
$$\Rightarrow \quad \boxed{V_{o1} = 15.85V}$$

For more problems (including nonlinear problems) go over previous exams (midterm(s) & final). Example

EE100 Sp 05 MT II.

Eg:

(Q:) Find V_x



Notice: op-amp must rail because if $V_n = V_p = 10\ V$

$\Rightarrow i_1 = \frac{15-10}{5k} = 1\ mA$, but this violates KCL at V_n $(1mA \neq 2mA)$

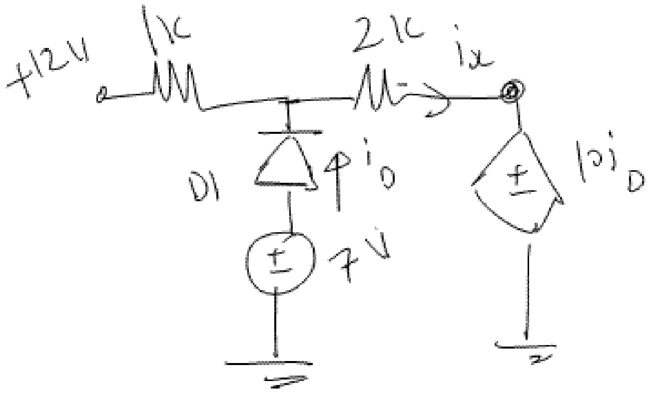
$\therefore V_n = 15\ V - (2mA)(5k)$

$= 5\ V$

$\therefore V_o = A(\underbrace{V_p}_{10} - \underbrace{V_n}_{5}) \to +\infty$, but op-amp rails at $V_{dd} = 2\ V$

$\therefore V_o = 2\ V \Rightarrow \boxed{V_n = 2V + (1/2\ k)(2mA) = 3\ V}$

Eg:

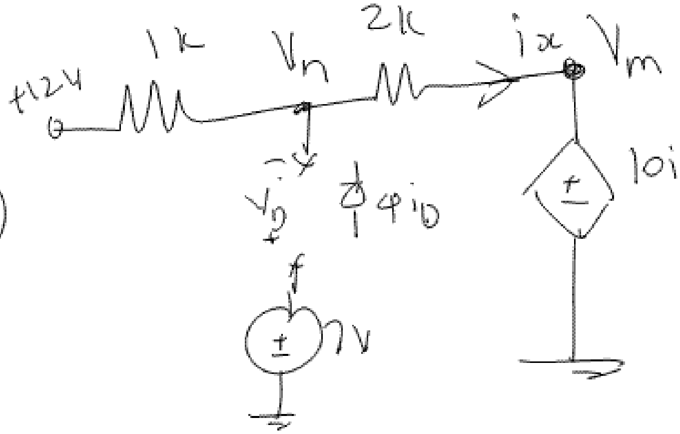


(Q:) Find i_x. Assume diode is ideal.

$i_x = 4$ mA

(A:) Assume D1 off!

(verify: if $V_D < 0$)



$i_D = 0$

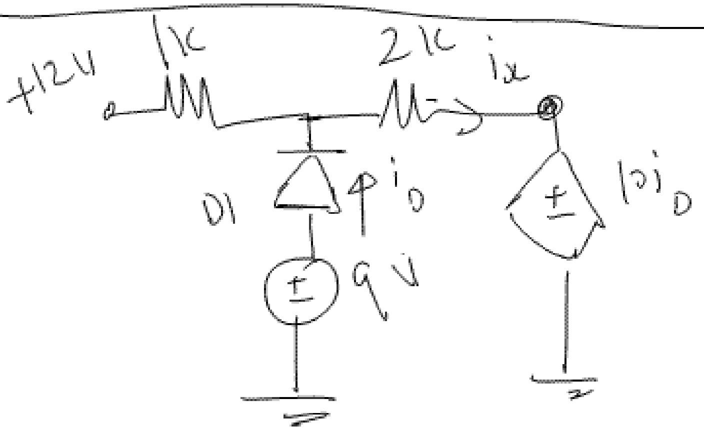
$\Rightarrow i_x = \dfrac{12 - V_m}{3k}$. But $V_m = 0$, since $i_D = 0 \Rightarrow 10 i_D = 0$

