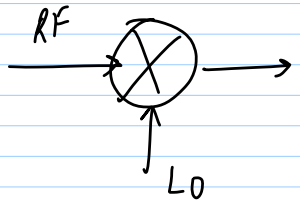
18-9-13

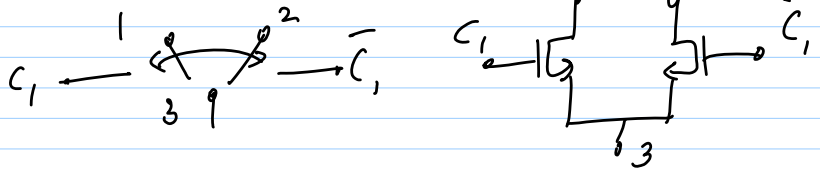
Lec 20

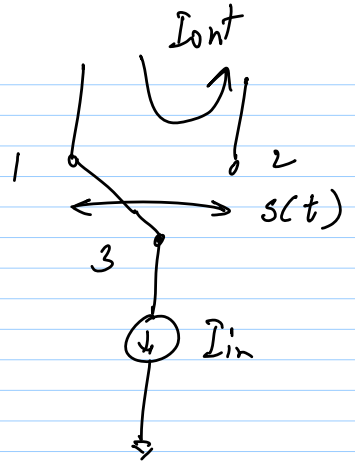
3-port mixers



* ideally generate only IM component
* CMOS - good switches

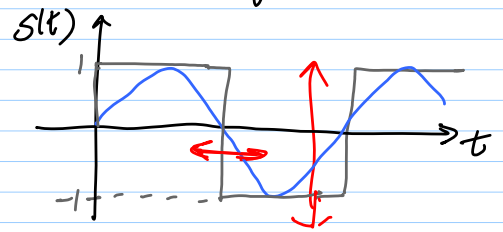
Single-balanced Mixer (active)





$$I_{out} = s(t) \cdot I_{in}$$

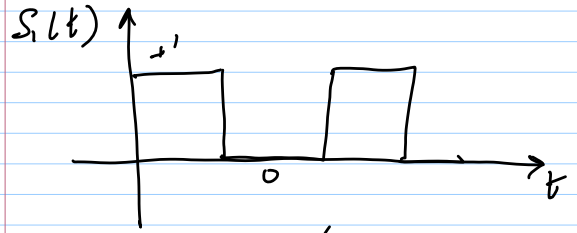
$$s(t) = \text{sgn}(\sin \omega_{LO} t)$$



$$I_{in} = i_{RF} + I_{DC}$$

$$i_{RF} = I_{RF} \cos \omega_{RF} t$$

$$s_1(t) = 0.5 + 0.5\, s(t)$$



$$I_{out}^{+} = (I_{DC} + I_{RF} \cos \omega_{RF} t) \cdot \{0.5 + 0.5\, s(t)\}$$

$$I_{out} = (I_{DC} + I_{RF} \cos \omega_{RF} t) \cdot \text{sgn}(\sin \omega_{LO} t)$$

Fourier Series of $s(t)$

$$s(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} [a_n \cos(n \omega_{LO} t) + b_n \sin(n \omega_{LO} t)]$$

$$\frac{a_0}{2} = 0$$

$a_n = 0$ because odd signal

$$b_n = \frac{2}{T_{LO}} \int_0^{T_{LO}} \text{sgn}(t) \sin(n \omega_{LO} t)\, dt$$

$$= \frac{4}{T_{LO}} \int_0^{T_{LO}/2} \sin(n\omega_{LO}t)\,dt$$

$$= \frac{4}{T_{LO}} \cdot \frac{1}{n\omega_{LO}} \left[-\cos(n\omega_{LO}t) \right]_0^{T_{LO}/2}$$

$$= \frac{2}{n\pi} \left[1 - \cos n\pi \right]$$

$$b_n = \begin{cases} 0 & \forall \text{ even } n \\ \frac{4}{n\pi} & \forall \text{ odd } n \end{cases}$$

$$s(t) = \frac{4}{\pi} \left[\sin\omega_{LO}t + \frac{1}{3}\sin 3\omega_{LO}t + \dots \right]$$

$$i_{out}(t) = \left[I_{DC} + I_{RF}\cos\omega_{RF}t \right] \cdot s(t)$$

$$= I_{DC} \cdot s(t) + I_{RF}\cos\omega_{RF}t \cdot s(t)$$

(I) (II)

