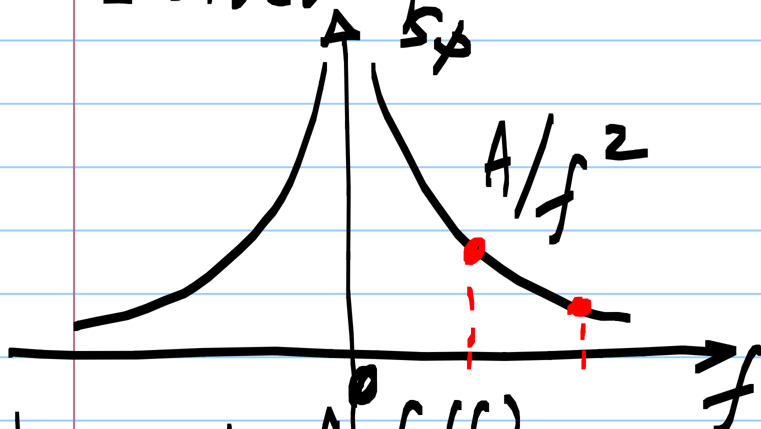
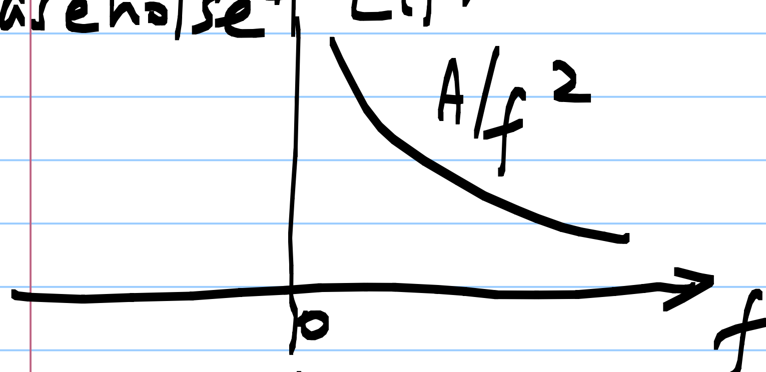
$V_p \cos(2\pi f_0 t + \phi(t))$

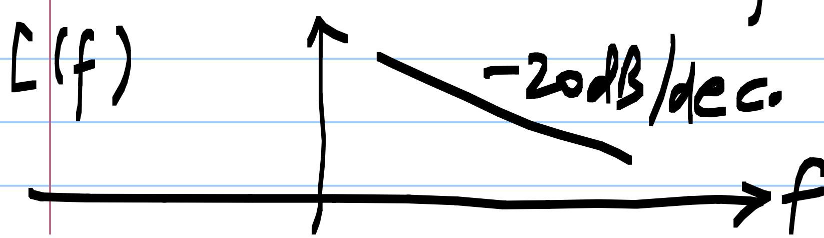
Oscillator phase noise due to thermal noise

