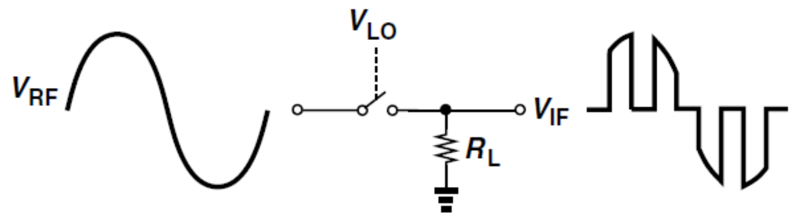
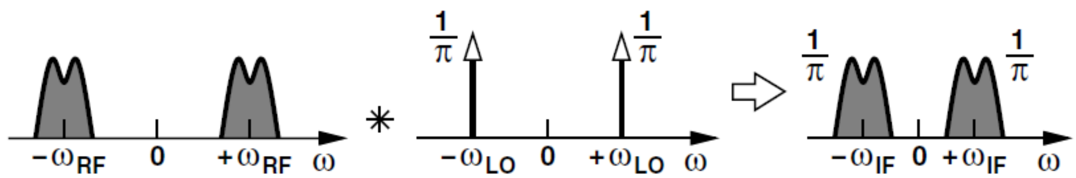
RF Mixers (II)

Passive Mixers

- "Return-to-Zero" Implementations:



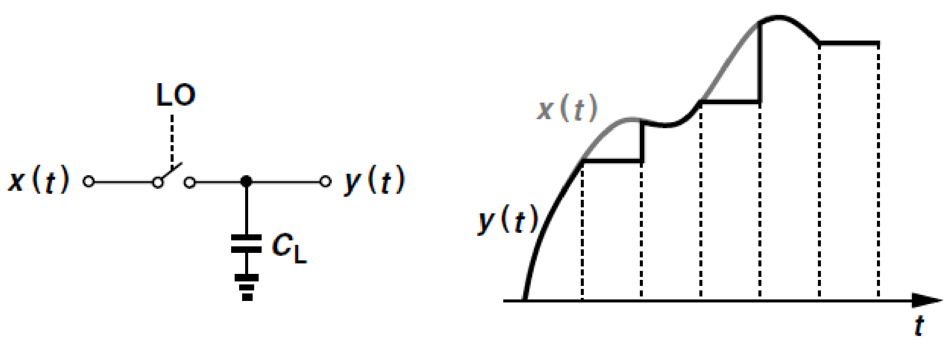
(a)



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:

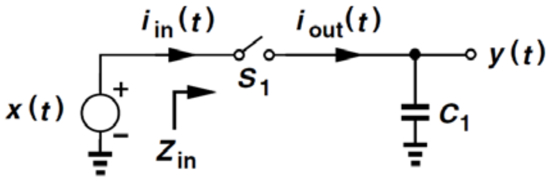
$$|Y_1(f) + Y_2(f)|_{IF} = \sqrt{\frac{1}{\pi^2} + \frac{1}{4}}[|X(f - f_{LO})| + |X(f + f_{LO})|]$$

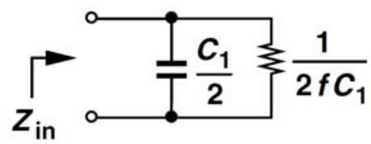
How about single-balanced and double-balanced?

Noise Calculation:

$$\overline{V^2_{n,in,SB}} = \frac{kT}{2\left(\frac{1}{\pi^2}+\frac{1}{4}\right)}\left(3.9R_1 + \frac{1}{2C_1 f_{LO}}\right)$$

Input impedance for $\omega \sim \omega_{LO}$:

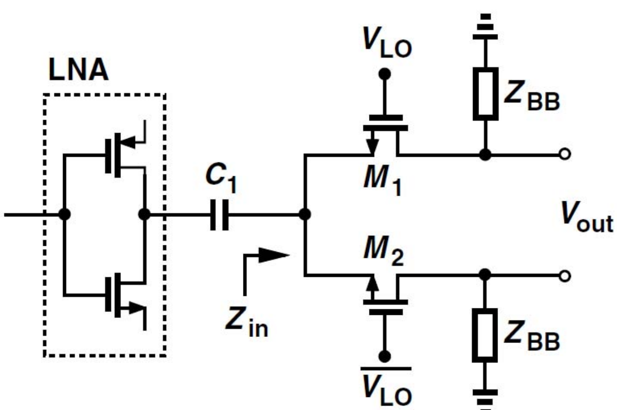


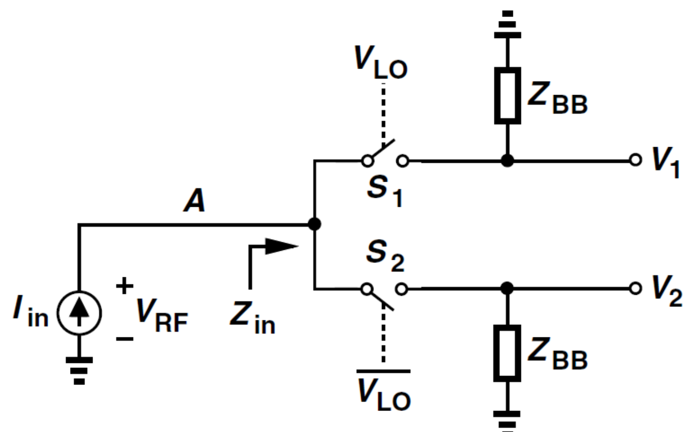


How about single-balanced and double-balanced?

- 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.

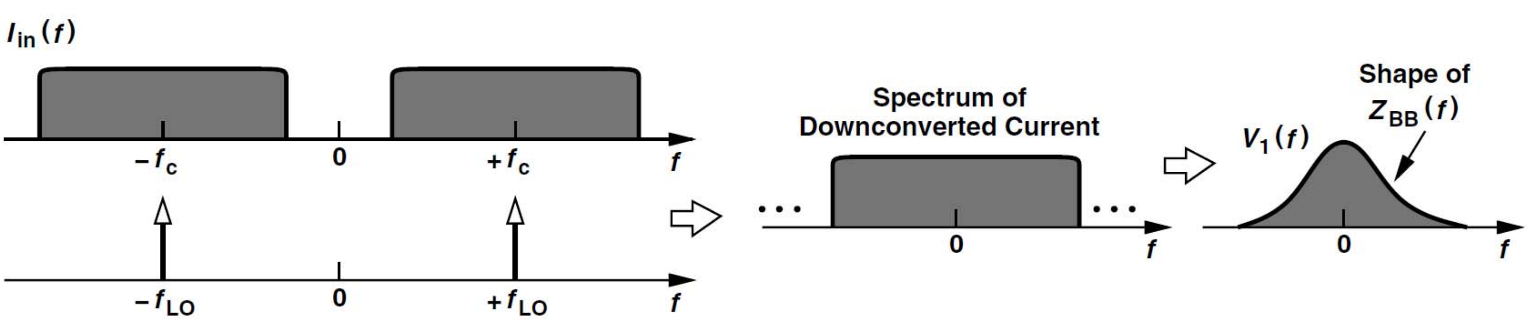
Case II: Current-Driven



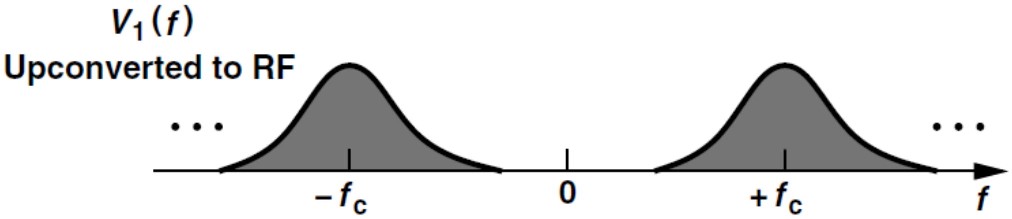


1. Assume a certain frequency response for Z_{BB}:

2. Apply a band-limited signal current:



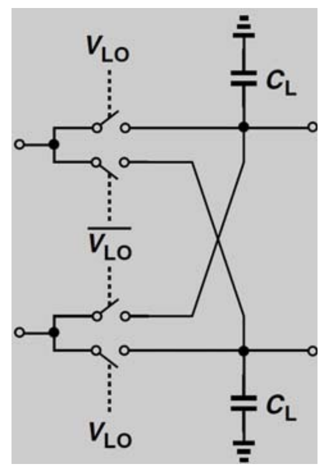
3. Now the baseband signal is mixed with LO and returns to node A:



→ **The baseband impedance is "translated" to f_C.**
→ **Can obtain very high Qs in RF!**

Noise and Nonlinearity:

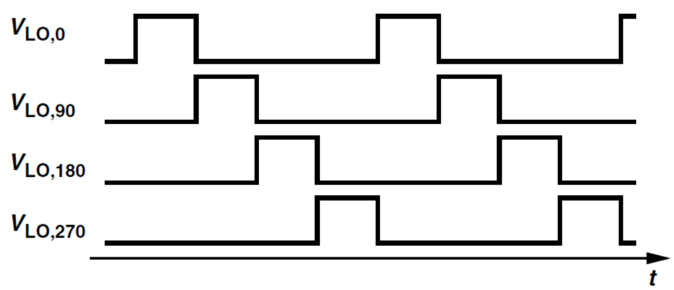
Since the switches are in series with a current source, they should contribute negligible noise and nonlinearity. In practice, though, some corruption occurs.



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]
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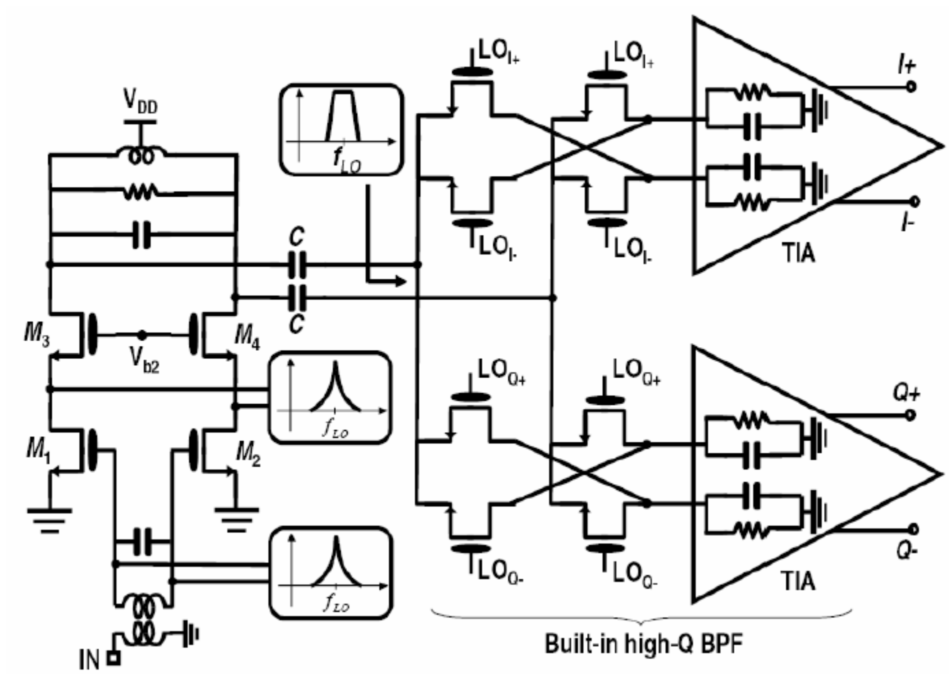
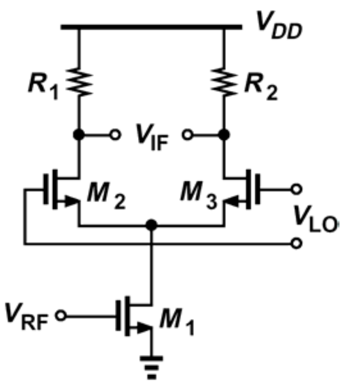
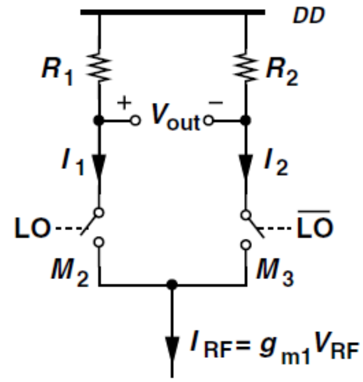
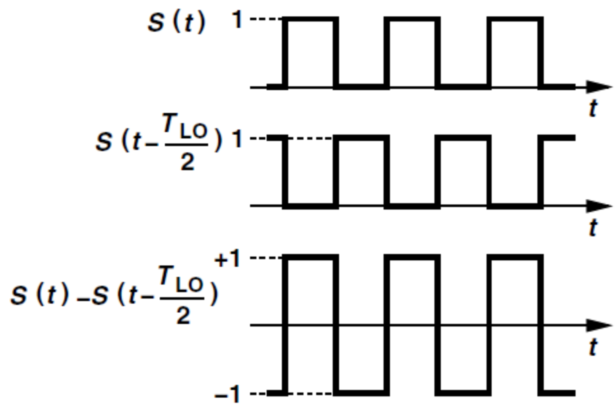


