EE6322 | VCO phase noise | 20/2/2018

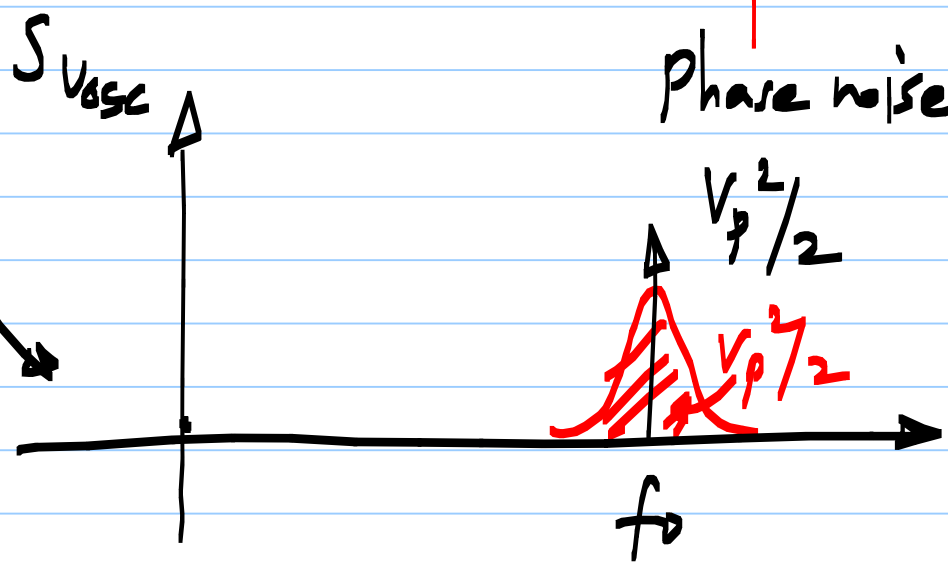
Ideal: $v_{osc} = V_p \cos(2\pi f_o t)$

Real: $V_p \cos(2\pi f_o t + \phi(t))$

phase noise

$$\sum_{k=1}^{\infty} V_k \cos(2\pi k f_o t + \Phi_k + k\phi(t))$$

$k^{th}$ harmonic has phase noise $k\phi(t)$




Voltage spectrum: $\propto \dfrac{1}{1 + \dfrac{(f-f_o)^2}{f_w^2}}$ Lorentzian shape

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

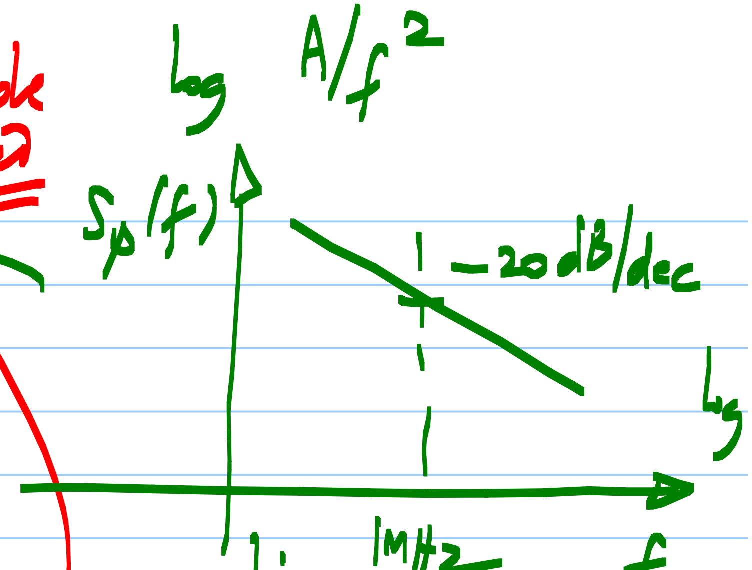
Phase noise:

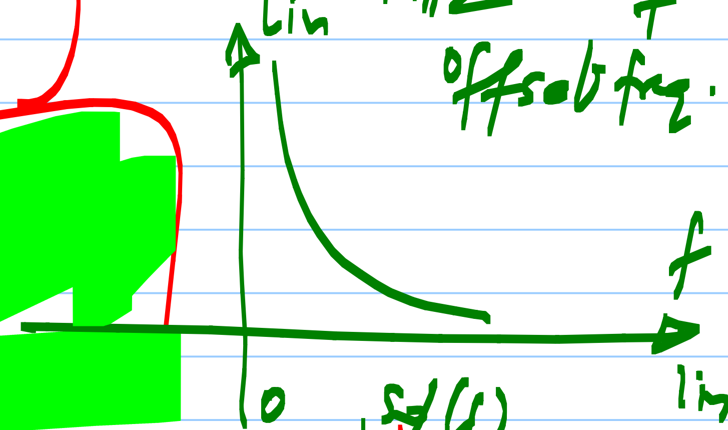
$\simeq V_p \cos(2\pi f_0 t) - \boxed{V_p\, \phi(t) \cdot \sin(2\pi f_0 t)}$

