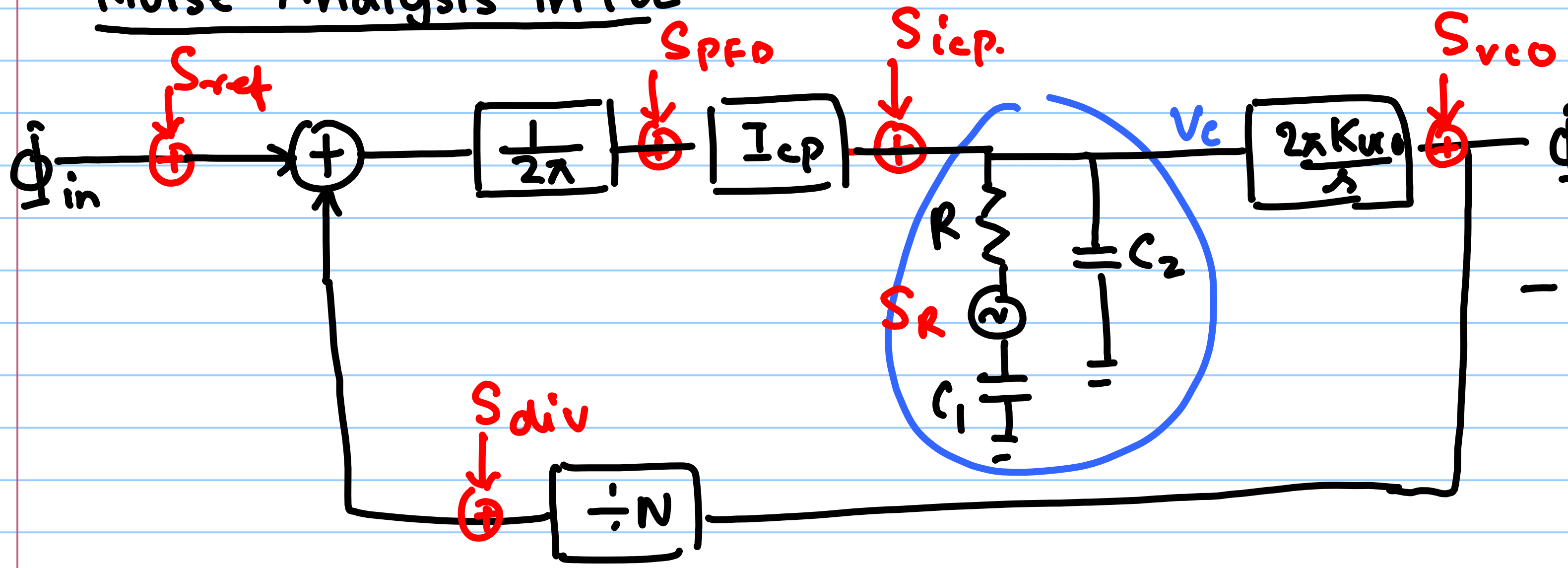
Note Title 06-09-2017

Lecture # 21

Noise Analysis in PLL



– Noise Power Spectral Density

Ref.

C.P.

R

VCO

Noise Transfer functions (NTF)

