RF Mixers (II)

Passive Mixers

- “Return-to-Zero” Implementations:

Conversion Gain:
How about single-balanced and double-balanced?

RX mixers are not very common in modern RF design.

- “Non-Return-to-Zero” (Sampling) Mixers: Case I: Voltage-Driven

Conversion Gain Calculation:

\[ |Y_1(f) + Y_2(f)|_{IF} = \sqrt{\frac{1}{\pi^2} + \frac{1}{4}[|X(f - f_{LO})| + |X(f + f_{LO})|]} \]

How about single-balanced and double-balanced?
Noise Calculation:

\[
V_{n,\text{in,SB}}^2 = \frac{kT}{2} \left( \frac{1}{\pi^2} + \frac{1}{4} \right) \left( 3.9R_1 + \frac{1}{2C_1f_{LO}} \right)
\]

Input impedance for \( \omega \sim \omega_{LO} \):

How about single-balanced and double-balanced?

- Flicker Noise: Passive mixers generate little flicker noise in the baseband output if the transistors do not enter saturation at any point during the cycle and carry no dc current.

Case II: Current-Driven

1. Assume a certain frequency response for \( Z_{BB} \):

2. Apply a band-limited signal current:
3. Now the baseband signal is mixed with LO and returns to node A:

\[ V_1(f) \]

Upconverted to RF

\[ \ldots \quad -f_c \quad 0 \quad +f_c \quad \ldots \]

→ The baseband impedance is “translated” to \( f_c \).
→ Can obtain very high Qs in RF!

Noise and Nonlinearity:

Since the switches are in series with a current source, they should contribute negligible noise and nonlinearity. In practice, though, some corruption occurs.

Problem of Current Division:

In a double-balanced mixer, the input current would split two ways, reducing the conversion gain:

→ Need to use 25% duty cycle for the LOs:

Example:
[Mirzaei, VLSI Symp. ‘10]
Active Mixers

- Conversion Gain:

$$V_{out}(t) = I_{RF}(t)R_D \cdot \frac{4}{\pi} \cos \omega_{LO} t + \cdots$$

- Voltage Headroom Issues:

$$V_{R,\text{max}} = V_{DD} - \left[ V_{GS1} - V_{TH1} + \left(1 + \sqrt{2}\right) \left(V_{GS2,3} - V_{TH2}\right) \right]$$

- Noise in Active Mixers

Periodically-Switched White Noise:

$$2kT R_S$$
Observations:
1. Noise current of M1 is periodically-switched.
2. \( R_D \)'s directly add noise to IF.
3. M2 and M3 contribute noise for only a fraction of the period.

If only 1 and 2 are considered:

\[ V_{n,X}^2 = \frac{1}{2} \left( I_{n,M1}^2 \right) R_D^2 + 4kTR_D \]

Referred to the input:

\[ V_{n,in}^2 = \pi^2 kT \left( \frac{g_m}{g_m} + \frac{2}{g_m^2 R_D} \right) \]

Flicker Noise in Active Mixers:

\[
\begin{align*}
I_{D2} & \quad t \\
I_{D3} & \quad t \\
\end{align*}
\]

Step 1:

\[ V_{CM} + V_{p,LO} \sin \omega_{LO}t + V_{n2}(t) = V_{CM} - V_{p,LO} \sin \omega_{LO}t \]

Step 2:

\[ |\Delta T| = \frac{|V_{n2}(t)|}{2V_{p,LO}\omega_{LO}} \]

Step 3:

\[ I_{n,out}(t) = \sum_{k = -\infty}^{+\infty} \frac{2I_{SS}V_{n2}(t)}{S_{LO}} \delta \left( t - k\frac{T_{LO}}{2} \right) \quad V_{n,out}(f)|_{k = 0} = \frac{I_{SS}R_D}{\pi V_{p,LO}} V_{n2}(f) \]