University of California
College of Engineering
Department of Electrical Engineering & Computer Sciences

Summer 2002

EECS 40 – **Problem Set #7**

Due: Monday July 22, 12 PM

Problem 1

(a) Text, Problem 4.19 . Note that the feedback from the output goes to the (-) terminal. The amplifier model of Fig 4.9 is drawn differently than the model for an op-amp (in the latter the (-) terminal is placed at the top). We want the exact answer with no simplifications.

(b) The same circuit, but find the Thévenin equivalent for the output C-D when the input voltage v_1 is a fixed value V_{NN}. Note that in both parts of this problem you cannot use the ideal op-amp technique.

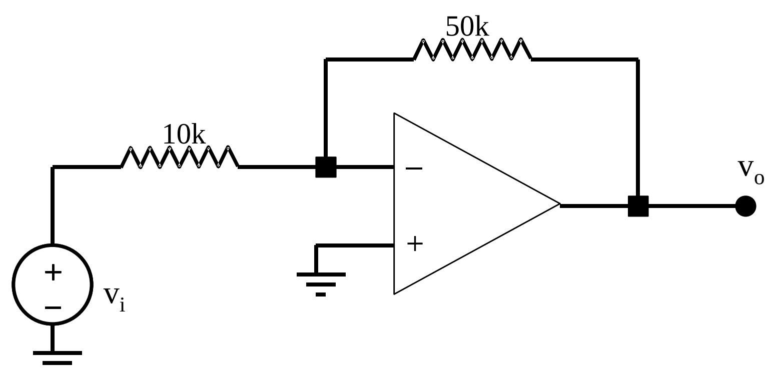
(c) Simplify the answers for (a) and (b) assuming Ri>>Ro (Do not oversimplify, we are not assuming that A is infinite. Thus the answer should still be in terms of A.

(d) Evaluate for Ri = 1M, Ro = 1K, A=10,000. The advantage of feedback should be quite clear from this example: You should find extremely high input resistance, extremely low output resistance and stable gain, largely independent of A.

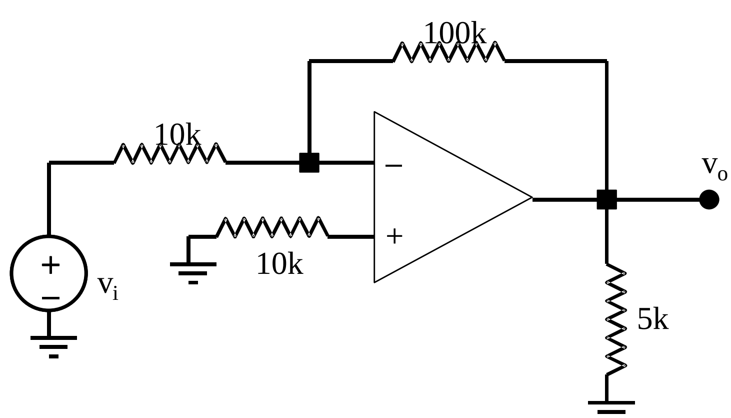
Problem 2

Parts (a)-(d): For each of the circuits with **ideal op-amps**, find the voltage gain v_o / v_i and the thevenin equivalent resistance looking in from the input. (Be sure to use the ideal op amp properties to make the job simple … these are very short, simple problems.)

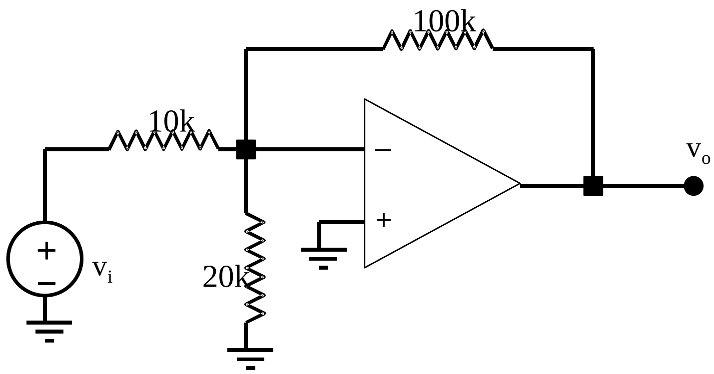
(a)



