NAME SOLUTIONS

MIDTERM EECS 140
FALL, 1997
R.W. BRODERSEN

* WRITE ANSWERS BELOW
* USE APPROXIMATIONS SO YOUR ANSWER IS WITHIN ±10% OF THE EXACT SOLUTION

1 a) 5

b) 2.75V.

c) .6V.

2 a) 2MΩ

b) 5m℧

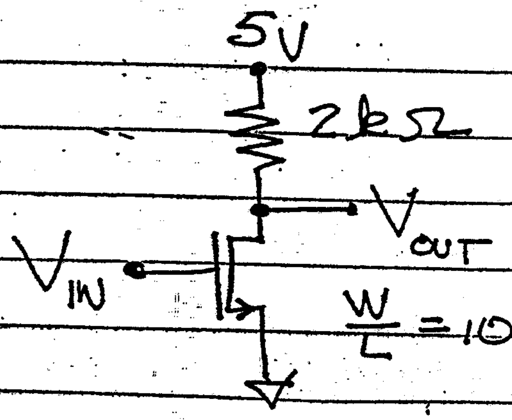
3 a) 390kΩ

b) 7×10^9 Ω

4 a) 6V.

b) ~~[illegible]~~ .04

1)



a) If $V_{IN} = 0V$, what is V_{OUT}?

$V_{OUT} = $ 5V.

Transistor cutoff, $I_{DS} = 0$

b) If $V_{IN} = 2.5V$, what is V_{OUT}? $V_{OUT} = 2.75$

(Saturation)

$$I_{DS} = \frac{k'}{2}\frac{W}{L}(V_{GS} - V_T)^2 = \frac{10^{-4}}{2} \cdot 10\,(1.5)^2$$

$$V_{OUT} = 5 - 2k\Omega \cdot I_{DS} = 5 - 2.25 = 2.75V$$

c) If $V_{IN} = 5.0V$, $V_{OUT} = .56$

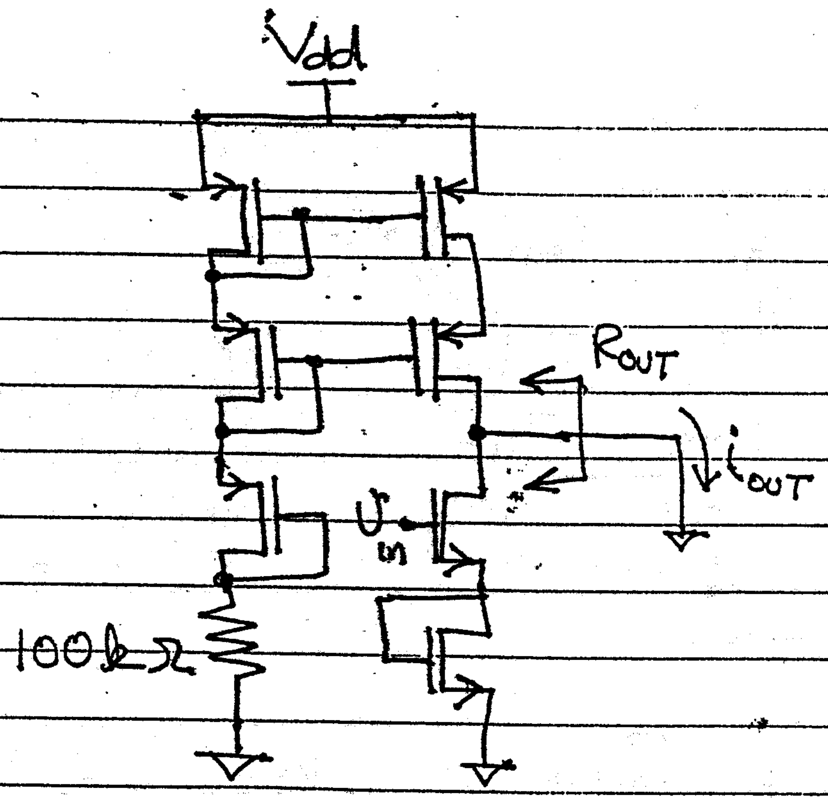
(Linear)

$$I_{DS} = k'\frac{W}{L}(V_{GS} - V_T)V_{ds} = 10^{-3}(4.0)\,V_{OUT}$$

$$V_{OUT} = 5 - 2k\,I_{DS} = 5 - 8V_{OUT}$$

$$V_{OUT} = 5/9 \text{ volt} = .56V.$$

2)



USE THESE SMALL SIGNAL VALUES FOR ALL THE TRANSISTORS

↓

$g_m = 10m℧$

$r_o = 1M\Omega$

$g_{mb} = 0℧$

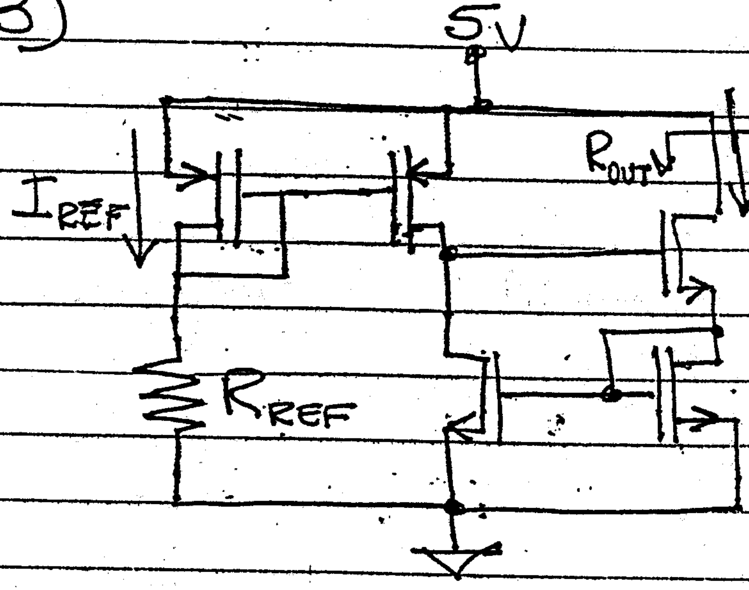
a) WHAT IS R_{OUT}? R_{OUT} $\underline{2M\ \Omega}$

