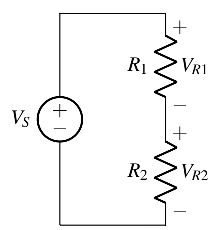
CSM 16A Designing Information Devices and Systems I
Fall 2020 Week 10

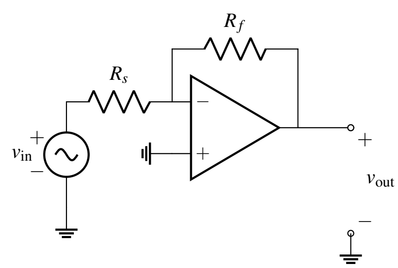
Reference: Op-Amp Example Circuits

Voltage Divider



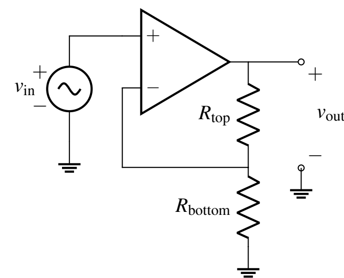
$$V_{R_2} = V_S\left(\frac{R_2}{R_1+R_2}\right)$$

Inverting Amplifier



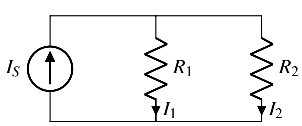
$$v_{out} = v_{in}\left(-\frac{R_f}{R_s}\right)$$

Noninverting Amplifier



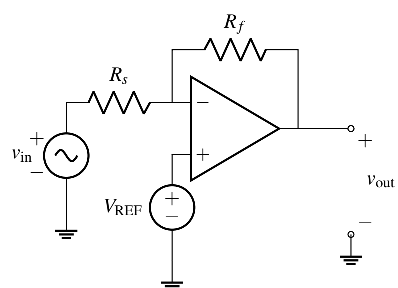
$$v_{out} = v_{in}\left(1+\frac{R_{top}}{R_{bottom}}\right)$$

Current Divider



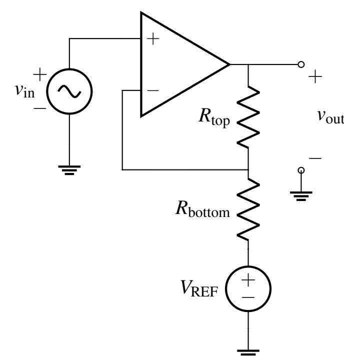
$$I_1 = I_S\left(\frac{R_2}{R_1+R_2}\right)$$

Inverting Amplifier with Reference



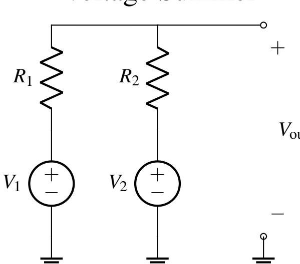
$$v_{out} = v_{in}\left(-\frac{R_f}{R_s}\right) + V_{REF}\left(\frac{R_f}{R_s}+1\right)$$

Noninverting Amplifier with Reference



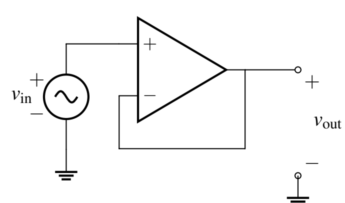
$$v_{out} = v_{in}\left(1+\frac{R_{top}}{R_{bottom}}\right) - V_{REF}\left(\frac{R_{top}}{R_{bottom}}\right)$$

Voltage Summer



$$V_{out} = V_1\left(\frac{R_2}{R_1+R_2}\right) + V_2\left(\frac{R_1}{R_1+R_2}\right)$$

