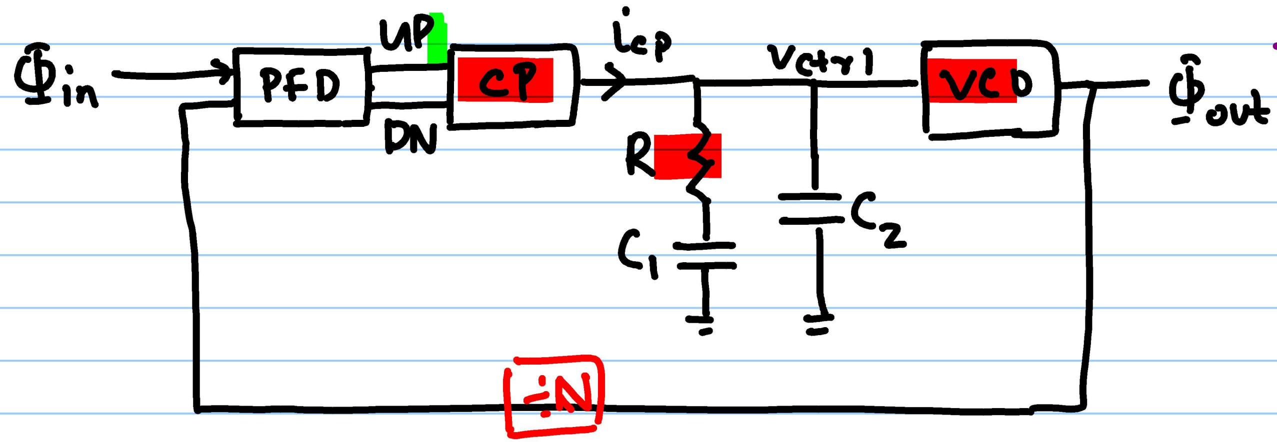
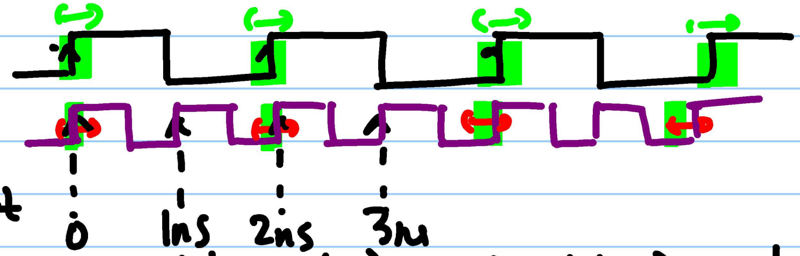
Lecture # 19

Note Title 31-08-2017

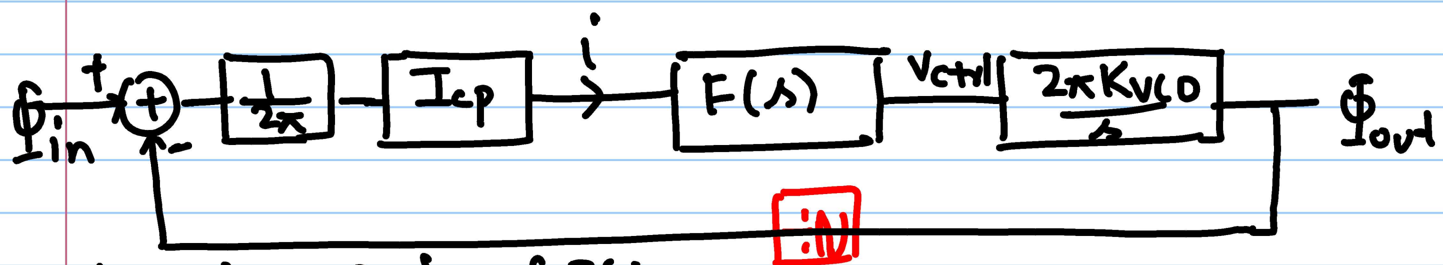
Charge-pump PLL





$$\frac{V_{ctrl}(s)}{I_{cp}(s)} = \left(R + 1/sC_1\right) \parallel \frac{1}{sC_2}$$

