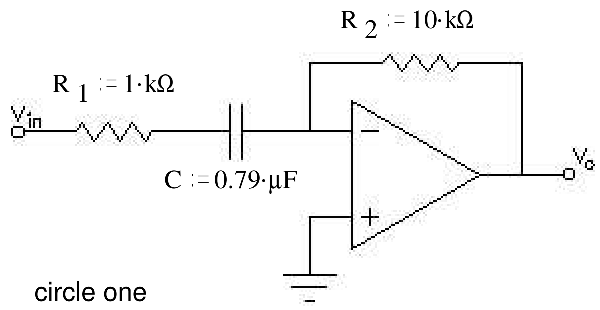
ECE 2100 Final given Spring 2001

(The space between problems has been removed.)

1. (24 pts)

a) Find: $\frac{v_o(j\omega)}{v_{in}(j\omega)}$ Express answer in terms of R_1, R_2, C, & $j\omega$.



b) Find the corner frequency of this circuit, f_c in Hz.

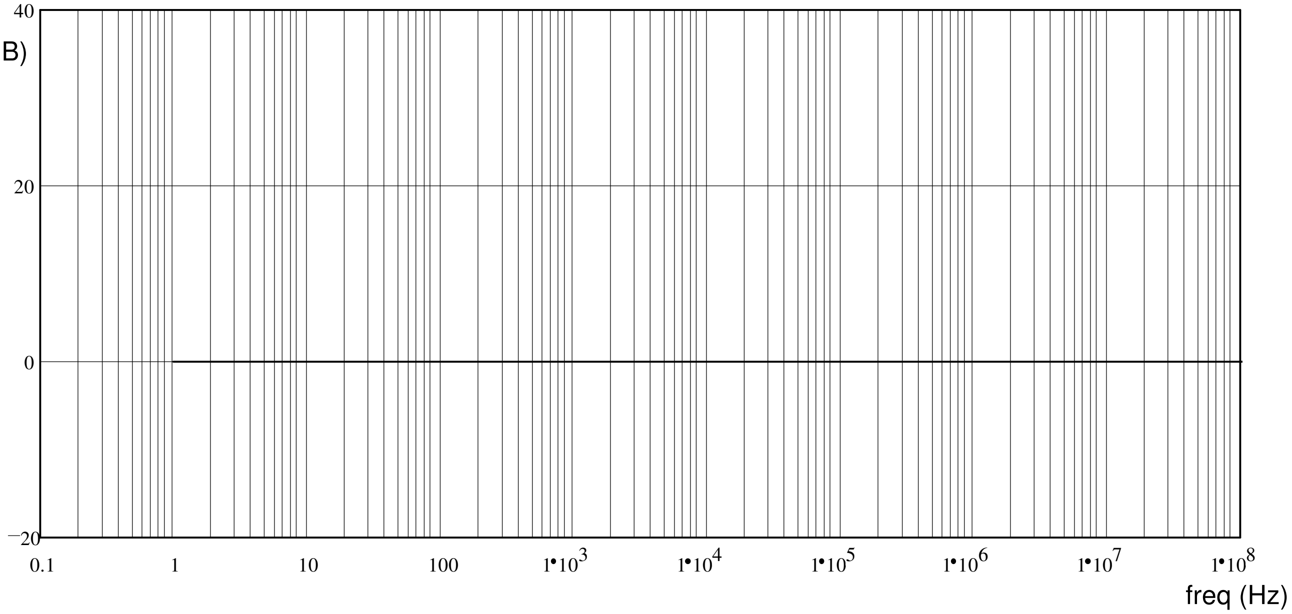
c) If the op-amp is ideal, what type of filter would this circuit be?

