Arduino/IOIO boards conversion circuits

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1 Circuit design for amplification and negative offset

The aim of this section is to describe how to design a circuit able to take a voltage V_{in} as an input, and produce

$$V_{\text{out}} = mV_{\text{in}} - q \tag{1}$$

where $m > 0$ is the amplification (or attenuation when $0 < m < 1$) of the input signal, and q is an offset, with $q > 0$.

The circuit able to perform this transformation is represented in Figure 1.

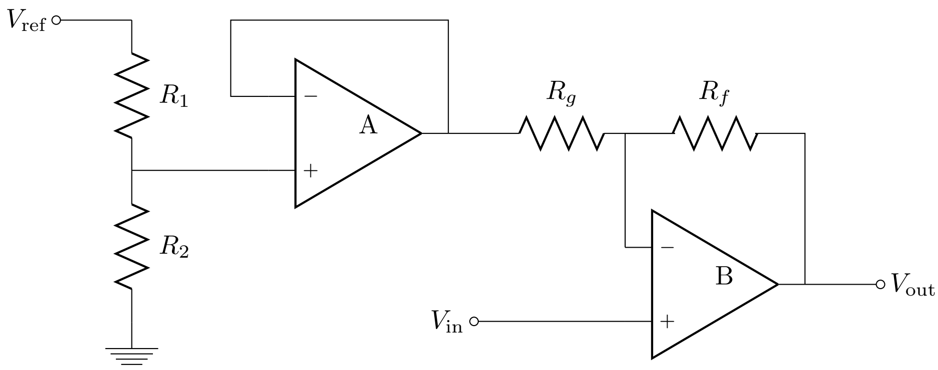

Figure 1: Circuit for the amplification with positive offset.

The components must be suitably chosen in order to obtain the conversion of (4). One can freely choose R_f and R_1, V_{ref} is given, and m and q depends on the conversion that one wants to obtain. The other quantities in the circuit depend on these as

$$\begin{aligned} R_g &= \frac{R_f}{m-1} \\ R_2 &= \frac{qR_1}{(m-1)V_{\text{ref}} - q} \end{aligned} \tag{2}$$

Notice that OpAmp A is not necessary, but it can be used to eliminate the interaction of gain resistors, and obtain more accurate conversion.

1.1 Example from 0-5V to −10-10V

In the case you want to convert a 0-5V signal (having a $V_{\mathrm{ref}} = 5\mathrm{V}$) to a −10-10V one, you need to use $m = 4$ and $q = 10$. Let's assume that you choose a $R_f = 30\mathrm{k}\Omega$, and $R_1 = 10\mathrm{k}\Omega$. The remaining component of the circuit become, according to (2), $R_g = 10\mathrm{k}\Omega$, and $R_2 = 20\mathrm{k}\Omega$.

2 Circuit design for amplification and negative offset with filter

In some cases, it is also useful to introduce a lowpass filter for the input signal to the circuit in order to eliminate possible noise. The modification to the circuit is represented in Figure 2, where two new components have been introduced: R_{lp}, and C_{lp}.

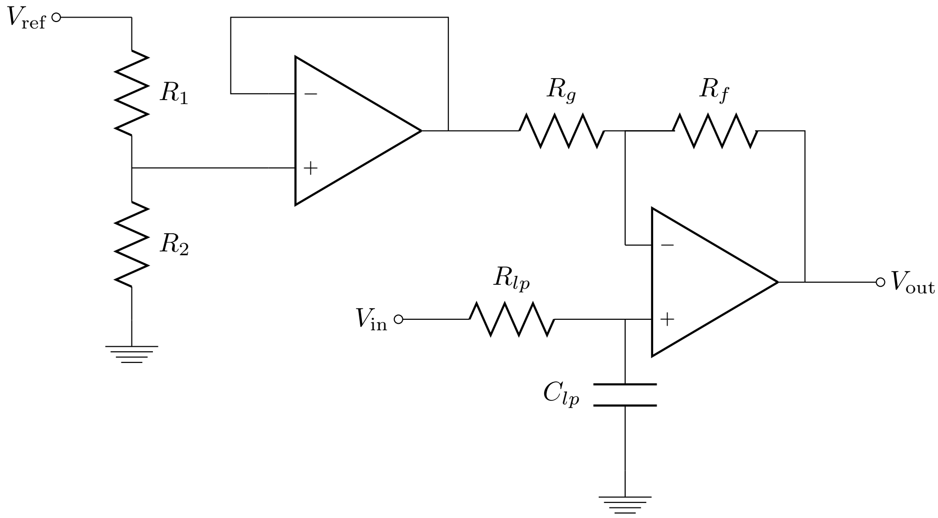

Figure 2: Circuit for negative offset with lowpass filter.

When one chooses the value of R_{lp}, the value for the capacitor can be obtained as

$$C_{lp} = \frac{1}{\omega_{lp} R_{lp}} = \frac{1}{2\pi f_{lp} R_{lp}} \tag{3}$$

where ω_{lp} is the bandwidth of the lowpass filter.

2.1 Example

Depending on the specific application, one needs to choose a larger or a smaller value for the bandwidth. Let's assume that $\omega_{lp} = 100\mathrm{rad/s}$ (corresponding to about $f_{lp} = 16\mathrm{Hz}$), and choosing a $R_{lp} = 10\mathrm{k}\Omega$, the capacitor becomes $C_{lp} = 1\mu\mathrm{F}$.

