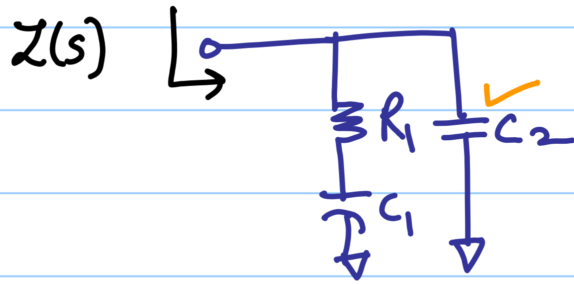
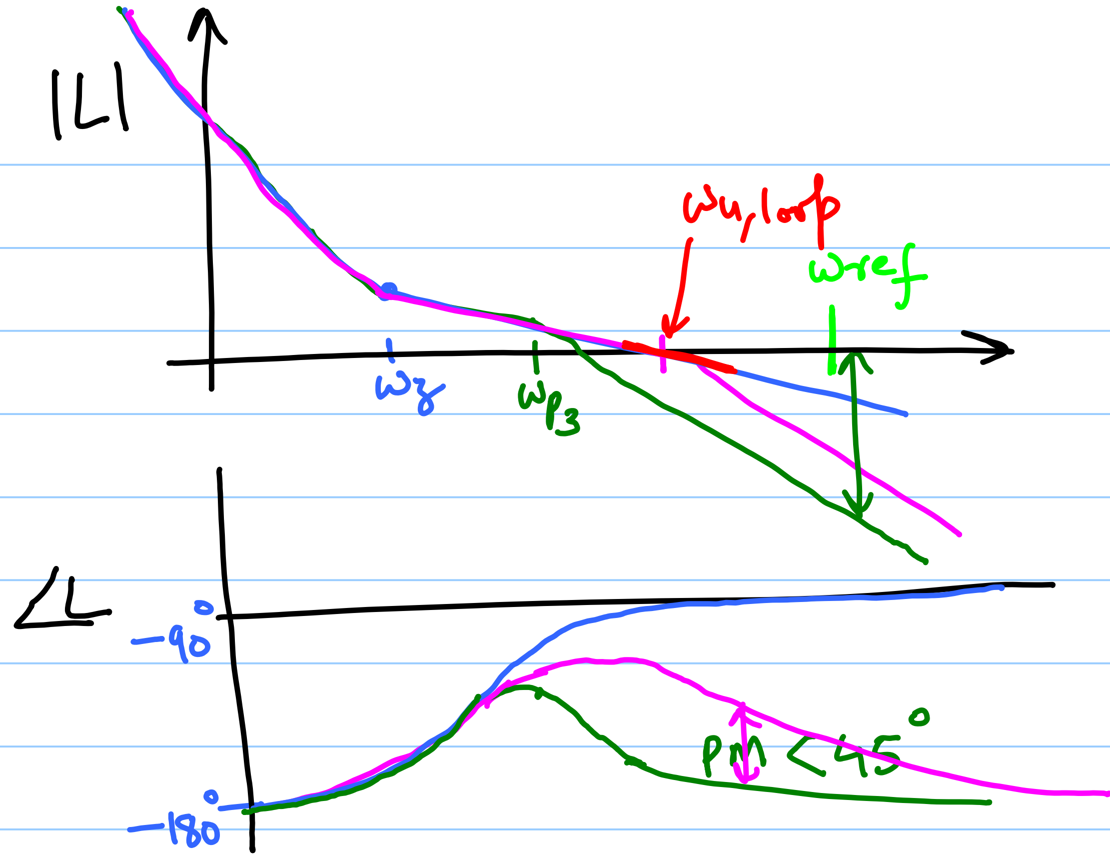
ECE 518 - Lecture 9

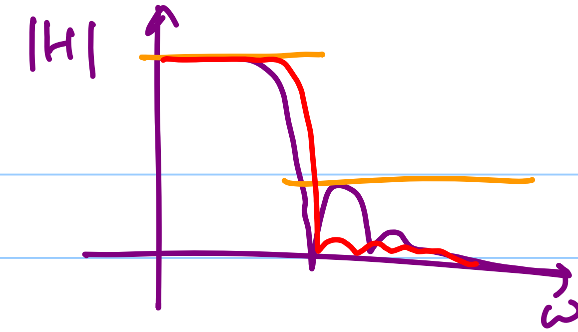
Note Title 2/12/2015

Type-II, 3rd order PLL



$$L(s) = \frac{K_{VCO}}{N}\frac{I_o}{s^2}\frac{(1+sR_1C_1)}{(1+sR_1\, C_1\|C_2)}\cdot\frac{1}{C_1+C_2}$$





