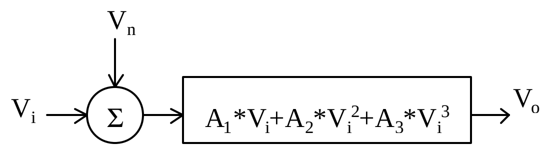
Bias Noise Mixing



▸ useful functions and identities
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Introduction

Noise from the bias circuit at frequency, wnoise, can mix with a jammer at frequency, ω_{RF} + wnoise, to generate a noisy signal at a desired frequency, ω_{RF}, in a low noise amplifier or in the driver of a mixer. In the switching pair of a mixer, noise mixes from the RF=LO+IF to IF frequencyand from Image=LO-IF to IF frequency

Inputs

$\omega_{off} := 900kHz$	Frequency offset of the jammer
$\omega_{RF} := 869MHz$	Frequency of desired signal
$P_{jamdBm} := -46dBm$	Power of Jammer
$\Delta f := 30kHz$	Bandwidth of Jammer
$\Delta f_{des} := 1.23MHz$	Bandwidth of Desired Signal
$\omega_{corner} := 100kHz$	1/f noise corner frequency
$R_{bias} := 1kohm$	Thermal noise resistance of bias circuitry and transistor
$Temp := 300K$	Operating Temperature in Kelvin
$L_e := 6nH$	Inductive Degeneration
$I_C := 3mA$	Bias Current
$r_b := 8ohm$	Base Resistance

Calculations

$\omega_{jammer} := \omega_{RF} + \omega_{off}$ $\omega_{jammer} = 869.9\,MHz$ Frequency of jammer

$S_{jammer} := \sqrt{2}\cdot\sqrt{10^{\frac{P_{jamdBm}}{10}}\cdot 1mW\cdot 50ohm}$ $S_{jammer} = 1.585\,mV$ Jammer Voltage 0-pk

$V_T := \frac{k\cdot Temp}{q}$ $V_T = 25.899\,mV$ Thermal Voltage

$g_m := \frac{I_C}{V_T}$ $g_m = 115.835\,\frac{mA}{V}$ Device Transconductance

$R_{eff} := R_{bias}\cdot\left(\frac{\frac{50ohm}{2}}{R_{bias} + \frac{50ohm}{2}}\cdot 2\right)^2 + \frac{1}{2\cdot g_m} + r_b$ $R_{eff} = 14.696\,ohm$ Effective Input Noise Resista

$V_n(f) := 4\cdot k\cdot Temp\cdot R_{eff}\cdot\left(1 + \frac{\omega_{corner}}{f}\right)$ Equivalent Input Noise Spect

$S_{noise} := \int_{\omega_{off}-\frac{\Delta f}{2}}^{\omega_{off}+\frac{\Delta f}{2}} V_n(f)\,df$ $S_{noise} = 8.13\times 10^{-3}\,\mu V^2$ Integrated Thermal Noise (rms)

$Z_e(\omega) := 2\cdot\pi\cdot j\cdot\omega\cdot L_e$ Emitter Impedance

$A_1(\omega) := \frac{g_m}{1 + g_m\cdot Z_e(\omega)}$ Approximate High Frequency with inductive degeneration.

$A_2(\omega_1,\omega_2) := \frac{g_m}{2\cdot V_T\cdot(1 + g_m\cdot Z_e(\omega_1))\cdot(1 + g_m\cdot Z_e(\omega_2))}$ Approximate High Frequency with inductive degeneration.

