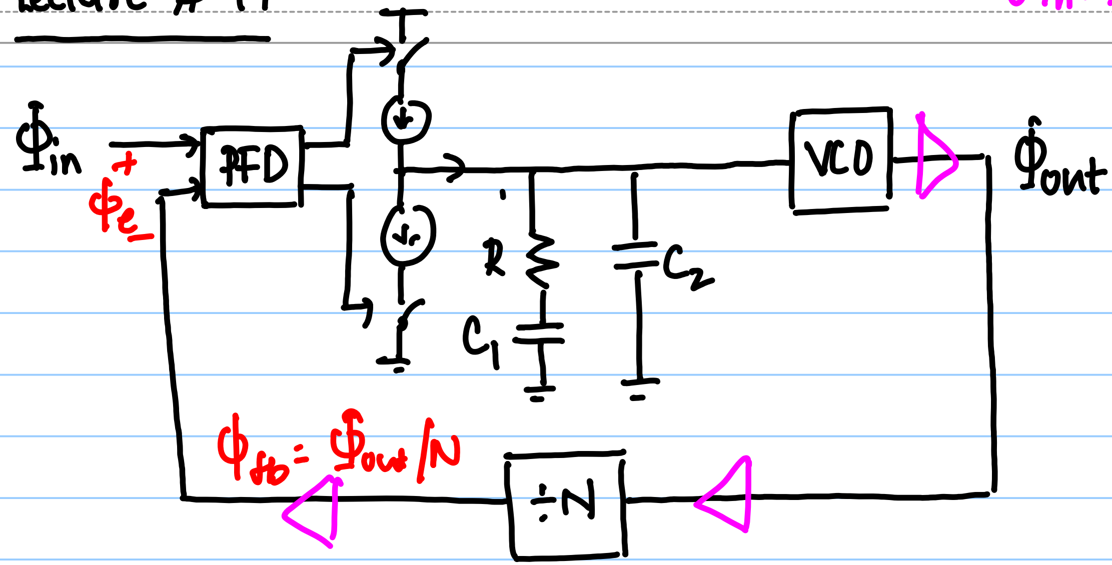
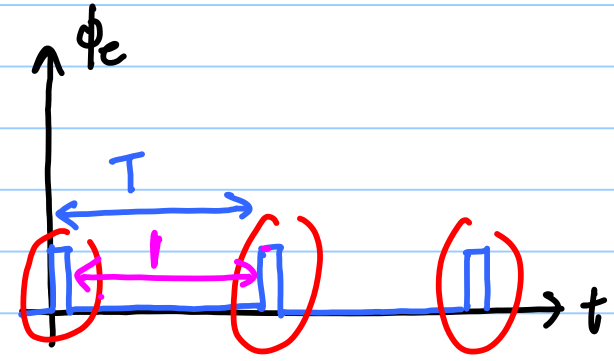
Note Title 28-06-2020

