UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
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EE140 **Midterm Exam** **Oct. 15, 2003**

Name: SOLUTIONS SID:

Use the following parameters:

$V_{t0(NMOS)} = V_{t0(PMOS)} = 0.4v$

$k'_{(NMOS)} = k'_{(PMOS)} = 10mA/V^2 = 10^{-2}\ A/V^2$

$F_f = 0.3v$; $\gamma = 1V^{1/2}$; $\lambda = 0.02$

Assume all W/L = 10

(10pts) 1. 1.27V.

(5pts) 2a. .5 V.

(5pts) 2b. .4 V.

(5pts) 2c. -.4 V.

(5pts) 3a. $-.91\times10^{-3}$ s.

(5pts) 3b. 550k Ω

(5pts) 3c. -500

(10pts) 4. 4.6kΩ

(10pts) 5. 1.1kΩ

(5pts) 6a. 3.3×10^{-3} s.

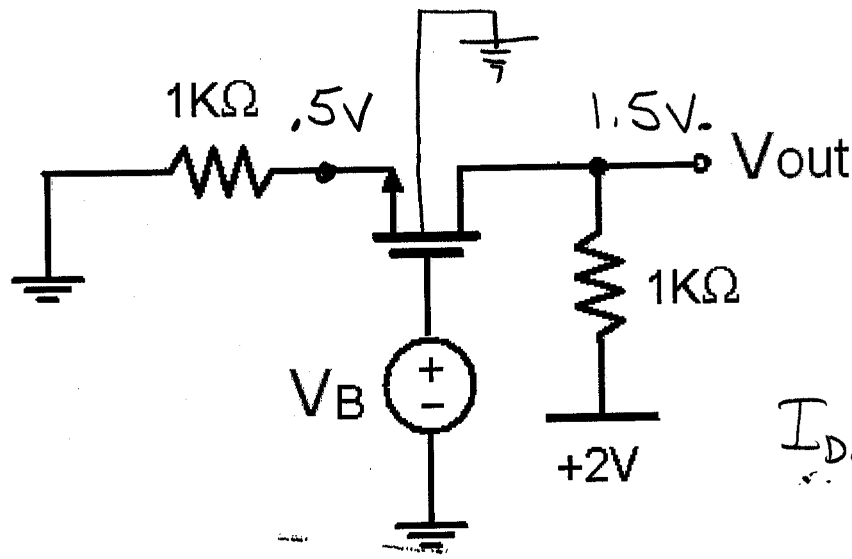
(5pts) 6b. 50Ω

(5pts) 6c. .16

(10pts) 7a. .5 ma

(10pts) 7b. 5×10^{5}

1.



$I_{DS} = \frac{.5V}{1k} = .5ma$

What is V_B so that Vout = 1.5v ? $V_B =$ 1.27 V

SAME CURRENT FOR BOTH RESISTORS
THEREFORE SAME VOLTAGE DROP = .5V.