2-sided spectrum

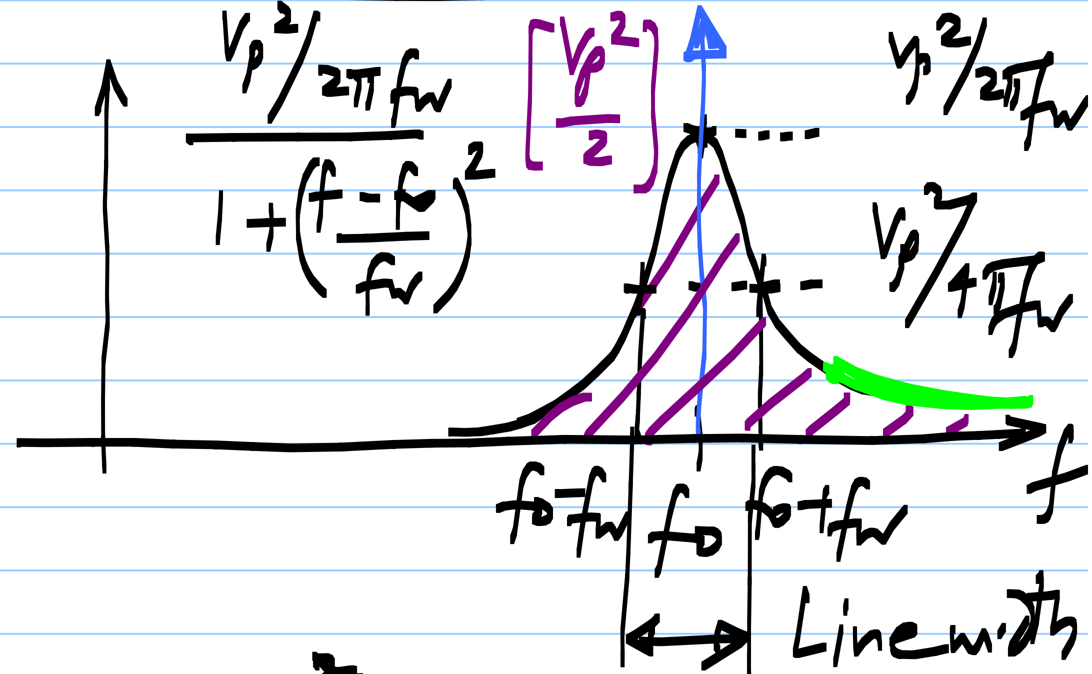


Phase noise





$$\frac{V_p^2/2\pi f_w}{1+\left(\frac{f-f_0}{f_w}\right)^2}$$



$$\frac{V_p^2}{2}\cdot\frac{f_w/\pi}{(f-f_0)^2} = \frac{V_p^2}{2}\cdot \mathcal{L}(f)$$

$\mathcal{L}(f) = -120 \, dBc/Hz$ @ 1MHz offset

$A : 1Hz$

$$\mathcal{L}(f) = \frac{A}{f^2} = \frac{1Hz}{(10^6 Hz)^2} = 10^{-12}/Hz \longrightarrow \underline{-120 \, dBc/Hz}$$

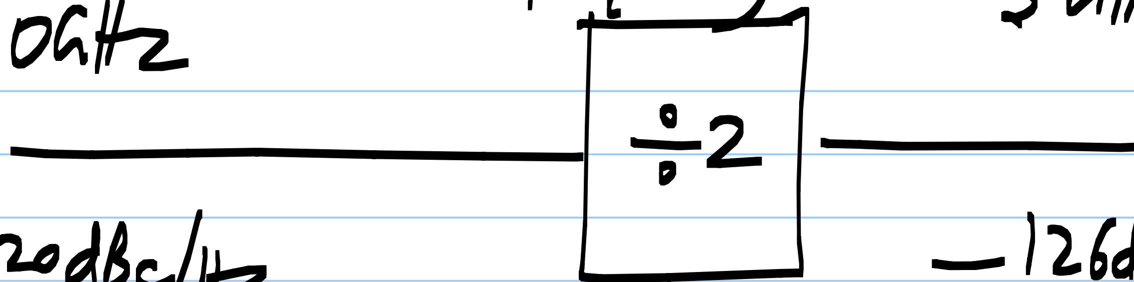
Line width $= 2\pi A \sim 6 \, Hz$

<u>10GHz oscillator</u>: <u>Good on-chip oscillator</u>.

