Finding the dominant source of non-linear distortion in an op-amp

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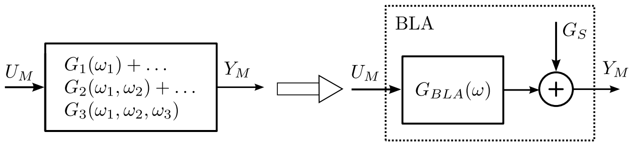

Figure 1: The BLA approximates the behaviour of the non-linear system as a linear system with a coloured noise source added to the output to model the distortion.

Most design flows for analog/RF circuits rely only on reasoning with linear time invariant systems. When the linear design flow is completed, the importance of non-linearities is assessed by identifying compression points and/or intercept points. These points provide a measure of the non-linear behaviour of the total circuit but don't show the relative importance of the different sources of non-linear distortion. If specifications are not met, the designer needs to be able to pinpoint the source of the problem to solve it efficiently.

In [1, 2, 3] a Volterra-based approach was used to localize the dominant non-linearity of the circuit in an analytic way. For larger circuits, this analytic approach yields lengthy, complex expressions. Overview is hence easily lost. These Volterra-based methods also require the replacement of the transistor model by an approximate analytic non-linear model.

Recently, the Best Linear Approximation (BLA) for non-linear systems has been developed [4]. It describes the behaviour of a non-linear system when the system is excited with an input signal that has a certain Power Spectral Density (PSD) and distribution. The BLA approximates the dynamic non-linear system by a linear Frequency Response Function (FRF) with a coloured noise source added to the output to model the non-linear distortion (Figure 1). It can be extracted quickly by performing transient simulations when exciting the circuit with a multisine excitation. No special transistor models are required here.

The noise-like properties of the non-linear distortion (proven by using the BLA[4]) enables the use of a classical noise analysis on the distortion sources. This new BLA-based noise analysis allows to determine the dominant source of non-linear distortion in a circuit, using plain transient simulations without the use of special transistor models or complicated analytical expressions.

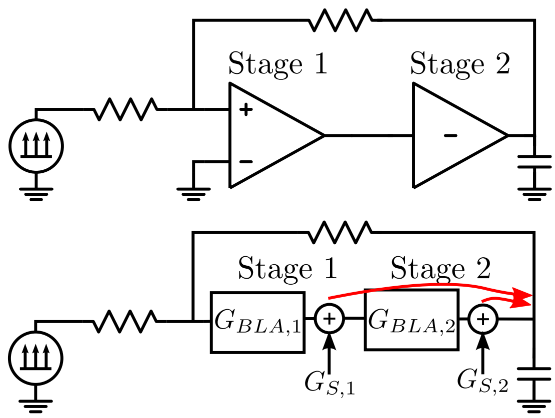

Figure 2: Since the distortion behaves as noise, we can apply a classical noise analysis to the distortion to determine the dominant source of distortion in the op-amp

We will explain the necessary steps to pinpoint the dominant source of non-linear distortion in a two-stage op-amp. The use of a clever combination of multisines, the BLA and small-signal analyses allows to determine the distortion introduced by every stage of the op-amp. This noise-like distortion can then be referred to the output by calculating the FRF between the distortion source and the output of the op-amp (see Figure 2). The analysis can be performed on the op-amp when it is placed in its feedback configuration. As an example, the simulation-based analysis method is applied to several different op-amps.

References

[1] P. Wambacq and W. Sansen, *Distortion Analysis of Analog Integrated Circuits*. Kluwer, 1998.

[2] B. Hernes and W. Sansen, “Distortion in single-, two- and three-stage ampliers,” *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 52, pp. 846–856, May 2005.

[3] S. O. Cannizzaro, G. Palumbo, and S. Pennisi, “Distortion analysis of miller-compensated three-stage amplifiers,” *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 53, pp. 961–976, May 2006.

[4] R. Pintelon and J. Schoukens, *System Identification. A Frequency Domain Approach*, ch. 3, pp. 73–118. John Wiley & Sons, Inc, 2 ed., 2012.