Texas A&M University
Department of Electrical and Computer Engineering

ECEN 326 – Electronic Circuits

Fall 2015

Exam #1

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are 5 pages in your exam
- You may use one double-sided page of notes and equations for the exam
- Good Luck!

Problem	Score	Max Score
1		40
2		60
Total		**100**

Name: SAM PALERMO

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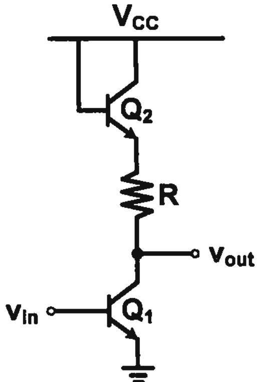
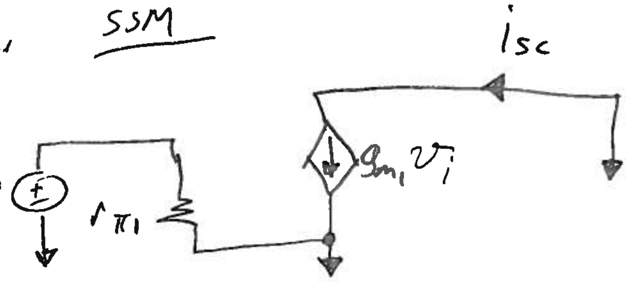
Problem 1 (40 points)
For the circuit shown below, assume that all transistors are operating in the active region and that $V_A=\infty$ for all transistors. Obtain expressions for the following:

a) Short-circuit transconductance, $\mathbf{G_m}$. Here use the book convention where i_{sc} flowing into the circuit is positive.
b) Output resistance, $\mathbf{R_{out}}$
c) Small-signal gain, $\mathbf{A_v=v_{out}/v_{in}}$
d) Input resistance, $\mathbf{R_{in}}$

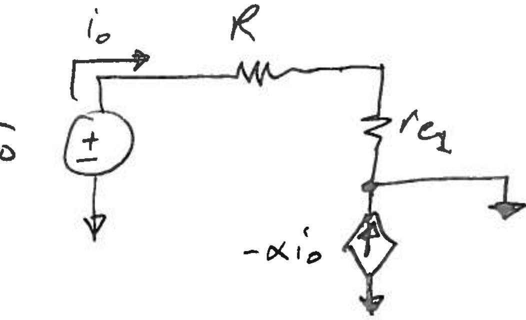


a. SSM



$$G_m = \frac{i_{sc}}{v_i} = \frac{g_{m1} v_i}{v_i} = g_{m1}$$

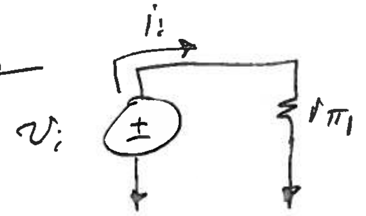
b. SSM



$$R_{out} = \frac{v_o}{i_o} = R + r_{e2}$$

c. $A_v = -G_m R_{out} = -g_{m1}(R + r_{e2})$

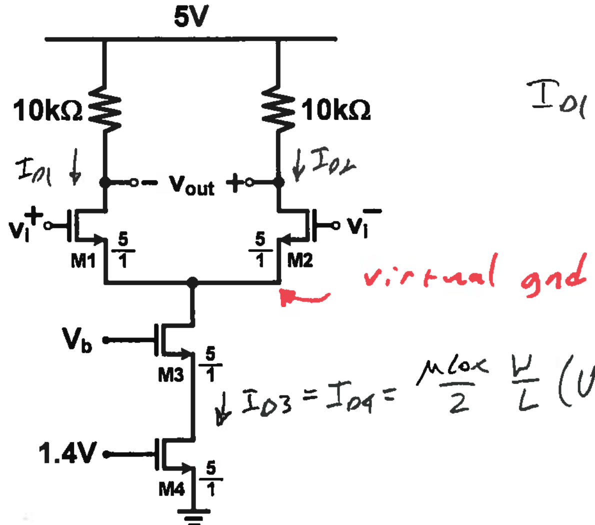
d. SSM



$$R_{in} = r_{\pi 1}$$

Problem 2 (60 points)
For the circuit shown below, assume that all transistors are operating in the saturation region. Use the following transistor parameters