10GHz

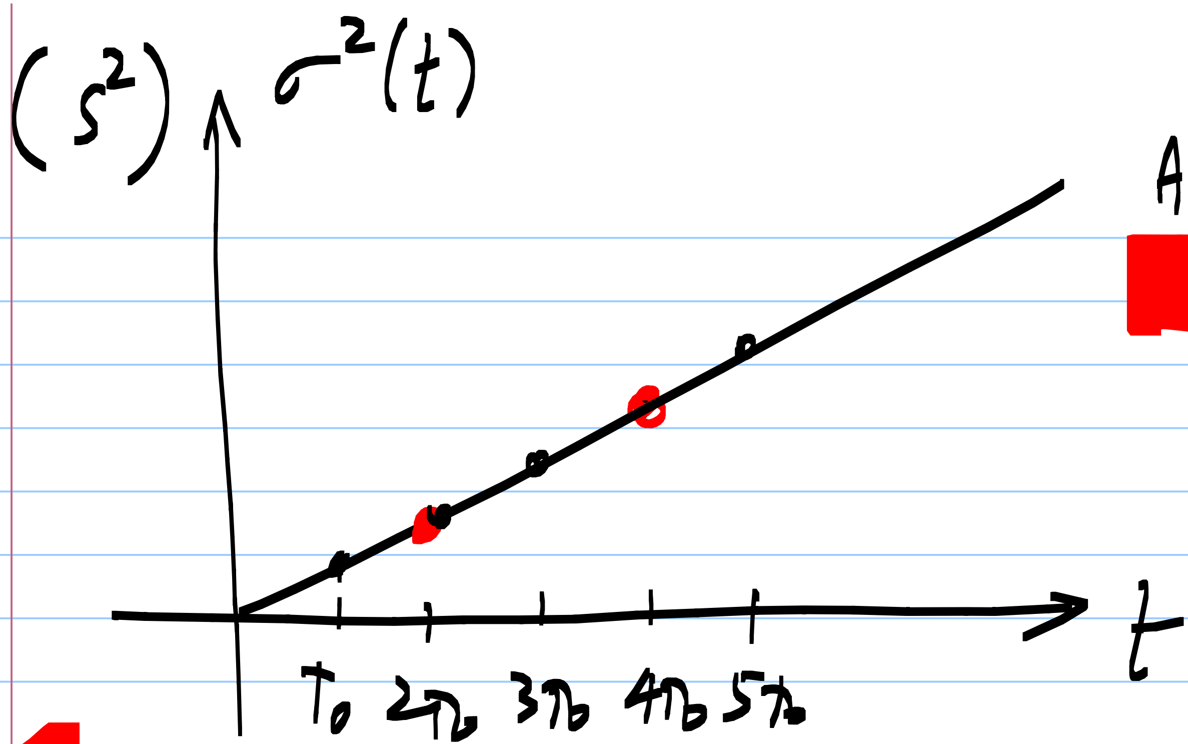
frequency Divider

5 GHz



$\underbrace{-120\,\text{dBc/Hz} \text{ @ } 1\,\text{MHz offset}}_{\frac{A}{f^2}}$

$\underbrace{-126\,\text{dBc/Hz} \text{ @ } 1\,\text{MHz offset}}_{\frac{A'}{f^2}}$



$A \underbrace{T_0}^{2} \cdot t$

T_0: period of the oscillator

$f_0 = 1/T_0$ → $\boxed{\div 2}$ → $f_0/2 = 1/2T_0$

$\frac{A}{f^2}$ freq. divider $\frac{A}{4f^2}$

Figure of merit: FoM_1 $\dfrac{f_0^2}{f^2} \cdot \dfrac{1}{\underbrace{\mathcal{L}(f)}_{A/f^2}} = \dfrac{f_0^2}{A} = \dfrac{1}{AT_0^2}$

LC: ~ 190 dB

Ring ~ 160–165 dB

Figure of merit:

$$\boxed{\frac{f_0^2}{f^2} \cdot \frac{1}{\mathcal{L}(f)} \cdot \frac{1}{P_d\,(\mathrm{mW})}}$$

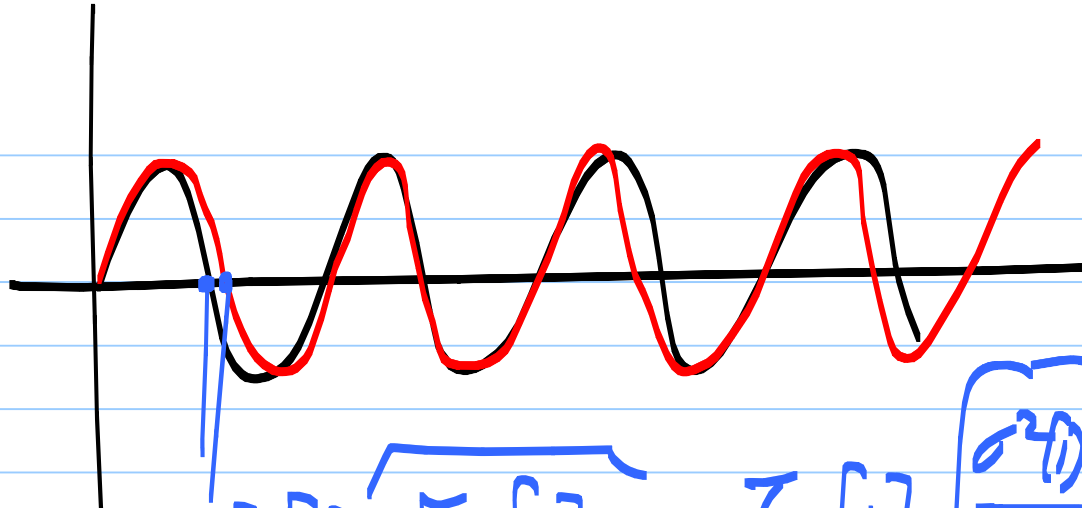
10GHz osc.