$\omega_{p_3} > \omega_{u,loop}$

for phase margin $> 45°$

Phase Margin

$$\phi_M = \tan^{-1}\left(\frac{\omega_{u,loop}}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_{u,loop}}{\omega_{p_3}}\right)$$

increases PM

decrease PM

$$= \tan^{-1}\left(R_1 C_1 \cdot \omega_{u,loop}\right) - \tan^{-1}\left(R_1 C_1 \| C_2 \cdot \omega_{u,loop}\right)$$

$$= \tan^{-1}(A) - \tan^{-1}(B)$$

$$= \tan^{-1}\left(\frac{A-B}{1-AB}\right)$$

from H. Rategh's JSSC 2000 paper:

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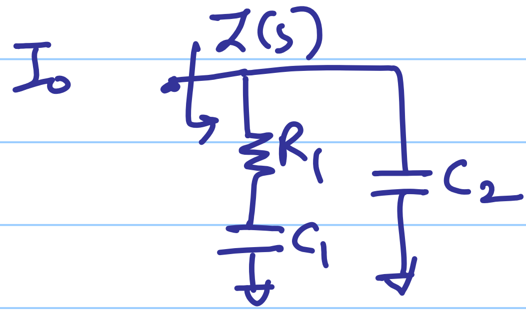


$$\boxed{b = \frac{C_1}{C_2}},$$

$$\omega_z = \frac{1}{R_1 C_1}$$

$$\omega_{p3} = \frac{1}{R_1 \frac{C_1 C_2}{C_1 + C_2}} = \frac{1}{R_1 C_1} \cdot \left(\frac{C_1 + C_2}{C_2}\right)$$

$$\boxed{\omega_{p3} = \omega_z \cdot (b+1)}$$

For a 3rd-order PLL, Type-II PLL

$$Z(s) = \frac{b}{b+1} \cdot \frac{\left(\frac{s}{\omega_z}+1\right)}{sC_1\left(\frac{s}{(b+1)\omega_z}+1\right)}$$

$$L(s) = \frac{K_{VCO} \cdot I_0}{N} \cdot \left(\frac{b}{b+1}\right) \cdot \frac{\left(\frac{s}{\omega_z}+1\right)}{s^2 C_1 \left(\frac{s}{\omega_z (b+1)}+1\right)} \longrightarrow ①$$

$$\left(\frac{s}{\omega_z (b+1)}+1\right) \longrightarrow \left(\frac{s}{\omega_{p3}}+1\right)$$

Phase margin of the loop:

$$\phi_M = \tan^{-1}\left(\frac{\omega_{u,loop}}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega_{u,loop}}{(b+1)\,\omega_z}\right)$$

$$\frac{\partial \phi_M}{\partial \omega_{u,loop}} = 0 \quad \text{for PM maxima}$$

$$\phi_M = \underbrace{\phi_{M,max}} \quad \text{when} \quad \omega_{u,loop} = \left(\sqrt{b+1}\right)\omega_z$$

$$\phi_{M,max} = \tan^{-1}\left(\sqrt{b+1}\right) - \tan^{-1}\left(\frac{1}{\sqrt{b+1}}\right) = f(b) \longrightarrow (2)$$

Max ϕ_M is function of $b = \frac{c_1}{c_2} > 1$

for $b < 1$ or $c_1 < c_2 \Rightarrow PM < 20^\circ$

$\hookrightarrow$ unstable loop

force $\boxed{\omega_{u,loop} = \sqrt{b+1}\ \omega_z}$ for maximizing PM $\rightarrow$ (3)

from (1) we have

$$\omega_{u,loop} \simeq \frac{K_{vco} \cdot I_o}{N}\left(\frac{b}{b+1}\right) \cdot \frac{1}{C_1 \omega_z} \longrightarrow (4)$$

combining (3) & (4)

