# EECS 140 FALL 2002

RW BRODERSEN

NAME SOLUTIONS

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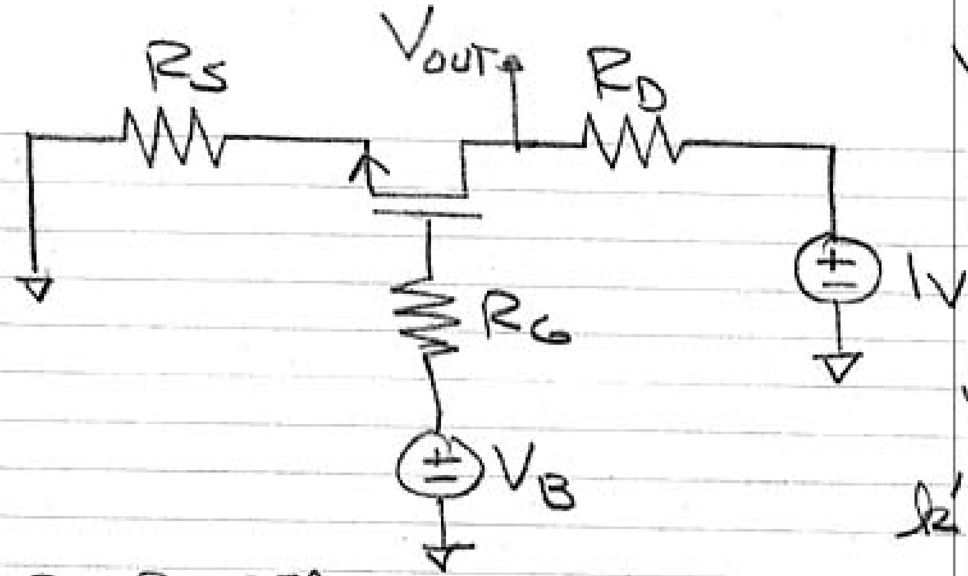
| | | | |
|---|---|---|---|
| (5) | 1 | .8 V | |
| (5) | 2 | 600 μA | |
| (4) | 3a | 15 kΩ | |
| (4) | b | −1 VOLTS | |
| (5) | 4 a | LINEAR | |
| | b | ~~W/L =~~ | |
| (5) | 5 a | 100 Ω | |
| (2) | b | .005 ℧ | |
| (2) | c | 50 Ω | |
| (2) | d | .01 ℧ | |
| (4) | 6a | 400 | |
| (4) | b | −1.45 V. | |
| (4) | 7 | $W/L_1 = 204$ | |
| (2) | | $W/L_2 = 816$ | |

TOTAL (45)

1)




$V_T = .3V$

$\gamma = 0$

$\lambda = 0$

$W/L = 32$

$k' = 100\,\mu A/V^2$

$R_S = R_D = R_G = 2.5k\Omega$

WHAT IS $V_B$ SO THAT $V_{OUT} = .75V$?

$V_B$ ___.8___ V.

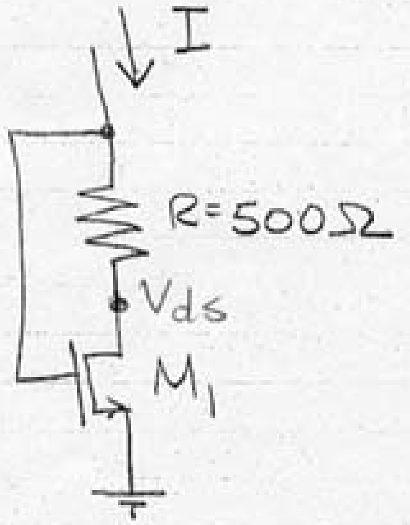
$$I_{DS} = \frac{1 - .75}{2.5k} = 100\mu A$$

$$-V_B + V_{GS} + I_{DS} R_S = 0$$

$$V_{GS} = V_T + \left(\frac{2 I_{DS}}{k' W/L}\right)^{1/2} = .3 + .25V$$

$$V_B = .3 + .25 + .25 = .8V.$$

2)




