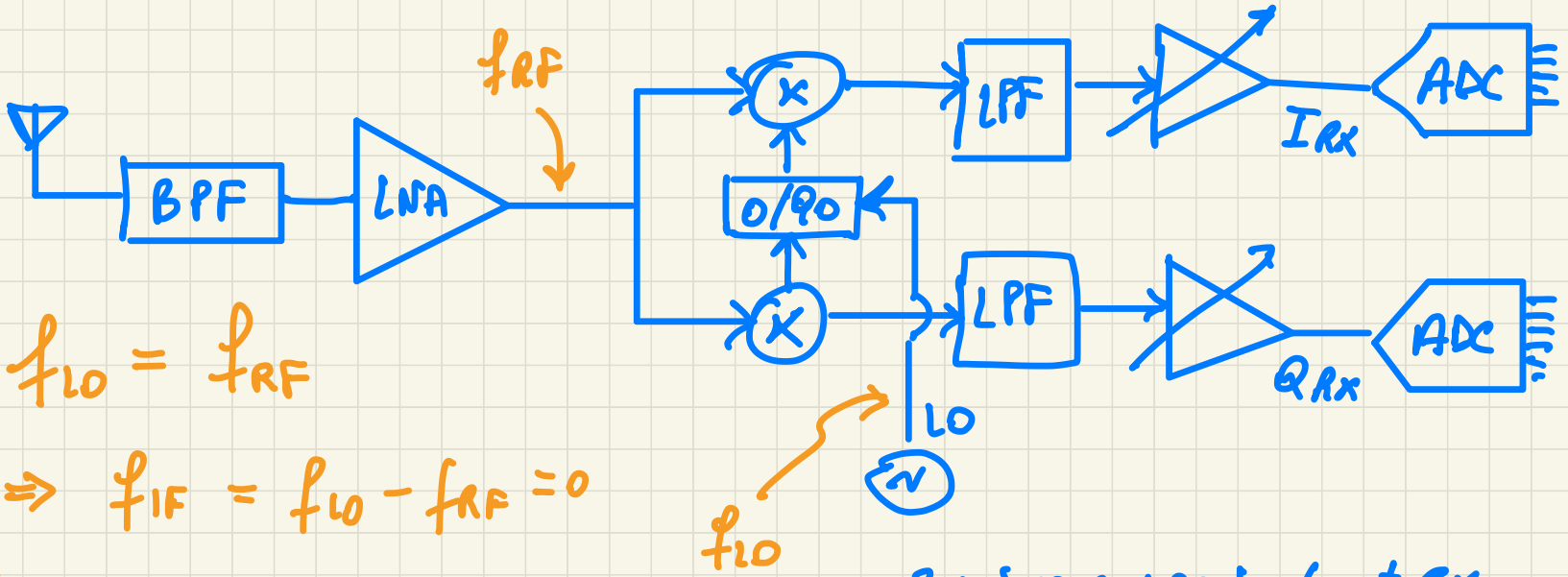
RF Circuit Design

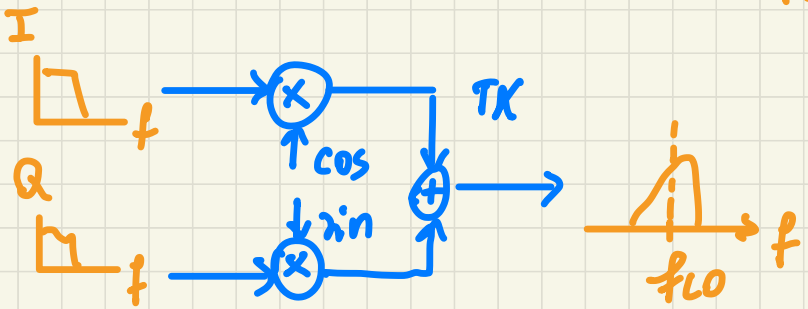
L22

Direct - Conversion RX (or zero-IF RX)



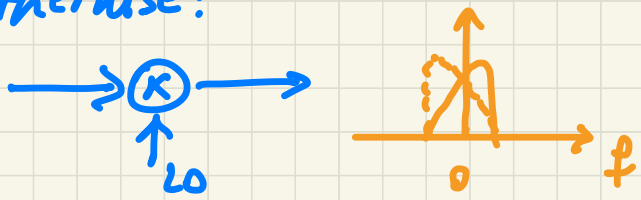
$f_{LO} = f_{RF}$

$\Rightarrow f_{IF} = f_{LO} - f_{RF} = 0$



2 mixers needed at RX

Otherwise:



Advantages :

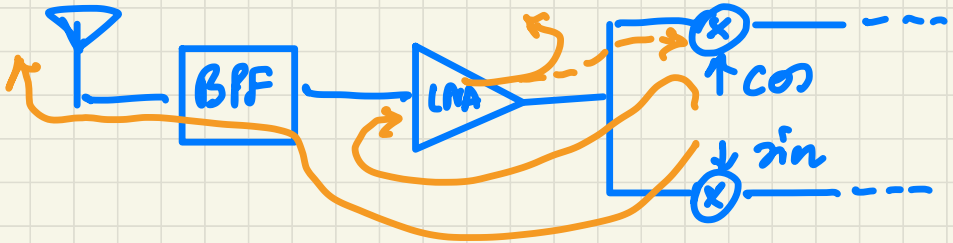
- Image problem apparently solved
  → no need for an IR filter
- Channel selection is performed with LPF (rather than BPF)
  → no need for offchip SAW filters

LPF filters can be implemented in silicon (sC active filters)

Direct-conv. RX architect. suitable for fully integration in silicon

Critical issues :

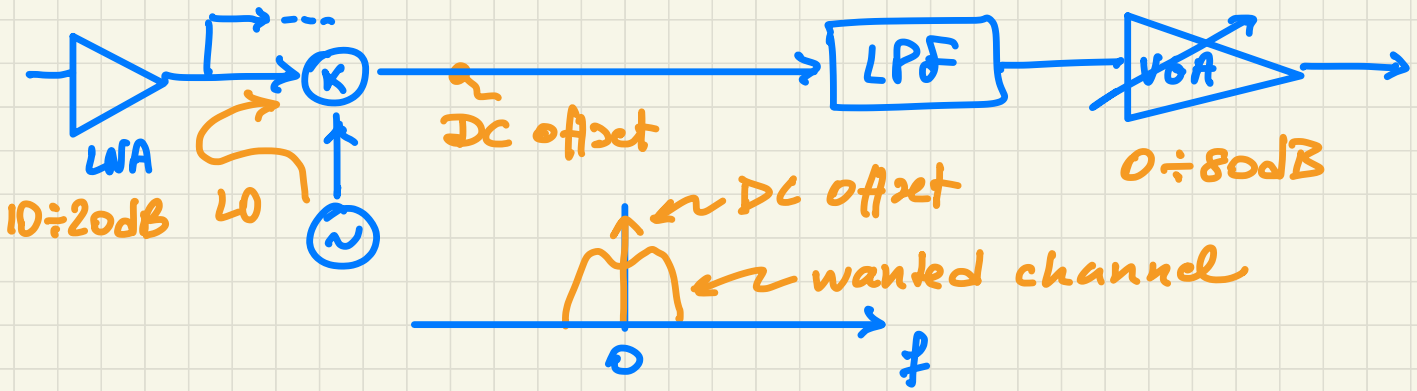
- LO leakage : - $f_{LO} = f_{RF}$ ⇒ LO is in LNA BW
  - LO signal has large power



⇓

LO signal can be emitted and Rx might violate radiation limits ($< -50 \div -80$ dBm)

- DC offsets :
  - * LO leakage ⇒ self mixing of LO
  - * Interfer leakage ⇒ self mixing of interferer

