



Vrije Universiteit Brussel



agency for Innovation
by Science and Technology

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

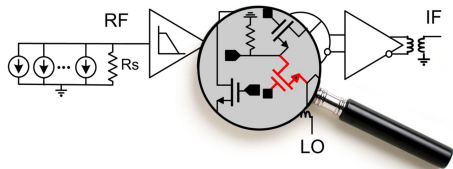
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Department ELEC

Analog design these days = LTI

Design flow based on Linear System Theory

- Non-linear performance is assessed last
- Modeling techniques too complicated → insight is lost
- No indication about the source of distortion



We need an analysis to pinpoint dominant non-linearity

Simple

Combines concepts known to designers

Intuitive

Gives insight into behaviour of the system

Easy to apply

Doesn't need special analyses or transistor models

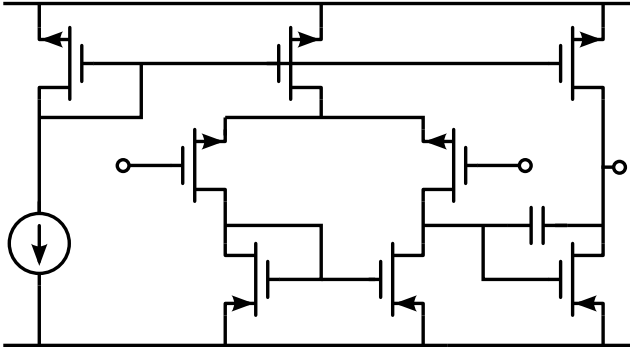
Overview

Noise analysis

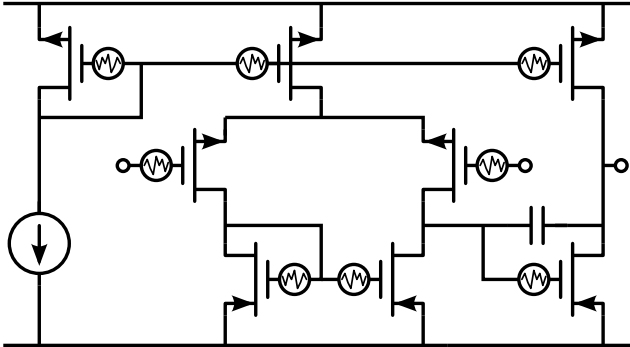
Best Linear Approximation

BLA-based noise analysis

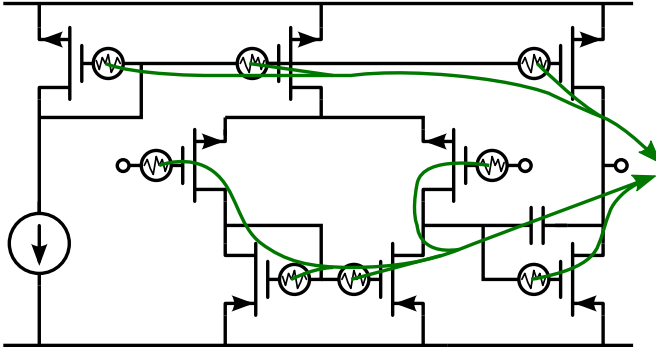
Noise analysis is a powerful design tool



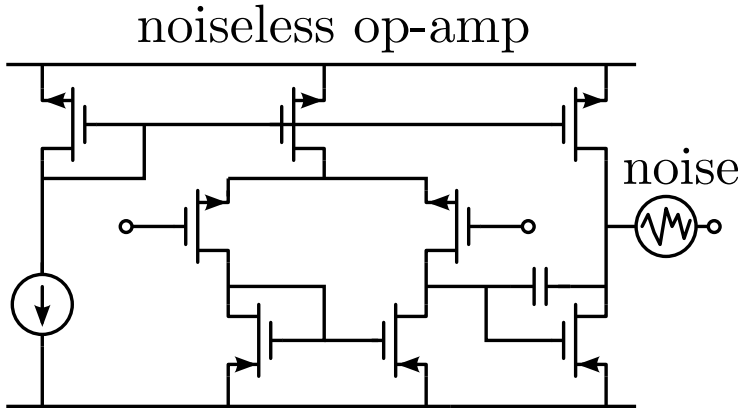
Noise analysis is a powerful design tool



