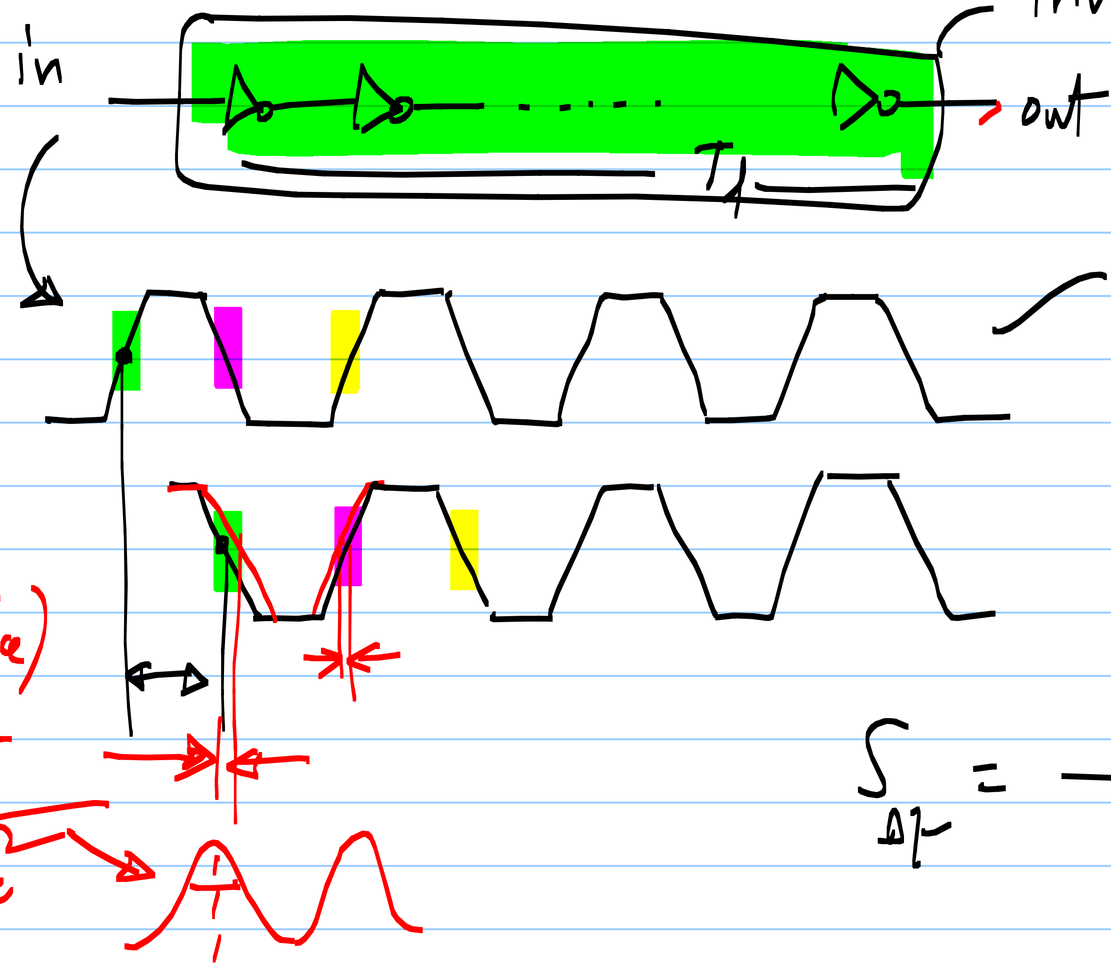
Lecture 21

Jitter and phase noise in oscillators

Noise in a delay line

Inverting delay line



osc. waveform in a noiseless oscillator

I/p ref. of the delay line $= v_n$

(variance) $\sigma_{v_n}^2$

