Texas A&M University
Department of Electrical and Computer Engineering

ECEN 326 – Electronic Circuits

Fall 2017

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 <u>one</u> double-sided page of notes and equations for the exam
- Good Luck!

Problem	Score	Max Score
1		50
2		50
Total		**100**

Name: SAM PALERMO

UIN:

Problem 1 (50 points)

For the circuit shown below, all transistors are operating in the saturation region. Use the following transistor parameters

$KP_N=\mu_nC_{ox}= 200\mu A/V^2$, $V_{TH,N} = 0.4V$

$KP_P=\mu_pC_{ox}= 100\mu A/V^2$, $V_{TH,P} = -0.4V$

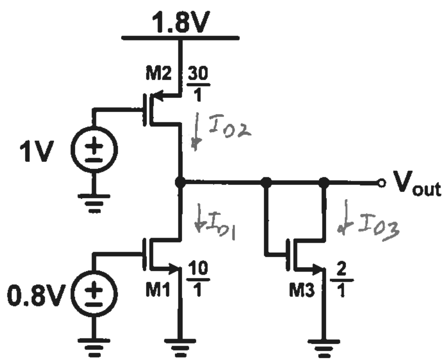
$\lambda_N=\lambda_P= 0.1V^{-1}$

$$I_D = \frac{\mu C_{ox}}{2}\frac{W}{L}(V_{GS}-V_{TH})^2$$

$$I_{D1} = \frac{200\mu}{2}(10)(0.8V-0.4)^2 = 160\mu A$$

$$I_{D2} = \frac{100\mu}{2}(30)(0.8-|-0.4|)^2 = 240\mu A$$

$$I_{D3} = I_{D2} - I_{D1} = 80\mu A$$



a) Calculate the DC operating points of the circuit, including I_{D1-3} and V_{out}. **Note, you can neglect λ effects for this part.**

$$V_{out} = V_{GS3} = V_{TH} + \sqrt{\frac{2I_D}{\mu C_{ox}\frac{W}{L}}}$$

$$= 0.4V + \sqrt{\frac{2(80\mu)}{200\mu(2)}} = 1.03V$$

I_{D1} = $160\mu A$

I_{D2} = $240\mu A$

I_{D3} = $80\mu A$

V_{out} = $1.03V$

Now a small-signal input v_{in} is applied to the gate of M1. Calculate (**give numbers**) the following:

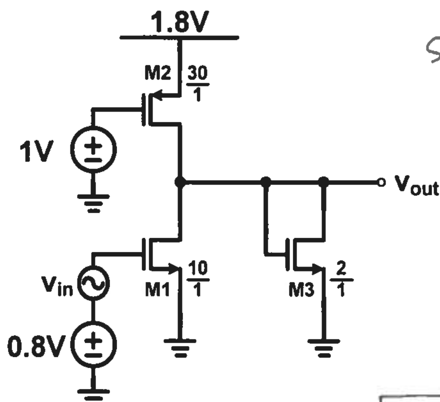
b) Short-circuit transconductance, $\mathbf{G_m}$. Here use the book convention where i_{sc} flowing into the circuit is positive.

c) Output resistance, $\mathbf{R_{out}}$

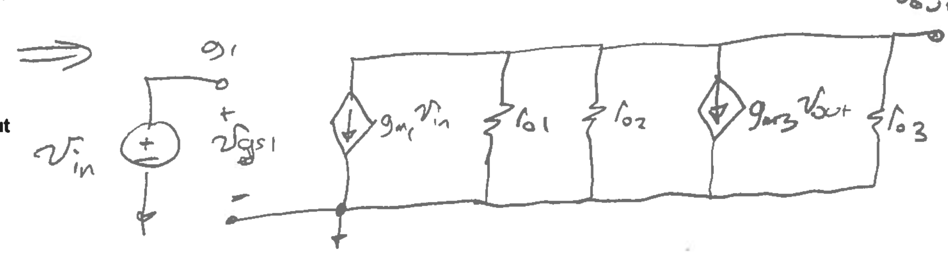
d) Small-signal gain, $\mathbf{A_v = v_{out}/v_{in}}$

e) Input resistance, $\mathbf{R_{in}}$

Note, you must include relevant λ effects for parts (b)-(e).

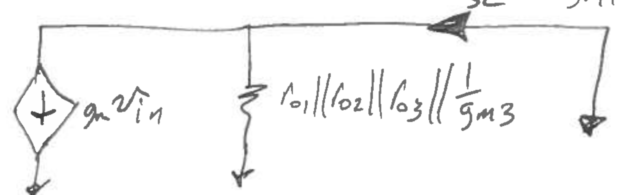


SSM ⇒



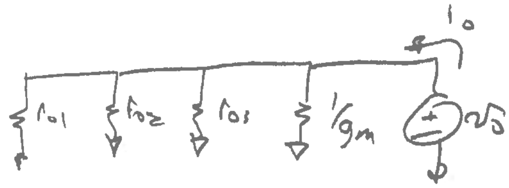
$i_{sc} = g_{m1} v_{in}$

b. For G_m ⇒



$$G_m = \frac{i_{sc}}{v_{in}} = \frac{g_{m1} v_{in}}{v_{in}} = g_{m1} = \sqrt{200\mu(10)(2)(160\mu)} = 800\mu A/V$$

c.



