Name: Solution

EE303 - Midterm Exam #2

Closed Book:
Two 8.5"x11" sheet of handwritten notes permitted
Calculator permitted

Important Notes:

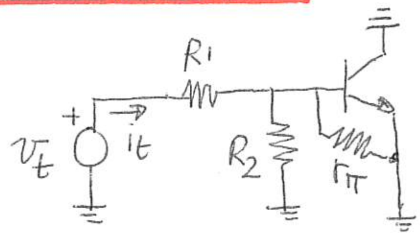
- Read each problem completely and thoroughly
- Summarize all your answers in the boxes provided on these exam sheets
- Make sure to mark the units on your answers!
- Do all your work on the exams sheets provided. If you use any additional sheets, please turn them in, so we can consider all work for partial credit
- Do not forget to put your name in the space above

Problem #	Points	Score
1	15	
2	10	
3	15	
4	10	
5	10	
6	15	
7	10	
TOTAL	**85**	

solution – problem 1

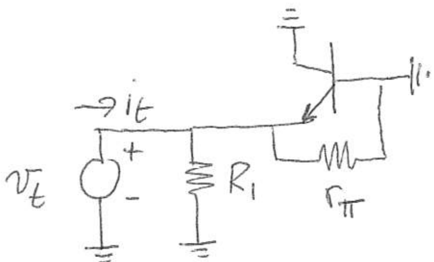
assume $r_o = \infty \Leftrightarrow V_A = \infty$

(a)



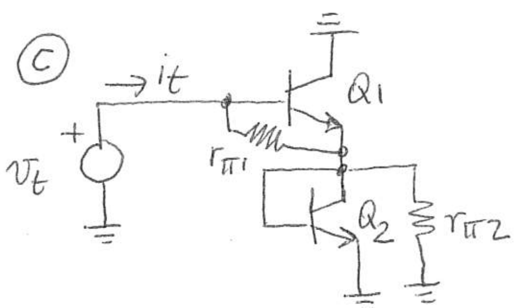
$$\frac{v_t}{i_t} = R_{in} = R_1 + R_2 \| r_\pi$$

(b)



$$\frac{v_t}{i_t} = R_1 \| r_\pi \| \frac{1}{g_m}$$

(c)

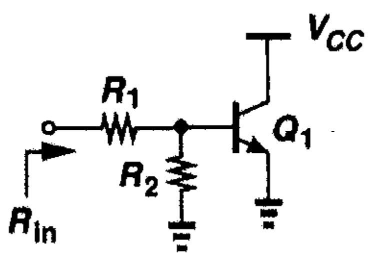


$$\frac{v_t}{i_t} = r_{\pi 1} + \left(r_{\pi 2} \| \frac{1}{g_{m2}}\right)(\beta_1 + 1)$$

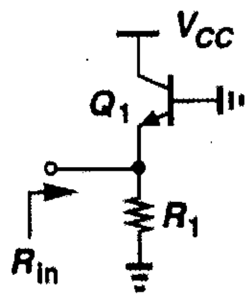
Name:

Problem 1 [15 pts]

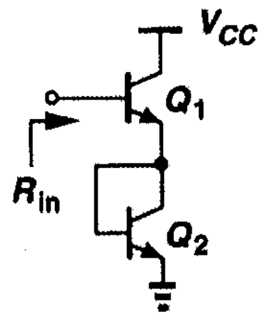
Compute the input resistance for the following circuits. Assume $V_A = \infty$



(a)



(b)

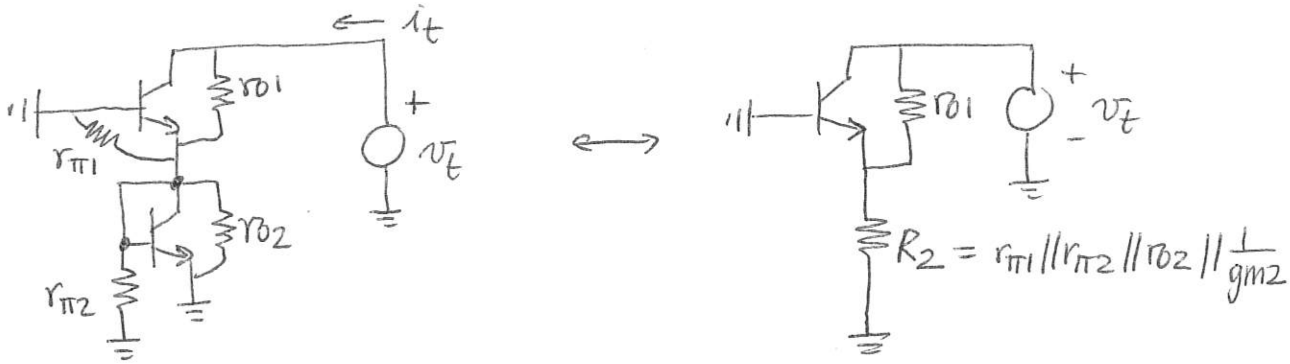


(c)