$\frac{\sigma_{v_n}^2}{slope^2}$

$$\Delta t = \frac{v_n}{slope}$$

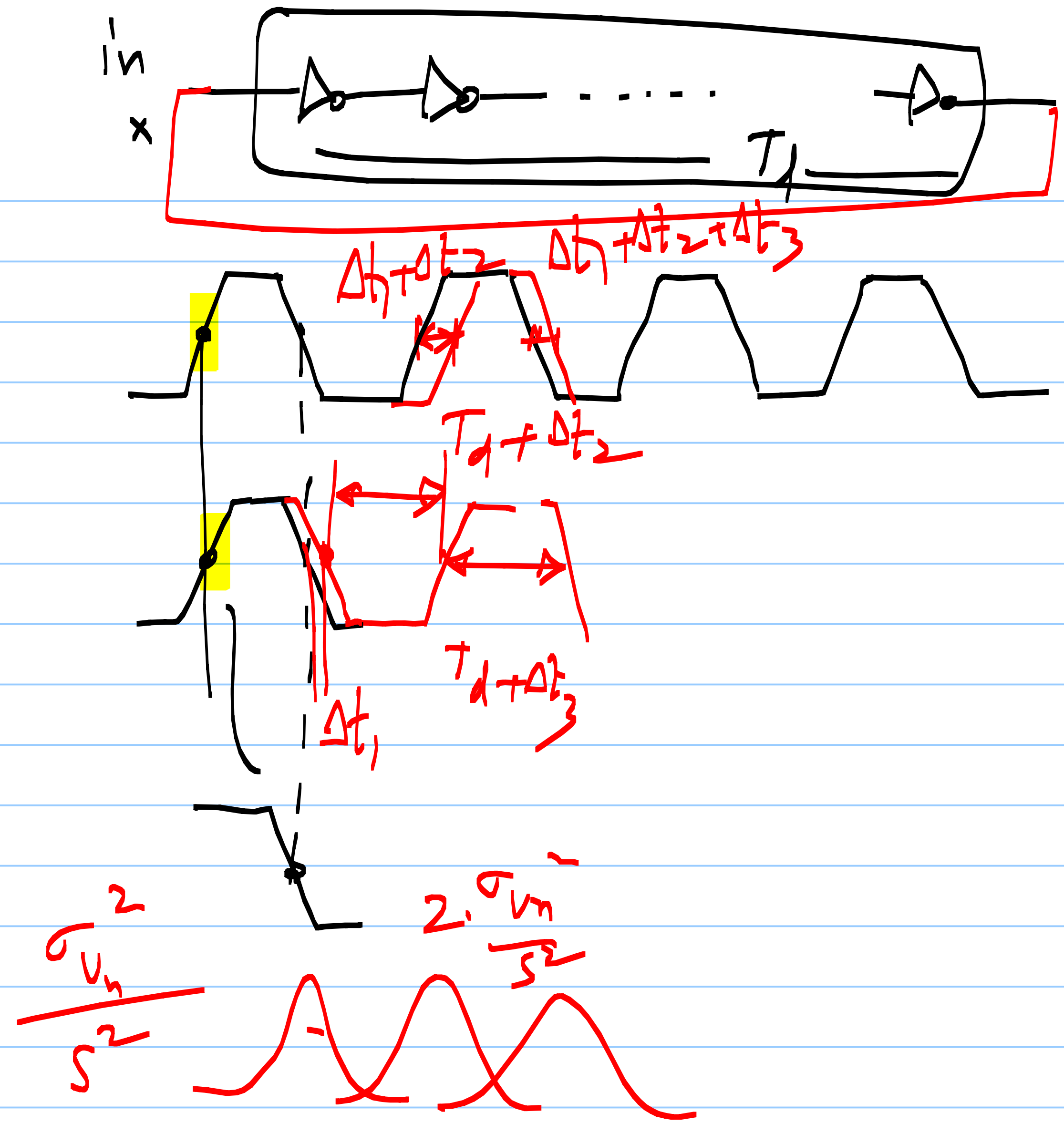
$$S_{\Delta t} = \frac{S_{v_n}}{|slope|^2}$$

Jitter ~~Noise~~ in a delay line

* Same PSD as the i/p ref. noise of the delay line

- white
- flicker ($1/f$)

