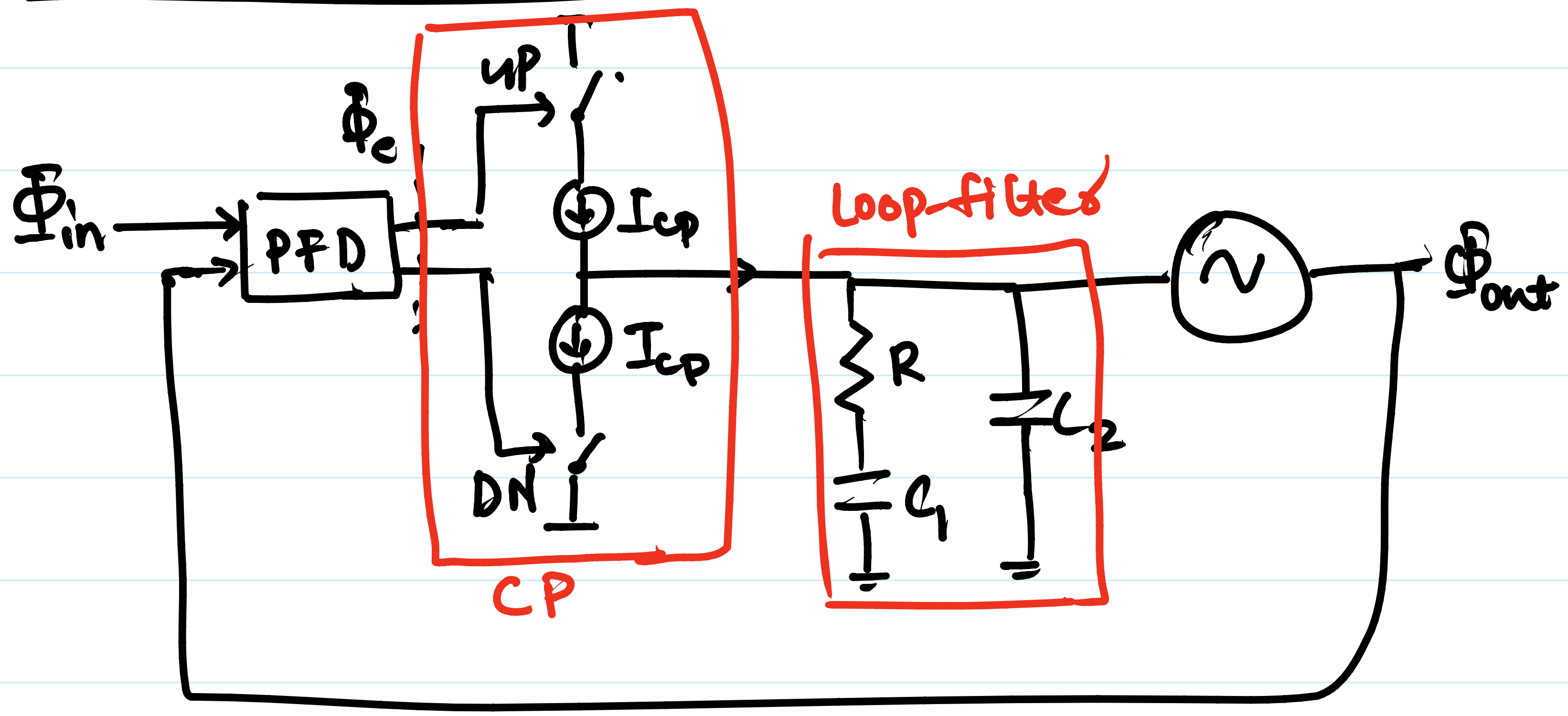
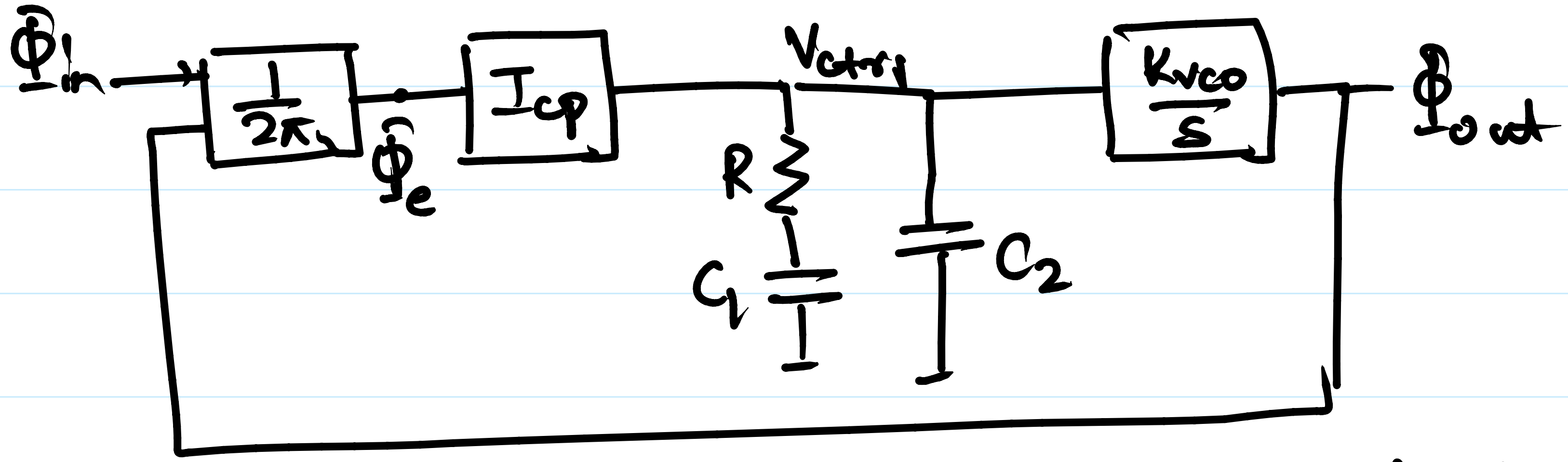
Lecture 10