−120dBc/Hz @ 1MHz

10mW

190dB

$$\frac{10^{\cancel{20}\,19}}{\cancel{10^{12}}} \cdot \frac{1}{\cancel{10^{-12}}} \cdot \frac{1}{\cancel{10}}$$

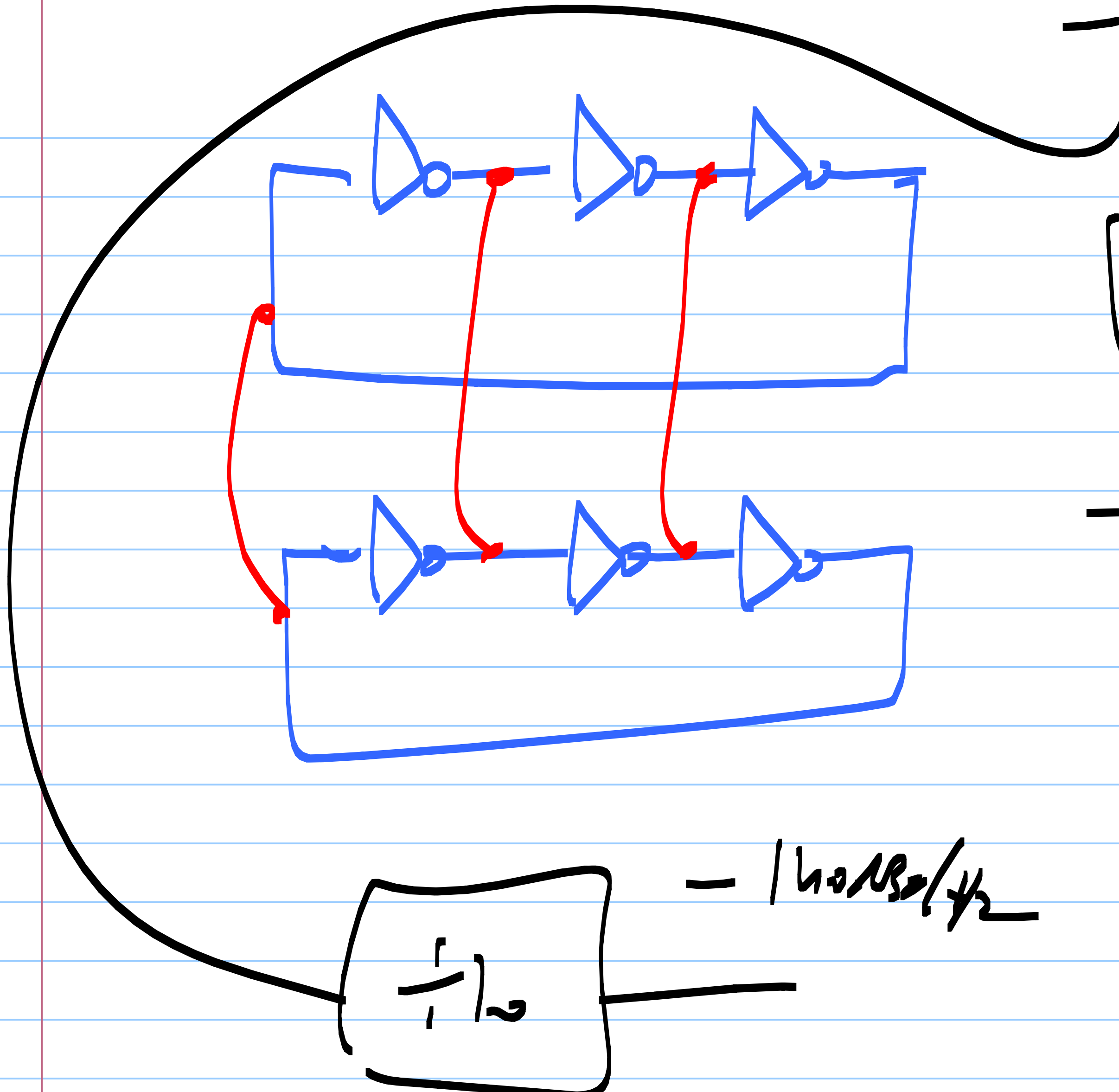


$\sigma^2[1]$ $\quad \tau_a[1] \quad \tau_b[1] \quad \frac{\sigma^2[1]}{2} \quad \frac{\tau_a[1] + \tau_b[1]}{2}$

$\tau_a[2] \quad \tau_b[2] \quad \frac{\tau_a[2] + \tau_b[2]}{2}$