(I) $\Rightarrow$ $\frac{4I_{DC}}{\pi}\left[\sin\omega_{LO}t + \frac{1}{3}\sin 3\omega_{LO}t + \dots \right]$

LO feed through

feed through of LO harmonics

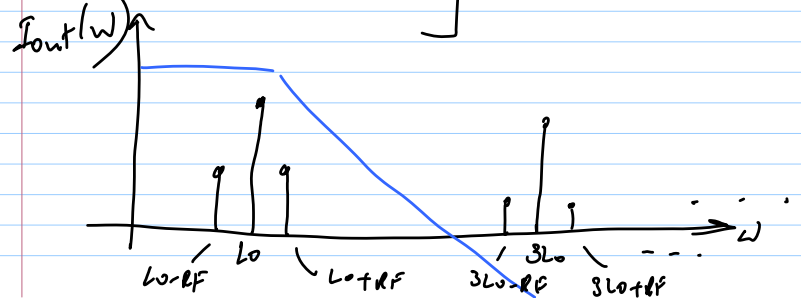
(II) $\Rightarrow$ $\frac{4I_{RF}}{\pi}\left[\cos\omega_{RF}t \sin\omega_{LO}t + \frac{1}{3}\cos\omega_{RF}t \sin 3\omega_{LO}t + \dots \right]$

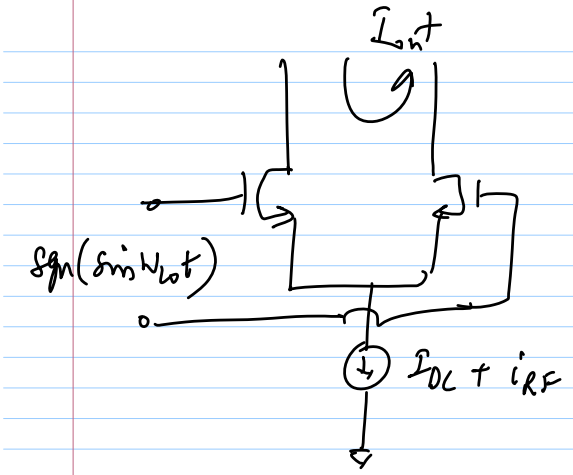
$$= \frac{2I_{RF}}{\pi}\left[\sin(\omega_{LO}-\omega_{RF})t + \sin(\omega_{LO}+\omega_{RF})t \right.$$

desired Rx term

$$+ \frac{1}{3}\sin(3\omega_{LO}-\omega_{RF})t + \frac{1}{3}\sin(3\omega_{LO}+\omega_{RF})t$$