Thursday, February 2, 2017 10:39 AM

Charge-pump based PLL



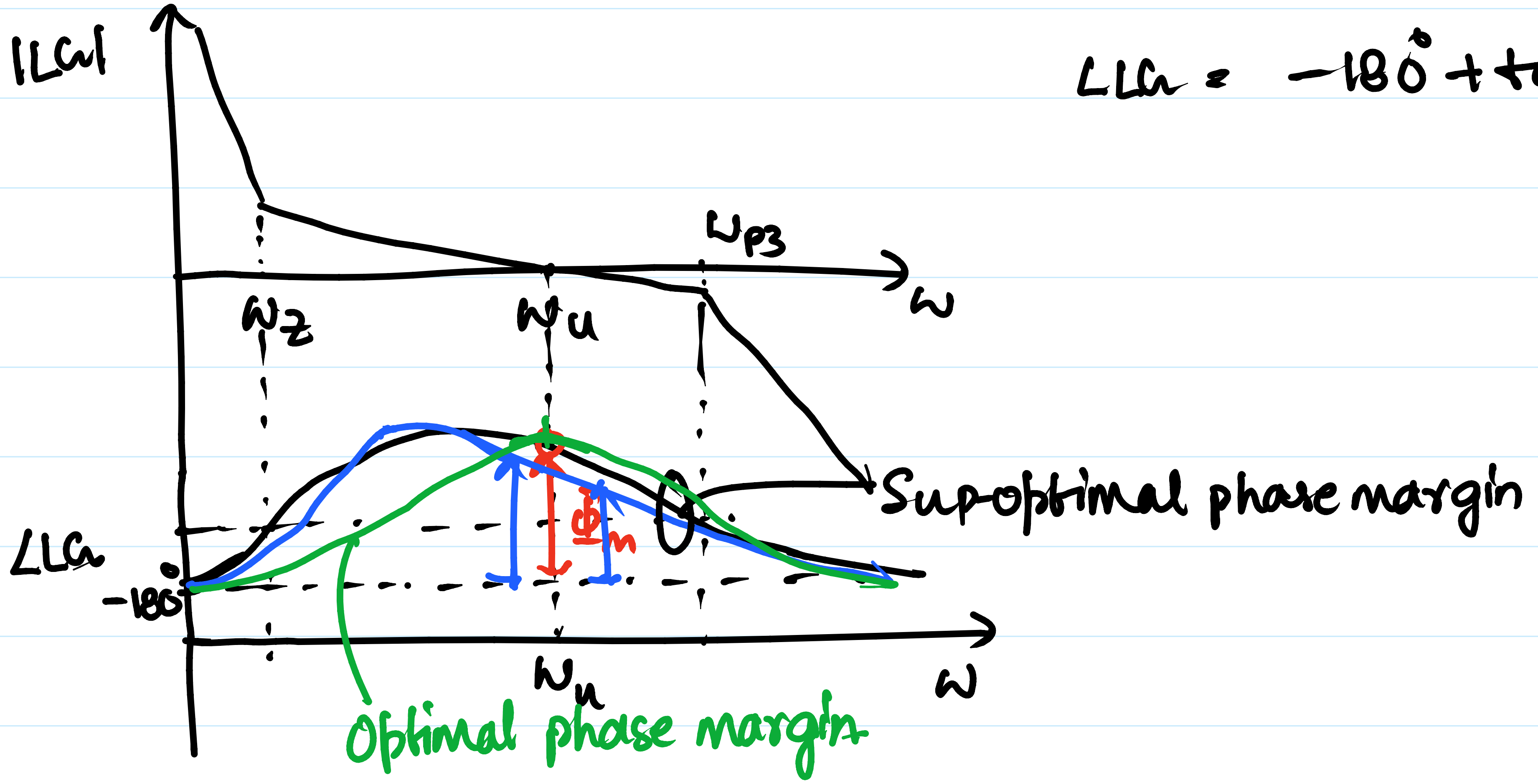


$$LG(s) = \frac{1}{2\pi} \times I_{cp} \times \frac{1}{sC_2} \frac{\left(s + \frac{1}{RC_1}\right)}{\left(s + \frac{1}{R\frac{C_1C_2}{C_1+C_2}}\right)} \frac{K_{VCO}}{s}$$

$$= \frac{I_{cp} K_{VCO}}{2\pi s^2 C_2} \frac{(s+\omega_z)}{(s+\omega_{p3})}$$

$\omega_z = \frac{1}{RC_1}$, $\omega_{p1} = \omega_{p2} = 0$, $\omega_{p3} = \frac{C_1+C_2}{R C_1 C_2} = \omega_z \left(\frac{C_1}{C_2}+1\right)$

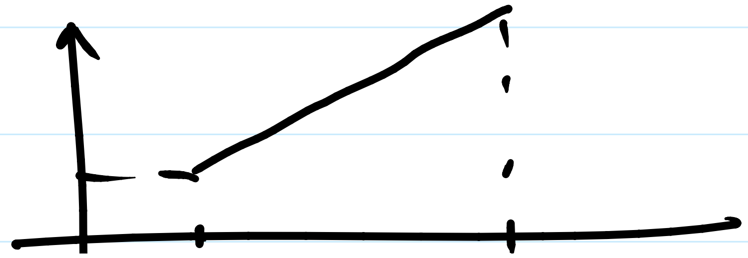
$\angle LG = -180^\circ + \tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p3}}\right)$

