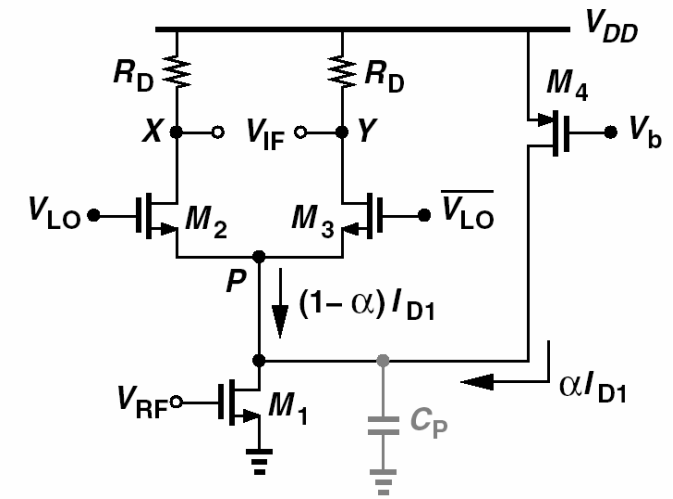
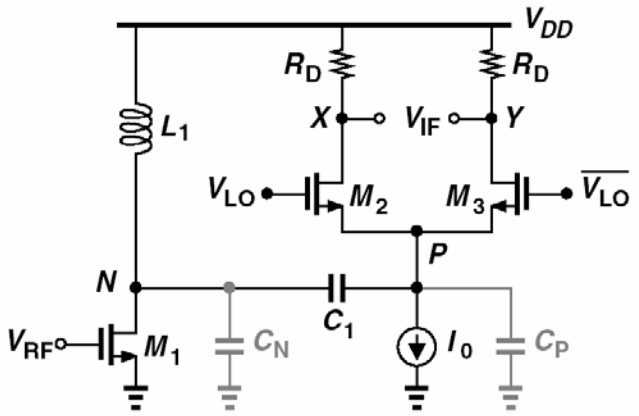
RF Mixers (III)

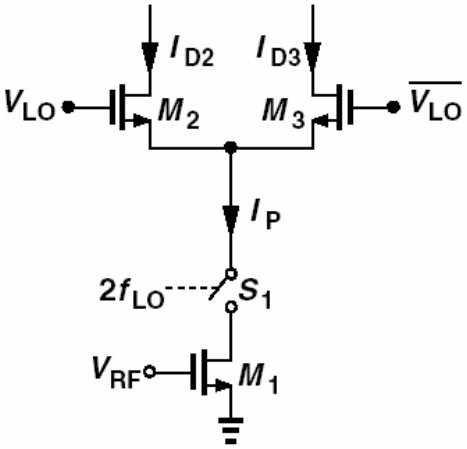
Methods of Reducing Flicker Noise in Active Mixers

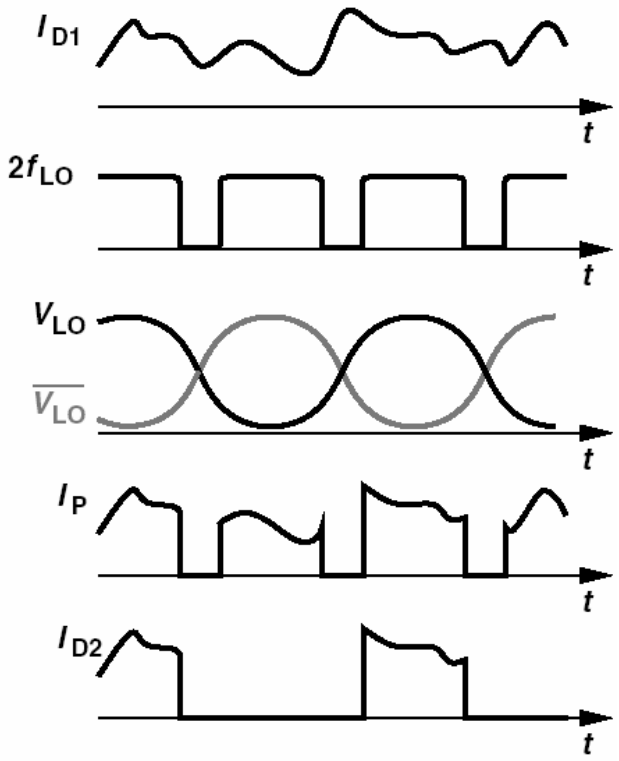
Key observation: Reduce I_{SS} but without degrading gain, thermal NF, etc.





