ECE 351 Final Exam
Fall 2005

Name_ Joe Solution_

Section_1_

CM___

Scores:
1)
2)
3)
4)

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 PSpecc during this exam.

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Problem 1 (25 Points):

\[ V_p = \frac{V_1 R_4}{R_3 + R_4} = \frac{V_1}{3} = V_m \quad \text{from (3) f.b.} \]

\[ I_X = \frac{V_1 - V_m}{R_1} = \frac{V_1 - 1.7V}{R_1} = \frac{2}{3} \frac{V_1}{R_1} = \frac{2V_1}{9k} \]

\[ I_3 = \frac{V_1}{R_3 + R_4} = \frac{V_1}{3k} = \frac{3V_1}{9k} \]

KCL @ \( V_1 \) \[ I_1 = I_X + I_3 = \frac{2V_1}{9k} + \frac{3V_1}{9k} = 0.375mA \]

\[ \Rightarrow V_1 = 0.675V \]

\[ \Rightarrow I_X = \frac{2V_1}{9k} = 150mA \]

\[ V_m = \frac{V_1}{3} = 0.225V \]

\[ V_0 = V_m - I_2 R_2 = V_m - I_X R_2 \]

\[ = 0.225V - (150mA)(4k) = -0.375V \]
For bias currents, set $I_{1W} = 0 \Rightarrow \text{Open}$
set $V_0 = \text{Short}$

- $R_m = R_2 \parallel (R_3 + R_4 + R_1) = 4k\Omega \parallel 6k\Omega = 2.4k\Omega$
- $R_p = R_4 \parallel (R_3 + R_1 + R_2) = 1k\Omega \parallel 9k\Omega = 900\Omega$

$\Rightarrow$ Need to add 1.5k$\Omega$ to $+$ terminal

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Problem 7: (10 Points)

Assume negative feedback.

a) Under what conditions is the circuit above a differentiator, \( V_o = K \frac{dV_{in}(t)}{dt} \), where \( K \) is a constant. (7 Points)

b) Design the circuit so that \( V_o = -0.005 \frac{dV_{in}(t)}{dt} \) for a frequency of 1 kHz. (13 Points)

The Ideal differentiators covered in class were:

\[
\frac{V_o}{V_{in}} = \frac{-R_1}{j\omega C_1} = -j\omega C_1
\]

for our circuit we have

\[
\frac{V_o}{V_{in}} = \frac{-R_1}{R_2 + \frac{1}{j\omega C_1}} = \frac{-j\omega C_1 R_1}{1 + j\omega C_1 R_2}
\]

So we want

\[
\frac{-j\omega C_1 R_1}{1 + j\omega C_1 R_2} = -j\omega C_1 R_1
\]

So we need

\[
1 + j\omega C_1 R_2 >> 1
\]

or

\[
\omega << \frac{1}{C_1 R_2}
\]
For \( V_0 = -0.005 \) \( \frac{dV(t)}{dt} = -RC \frac{dV(t)}{dt} \)

Choose \( R_C = 0.005 \) \( \Rightarrow C = 0.1 \mu F, \quad R_I = 50k\Omega \)

We also need \( \omega \ll \frac{1}{CR_2} \)

Choose \( \omega \leq \left(\frac{1}{CR_2}\right)/10 \)

OR \( R_2 \leq \frac{1}{10\omega C} \)

OR \( R_2 \leq \frac{1}{10(2\pi \cdot 1000Hz)(0.1\mu F)} \)

OR \( R_2 \leq 159 k\Omega \)
Problem 3: (30 Points)

For the circuit above:

a) Find and equation for the output voltage. (15 Points)
b) Add a resistor to the circuit to eliminate the effects of bias currents. (5 Points)
c) Using a TL074 OPAMP, find the bandwidth of this circuit. (10 Points)

\[ V_P = V_{in1} \]
\[ V_m = V_{in2} \frac{R_x}{R_x + R_4} \]
where \[ R_x = R_s + R_4/R_3 = 10K \]

\[ V_m \bigg|_{V_{in}=0} = \frac{V_{in2}}{2} \]

Now find \( V_m \) due to \( V_o \)

\[ R_f = R_1(R_5+R_4) = 6K \]
\[ R_1 = \frac{V_o}{R_5+R_3} = \frac{V_o}{16} \]
\[ V_m \bigg|_{V_o} = \frac{V_o \cdot R_4}{R_5+R_4} = \frac{V_o}{3} \]
\[ V_m \bigg|_{V_o} = \frac{V_o}{4} \]
SO \Delta V = V_w. \quad V_m = \frac{V_{w^2}}{2} + \frac{V_0}{4}

Set \Delta V = V_m \Rightarrow V_w = \frac{V_{w^2}}{2} + \frac{V_0}{4}

\Rightarrow V_0 = 4\left[V_w - \frac{V_{w^2}}{2}\right]

b) \quad R_p = R_b = 10k \quad R_m = R_7/\left[R_5 + R_3R_4\right] = 5k

Need 5k added to (c) Terminal

c) \quad V_m = \frac{V_{w^2}}{2} + \frac{V_0}{4} \quad \Rightarrow F = \frac{1}{F}

For the TL072, \quad F_0 = 3\text{mHz}

\Rightarrow F_{3dB} = F A_0 = \frac{3}{4} \text{mHz} = 750 \text{kHz}
Problem 4: (25 Points)

Assume that the output is limited to ±15 V and \( V_{in} \) is a DC voltage.

a) Draw the transfer curve. (5 points)

b) Find numerical values for the UTP and LTP. (20 points)

This appears to be an inverting Schmitt Trigger

\[
V_m = \frac{V_{in} R_1}{R_1 + R_2} + \frac{V_{ref} R_2}{R_1 + R_2}
\]

\[
V_P = \frac{V_{o} R_4}{R_3 + R_4}
\]

The circuit flips when \( V_P = V_m \). Set \( V_P = V_m \) and solve for \( V_{in} \)
\[ \frac{V_0}{R_4} = \frac{V_{in}}{R_{1}+R_2} + \frac{V_{res}}{R_1+R_2} \]

\[ V_{in} = \left( \frac{V_0}{R_3+R_4} - \frac{V_{res}}{R_1+R_2} \right) \left( \frac{R_1+R_2}{R_1} \right) \]

UTP occurs when \( V_0 = +15V \)

\[ UTP = \left( \frac{15}{R_3+R_4} - \frac{V_{res}}{R_1+R_2} \right) \left( \frac{R_1+R_2}{R_1} \right) \]

LTP occurs when \( V_0 = -15V \)

\[ LTP = \left( \frac{-15}{R_3+R_4} - \frac{V_{res}}{R_1+R_2} \right) \left( \frac{R_1+R_2}{R_1} \right) \]