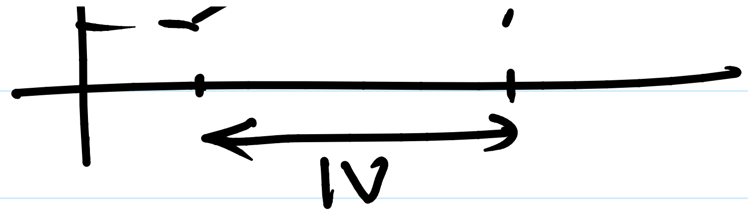


Desired: ω_u, Φ_m

To find: ω_z , ω_{p3} , I_{cp}

K_{VCO} $\Delta F = 1\,GHz$, $\Delta V_{ctrl} = 1V \rightarrow 100\,mV$





Optimal $\Phi_m \Rightarrow$ $$\left.\frac{d\Phi_m}{d\omega}\right|_{\omega=\omega_u} = 0$$

$$\Phi_m = \tan^{-1}\left(\frac{\omega_u}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_u}{\omega_{p3}}\right) = \angle LG\Big|_{\omega=\omega_u} - (-180^\circ)$$

$$\frac{d\Phi_m}{d\omega_u} = \frac{1}{\omega_z}\,\frac{1}{1+\left(\frac{\omega_u}{\omega_z}\right)^2} - \frac{1}{\omega_{p3}}\,\frac{1}{1+\left(\frac{\omega_u}{\omega_{p3}}\right)^2} = 0$$

