Texas A&M University
Department of Electrical and Computer Engineering

ECEN 326 – Electronic Circuits

Fall 2015

Exam #3

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		35
2		35
3		30
Total		**100**

Name: SAM PALERMO

UIN:

Problem 1 (35 points)

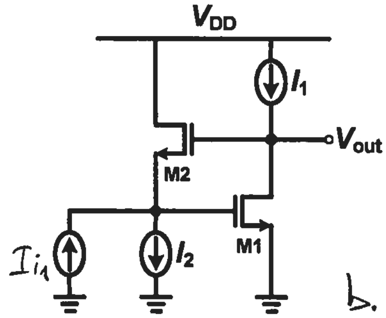
For the circuit shown below, assume that all transistors are operating in the saturation region and that $\lambda>0$.

a. What type of feedback is present in the circuit?

b. Give expressions for the **open-loop** gain (V_{out}/I_{in}), input resistance, and output resistance. Make sure to include feedback loading effects.

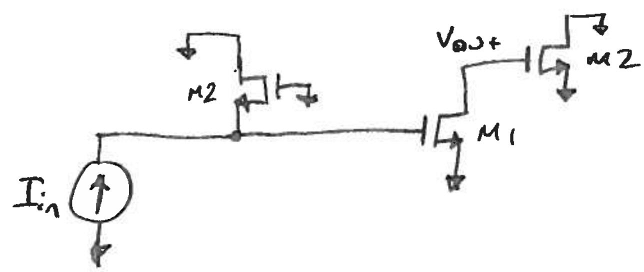
c. What is the feedback factor, K?

d. Give expressions for the **closed-loop** gain (V_{out}/I_{in}), input resistance, and output resistance.



a. Voltage (Sensing) – Current (Return) Feedback or Shunt (FB) – Shunt (Sensing)

b. Breaking Loop



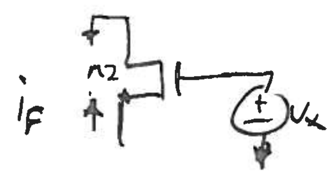
$$R_{OL}=\frac{V_{out}}{I_{in}}=\left(\frac{1}{g_{m2}}\|r_{o2}\right)\left(-g_{m1}r_{o1}\right)$$

$$R_{in,OL}=\left(\frac{1}{g_{m2}}\|r_{o2}\right)$$

$$R_{out,OL}=r_{o1}$$

For K:

c.



$$K=\frac{i_F}{V_x}=-g_{m2}$$

d.

$$R_{CL}=\frac{R_{OL}}{1+KR_{OL}}=\frac{-g_{m1}r_{o1}\left(\frac{1}{g_{m2}}\|r_{o2}\right)}{1+g_{m1}r_{o1}g_{m2}\left(\frac{1}{g_{m2}}\|r_{o2}\right)}$$

$$R_{in,CL}=\frac{R_{in,OL}}{1+KR_{OL}}=\frac{\left(\frac{1}{g_{m2}}\|r_{o2}\right)}{1+g_{m1}r_{o1}g_{m2}\left(\frac{1}{g_{m2}}\|r_{o2}\right)}$$

$$R_{out,CL}=\frac{R_{out,OL}}{1+KR_{OL}}=\frac{r_{o1}}{1+g_{m1}r_{o1}g_{m2}\left(\frac{1}{g_{m2}}\|r_{o2}\right)}$$

Problem 2 (35 points)

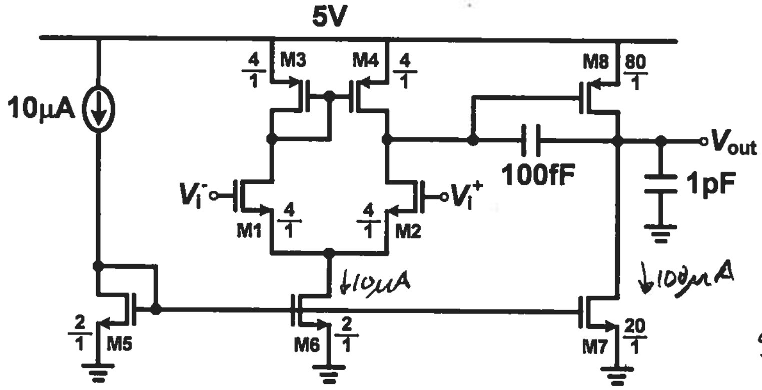
For the circuit shown below, assume that all transistors are operating in the saturation region. Also assume that the amplifier is well-designed with one dominant pole and that we can neglect any zero effects.