$V_{SB} = .5$

$$V_T = V_{TO} + \gamma\left[(2\phi_f + V_{SB})^{1/2} - (2\phi_f)^{1/2}\right]$$

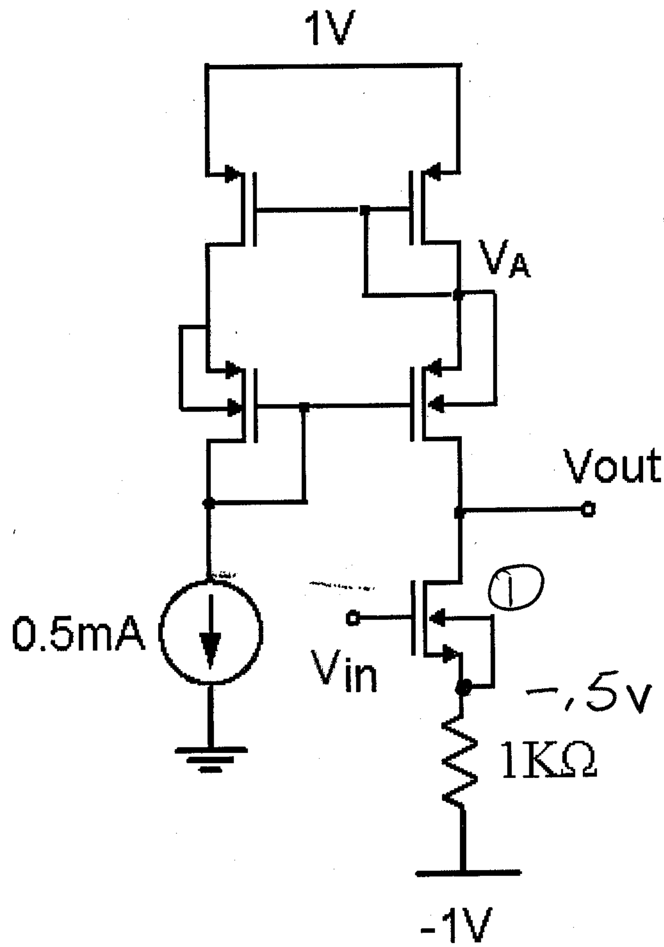
$$= .4 + 1\left[(.6 + .5)^{1/2} - .6^{1/2}\right]$$

$$= .67$$

$$V_{DSAT} = \left(\frac{2 I_{DS}}{k' W/L}\right)^{1/2} = \left(\frac{2 \times .5 \times 10^{-3}}{10^{-2} A/V^2 \times 10}\right)^{1/2} = .1$$

$$V_B = V_T + V_{DSAT} + .5 = .67 + .1 + .5 = 1.27$$

2.



$V_{DSAT} = .1V.$
FOR $I_{DS} = .5mA$

a. What is the voltage at V_A? $V_A = 1 - V_T - V_{DSAT}$

$= 1 - .4 - .1 = .5V.$

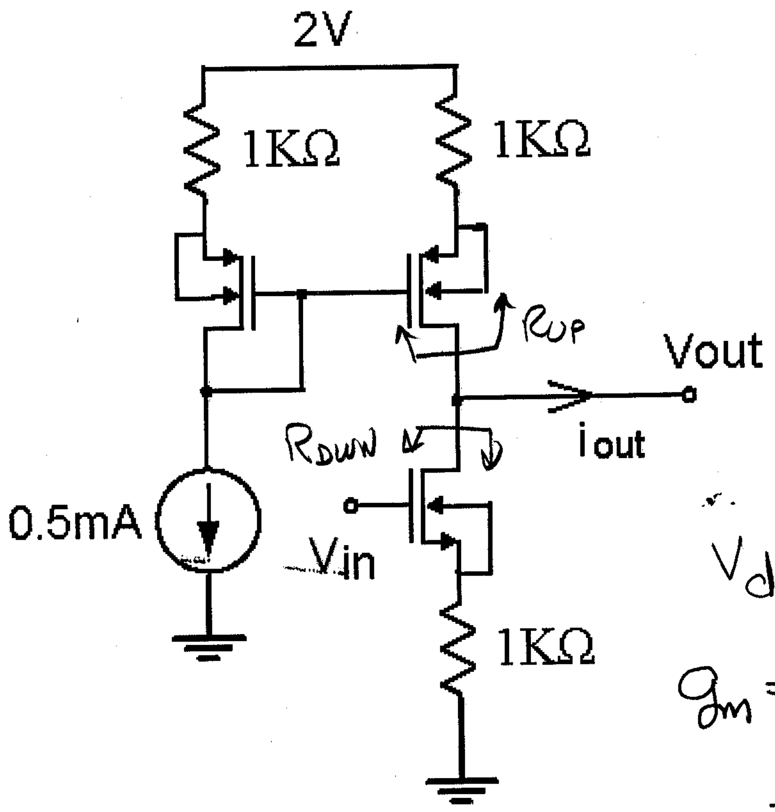
b. What is the maximum swing in the positive direction at Vout?

$$V_{MAX,POS} = V_A - V_{DSAT} = .4V$$

c. What is the most negative swing at Vout?

$$V_{MAX,NEG} = V_{S,1} + V_{DSAT} = -.5 + .1 = -.4V.$$

3.



