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!

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Name: ____________________________

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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, \( G_m \).

b) Output resistance, \( R_{out} \).

c) Small-signal gain, \( A_v = \frac{V_{out}}{V_{in}} \).

d) Input resistance, \( R_{in} \).

\[ G_m = \frac{i_{sc}}{V_{in}} = \frac{\alpha V_{in}}{v_{c2} + R_E} = \frac{g_m}{1 + \frac{g_m R_E}{\alpha}} \]

\[ R_{out} = R_{\pi 2} \parallel R_C \]

\[ A_v = -G_m R_{out} = -\frac{\alpha (R_{\pi 2} \parallel R_C)}{v_{c2} + R_E} = -\frac{g_m}{1 + \frac{g_m R_E}{\alpha}} \]

\[ R_{in} = R_{\pi 1} \parallel (\beta + 1) R_E \]

\( v_{c2} \)
Problem 2 (50 points)
For the circuit shown below, assume that all transistors are operating in the saturation region.
Use the following transistor parameters
\[ K_{P_N} = \mu_{n}C_{ox} = 200 \mu A/V^2, \ V_{TH,N} = 0.4V \]
\[ K_{P_P} = \mu_{p}C_{ox} = 100 \mu A/V^2, \ V_{TH,P} = -0.4V \]
\[ \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0 \]
\[ \lambda_7 = 0.1 \text{V}^{-1} \]

![Circuit Diagram]

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 \( \lambda \) effects for this part.

\[ I_{D1} = \frac{M_{N}C_{ox} \cdot V_{i}}{2} \left( V_{G1} - V_{TH} \right)^2 = \frac{200 \mu A}{2} (10)(1V-0.4V)^2 = 360 \mu A \]
\[ I_{D1} = \frac{I_{D0}}{2} = 180 \mu A \]

\[ I_{D3} = 80 \mu A \]
\[ I_{D5} = 100 \mu A \]
\[ I_{D7} = 360 \mu A \]

\[ I_{D3} = I_{D1} - I_{D5} = 80 \mu A \]
Calculate (give numbers) the following. Include λ effects, if necessary.
b) Small-signal differential mode gain, \( A_{DM} = \frac{V_{out}}{(V_{i1} - V_{i2})} \).
c) Tail current source impedance, \( R_{tail} \)
d) Common-mode gain, \( A_{CM} = \frac{V_{out,CM}}{V_{in,CM}} \)

\[
\begin{align*}
\text{Equivalent } &\frac{1}{2} \text{ Circuit} \\ \text{gm} &= \frac{g_{m1}}{g_{m3}} \\
R_{out} &= \frac{1}{g_{m3}} \\
A_{V} &= \frac{V_{o}^{+}}{V_{i1}} = -\frac{V_{o}^{+}}{V_{i1}} = -\left( -\frac{g_{m1}}{g_{m3}} \right) R_{tail} \\
g_{m1} &= \sqrt{\mu C_0 \frac{W_{D1}}{2}} = \sqrt{200 \mu}(10)(2)(180 \mu) \\
g_{m3} &= \sqrt{\mu C_0 \frac{W_{D2}}{2}} = \sqrt{200 \mu}(1)(2)(89 \mu) \\
A_{V} &= \frac{g_{m1}}{g_{m3}} = \frac{849 \text{ mS}}{179 \text{ mS}} = 4.74 \% \\
R_{tail} &= \frac{1}{A_{V}} = \frac{1}{4.74} = 21.2 \text{ kΩ} \\
A_{CM} &= -\frac{g_{m1}}{g_{m3}} \frac{R_{out}}{1 + 2\left(\frac{g_{m1}}{g_{m3}}\right)27.8 \text{ kΩ}} \\
&= -\frac{4.74 \%}{1 + 2(849 \text{ mS})(27.8 \text{ kΩ})} \\
&= -78.3 \times 10^{-3} \text{ V/V}
\end{align*}
\]