lecture # 17

$v_{in}(t)\,u(t)$ → [delay] → $v_{in}(t)\; u(t-\tau_d)$



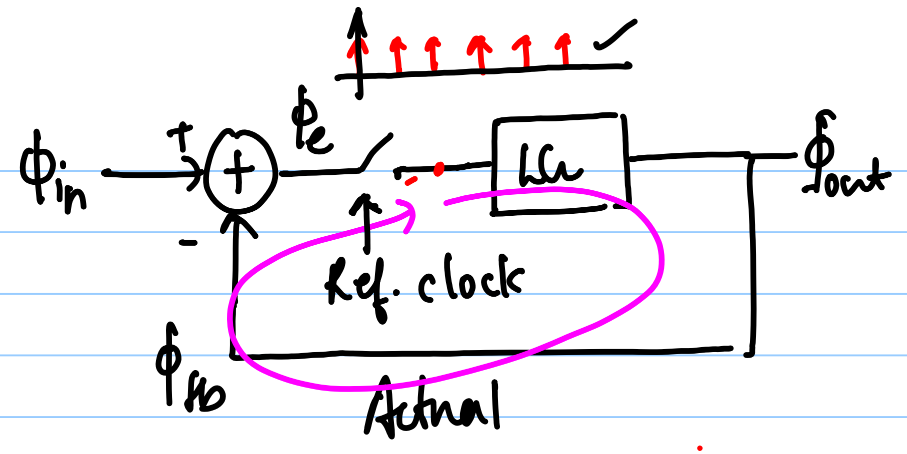


$$LG(s) = \frac{1}{2\pi} I_{cp} \left\{ \left(R + \frac{1}{sC_1}\right) \parallel \frac{1}{sC_2} \right\} \frac{2\pi K_{vco}}{s} \times \frac{1}{N} \times e^{-s\tau_d}$$

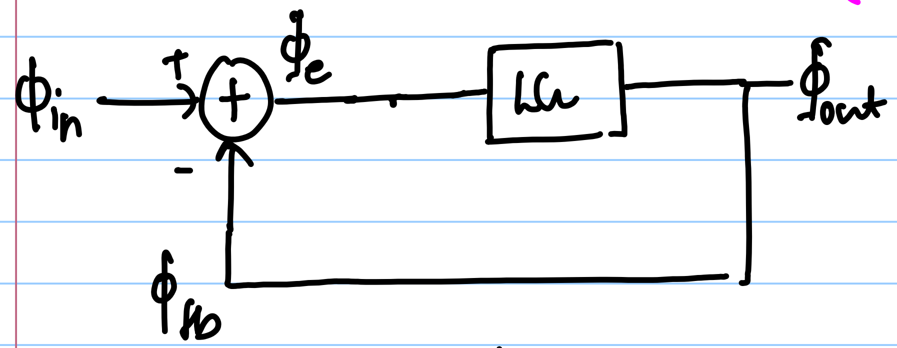
- Given ω_u (open loop) $\approx \omega_{3dB}$ (closed loop) & ϕ_m
- $\frac{C_1}{C_2} = 2\left(\tan^2\phi_m + \tan\phi_m \sqrt{1+\tan^2\phi_m}\right)$
- $\omega_z = \frac{\omega_u}{\sqrt{1+\frac{C_1}{C_2}}}$
- Choose R, $C_1 = \frac{1}{\omega_z R}$

$$\angle LG = -180^\circ + \tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p3}}\right) - \tan^{-1}(\omega\tau_d)$$

$$e^{-s\tau_d} = \frac{e^{-s\tau_d/2}}{e^{+s\tau_d/2}} \approx \frac{1 - s\tau_d/2}{1 + s\tau_d/2}$$



Actual



Model

Impulse Invariance Transformation

- Calculate impulse response $h(t)$
- Sample $h(t)$ by periodic impulse train to get $L_G(nT)$
- $L_G(nT) \xrightarrow{z} L_G(z)$
- Closed loop transfer function with $L_G(z)$