1) high-pass	2) low-pass	3) band-pass
4) band-reject	5) no type of filter	6) coffee

circle one

d) The op-amp is not ideal, it has a unity-gain bandwidth (gain-bandwidth product): $f_T := 2\cdot MHz$

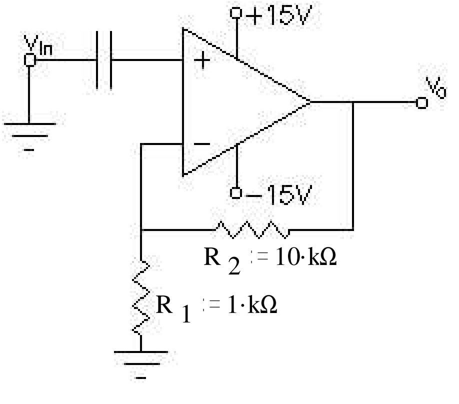
Draw the Bode plot of this circuit below.

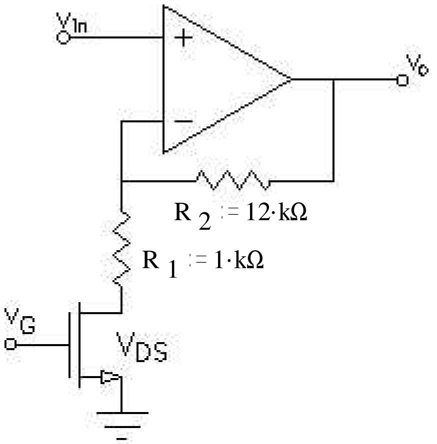


2. Problem 2 is shown on the next page (out of order).

3. (4 pts) Why is a sinusoidal waveform NOT really a signal?

4. (4 pts) If you built the circuit at right in the lab, with a real LM741, what should you expect to measure at the output?





5. (13 pts) The circuit at right is operated so that the v_{DS} is small.

MOSFET characteristics: $k'_n\cdot\frac{W}{L} = K := 2\cdot\frac{mA}{V^2}$ $V_t := 1.5\cdot V$

a) Find the gain (v_o/v_{in}) of this circuit if: $V_G := 4\cdot V$

b) Find a general expression for the gain as a function of R_1, R_2, V_G, and the characteristics of the MOSFET.

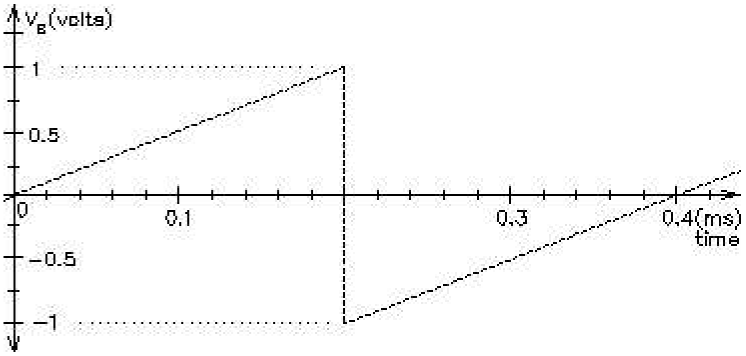
2. (22 pts)

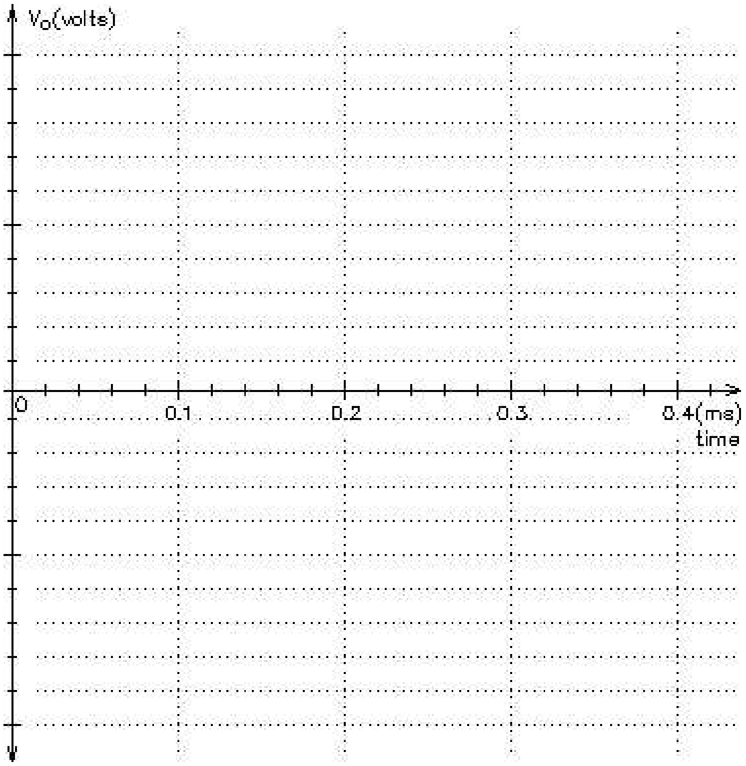
a) Assume the op amp is ideal (doesn't even clip). The input waveform (v_S) is as shown. Accurately draw the output voltage (v_o) you expect to see. Draw the output on the graph provided and label the vertical axis.