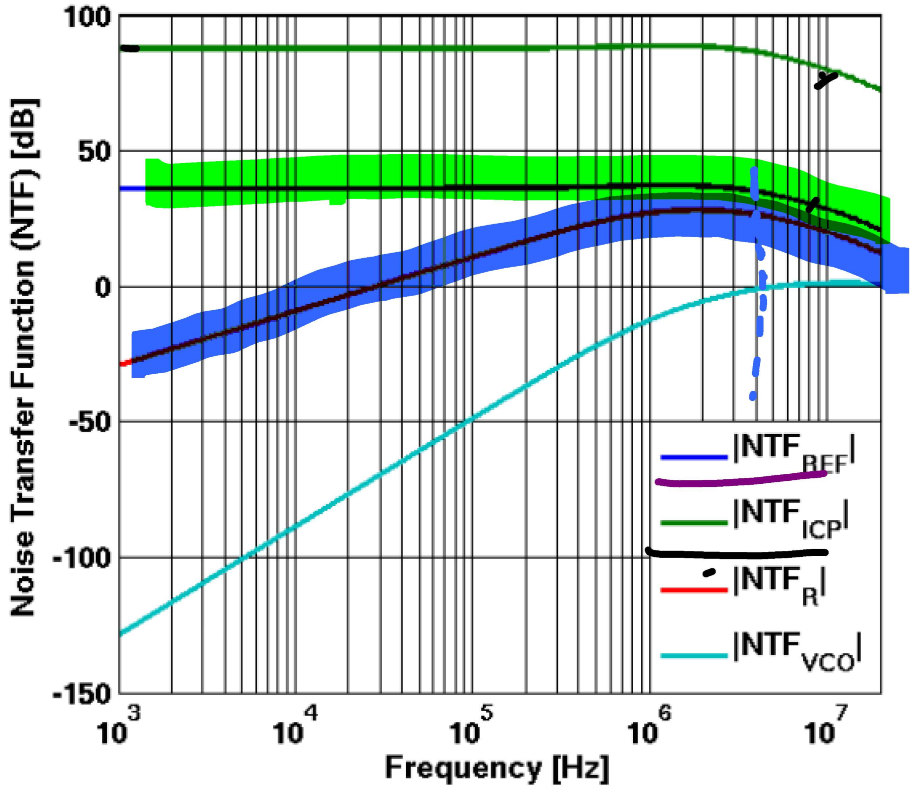
Ref.

$NTF_{ref} = \frac{N \times LG}{1+LG}$

$NTF_{cp} = \frac{2\pi}{I_{cp}} NTF_{ref}$

$NTF_{vco} = \frac{1}{1+LG}$

$NTF_R = H(s) \frac{2\pi K_{vco}}{s} NTF_{vco}$



$f_{ref} = 40\ MHz$

$K_{VCO} = 100\ MHz/V$

✓ $R = 1\ k\Omega$

✓ $\omega_u = 2\pi f_{ref}/10 = 2\pi \times 4\ Mrad/s$

✓ $\Phi_m = 70^\circ$, $N = 64$

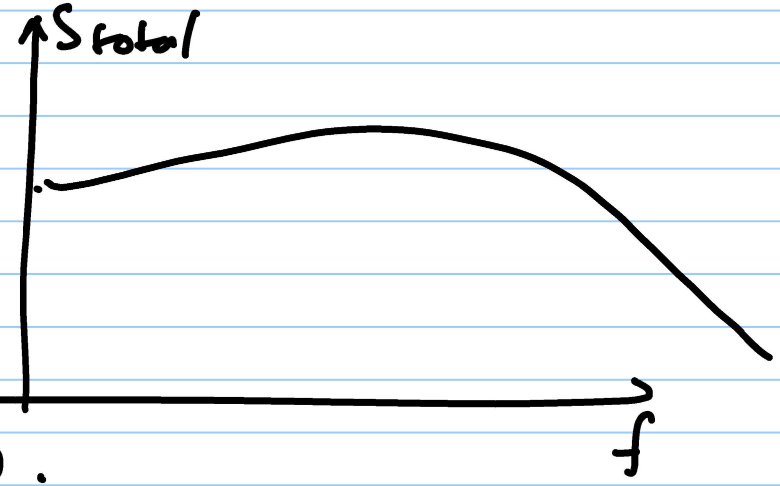
C_1 , C_2 , I_{cp}.

LG

$f_{out} = 64 \times 40\ MHz$

$= 2.56\ GHz$

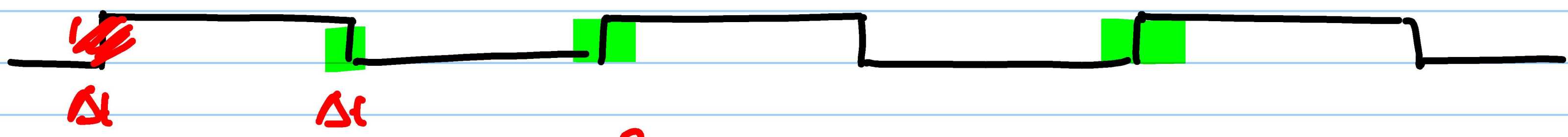
$$S_{total} = S_{ref}|NTF_{ref}|^2 + S_{icp}|NTF_{cp}|^2 + S_R|NTF_R|^2 + S_{VCO}|NTF_{VCO}|^2$$



