EE 538 Spring 2020
Analog Circuits for Sensor Systems
University of Washington Electrical & Computer Engineering

Instructor: Jason Silver
Homework #4 (40 points)
Due Saturday, May 2, Submit on Canvas

Please show your work.

Problem 1: DC analysis of inverting and non-inverting amplifiers

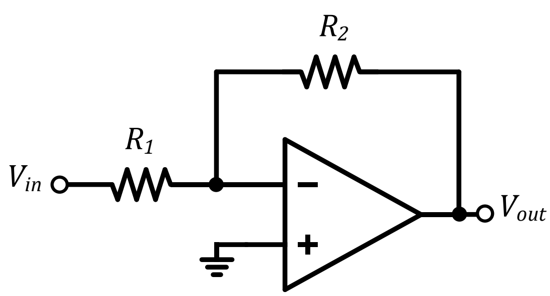

Figure 1a. Inverting amplifier

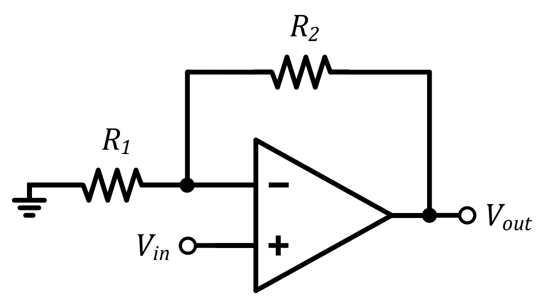

Figure 1b. Non-inverting amplifier

For the two amplifiers shown above, the opamp has open-loop DC gain A_0, input resistance R_{in}, and output resistance R_{out}. For the Ltspice parts, use the UniversalOpamp2 (SpiceModel level.1), with R_1 = 1kΩ and R_2 = 10kΩ. The default open-loop output resistance for the opamp model is 0.1Ω. You can use the 'DC Transfer' analysis.

a) (5 points) For the inverting and non-inverting amplifiers shown in Fig 1a and 1b, determine *expressions* for each of the following assuming $A_0 \rightarrow \infty$ (infinite open-loop gain). Provide comments on how each closed-loop parameter compares to its open-loop counterpart.
   1. Closed-loop gain (V_{out}/V_{in}).
   2. Closed-loop output resistance.
   3. Closed-loop input resistance.

b) (5 points) Repeat Part a assuming A_0 is finite. Try to develop some intuition regarding how each parameter depends on A_0 and the feedback factor β. Check your answer by setting $A_0 \rightarrow \infty$ and comparing to your answer in Part a.

c) (2.5 points) Assuming the opamp has a voltage offset v_{OS}, what is the resulting output offset for each structure? Assume $A_0 \rightarrow \infty$. Check your answer in Ltspice.

d) (2.5 points) Assuming the opamp has input bias current I_B, what is the resulting output offset for each structure? Assume $A_0 \rightarrow \infty$.

Problem 2: Opamp circuit transient response

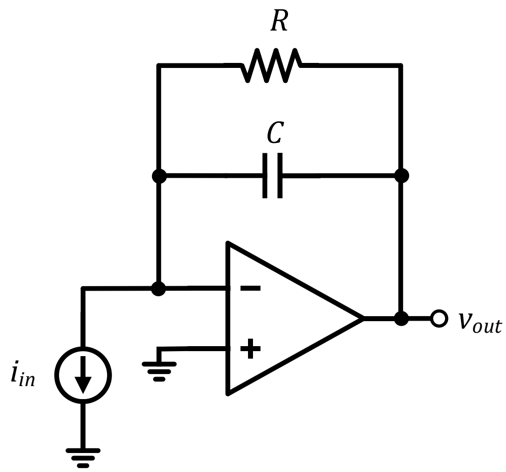

Figure 2a. Current-input integrator

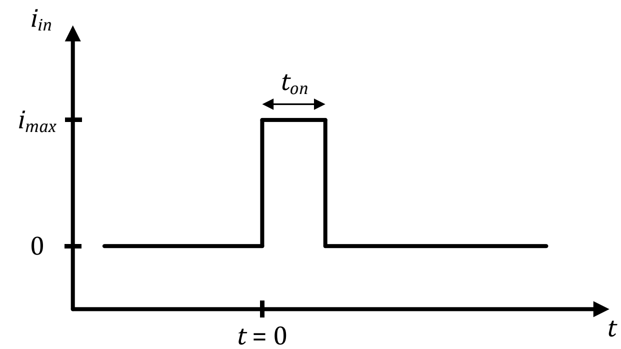

Figure 2b. Input current pulse

For the following, assume ideal opamp behavior.

a) (2.5 points) Determine an expression for the transfer function v_{out}/i_{in}.
b) (5 points) Determine an expression for the transient response of the circuit. What is the value of v_{out} (in terms of R, C, i_{max}, and t_{on}) at time $t = t_{on}$?

Bonus (2 points): Design the circuit (i.e. determine R and C) to function as an integrator, such that $v_{out}(t_{on}) = i_{max}/C$ with less than 0.1% error. Use $i_{max} = 10\mu A$ and ensure v_{out} doesn't exceed a bipolar supply voltage of $\pm 2.5V$. Verify your design in Ltspice.

Problem 3. Difference amplifier

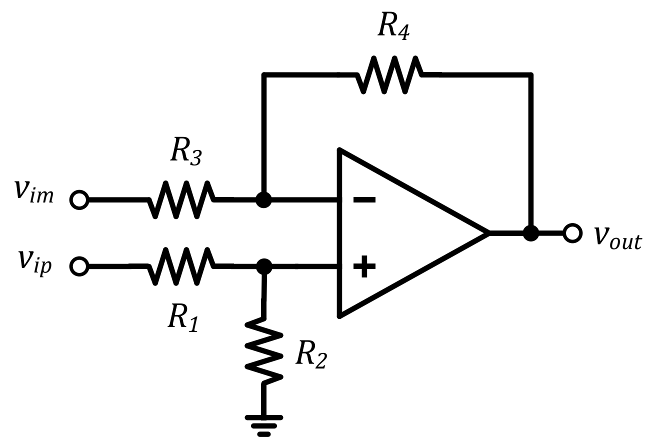

Figure 3. Difference amplifier

For the following, the opamp has a DC gain (A_0) of 100 dB and a unity-gain bandwidth (f_T) of 10MHz but is otherwise ideal ($R_{in} = \infty$ and $R_{out} = 0$). $R_1 = R_2 = R_3 = R_4 = 10\text{k}\Omega$.

a) (2.5 points) Sketch the Bode magnitude and use the graph to approximate the 3dB bandwidth. Sketch the Bode phase plot.
b) (5 points) Calculate the DC gain and 3dB bandwidth of the closed-loop transfer function $v_{out}/(v_{ip} - v_{im})$. Sketch the Bode magnitude and phase of the closed-loop transfer function.
c) (5 points) What is the resistance "looking into" each input (v_{im} and v_{ip})?
d) (5 points) Check your answers to Parts b and c in Ltspice using the Analog Devices opamp model for the AD8691.