$KP_N=\mu_nC_{ox}=200\mu A/V^2$, $V_{TH,N}=0.4V$
$\lambda_1=\lambda_2=0$
$\lambda_3=\lambda_4=0.1V^{-1}$



$I_{D1}=I_{D2}=\frac{I_{D3}}{2}=250\mu A$

$I_{D3}=I_{D4}=\frac{\mu C_{ox}}{2}\frac{W}{L}(V_{GS}-V_T)^2=\frac{200\mu}{2}\left(\frac{5}{1}\right)(1.4-0.4)^2=500\mu A$

a) Calculate the DC current flowing through the transistors. Here assume that V_b and the input common-mode is sufficient to keep all the transistors operating in the saturation region. **Also, you can neglect λ effects for this part.**

I_{D1} = 250μA

I_{D2} = 250μA

I_{D3} = 500μA

I_{D4} = 500μA

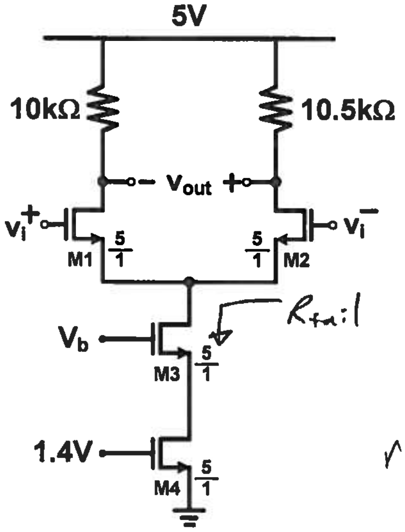
b) Calculate the small-signal differential mode gain, $A_{DM}=v_{out}/(v_i^+-v_i^-)$. Include λ effects, if necessary.

$A_{DM}=g_{m1}R_D$

$g_{m1}=\sqrt{\mu C_{ox}\frac{W}{L}2I_D}=\sqrt{200\mu\left(\frac{5}{1}\right)(2)(250\mu A)}=707\mu A/V$

$A_{DM}=(707\mu A/V)(10k\Omega)=7.07\ V/V$

c) As shown in the circuit below, during manufacturing a mismatch appears in the load resistors. Calculate the common-mode to differential-mode conversion gain, $A_{CM\text{-}DM}$. Include λ effects, if necessary.



$$A_{CM\text{-}DM} = \frac{\Delta R_D}{\frac{1}{g_{m1}} + 2R_{tail}}$$

$$R_{tail} = r_{o3} + r_{o4} + g_{m3} r_{o3} r_{o4}$$

$$r_{o3} = r_{o4} = \frac{1}{\lambda I_D} = \frac{1}{(0.1)(500\mu)} = 20k\Omega$$

$$g_{m3} = \sqrt{\mu C_{ox} \frac{W}{L} 2I_D} = \sqrt{(200\mu)(\tfrac{5}{1}) 2(500\mu)} = 1\, mA/V$$

$$A_{CM\text{-}DM} = \frac{500}{\frac{1}{707\mu A/V} + 2(20k + 20k + (1m)(20k)^2)} = 567\times10^{-6}$$

$$A_{CM\text{-}DM} = 567\times10^{-6} = -64.9\,dB$$

d) Calculate the common-mode rejection ration, CMRR = ($A_{DM}/A_{CM\text{-}DM}$). Here you can use the A_{DM} calculated in part (b).

$$CMRR = \frac{A_{DM}}{A_{CM\text{-}DM}} = \frac{7.07}{567\times10^{-6}} = 12.5\times10^{3} = 81.9\,dB$$

Scratch Paper