∴ $\underline{i_x = 4 \text{ mA}}$ ∴ $V_n = 12 - (1k)(4mA)$

$= 8V$

∴ $V_D = 7 - 8 = -1 < 0$ ✓

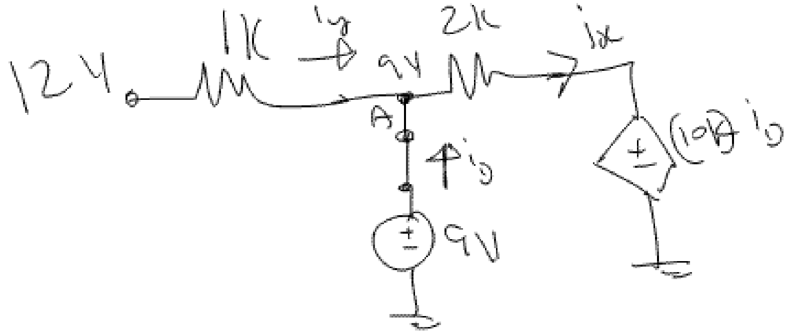
(kii)



Find i_x. (notice 9 V supply)

From previous problem, diode off will not work!

∴ Assume diode is on.



$$i_y = \frac{12-9}{1k} = 3 \text{ mA}$$

$$i_x = 3\text{mA} + i_D \quad [\text{KCL @ A}] \quad — ①$$

$$\text{But, } i_x = \frac{9-(10k)i_D}{2k} \quad — ②$$

Substitute ② in ① $\Rightarrow \dfrac{9-(10k)i_D}{2k} = 3\text{mA} + i_D$

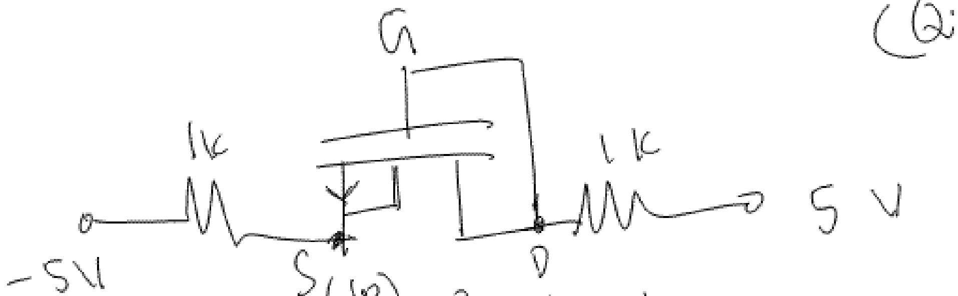
$$\Rightarrow 9-(10k)i_D = (3\text{ mA})(2k) + i_D(2k)$$

$$\Rightarrow 9-6 = (12000)\, i_D$$

$$\Rightarrow i_D = \frac{3}{12000} = 0.25 \text{ mA}$$

$\therefore$ $i_x = 3\text{mA} + 0.25\text{mA}$ (from ①) $\Rightarrow \boxed{i_x = 3.25 \text{ mA}}$

Eg:



$\left(\frac{W}{L}\right) = \frac{2}{1}$, $V_{TO} = 1$ V

KP = 50 $\mu A/V^2$

(Q:) Find V_{DS} for the transistor circuit.

Sol: (1) Identify G, D & S. ✓

(2) Educated guess of transistor mode [cutoff, triode, saturation]

Here, transistor is always saturated,

Since $V_G = V_D$, $V_{DS} \geq V_{GS} - V_{TO}$ ← saturation condition

$\Rightarrow V_{GS} \geq V_{GS} - V_{TO}$ — ①

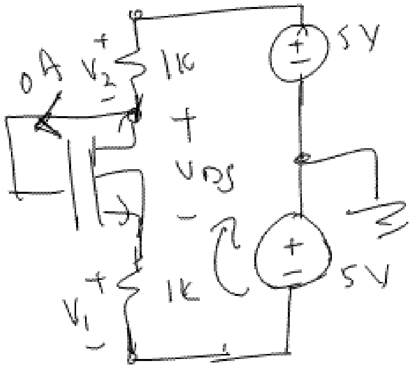
① is always true, $V_{TO} > 0$

(3) $$I_{DS} = \frac{1}{2} KP \left(\frac{W}{L}\right) \left(V_{GS} - V_{TO}\right)^2$$

$$= \left(\frac{1}{2}\right)\left(50 \frac{\mu A}{V^2}\right)\left(\frac{2}{1}\right)\left[V_{DS} - 1\right]^2$$

