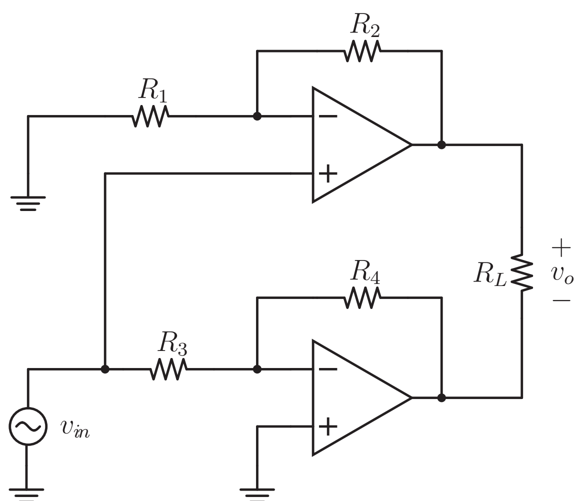
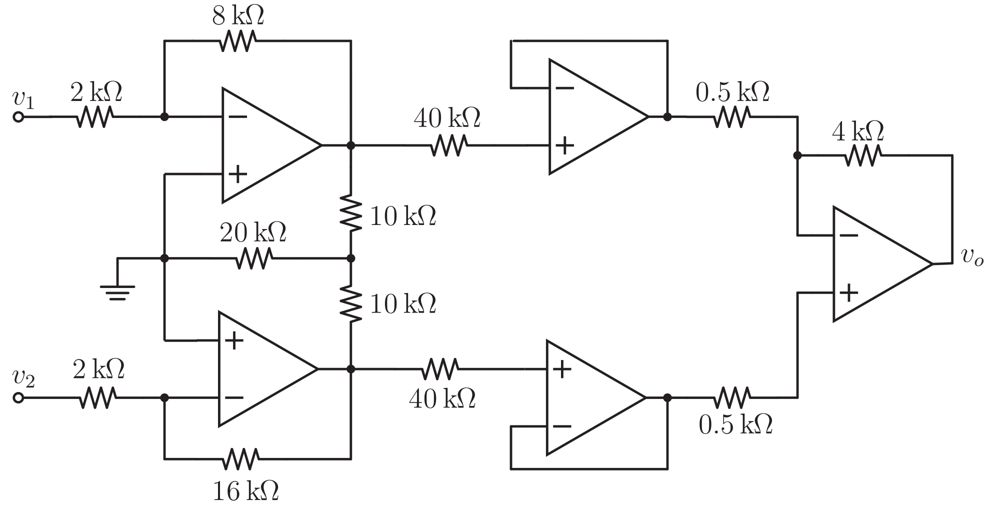
Problem Set 4 (rev B)
Due Wednesday (5pm), March 7, 2012

1. Consider the following bridge amplifier circuit. (a) Start by finding an expression for the voltage gain $G_v = \frac{v_o}{v_{in}}$. Note that the output is measured across the load resistor R_L, which is not connected to ground.

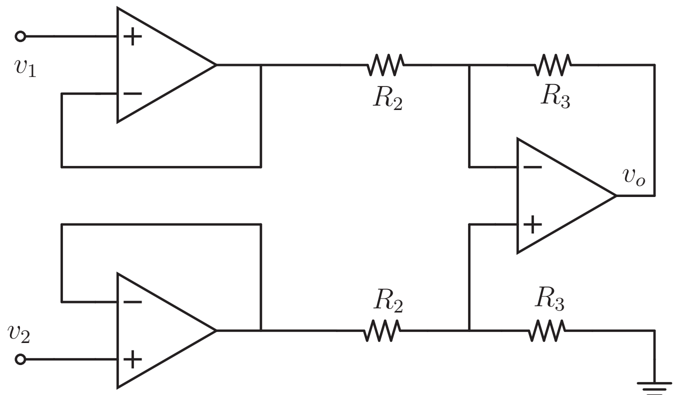


(b) Now suppose that the two op amps are each supplied by $\pm V_s$. Consider the two amplifiers just before each of them starts clipping. What is the maximum output voltage that can be obtained across R_L? Why can this be useful, considering potential limitations of the supply voltages?