$\tau_a[3] \quad \tau_b[3] \quad \frac{\tau_a[3] + \tau_b[3]}{2}$

$\vdots \quad \vdots$



−120dBc/Hz @ 1MHz

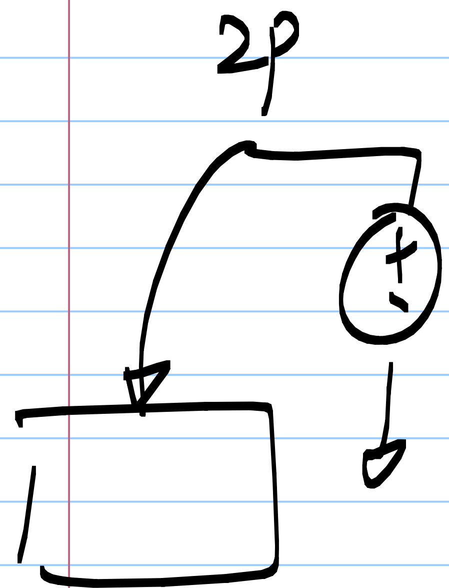
@ 10GHz $\underbrace{f_{osc}}_{10mW}$

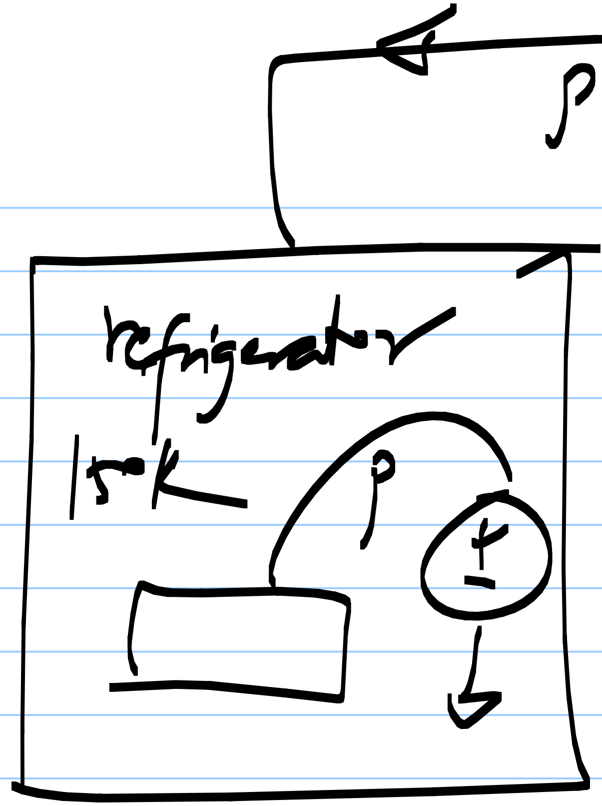
$\boxed{190dB}$

1GHz osc.

−120dBc/Hz @ 1MHz

1mW





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300k