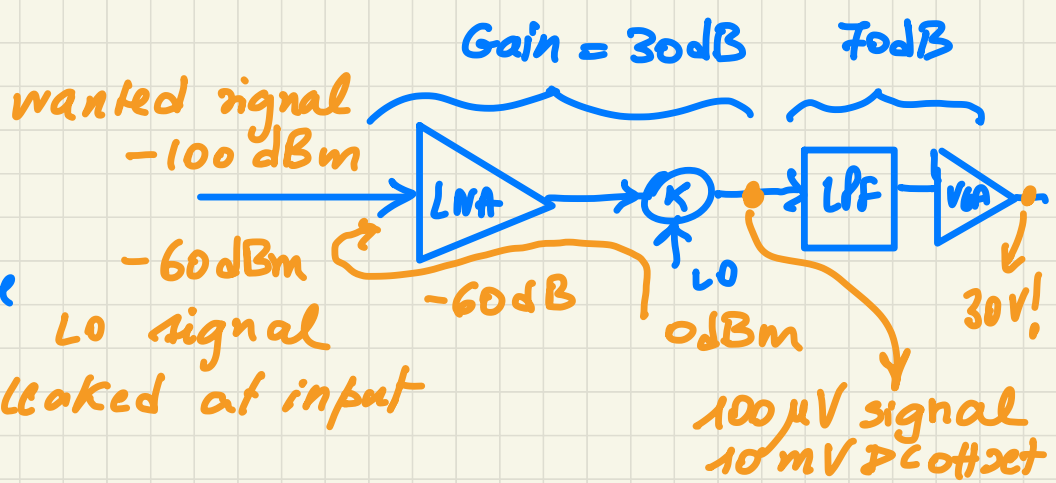


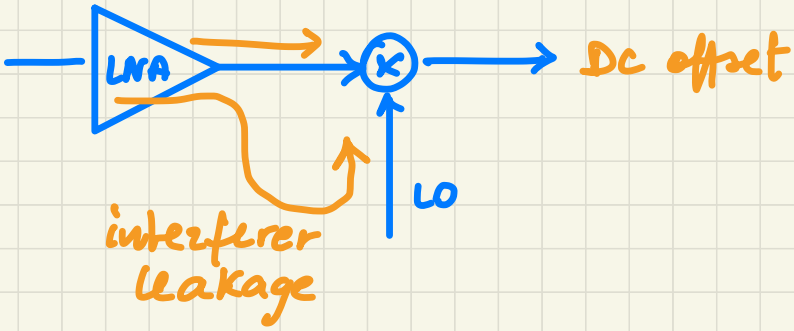
few mV of DC offset can saturate the VGA

$P_S = -100\ dBm$

$P_{LO} = 0\ dBm$

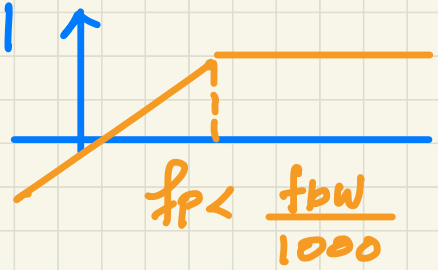
VGA would saturate due to the 10mV DC offset

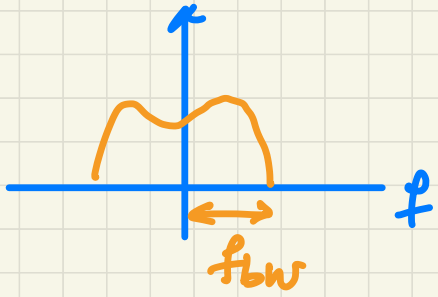




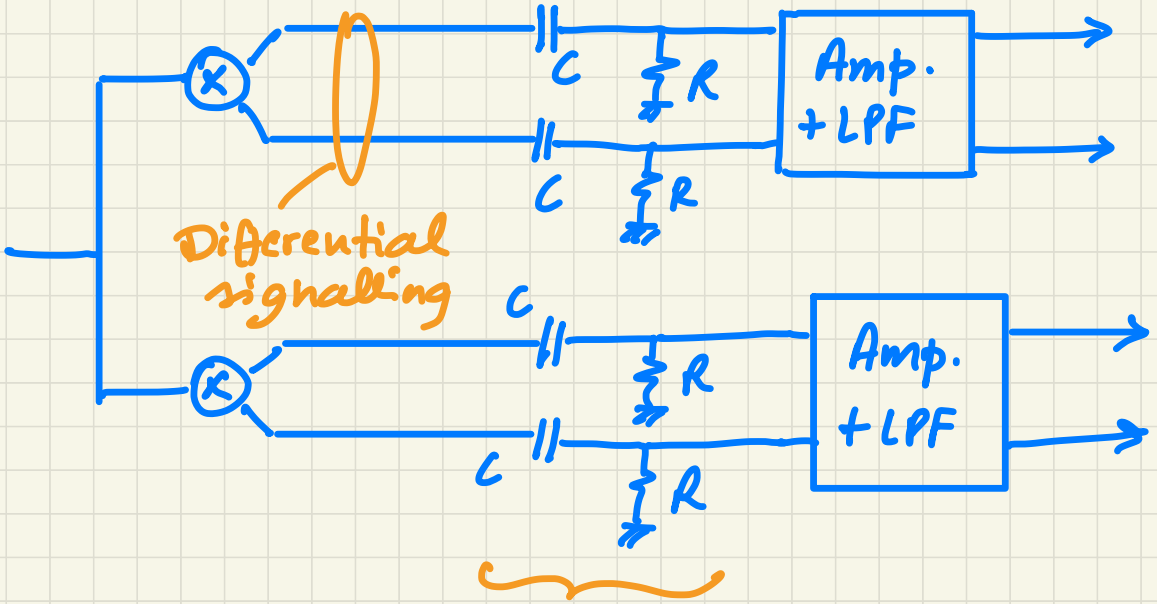
How can we filter DC offsets ?

