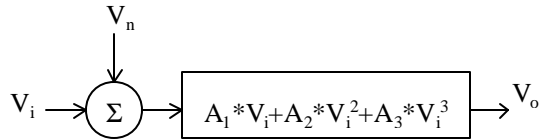




Bias Noise Mixing



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

Table of Contents

- I. Introduction
- II. Inputs
- III. Calculations
- IV. Hand Calculation Simplifications
- V. Noise Figure Increase when Noise is Doubled.
- IX. Copyright and Trademark Notice

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

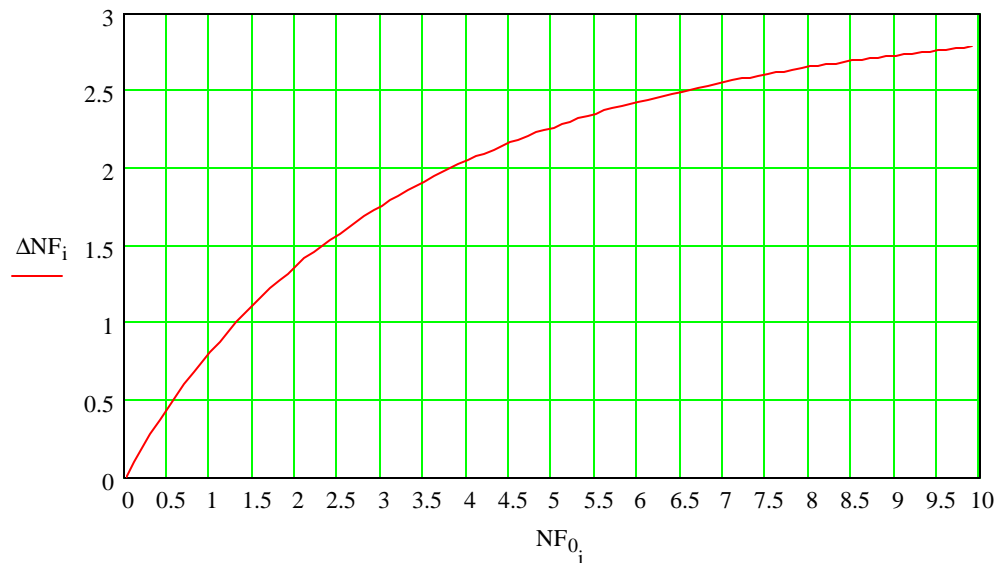
Here is a interesting side calculation. If you double the noise in a circuit how much does the noise figure increase? For large noise figures it is 3dB. For small noise figure the dB's double. This is useful for comparing the noise of a differential circuit to a single-ended circuit, such as a differential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

$N := 100$

$i := 1..N$

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

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



Copyright and Trademark Notice

All software and other materials included in this document are protected by copyright, and are owned or controlled by Circuit Sage.

The routines are protected by copyright as a collective work and/or compilation, pursuant to federal copyright laws, international conventions, and other copyright laws. Any reproduction, modification, publication, transmission, transfer, sale, distribution, performance, display or exploitation of any of the routines, whether in whole or in part, without the express written permission of Circuit Sage is prohibited.