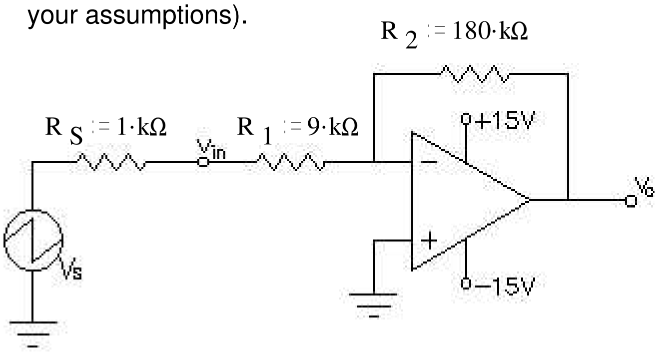
b) If you actually make the circuit with an LM741, the output waveform may be a little different. Accurately show how the real output differs from the ideal. label any newly drawn lines "real".

Label important voltages OR times so that each important point on the waveform is clear.

Note: Some of the characteristics of this op amp are unimportant and won't significantly change the output. You may neglect any characteristics which will affect the output by less than 5% (you don't need to prove your assumptions).







LM741 Op amp Characteristics

Differential gain:	$A_v := 100000$
Unity-gain bandwidth:	$f_T := 2 \cdot MHz$
Output swing limits:	within 2 V of supplies L+ = V+ - 2V L- = V- + 2V
Slew rate:	$SR := 1 \cdot \frac{V}{\mu s}$
Input bias current:	$I_B := -80 \cdot nA$

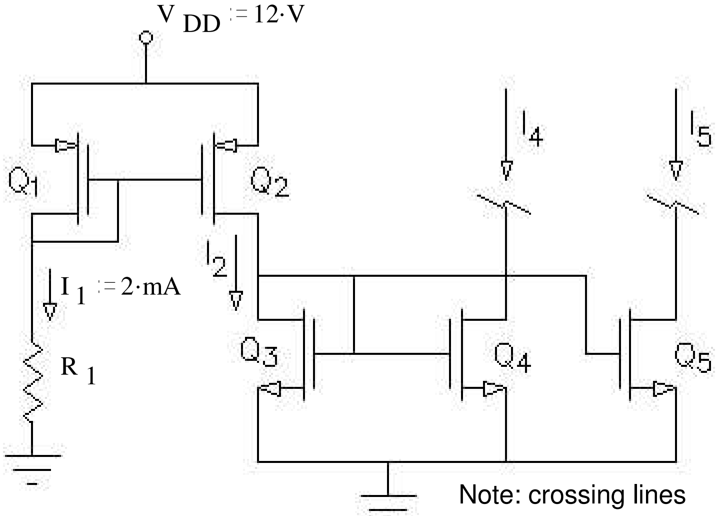
6. (14 pts) All the MOSFETS shown are built on the same IC, using the same process. The only differences between them are their physical dimensions and the k'_n, k'_p difference.