$r_o = \frac{1}{\lambda I_{DS}} = 10^5 \Omega$

$V_{dsAT} = .1V$

$g_m = \frac{2 I_{DS}}{V_{dsAT}} = 10^{-2} S.$

a. **What is Gm = i_{out} / v_{in} ?**

$G_m = \frac{-g_m}{1 + g_m(1k\Omega)} = \frac{-10^{-2}}{1.1} = -.91 \times 10^{-3} \mho$

b. **What is Rout ?**

$R_{UP} = r_o(1 + g_m(1k)) = 10^5 \times 10^{-2} \times 10^3 \times 1.1 = 1.1 \times 10^6 \Omega$

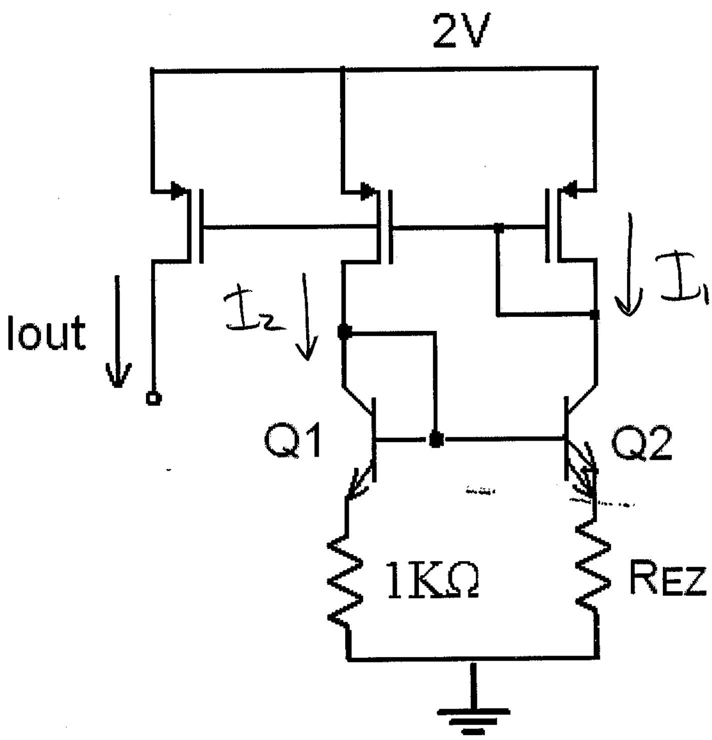
$R_{DOWN} = \text{SAME} = 1.1 \times 10^6$

$R_{OUT} = 550 k\Omega$

c. **What is Av ?**

$A_v = G_m R_{OUT} = .91 \times 10^{-3} \times 5.5 \times 10^5 = -500$

4.



For the bipolar:

A_E = 1 for Q1
A_E = 4 for Q2
V_{th} = 26mV

$I_1 = I_{OUT} = I_2$
BY CURRENT SOURCE CONNECTION

$I_{S2} = 4 I_{S1}$

What is the value of R_{EZ} that sets Iout = 10uA?

R_{EZ} = 4.6kΩ

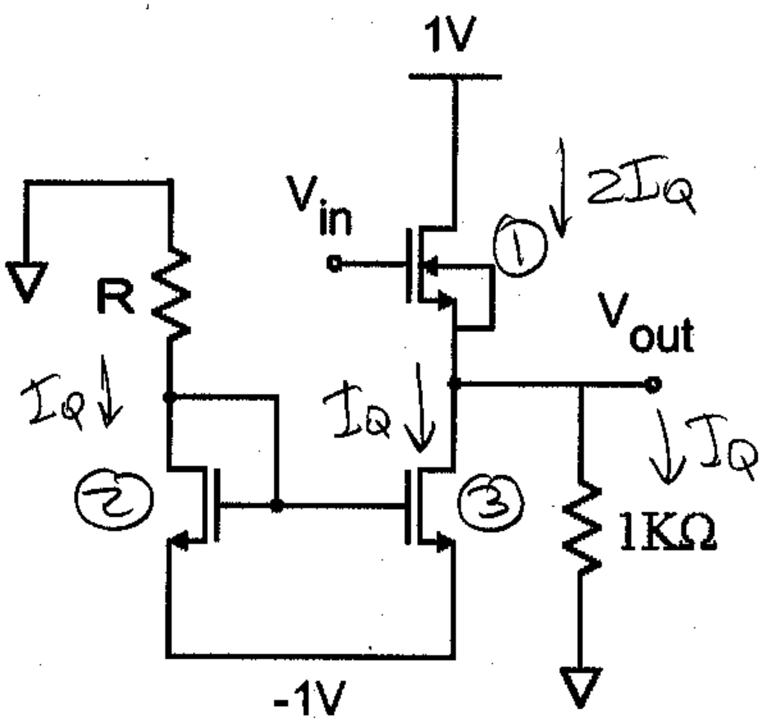
$$V_{BE1} + I_1 \, 1k\Omega = V_{BE2} + I_1 R_{EZ}$$