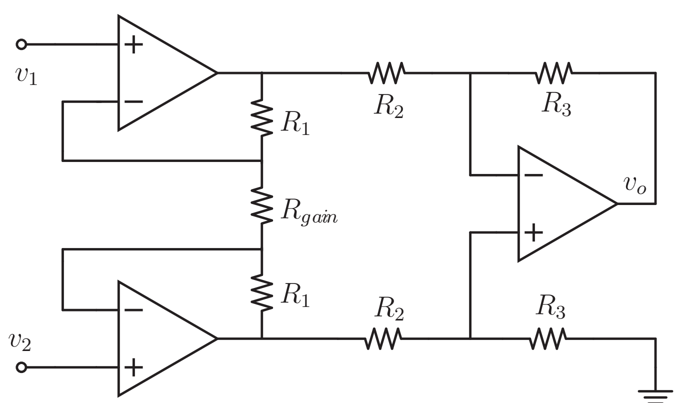
2. Find v_o in terms of v_1 and v_2.



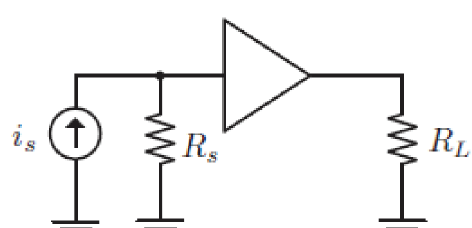
3. Recall that the instrumentation amplifier is a useful alternative to the simpler differential amplifier. This is because the voltage followers at the voltage inputs provide high input resistance to prevent loading effects. (a) With this in mind, find an expression for v_o in terms of the inputs v_1 and v_2.



(b) The above circuit is nice, but recall that we can also add in a few resistors to the first stage for an additional gain factor. This also allows us to eliminate any common-mode gain. Derive the new relationship for v_o in terms of v_1 and v_2.

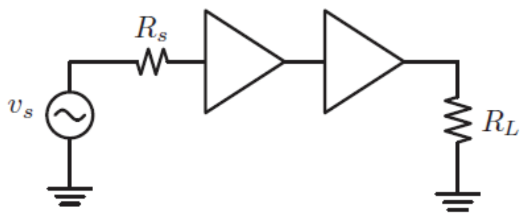


4. The tranconductance amplifier below has the following specs: $G = 10000$, $R_{in} = 100\,\Omega$, $R_{out} = 10\,\text{k}\Omega$. Also, $R_L = 2\,\text{k}\Omega$ and $R_s = 5\,\text{k}\Omega$.



(a) Draw the equivalent circuit using the transconductance amplifier model.
(b) Calculate the effective transconductance gain $G_{msc} = \frac{i_o}{v_i}$ for this configuration.
(c) Calculate the output signal current if the input current source is $i_s = 1\,\mu$A.

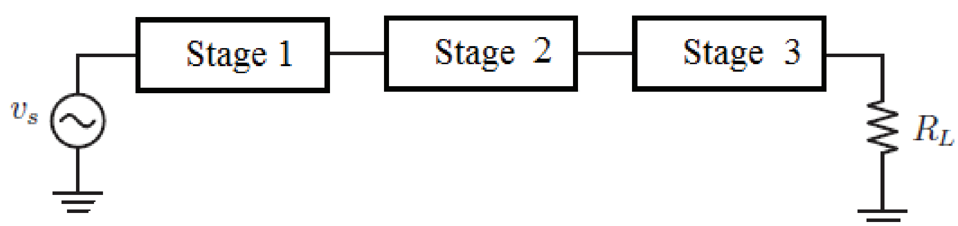
5. Consider the cascade of amplifiers shown below, with $v_s = 1\,$V, $R_s = 1\,$kΩ, and $R_L = 100\,\Omega$. One of the amplifiers is a voltage amplifier, while the other one is a current amplifier. They have the characteristics listed in the table below.