a) R_{in}	
b) R_{in}	
c) R_{in}	

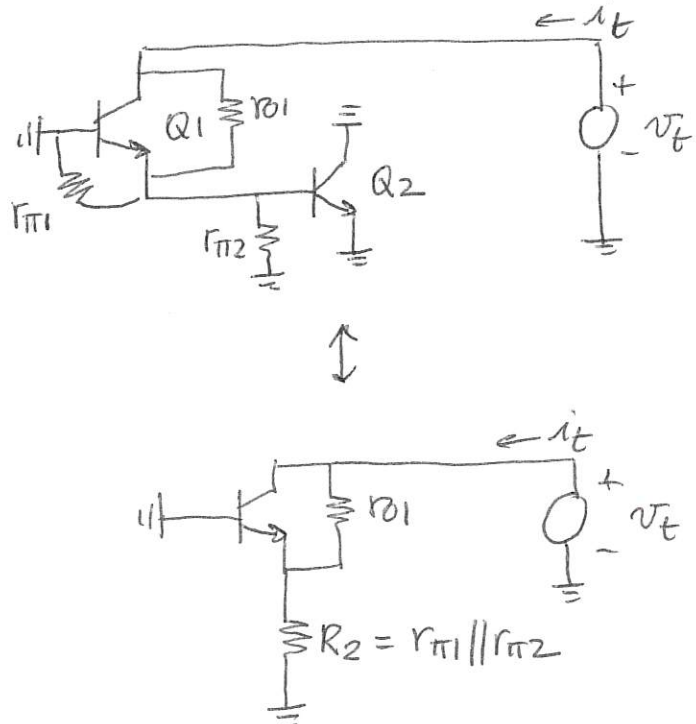
solution – problem 2

(a)



$$\frac{v_t}{i_t} \cong r_{o1}\left(1 + g_{m1} R_2\right) \quad \text{or more precisely: } \frac{v_t}{i_t} = r_{o1}\left(1 + g_{m1} R_2\right) + R_2$$

(b)



$$\frac{v_t}{i_t} = R_{out} \cong r_{o1}\left(1 + g_{m1} \cdot R_2\right)$$

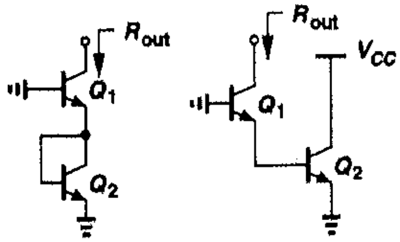
or more precisely:

$$\frac{v_t}{i_t} = r_{o1}\left(1 + g_{m1} \cdot R_2\right) + R_2$$

Name: ____

Problem 2 [10 pts]

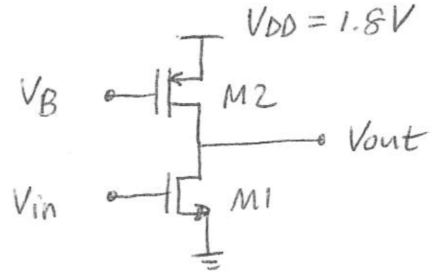
Compute the output resistance for the following circuits. Assume V_A is finite:



(a) (b)

