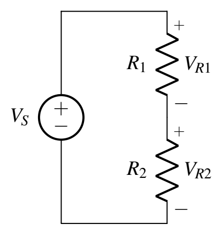
# CSM 16A Designing Information Devices and Systems I
# Fall 2020 Week 10

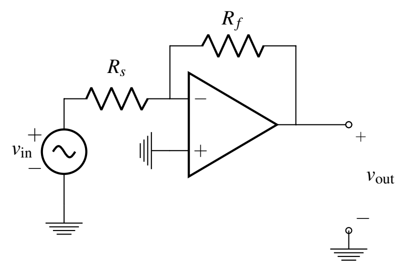
## Reference: Op-Amp Example Circuits

### Voltage Divider



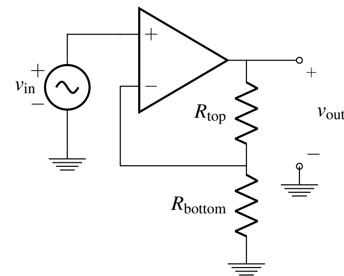

$$V_{R_2} = V_S\left(\frac{R_2}{R_1+R_2}\right)$$

### Inverting Amplifier



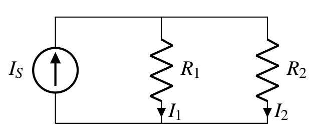

$$v_{\text{out}} = v_{\text{in}}\left(-\frac{R_f}{R_s}\right)$$

### Noninverting Amplifier



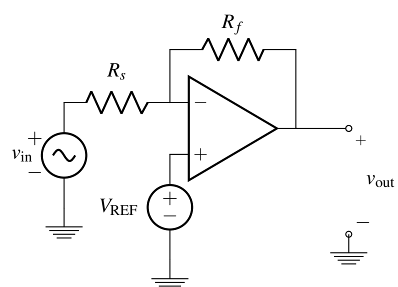

$$v_{\text{out}} = v_{\text{in}}\left(1+\frac{R_{\text{top}}}{R_{\text{bottom}}}\right)$$

### Current Divider



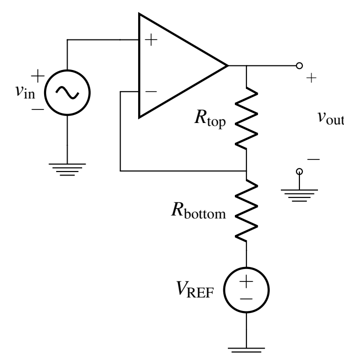

$$I_1 = I_S\left(\frac{R_2}{R_1+R_2}\right)$$

### Inverting Amplifier with Reference



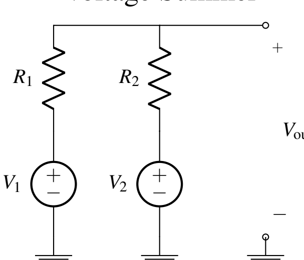

$$v_{\text{out}} = v_{\text{in}}\left(-\frac{R_f}{R_s}\right) + V_{\text{REF}}\left(\frac{R_f}{R_s}+1\right)$$

### Noninverting Amplifier with Reference



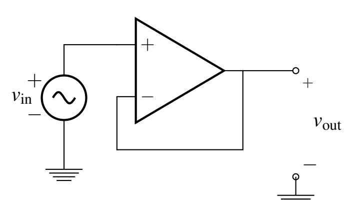

$$v_{\text{out}} = v_{\text{in}}\left(1+\frac{R_{\text{top}}}{R_{\text{bottom}}}\right) - V_{\text{REF}}\left(\frac{R_{\text{top}}}{R_{\text{bottom}}}\right)$$

### Voltage Summer




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

### Unity Gain Buffer




$$v_{\text{out}} = v_{\text{in}}$$

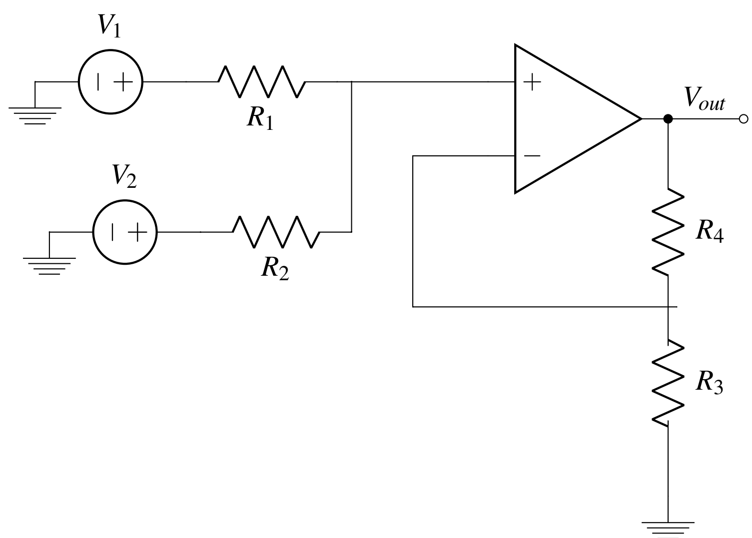
 

**1. Voltage Summers**

**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 $G = 0.5$?

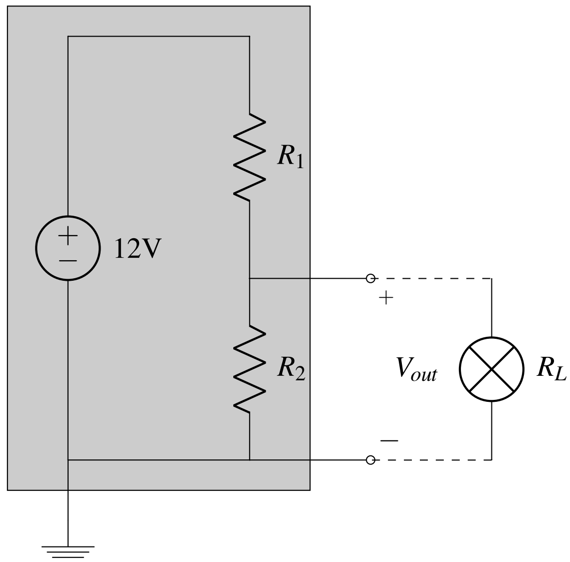
**3. Op Amps as Buffers**

**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. $V_{R_2} = V_{out} = 6\text{V}$.




(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.