$$F(s) = \frac{(1+sC_1R)/sC_1}{\frac{1}{sC_2} + \frac{1+sC_1R}{sC_1}}$$



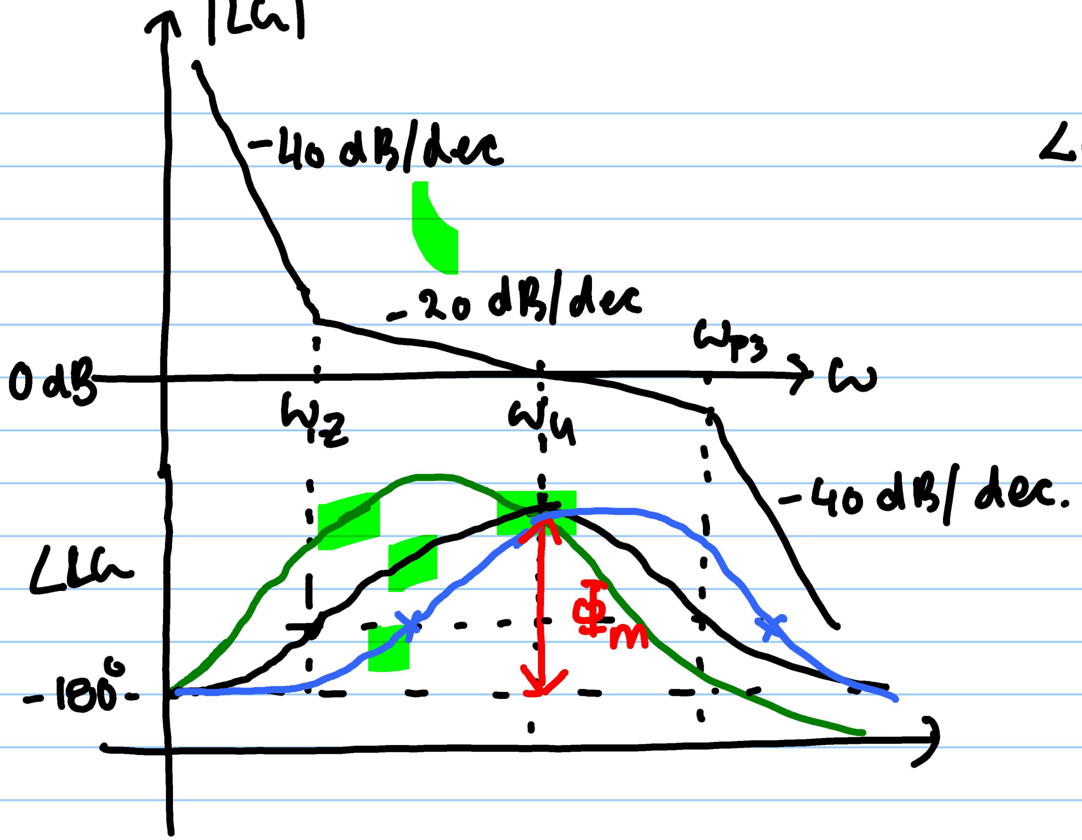
Open loop gain of PLL

$$LG(s) = \frac{I_{cp}}{2\pi} F(s) \times \frac{2\pi K_{vco}}{s}$$

$$= \frac{I_{cp} K_{vco}}{s^2 C_2} \frac{(s+\omega_z)}{(s+\omega_{p3})} \quad (1)$$

$$\omega_z = \frac{1}{RC_1}, \quad \omega_{p1} = \omega_{p2} = 0.$$

$$\omega_{p3} = \frac{1}{RC_1C_2/(C_1+C_2)}.$$

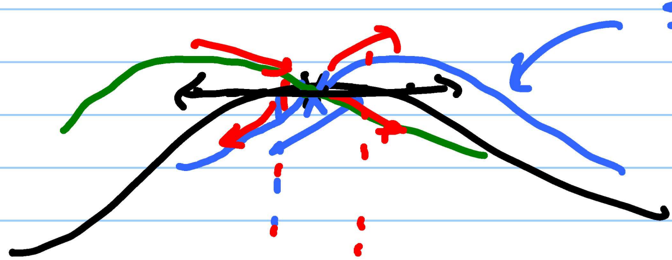


$$\angle LG = -180^\circ + \tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p3}}\right) \quad -(2)$$