$k'_p = 0.4 \cdot k'_n$

$\frac{W_2}{L_2} = 3 \cdot \frac{W_1}{L_1}$ $\frac{W_3}{L_3} = 2 \cdot \frac{W_1}{L_1}$

$\frac{W_4}{L_4} = 2.5 \cdot \frac{W_1}{L_1}$ $\frac{W_5}{L_5} = 6 \cdot \frac{W_1}{L_1}$

All transistors are operating in saturation.

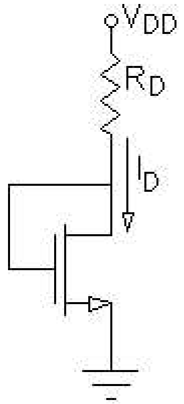


Note: crossing lines don't connect

a) Find I_2 b) Find I_4

c) Find I_5 d) $K_1 := 2 \cdot \frac{mA}{V^2} = k'_p \cdot \frac{W_1}{L_1}$ $V_{t1} := -1.5 \cdot V$ Find R_1

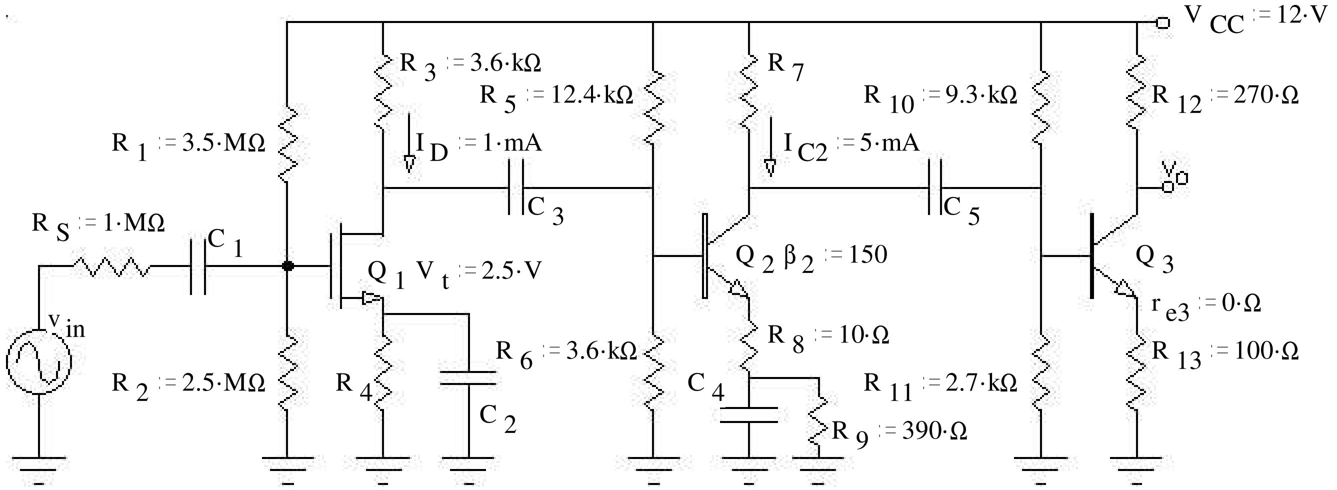
7. (8 pts) Assuming you know V_t $k'_n\cdot\frac{W}{L}$ R_D and V_{DD}



Derive an expression for I_D or show the equation that you' d have to solve in order to find I_D. If you leave your answer as an equation, it must be in a polynomial form for easy solution.

I suggest that you take an equation you already have and modify it to fit this circuit. Deriving it from scratch will take too long for 8 points.

8. (47 pts) You may assume all transistors are operating in the active region.