$$\Rightarrow \omega_{u,loop} = \frac{K_{vco} I_o}{N}\left(\frac{b}{b+1}\right) \cdot \frac{1}{C_1} \cdot \frac{1}{\omega_z} = \sqrt{b+1} \cdot \omega_z$$

$$\boxed{\frac{K_{vco} \cdot I_o}{N} = \frac{(b+1)^{3/2}}{b} C_1 \omega_z^2} \longrightarrow (4)$$

from (2)

$$\phi_M = \tan^{-1}\left(\frac{b}{2\sqrt{1+b}}\right) \longrightarrow (5)$$

$$b = 2\left(\tan^2\phi_M + \tan\phi_M\sqrt{1+\tan^2\phi_M}\right) \longrightarrow (6)$$

Also, $\zeta = \frac{1}{2}\left(\frac{C_1}{C_1 \| C_2}\right)^{1/4} \longrightarrow (7)$

$\zeta = 0.783$ for $b = \frac{C_1}{C_2} = 5$

$= \frac{1}{\sqrt{2}}$

Design Procedure:

① find K_{VCO} from simulation (unit $\frac{Hz}{V}$)

② choose a desired phase margin (ϕ_m) and find b from Eq ⑥

③ choose a loop bandwidth ($\omega_{u,loop}$) and find ω_z from Eqn ③

④ Select C_1 & I_0 such that Eqn ④ is satisfied

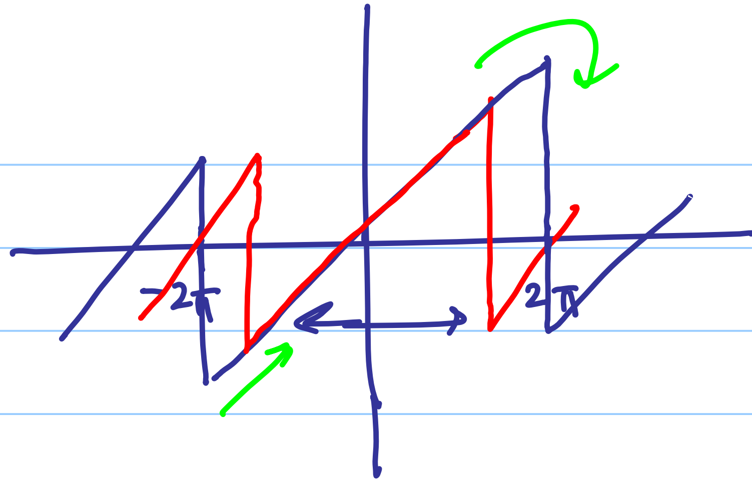
⑤ $\omega_z = \frac{1}{R_1 C_1} \Rightarrow R_1 = \frac{1}{\omega_z C_1}$