$$\frac{\omega_z}{\omega_{p3}}\left[1+\left(\frac{\omega_u}{\omega_z}\right)^2\right] = 1+\left(\frac{\omega_u}{\omega_{p3}}\right)^2$$

$$\frac{\omega_z}{\omega_{p3}} - 1 = \omega_u^2\left[-\frac{\cancel{\omega_z}}{\omega_{p3}}\cdot\frac{1}{\omega_z^{\cancel{2}}} + \frac{1}{\omega_{p3}^2}\right]$$

$$\frac{\omega_z}{\omega_{p3}} - 1 = \frac{\omega_u^2}{\omega_{p3}}\left[-\frac{1}{\omega_z} + \frac{1}{\omega_{p3}}\right]$$

$$= \frac{\omega_u^2}{\omega_z\,\omega_{p3}}\left[\frac{\omega_z}{\omega_{p3}} - 1\right]$$

$$= \frac{\quad}{\omega_z \omega_{p3}} \left(\frac{\quad}{\omega_{p3}} - 1 \right)$$

$$\boxed{\omega_u = \sqrt{\omega_z \omega_{p3}} = \omega_z \sqrt{1 + \frac{C_1}{C_2}}}$$

$$\Phi_m = \tan^{-1}\left(\sqrt{1 + \frac{C_1}{C_2}}\right) - \underbrace{\tan^{-1}\left(\frac{\omega_u}{\omega_z \left(1 + \frac{C_1}{C_2}\right)}\right)}_{\tan^{-1}\left(\frac{1}{\sqrt{1 + \frac{C_1}{C_2}}}\right)}$$

$$\Phi_m = \tan^{-1}\left(\sqrt{1 + \frac{C_1}{C_2}}\right) - \tan^{-1}\left(\frac{1}{\sqrt{1 + \frac{C_1}{C_2}}}\right)$$

$$\tan(\Phi_m) = \frac{\sqrt{1 + \frac{C_1}{C_2}} - \frac{1}{\sqrt{1 + \frac{C_1}{C_2}}}}{1 + 1}$$

$$\tan(A - B) = \frac{\tan A - \tan B}{1 + \tan A \cdot \tan B}$$

$$= \frac{\frac{C_1}{C_2}}{2\sqrt{1 + \frac{C_1}{C_2}}}$$

$$\left(\frac{C_1}{C_2}\right)^2 - 4\left(1+\frac{C_1}{C_2}\right)\tan^2\Phi_m = 0$$

$$\frac{C_1}{C_2} = \frac{4\tan^2\Phi_m + \sqrt{16\tan^4\Phi_m + 16\tan^2\Phi_m}}{2}$$

$$= 2\tan^2\Phi_m + 2\tan\Phi_m\sqrt{\tan^2\Phi_m + 1}$$

$$\boxed{\frac{C_1}{C_2} = 2\tan\Phi_m\left[\tan\Phi_m + \sqrt{1+\tan^2\Phi_m}\right]}$$

$$\omega_u,\ \Phi_m,\ \frac{d\Phi}{d\omega_u} = 0$$

Design Procedure for type-II, order 3 CP-PLL

1.) $\omega_u,\ \Phi_m$

2) $K_c = \frac{C_1}{C_2} = 2\tan\Phi_m\left[\tan\Phi_m + \sqrt{1+\tan^2\Phi_m}\right]$