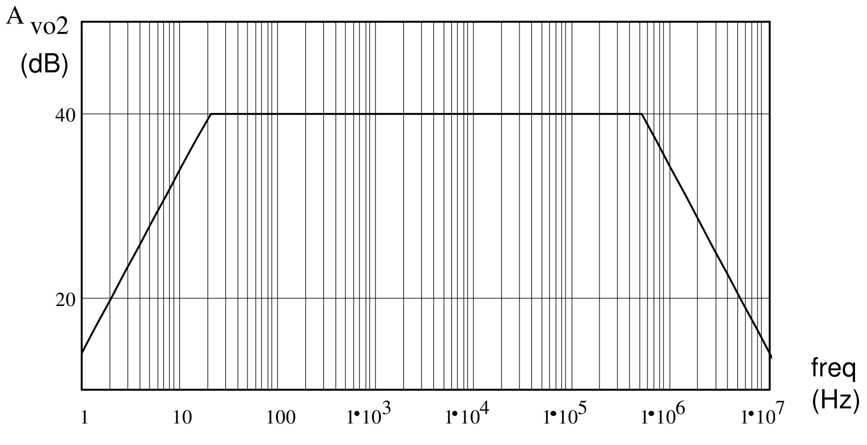
Assume that $V_{A2} = V_{A3} = \infty$

a) For Q_1: $k'_n\cdot\frac{W}{L} = K := 2\cdot\frac{mA}{V^2}$ $V_t := 2.5\cdot V$ Find R_4.

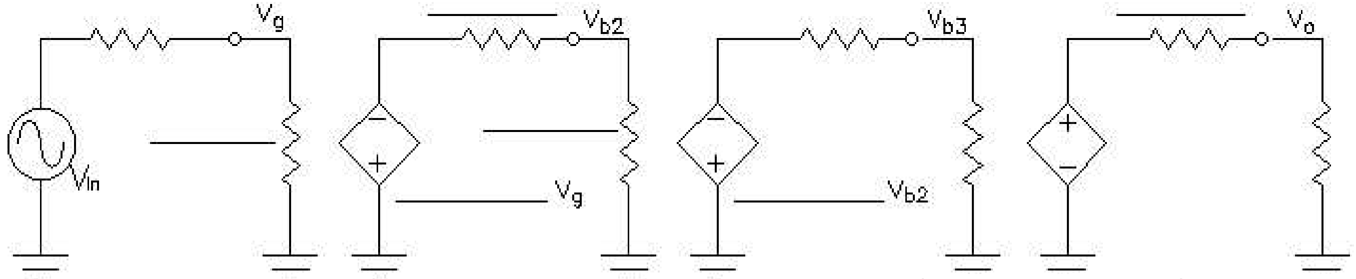
b) What is the unloaded gain of the first stage. (without the second stage connected) $\lambda := 0.025\cdot\frac{1}{V}$ $V_{A1} := \frac{1}{\lambda}$

c) Find R_{in} for the second stage. R_{in2} = ? $V_{A1} = 40\cdot V$

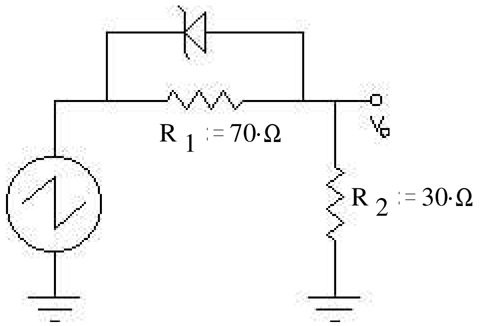
d) The Bode plot at right represents the unloaded gain of the second stage. (without the third stage connected). Neglect r_o. What is the value of R_7?