3 Circuit design for amplification and positive offset

The aim of this section is to describe how to design a circuit able to take a voltage V_{in} as an input, and produce

$$V_{\text{out}} = mV_{\text{in}} + q \tag{4}$$

where $m > 0$ is the amplification (or attenuation when $0 < m < 1$) of the input signal, and q is an offset, with $q > 0$.

The circuit able to perform this transformation is represented in Figure 3.

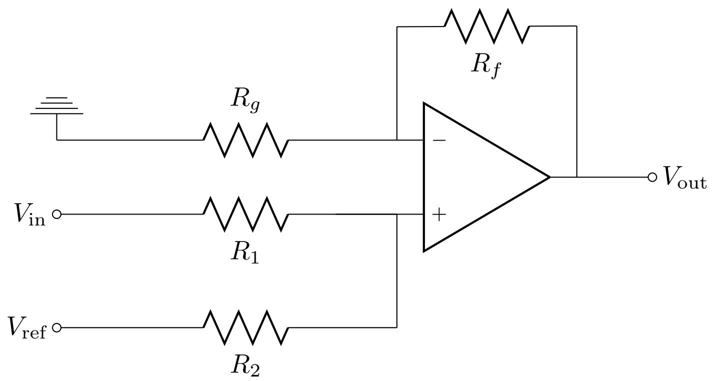

Figure 3: Circuit for the amplification with positive offset.

The components must be suitably chosen in order to obtain the conversion of (4). One can freely choose R_f and R_1, V_{ref} must be chosen with some attention, and m and q depends on the conversion that one wants to obtain. The other quantities in the circuit depend on these as

$$R_2 = \frac{V_{\text{ref}} R_1 m}{q} \quad R_g = \frac{R_2 R_f}{m(R1 + R2) - R2} \tag{5}$$

3.1 Example from -10-10V to 0-$V_{o,\max}$V

In the case you want to convert a -10-10V signal to a 0-$V_{o,\max}$V one, with $V_{o,\max} < 20$ (because our purpose is attenuate), you need to use $m = V_{o,\max}/20$ and $q = V_{o,\max}/2$. According to (6) we then have

$$\begin{aligned} R_2 &= \frac{R_1 V_{\text{ref}}}{10} \\ R_g &= \frac{20 R_f V_{\text{ref}}}{V_{o,\max}(10 + V_{\text{ref}}) - 20 V_{\text{ref}}} \end{aligned} \tag{6}$$

Notice that the denominator of R_g depends on the values of $V_{o,\max}$ and of V_{ref}, and may be negative. If both V_{ref} must be positive for any reason, and remembering that the purpose is attenuating the signal $V_{o,\max} < 10$ we need to choose its value according to the relation

$$V_{\text{ref}} < \frac{q}{1 - m} = \frac{10 V_{o,\max}}{20 - V_{o,\max}} \tag{7}$$

If we choose, for instance $V_{o,\max} = 3\text{V}$, a feasible voltage is to use $V_{\text{ref}} = 1.5\text{V}$, obtaining

$$R_2 = \frac{3R_1}{20} \qquad R_g = \frac{20R_f}{3} \tag{8}$$

Let's assume that you choose a $R_1 = 20k\Omega$, and $R_f = 30\text{k}\Omega$. The remaining component of the circuit become, according to (8), $R_2 = 3\text{k}\Omega$, and $R_g = 200\text{k}\Omega$.

4 Circuit design for amplification and negative offset with filter

In some cases, it is also useful to introduce a lowpass filter for the input signal to the circuit in order to eliminate possible noise. The modification to the circuit is represented in Figure 4, where only one component have been introduced: C_{lp}.

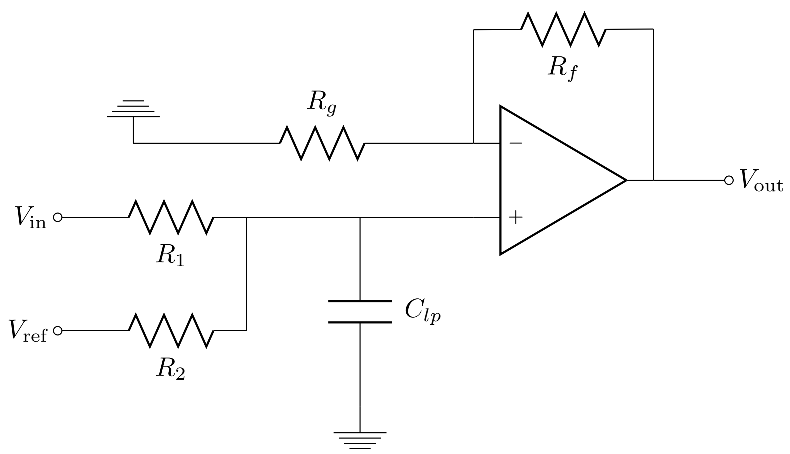

Figure 4: Circuit for positive offset with lowpass filter.

The value for the capacitor can be obtained as

$$C_{lp} = \frac{1}{\omega_{lp} R_1} = \frac{1}{2\pi f_{lp} R_1} \tag{9}$$

where ω_{lp} is the bandwidth of the lowpass filter.

4.1 Example

Depending on the specific application, one needs to choose a larger or a smaller value for the bandwidth. Let's assume that $\omega_{lp} = 500\text{rad/s}$ (corresponding to about $f_{lp} = 16\text{Hz}$), and having chosen before $R_1 = 20k\Omega$, the capacitor becomes $C_{lp} = 100\text{nF}$.