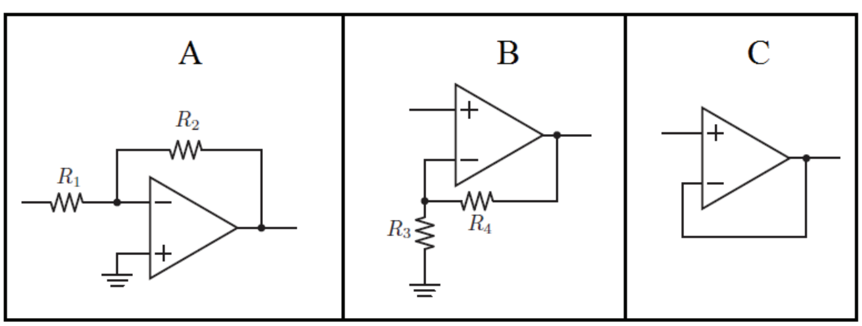


Amp A	Amp B
$A_v = 8$	$A_i = 10$
$R_{in} = 1$kΩ	$R_{in} = 10$
$R_{out} = 1\Omega$	$R_{out} = 1$MΩ

(a) What amplifier order (i.e., AB or BA) maximizes the power gain at the load R_L? Compare to the power gain in the absence of both amplifiers.
(b) For the amplifier order AB, does the second stage (B) deliver more power to the load, or does it hurt power delivery?
(c) For the amplifier order AB, what is the valid input voltage range if each amplifier is supplied by rails at $\pm 10\,$V?

6. In the schematic below, the voltage source v_s is separated from the load resistor R_L by three amplifier stages. We have three different amplifier configurations as shown below.

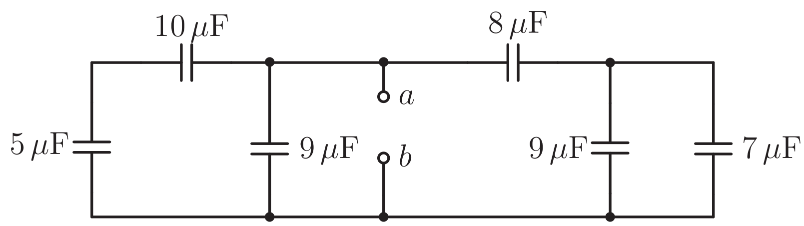




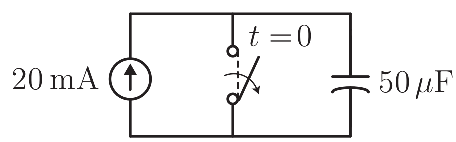
(a) Suppose we go with the sequence BAC. If $R_1 = 2\,$kΩ, $R_2 = 6\,$kΩ, $R_3 = 4\,$kΩ, and $R_4 = 8\,$kΩ, calculate the overall voltage gain for the above circuit. What is the load resistance as seen by the voltage source?

(b) Repeat the above calculations for the sequence ABC. Which of the two is better?
(c) What is the voltage gain in both cases if we omit the third stage (C)? What is its purpose of having it in the circuit?

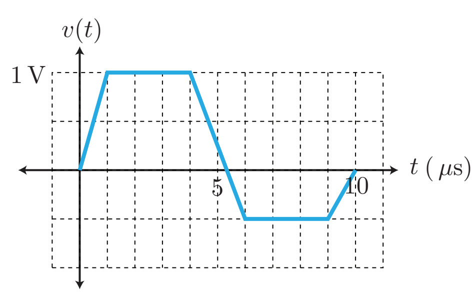
7. Find the equivalent capacitance between the two terminals shown below.



8. Find the voltage, power, and stored energy at $t = 50\,\text{ms}$ for the capacitance in the following circuit. Assume that the switch opens at $t = 0$ and that there is no initial charge on the capacitor.



9. Suppose now instead that a voltage source is connected to the capacitor in the above circuit, in place of the current source. The voltage is a function of time and is given by the following plot.



Draw the current through as a function of time. Find the net charge and energy transferred to the capacitor.

10. Suppose that the two capacitors below are initially uncharged. Then we connect a 15 V source as shown. Find the voltages v_1 and v_2 by considering the conservation of charge on each plate.