s-domain — z-domain

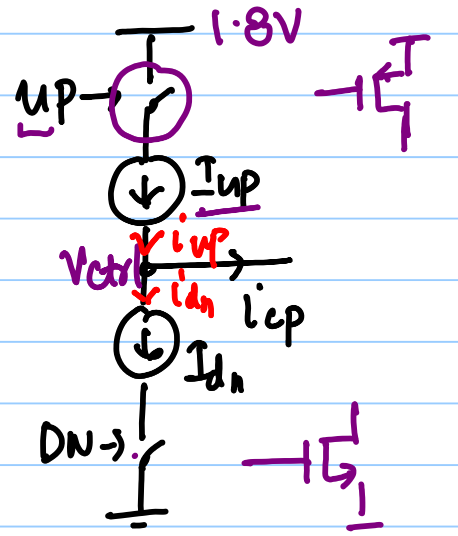
$L_G(s)$ — $H(z)$

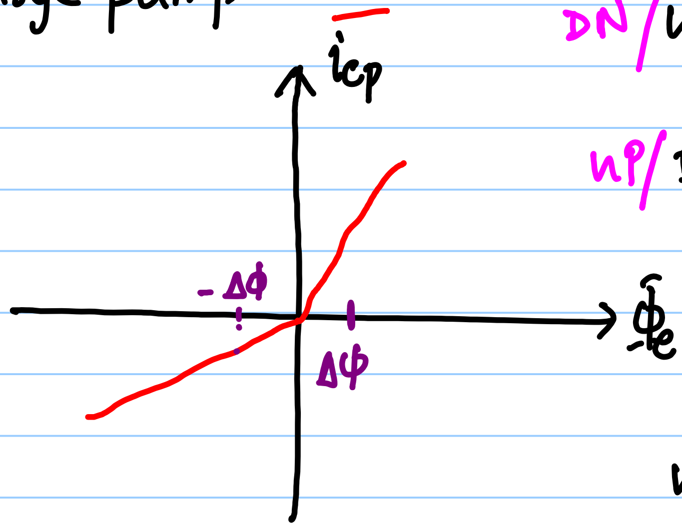
∴ $H(s)$ matches quite well $H(z)$ for $\frac{f_{ref}}{f_{BW}} \leq 10$ or $f_{BW} \leq \frac{f_{ref}}{10}$

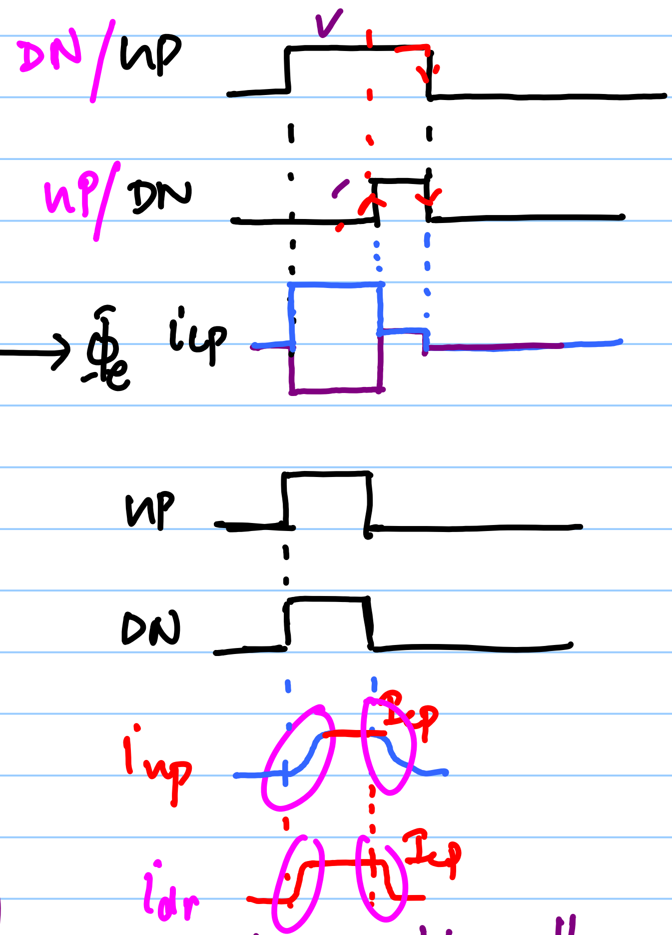
- for higher bandwidth $f_{BW} < \frac{f_{ref}}{2}$, we should use $L_G(z)$.

Sources of Non-Linearity

- Non-linearity in charge pump







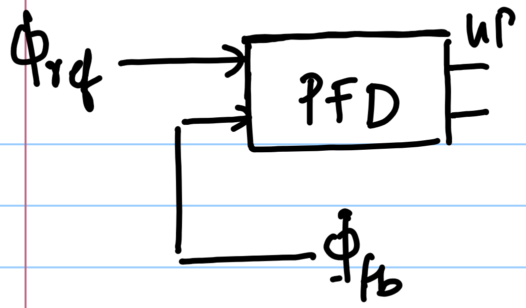
always $I_{up} = I_{dn} + \Delta I$ static non-linearity