1) AC coupling





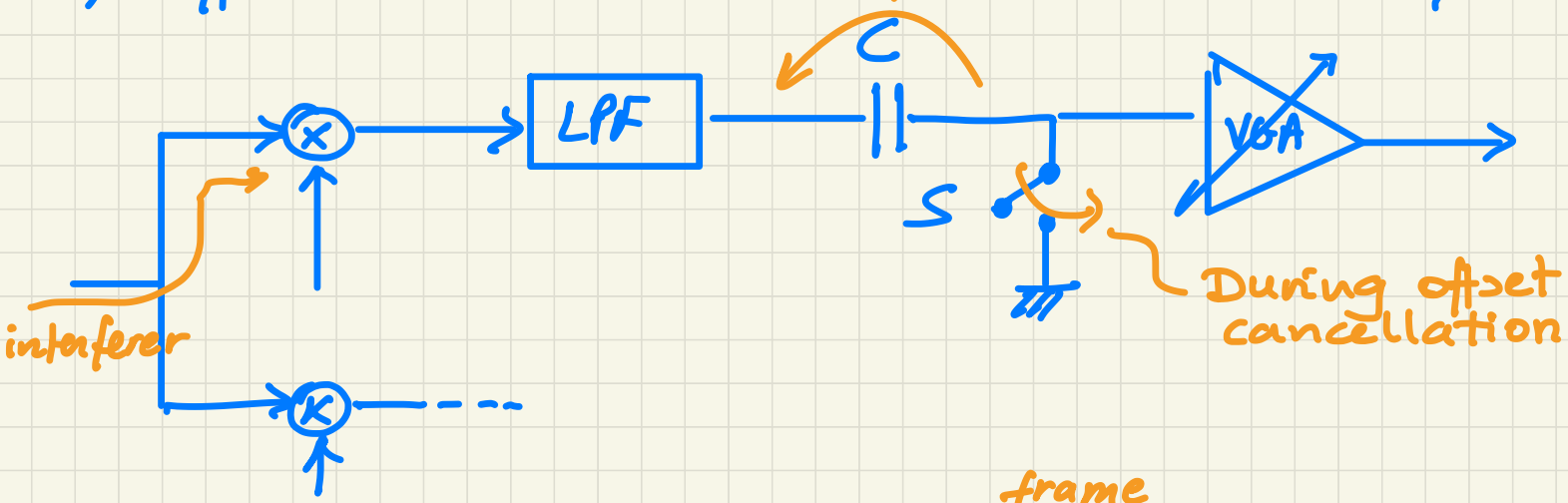
$f_{BW} = 100\,KHz \Rightarrow f_P = 100\,Hz$

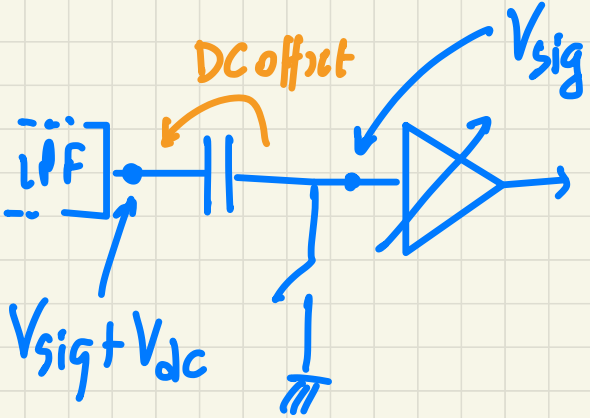


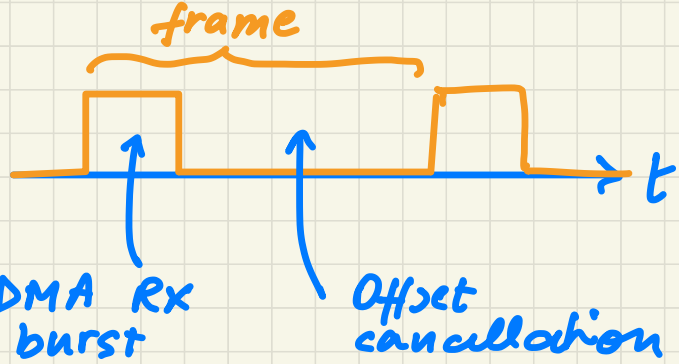
- AC coupling requires 4 capacitances
- R resistors introduce noise (degrading SNR)

