ECE 351 Final Exam
Fall 2009

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Section 2

CM 123

Scores:
1) 25
2) 25
3) 25
4) 25

Total 100

I pledge on my honor that I did not copy any of this exam, and that this work is entirely my own. Furthermore, I did not use PSpice during this exam, except for the lab quiz.

[Signature]

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Problem 1 (25 Points):

Find an expression for the gain \( \frac{V_o}{V_{in}} \).

Negative Resistance Circuit

Problem Tells Us To Find The Gain

\( \Rightarrow \) must be an amplifier and not a Schmitt Trigger

\( V_x = 2V_A \)

\( R_{in} \Rightarrow \frac{V_A}{I_{in}} = -R_y \)

\( I_{in} = \frac{V_A - 2V_A}{R_y} = \frac{-V_A}{R_y} \)

\( R_{in} = -R_y \)
So our Amplifier circuit is

\[ V_m = V_{in} \]
\[ V_p = V_0 \left[ \frac{-R_y}{R_x + (-R_y)} \right] = -V_0 \cdot \frac{R_y}{R_x - R_y} \]

\[ V_0 = G \left[ V_p - V_m \right] = G \left[ -V_0 \frac{R_y}{R_x - R_y} - V_{in} \right] \]

\[ V_0 \left[ 1 + G \frac{R_y}{R_x - R_y} \right] = -G V_{in} \]

\[ \frac{V_0}{V_{in}} = \left[ \frac{-G}{1 + G \frac{R_y}{R_x - R_y}} \right] \]

For \( G \to \infty \)

\[ \frac{V_0}{V_{in}} = \frac{-G}{G \left( \frac{R_y}{R_x - R_y} \right)} = -\left( \frac{R_x - R_y}{R_y} \right) = \frac{R_y - R_x}{R_y} \]
Problem 2: (25 Points)

Determine if the circuit above is an amplifier or a Schmitt trigger. If it is an amplifier, find a numerical value for the gain. If it is a Schmitt trigger, plot the transfer curve and label Vomax, Vomin, UTP, and LTP with numerical values.

\[ V_{o} = V_{omax} = 15 \]

\[ UTP = 5V \]

\[ LTP = V_{inin} = -15V \]

Find UTP: \[ V_o = V_{omax} = 15 \]

\[ V_p = \frac{V_o \times R_{26}}{R_{25} + R_{26}} = \frac{V_o \times 1K}{1K + 6K} = \frac{15V}{7} \]

\[ V_m = \frac{V_{inin} \times R_{23}}{R_{23} + R_{24}} + \frac{-V_2 \times R_{24}}{R_{23} + R_{24}} \]

\[ = \frac{V_{inin} \times 6}{7} - 15V \left( \frac{1}{7} \right) \]
Set $V_p = V_m$ solve for $V_{in}$

$$V_{in} \left( \frac{6}{7} \right) - 15V \left( \frac{1}{7} \right) = \frac{15}{7} V$$

$$V_{in}(6) - 15V = 15V \quad \Rightarrow \quad V_{in} = 5V = VTP$$

For LTP - same equations except $V_0 = -15V$

$$V_p = \frac{V_0 R_{20}}{R_{25} + R_{20}} = \frac{-15V}{7}$$

$$V_m = V_{in} \left( \frac{6}{7} \right) - 15V \left( \frac{1}{7} \right)$$

Set $V_p = V_m$ solve for $V_{in}$

$$V_{in} \left( \frac{6}{7} \right) - \frac{15V}{7} = \frac{-15V}{7}$$

$$V_{in} = 0 = LTP$$
Problem 3: (25 Points)

The circuit above is a current source.

a) Specify values for R28 and R27 so that the current through the load is constant at 1 mA. (15 Points)

b) Find an Equation for Vo. (10 Points)

\[ I = \frac{(V_x + SV) - V_x}{R_{27}} = \frac{SV}{R_{27}} \]

Since \( I_F = 0 \) ⇒ \( I_{Load} = I = \frac{SV}{R_{27}} \)

For \( I_{Load} = 1 \)mA Choose \( R_{27} = 5 \)kΩ

R28 can be anything

b) Cannot Determine Vo without Knowing the Load!

Or Vo is determined by the Load.
Problem 4: (25 Points)

The specifications for the OPAMP in the circuit above are:
- $I_B = 100 \text{ nA}$
- $F_T = 3 \text{ MHz}$ (Unity gain bandwidth)

a) Find the upper -3 dB Frequency of the circuit. (15 Points)
b) Add a resistor to the circuit to eliminate the output due to bias currents. The added elements should leave the gain and frequency response of the circuit unchanged. (10 Points)

\[ V_m = G \cdot V_{in2} + F \cdot V_0 \]

Find $V_m$ due to $V_0$, the coefficient is $F$

\[ V_m = V_1 \cdot \frac{R_7}{R_7 + R_S} = V_1 \left( \frac{10}{5 + 10} \right) = \frac{2}{3} V_1 \]

Now find $V_1$

Let $R_{eq} = R_4 || (R_S + R_7) = 10k || 15k = 6k$
So we have

\[ V_1 = V_0 \left( \frac{6K}{6K + 10K} \right) = V_0 \left( \frac{3}{8} \right) \]

\[ V_m = \frac{2}{3} V_1 = \frac{2}{3} \left( \frac{3}{8} \right) V_0 = \frac{V_0}{4} \]

\[ \Rightarrow f = \frac{1}{4} \]

\[ F_{3dB} = \alpha + F A_0 \approx F A_0 = \left( \frac{1}{4} \right) (3 \text{ MHz}) = 750 \text{ KHz} \]

b) Set \[ V_{m1} = V_{m2} = V_0 = 0 = \text{ short to ground} \]

\[ R_P = 10K \quad R_m = 5K \]

\[ \Rightarrow \text{ add 5K to circuit as shown on p.8} \]