Calculate the following using these transistor parameters.

$KP_N=\mu_n C_{ox}=200\mu A/V^2$, $V_{TH,N}=0.4V$, $\lambda_N=0.1V^{-1}$

$KP_P=\mu_p C_{ox}=100\mu A/V^2$, $V_{TH,P}=-0.4V$, $\lambda_P=0.1V^{-1}$

Low-frequency gain ($A_{DC}=V_{out}/(V_i^+-V_i^-)$), dominant pole ($\omega_{p1}$), second pole ($\omega_{p2}$), unity-gain frequency (ω_{GX}), and worst-case phase margin (PM).



$$A_{DC}=\left(\frac{-g_{m2}}{g_{o2}+g_{o4}}\right)\left(\frac{-g_{m8}}{g_{o7}+g_{o8}}\right)$$

$$g_{m2}=\sqrt{(200\mu)\left(\frac{4}{1}\right)(2)(5\mu)}=89.4\mu A/V$$

$$g_{o2}=g_{o4}=\lambda I=(0.1V^{-1})(5\mu A)=0.5\mu$$

$$g_{m8}=\sqrt{(100\mu)\left(\frac{80}{1}\right)(2)(100\mu)}=1.26\,mA/V \qquad g_{o7}=g_{o8}=(0.1V^{-1})(100\mu A)=10\mu$$

$$A_{DC}=\left(\frac{89.4\mu}{0.5\mu+0.5\mu}\right)\left(\frac{1.26m}{10\mu+10\mu}\right)=5.63\times10^3$$

$$\omega_{p1}=-\frac{(g_{o2}+g_{o4})(g_{o7}+g_{o8})}{g_{m8}C_c}=-\frac{(0.5\mu+0.5\mu)(10\mu+10\mu)}{(1.26m)(100f)}=-159\,Krad/s=-25.3\,KHz$$

$$\omega_{p2}=-\frac{g_{m8}}{C_L}=-\frac{1.26m}{1p}=-1.26\,Grad/s=-201\,MHz$$

$$\omega_{GX}=\frac{g_{m2}}{C_c}=\frac{89.4\mu}{100f}=894\,Mrad/s=142\,MHz$$

$$PM=\tan^{-1}\left(\frac{\omega_{p2}}{\omega_{GX}}\right)=\tan^{-1}\left(\frac{201\,MHz}{142\,MHz}\right)=54.8^\circ$$

A_{DC} = 5.63×10^3 V/V

ω_{p1} = -159 Krad/s

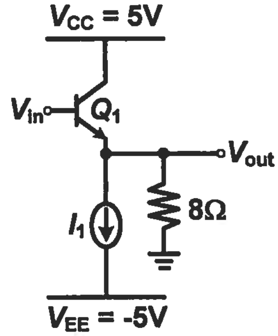
ω_{p2} = -1.26 Grad/s

ω_{GX} = 894 Mrad/s

PM = 54.8°

Problem 3 (30 points)

The circuit shown below should be designed to deliver 1W into an 8Ω load resistor with minimal distortion. Determine I_1, the average power consumed by Q_1, and the average power consumed by I_1.



$$P_{avg} = \frac{V_p^2}{2R_L}$$

$$V_p = \sqrt{2R_L P_{avg}} = \sqrt{2(8\Omega)(1W)} = 4V$$

$$I_p = \frac{V_p}{R_L} = \frac{4V}{8\Omega} = 0.5A \Rightarrow I_1 = 0.5A$$

$$P_{avg,Q1} = I_1\left(V_{CC} - \frac{V_p}{2}\right) = 0.5A\left(5V - \frac{4V}{2}\right) = 1.5W$$

$$P_{avg,I1} = -I_1 V_{EE} = -(0.5A)(-5V) = 2.5W$$

I_1 = 0.5A

$P_{av,Q1}$ = 1.5W

$P_{av,I1}$ = 2.5W

Scratch Paper