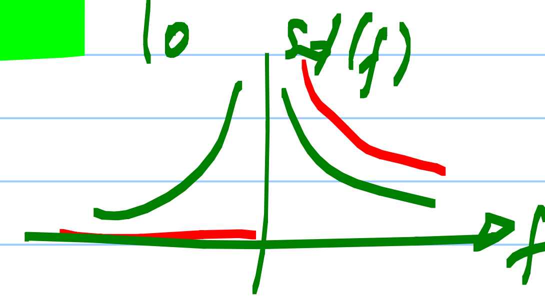
$S_\phi(f)$

$\frac{V_p^2}{2}$

when $S_\phi$ is double sided

Approximate voltage spectrum: $\dfrac{V_j^2}{2} S_\phi(f-f_0)$

(away from $f_0$)

double sided

$$\boxed{S_\phi(f) : \frac{A}{f^2}}$$

$$\frac{V_p^2}{2} \cdot \frac{A}{(f-f_0)^2}$$

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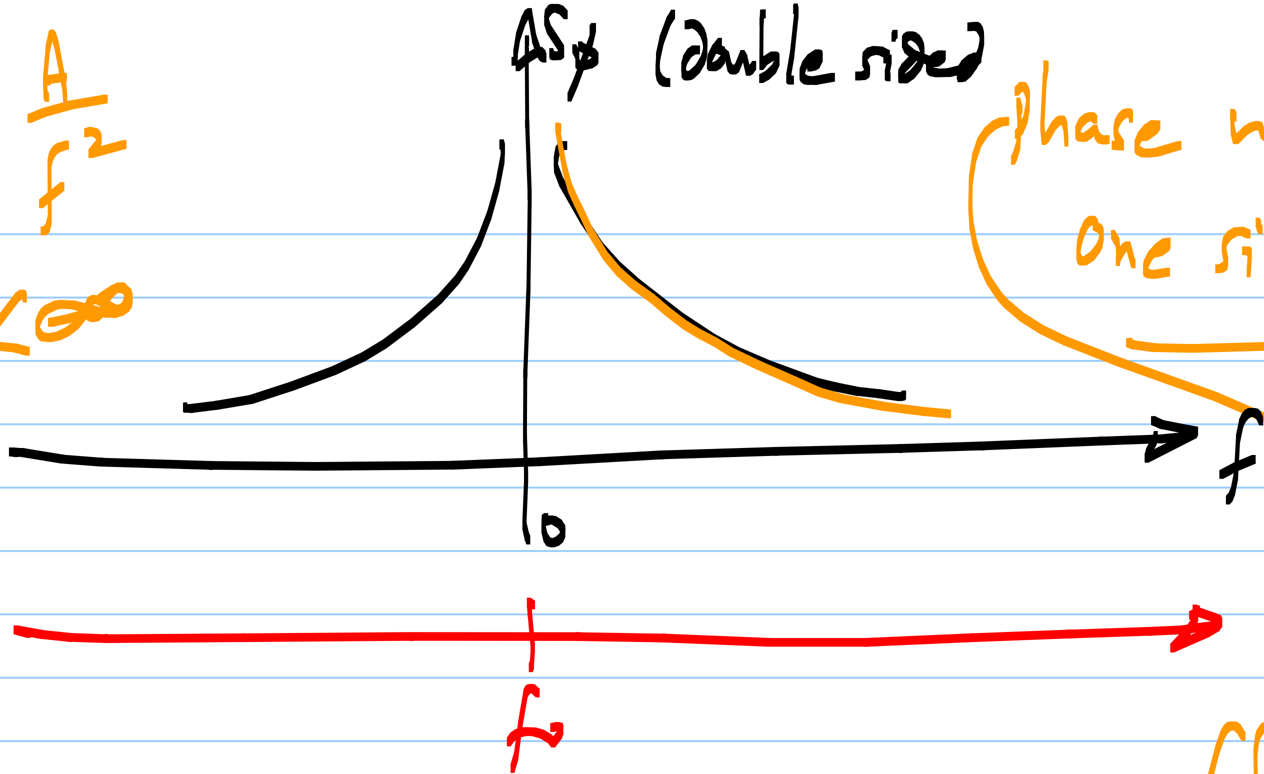
$$\cdot \frac{\quad}{(f-f_0)^2} \simeq \frac{\alpha}{1+\frac{(f-f_0)^2}{f_W^2}} \simeq \frac{\quad}{(f-f_0)^2}$$