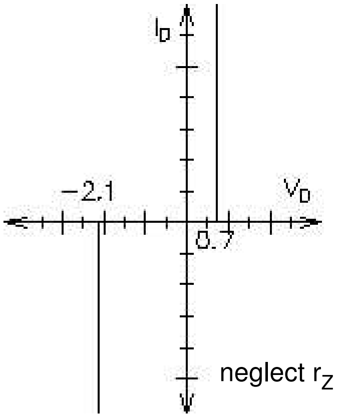


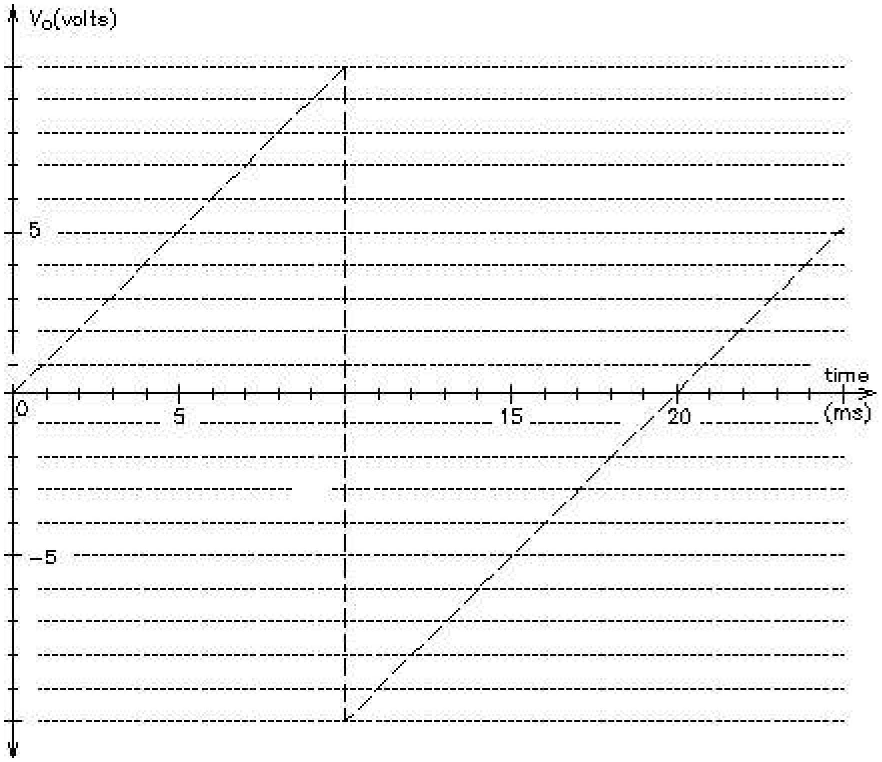
e) Fill in the resistor blanks in the small signal model below with numbers. Neglect r_o of the third stage. Fill in the dependent source blanks with gain factors. If there' s no blank, don' t put anything down.



9. (22 pts) A voltage waveform (dotted line) is applied to the circuits shown. <u>Accurately</u> draw the output waveform (v_o) you expect to see. The characteristic curve for the 2.1-V silicon zener diode is also shown. Label important times **<u>and</u>** voltage levels.

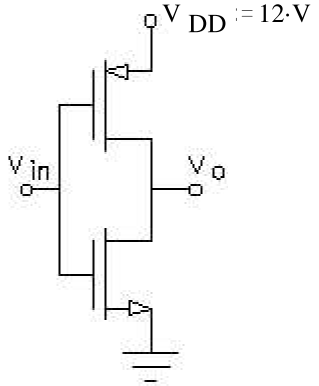


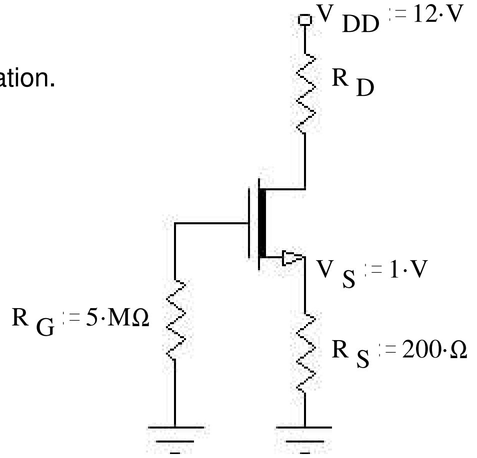




10. (8pts)The MOSFETs in the circuit shown are matched and both have: $|V_t| = 3 \cdot V$

Find V_{IL}, V_{IH}, and the noise margins.