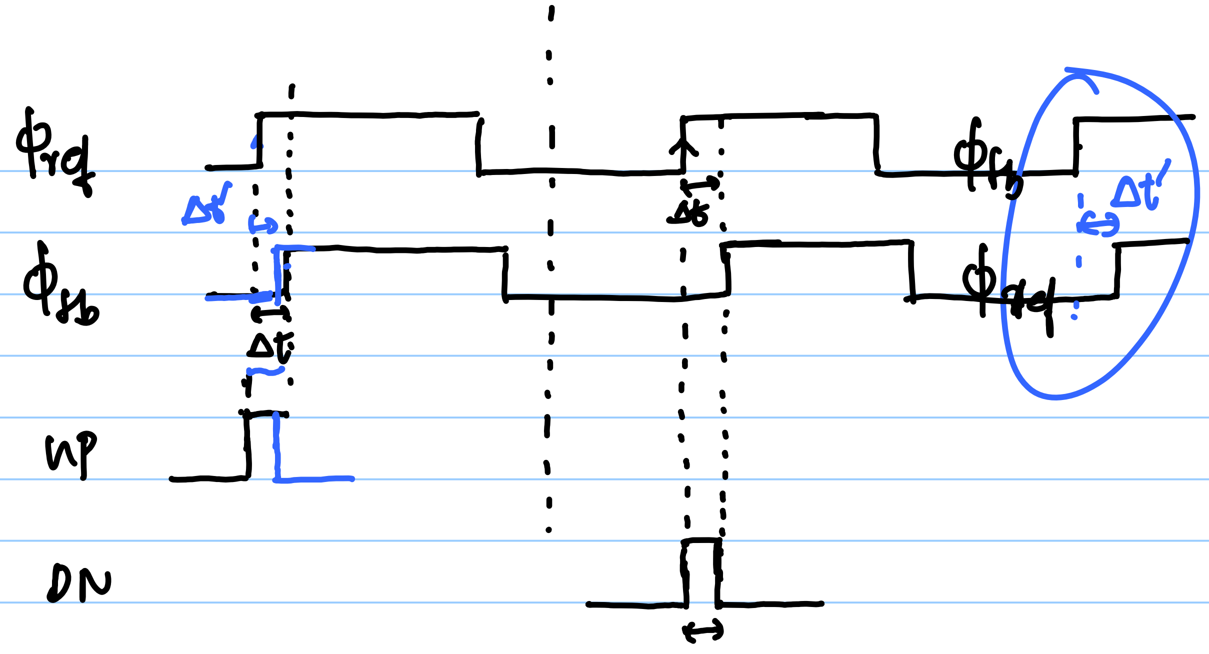
@ $V_{ctrl} = 0.9V$, $I_{up} = I_{dn}$

$V_{ctrl} = 1.2V$, $I_{up} < I_{dn}$

$V_{ctrl} : 0.6V$, $I_{up} > I_{dn}$

} dynamic non-linearity.

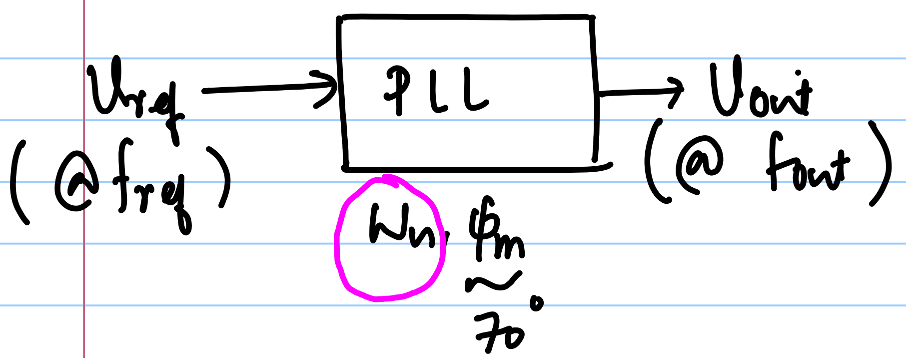




$\phi_e = \phi_{ref} - \phi_{fb}$

$y = f(x)$

- Unity gain frequency (ω_u) & Phase Margin (ϕ_m)



- Minimum jitter @ o/p clock. ✓
- Minimum power consumption in PLL.

