Noise analysis of OPAMPs

Abstract

A quick intro to noise equations in OPAMPs.

Index Terms

JFET

I. OPAMP gain

Figure 1 shows two flavors of OPAMP amplification modes.

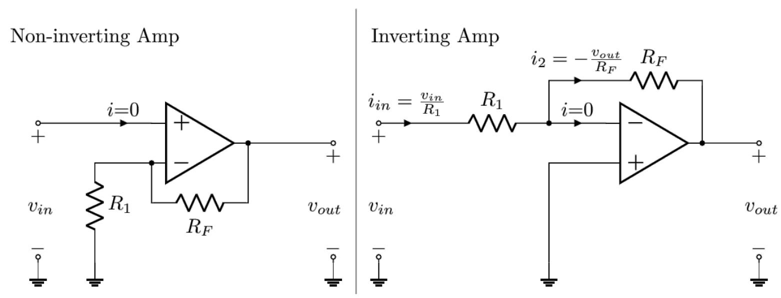

Figure 1: Two flavors of amplifications using OPAMP. An ideal OPAMP has infinite gain and draws no input current. The analysis is done by setting $v_- = v_+$ and $i = 0$ and using Kirchhoff's current and voltage laws.

The gain analysis is done by setting $v_- = v_+$ and $i = 0$ to get the input output relations:

$$v_{out}^{non-inv} = v_{in}\frac{R_F + R_1}{R_1}, \text{ and } \quad v_{out}^{inv} = -v_{in}\frac{R_F}{R_1}, \tag{1}$$

A larger amplification can be reached by selecting large $\frac{R_F}{R_1}$. An OPAMP has inherent voltage and current noise. The current noise couples to the input impedance.

The output noise can be calculated by projecting the noise items into the input terminals[1]. Consider the non-inverting amp in Fig. 2 for noise analysis.

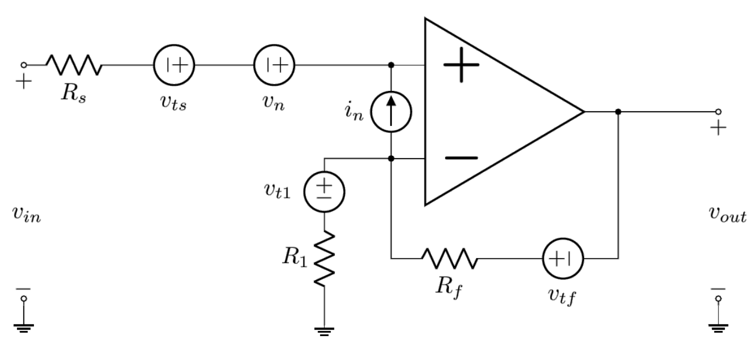

Figure 2: The circuit for noise analysis in non-inverting circuit. Resistors have thermal noise. OPAMP has noise in the input voltage and current. The input current noise passes through Z_{in}.

email: quarktetra@gmail.com
Find the interactive HTML-document here.

The voltages at the OPAMP inputs:

$$v_+ = v_s + v_{ts} + v_n + i_n R_S = v_- = (v_o + v_{tf})\frac{R_1}{R_1 + R_F} + v_{t1}\frac{R_F}{R_1 + R_F} - i_n \frac{R_1 R_F}{R_1 + R_F} \tag{2}$$

Solving for the output noise:

$$v_o = (1 + R_F/R_1)\left(v_s + v_{ts} + v_n + i_n \left[R_S + \frac{R_1 R_F}{R_1 + R_F}\right] - \frac{v_{tf} R_1 + v_{t1} R_F}{R_1 + R_F}\right) \tag{3}$$

OPAMPs typically use BJTs in the input stages, which generate much greater noise currents at the input. These noise currents flowing into high impedances, the red term in Eq. (3) , create large equivalent input noise.

Let us now consider the inverting amp in Fig. 3 which shows the circuit diagram for noise analysis.

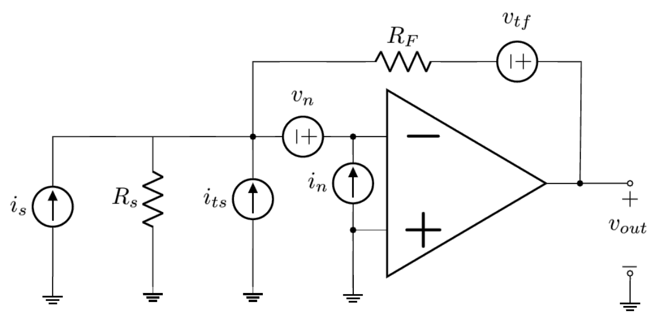

Figure 3: The circuit for noise analysis in inverting circuit. <span class='plus'>... [+] <span class='expanded-caption'> Resistors have thermal noise. OPAMP has noise in the input voltage and current. The input current noise passes through Z_{in}..

An alternative analysis method uses Norton equivalent elements. Thermal noise voltages can be converted to currents when convenient.

The voltages at the OPAMP inputs:

$$v_+ = v_n + (i_s + i_{ts} + i_n) R_S || R_F + (v_{tf} + v_o)\frac{R_S}{R_S + R_F} = v_- = 0. \tag{4}$$

Solve for the output noise:

$$v_o = -\frac{R_F}{R_S}\left(R_S\left[i_s + i_{ts} + \frac{v_{tf}}{R_F}\right] + v_n \frac{R_F + R_S}{R_F} + i_n R_S\right) \tag{5}$$

We see again the noise current, the red term in Eq. (5) , flowing into high impedances R_S, creating large equivalent noise.

[1] W. M. Leach, "Fundamentals of low-noise analog circuit design," *Proceedings of the IEEE*, vol. 82, no. 10, pp. 1515–1538, 1994, doi: 10.1109/5.326411.