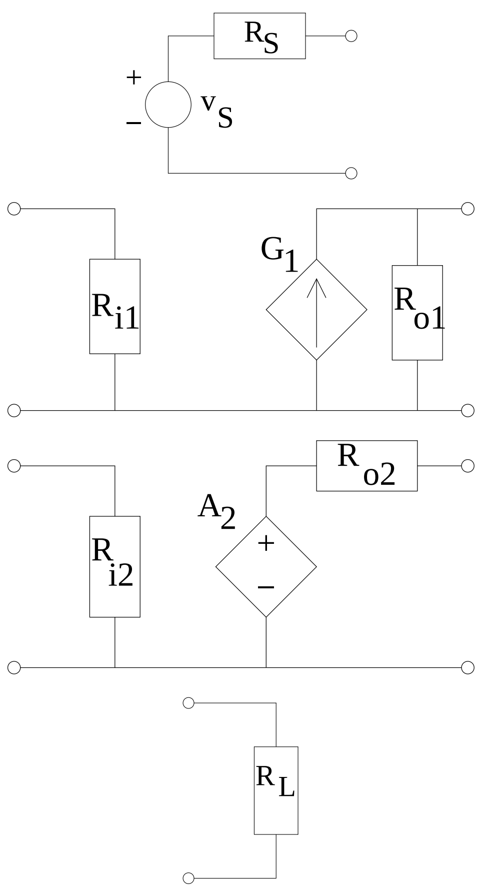
EE 321 Analog Electronics, Fall 2010
Exam 1 September 27, 2010

Rules: This is a closed-book exam. You may only use what you can remember and/or derive. The exam will last 50 minutes. Each problem counts equally toward your grade. None of the problems require long calculations.

Amplifier cascade

Consider four components: A voltage source with output resistance $1\,\text{k}\Omega$, a transconductance amplifier with input resistance $1\,\text{k}\Omega$, gain $G_1 = 10\,\text{A/V}$, and output resistance $100\,\Omega$, a voltage amplifier with input resistance $1\,\text{k}\Omega$, gain $A_2 = 100$, and output resistance $2\,\text{k}\Omega$, and a load with resistance $100\,\Omega$.

1. **Draw each of the four components.**



2. **What is the total gain, v_O/v_S if the components are connected in the sequence in which they are described above?**

   We have

$$\begin{aligned}\frac{v_O}{v_S} &= \frac{v_{i1}}{v_S}\frac{v_{o1}}{v_{i1}}\frac{v_{i2}}{v_{o1}}\frac{v_{o2}}{v_{i2}}\frac{v_O}{v_{o2}} \\ &= \frac{R_{i1}}{R_{i1}+R_S} G_1 \left(R_{o1}||R_{i2}\right) A_2 \frac{R_L}{R_L+R_{o2}}\end{aligned}$$

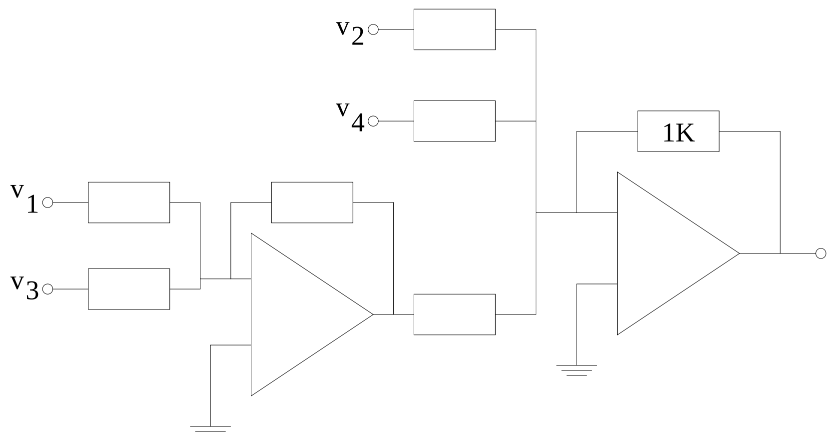
where each term corresponds to a fraction above, except that $\frac{v_{i2}}{v_{o1}} = 1$ was omitted. Inserting values we get

$$\frac{v_O}{v_S} = \frac{1}{1+1} \times 10 \times \frac{100 \times 1000}{100+1000} \times 100 \times \frac{100}{100+2000} = 2164$$

Summer

You can make a circuit which implements the function $v_O = v_1 - v_2 + v_3 - v_4$ with two inverting summers (made from op-amps) in sequence. The first op-amp takes the voltages which add positively, and the second takes the output of the first and the voltages which add negatively.