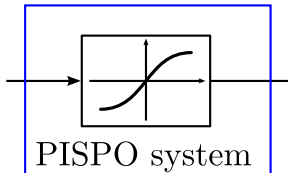
Noise analysis is a powerful design tool



Noise analysis is a powerful design tool

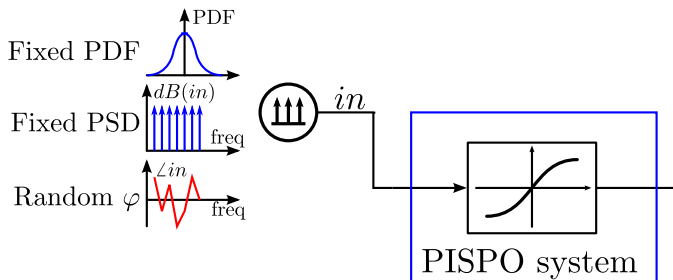


The Best Linear Approximation: intuitive way to look at NL systems

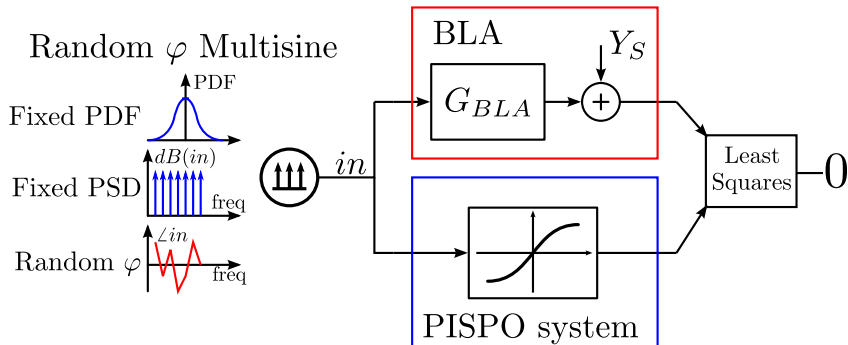


The Best Linear Approximation: intuitive way to look at NL systems

Random φ Multisine

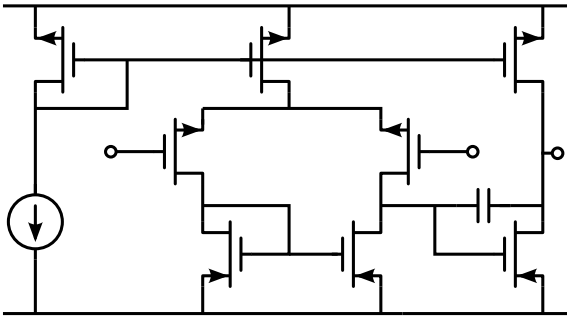


The Best Linear Approximation: intuitive way to look at NL systems

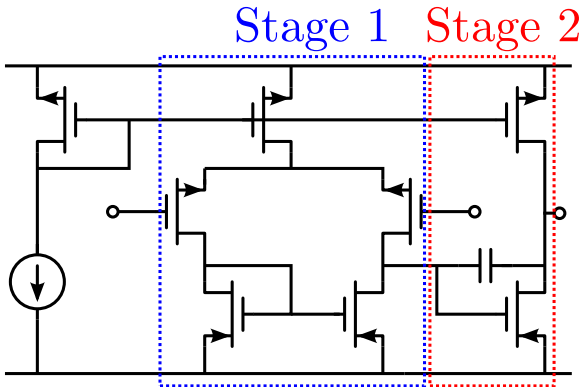


Y_s is uncorrelated with in . It can be considered as noise

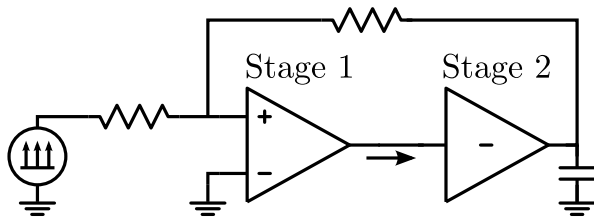
Combine BLA and noise analysis on a design example