11. (14pts) Assume the depletion-type MOSFET shown is operating in saturation.

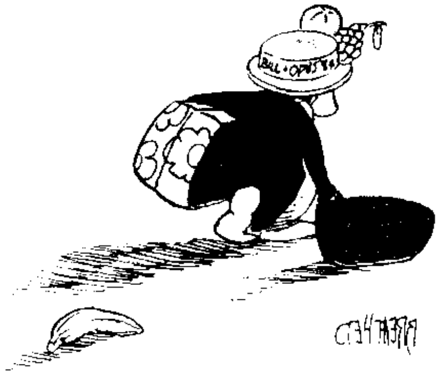
a) Find $K = k'_n \cdot \frac{W}{L}$ $\quad V_t := -3 \cdot V$

b) I want the to stay in saturation. What is the biggest R_D that I can use?

12. Do you want your grade and scores posted on my door and on the internet? Yes No (Circle one)

If your answer is yes, then provide some sort of alias or password: ______________________

The grades will be posted on my door in alphabetical order under the alias that you provide here. I will not post grades under your real name. The internet version will be an excel spreadsheet which you can download. Both will show all your homework, lab, and exam scores.



EE 2100 Final

Name ____________________________

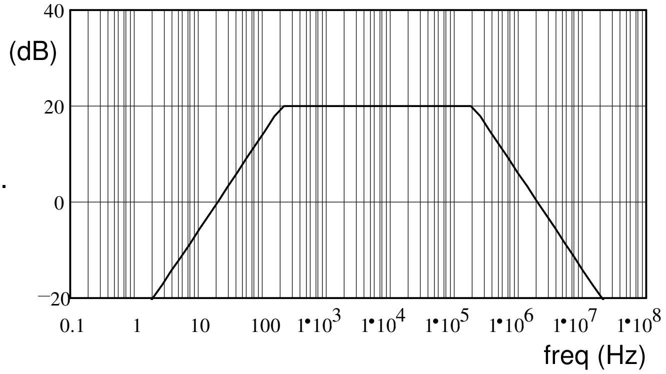
Scores:

page 1 _________ / 46 pts
page 2 _________ / 42 pts
page 3 _________ / 47 pts
page 4 _________ / 45 pts

Total _________ / 180 pts

Answers

1.a) $\frac{v_o(j\omega)}{v_{in}(j\omega)} = \frac{R_2}{R_1 + \frac{1}{j \cdot \omega \cdot C}}$ b) 201Hz c) high pass d)



2.a) straight lines between the following points:
(0ms,0V), (0.2ms,-18V), (0.2ms,18V), (0.4ms,0V), repeat.

b) straight lines between the following points:
(0ms,0V), (0.144ms,-13V), (0.2ms,-13V), (0.226ms,13V), (0.256ms,13V), (0.4ms,0V), repeat.

3. Doesn' t carry information

4. 13V "rail" 5.a) 11 b) $A_v = \frac{R_2}{R_1 + \frac{1}{K \cdot (V_G - V_t)}} + 1$

6.a) 6mA b) 7.5mA c) 18mA d) 4.54kΩ

7. Solve for I_D: $0 = R_D^2 \cdot I_D^2 - 2 \cdot \left[(V_{DD} - V_t) \cdot R_D + \frac{1}{k'_n \cdot \frac{W}{L}} \right] \cdot I_D + (V_{DD} - V_t)^2$

8.a) 1.5kΩ b) 6.61 c) 1.25kΩ d) 1.5kΩ e) $R_{in1} = 1.46k\Omega$, $R_{o1} = 3.3k\Omega$, $R_{in2} = 1.25k\Omega$, $A_{o2} = 100$, $R_{o3} = 270\Omega$

9. straight lines between the following points:
(0ms,0V), (3ms,0.9V), (10ms,7.9V), (10ms,-9.3V), (19ms,-0.3V), (20ms,0V), repeat.

10. 5.25V, 6.75V, 5.25V 11.a) $2.5mA/V^2$ b) 1.8kΩ