$I_{outnoise} := \left|A_2(\omega_{jammer},-\omega_{off})\right|\cdot\sqrt{S_{noise}\cdot 2\cdot S_{jammer}}$ $I_{outnoise} = 1.151\times 10^{-4}\,\mu A$ Noise at the output of the am

$S_{innoise} := \left(\frac{I_{outnoise}}{\left|A_1(\omega_{RF})\right|}\right)^2\cdot\frac{1}{\Delta f_{des}}$ $\sqrt{S_{innoise}} = 3.515\times 10^{-3}\,\frac{nV}{\sqrt{Hz}}$ Input Noise Spectrum

$NF := 10\cdot\log\left[1 + \frac{S_{innoise}}{4\cdot k\cdot Temp\cdot(50ohm)}\right]$ $NF = 6.465\times 10^{-5}\,dB$ Noise Figure due to mixed nc

$NF := 10\cdot\log\left(1 + \frac{R_{eff}}{50ohm}\right)$ $NF = 1.119\,dB$ Noise Figure without jammer

Hand Calculation Simplifications

$$NF = 10\cdot\log\left[1 + \frac{\left(\left|A_2(\omega_{RF} + \omega_{off}, -\omega_{off})\right|\right)^2}{\left(\left|A_1(\omega_{RF})\right|\right)^2}\cdot\frac{R_{eff}}{50}\cdot\left(\Delta f + \omega_{corner}\cdot\ln\left(\left|\frac{\omega_{off} + \frac{\Delta f}{2}}{\omega_{off} - \frac{\Delta f}{2}}\right|\right)\right)\cdot S_{jammer}^{\ 2}\right]$$

$$NF = 10\cdot\log\left[1 + \left(\frac{S_{jammer}}{I_C\cdot\omega_{RF}\cdot L_e}\right)^2\cdot\frac{R_{eff}}{50ohm}\cdot\left(\frac{\Delta f}{\Delta f_{des}} + \frac{\omega_{corner}}{\Delta f_{des}}\cdot\ln\left(\left|\frac{\omega_{off} + \frac{\Delta f}{2}}{\omega_{off} - \frac{\Delta f}{2}}\right|\right)\right)\right]$$

dB Increase from Noise Doubling

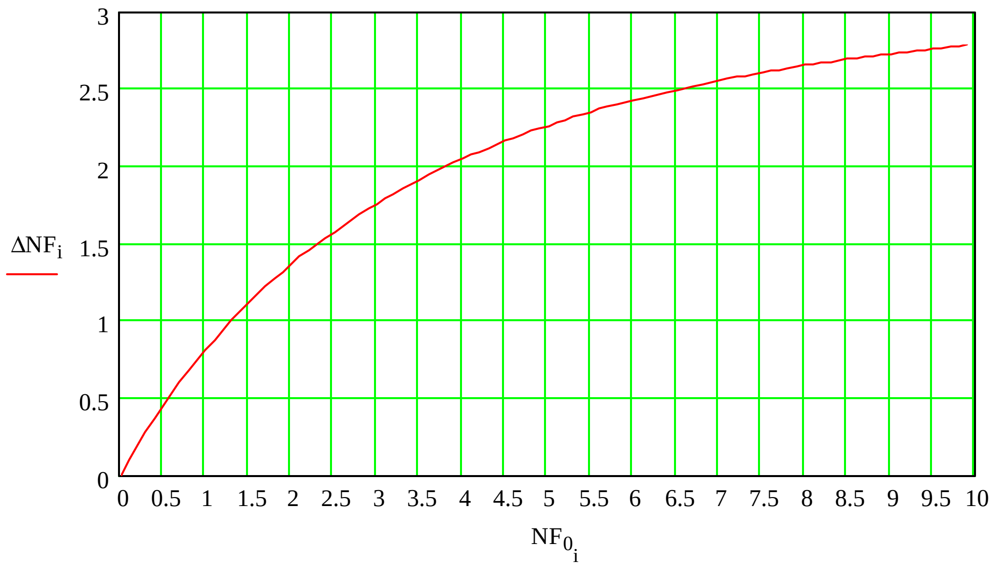
Here is a interesting side calculation. If you double the noise in a circuit how much does the noise figure increase? For large noise figures it is 3dB. For small noise figure the dB's double. This is useful for comparing the noise of a differential circuit to a single-ended circuit, such as a differential LNA to a single-ended LNA.

$N := 100$

$i := 1..\ N$

$NF0_i := \frac{i-1}{N}\cdot 10$

$\Delta NF_i := 10\log\left[1 + \left(10^{\frac{NF0_i}{10}} - 1\right)\cdot 2\right] - NF0_i$



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