$$\boxed{I_{DS} = 50 \frac{\mu A}{V^2} \left[V_{DS} - 1\right]^2}$$

One equation, two unknowns. One more equation,



KVL: $V_1 + V_{DS} + V_2 - 5 - 5 = 0$

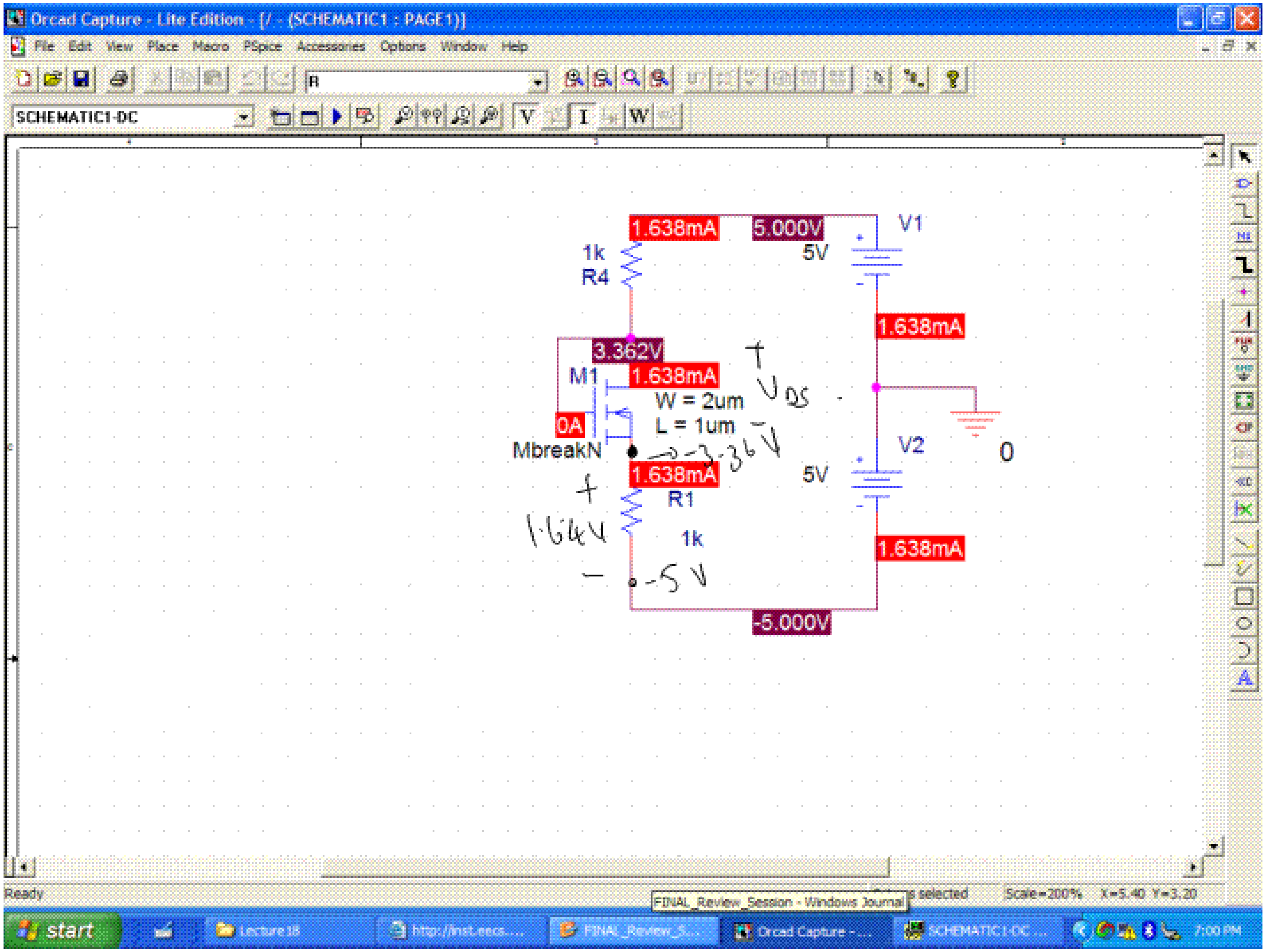
$$\Rightarrow (I_{DS})(1k) + V_{DS} + (I_{DS})(1k) = 10V$$

