EECS 140
MIDTERM 2
FALL 1998

Name : SOLUTIONS

Assume the W/L = 10 for all transistors unless otherwise indicated.

$V_{TN} = V_{TP} = 0.5V$

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

$\gamma_n = \gamma_p = 0$

$\lambda_n = \lambda_p = 0.01$

$C_{GS} = 100ff$

$C_{GD} = C_{GB} = C_{DB} = C_{SB} = 10ff$

(4) 1a. V_{max} = 3.08

(4) b. V_{min} = 3.65

(4) c. 47 %

(10) 2. W/L = .43

(5) 3. R_{out} = 37MΩ

(5) v_{out}/v_{in} = 3.4×10^3

(5) 4. ω_{p1} = 1.9k RAD/SEC

(5) ω_{p2} = 110k RAD/SEC

(4) 5a. SHUNT-SHUNT

(4) b. f = -1×10^{-4}

(4) c. T' = 210

(10) 6. w_c = 450 RAD/SEC

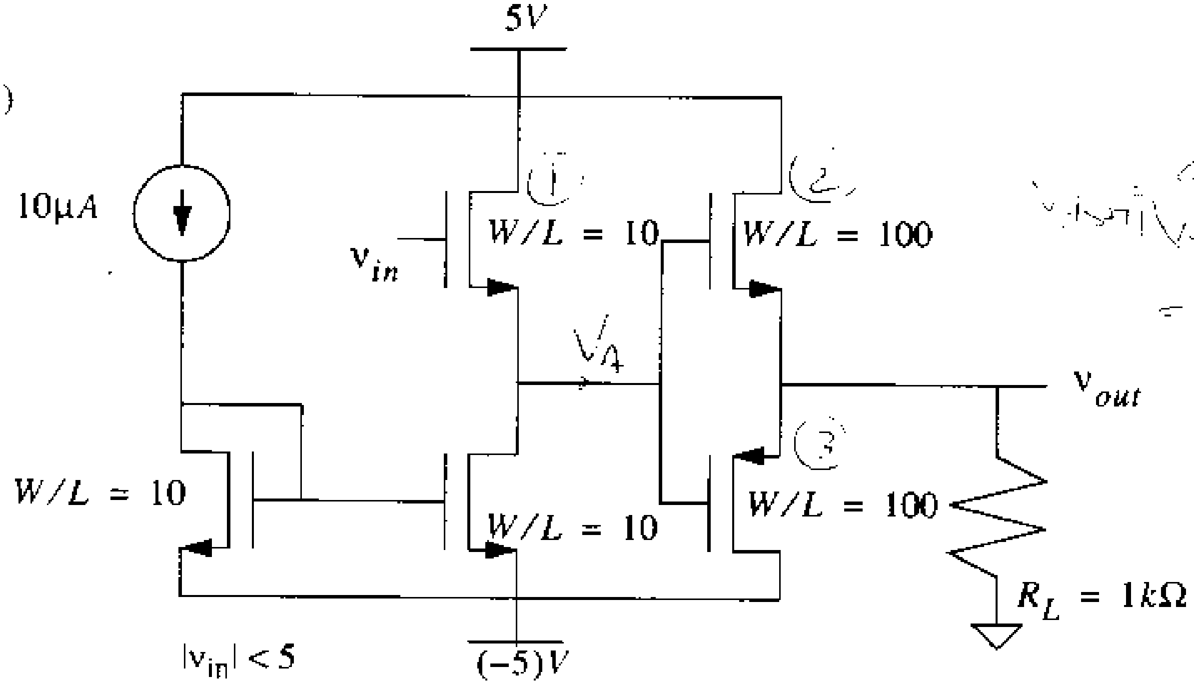
(4) 7. A_{dm} = 21

(4) A_{cm} = .5

(4) v_{out}/v_{in} = -10.2

SHOW YOUR WORK!!

