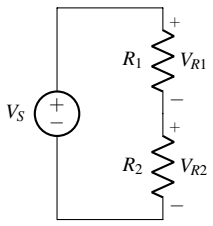
EECS 16A Designing Information Devices and Systems I
Fall 2018 Discussion 10A

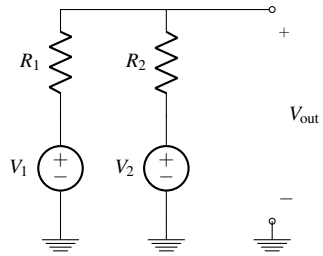
For Reference: Circuits Cookbook, Abridged

Voltage Divider



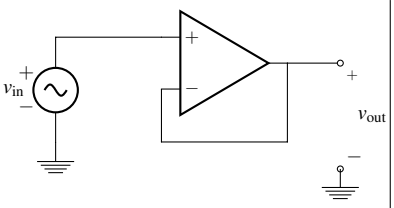
$$V_{R2} = V_S\left(\frac{R_2}{R_1+R_2}\right)$$

Voltage Summer



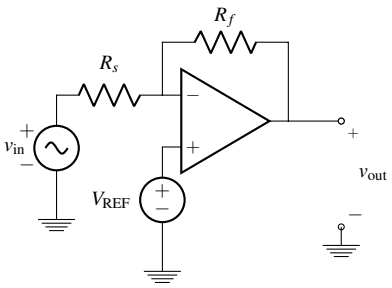
$$V_{\text{out}} = V_1\left(\frac{R_2}{R_1+R_2}\right) + V_2\left(\frac{R_1}{R_1+R_2}\right)$$

Unity Gain Buffer



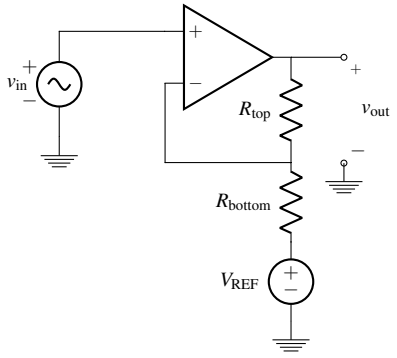
$$\frac{v_{\text{out}}}{v_{\text{in}}} = 1$$

Inverting Amplifier



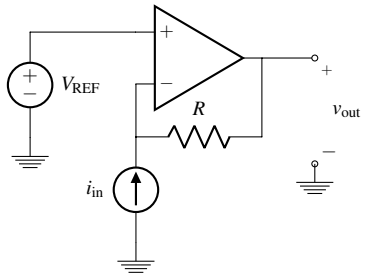
$$v_{\text{out}} = v_{\text{in}}\left(-\frac{R_f}{R_s}\right) + V_{\text{REF}}\left(\frac{R_f}{R_s}+1\right)$$

Non-inverting Amplifier



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

Transresistance Amplifier



$$v_{\text{out}} = i_{\text{in}}(-R) + V_{\text{REF}}$$

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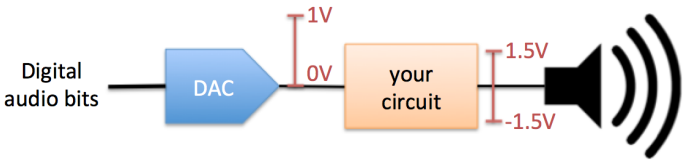
1. Noise Cancelling Headphones

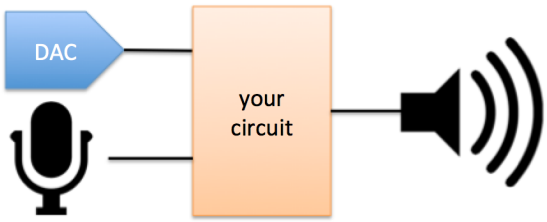
The basic goal of a noise cancelling headphones is for the user to hear only the desired audio signal and not any other sounds from external sources. In order to achieve this goal, noise cancelling headphones include at least one microphone that listens to what you might have otherwise heard from external sources, and then feeds a signal in to your speakers that cancels (subtracts out) that externally-generated sound.

(a) Let's start by looking at the most basic part of the headphones: driving the speaker itself with the audio stream we would like to hear. In our system, the source of the audio comes from a digital-to-analog converter (DAC) that translates digital bits to analog voltages. It can be modeled as a voltage source with min/max values of 0 V and 1 V and a 50 Ω source resistance. The speaker can be modeled as an 8 Ω resistor, but in order to produce loud enough sounds and not damage the speaker (driving the speaker with non-zero average voltage can damage the transducer within the speaker), it needs to be driven with a range of −1.5 V to 1.5 V (relative to the ground connected to the DAC, which is the same ground used throughout the system).



You are provided two voltage sources with values −1.5 V and 1.5 V, an op-amp, and any resistors you would like. Design a circuit that could drive the speaker while meeting the specifications above. Draw a block diagram for the circuit you design before you actually determine the components necessary.

(b) Now let's look at implementing the noise cancellation. In this problem, we will assume that we do not have access to software and therefore cannot digitally remove the noise (as do most noise cancelling headphones). We will therefore focus on implementing the cancellation physically, which is to directly take the (analog) voltage produced by the microphone and subtract it out from the voltage we feed to the speaker.



Let's assume that the microphone can be modeled as a voltage source with min/max values of 0 V and 1 V (relative to the DAC's ground) and a 10 kΩ source resistance. However, because the materials in the headphones attenuate some of the external sound, the loudest signals picked up by the microphone should correspond to a voltage range of only −125 mV to +125 mV driven onto the speaker.
Again draw a block diagram for your solution first.

Expand the circuit from part (a) to take the signal from the microphone and subtract it out from the signal that will be driven on to the speaker. You can use op-amps and resistors to do this, but no new voltage sources (except for the model of the microphone of course). However, note that since our speaker driver now needs to handle both the cancellation and the desired audio signal, you can assume that the supply voltages fed to the op-amp have sufficiently large magnitude to ensure that they never clip (reach the power rails). In other words, you should continue to assume that you have ±1.5 V voltage sources available to use in the rest of your circuit, but the op-amps are now supplied by a separate set of larger, sufficient voltage sources.

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