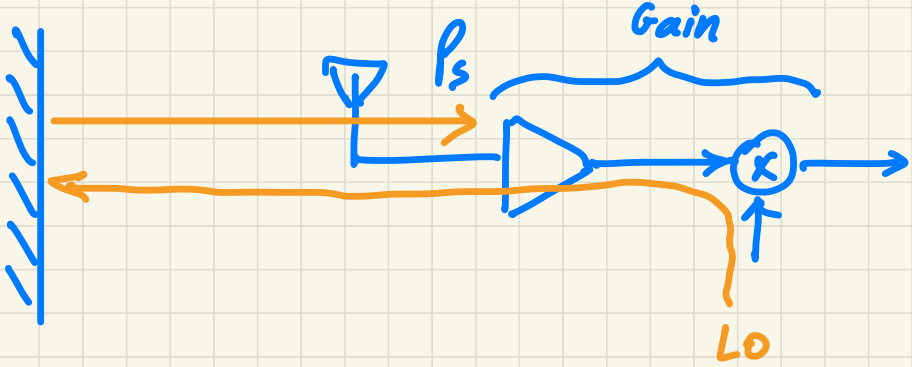
↳ very large capacitances to make LF poles

2) Offset cancellation — DC offset — in TDMA systems





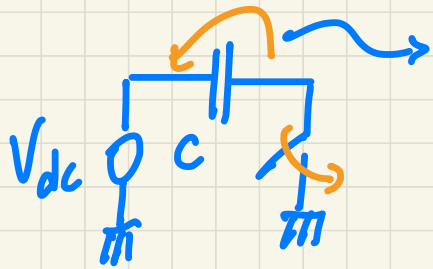




LO leakage and DC offset will depend on reflections
⇒ variable on time

Switched cap offset cancellation:

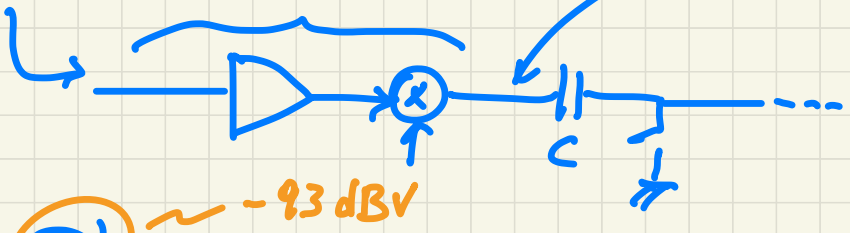
- solves the low-frequency pole issue
- does not solve the noise issue:



$V_{dc} + V_{noise}$

$$\overline{V_{noise}^2} = \frac{KT}{C}$$

e.g. $P_s = -110\,dBm$ Gain = 30dB

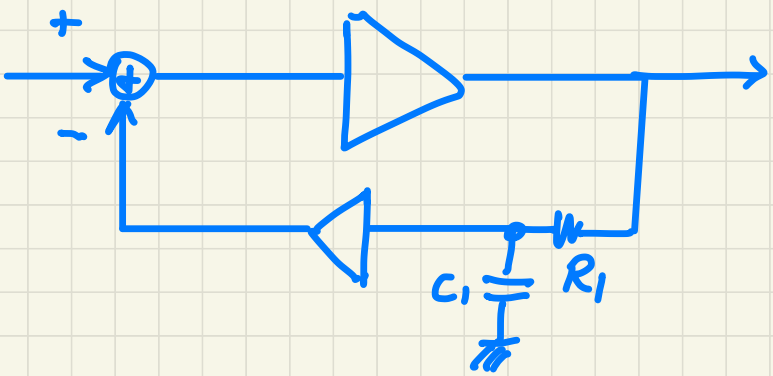


P_s' ~ -93 dBV

$$SNR = \frac{P_s'}{KT/C} > 15\,dB \Rightarrow C > 250\,pF$$

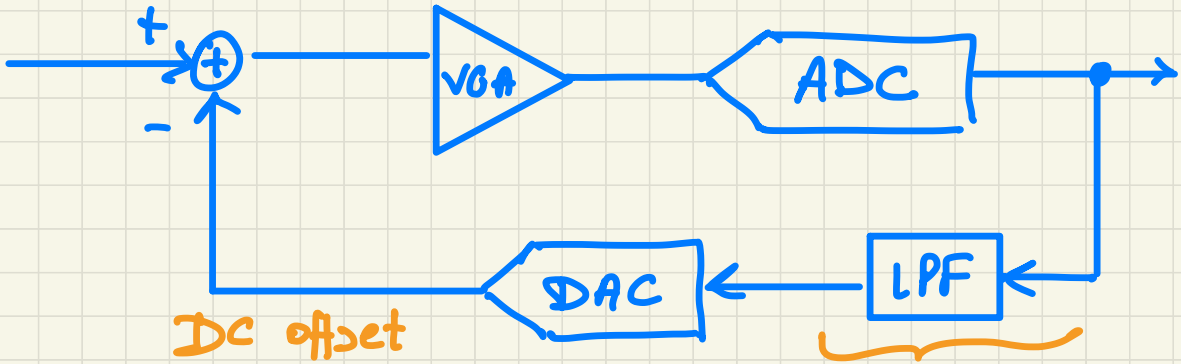
KT/C [V^2] ~ -108 dBV

3) Offset cancellation with feedback



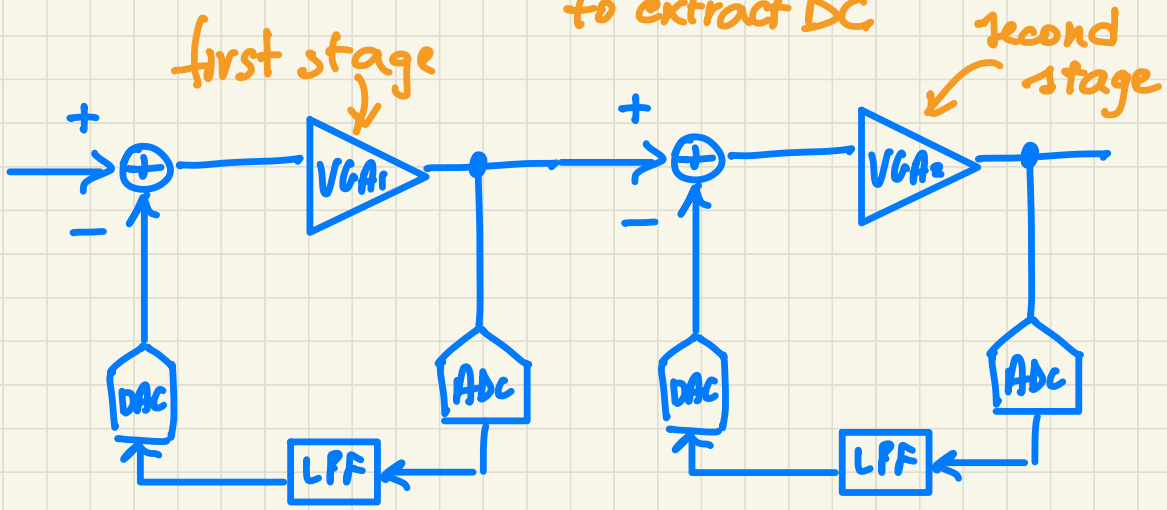
requires larger C_1 than C of the ac-coupling

4)