Total Noise Power ($\overline{\Phi}^2_{n,total}$)

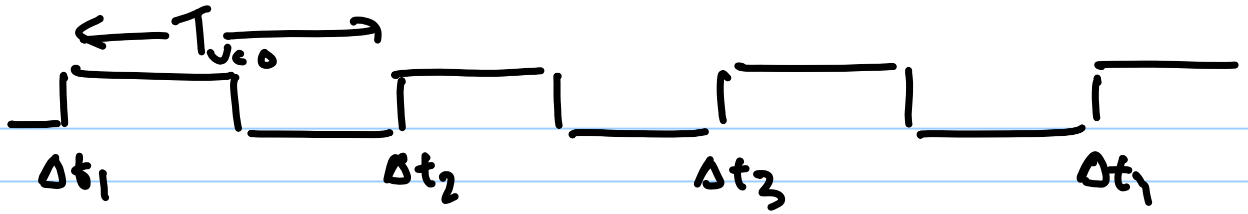
$$\overline{\Phi}^2_{n,total} = \int S_{total} \cdot df$$

trapz command in Matlab.



$$\Delta t \rightarrow \left(2\pi \cdot \frac{\overline{\Delta t}}{T_{VCO}}\right)^2 ✓$$

$$\sigma_{\Delta t}^2 = \left(\frac{T}{2\pi}\right)^2 \overline{\Phi}^2_{n,total} \Rightarrow \sigma_{\Delta t} = \frac{T}{2\pi}\sqrt{\int S_{total} \cdot df}$$