* Jitter $\downarrow$ if $\underbrace{\text{slope} \uparrow}_{\text{increasing the current}}$



1. $T_d + \Delta t_1$
2. $T_d + \Delta t_2$

noiseless case

$$\Delta t_1 = \frac{v_n}{S}$$

$$\Delta t_2 = \frac{v_n}{S}$$

$$\Delta t_{osc}[n] = \sum_{k=1}^{n} \Delta t_{d}[k] \times \frac{2\pi}{T_0}$$

$$\Delta\phi_{osc}[n] = \sum_{k=1}^{n} \Delta\phi_{d}[k]$$

$$\Delta\phi_{osc}[n] - \Delta\phi_{osc}[n-1] = \Delta\phi_{d}[n]$$

$$\Delta\phi_{osc}(z) = \frac{\Delta\phi_{d}(z)}{1 - z^{-1}}$$

$$z = \exp(j 2\pi f \cdot T_0)$$

Oscillator jitter:

Accumulation of jitter in the delay line

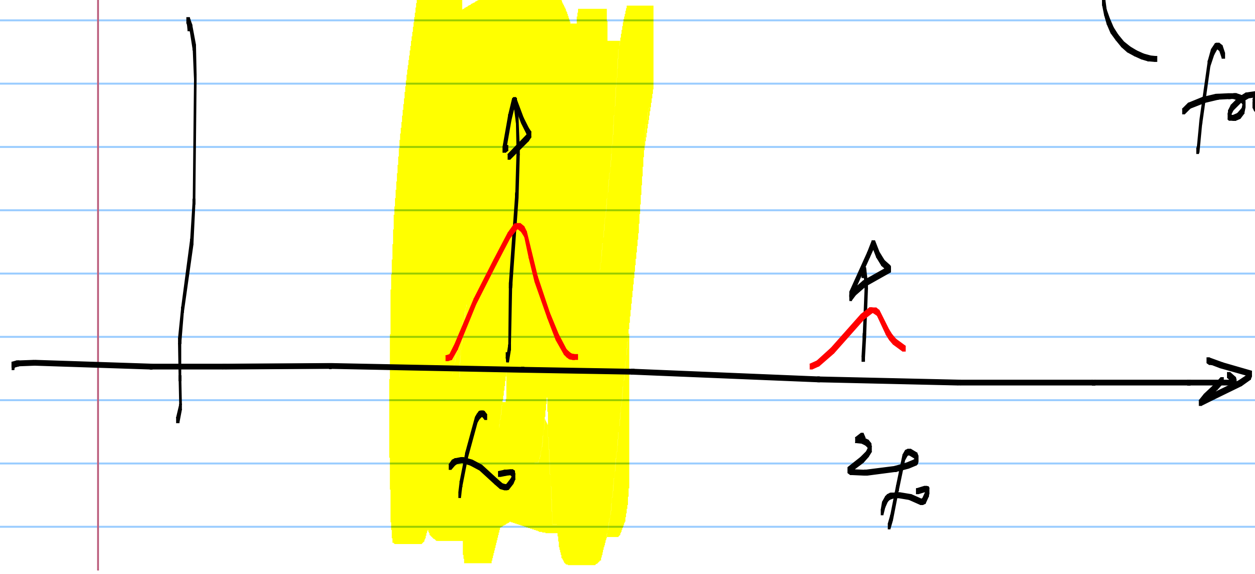
$$\overbrace{S_{\phi_n}(f)}^{\text{osc.}} = \frac{\overbrace{S_{\phi_d}(f)}^{\text{delay line}}}{\left|1 - \exp(-j2\pi f T_0)\right|^2} \approx \boxed{\frac{S_{\phi_d}(f)}{4\pi^2 f^2 T_0^2}}$$