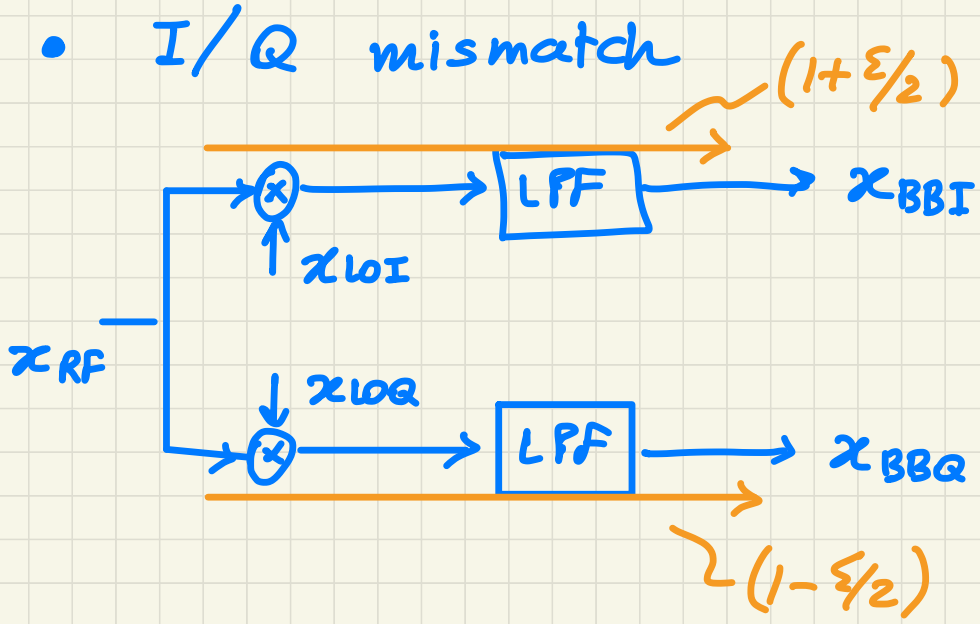
two-step :

to avoid saturation of VGA



Most used in CMOS

- I/Q mismatch



two paths

- amplitude mismatch ε
- phase mismatch θ

$$x_{RF}(t) = x_I(t) \cdot \cos \omega_0 t + x_Q(t) \sin \omega_0 t$$

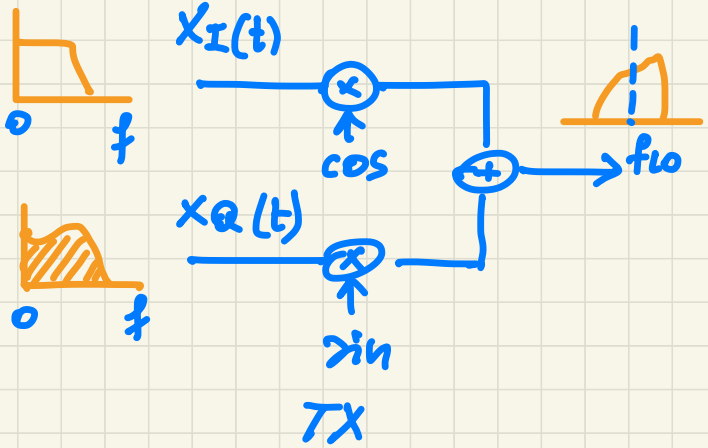
$$\begin{cases} x_{LOI}(t) = 2(1+\varepsilon/2)\cos(\omega_0 t + \theta/2) \\ x_{LOQ}(t) = 2(1-\varepsilon/2)\sin(\omega_0 t - \theta/2) \end{cases}$$

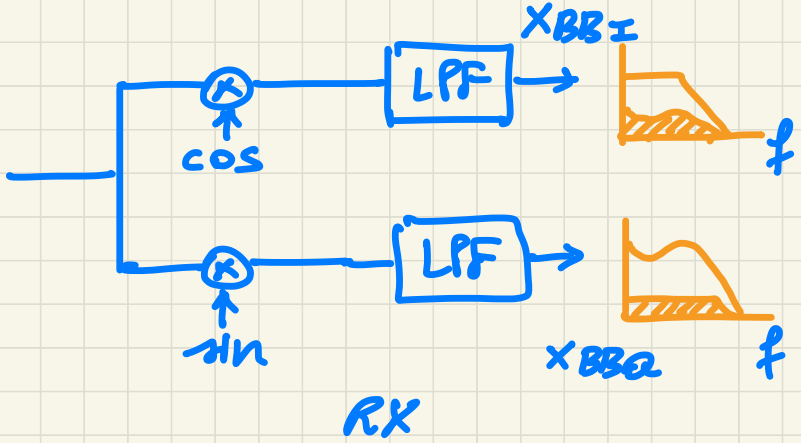
$$\Rightarrow \begin{cases} x_{BBI} = \underbrace{x_I(t)\cdot(1+\varepsilon/2)\cos\frac{\theta}{2}}_{\text{wanted signal component}} \\ \qquad\qquad \underbrace{-\,x_Q(t)\cdot(1-\varepsilon/2)\cdot\sin\theta/2}_{\text{image leakage}} \\ x_{BBQ} = \underbrace{x_Q(t)\cdot(1-\varepsilon/2)\cdot\cos\theta/2}_{\text{wanted signal component}} \\ \qquad\qquad \underbrace{-\,x_I(t)\cdot(1-\varepsilon/2)\cdot\sin\theta/2}_{\text{image leakage}} \end{cases}$$

