# Texas A&M University
# Department of Electrical and Computer Engineering

## ECEN 326 – Electronic Circuits

## Spring 2022

## 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 | | 50 |
| 2 | | 50 |
| **Total** | | **100** |

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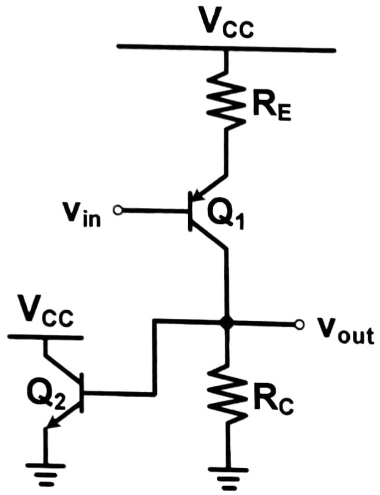
UIN:

Prof. Sam Palermo ECEN 326 Exam #1 February 24, 2022

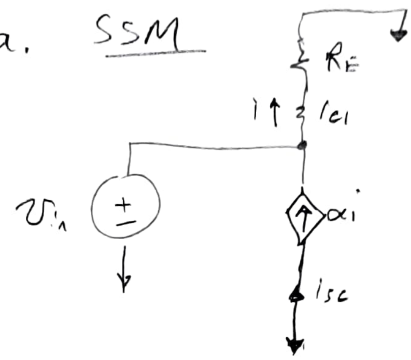
Problem 1 (50 points)

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, $\mathbf{G_m}$.
b) Output resistance, $\mathbf{R_{out}}$
c) Small-signal gain, $\mathbf{A_v=v_{out}/v_{in}}$
d) Input resistance, $\mathbf{R_{in}}$



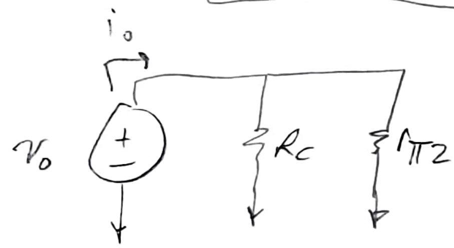

a. SSM




$$i_{sc} = \alpha i = \frac{\alpha v_{in}}{r_{e1} + R_E}$$

$$G_m = \frac{i_{sc}}{v_{in}} = \frac{\alpha}{r_{e1} + R_E} = \frac{g_{m1}}{1 + \frac{g_{m1} R_E}{\alpha}}$$

b. SSM



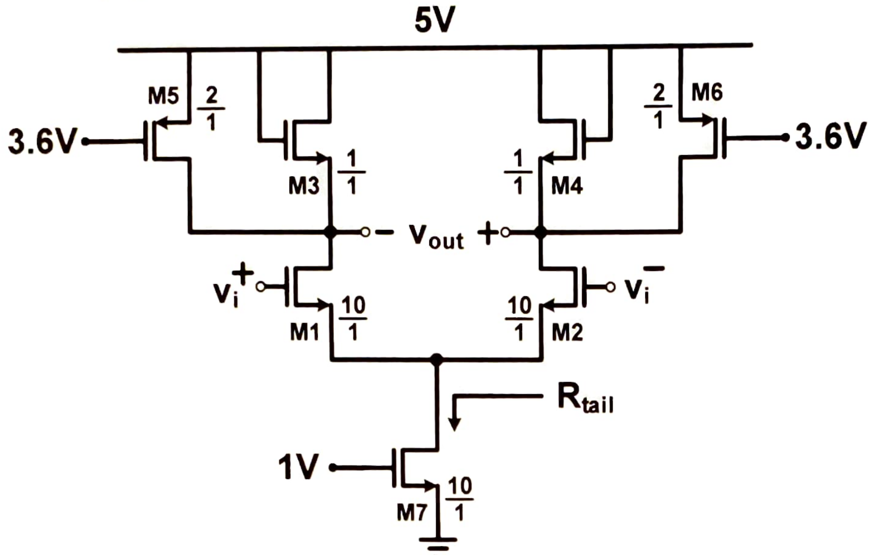

$$R_{out} = r_{\pi 2} \| R_C$$

c. $$A_v = -G_m R_{out} = -\frac{\alpha (R_C \| r_{\pi 2})}{r_{e1} + R_E} = -\frac{g_{m1}(R_C \| r_{\pi 2})}{1 + \frac{g_{m1} R_E}{\alpha}}$$

d. $$R_{in} = r_{\pi 1} + (\beta + 1) R_E$$

Problem 2 (50 points)
For the circuit shown below, assume that all transistors are operating in the saturation region. Use the following transistor parameters