Unity Gain Buffer



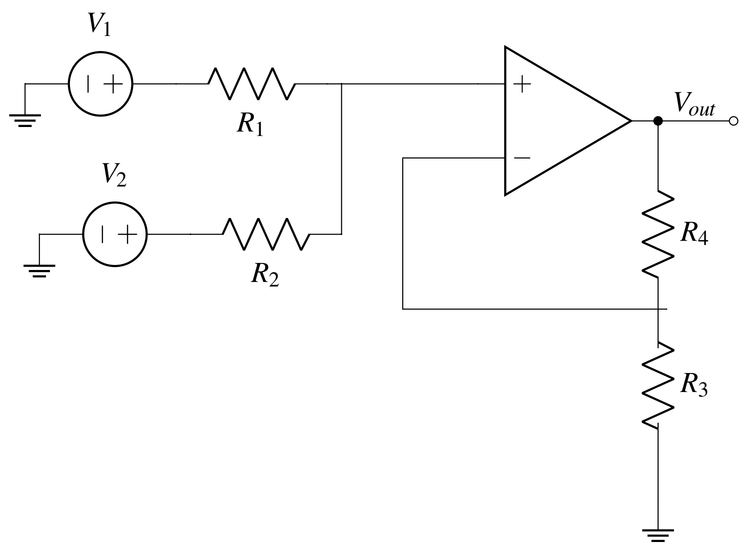
$$v_{out} = v_{in}$$

1. Voltage Summers

Learning Goal: This problem uses basic circuit analysis techniques to find the response of a summer circuit.

Relevant Notes: Note 19 goes different op-amp circuit topology and corresponding derivations.

(a) Calculate V_{out} in terms of V_1 and V_2. Assume that $R_1 = R_2$. Use superposition.



(b) What values should we select for R_1, R_2, R_3, and R_4 such that $V_{out} = V_1 + 2V_2$?

2. Multi-stage Amplifier

Learning Goal: The objective of this problem is to understand how multiple stages of op-amp circuits can be used to achieve a specific circuit gain.

Relevant Notes: Note 19 Section 19.5 goes over inverting and non-inverting amplifiers.

(a) What is the range of values that we can scale V_{in} by when using a non-inverting op amp? (What are possible values for the gain?)

(b) What is the range of values that we can scale V_{in} by when using an inverting op amp? (What are the possible values for the gain?)

(c) Can you design a single inverting/ non-inverting amplifier with circuit gain $G = 0.5$? If not, what range of gain values is not reachable using a single inverting op amp or a single non-inverting op amp?

(d) How would you construct a circuit using inverting/ non-inverting amplifiers so that the overall circuit gain is $G = 0.5$?

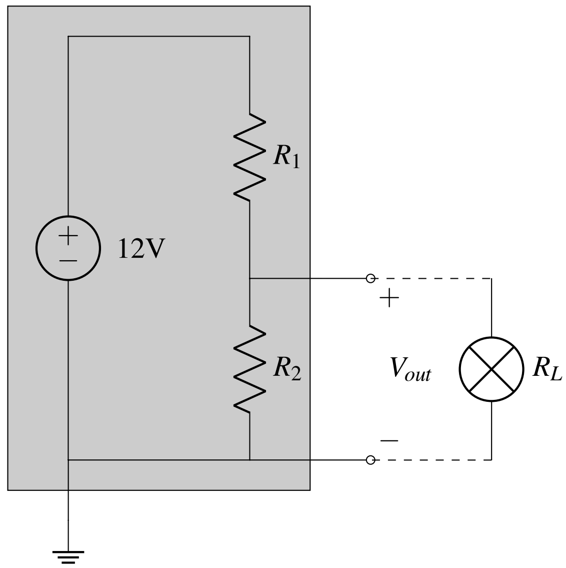
3. Op Amps as Buffers

Learning Goal: This problem helps understand the operating principle of an op-amp buffer and how it helps with loading.

Relevant Notes: **Note 19 Section 19.7** goes different op-amp circuit topology and corresponding derivations.

Now we will revisit a problem that you might have seen before, with our new knowledge of op-amps. We have access to a circuit inside a 'black box' as shown below, with two terminal coming out of it.

(a) We need a voltage of 6V power a light bulb with resistance R_L. Design R_1 and R_2 inside the black box so that the voltage across R_2 is exactly equal to this required voltage **when the bulb is not connected**; i.e. $V_{R_2} = V_{out} = 6$V.



(b) Now let us connect the bulb R_L across R_2. What is the voltage across R_1, R_2 and R_L when the bulb is connected when $R_L = R_2$? Use the values of R_1 and R_2 from the last part. Will the light bulb turn on? What happens if $R_L = 2R_2$?

(c) Using your knowledge of op-amps, how could you resolve this issue of V_{out} changing based on the value of R_L? Think about how you might use an op-amp buffer.