delay line $\cos(2\pi f_0 t + \phi_n)$

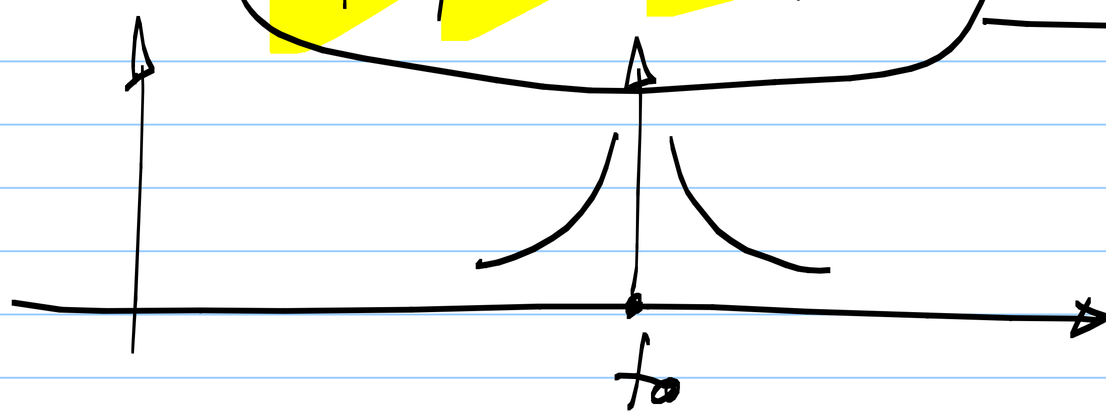
osc. ~~frequency~~ Period

freq. of variation of ϕ_n

$f T_0 \ll 1$

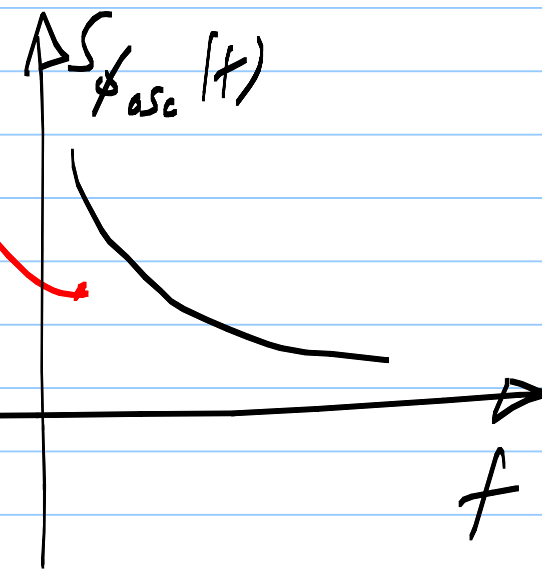