(a) R_{out} =	
(b) R_{out} =	

solution - problem 3



$Av = 10$

$I_D = I_{D1} = I_{D2} = 0.5mA$

$\lambda_1 = 0.1\ V^{-1}$

$\lambda_2 = 0.15\ V^{-1}$

$\mu_n C_{ox} = 200\ \mu A/V^2$

$\mu_p C_{ox} = 100\ \mu A/V^2$

$|V_{TH}| = 0.4\ V$

$(W/L)_2 = \frac{20}{0.18}$

(a)

$$A_v = g_{m1} \cdot (r_{o1} \| r_{o2}) \Rightarrow g_{m1} = \frac{A_v}{r_{o1} \| r_{o2}}$$

$$r_{o1} \cong \frac{1}{\lambda_1 \cdot I_D} = 20\ K\Omega$$

$$r_{o2} \simeq \frac{1}{\lambda_2 \cdot I_D} = 13.33\ K\Omega$$

$$r_{o1} \| r_{o2} \cong 8\ K\Omega$$

$$g_{m1} = \frac{10}{8K} = 1.25\ mS$$

$$g_{m1} = \frac{2I_D}{V_{ov_1}} \rightarrow V_{ov1} = \frac{2I_D}{g_{m1}} = 0.8\ V$$

$$I_D \cong \frac{\mu_n C_{ox}}{2} \left(\frac{W}{L}\right)_1 V_{ov_1}^2$$

$$\left(\frac{W}{L}\right)_1 = \frac{2I_D}{\mu_n C_{ox} V_{ov_1}^2} = \frac{1m}{200\mu \cdot 0.8^2} \cong 7.8125$$

(b)

$$V_B = V_{DD} - V_{SG_p}$$

$$V_{SG_p} = |V_{TH_p}| + \sqrt{\frac{2I_D}{\mu_p C_{ox} (W/L)_2}} = 0.4 + \sqrt{\frac{1m}{100\mu \cdot 20/0.18}} = $$

$$\simeq 0.7\ V$$

$$V_B = 1.8 - 0.7 = 1.1\ V$$

Name: ______________________________

Problem 3 [15 pts]

The CS stage of Fig. 7.56 must provide a voltage gain of 10 with a bias current of 0.5 mA. Assume $\lambda_1 = 0.1\ V^{-1}$, and $\lambda_2 = 0.15\ V^{-1}$.

(a) Compute the required value of $(W/L)_1$.

(b) If $(W/L)_2 = 20/0.18$, calculate the required value of V_B.

$\mu_p C_{ox} = 200\ \mu A/V^2$

$\mu_p C_{ox} = 100\ \mu A/V^2$

$V_{THn} = 0.4\ V$

$V_{THp} = -0.4\ V$

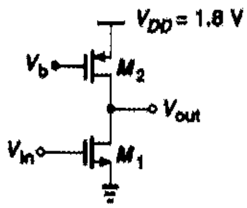
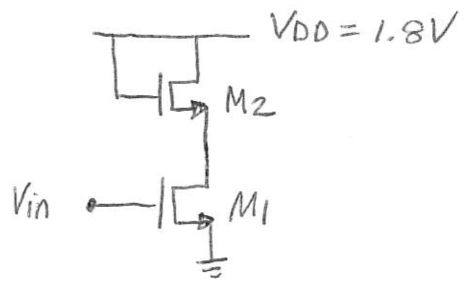


Figure 7.56

$(W/L)_1$ =	
V_B =	

problem 4 - solution



$A_V = 3$

$(W/L)_1 = 20/0.18$

assume $\lambda = 0$

$\mu_n C_{ox} = 200\ \mu A/V^2$

$V_{TH} = 0.4V$

$$A_V = g_{m1} \cdot \frac{1}{g_{m2}}$$

$$I_{D1} = I_{D2} \triangleq I_D$$

$$V_{ov1} = \sqrt{\frac{2 \cdot I_D}{\mu_n C_{ox} (W/L)_1}} \qquad V_{ov2} = \sqrt{\frac{2 I_D}{\mu C_{ox} (W/L)_2}}$$

$$g_{m1} = \frac{2 I_D}{V_{ov1}} \qquad g_{m2} = \frac{2 I_D}{V_{ov2}}$$

$$A_V = \frac{g_{m1}}{g_{m2}} = \frac{V_{ov2}}{V_{ov1}} = \sqrt{\frac{(W/L)_1}{(W/L)_2}}$$

$$(W/L)_2 = (W/L)_1 / (g_{m1}/g_{m2})^2 =$$

$$= \frac{20}{0.18} \cdot \frac{1}{9} = 12.35$$

Name:

Problem 4 [10 pts]

We wish to design the circuit shown in Fig. 7.59 for a voltage gain of 3. If $(W/L)_1 = 20/0.18$, determine $(W/L)_2$. Assume $\lambda = 0$.