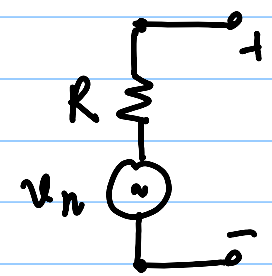
- Relationship b/w jitter @ o/p and unity freq. of PLL.

Sources of Noise in PLL

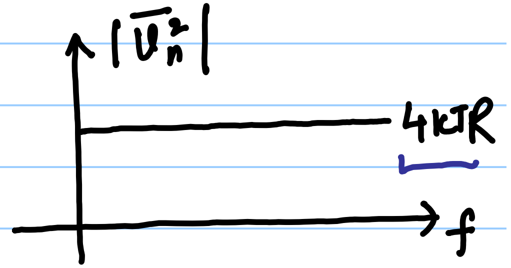
- Extrinsic noise sources. (Deterministic Noise Sources)
  - supply noise
  - substrate noise
  - coupling to unwanted signal
- Intrinsic noise sources (Random)
  - Thermal Noise
  - Flicker Noise.

Basic noise elements

- Resistor

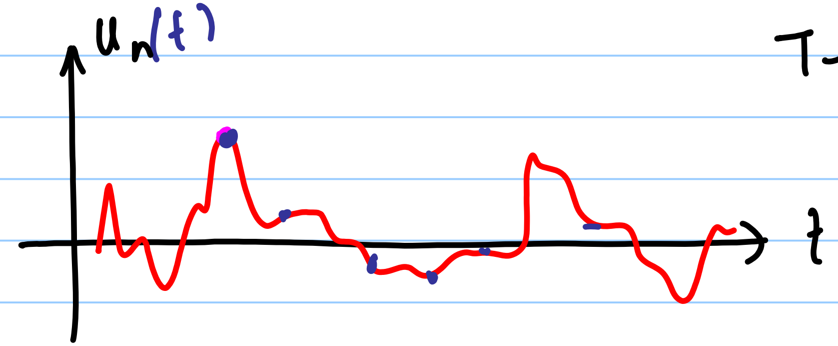


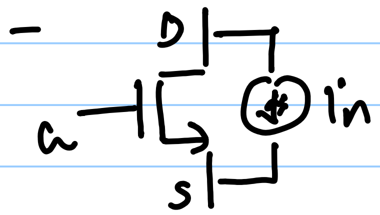
$$\frac{\overline{v_n^2}}{\Delta f} = 4kTR$$



k - Boltzmann's constant.