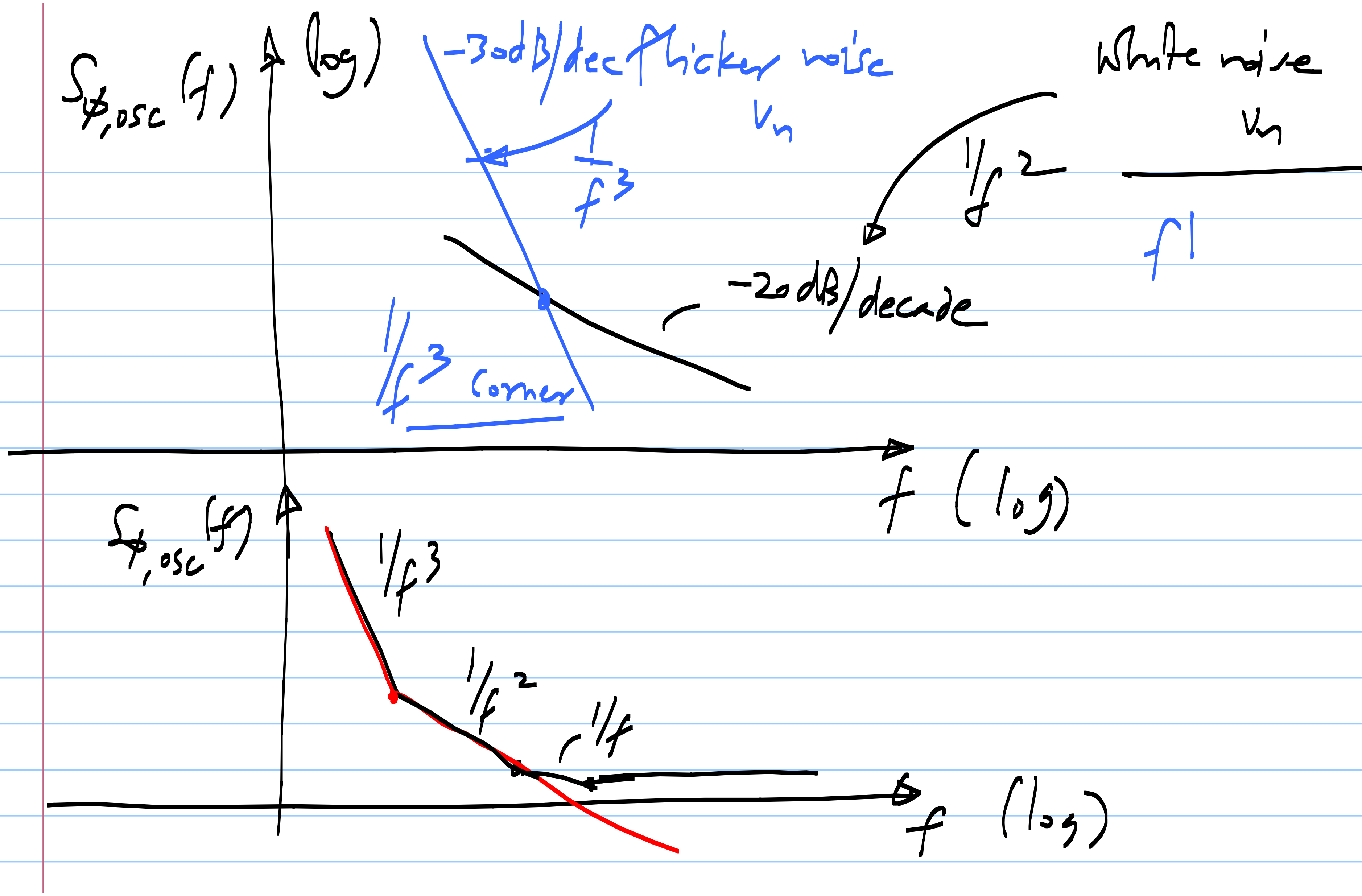
$$S_{\phi_{osc}}(f) = \frac{S_{\phi_d}(f)}{4\pi^2 f^2 T_0^2} = \boxed{\frac{S_{v_n}(f)}{|S|^2}\,\frac{f_0^2}{4\pi^2 f^2}}$$