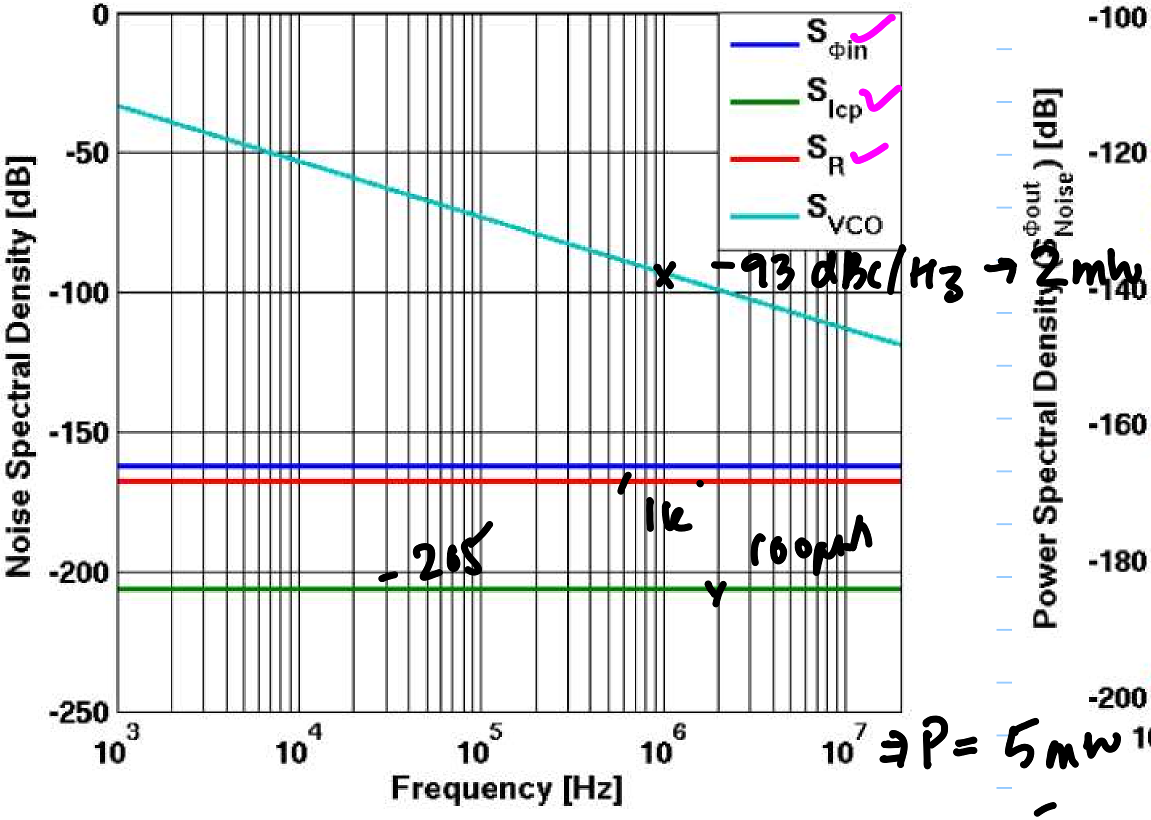


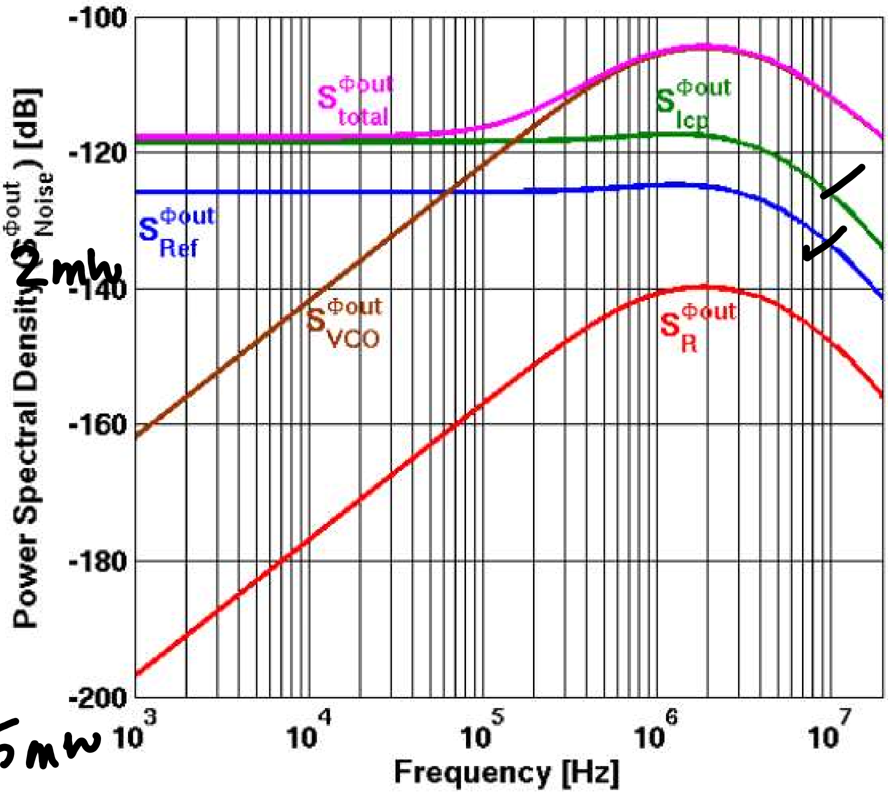
$\sigma^2 = E[(x-\bar{x})]$

$\sigma_{\Delta t}^2 = \frac{1}{N}\sum(\Delta t(k) - \bar{\Delta t}_0)^2$

$\sigma_{\Delta t}$: r.m.s jitter at o/p clock.

