Prof. Seth Sanders

EECS 140 **Spring 2005**

Midterm Exam
March 15, 2005
Time Allowed: 80 minutes

SOLUTIONS

Name:____________________, ____________________
Last First

Student ID #:______________, Signature:____________________

- This is a closed-book exam, except for use of one 8.5 x 11 inch sheet of your notes.
- Show all your work to receive full or partial credit. Write your answers clearly in the spaces provided.
- No electronic devices of any kind may be used.

Problem #:	Points:
1	/60
2	/40
Total	/100

1.) (60 points total)

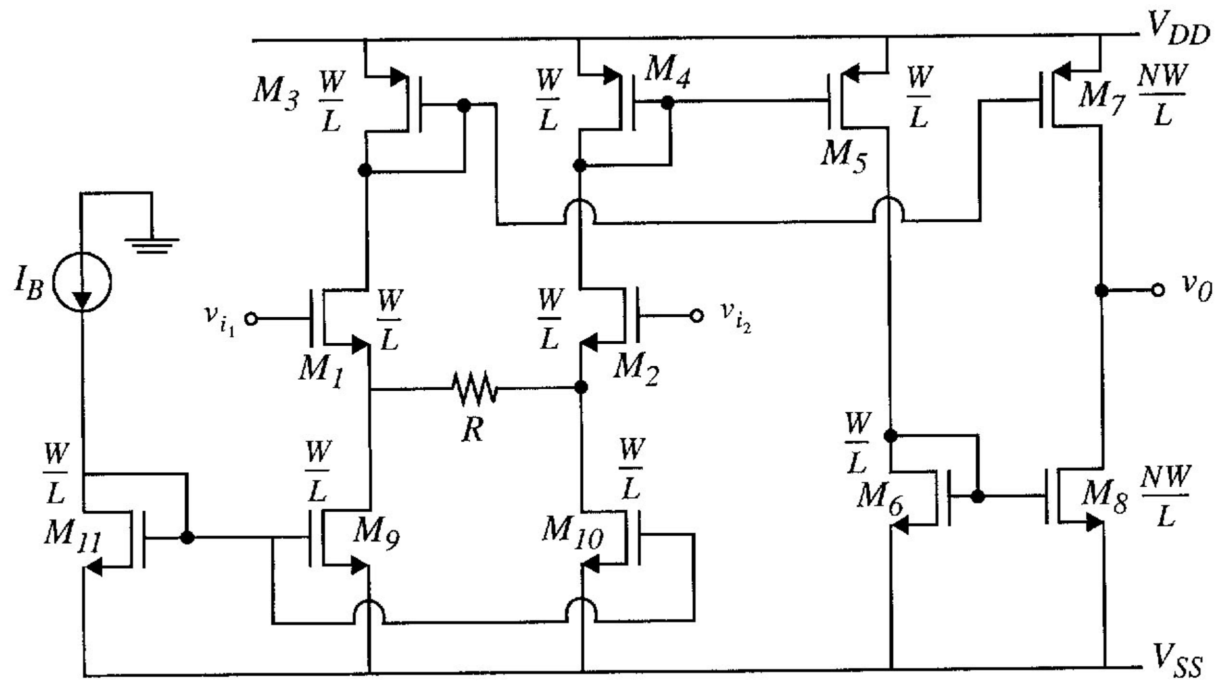

Figure 1: Current Mirror Op-Amp

a.) (10 points)

Suppose inputs v_{i_1} and v_{i_2} are grounded, i.e. $v_{i_1} = v_{i_2} = 0$.

Determine the dc bias values for the following variables: (see next page) (You may neglect the r_O of all transistors for this.)

Leave your results in symbolic form involving I_B, k'_p, k'_n, etc.

I_{D_1}	I_B
I_{D_2}	I_B
I_{D_6}	I_B
I_{D_8}	$N I_B$
ΔV_1	$\sqrt{\frac{2 I_B}{k_n W/L}}$
ΔV_2	ΔV_1
ΔV_3	$\sqrt{\frac{2 I_B}{k_p W/L}}$
ΔV_4	ΔV_3
ΔV_5	ΔV_3
ΔV_6	ΔV_1
ΔV_7	ΔV_3
ΔV_8	ΔV_1
ΔV_9	ΔV_1
ΔV_{10}	ΔV_1
V_0	$V_{SS} + \Delta V_{6,8} + V_{t6,8}$

b.)(10 points)
Determine the common mode input range for the circuit, that is consistent with all transistors remaining active.

$$V_{SS} + \Delta V_9 + \Delta V_1 + V_{t1} < V_i < V_{DD} + V_{t1} - |V_{t3}| - |\underbrace{V_{dsat3}}_{\Delta V_3}|$$

c.)(10 points)
Determine the output voltage range, that is consistent with all transistors remaining active.

$$V_{SS} + \Delta V_8 < V_o < V_{DD} - |\Delta V_7|$$

d.) (10 points)
Determine R_{out}.

$$r_{o7} \, // \, r_{o8}$$

e.)(10 points)

Determine the differential mode circuit G_m, i.e. $G_{m_{dm}} = \left.\frac{i_{out}}{v_{i_d}}\right|_{v_{out}=0}$; $v_{i_d} = v_{i_1} - v_{i_2}$.