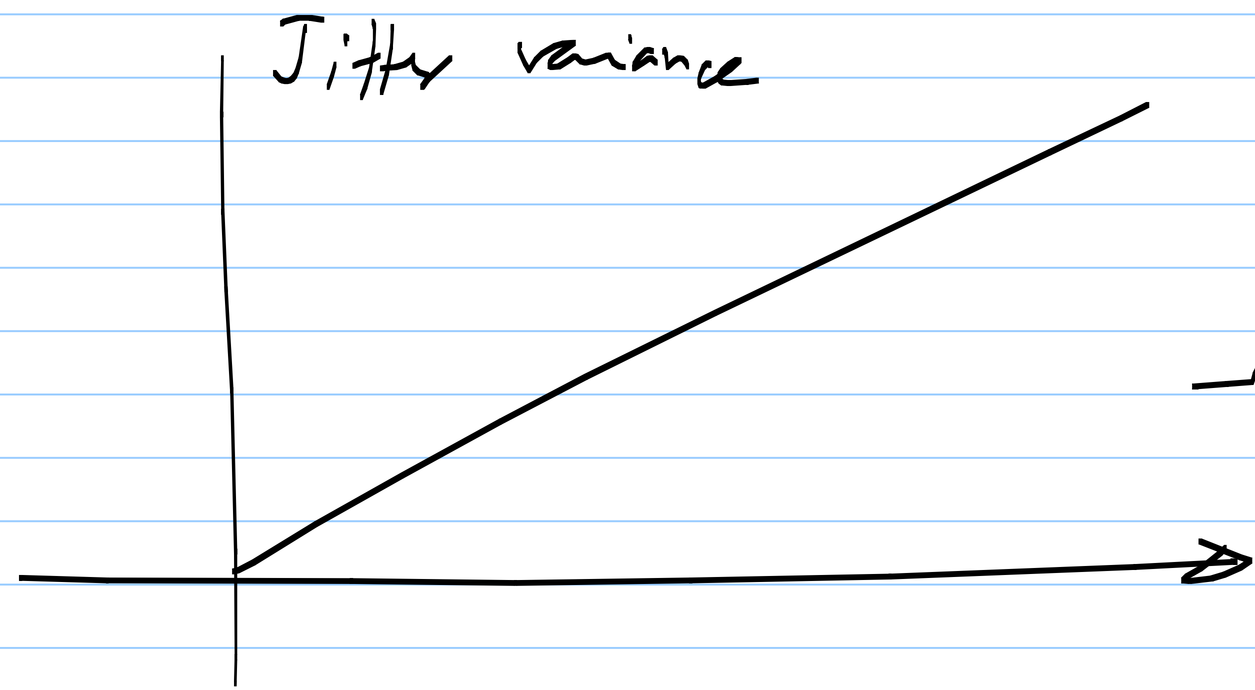
osc. freq.

