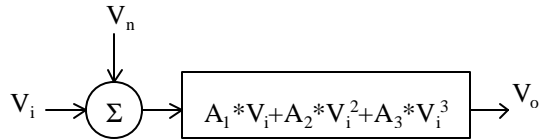




Bias Noise Mixing



- ▢ useful functions and identities
- ▢ Units
- ▢ Constants

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Introduction

Noise from the bias circuit at frequency, ω_{noise} , can mix with a jammer at frequency, $\omega_{RF} + \omega_{noise}$, 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 frequency and from $Image=LO-IF$ to IF frequency

Inputs

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

Calculations

$$\omega_{\text{jammer}} := \omega_{\text{RF}} + \omega_{\text{off}}$$

$$\omega_{\text{jammer}} = 869.9 \text{ MHz}$$

Frequency of jammer

$$S_{\text{jammer}} := \sqrt{2} \cdot \sqrt{10^{\frac{P_{\text{jamdBm}}}{10}} \cdot 1 \text{ mW} \cdot 50 \text{ ohm}}$$

$$S_{\text{jammer}} = 1.585 \text{ mV}$$

Jammer Voltage 0-pk

$$V_T := \frac{k \cdot \text{Temp}}{q}$$

$$V_T = 25.899 \text{ mV}$$

Thermal Voltage

$$g_m := \frac{I_C}{V_T}$$

$$g_m = 115.835 \frac{\text{mA}}{\text{V}}$$

Device Transconductance

$$R_{\text{eff}} := R_{\text{bias}} \cdot \left(\frac{\frac{50 \text{ ohm}}{2}}{R_{\text{bias}} + \frac{50 \text{ ohm}}{2}} \cdot 2 \right)^2 + \frac{1}{2 \cdot g_m} + r_b$$

$$R_{\text{eff}} = 14.696 \text{ ohm}$$

Effective Input Noise Resista

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

Equivalent Input Noise Spect

$$S_{\text{noise}} := \int_{\omega_{\text{off}} - \frac{\Delta f}{2}}^{\omega_{\text{off}} + \frac{\Delta f}{2}} V_n(f) df$$

$$S_{\text{noise}} = 8.13 \times 10^{-3} \mu\text{V}^2$$

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.

$$I_{\text{outnoise}} := |A_2(\omega_{\text{jammer}}, -\omega_{\text{off}})| \cdot \sqrt{S_{\text{noise}} \cdot 2} \cdot S_{\text{jammer}}$$

$$I_{\text{outnoise}} = 1.151 \times 10^{-4} \mu\text{A}$$

Noise at the output of the amp

$$S_{\text{innoise}} := \left(\frac{I_{\text{outnoise}}}{|A_1(\omega_{\text{RF}})|} \right)^2 \cdot \frac{1}{\Delta f_{\text{des}}}$$

$$\sqrt{S_{\text{innoise}}} = 3.515 \times 10^{-3} \frac{\text{nV}}{\sqrt{\text{Hz}}}$$

Input Noise Spectrum

$$\text{NF} := 10 \cdot \log \left[1 + \frac{S_{\text{innoise}}}{4 \cdot k \cdot \text{Temp} \cdot (50 \text{ ohm})} \right]$$

$$\text{NF} = 6.465 \times 10^{-5} \text{ dB}$$

Noise Figure due to mixed nc

$$\text{NF} := 10 \cdot \log \left(1 + \frac{R_{\text{eff}}}{50 \text{ ohm}} \right)$$

$$\text{NF} = 1.119 \text{ dB}$$

Noise Figure without jammer

Hand Calculation Simplifications

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

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

dB Increase from Noise Doubling

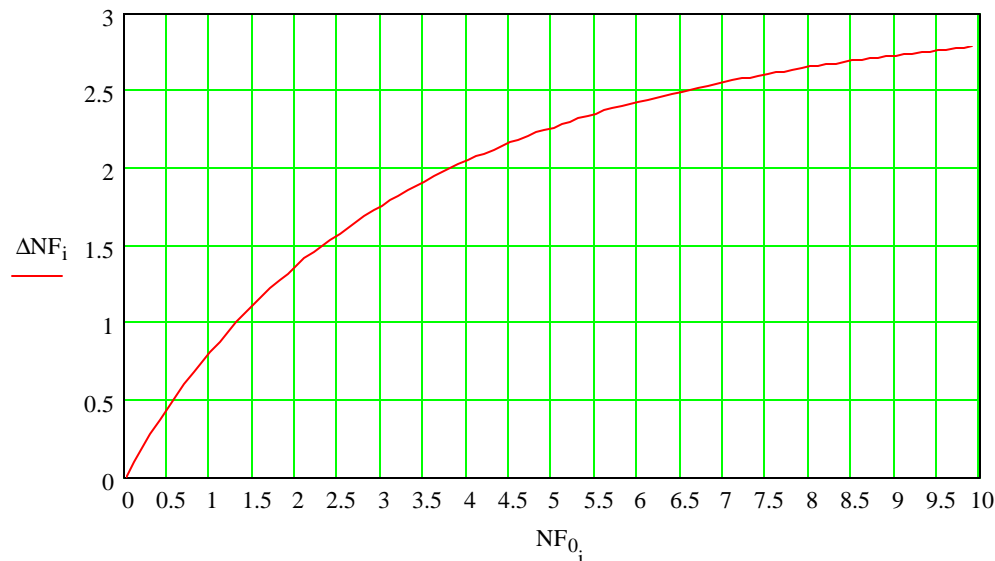
Here is a interesting side calculation. If you double the noise in a circuit how much does the noise figure increase? For large noise figures it is 3dB. For small noise figure the dB's double. This is useful for comparing the noise of a differential circuit to a single-ended circuit, such as a differential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

$N := 100$

$i := 1..N$

$$NF_{0_i} := \frac{i-1}{N} \cdot 10$$

$$\Delta NF_i := 10 \log \left[1 + \left(\frac{NF_{0_i}}{10} - 1 \right)^2 \right] - NF_{0_i}$$



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