T - temperature in Kelvin

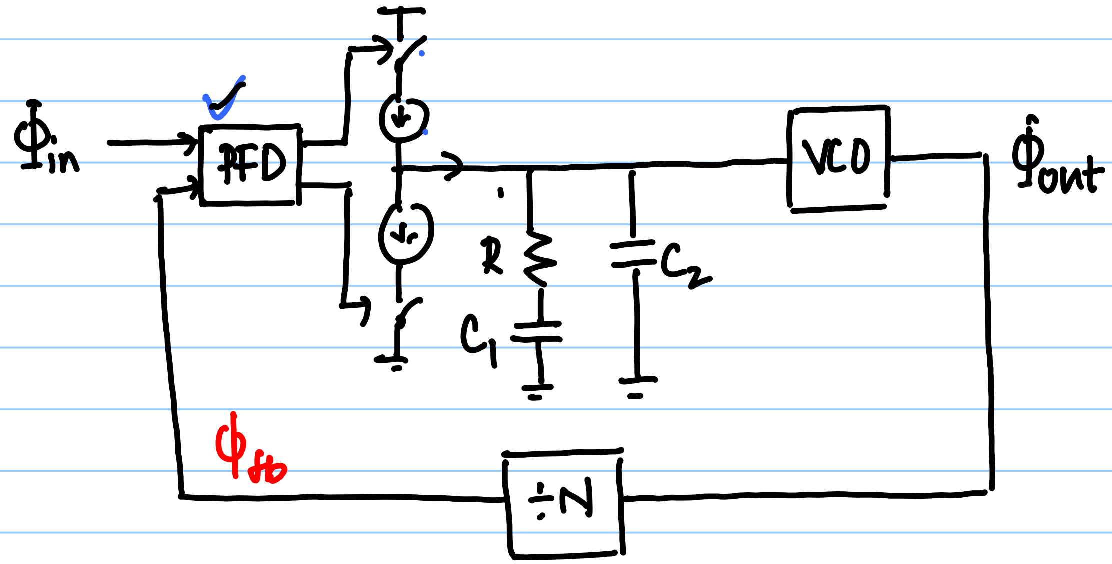


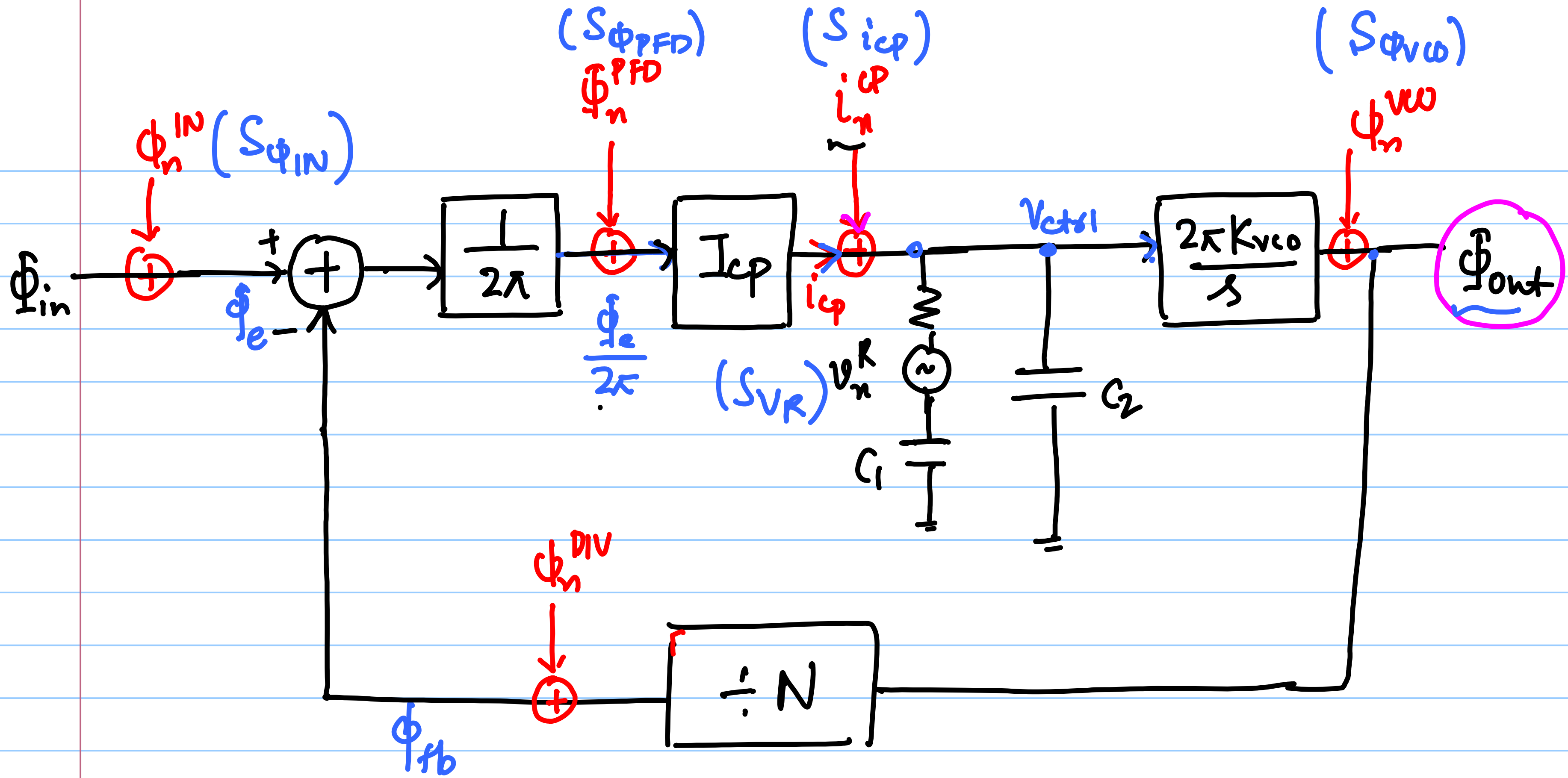


$$\frac{\overline{i_n^2}}{\Delta f} = \frac{4kT\gamma}{g_m}$$

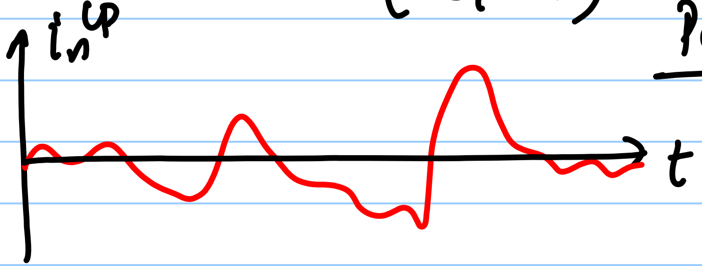
γ: technology constant $\quad \frac{2}{3} < \gamma < 2$

g_m: tansconductance.





1. Identify all noise sources.
2. Calculate (simulate) the noise power spectral density of each noise source ($S_i(f)$)



$\xrightarrow{\text{Power Spectral Density}}$ $S_{cp}(f)$

3. Noise transfer function (NTF) for each noise source to the o/p.

$NTF = \frac{Y(s)}{X(s)}$

4. find contribution of each source to the o/p. $|NTF_i|^2 \times S_i(f)$

$$v_{in}(t) \xrightarrow{\mathcal{F}} V_{in}(f) \xrightarrow{|\;|^2} |V_{in}(f)|^2$$

5. $\sum |NTF_i|^2 S_i(f)$