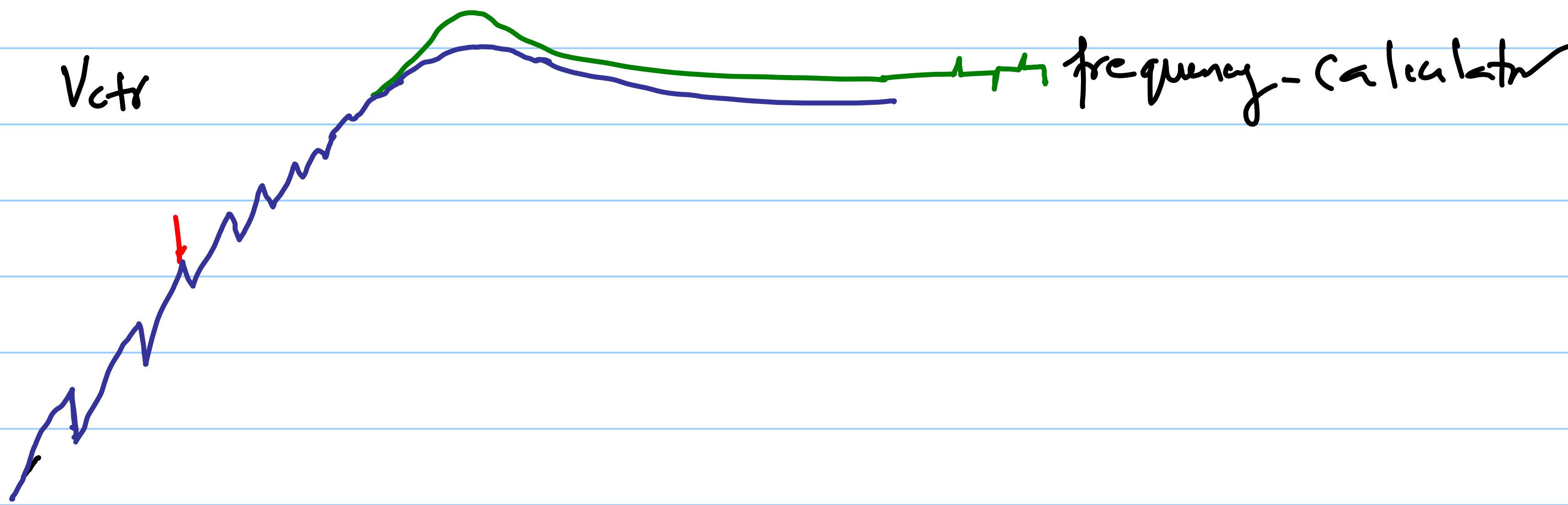
estimate noise contribution from R_1

if too noisy go back to step ④ and

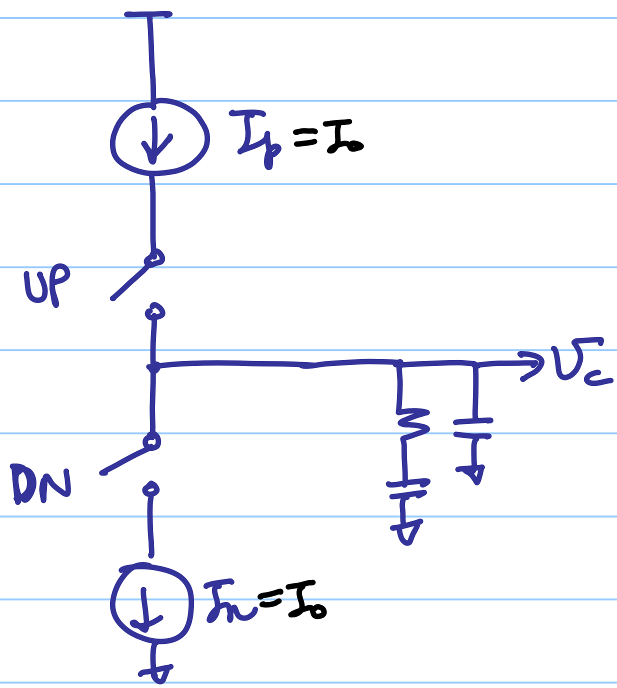
change c_1

PFD

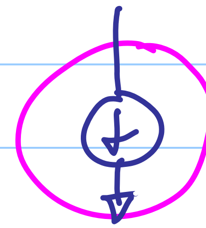


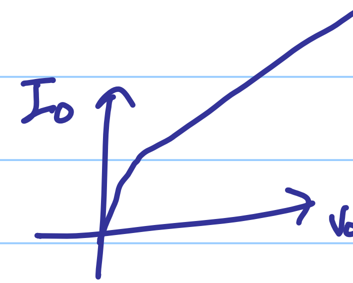


Charge Pump :