$$R_{out} = r_{o1}||r_{o2}||r_{o3}||\frac{1}{g_{m3}} = \frac{1}{g_{o1}+g_{o2}+g_{o3}+g_{m3}}$$

$$g_{o1} = \lambda I_{D1} = (0.1V^{-1})(160\mu A/V) = 16\mu A/V \quad g_{o2} = 24\mu A/V \quad g_{o3} = 8\mu A/V$$

$$g_{m3} = \sqrt{200\mu(2)(2)(80\mu)} = 253\mu A/V$$

$$R_{out} = \frac{1}{16\mu + 24\mu + 8\mu + 253\mu} = 3.32k\Omega$$

d. $A_v = -G_m R_{out} = -(800\mu A/V)(3.32k\Omega) = -2.66\ V/V$

e. $R_{in} = \infty$ (MOSFET input)

Problem 2 (50 points)

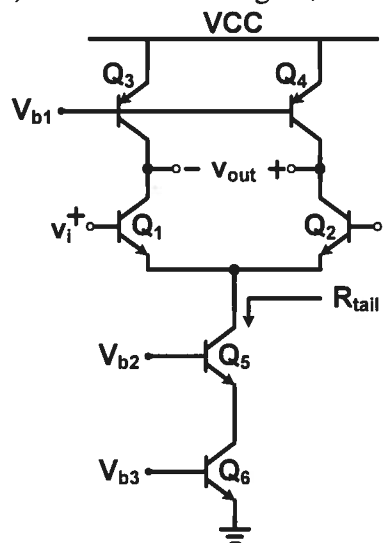
For the differential amplifier circuit shown below, assume that all transistors are operating in the active region and that $V_A \neq \infty$ for all transistors. Obtain expressions for the following:

a) Small-signal differential-mode gain, $A_{DM}=v_{out}/(v_i^+ - v_i^-)$

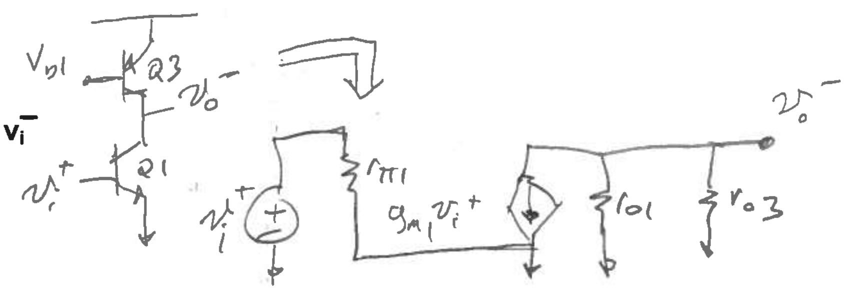
b) **Differential R_{in}**

c) Tail current source impedance, R_{tail}

d) Common-mode gain, $A_{CM}=V_{out,CM}/V_{in,CM}$



a. Equivalent Diff. ½ Circuit



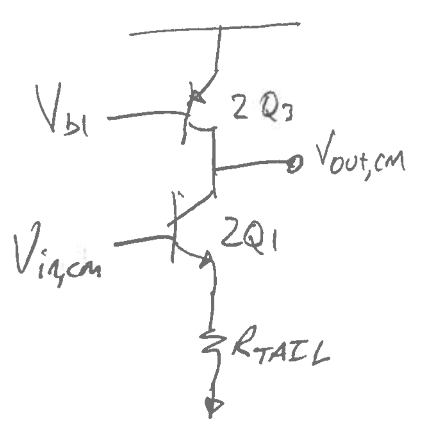
$$v_o^- = -g_{m1} v_i^+ (r_{o1} \| r_{o3})$$

$$A_V = \left(\frac{v_o^+}{v_i^+}\right) = (-1)\left(\frac{v_o^-}{v_i^+}\right) = g_{m1}(r_{o1} \| r_{o3})$$

b. Differential $R_{in} = 2 r_{\pi 1}$

c. $R_{tail} = r_{o5} + r_{o6} \| r_{\pi 5} + g_{m5} r_{o5} (r_{o6} \| r_{\pi 5})$

d. Equivalent CM Circuit



$$A_{CM} = \frac{-\alpha\left(\frac{r_{o3}}{2} \Big\| \left[\frac{r_{o1}}{2} + R_{TAIL} \Big\| \frac{r_{\pi 1}}{2} + g_{m1} r_{o1}\left(R_{tail} \Big\| \frac{r_{\pi 1}}{2}\right)\right]\right)}{\frac{r_{e1}}{2} + R_{TAIL}}$$

$$\approx \frac{-\alpha \frac{r_{o3}}{2}}{\frac{r_{e1}}{2} + R_{TAIL}} = \frac{-g_{m1} r_{o3}}{1 + 2 g_{m1} R_{TAIL}}$$

Scratch Paper