$\mu_n C_{ox} = 200\ \mu A/V^2$

$V_{TH} = 0.4V$

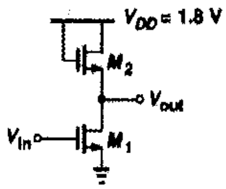
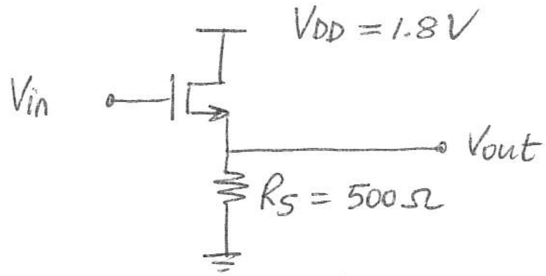


Figure 7.59

$(W/L)_2 =$	

problem 5 – solution



$W/L = 30/0.18$

$\lambda = 0$

$A_V = 0.8$

$\mu C_{ox} = 200\,\mu A/V^2$

$$A_V = \frac{g_m R_S}{1 + g_m R_S} = 0.8$$

$$A_V + A_V g_m R_S = g_m R_S \rightarrow A_V = g_m (R_S - A_V R_S) \rightarrow$$

$$g_m = \frac{A_V}{R_S - A_V R_S} = \frac{0.8}{500 - 500 \cdot 0.8} \cong 8\ mS$$

$$g_m = \frac{2 I_D}{V_{OV}}$$

$$I_D = \frac{\mu C_{ox}}{2}\left(\frac{W}{L}\right) V_{OV}^2 \rightarrow V_{OV} = \sqrt{\frac{2 I_D}{\mu C_{ox}(W/L)}}$$

$$g_m = \sqrt{2 I_D \mu C_{ox} (W/L)}$$

$$I_D = \frac{g_m^2}{2 \mu C_{ox} (W/L)} = \frac{8^2 \times 10^{-6}}{2 \cdot 200 \times 10^{-6} \cdot 30/0.18} =$$

$$= 0.96\ mA$$

$$V_{GS} = V_{OV} + V_{TH}$$

$$V_{OV} = \sqrt{\frac{2 I_D}{\mu C_{ox}(W/L)}} = \sqrt{\frac{2 \times 0.96m}{200\mu \cdot 30/0.18}} \cong 240\ mV$$

$$V_{GS} = 640\ mV$$

$$\underline{V_G} = V_{GS} + V_S = V_{GS} + R_S \cdot I_D = 640mV + 500\Omega \times 0.96mA =$$

$$\simeq \underline{1.12\ V}$$

Name:

Problem 5 [10 pts]

$\mu C_{ox} = 200\ \mu A/V^2$

We wish to design the source follower shown in Fig. 7.77 for a voltage gain of 0.8. If $W/L = 30/0.18$ and $\lambda = 0$, determine the required gate bias voltage.

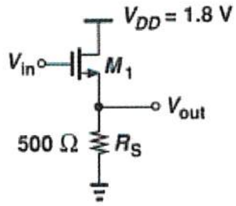
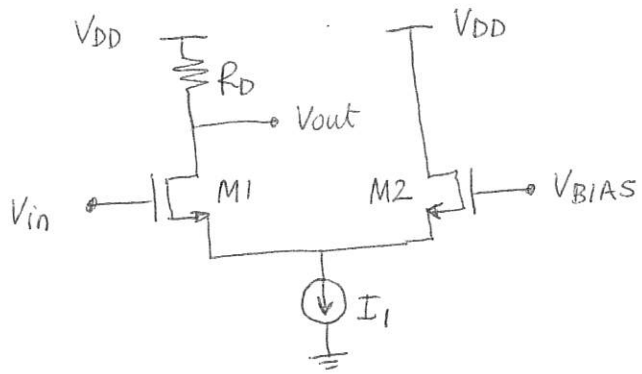