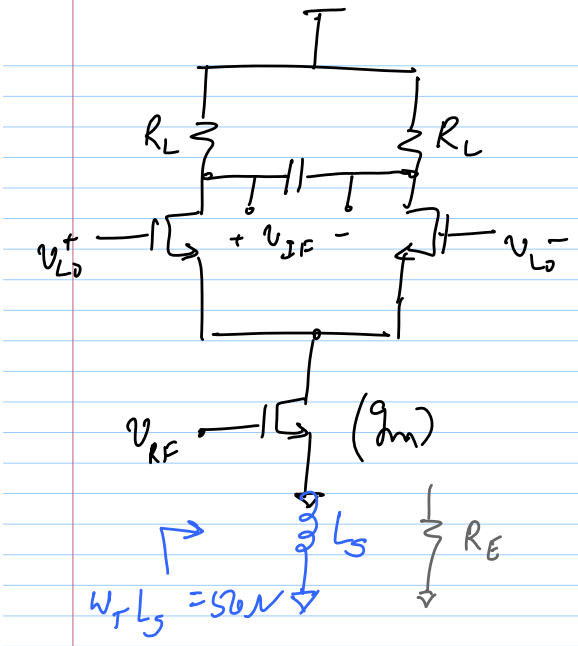
$$\left. + \dots \right]$$



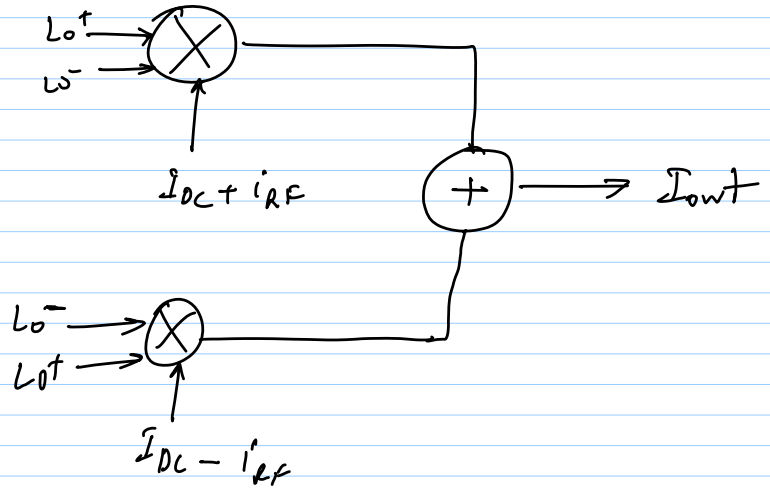


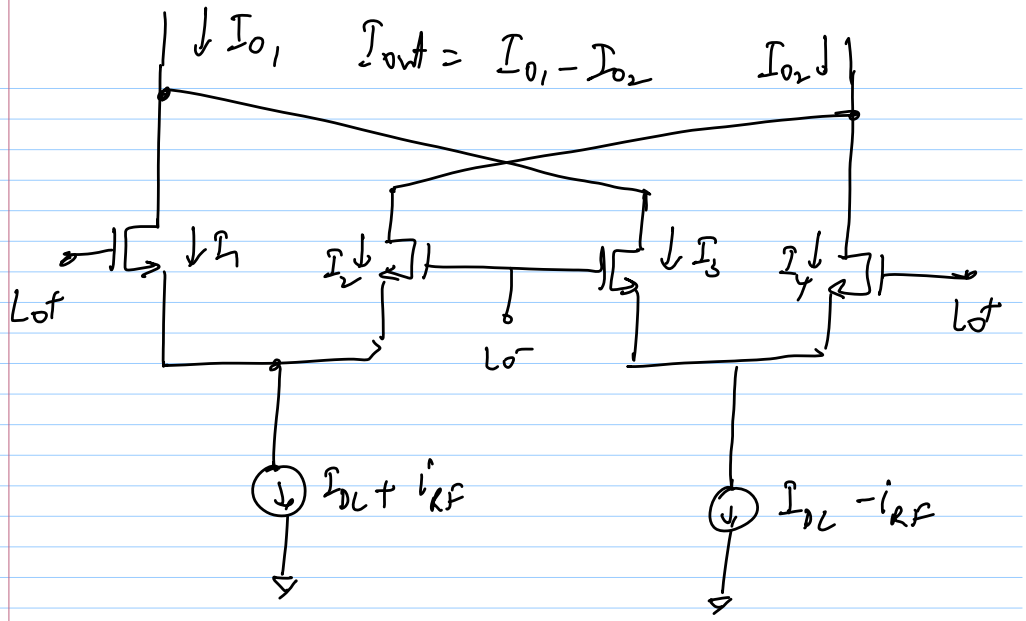
* poor LO feedthrough
* Input RF in the form of current → V-I conversion non-linearity

* $G_C = \frac{2}{\pi} g_m R_L$ (mixer output load)



Double-balanced mixer





Gilbert Cell Double-balanced Mixer

$$I_{out} = (I_1 + I_3) - (I_2 + I_4)$$

$$= (I_1 - I_2) - (I_4 - I_3)$$

$$= \frac{4}{\pi} I_{RF} \left[\sin(\omega_{LO} - \omega_{RF})t + \sin(\omega_{LO} + \omega_{RF})t \right.$$

$$\left. + \frac{1}{3}(3\omega_{LO} \pm \omega_{RF}) + \cdots \right]$$

* Excellent LO-IF isolation (depends on matching)
* Conversion gain $G_c = \frac{4}{\pi} g_m R_L$

* Isolation:
  - → LO waveform
  - → LO device mismatch
  - → RF " "
  - → R_L mismatch