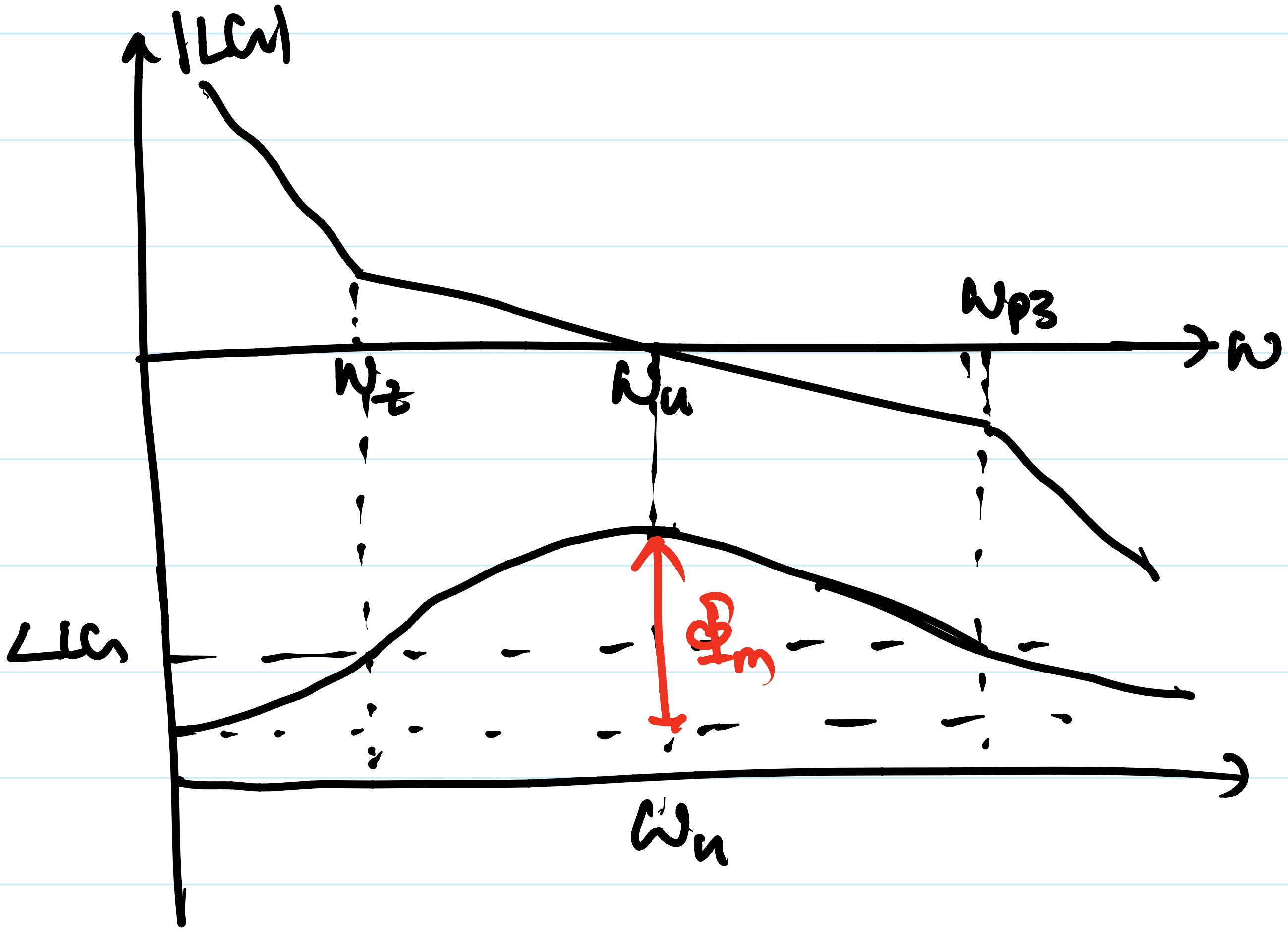
3) $\omega_z = \frac{\omega_u}{\sqrt{1+K_c}}, \quad \omega_{p3} = \omega_z(1+K_c)$

4) Choice for R – based on noise

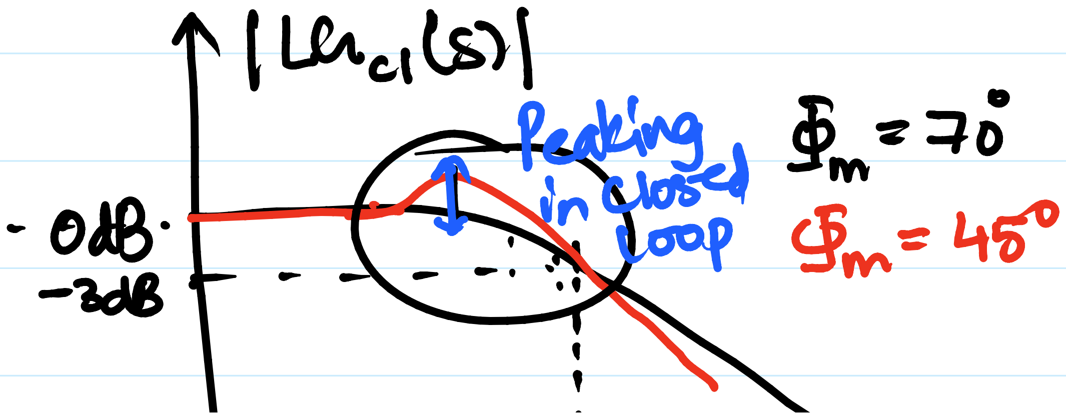
$$\omega_z = \frac{1}{RC_1} \Rightarrow C_1 \xrightarrow{K_C} C_2$$