Q component leaking into the I path for non-zero θ

$\varepsilon \Rightarrow$ gain error

$\theta \Rightarrow$ crosstalk or image leckage





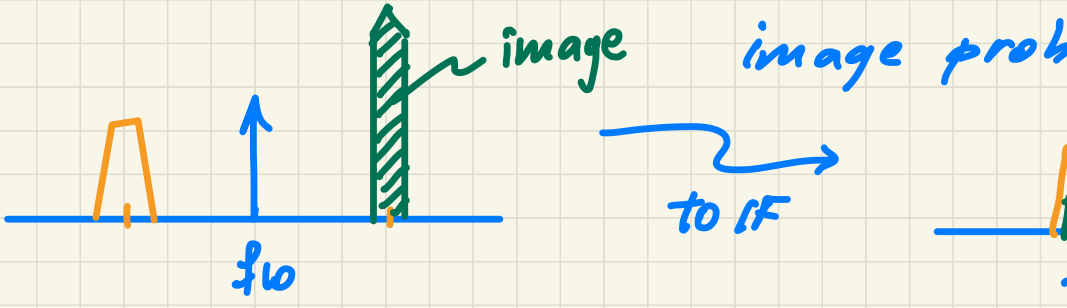


image problem in heterodyne

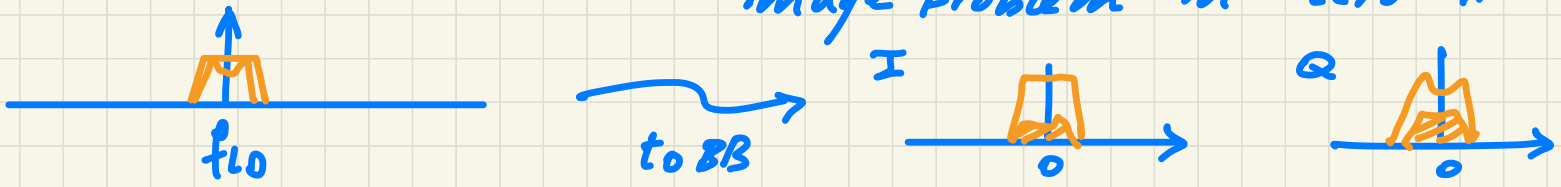


image problem in zero-IF

$x_{LO_I}(t)$

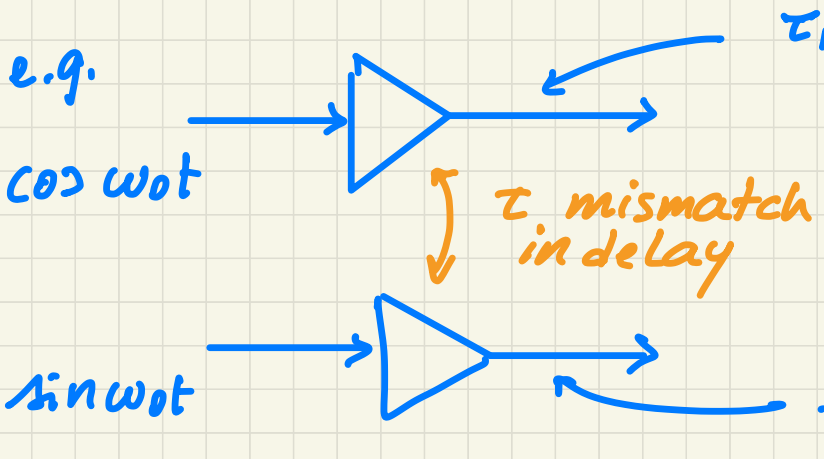
$x_{LO_Q}(t)$

θ delay error

$$\sin\left(\omega_0 t - \frac{\theta}{2}\right) =$$

$$= \sin\left(\omega_0 t - \frac{\omega_0 \tau}{2}\right)$$

$$\theta = \omega_0 \tau = 2\pi f_0 \cdot \tau$$



$$\tau = \tau_1 - \tau_2$$

$$\Delta\tau/\tau \cong \Delta R/R + \Delta C/C$$

$\Rightarrow$ the larger ω_0, the higher will be the phase error