RF Mixers (III)
Methods of Reducing Flicker Noise in Active Mixers

Key observation: Reduce $I_{SS}$ but without degrading gain, thermal NF, etc.

Or other clever schemes:

[Pullela, ISSCC06]
Nonlinearity in Mixers

Voltage-driven passive mixers: The LO has a finite transition time, and the on-resistance varies during this time:

Active mixers:

IP3:
(1) V/I converter nonlinearity
(2) When one diff pair device enters triode while the other is on:

IP2:
Asymmetries in the circuit, e.g., between diff pair devices:
Observations:
1. Should the effect of Vos be similar to that of 1/f noise?

2. The differential output current contains a dc term equal to:
   \[(4\Delta T/T_{LO})I_{SS} = V_{OS}I_{SS}/(\pi V_{p,LO})\]

3. If we replace Iss with a V/I device and assume two tones, the input transistor generates a beat:
   \[V_{PE} = V_m \cos \omega_1 t + V_m \cos \omega_2 t + V_{GS0}\]
   \[I_{IM2} = \frac{1}{2}\mu_n C_{ox} \frac{W}{L} V_m^2 \cos(\omega_1 - \omega_2) t\]

4. Need to equate the feedthrough amplitude to the fundamental amplitude:
   \[\frac{1}{2}\mu_n C_{ox} \frac{W}{L} V_{IIP2}^2 \frac{V_{OS}R_D}{\pi V_{p,LO}} = \frac{2}{\pi} g_{m1} R_D V_{IIP2}\]

The IIP2 is thus given by:

For example, if overdrive = 250 mV, LO peak swing = 300 mV, and Vos = 10 mV, then IIP2 = 30 Vp (~ 40 dBm).

Active Mixer Design Example

- Design Specs:
  \(V_{DD} = 1.2\) V, 65-nm CMOS, \(I_{DD} = 2\) mA, single-ended
  LO swing = 400 mVp

- Design limited by voltage headroom; Assign:
  \(V_{DS1} = 300\) mV \(\Rightarrow W_1 = 15\) um
  \(g_{m1} = 12.75\) ms
  \(V_{DS2,3,eq} = 150\) mV \(\Rightarrow W_{2,3} = 20\) um
  \(\Rightarrow \) drop across \(R_D = 600\) mV
  \(\Rightarrow \) Choose \(R_D = 500\) ohms

- Choose \(C_1 = C_2 = 2\) pF to suppress LO feedthrough.
IIP3 Estimate:

Input peak amplitude: 40 mV

Compression Characteristic:

Quick Calculations:

• Voltage Conversion Gain:

\[ A_v = \frac{2}{\pi} g_{m1} R_D \]

• Noise Figure:

\[
\frac{V_{n,inn}^2}{V_{n,inn}^2} = \pi^2 kT \left( \frac{\gamma}{g_{m1}} + \frac{2}{g_{m1}^2 R_D} \right) = 4.21 \times 10^{-18} \text{ V}^2/\text{Hz},
\]

\[ \text{NF}_{SSB} = 1 + \frac{V_{n,inn}^2}{4kT R_S} = 6.1 \left( = 7.84 \text{ dB} \right) \]