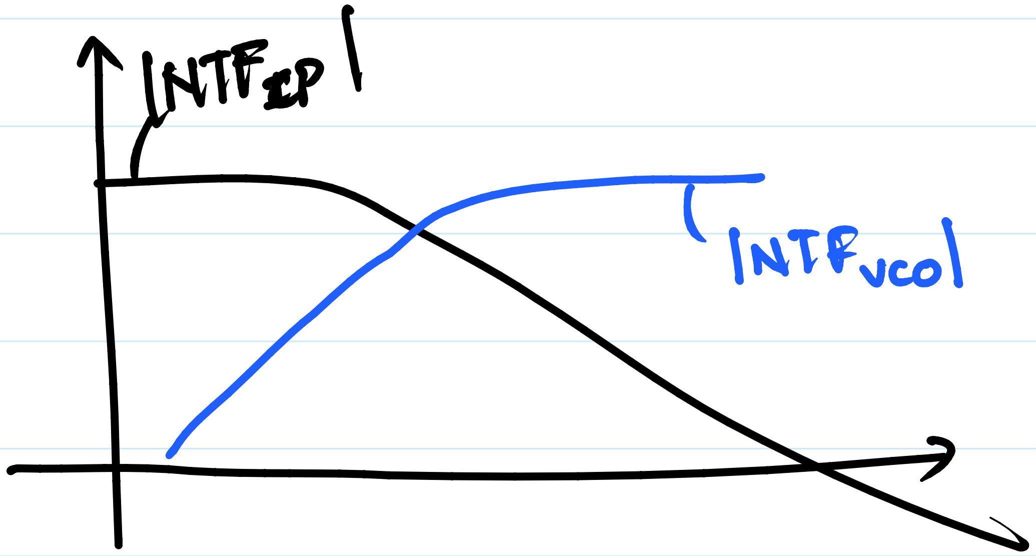
5) $$|LG(\omega_u)| = 1 \Rightarrow \left|\frac{I_{cp} K_{vco}}{2\pi \omega_u^2 C_2}\right|^2 \frac{\omega_u^2+\omega_z^2}{\omega_u^2+\omega_{p3}^2} = 1$$

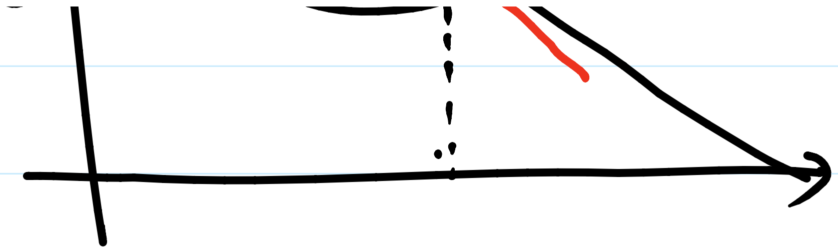
$\Rightarrow I_{cp}$



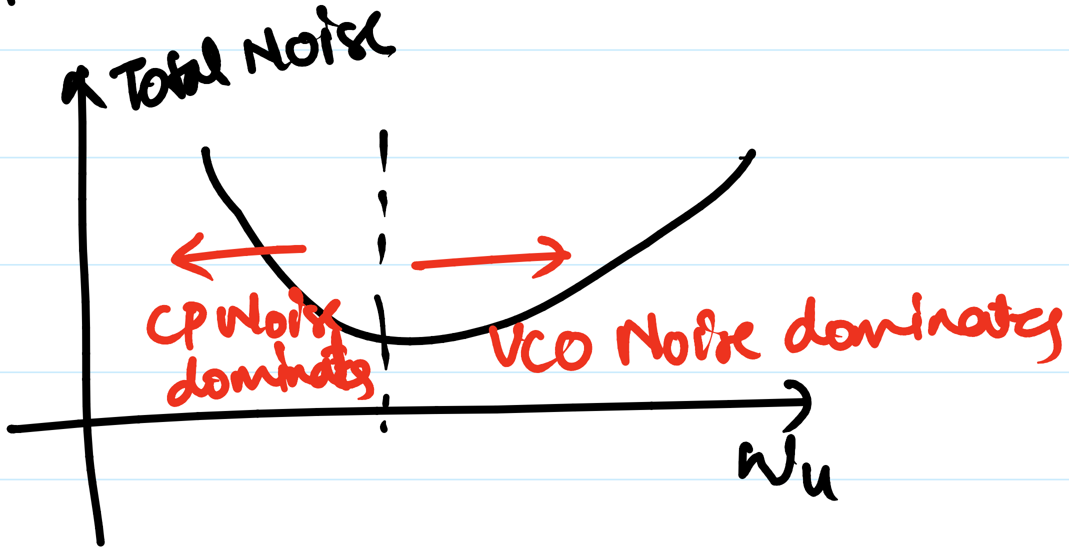
$$LG_{cl} = \frac{\Phi_{out}(s)}{\Phi_{in}(s)} = \frac{LG(s)}{1+LG(s)}$$