$$V_{BE1} = V_{TH} \ln \frac{I_1}{I_{S1}}$$

$$V_{BE2} = V_{TH} \ln \frac{I_2}{I_{S2}} = V_{TH} \ln \frac{I_1}{4 I_{S1}}$$

$$R_{EZ} = 1k\Omega + \frac{V_{TH} \ln 4}{10\mu A} = 4.6k$$

5.



-1V ≤ Vin ≤ 1V

$V_{DSAT1} = \sqrt{2}\, V_{DSAT3}$

What is the value of R which gives the maximum efficiency ?

R =

(Hint: Find an expression for R before you plug in numbers)

V_{MAX+} IS $1 - V_{TO} - V_{DSAT1}$ WHICH IS LESS THAN $V_{MAX-} = 1 - V_{DSAT3}$ ($V_{DSAT1} > V_{DSAT3}$)

SO $I_Q = \dfrac{1 - V_{TO} - V_{DSAT1}}{1k}$; $I_Q = \left[.6 - \left[\dfrac{2 \cdot 2 I_Q}{k' W/L}\right]^{1/2}\right] 10^{-3}$

$= \left[.6 - [40 I_Q]^{1/2}\right] 10^{-3}$

ITERATING ;

I_Q^{IN}	I_Q^{OUT}
1 ma	.4 ma
.4 m	.47 ma
.47 m	.46 ma

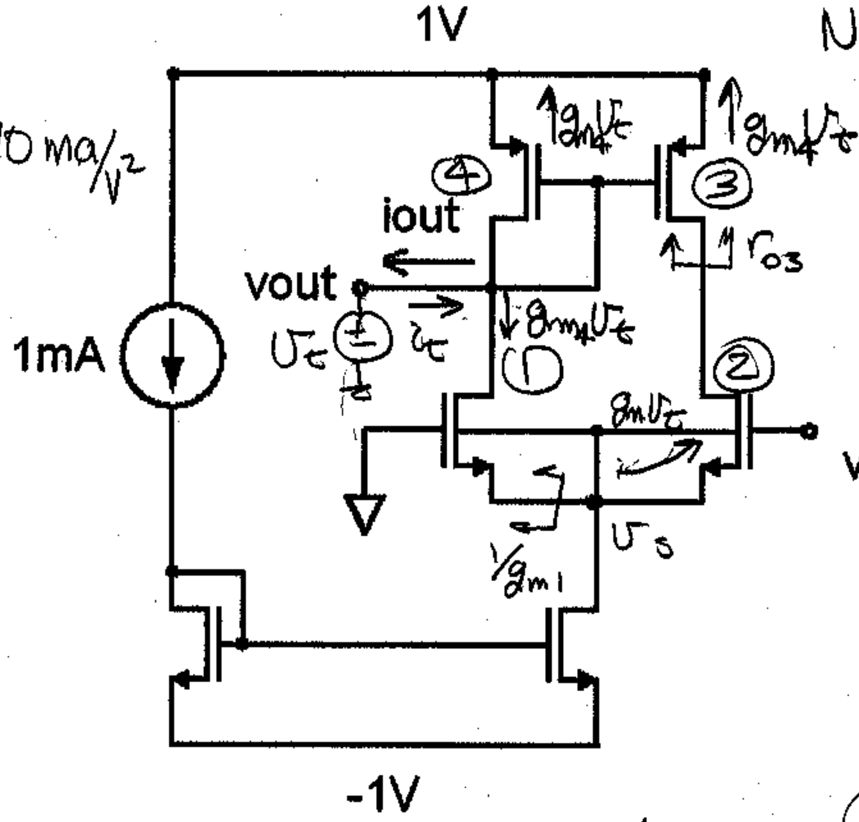
$R = \dfrac{1 - V_{TO} - (20 I_Q)^{1/2}}{.46 \times 10^{-3}} = 1.1\,k\Omega$