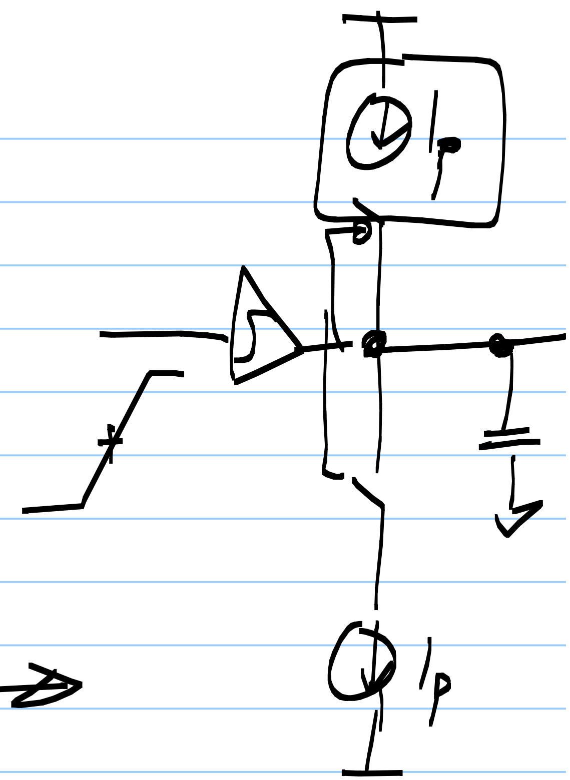
phase noise plot



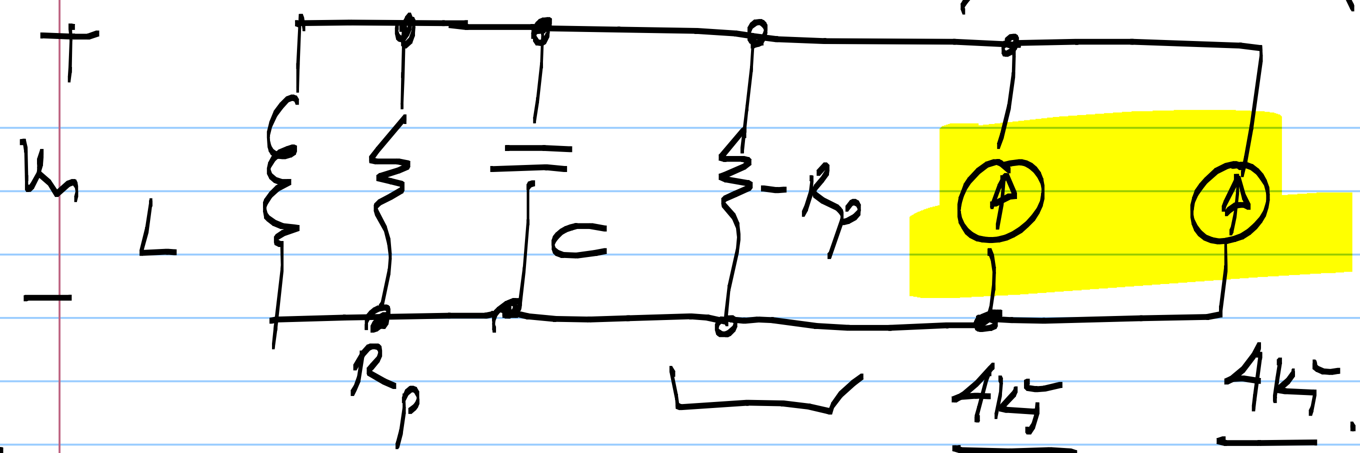

$S_{\phi,osc}(f)$
(log)
-30dB/dec flicker noise
v_n
$\frac{1}{f^3}$
White noise
v_n
$1/f^2$
$f1$
-20dB/decade
$1/f^3$ corner
f (log)
$S_{\phi,osc}(f)$
$1/f^3$
$1/f^2$
$1/f$
f (log)

Osc w/ (white noise)





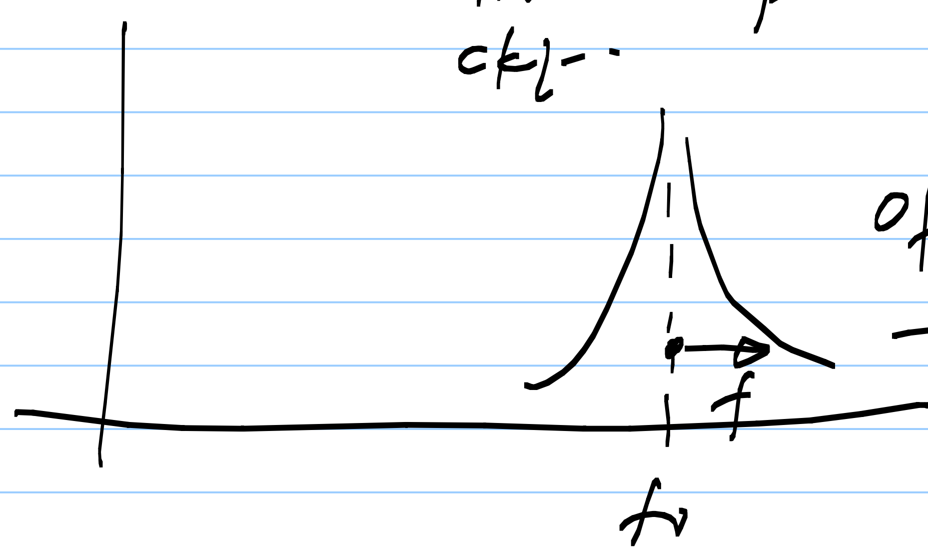
white



active ckt...

$$\frac{4kT}{R_p} \qquad \frac{4kT}{R_p}\cdot 8 \;\propto\; \frac{f_0^2}{f^2}$$

Leeson



offset frequency

LC oscillator:

$$S_\phi = \frac{kTR_p(1+\gamma)}{V_p^2 Q^2} \cdot \frac{f_0^2}{f^2}$$

peak of the osc. waveform

Excess noise factor of the -ve resistance

Ring oscillator:

$$S_\phi = \frac{32}{3} \frac{kT}{(V_{GS}-V_T) I_p} \cdot \left(\frac{f_0}{f}\right)^2$$

Avg $(V_{GS}-V_T)$

charging & discharging current