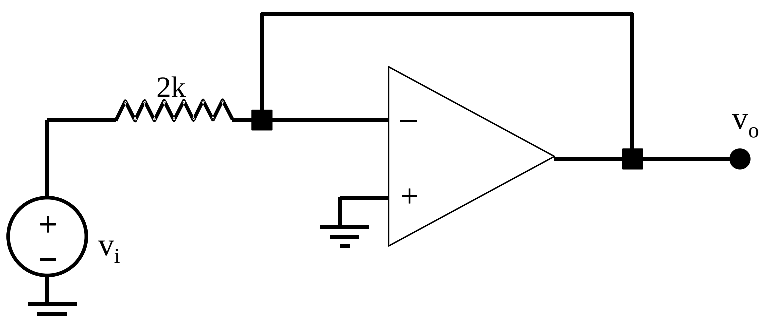
(b)



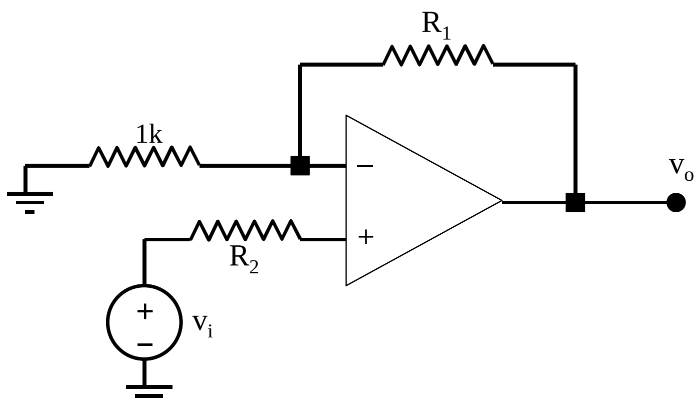
(c)



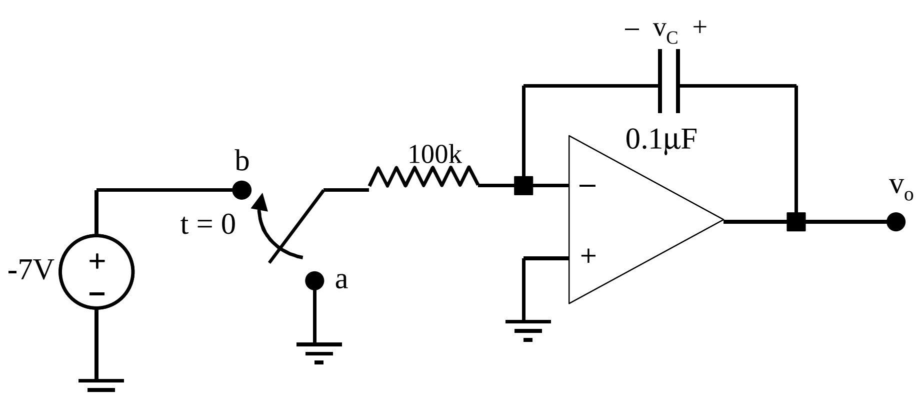
(d)



(e): Find the values of R_2 and R_1 such that $v_o / v_i = 100$. Do you really need to know the value of R_2?



Problem 3



For the circuit above, assume that

- the op-amp is ideal
- the capacitor is initially uncharged

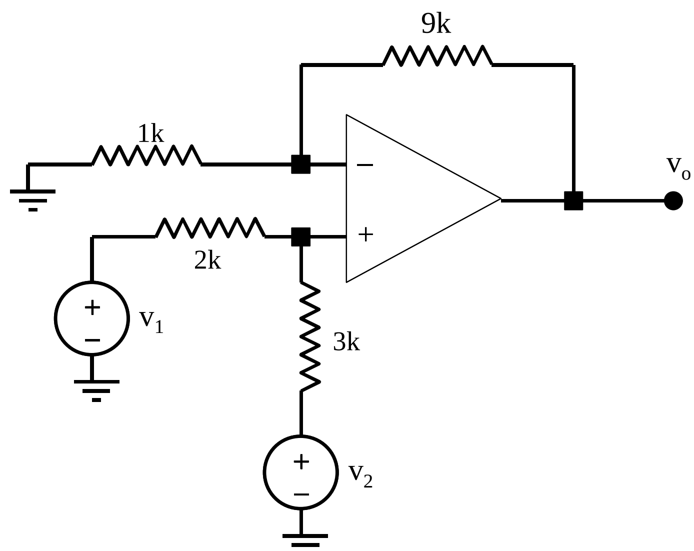
- the op-amp has a lower rail voltage of –12V and an upper rail voltage of 12V

At t = 0, the switch moves from node a to node b. Note that this is *not* an RC problem: you need to use the capacitor current-voltage relationship, and you need to integrate.