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

ω_u: unity gain frequency

<u>Required</u> : ω_u, Φ_m



For ω_{p3} is higher – time domain response is fast.

$$|L_G(\omega_u)| = 1$$

$$\Phi = \tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_{p3}}\right)$$

$$\left.\frac{d\Phi}{d\omega}\right|_{\omega=\omega_u} = 0 \Rightarrow \boxed{\omega_u^2 = \omega_z \cdot \omega_{p3}} \checkmark$$

$$\omega_z = \frac{1}{RC_1}, \quad \omega_{p3} = \frac{1}{RC_1C_2/(C_1+C_2)}$$

$$\left.\frac{d\Phi}{d\omega}\right|_{\omega=\omega_u} = \frac{1}{1+\left(\frac{\omega_u}{\omega_z}\right)^2} \times \frac{1}{\omega_z} - \frac{1}{1+\left(\frac{\omega_u}{\omega_{p3}}\right)^2} \times \frac{1}{\omega_{p3}} = 0$$

$$\Rightarrow \cancel{\frac{\omega_{p3}}{\omega_z}} = \frac{1+\left(\frac{\omega_u}{\omega_z}\right)^2}{1+\left(\frac{\omega_u}{\omega_{p3}}\right)^2} = \frac{\omega_z^2+\omega_u^2}{\omega_{p3}^2+\omega_u^2} \times \frac{\omega_{p3}^2}{\omega_z^2}$$

$$\frac{\omega_z}{\omega_{p3}} = \frac{\omega_z^2+\omega_u^2}{\omega_{p3}^2+\omega_u^2}$$

$$\omega_z\omega_{p3}^2 + \omega_z\omega_u^2 = \omega_{p3}\omega_z^2 + \omega_{p3}\omega_u^2$$

tan → $\Phi_m = \tan^{-1}\left(\frac{\omega_u}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_u}{\omega_{p3}}\right)$

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

$$\left.\begin{array}{l} - \omega_u,\ \Phi_m \\ - \left.\frac{d\Phi}{d\omega}\right|_{\omega=\omega_u} = 0 \end{array}\right\} \Rightarrow \frac{C_1}{C_2} \checkmark, \quad \omega_u^2 = \omega_z \cdot \omega_{p3} \checkmark$$

$I_{cp}, R, C_1, C_2, K_{vco}$ (PLL parameters)

$$\omega_u^2(\omega_{p3}-\omega_z) = \omega_{p3}\omega_z(\omega_{p3}-\omega_z)$$

– Choose R (Noise perspective)

$$\omega_z = \frac{1}{RC_1}$$

$$\left(\frac{\omega_z}{\omega_u}\right) = f(\tan\Phi_m)$$

$$\omega_z = \frac{1}{RC_1} \Rightarrow C_1 = \frac{1}{R\omega_z}$$

R, C_1, C_2

$$|LG| = \frac{I_{cp} \cdot K_{vco}}{\omega_u^2 C_2}\sqrt{\frac{\omega_u^2+\omega_z^2}{\omega_u^2+\omega_{p3}^2}} = 1$$

$\Rightarrow I_{cp}$.

$$\omega_u^2 = \omega_z \cdot \omega_{p3}$$

$$\Phi_m = \tan^{-1}\left(\frac{\omega_u}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_u}{\omega_{p3}}\right)$$

$$= \tan^{-1}\left(\frac{\omega_u}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_z}{\omega_u}\right)$$

$$\tan(\Phi_m) = \frac{\frac{\omega_u}{\omega_z} - \frac{\omega_z}{\omega_u}}{1+1}$$

$$\underbrace{\frac{\omega_u}{\omega_z}}_{1/x} - \underbrace{\frac{\omega_z}{\omega_u}}_{x} = 2\tan\Phi_m.$$