1)



$V_{dsat} = \left(\frac{2(10 \mu A)}{\mu_n C_{ox} W/L}\right)^{1/2} = .14$

1. What is the maximum voltage at V_{out} ? $\underline{3.08V}$

$V_{out,max} = V_{in,max} - (V_T + V_{dsat1}) - (V_T + V_{dsat2})$

$= 5 - .5 - .14 - .5 - V_{dsat2}$

$= 3.86 - \left(\frac{2 V_{out}/R_L}{\mu' \cdot 100}\right)^{1/2}$

$V_{out}^2 - 7.9 V_{out} + 14.9 = 0 \qquad V_{out} = 4.8, 3.08$

2. What is the minimum voltage ? $\underline{-3.65}$

Assume M_3 in linear, $V_A = -5$

$V_{out} = -5 + V_T + V_{dsat3} = -4.5 + \left(\frac{2 V_{out}/R_L}{\mu' \cdot 100}\right)^{1/2}$

$V_{out}^2 + 9.2 V_{out} + 20.7 = 0$

$V_{out} = -3.65, -5.55$

3. What is the efficiency of this circuit ? $\underline{47}$ %

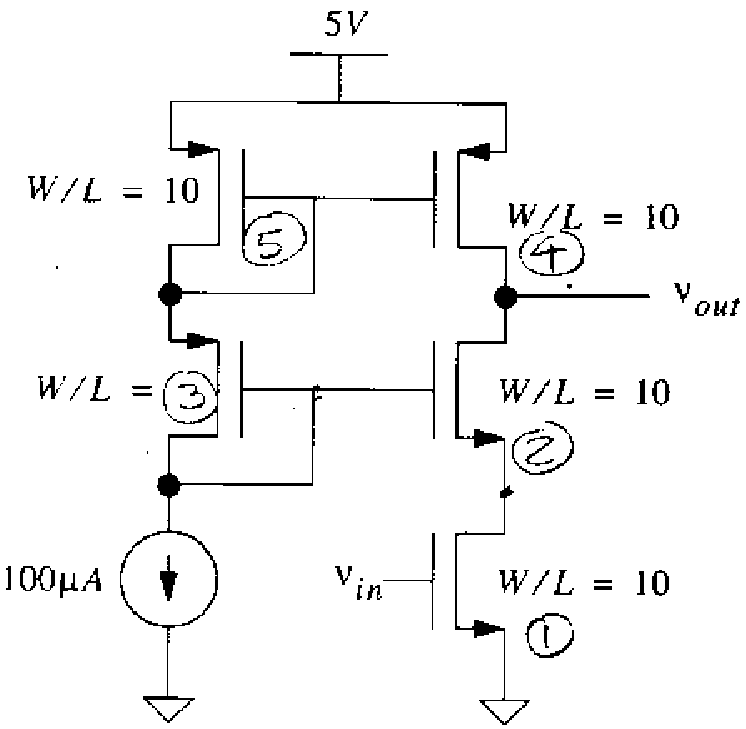
Max swing $\pm 3.08V$

$P_{supply} = 2(10V \cdot 10\mu A) + (2)5 \frac{1}{\pi} \frac{V_o}{R_L}$

$= 4 \times 10^{-4} + 10^{-2} \frac{3.08}{\pi} = 10 mW$

$P_L = \frac{V_o^2}{2R_L} = \frac{1}{2} \frac{(3.08)^2}{10^3} = 4.7 mW \qquad \eta = \frac{P_L}{P_{supply}} = 47\%$

2)



What is the value of the missing W/L so that the output swing is maximum? W/L = .43

$$V_{1,DSAT}(100\mu A) = \left(\frac{2(100)\,\mu A}{100\,\frac{\mu A}{V^2}\cdot 10}\right)^{1/2} = .45V$$