$$\frac{|f-f_0|}{f_W} \gg 1$$

$\alpha = V_p^2/2;$ $\quad \underline{A = f_W^2}$

$S_\phi(f) = \frac{A}{f^2}$

$-\infty < f < \infty$




Phase noise $\mathcal{L}(f)$

One side of $S_\phi(f)$

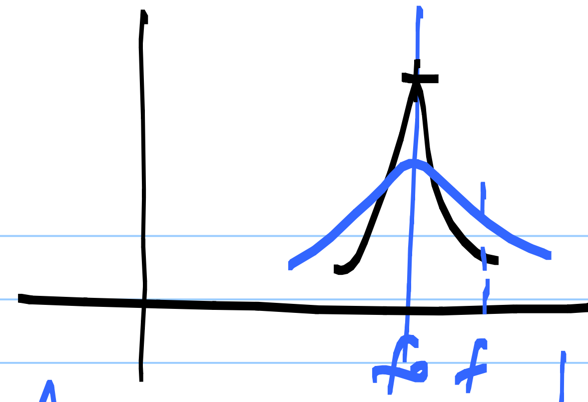
$\mathcal{L}(f) = \frac{A}{f^2}$

$f > 0$

$$\text{mean squared } \phi = \int_{-\infty}^{\infty} S_\phi(f)\, df$$

$$= \int_0^{\infty} 2\mathcal{L}(f) \cdot df$$

$$\frac{\cancel{X}\ \alpha/f_w}{1+\frac{(f-f_0)^2}{f_w^{\,2}}}$$




$f_w$ : line width

$$\frac{A}{(f-f_0)^2} \simeq \frac{1}{1+\left(\frac{f-f_0}{f_w}\right)^2}$$

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$\mathcal{L}(f)$ : $\frac{A}{f^2}$ $\frac{1}{Hz}$ $\frac{dBc}{Hz}$ dB relative to the carrier

offset frequency

$f_0 = 10\,\text{GHz}$; $T_0 = 100\,\text{ps}$;

10GHz oscillator : @ 1MHz offset. PN: $-120\,\text{dBc/Hz}$

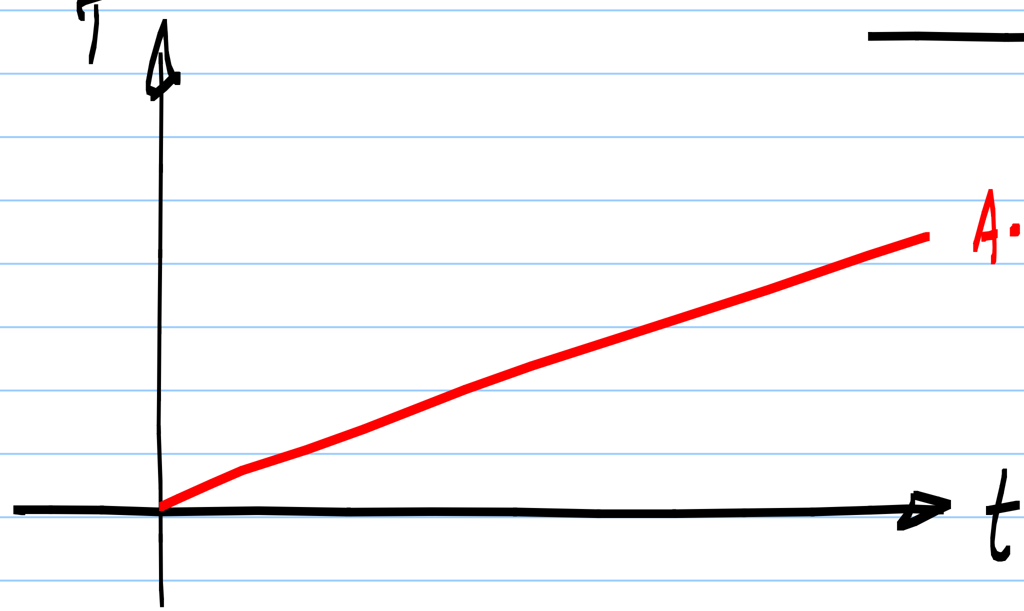
$$\mathcal{L}(1\,\text{MHz}) = -120\,\text{dBc/Hz} = 10^{-12}/\text{Hz}$$