Figure 7.77

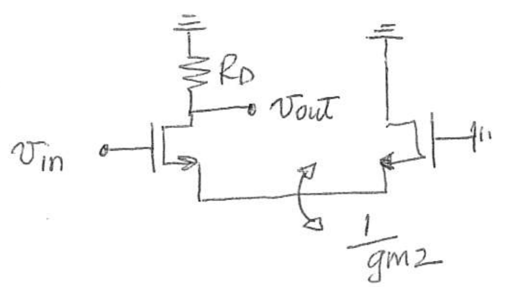
V_G =	

Solution problem 6



assume $\lambda = 0$

(a)



$$A_v = \frac{v_{out}}{v_{in}} = -\frac{g_{m1} \cdot R_D}{1 + g_{m1}/g_{m2}}$$

(b) $R_{in} = \infty$

(c) $R_{out} = R_D$

↖ assuming λ of transistors is negligible

otherwise

$$R_{out} = R_D \,||\, \left[r_{o1}\left(1 + g_{m1} \cdot \left(\frac{1}{g_{m2}} \,||\, r_{o2}\right)\right) + \frac{1}{g_{m2}} \,||\, r_{o2} \right]$$

$$\approx R_D \,||\, \left[r_{o1}\left(1 + g_{m1}/g_{m2}\right) \right]$$

↑

$r_{o2} \gg \frac{1}{g_{m2}} \longleftrightarrow r_{o2} g_{m2} \gg 1$

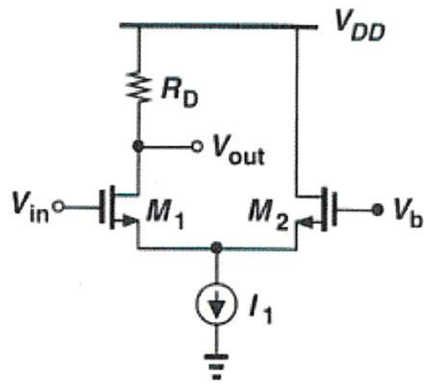
&

$\frac{r_{o1} g_{m1}}{g_{m2}} \gg \frac{1}{g_m} \longleftrightarrow r_{o1} g_{m1} \gg 1$

Name:

Problem 6 [15 pts]

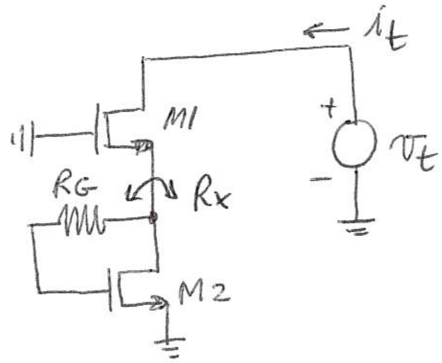
Calculate the voltage gain, the input impedance and the output impedance of the circuit depicted in fig. Assume channel length modulation is negligible.
NOTE: V_b is a DC bias voltage.



$A_V = v_{out}/v_{in} =$	
$R_{in} =$	
$R_{out} =$	

problem 7 – solution

(a)



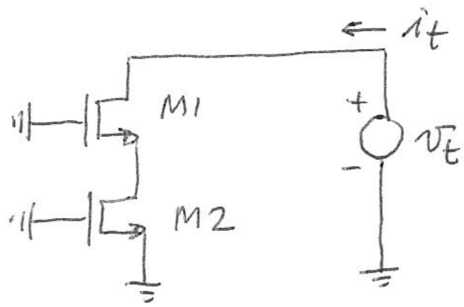
$$R_x = \frac{1}{g_{m2}} \parallel r_{o2}$$

$$\frac{v_t}{i_t} \cong r_{o1}\left(1 + g_{m1} \cdot \frac{1}{g_{m2}}\right)$$

or more accurately:

$$\frac{v_t}{i_t} = r_{o1}\left(1 + g_{m1} R_x\right) + R_x$$

(b)



$$\frac{v_t}{i_t} \cong r_{o1}\left(1 + g_{m1} \cdot r_{o2}\right) \approx g_{m1} r_{o1} r_{o2}$$

or more accurately

$$\frac{v_t}{i_t} = r_{o1}\left(1 + g_{m1} \cdot r_{o2}\right) + r_{o2}$$

Name: ______________________________

Problem 7 [10 pts]

Compute the output resistance of the circuits depicted in Fig. 9.50. Assume all of the transistors operate in saturation and $g_m r_O \gg 1$.

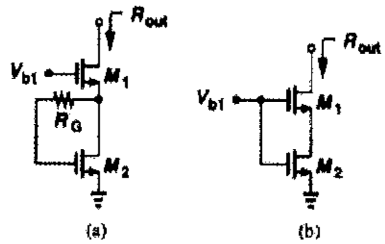


Figure 9.50

(a) R_{out} =	
(b) R_{out} =	