3. **Sketch the circuit and label the inputs and the output.**



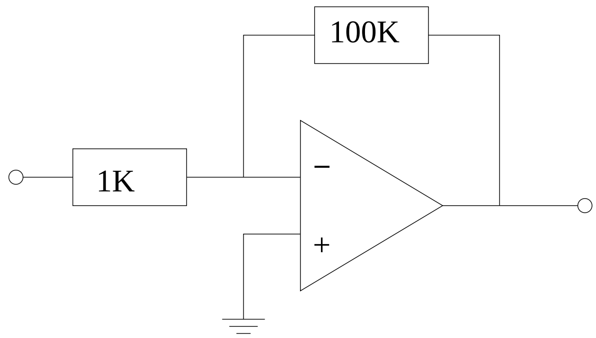
4. **Determine the values of all resistors if the feedback resistor of the second op-amp is $R_{f2} = 1\,\text{k}\Omega$.**

   We can assign all other resistors to $1\,\text{k}\Omega$ as well to obtain the correct gains.

Finite open-loop gain

Consider a non-ideal op-amp which has open-loop gain $A_{vo} = 100$.

5. **Design a inverting circuit with input resistance $1\,\text{k}\Omega$ and feedback resistance equal to what you would choose for a gain of -100 when using an ideal op-amp.**



6. **Compute the actual gain. Hint: $v_- = \frac{v_o R_1 + v_s R_2}{R_1 + R_2}$**

We have $v_O = -Av_-$, which we can use to eliminate v_- in the given equation,

$$-\frac{v_O}{A} = \frac{v_o R_1 + v_s R_2}{R_1 + R_2}$$

Next we isolate v_O,

$$v_O \left(\frac{1}{A} + \frac{R_1}{R_1 + R_2} \right) = -\frac{v_S R_2}{R_1 + R_2}$$

$$\frac{v_O}{v_S} = -\frac{\frac{R_2}{R_1 + R_2}}{\frac{1}{A} + \frac{R_1}{R_1 + R_2}}$$

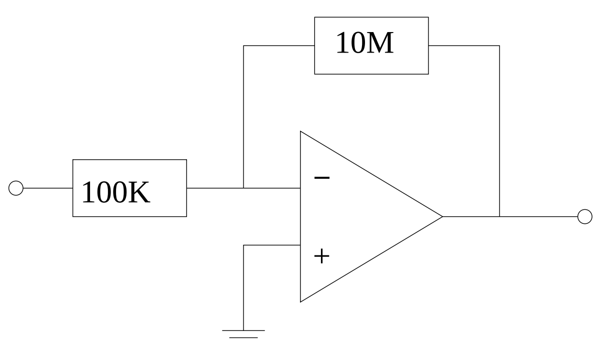
Inserting the known values, $A = 100$, $R_1 = 1\,\text{k}\Omega$, and $R_2 = 100\,\text{k}\Omega$, we get

$$\frac{v_O}{v_S} = -\frac{\frac{100}{1+100}}{\frac{1}{100} + \frac{1}{1+100}} = 49.8$$

Offset voltage and bias current

Consider a non-ideal op-amp with $V_{OS} = 3\,\text{mV}$, $I_B = 100\,\text{nA}$.

7. **Using this op-amp design an amplifier with input resistance of $100\,\text{k}\Omega$ and gain of -100.**



8. **Derive the expression for the output offset and compute a value assuming that V_{OS} and I_B are both positive.**

Actually it is slightly unclear what s meant with "both positive," so several different answers are acceptable. We can use superposition. V_{OS} is amplified by the non-inverting gain, 101, and I_B results in an output voltage $I_B R_2$, so the total output is

$$v_O = V_{OS}\left(1 + \frac{R_2}{R_1}\right) + I_B R_2$$

Inserting known values we get

$$\begin{aligned} v_O =& 3 \times 10^{-3} \times 101 + 100 \times 10^{-9} \times 10 \times 10^6 \\ =& 1.3\,\text{V} \end{aligned}$$