$\sigma_{\Delta t} = 0.8ps$

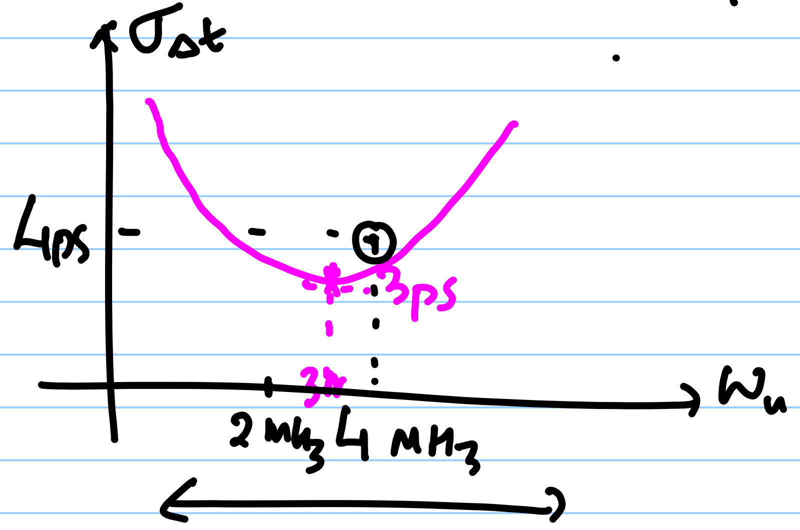




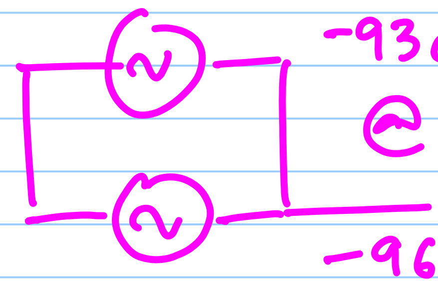
$P = 5\,mW$

ω_n, Φ_m, K_{VCO}, R $\longrightarrow$ C_1, C_2, I_{cp} $\xrightarrow{\text{Noise contribution of all blocks}}$ $\sigma_{\Delta t}$ @ o/p.

$4\,ps \xrightarrow{\text{Power cons!}} 3\,ps.$



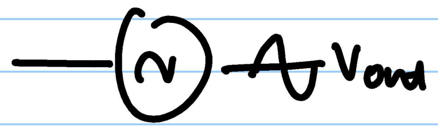
$P = 1\,mW$

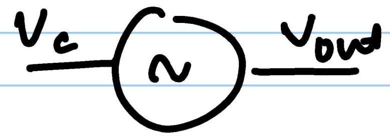


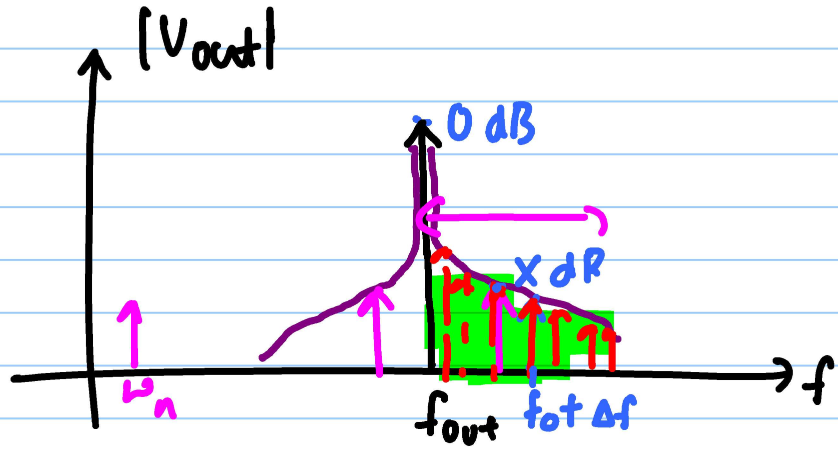
$$\left(\frac{2\pi}{I_{cp}}\right)^2 \frac{8kT}{3} g_m$$

$$\frac{4\pi^2}{I_{cp}^2} \times \frac{8kT}{3} \times \frac{2I_{cp}}{V_{ov}}$$

VCO Phase Noise







$(0-x)$ dBc/Hz @ Δf

-93 dBc/Hz @ 1MHz

$$V_{out} = \sin\left(\omega_o t + K_{vco}\int v_c \cdot dt\right)$$

$$= \sin\left(\omega_o t + K_{vco}\int a_n \sin(\omega_n t) \cdot dt\right)$$

$$= \sin\left(\omega_o t + \underbrace{\frac{K_{vco}\, a_n}{\omega_n}}_{\alpha}\left(-\cos(\omega_n t)\right)\right).$$

$$= \sin\left(\omega_0 t - \underline{\alpha \cdot \cos(\omega_n t)}\right)$$

$$= \sin(\omega_0 t) \cdot \cos(\alpha \cdot \cos(\omega_n t)) - \cos(\omega_0 t) \cdot \sin(\alpha \cdot \cos(\omega_n t))$$

$$= \sin(\omega_0 t) \cdot 1 - \cos(\omega_0 t) \cdot \alpha \cdot \cos(\omega_n t)$$

$$= \sin(\omega_0 t) - \frac{\alpha}{2}\left[\cos(\overline{\omega_0 + \omega_n}\, t) + \cos(\overline{\omega_0 - \omega_n}\, t)\right]$$