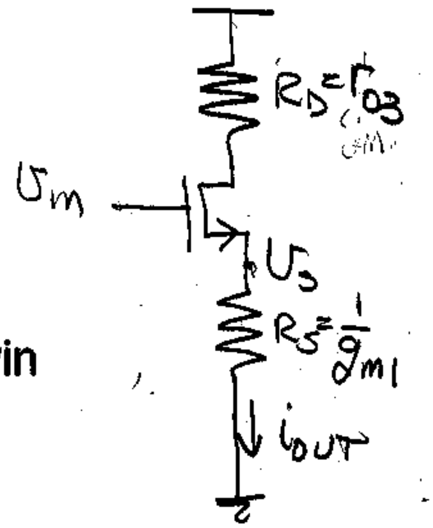
$I_Q = .46 \times 10^{-3}$

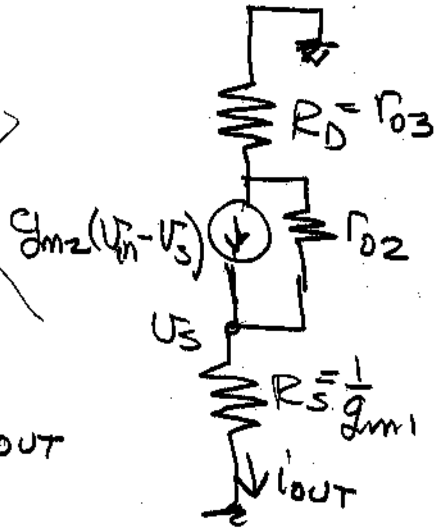
6.

NEED TO SOLVE

$g_m = 10\ mA/V^2$







a. What is Gm? $i_{OUT} = g_m (v_{in} - v_S)\left(\frac{r_{o2}}{r_{o2}+R_D+R_S}\right)$

$v_S = i_{OUT} R_S$

$i_{OUT} = g_{m2} v_{in}\underbrace{\left(\frac{r_{o2}}{r_{o2}+R_D+R_S}\right)}_{1/2} - \underbrace{g_{m2}R_S}_{1}\underbrace{\left(\frac{r_{o2}}{r_{o2}+R_D+R_S}\right)}_{1/2} i_{OUT}$