$$NTF_{IN} = \frac{\hat{\Phi}_{OUT}}{\Phi_{IN}} = N \cdot \frac{LG(s)}{1+LG(s)}$$

$$NTF_{PFD} = 2\pi \cdot \frac{\hat{\Phi}_{out}}{\Phi_{IN}} = 2\pi \cdot N \cdot \frac{LG(s)}{1+LG(s)}$$

$$NTF_{CP} = \frac{2\pi}{I_{CP}} \quad N \cdot \frac{LG}{1+LG}$$

$$NTR_{DIV} = \frac{\Phi_{out}}{\Phi_{IN}} = N \cdot \frac{LG(s)}{1+LG(s)}$$

$$NTF_{VCO} = \frac{\hat{\Phi}_{out}}{\Phi_{VCO}} = \frac{1}{1+LG(s)}$$

$$NTF_R = \frac{q_{out}}{V_n^R} = \frac{1/sC_2}{\frac{1}{sC_2} + R + \frac{1}{sC_1}} \times \frac{2\pi K_{VCO}}{s} \times \frac{1}{1+LL}$$

$$= \frac{1/sC_2}{\frac{C_1 + sRC_1C_2 + C_2}{sC_1C_2}} \; \frac{2\pi K_{VCO}}{s} \; \frac{1}{1+LL}$$

$$= \frac{C_1}{C_1+C_2} \; \frac{1}{1 + \frac{sRC_1C_2}{C_1+C_2}} \; \frac{2\pi K_{VCO}}{s} \; \frac{1}{1+LL}.$$