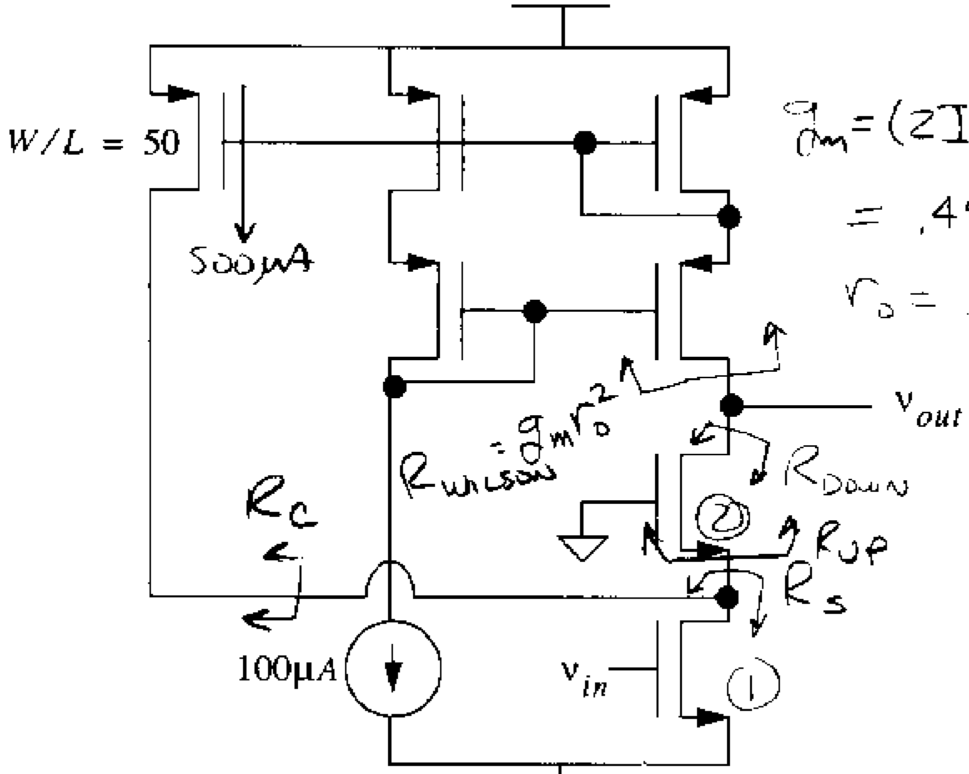
$$5 = V_{dSAT1} + (V_{dSAT2} + V_{T2}) + (V_{dSAT3} + V_{T3}) + (V_{dSAT5} + V_{T5})$$

$$V_{dSAT3} = 5 - (1.5) - 3(.45) = 2.15$$

$$= \left(\frac{2(100)}{100\,(W/L)}\right)^{1/2}$$

$$\left(W/L\right)_3 = .43$$

3) Assume v_{in} is set so that $v_{out} = 0$



$g_m = (2 I_D k' \frac{W}{L})^{1/2}$

$= .45 \times 10^{-3}$ 25

$r_o = \frac{1}{\lambda I_D} = \frac{1}{(.01)(100\mu)}$

$= 1 M\Omega$

a) What is R_{out} <u>37MΩ</u> ?

-5V

$R_{WILSON} = .45 \times 10^{-3} \times 10^{12} = 450 M\Omega$

$R_S = \frac{1}{\lambda 5 (100\mu A)} \| \frac{1}{\lambda 6 (100\mu A)} = 91 k\Omega$

$R_{DOWN} = (g_{m_2} R_S) r_{o_2} = .45 \times 10^{-3} \times 91 \times 10^3 \times 10^6 = 41 M\Omega$

b) What is $\frac{v_{out}}{v_{in}}$ <u>3,400</u> ?