Combine BLA and noise analysis on a design example



System in its feedback configuration



Simulate response to multisine

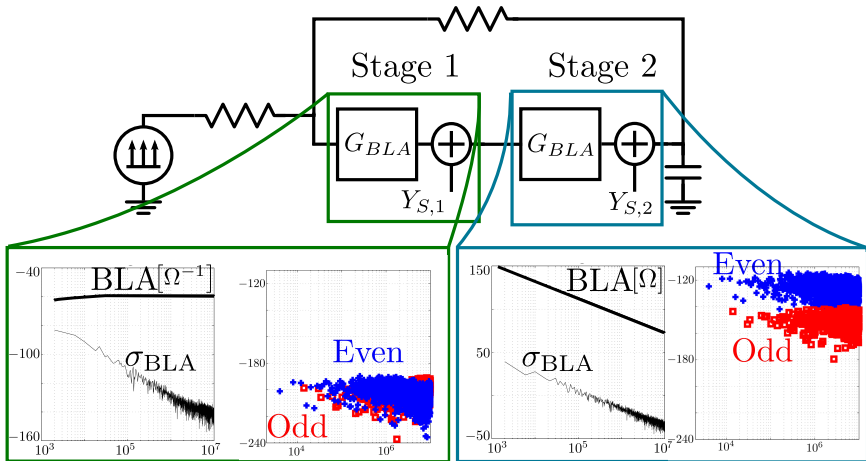
The figure illustrates the simulation of a two-stage amplifier's response to a multisine signal. The circuit consists of an AC voltage source connected to a resistor, which is in series with the non-inverting input (+) of Stage 1. The inverting input (-) of Stage 1 is grounded. The output of Stage 1 is connected to the non-inverting input (+) of Stage 2. The inverting input (-) of Stage 2 is grounded. A feedback resistor is connected between the output of Stage 2 and its non-inverting input (+). The output of Stage 2 is also connected to a capacitor, which is grounded.

Four plots show the magnitude spectrum of the signal at different stages:

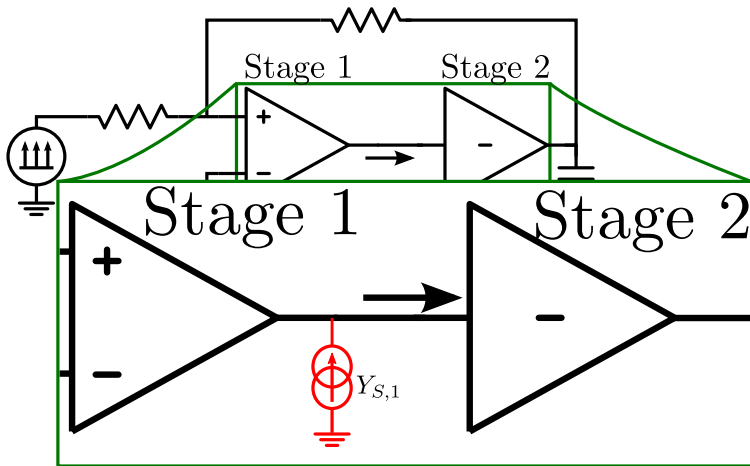
- Plot 1:** Shows the input signal, a flat line at approximately -50 dB across the frequency range from 10^4 to 10^6 Hz.
- Plot 2:** Shows the signal after Stage 1. The magnitude increases with frequency, reaching about -100 dB at 10^6 Hz. The plot includes blue dots and red squares representing data points.
- Plot 3:** Shows the signal after Stage 2. The magnitude continues to increase, reaching about -150 dB at 10^6 Hz. The plot includes blue dots and red squares representing data points.
- Plot 4:** Shows the signal after the output capacitor. The magnitude is flat at approximately -50 dB. The plot is labeled "Excited" and includes blue dots and red squares representing data points.

The x-axis for all plots is frequency [Hz] on a logarithmic scale from 10^4 to 10^6 . The y-axis represents magnitude in dB, with values ranging from -150 to 50.