$V_T = .3V$

$\gamma = 0$

$\lambda = 0$

$W/L = 1$

$k' = 100\,\mu A/V^2$

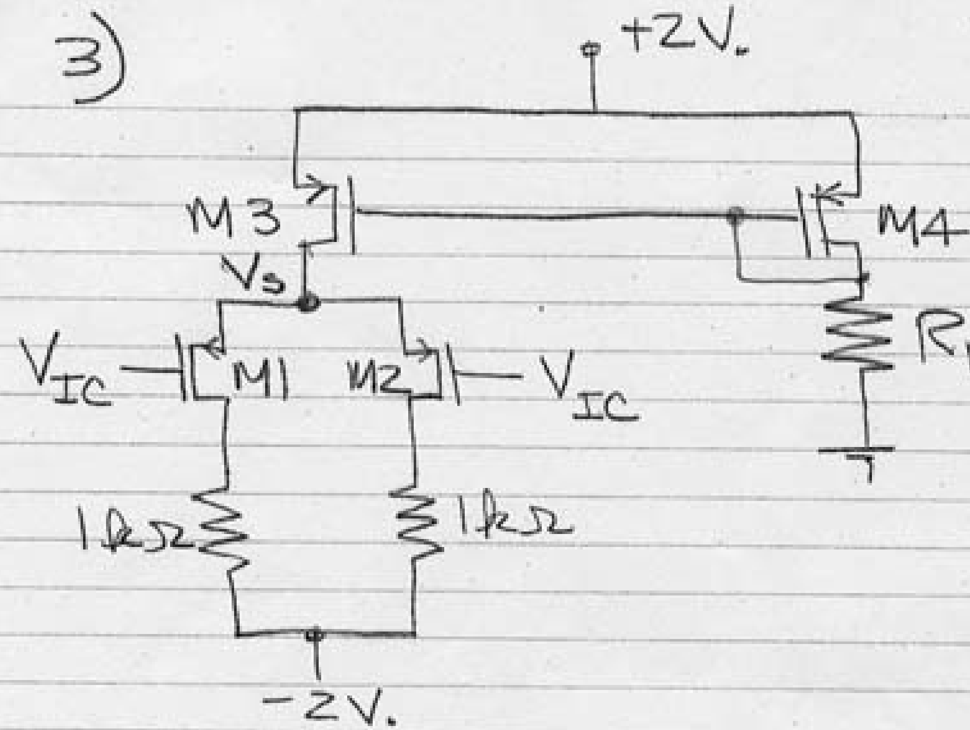
AT WHAT CURRENT DOES M1 GO FROM SATURATION TO LINEAR?

$$V_{gs} - I(500) = V_{dSAT}$$

$$V_T + \cancel{V_{dSAT}} - I(500) = \cancel{V_{dSAT}}$$

$$I = \frac{V_T}{500} = \frac{.3}{500} = .6mA$$

3)




$V_T = -.3V$

$\gamma = 0$

$\lambda = .01\,V^{-1}$

$\left(\frac{W}{L}\right)_{1,2,4} = 50$

$\left(\frac{W}{L}\right)_3 = 100$

$V_{IC} = -1.5V$

$k' = 100\,\mu A/V^2$

a) CALCULATE $R_{REF}$ SO THAT $I_{DS4} = 100\mu A$

$R_{REF}$ <u>15kΩ</u>

$$2 - (100\mu A)R_{REF} = V_{SG4} = V_T + \left(\frac{2\,(100\mu A)}{100\mu A/V^2\ 50}\right)^{1/2}$$

$$2 - 100\mu A(R_{REF}) = .3 + .2$$

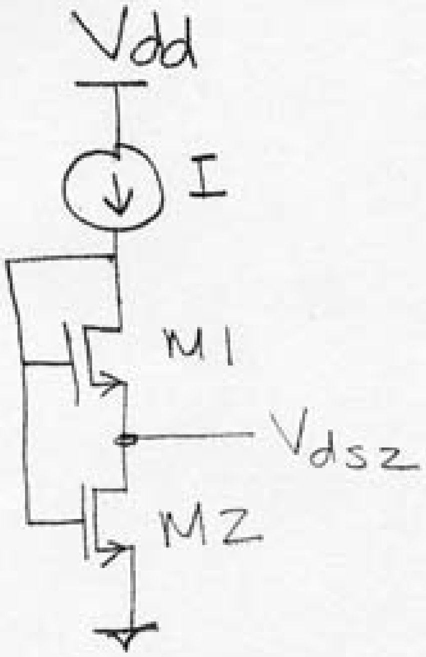
$$R_{REF} = \frac{1.5}{10^{-4}} = 15k\Omega$$

b) WHAT IS THE VOLTAGE AT THE SOURCE OF $M_1$ & $M_2$? $V_S =$ <u>$-1V.$</u>

$$V_S = V_{IC} + V_{GS} = -1.5 + .2 + .3$$

$$= -1V.$$

4)




YOU DON'T NEED TO KNOW THE VALUE OF I

$\gamma \neq 0$

$(W/L)_1 \neq (W/L)_2$

a) WHAT IS THE REGION OF OPERATION OF M2 AND WHY?

Is $V_{GS2} - V_{T2} \overset{?}{>} V_{DS2}$, IF SO THEN $M_2$ IS IN LINEAR.

FROM CIRCUIT $V_{DS2} = V_{GS2} - V_{GS1}$

SUBSTITUTING $V_{GS2} - V_{T2} \overset{?}{>} V_{GS2} - V_{GS1}$

OR $V_{GS1} \overset{?}{>} V_{T2}$

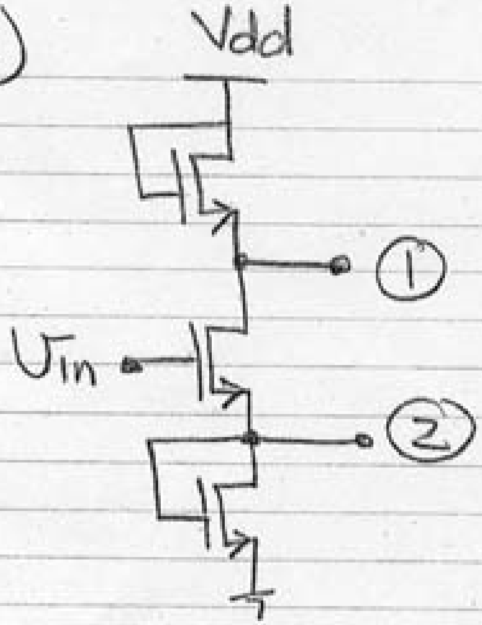
SINCE $V_{GS1} = V_{DSAT1} + V_{TO} + \gamma (V_{ds2})^{1/2}$

& $V_{T2} = V_{TO}$

WE HAVE $V_{DSAT1} + \gamma (V_{DS2})^{1/2} \overset{?}{>} 0$

<u>YES</u> IT IS - SO M2 IS IN LINEAR.

5)




ASSUME THE FOLLOWING VALUES FOR ALL THE TRANSISTORS

$r_o = 1M\Omega$, $g_m = .01\mho$

$g_{mb} = 0$

a) WHAT IS $R_{OUT}$ AT ①? 100 $\Omega$

$g_m \| r_o(1 + g_m \frac{1}{g_m}) \approx g_m$

b) WHAT IS $G_m$ AT ①? .005 $\mho$

$$G_m = \frac{g_m}{1 + g_m\left(\frac{1}{g_m}\right)} = \frac{g_m}{2}$$

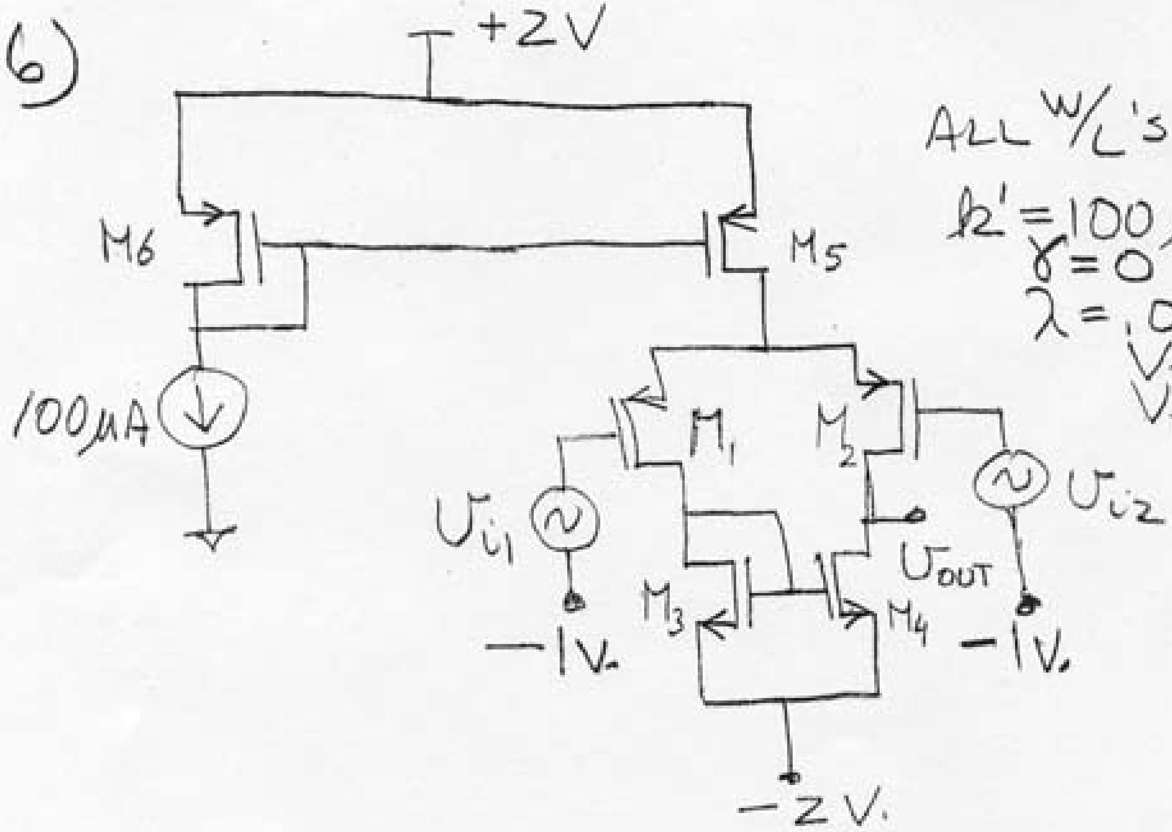
c) WHAT IS $R_{OUT}$ AT ②? 50 $\Omega$

$\frac{1}{g_m} \| \frac{1}{g_m}$

d) WHAT IS $G_m$ AT ②? .01 $\mho$

$G_m$ OF SOURCE FOLLOWER IS $g_m$

6)




ALL $W/L$'s = 16

$k' = 100\,\mu A/V^2$

$\gamma = 0$

$\lambda = .01$

$V_{Tp} = -.3$

$V_{Tn} = .3$

a) WHAT IS THE GAIN $\dfrac{U_{OUT}}{U_{i1} - U_{i2}}$ ? $g_m R_{OUT} = 400$ ________

$I_{DS} = 50\mu A$

$V_{DSAT,1} = \left(\dfrac{2 \cdot 50\mu A}{10^{-4} \times 16}\right)^{+1/2} = .25V$

$g_m = \dfrac{2 I_{DS}}{V_{dSAT}} = .4 \times 10^{-3}\,s.$

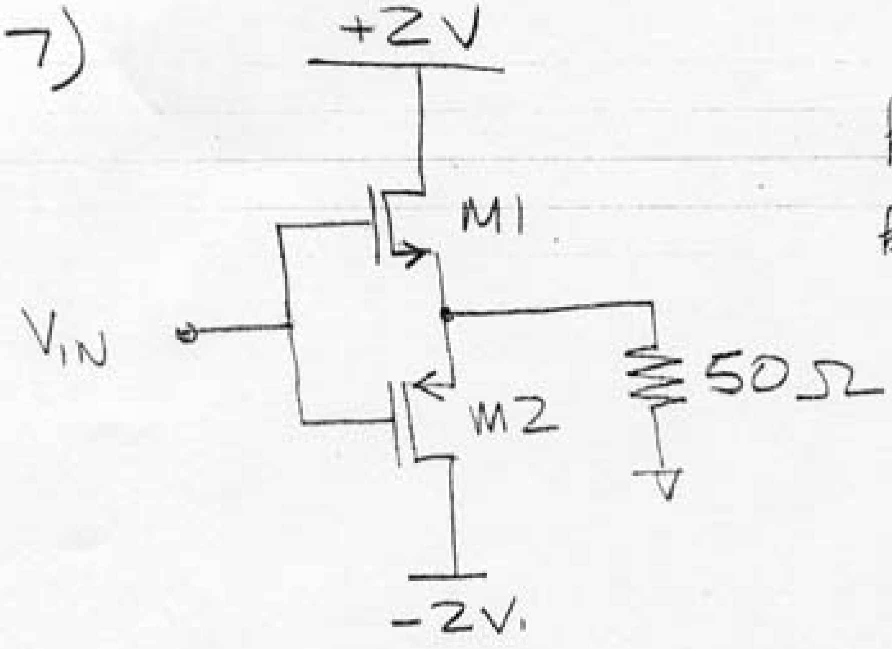
$r_{OUT} = (r_{o4} \| r_{o2}) = \dfrac{1}{2 \times 50 \times 10^{-6} \times .01} = 10^6$

b) WHAT IS THE DC VOLTAGE AT $U_{OUT}$?

<u>-1.45</u> V.

$-2 + V_T + V_{dSAT} = -2 + .3 + .25 = -1.45V$

7)




$k_n' = 400\,\mu A/V^2$

$k_p' = 100\,\mu A/V^2$

$\gamma = \lambda = 0$

$V_{Tn} = 0.3\ V.$

$V_{Tp} = -0.3\ V$

WHAT ARE THE W/L 'S OF M1 & M2 SO THAT THE OUTPUT CAN SWING ±1 V. IF THE INPUT CAN GO TO THE SUPPLIES (±2V)? $(W/L)_1$ 204

$(W/L)_2$ 816

$$I_{DS} = \frac{1V}{50\Omega} = 20ma$$

FOR M1: $20\times10^{-3} = \frac{k_n'}{2}\frac{W}{L}(2-1-.3)^2$

$$\left(\frac{W}{L}\right)_1 = \frac{20\times10^{-3}\times2}{400\times10^{-6}(.7)^2} = 204$$

THE $k'$ OF $M_2$ IS 1/4 THAT OF $M_1$

SO $\left(\frac{W}{L}\right)_2 = 4\left(\frac{W}{L}\right)_1$