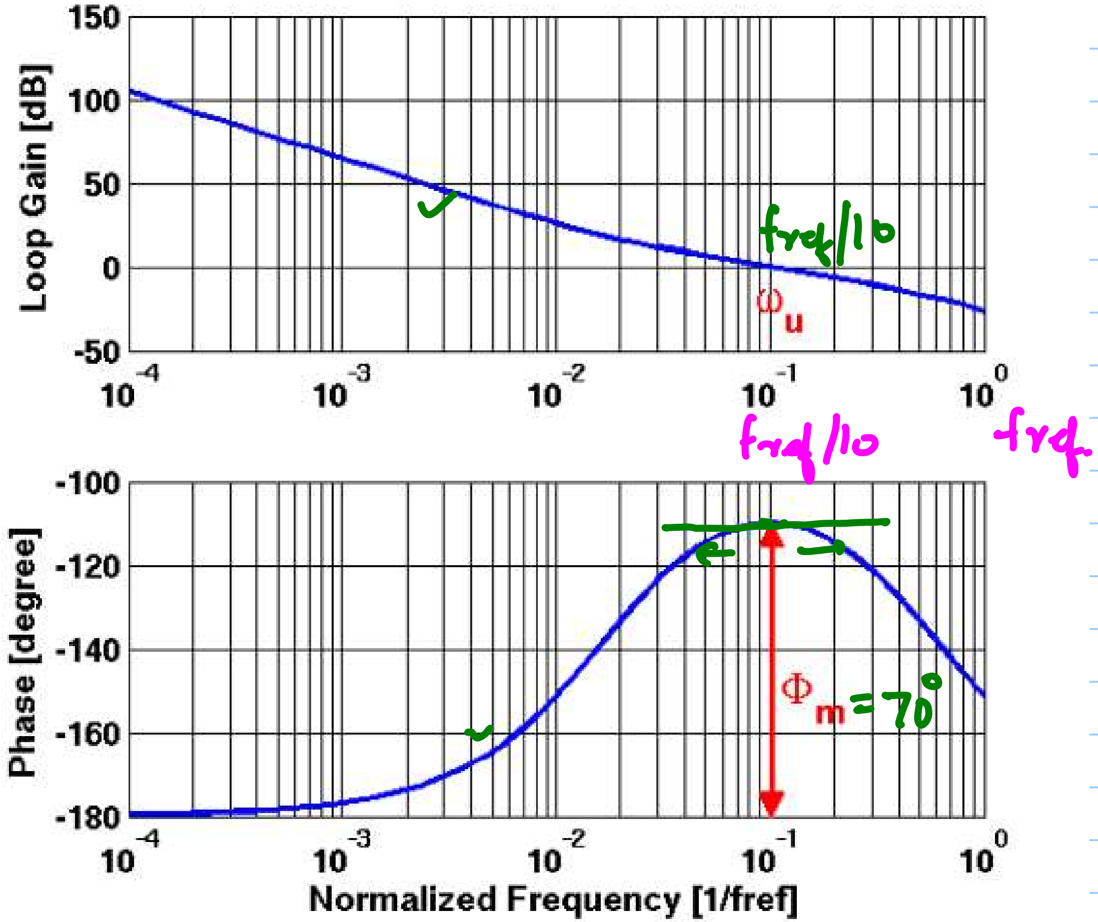
$$x - 1/x + 2\tan\Phi_m = 0$$

$$x^2 + 2x\tan\Phi_m - 1 = 0$$

$$\frac{\omega_z}{\omega_u} = x = \frac{-2\tan\Phi_m + \sqrt{4\tan^2\Phi_m + 4}}{2} \checkmark$$

Given: $\omega_u, \Phi_m \Rightarrow \omega_z, \omega_{p3} \xrightarrow{R} C_1 \longrightarrow C_2$

$\xrightarrow{K_{VCO}} I_{CP}$.