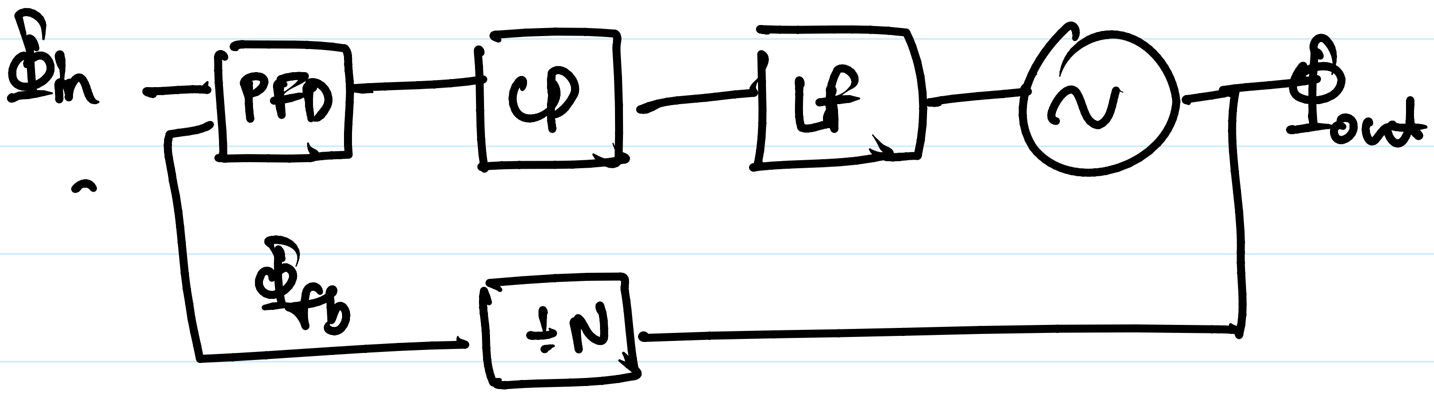


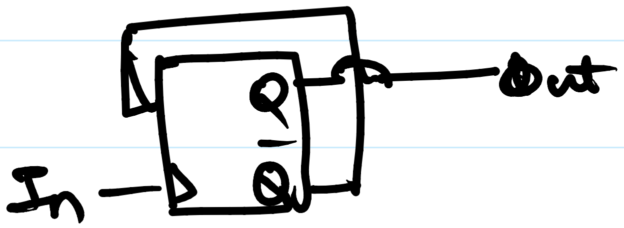


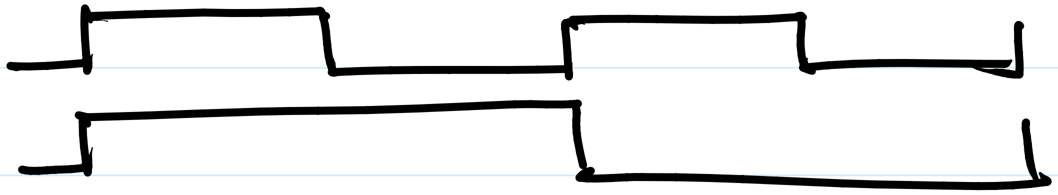
NTF_{CP} = Noise Transfer function for Charge pump



Charge-pump PLL as clock multiplier







$$f_{out} = N f_{ref}$$

$$L_G = \frac{I_{cp} K_{vco} \, 1}{2\pi \; s^2 C_2} \; \frac{s+\omega_z}{s+\omega_{p3}} \times \frac{1}{N}$$