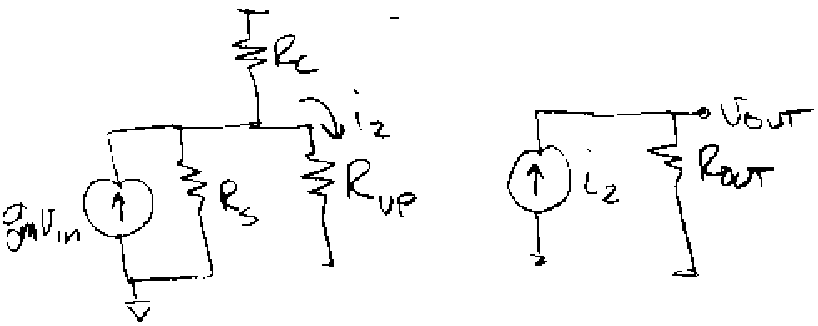
$R_{OUT} = R_{WILSON} \| R_{DOWN}$

$= 450 M\Omega \| 41 M\Omega$

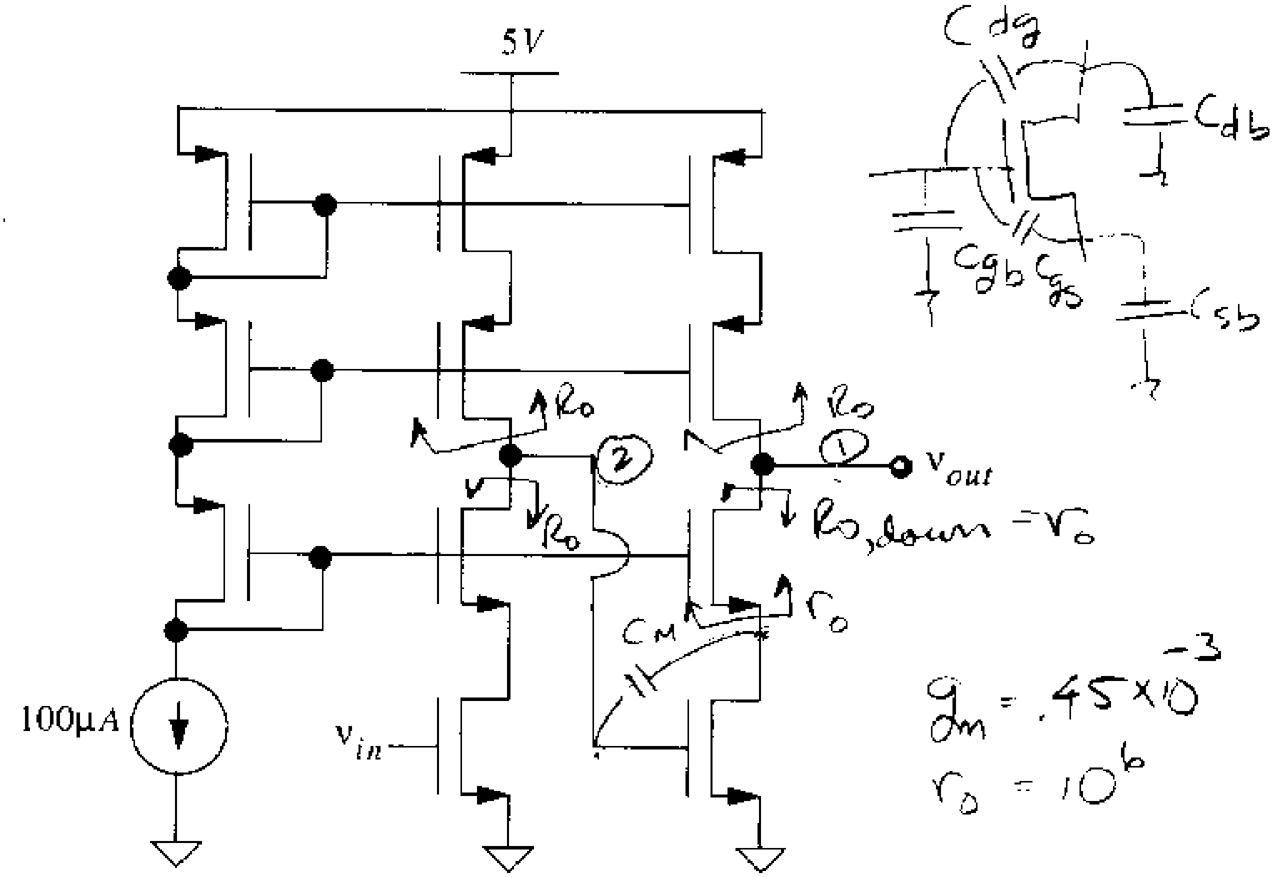
$= 37 M\Omega$

$\frac{v_{out}}{v_{in}} = g_m \frac{R_S \| R_C}{R_{UP} + R_S \| R_C} R_{OUT} = (2 \times 600\mu A \times 100\mu A / 2 \cdot 10)^{1/2} \left(\frac{1/1}{1/1 + 1} \right) 37 M\Omega$

$= 3.4 \times 10^3$



4)



$g_m = .45 \times 10^{-3}$

$r_o = 10^6$

What are the 2 lowest poles of this circuit?

ω_{p1} 110 kRAD/SEC

ω_{p2} 1.9 kRAD/SEC

$C_1 = 2(C_{db} + C_{gd}) = 40\,fF$

$R_o = g_m r_o^2 = .45 \times 10^{-3} \cdot 10^{12}$

$= 450\,M\Omega$

ASSUMING ALL IN SATURATION

$$\omega_{p1} = \frac{1}{\left(\frac{R_o}{2}\right) C_1} = \frac{1}{225 \times 10^6 \cdot 40 \times 10^{-15}}$$

$= 110\,k$ RAD/SEC

$$\omega_{p2} = \frac{1}{\frac{R_o}{2}\left(C_1 + C_M + C_{gb} + C_{cgs}\right)}$$

$$\omega_{p2} = \frac{1}{225 \times 10^6 \times (40fF + 2250fF + 10fF + 100fF)}$$

2400 fF

$= 1.9$ kRAD/SEC

$C_M = g_m (r_o \| r_o) C_{gd} =$

$= .45 \times 10^{-3} \times 10^6/2 \times 10\,fF$

$= 2250\,fF$