$KP_N=\mu_n C_{ox}=200\mu A/V^2$, $V_{TH,N}=0.4V$
$KP_P=\mu_p C_{ox}=100\mu A/V^2$, $V_{TH,P}=-0.4V$
$\lambda_1=\lambda_2=\lambda_3=\lambda_4=\lambda_5=\lambda_6=0$
$\lambda_7=0.1V^{-1}$




a) Calculate (**give numbers**) the DC current flowing through the transistors requested below. Here assume that 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.**

$I_{D1} = 180\mu A$
$I_{D3} = 80\mu A$
$I_{D5} = 100\mu A$
$I_{D7} = 360\mu A$

$$I_{D7} = \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS}-V_{TN})^2 = \frac{200\mu}{2}(10)(1V-0.4V)^2 = 360\mu A$$

$$I_{D1} = \frac{I_{D7}}{2} = 180\mu A$$

$$I_{D5} = \frac{\mu_p C_{ox}}{2}\frac{W}{L}(V_{SG}-|V_{TP}|)^2 = \frac{100\mu}{2}(2)(1.4V-|-0.4V|)^2 = 100\mu A$$

$$I_{D3} = I_{D1} - I_{D5} = 80\mu A$$

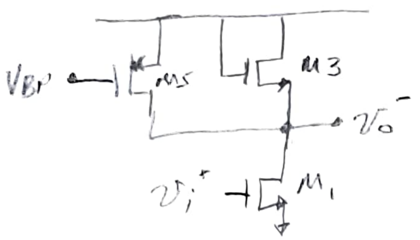
Calculate (**give numbers**) the following. **Include λ effects, if necessary**.

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

c) Tail current source impedance, $\mathbf{R_{tail}}$

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

b. Equivalent ½ Circuit




w/ $\lambda_1 = \lambda_3 = \lambda_5 = 0$

$G_M = g_{m1}$ $\quad R_{out} = \frac{1}{g_{m3}}$

$$A_V = \frac{v_o^+}{v_i^+} = -\frac{v_o^-}{v_i^+} = -(-G_m R_{out}) = \frac{g_{m1}}{g_{m3}}$$

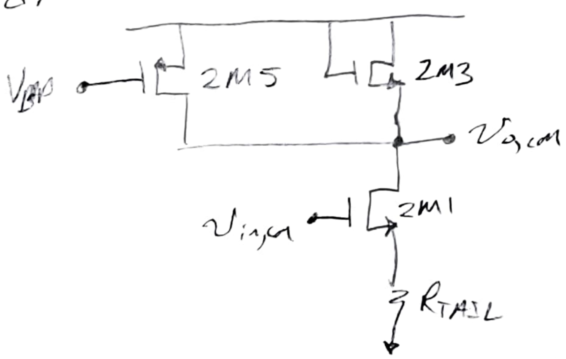
$$g_{m1} = \sqrt{\mu_n C_{ox} \frac{W}{L} 2 I_{D1}} = \sqrt{(200\mu)(10)(2)(180\mu)} = 849 \,\mu A/V$$

$$g_{m3} = \sqrt{\mu_n C_{ox} \frac{W}{L} 2 I_{D3}} = \sqrt{200\mu(1)(2)(80\mu)} = 179 \,\mu A/V$$

$$A_V = \frac{g_{m1}}{g_{m3}} = \frac{849 \,\mu A/V}{179 \,\mu A/V} = 4.74 \, V/V$$

c. $$R_{tail} = r_{o7} = \frac{1}{\lambda I_{D7}} = \frac{1}{(0.1V^{-1})(360\mu A)} = 27.8 k\Omega$$

d. CM Equivalent Circuit




$$G_M = \frac{2g_{m1}}{1 + 2g_{m1} R_{TAIL}} \qquad R_{OUT} = \frac{1}{2g_{m3}}$$

$$A_{cm} = -G_m R_{OUT} = \frac{-\frac{g_{m1}}{g_{m3}}}{1 + 2g_{m1} R_{TAIL}}$$

$$A_{cm} = \frac{-4.74 \, V/V}{1 + 2(849 \,\mu A/V)(27.8 k\Omega)} = -98.3 \times 10^{-3} \, V/V$$

## Scratch Paper