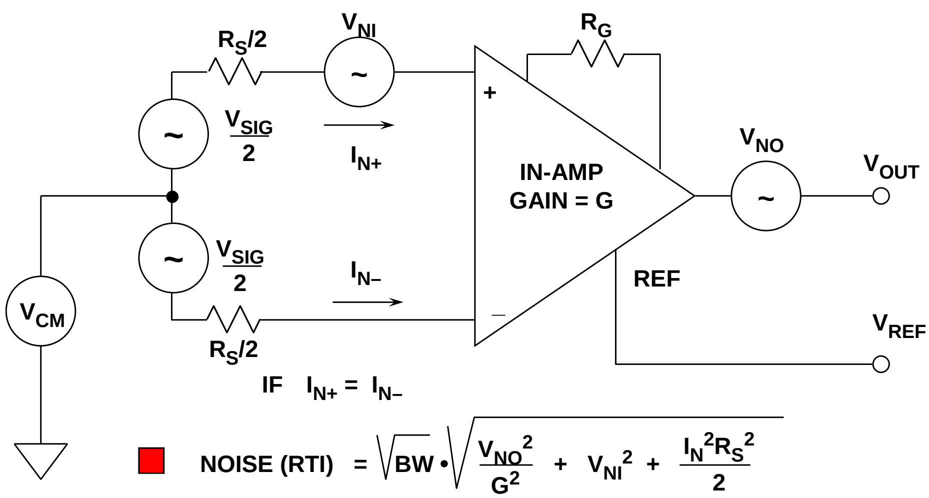
In-Amp Noise

Since in-amps are primarily used to amplify small precision signals, it is important to understand the effects of all the associated noise sources. The in-amp noise model is shown in Figure 1, below.



- NOISE (RTI) $= \sqrt{BW}\cdot\sqrt{\dfrac{V_{NO}^2}{G^2} + V_{NI}^2 + \dfrac{I_N^2 R_S^2}{2}}$
- NOISE (RTO) $= \sqrt{BW}\cdot\sqrt{V_{NO}^2 + G^2\left[V_{NI}^2 + \dfrac{I_N^2 R_S^2}{2}\right]}$
- BW = 1.57 × IN-AMP Bandwidth @ Gain = G

Figure 1: In-Amp Noise Model

There are two sources of input voltage noise. The first is represented as a noise source, V_{NI}, in series with the input, as in a conventional op amp circuit. This noise is reflected to the output by the in-amp gain, G. The second noise source is the output noise, V_{NO}, represented as a noise voltage in series with the in-amp output. The output noise, shown here referred to V_{OUT}, can be referred to the input by dividing by the gain, G.

There are also two noise sources associated with the input noise currents I_{N+} and I_{N-}. Even though I_{N+} and I_{N-} are usually equal ($I_{N+} \approx I_{N-} = I_N$), they are *uncorrelated*, and therefore, the noise they each create must be summed in a root-sum-squares (rss) fashion. I_{N+} flows through one half of R_S, and I_{N-} the other half. This generates two noise voltages, each having an amplitude, $I_N R_S/2$. Each of these two noise sources is reflected to the output by the in-amp gain, G.

The total output noise is calculated by combining all four noise sources in an rss manner:

$$\text{NOISE(RTO)} = \sqrt{\text{BW}}\sqrt{V_{NO}{}^2 + G^2\left(V_{NI}{}^2 + \frac{I_{N+}{}^2 R_S{}^2}{4} + \frac{I_{N-}{}^2 R_S{}^2}{4}\right)}\ . \qquad \text{Eq. 1}$$

If $I_{N+} = I_{N-} = I_N$,

$$\text{NOISE(RTO)} = \sqrt{\text{BW}}\sqrt{V_{NO}{}^2 + G^2\left(V_{NI}{}^2 + \frac{I_N{}^2 R_S{}^2}{2}\right)}\ . \qquad \text{Eq. 2}$$

The total noise, referred to the input (RTI) is simply the above expression divided by the in-amp gain, G:

$$\text{NOISE(RTI)} = \sqrt{\text{BW}}\sqrt{\frac{V_{NO}{}^2}{G^2} + \left(V_{NI}{}^2 + \frac{I_N{}^2 R_S{}^2}{2}\right)}\ . \qquad \text{Eq. 3}$$

In-amp data sheets often present the total voltage noise RTI as a function of gain. This noise spectral density includes both the input (V_{NI}) and output (V_{NO}) noise contributions. The input current noise spectral density is specified separately.

As in the case of op amps, the total in-amp noise RTI must be integrated over the applicable in-amp closed-loop bandwidth to compute an rms value. The bandwidth may be determined from data sheet curves that show frequency response as a function of gain.

Regarding this bandwidth, some care must be taken in computing it, as it is often *not* constant bandwidth product relationship, as is true with VFB op amps. In the case of the AD620 in-amp family for example, the gain-bandwidth pattern is more like that of a CFB op amp. In such cases, the safest way to predict the bandwidth at a given gain is to use the curves supplied within the data sheet.

REFERENCES

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