Or other clever schemes:

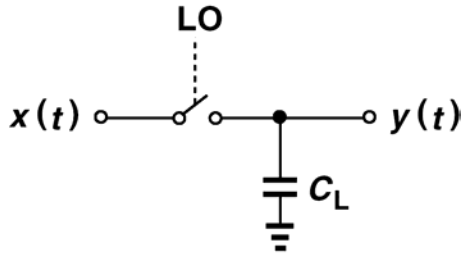




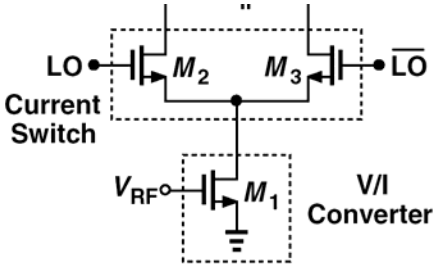
[Pullela, ISSCC06]

Nonlinearity in Mixers

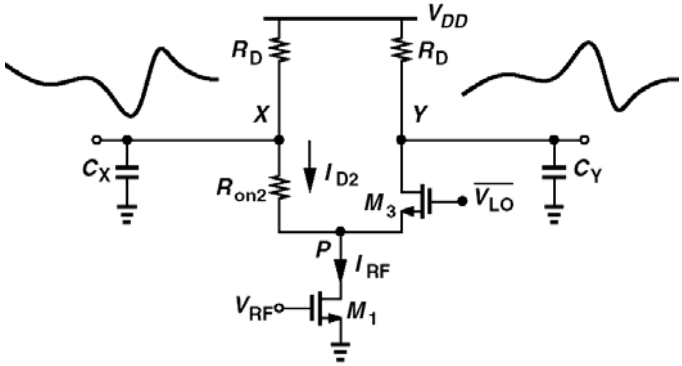
Voltage-driven passive mixers: The LO has a finite transition time, and the on-resistance varies during this time:



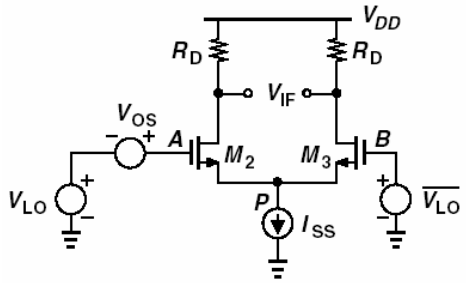
Active mixers:

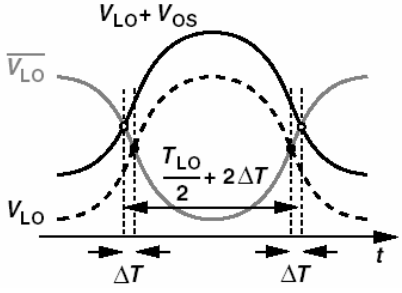


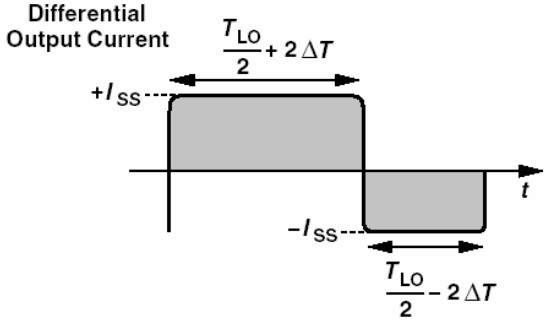
IP3:
(1) V/I converter nonlinearity
(2) When one diff pair device enters triode while the other is on:

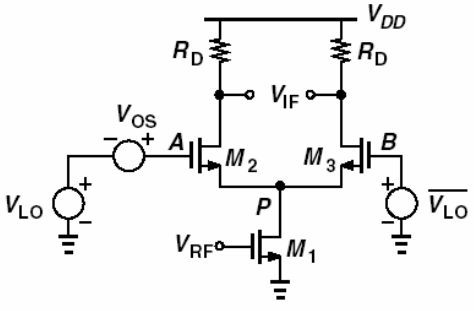


IP2:
Asymmetries in the circuit, e.g., between diff pair devices:









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:

$$V_{RF} = V_m \cos\omega_1 t + V_m \cos\omega_2 t + V_{GS0}$$
$$I_{IM2} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_m^2 \cos(\omega_1 - \omega_2)t$$

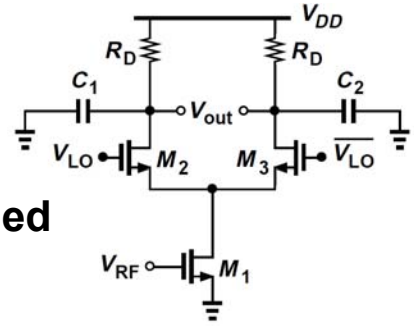
4. Need to equate the feedthrough amplitude to the fundamental amplitude:

$$\frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{IIP2}^2\frac{V_{OS}R_D}{\pi V_{p,LO}} = \frac{2}{\pi}g_{m1}R_D V_{IIP2}$$

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

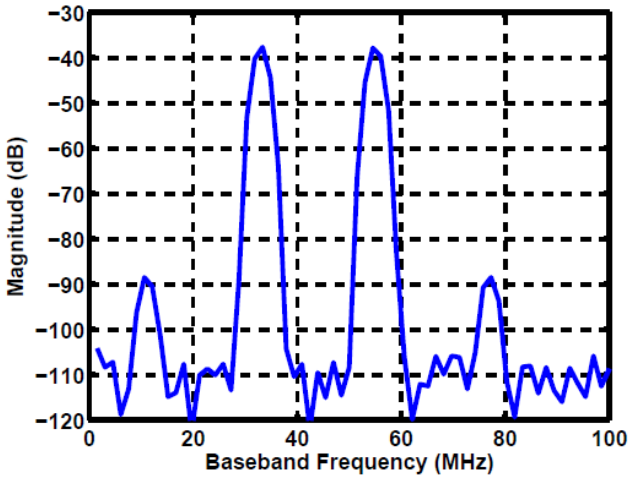


- **Design Specs:**
  V_{DD} = 1.2 V, 65-nm CMOS, I_{DD} = 2 mA, single-ended
  LO swing = 400 mV_p
- **Design limited by voltage headroom; Assign:**
  V_{DS1}= 300 mV → W_1 = 15 um
  g_{m1}= 12.75 ms
  $V_{DS2,3,eq}$ = 150 mV → $W_{2,3}$ = 20 um
  → drop across R_D = 600 mV
  → Choose R_D = 500 ohms

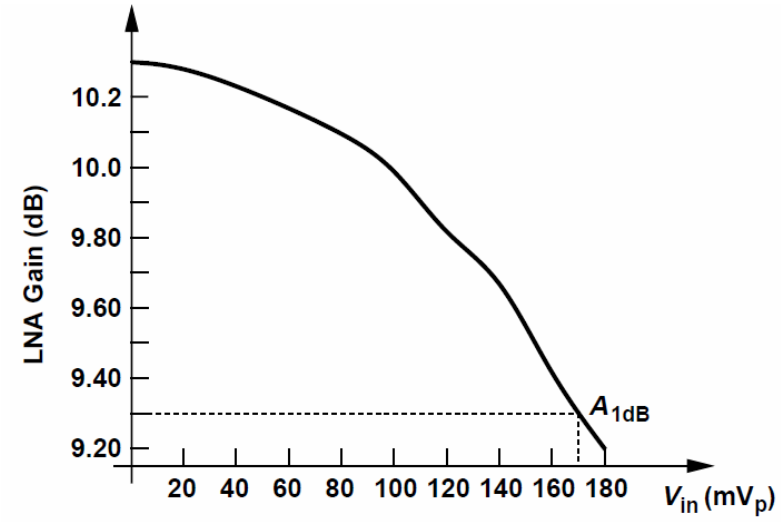
- **Choose C_1 = C_2 = 2 pF to suppress LO feedthrough.**

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:**

$$\overline{V_{n,in}^2} = \pi^2 kT \left(\frac{\gamma}{g_{m1}} + \frac{2}{g_{m1}^2 R_D} \right)$$
$$= 4.21 \times 10^{-18}\ \mathrm{V^2/Hz},$$

$$\Rightarrow \mathrm{NF}_{SSB} = 1 + \frac{\overline{V_{n,in}^2}}{4kTR_S}$$
$$= 6.1\ (= 7.84\ \mathrm{dB})$$