$$R_{OUT} = g_m r_o^2 \,\|\, r_o\left[1 + g_m \frac{1}{g_m}\right] \approx 2r_o$$

b) WHAT IS $G_m \left(= \frac{i_{OUT}}{v_{in}}\right) = \underline{5\ m℧}$

$$G_m = \frac{g_m}{1 + g_m\left(\frac{1}{g_m}\right)} = \frac{g_m}{2} = \frac{10m℧}{2}$$

3)



ALL W/L's = 10

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

$\lambda_n = \lambda_p = .01$

$V_{Tn} = V_{Tp} = 1V.$

$\gamma_n = \gamma_p = 0$

a) WHAT IS R_{REF} SO THAT $I_{OUT} = 10\mu A$?

R_{REF} ______ Ω

$$R_{REF} = \frac{5 - V_T - V_{dSAT}}{I_{ds}} = \frac{5 - 1 - \left(\frac{2 I_{ds}}{k' W/L}\right)}{10^{-5}}$$

$$= \frac{5 - 1 - .14}{10^{-5}} = 390k\Omega$$

b) WHAT IS R_{OUT}? 7×10^9 Ω

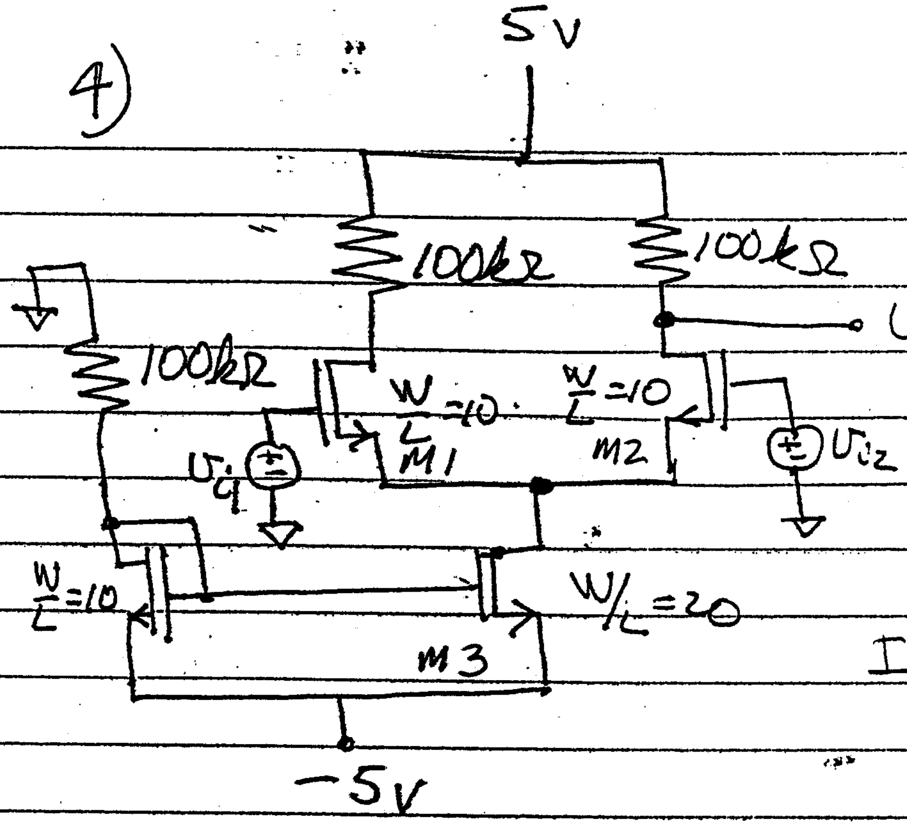
$$R_{OUT} = \frac{g_m r_o^2}{2} = 7 \times 10^9\ \Omega$$

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

$$= .14\ m\mho$$

$$r_o = \frac{1}{10^{-2} \cdot 10^{-5}} = 10M\Omega$$

4)



$k' = 100\ \frac{\mu A}{V^2}$

$\lambda = .01$

$V_T = 1V$

$\gamma = 0$

$I_{DS} \approx \frac{5-1}{10^5} = 40\,\mu A$

a) WHAT IS THE SIGNAL SWING AT V_{OUT} ($V_{MAX} - V_{MIN}$) 6V

+5 IN THE POSITIVE DIRECTION

$-V_T$ IN THE NEGATIVE $= -1V$

b) WHAT IS $\frac{V_{OUT}}{V_{ic}}$? ~~[illegible]~~ .04

$$g_m = \left(2k'\frac{W}{L}I_{DS}\right)^{1/2} = \left(2 \cdot 40\times10^{-6} \times 10 \times 10^{-4}\right)^{1/2}$$

$$= \left(8\times10^{-8}\right)^{1/2} \cong .28\,m\mho$$

$$r_{o3} = \frac{1}{\lambda\, 80\mu A} = \frac{1}{(.01)\,80\times10^{-6}} \cong 1.25\times10^{6}\,\Omega$$

$$G_m = \frac{g_m}{1+g_{m2}r_{o3}} \approx \frac{1}{2r_{o3}}$$

$$R_{OUT} = r_{o2}(1+g_{m2}r_{o3}) \,\|\, 100k$$

$$\approx 100k$$

$$A_v = G_m R_{OUT} = .04$$