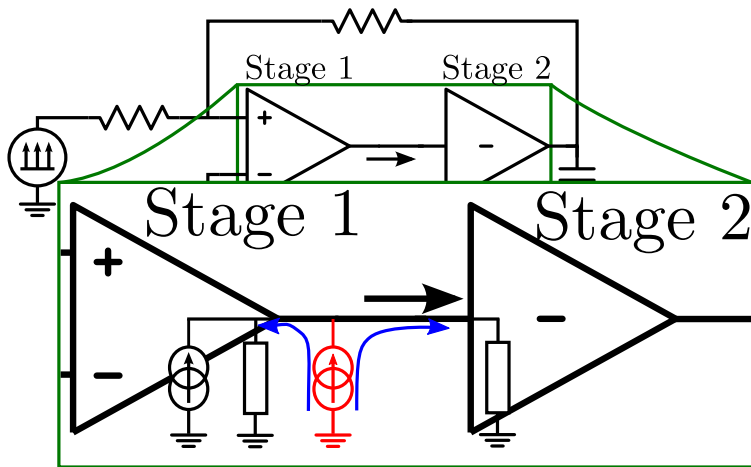
Calculate BLA in feedback



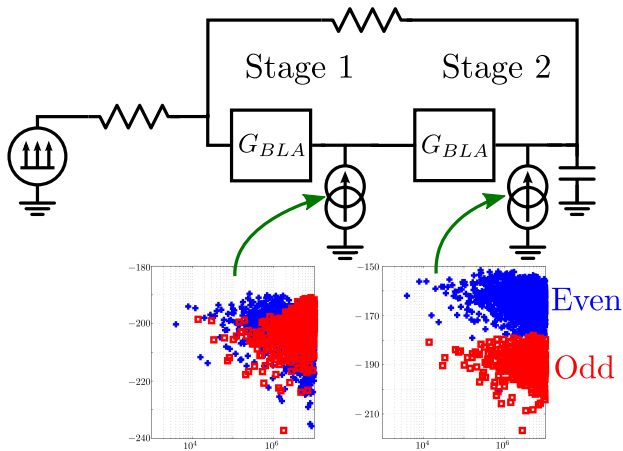
While adding distortion with a signal source...



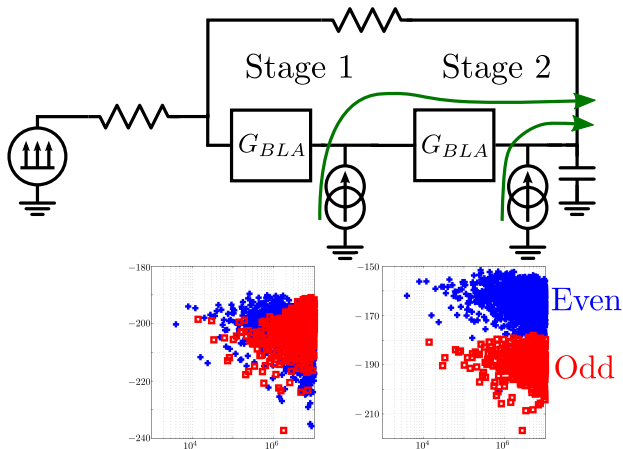
Finite impedance must be taken into account



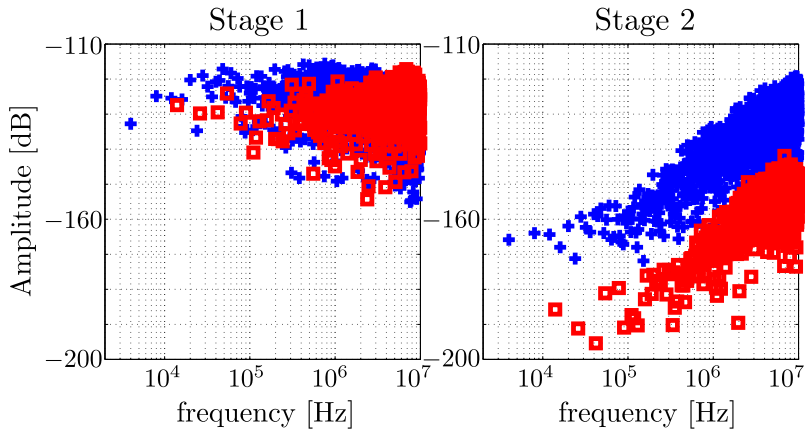
Distortion noise source PSD is obtained



Finally: Refer to the output



First stage is the dominant source



The BLA-based noise analysis allows to find the source of distortion

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