(a) Express the relationship between v_c and v_o.
(b) Find the current though the 0.1μF capacitor after t = 0 (not for all time, just until the op-amp hits one of the rails, after which time it ceases to be an ideal op-amp).
(c) Write a simple differential equation relating the current through the .1μF capacitor and v_c. Solve it to find $v_c(t)$ during this same time. (Don't panic it is a very easy ODE!)
(d) Sketch $v_c(t)$ from $0 < t < 25$ms. Keep in mind the op-amp's rail voltages and note that the output will remain stuck at whatever rail voltage it hits.!

Hint: though this problem somehow looks complicated, it is quite easy. Remember the ideal op-amp and the capacitor properties, and simply follow the instructions (a) to (d). Again, be warned this is not an RC problem and the solution is not an exponential.

Problem 4



(a) Use superposition to find the output voltage of the above circuit in terms of v_1 and v_2.
(b) If the 1k resistor is disconnected from ground and connected to a third power source v_3, use superposition to find v_o in terms of v_1, v_2, and v_3.

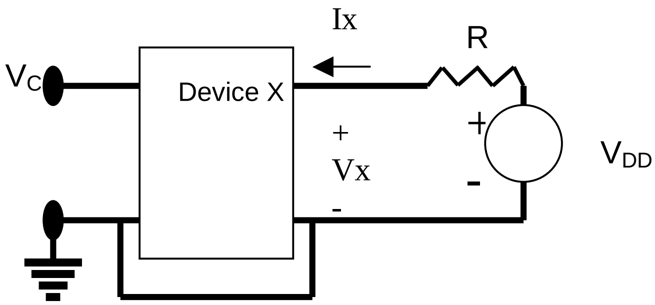
Problem 5

Op-amps are often sold as "dual" or "quad" or "hex", in other words many in one package. Thus it is very practical to use several op-amps to achieve some desired circuit function. Suppose on your Calbot you want to use a pair of photodiodes for "steering", in other words turn the Calbot right or left according to whether more current falls on the right or left mounted photodiode. For this purpose we regard the photodiode as a current source that outputs a positive current of 0-1mA, depending on the intensity of the light on it. (And the photodiode wants to have very little voltage across it).

Can you design a circuit using 1 to 4 op-amps and some resistors to produce a voltage which is positive 0 to 5 V for light on diode 1 > light on diode 2, and which is negative 0 to -5V for the opposite case. We want 5V out when the difference in current is 1mA. Hint: You use op amps buffer signals, to reverse the sign of signals or to sum signals. Example 4.11 , page 163 in the text uses a bunch of op amps to similarly achieve some desired linear function. Example of

buffering: The op amp supplies a current but wants to "see" a low resistance. What op amp form has a very low input resistance and produces a voltage proportional to the current at the input?
We treat these op amps as ideal and assume the output never reaches the rails in this problem.

Problem 6 (review) Consider the following circuit involving a three terminal device.



R = 10K
V_{DD}= 1V

The device x has the following properties:

V_c	$V_x < 0.5V$	$V_x > 0.5V$
0	$I_x = 0$	$I_x = 0.1nA$
.5	$I_x = 1nA$	$I_x = 1nA$
1	$I_x = 10^{-4}\ V_x$	$I_x = 50\mu A$
1.5	$I_x = 2 \times 10^{-4}\ V_x$	$I_x = 100\mu A$
2	$I_x = 3 \times 10^{-4}\ V_x$	$I_x = 150\mu A$

a) Sketch the parametric I-V characteristics of the device X for the 5 given values of V_c. Make all sketches on the same set of axes (and use linear scales).
b) Find the current I_x and voltage V_x for each of the above 5 values of V_c using the load-line method.

Problem 7
You need a non-inverting comparator to detect logic levels of "**0**" = 0V and "**1**" = 3V. You have a variable power supply (that means you can select the voltage), a bunch of "rail to rail" op amps, and a 1.5V battery. Can you throw together a working comparator for this application using these parts? (Show the circuit diagram). Ideally the output of the comparator should be 0V if the input is less than 1.5V, and should be 3V if the input is greater than 1.5V.