Active Mixers



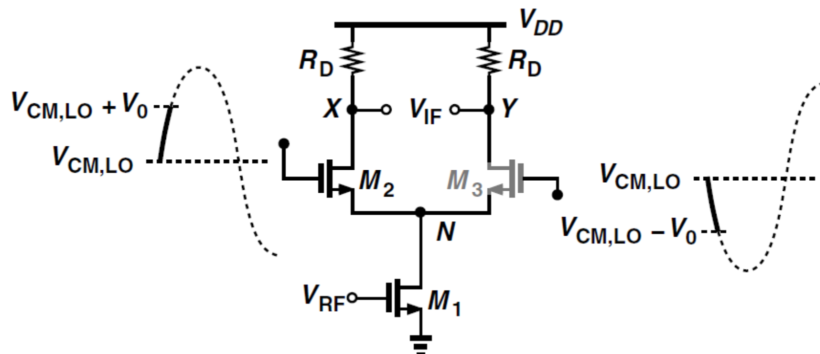




$$V_{out}(t) = I_{RF}(t)R_D \cdot \frac{4}{\pi}\cos\omega_{LO}t + \cdots$$

- Conversion Gain :

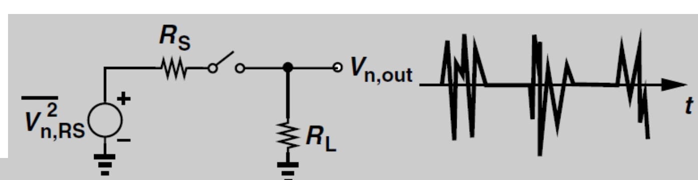
- Voltage Headroom Issues :

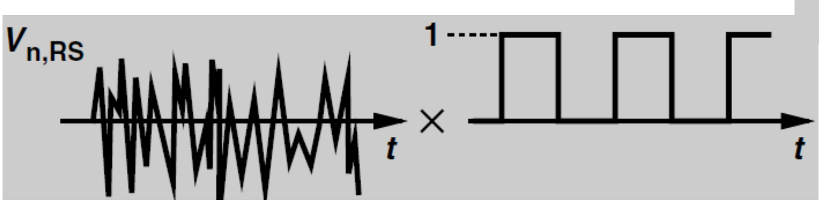


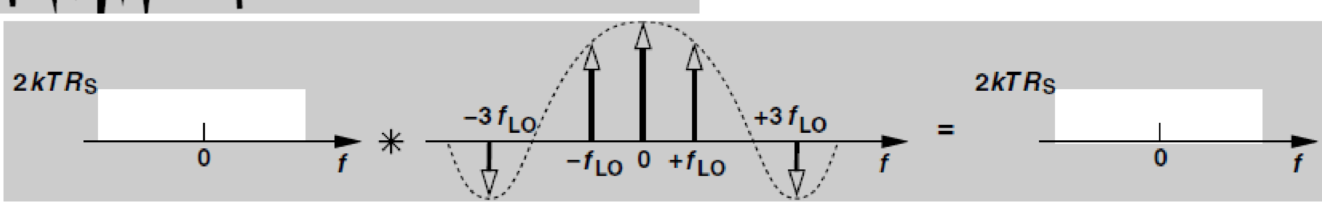
$$V_{R,max} = V_{DD} - \left[V_{GS1} - V_{TH1} + \left(1 + \frac{\sqrt{2}}{2}\right)(V_{GS2,3} - V_{TH2})\right]$$