$\omega_u = \frac{\omega_{fref}}{10}$, $\Phi_m = 70°$

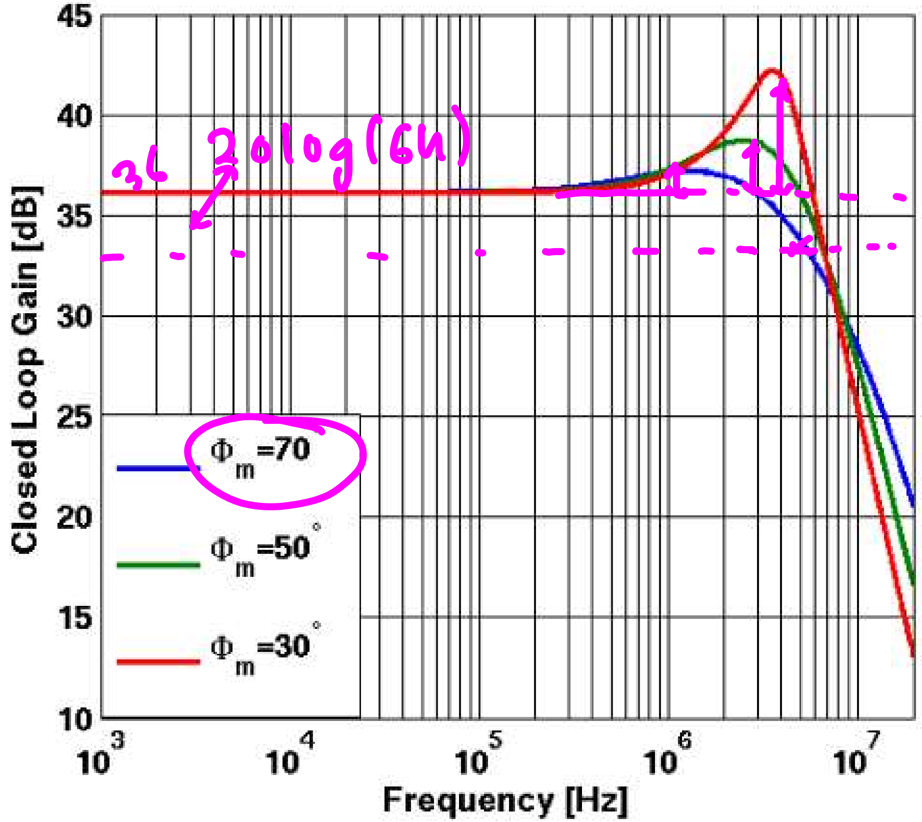
$K_{VCO} = 100\,MHz/V$, $R = 1k\Omega$

$$\frac{\Phi_{out}}{\Phi_{in}} = \frac{LG}{1+LG}$$

$$= N \cdot \frac{LG}{1+LG}$$

$$\frac{\Phi_{out}}{\Phi_{in}} = \frac{LG}{1+LG} \quad \text{(w/o freq. multiplication)}$$

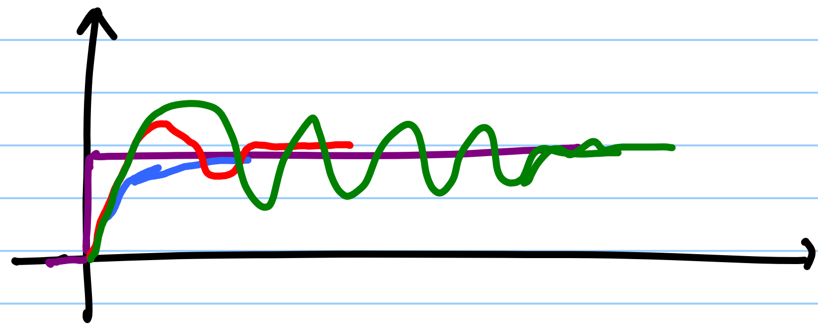
$$= N \cdot \frac{LG}{1+LG} \quad \text{(w/ freq. multiplication)}$$



$f_{ref} = 40\,\text{MHz}.$

$\boxed{N = 64}$

$f_{out} = 2.56\ \text{GHz}.$



$\underbrace{\omega_u}_{\text{Noise @ o/p}}$, Φ_m, K_{vco}, R