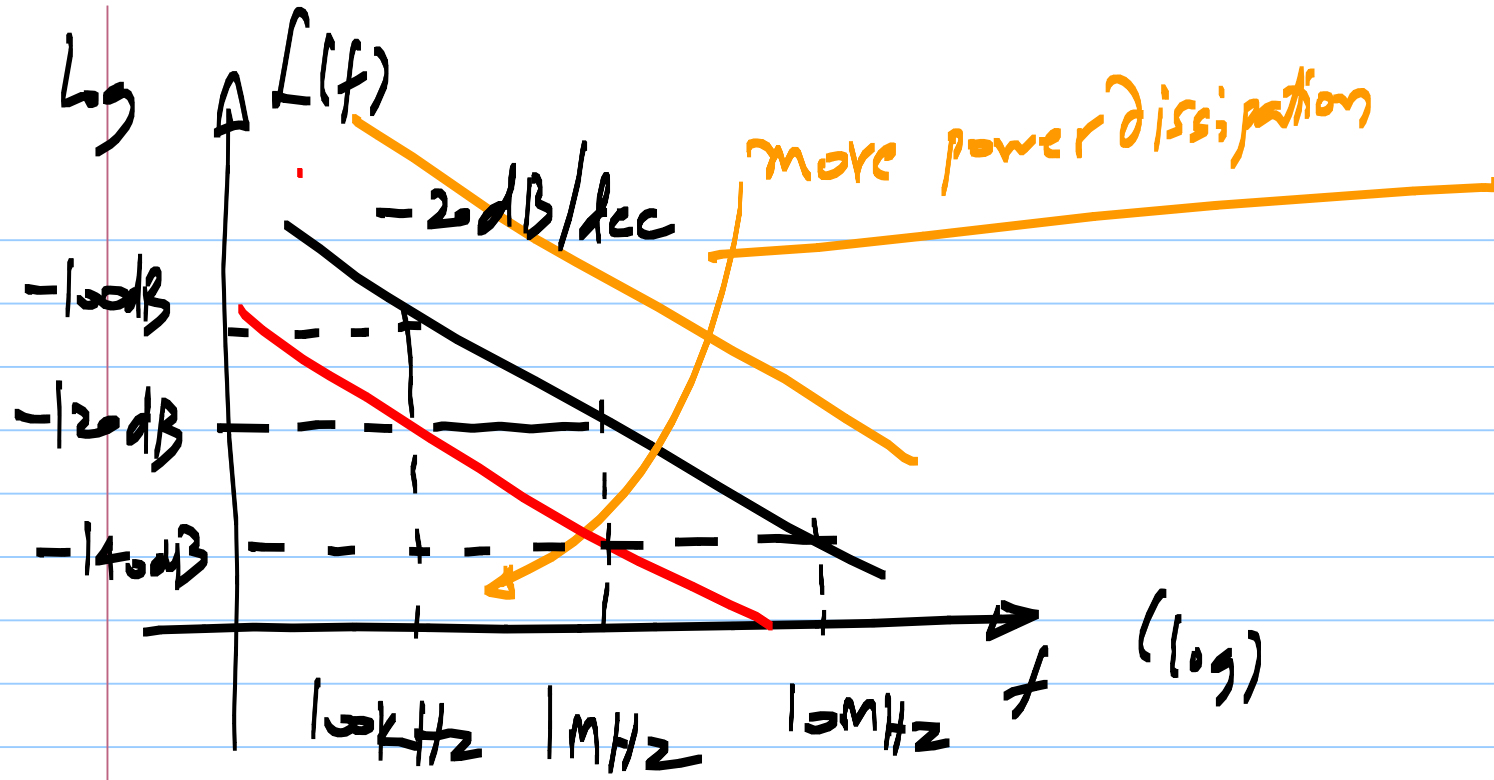
Mean sq. value

Period jitter $= AT_0^3$ period

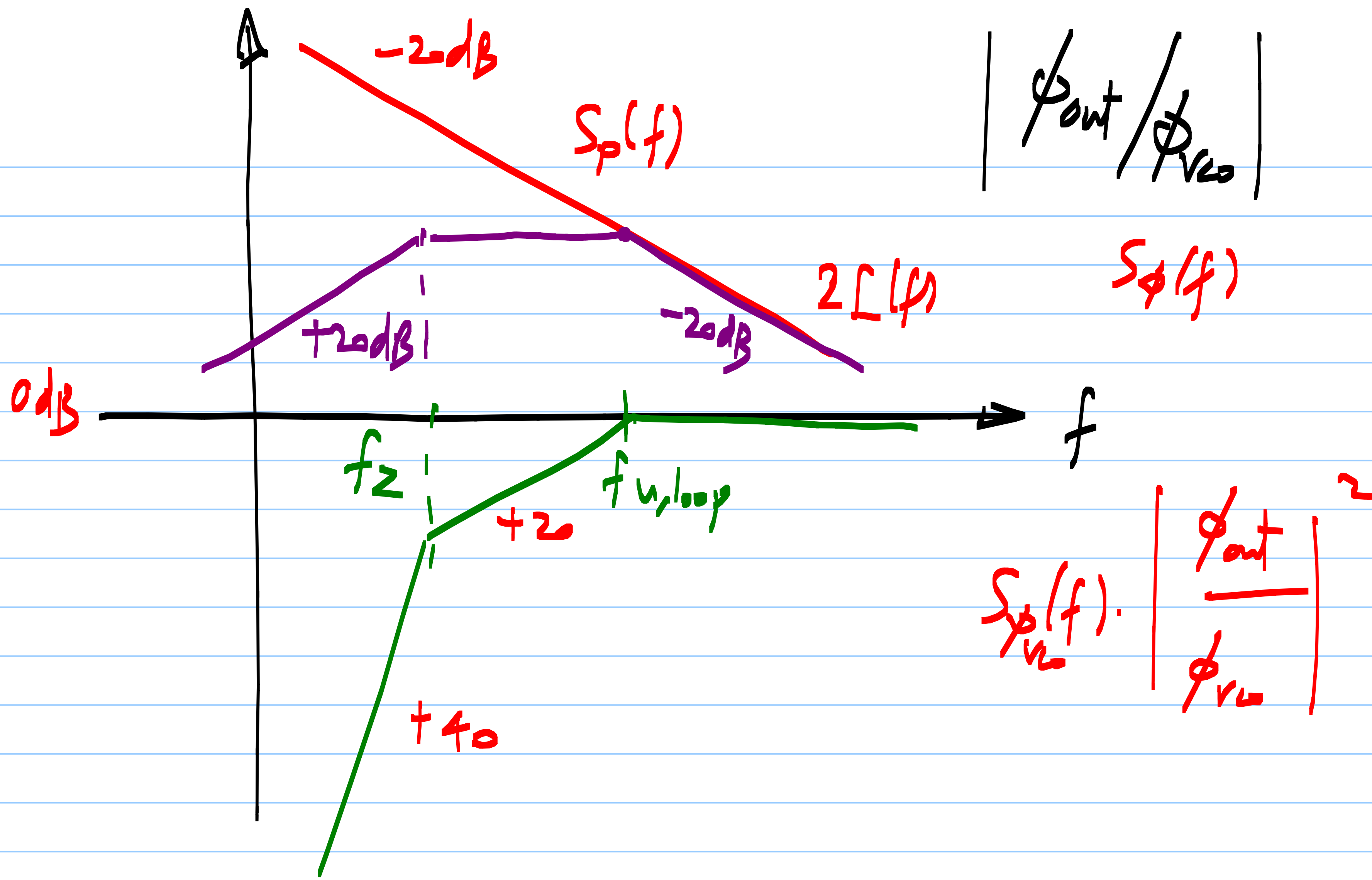
rms jitter : $10^{-15}\,s = 1\,fs$

$$= \frac{A}{f^2} = \frac{1}{f^2}\;\frac{1}{\text{Hz}}$$





Log
$\mathcal{L}(f)$
-20dB/dec
more power dissipation
-100dB
-120dB
-140dB
100kHz
1MHz
10MHz
f
(log)


0dB
-20dB
$S_p(f)$
+20dB
-20dB
$2\mathcal{L}(f)$
$f$
$f_z$
$f_{u,loop}$
+20
+40
$|\phi_{out}/\phi_{vco}|$
$S_\phi(f)$
$S_{\phi_{vco}}(f) \cdot \left| \frac{\phi_{out}}{\phi_{vco}} \right|^2$