$$\frac{2g_{m1} \cdot N}{2 + g_{m1}R} \quad \text{or} \quad \frac{N g_{m1}}{1 + g_{m1}\frac{R}{2}}$$

(ignoring body effect)

f.) (10 points)

Determine the common mode voltage gain: $A_{v-cm} = \frac{v_0}{v_{i_{cm}}}$.

$$\frac{1}{1 + g_{m1} r_{o9}}$$

2.) (40 points total)

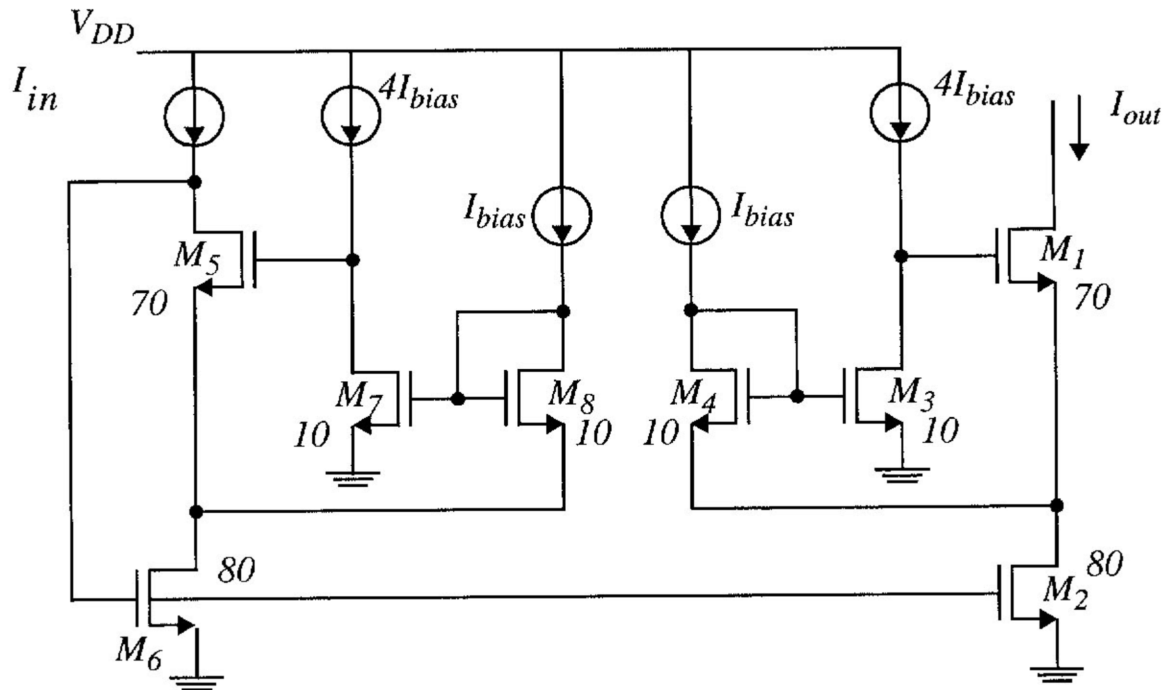

Figure 2: Current Mirror

In the current mirror of Figure 2, all devices have $\frac{W}{L}$'s as shown in the figure.

a.) (10 points)
Assuming all devices are biased in the active region, determine the nominal bias values for the following (see the next page).

Leave your answers as expressions involving V_T's, k', I_B, I_{ref}, $\frac{W}{L}$ etc.:

I_{out}	I_{in}
V_{GS1}	$V_{t1} + \sqrt{\frac{2I_{in}}{k'(W/L)_1}}$
V_{GS2}	$V_{t2} + \sqrt{\frac{2(I_{in}+I_{bias})}{k'(W/L)_2}}$
V_{GS3}	$V_{t3} + \sqrt{\frac{2.4 I_{bias}}{k'(W/L)_3}}$
V_{GS4}	$V_{t4} + \sqrt{\frac{2 I_{bias}}{k'(W/L)_4}}$
V_{GS5}	V_{GS1}
V_{GS6}	V_{GS2}
V_{GS7}	V_{GS3}
V_{GS8}	V_{GS4}

b.) (10 points)
Determine the minimum output voltage that keeps all devices in the active region.

$$V_{o,min} = V_{GS3} - V_{GS4} + \Delta V_1$$
$$= \Delta V_3 + V_{T3} - \Delta V_4 - V_{T4} + \Delta V_1$$

c.) (10 points)
Determine R_{out} for this circuit assuming all devices are active. Express your answer as a formula involving transistor small signal parameters like $g_{m_{1-8}}$, $r_{0_{1-8}}$, etc.

Loop gain $= g_{m3} r_{o3} = A_L$

$R_{out} = g_{m1} r_{o1} r_{o2} (1 + A_L)$

$= g_{m1} r_{o1} r_{o2} (1 + g_{m3} r_{o3})$

d.) (10 points)
Briefly explain the purposes of M_3, M_4, M_5, M_7 and M_8 in this circuit.

- M_3 is a common source amplifier used in a feedback loop to increase output resistance of M1-M2 cascode connection.
- M_4 provides level shifting so that the drain of M_2 is biased at about ΔV_2.
- M_5, M_7, M_8 provide for symmetry in the ckt keep drain voltage at M_6 approx equal to that of M_2