$$G_m = \frac{g_{m2}}{3} = 3.3\ mA/V^2$$

~~**b. What is Rout?**~~

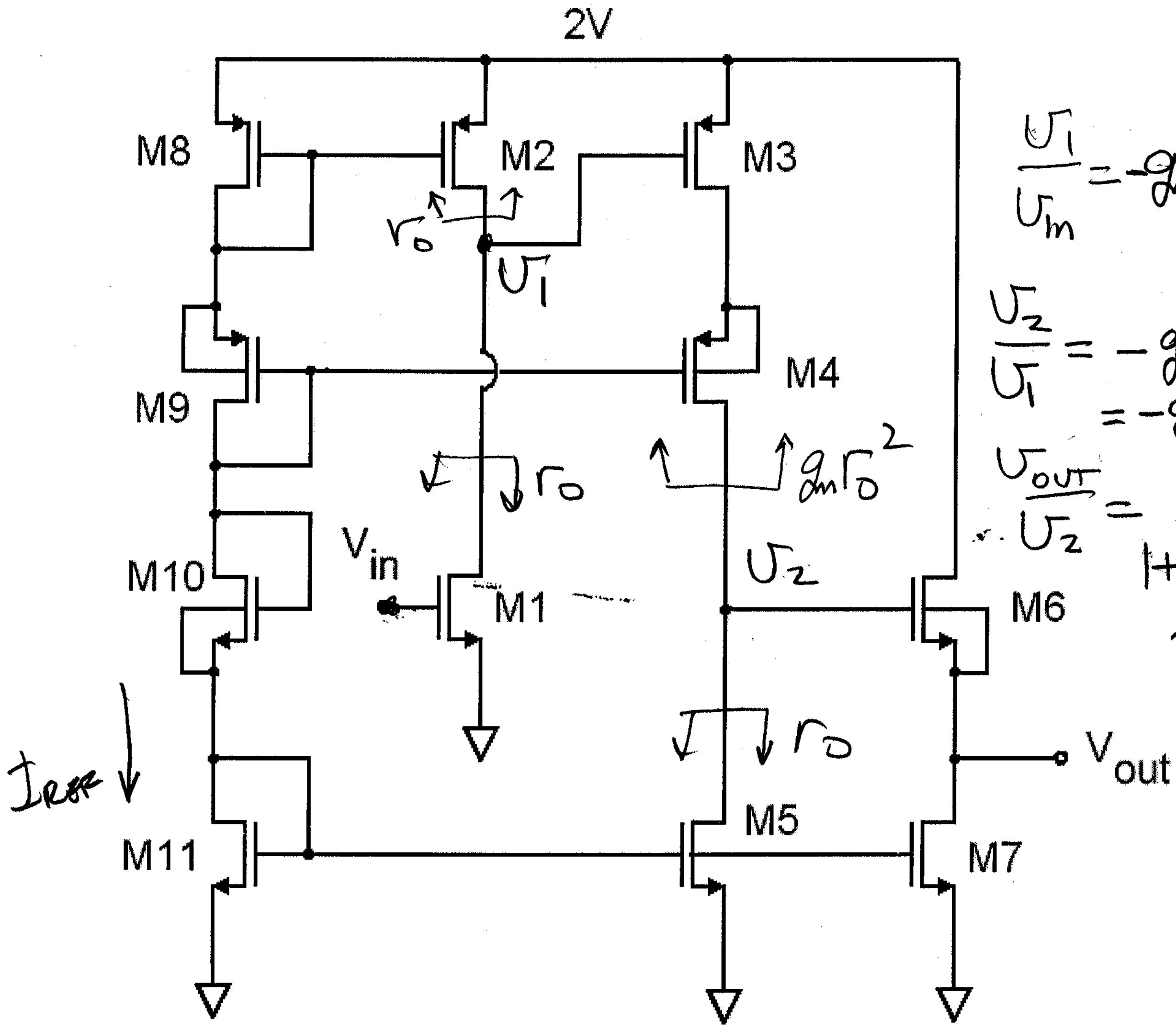
$i_t = 2g_{m4}v_t + \frac{v_t}{r_{o1}} \approx 2g_{m4}v_t$

$R_{OUT} = \frac{1}{2g_{m4}} = 50\Omega$

c. What is Av?

$A_v = G_m R_{OUT} = \frac{1}{6}$

7.



$$\frac{v_1}{v_{in}} = -g_m \frac{r_o}{2}$$

$$\frac{v_2}{v_1} = -g_m(r_o \| g_m r_o^2) = -g_m r_o$$

$$\frac{v_{OUT}}{v_2} = \frac{g_m r_o}{1 + g_m r_o} \approx 1$$

a. **What is the I_{DS} of transistor M6?** $2V = 4(V_T + V_{DSAT})$

$V_{DSAT} = .5 - .4 = .1$

$I_{DS} = .5\text{ mA}$

b. **Assume that $g_m = 0.01$, $r_o = 100k\Omega$, $g_{mb}=0$, for all the transistors. What is v_{out}/v_{in}?**

$$\frac{v_{OUT}}{v_{in}} = \frac{(g_m r_o)^3}{2} = \frac{10^6}{2} = 5 \times 10^5$$