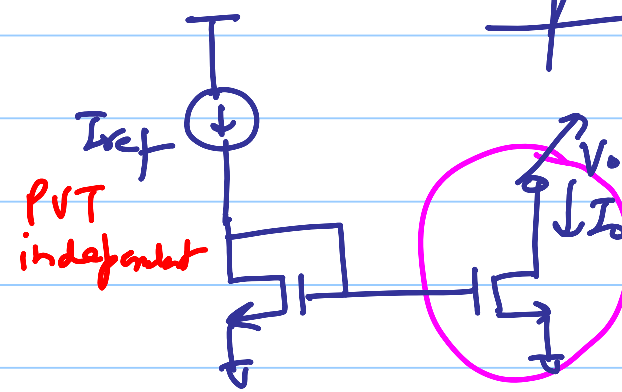


$I_p = I_o$
UP
V_c
DN
$I_n = I_o$

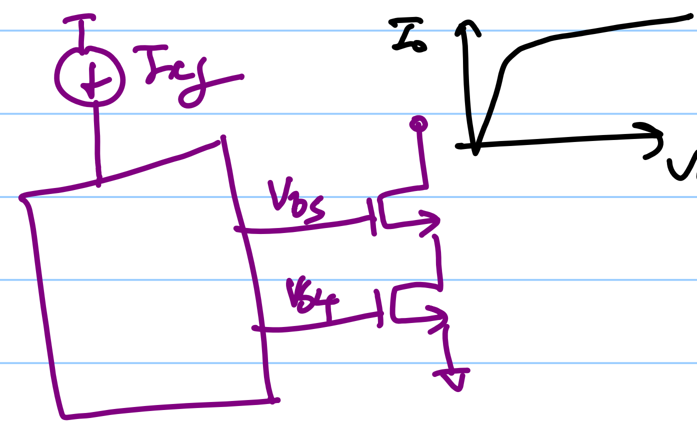




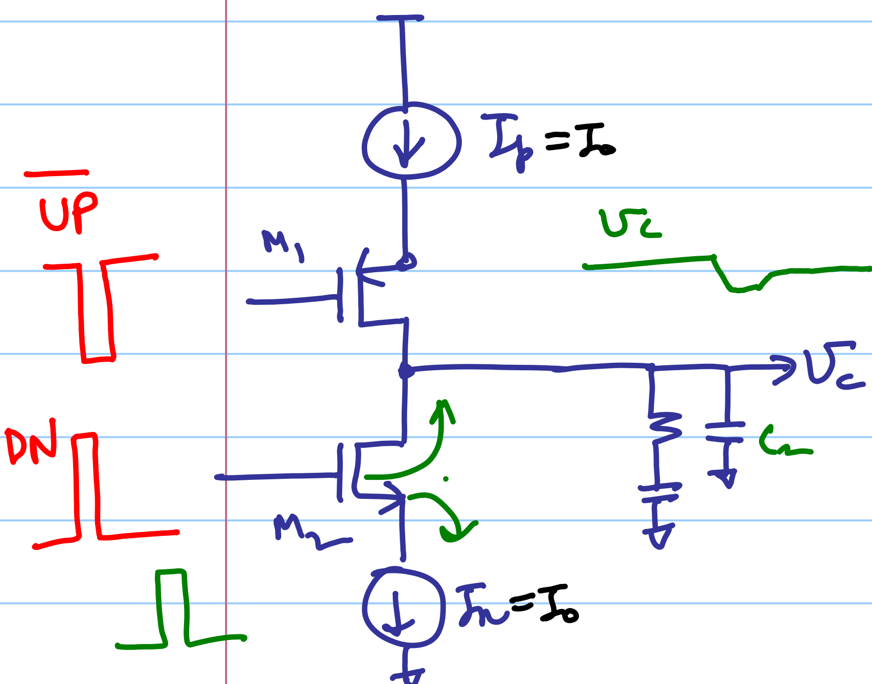
I_o
V_o

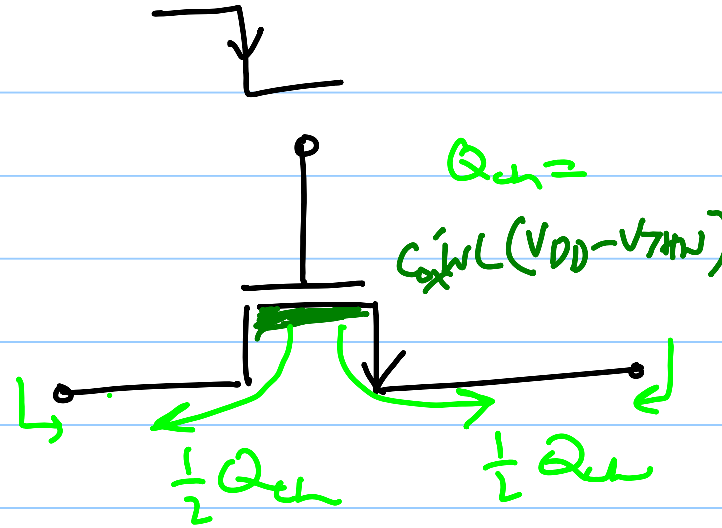


Iref
PVT independent
V_o
I_o



Iref
V_{B3}
V_{B4}
I_o
V_o





charge injection