$$\Rightarrow \boxed{I_{DS} = \frac{10 - V_{DS}}{2K}}$$

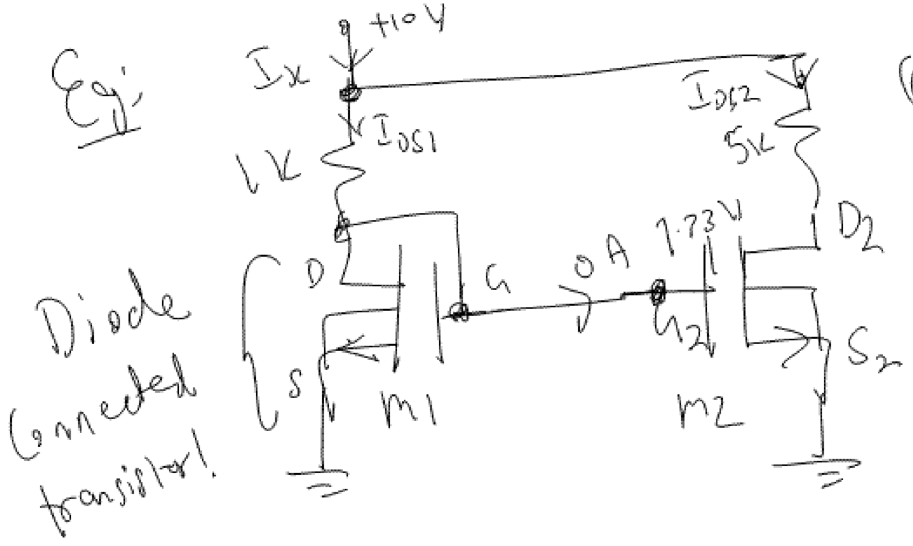
$$\therefore \frac{10 - V_{DS}}{2K} = (50 \times 10^{-6})(V_{DS} - 1)^2$$

$$\Rightarrow \boxed{V_{DS} = 6.724\ V},\ -\cancel{14\ V}\ \underline{\text{Nmos}}$$

Check in PSPICE: $V_{DS} = 3.36 - (-3.36) = 6.72$ V ✓



Eg:



(Q:) Find I_x

Assume $\left(\frac{W}{L}\right) = \left(\frac{2}{1}\right)$, $KP = 50\ \frac{\mu A}{V^2}$, $V_{T0} = 1$ V

for both m1 & m2

$$I_x = I_{DS1} + I_{DS2} \quad (KCL)$$

I_{DS1} is easy to find ⇒ m1 is saturated.

i.e.:

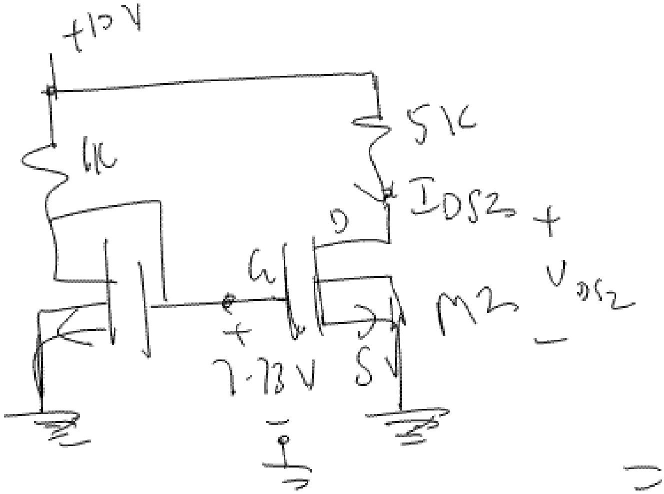
$$\frac{10 - V_{DS1}}{1k} = \frac{1}{2}(KP)\left(\frac{W}{L}\right)\left(\underset{\underset{V_{DS1}}{\shortparallel}}{V_{GS1}} - V_{T0}\right)^2$$

⇒ Solve for $V_{DS1} = 7.73\text{ V}$, ~~-2.5 V~~

∴ $V_{DS1} = V_{D1} - \overset{0}{\cancel{V_{S1}}} = 7.73\text{ V}$

⇒ $\boxed{V_{D1} = V_{G} = 7.73\text{ V}}$

Now, solve for I_{DS2}:



Guess M2 is saturated:

$V_{DS2} = 5.32\text{ V}$ ← Good!

$V_{GS_2} - V_{TO} = 6.73\text{ V}$

∴ $V_{DS_2} \not> V_{GS_2} - V_{TO}$

⇒ M2 is triode

∴ Assuming m2 in triode, $V_{DS2} = 10 - 7.3V$

$= 2.7V$ ✓

∴ $\boxed{I_x = 3.72 \text{ mA}}$

Verify in PSPICE: