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MIDTERM

EECS 140
FALL 2000

USE THE FOLLOWING PARAMETERS UNLESS STATED OTHERWISE

ASSUME ALL W/L'S ARE 10.

$V_{Tn} = V_{Tp} = .5V.$

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

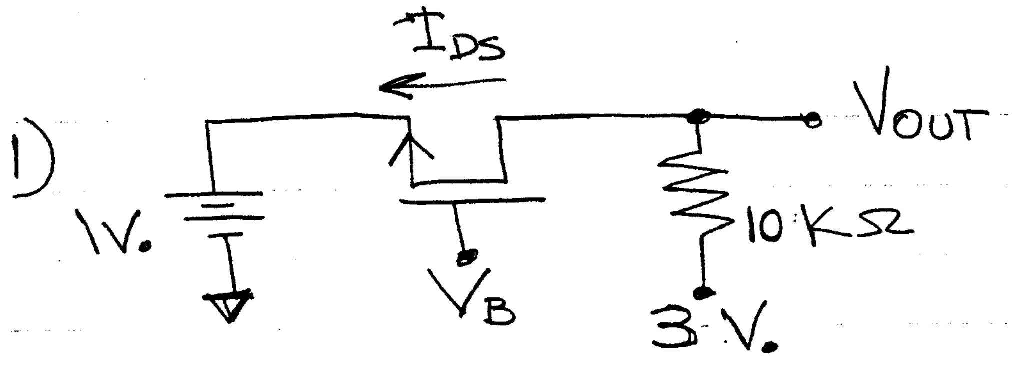
$\lambda_n = \lambda_p = .01$

$\gamma_n = \gamma_p = 0$

SHOW YOUR WORK! MAKE APPROXIMATIONS TO WITHIN ±10%.

1. V_B 1.95 V.
2. a) 10.5 kΩ
   b) 225 MΩ
3. A_v −1000
4. a) 500 kΩ
   b) 8.8 or 10
5. 1.18 V
6. a 1.55 V.
   b .45 V.
7. a) max .31
   min −.05
   b) .1 % %

1)



WHAT IS THE VOLTAGE AT V_B SO THAT V_{OUT} IS 2 VOLTS?

V_B 1.95V.

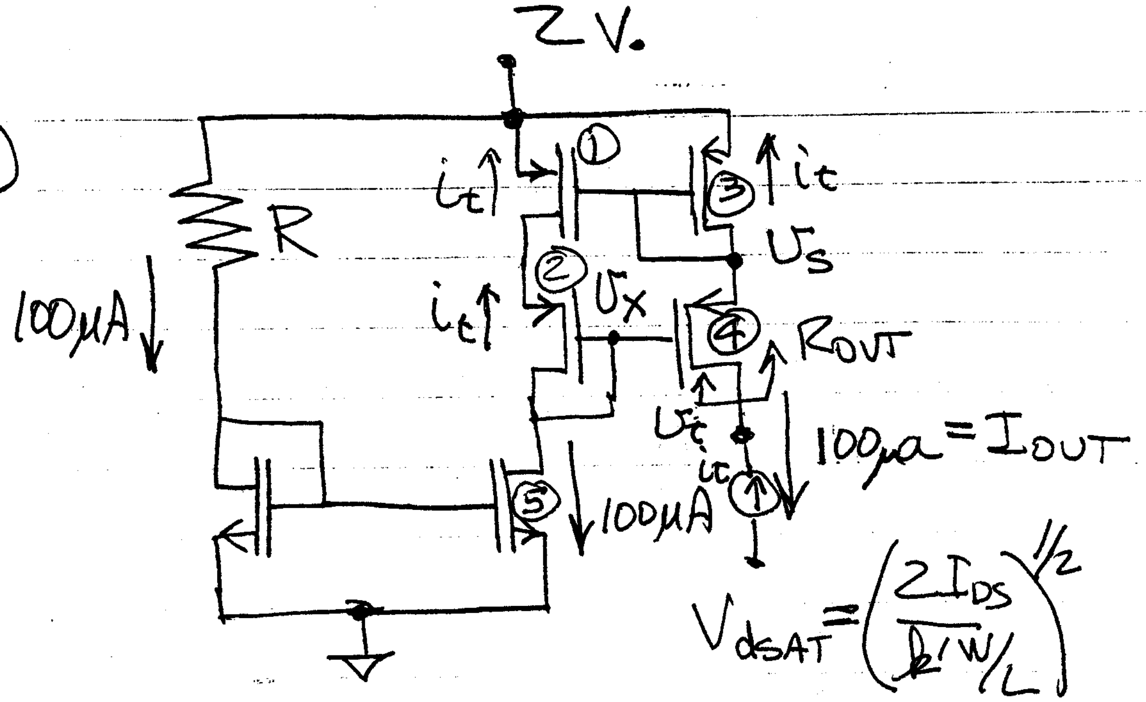
$$I_{DS} = \frac{3-2}{10\,k\Omega} = 100\,\mu A$$

$$= \frac{k' W/L}{2}(V_B - 1 - V_T)^2$$

$$= \frac{(10^{-4})10}{2}(V_B - 1 - .5)^2$$

$V_B = 1.95$ v.

2)



$$V_{dSAT} = \left(\frac{2 I_{DS}}{k' W/L}\right)^{1/2} = .45V.$$

a) WHAT IS R SO THAT $I_{OUT} = 100\,\mu a$? <u>10.5 kΩ</u>

$(100\mu A)R = 2 - V_T - V_{dSAT}$

$= 2 - .5 - .45 = 1.05V.$

$R = 10.5\,k\Omega$

b) WHAT IS THE OUTPUT RESISTANCE, R_{OUT} ? <u>225 M Ω</u> $v_s \approx 0$

WILSON SOURCE:

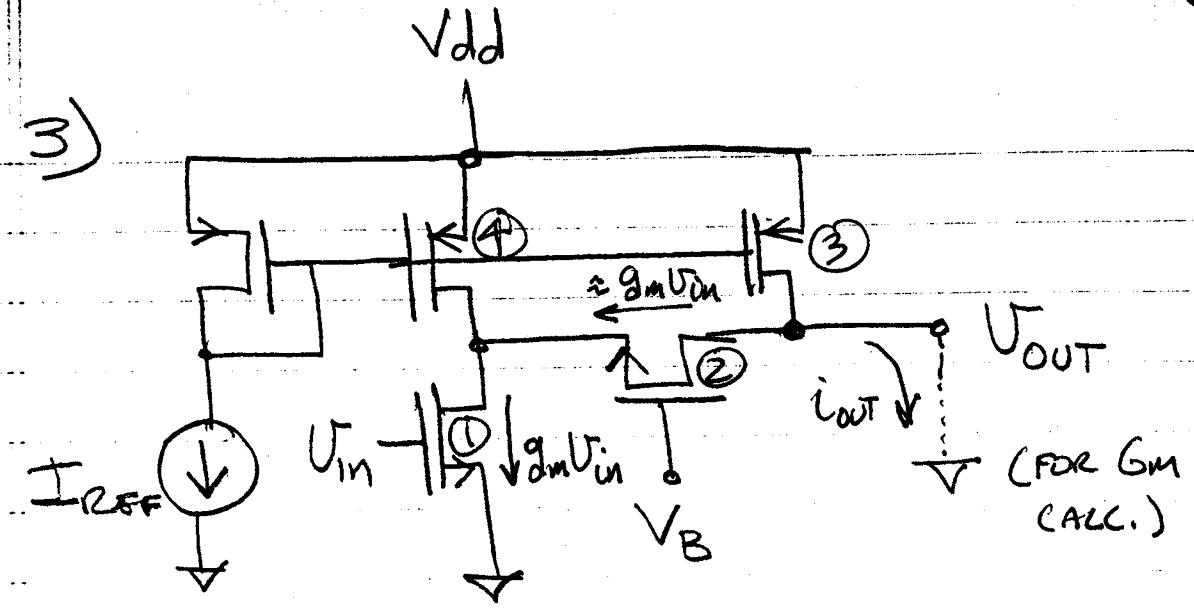
$v_t = r_{o4}(i_t - g_{m4} v_x)$

$v_x = -i_t(r_{o1} \| r_{o5})$

$R_{OUT} = \frac{g_m r_o^2}{2} = 225\,M\Omega$

$v_t = i_t r_o \left(1 + g_m \frac{r_o}{2}\right) \approx \frac{g_m r_o^2}{2} i_t$

3)



ASSUME THE FOLLOWING SMALL SIGNAL PARAMETERS FOR ALL TRANSISTORS

$g_m = .001\,℧ \quad \chi = .1$

$r_o = 1\,M\Omega$

WHAT IS THE GAIN, v_{OUT}/v_{in}? $\underline{-1000}$

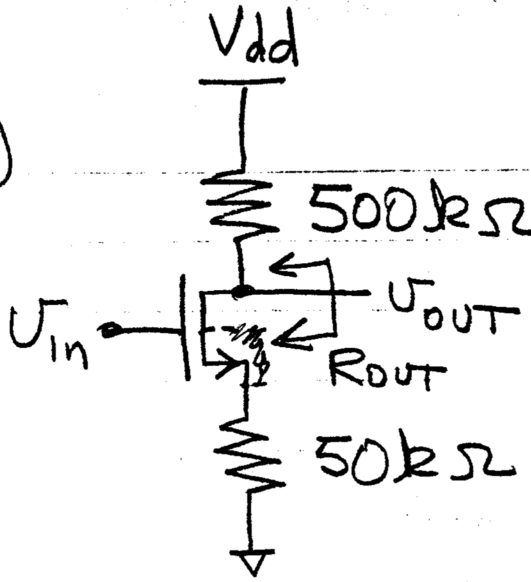
$v_{OUT} \simeq -g_{m1} v_{in} \qquad G_m = -g_{m1}$

$R_{OUT} = r_{o3} \| r_{o2}(1 + g_{m2}(r_{o4} \| r_{o1}))$

$\approx r_{o3}$

$A_v = -g_{m1} r_{o3} = -1000$

4)



ASSUME
$r_o = 1M\Omega$
$g_m = .001$
$\chi = .1$

a) WHAT IS ROUT? 500 kΩ

$$R_{OUT} = 500k\Omega \,||\, r_o\left(1 + \underbrace{g_m(1+\chi)50k\Omega}_{55}\right)$$

$$\approx 500k\Omega$$

b) WHAT IS THE GAIN? 8.8 or 10

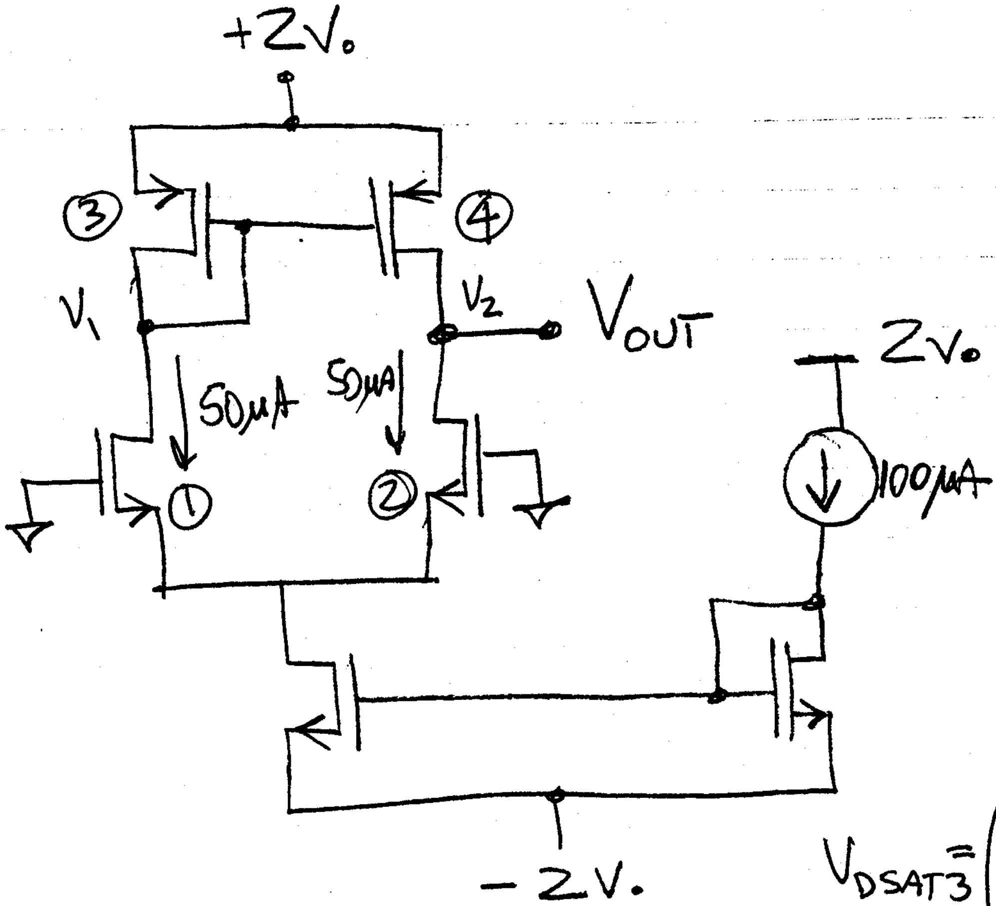
$$G_m = \frac{-g_m}{1 + g_m(1+\chi)50k\Omega} \approx \frac{-1}{55k\Omega}$$

$$A_v = G_m R_{OUT} = -\frac{500k\Omega}{55k\Omega} \approx 8.8$$

OR $\chi = 0$

$A_v = 10$

5)



$V_{DSAT3} = \left(\frac{2\,(50\mu A)}{\mu' W/L} \right)^{1/2} = .32V$

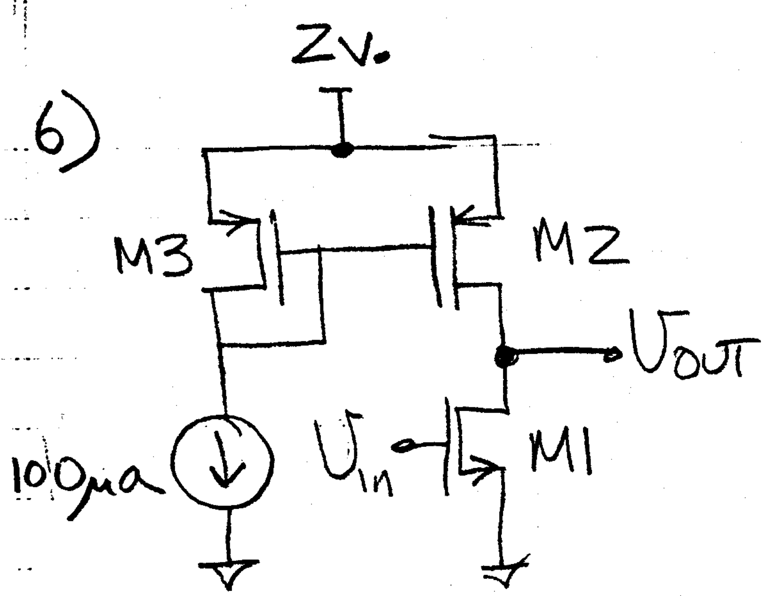
WHAT IS THE DC VOLTAGE AT V_{OUT}? 1.18 V.

B SINCE $I_{DS1} = I_{DS2}$ THEN $V_1 = V_2$

$V_1 = 2 - V_{T3} - V_{DSAT3} = 2 - .5 - .32V.$

$= 1.18V.$

6)



$$V_{DSAT} = \left(\frac{2(100\mu A)}{k' W/L}\right)^{1/2} = .45V.$$

WHAT IS THE MAXIMUM AND MINIMUM VOLTAGE AT V_{OUT} THAT KEEPS ALL DEVICES IN SATURATION?

a) $V_{OUT,MAX}$ 1.55V. b) $V_{OUT,MIN}$ .45V.

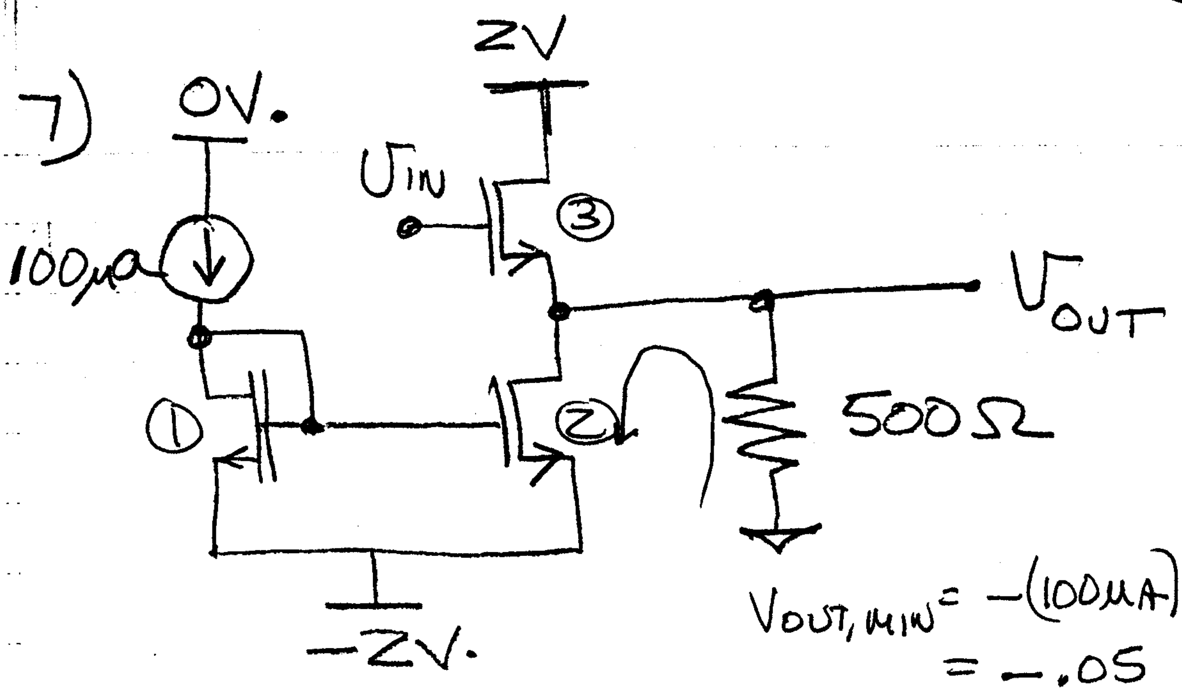
$V_{OUT,MAX}$ OCCURS WHEN M2 SATURATES

$$V_{OUT,MAX} = 2 - V_{DSAT\,2} = 1.55V.$$

$V_{OUT,MIN}$ OCCURS WHEN M1 SATURATES

$$V_{OUT,MIN} = V_{DSAT,1} = .45V.$$

7)



$V_{OUT,MIN} = -(100\mu A)500\Omega$
$= -.05$

a) WHAT IS THE MAXIMUM & MINIMUM VOLTAGE AT V_{OUT}

$V_{OUT,MAX}$ <u>.31</u> , $V_{OUT,MIN}$ <u>−.05</u>

$$V_{OUT,MAX} = 2 - V_{T3} - V_{DSAT3} \quad (V_{IN} = V_{DD})$$

$$= 1.5 - \left(\frac{2\left(100\mu A + \frac{V_{OUT,MAX}}{R}\right)}{k' W/L} \right)^{1/2}$$

$$V_{OUT,MAX}^2 - 7V_{OUT,MAX} + 2.05 = 0$$

$$V_{OUT,MAX} \approx .31$$

b) WHAT IS THE EFFICIENCY IN PERCENT INCLUDING ALL TRANSISTORS AND THE CURRENT SOURCE IF THE OUTPUT SWING IS A SINEWAVE WITH A 0.5 VOLT PEAK TO PEAK AMPLITUDE <u>.1</u> %

$$P_{SUPPLY} = (-2)(-I_{DS1}) + (-2)(-I_{DS2}) + 2\,I_{DS3}$$

$$= 6\,(100\mu A) = 6\times10^{-4}\ \text{MAX}$$

$$P_{LOAD} = \frac{1}{2}\frac{(.05/2)^2}{500} = .62\times10^{-6}\,W \qquad EFF = \frac{.62\times10^{-6}}{6\times10^{-4}}$$

$$= .1\%$$