- Noise in Active Mixers

Periodically-Switched White Noise:





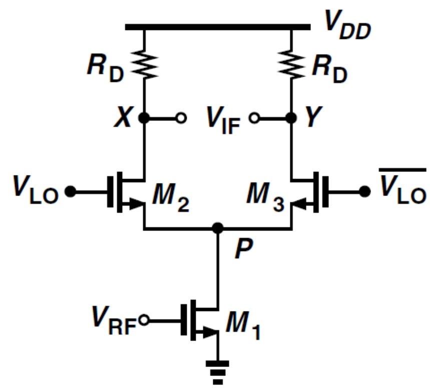


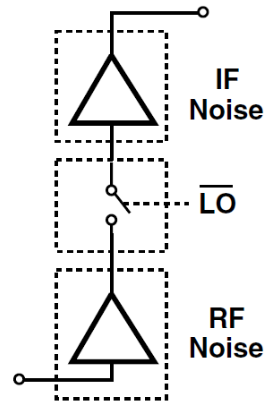
Observations:

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.





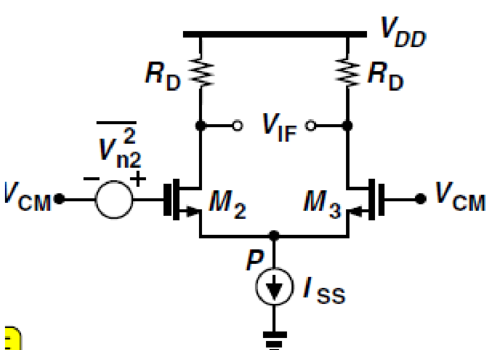
If only 1 and 2 are considered:

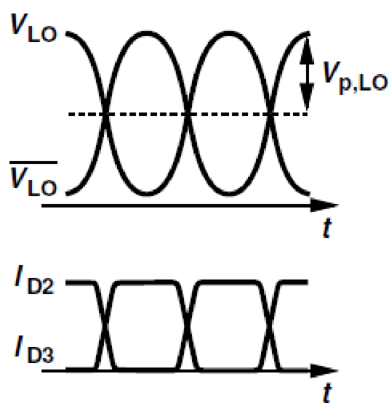
$$\overline{V_{n,X}^2} = \frac{1}{2}\left(\overline{I_{n,M1}^2}\right) R_D^2 + 4kTR_D$$

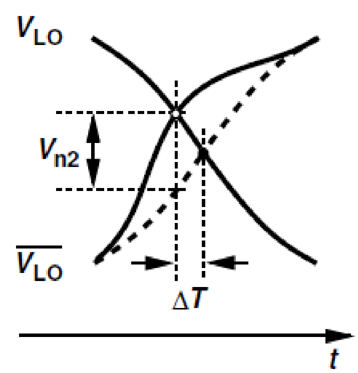
Referred to the input:

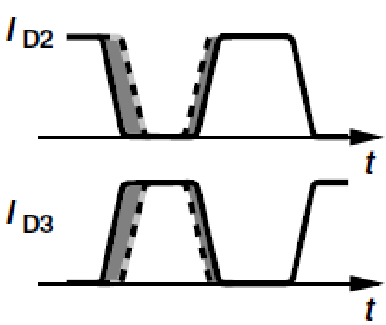
$$\overline{V_{n,in}^2} = \pi^2 kT\left(\frac{\gamma}{g_{m1}} + \frac{2}{g_{m1}^2 R_D}\right)$$

Flicker Noise in Active Mixers:









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:

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