Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Summer 2018

Exam #2

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: SAM PALERMO

UIN: ____________________________
Problem 1 (30 points)
For all the circuits below, use the constant-voltage-drop diode model (\(V_D=0.7\) V), \(V_T=25.9\) mV, and \(n=1\).

a) Find \(V_{OUT}\), \(I_D\), and the small signal diode resistance, \(r_d\). (15 points)

\[
\begin{align*}
\text{If diode is reverse biased, } V_{OUT} = 5 \text{ V} = V_D \\
\Rightarrow & \text{Not consistent with diode model} \\
\text{Diode must be forward biased.} \\
1 \text{ mA} + \frac{V_{OUT}}{5 \text{ k}\Omega} + \frac{V_{OUT} - 0.7 \text{ V}}{5 \text{ k}\Omega} &= 0 \\
2V_{OUT} - 0.7 \text{ V} &= 5 \text{ V} \\
V_{OUT} &= \frac{2.85 \text{ V}}{5 \text{ k}\Omega} = 430 \mu\text{A} \\
I_D &= \frac{V_T}{I_D} = \frac{25.9 \text{ mV}}{430 \mu\text{A}} \\
r_d &= \frac{2.85 \text{ V} - 0.7 \text{ V}}{5 \text{ k}\Omega} = 60.2 \Omega
\end{align*}
\]

Sketch the below 2 circuits’ transfer characteristic, \(V_{OUT}\) vs \(V_{IN}\), for \(V_{IN}\) ranging from ±10V. Assume the op-amp is ideal except that the op-amp output saturates at ±6V.

b. (8 points)

c. (7 points)
Problem 2 (35 points)
Assume for problem 2 that the transistor $\beta=150$, $V_{BE}=0.7V$, and $V_T=25.9mV$.

a) Calculate the DC values for $V_C$, $V_B$, $V_E$, $I_C$, $I_B$, and $I_E$. Compute the AC small signal parameters $g_m$, $r_x$, $r_c$. (18 points)

\[ V_C = 10 - 2k(1.25mA) = 7.5V \]
\[ V_E = 2k(1.26mA) = 2.52V \]
\[ V_B = V_E + 0.7 = 3.22V \]

\[ V_T = \frac{V_E}{I_B} = \frac{25.9mV}{8.34\mu A} = 3.11k\Omega \]
\[ r_e = \frac{V_T}{I_E} = \frac{25.9mV}{1.26mA} = 20.2k\Omega \]

\[ I_C = \frac{3.33V - 0.7V}{2k + \frac{13.3k}{151}} = 1.26mA \]
\[ I_B = \frac{I_E}{\beta+1} = \frac{8.34\mu A}{150+1} = 54\mu A \]
\[ I_C = \frac{1.25mA}{25.9mV} = 48.3mV/A \]
\[ g_m = \frac{I_C}{V_T} = \frac{1.25mA}{25.9mV} = 48.3mA/V \]
\[ r_x = \frac{3.11k\Omega}{25.9mV} = 3.11k\Omega \]
\[ r_c = 20.2k\Omega \]

b) Sketch the small-signal model of the circuit. Assume that the capacitors act as AC shorts and that the transistor’s $r_o$ is infinite (can be neglected). (11 points)

\[ A_V = \frac{V_o}{V_i} = \frac{g_m(V_{be})}{r_e} = 48.3mA/(2k||10k) \]

\[ A_V = 80.5 \frac{V}{V} \]
\[ R_{in} = 20.4k\Omega \]
\[ R_{out} = 2k\Omega \]
Problem 3 (35 points)
Assume for Problem 3 that the transistors are operating in active mode and that the capacitors act as AC shorts and that the transistors' $r_o$ is infinite (can be neglected). For the 2-stage amplifier below, give expressions for the small signal parameters requested below.

\[ R_{in1} = R_{B11} \parallel \left[ r_{\pi 1} + (B+1)R_{E1} \right] \]

\[ R_{out1} = R_C \]

\[ R_{in2} = R_{B34} \parallel \left[ r_{\pi 2} + (B+1)(R_{E3} \parallel R_L) \right] \]

\[ R_{out2} = R_{E3} \parallel \left[ R_{E2} + \frac{R_C \parallel R_{B34}}{B+1} \right] \]

\[ A_{v1} = \frac{v_{o1}}{v_i} = -\frac{g_m (R_C \parallel R_{in2})}{\alpha + g_m R_{E1}} \]

\[ A_{v2} = \frac{v_o}{v_{o1}} = \frac{R_{E3} \parallel R_L}{R_{E2} + R_{E3} \parallel R_L} \]

Total $A_v = \frac{v_o}{v_i} = A_{v1} \cdot A_{v2}$
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