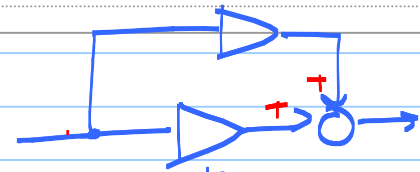
ECE 518 - Lecture 15

Note Title 3/12/2013

$$L(s) = \frac{2\pi K_{VCO}}{N\cdot s}\Big[\underbrace{\frac{K_{PD,I}}{s}}_{I} + \underbrace{K_{PD}}_{P}\Big]$$

K_{PD} proportional path



$\frac{K_{PD,I}}{s}$

Find ω where $|L(j\omega)| = 1$

$$\Rightarrow L(s) = \frac{2\pi K_{VCO}}{N\cdot s}\,\frac{K_{PD,I}}{s}\left[1 + \frac{s K_{PD}}{K_{PD,I}}\right]$$

$\left(1 + \frac{s}{\omega_z}\right) \cong \frac{s}{\omega_z}$

$\omega_z \rightarrow \frac{K_{PD,I}}{K_{PD}}$

$$\cong \frac{2\pi K_{VCO}}{N}\,\frac{\cancel{K_{PD,I}}}{s^{\cancel{2}}}\cdot\frac{\cancel{s}\,K_{PD}}{\cancel{K_{PD,I}}}$$

around GX point

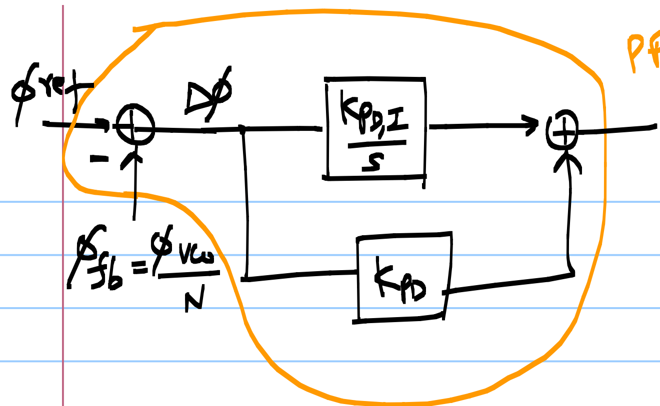
$$= \left|\frac{2\pi K_{VCO} K_{PD}}{N\, s}\right| = 1$$

$$\Rightarrow \boxed{\omega_{u,loop} \cong \frac{2\pi K_{VCO}\cdot K_{PD}}{N}}$$

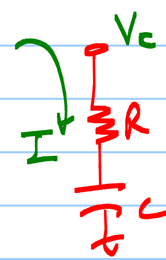
Similar to the Type I PLL

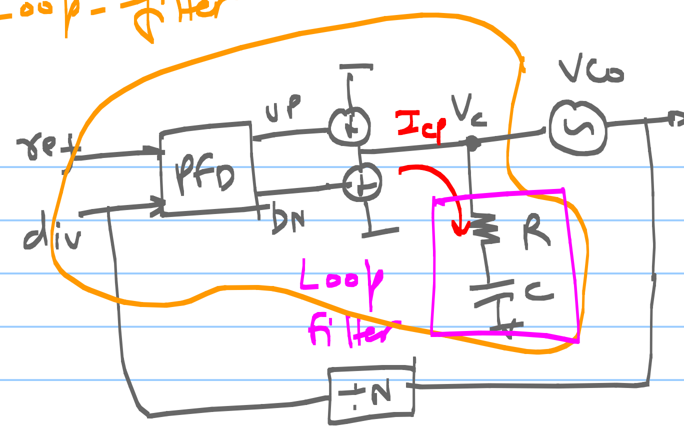
unity loop-gain frequency

PFD + CP ⟶ Loop-filter



Phase-domain incremental model





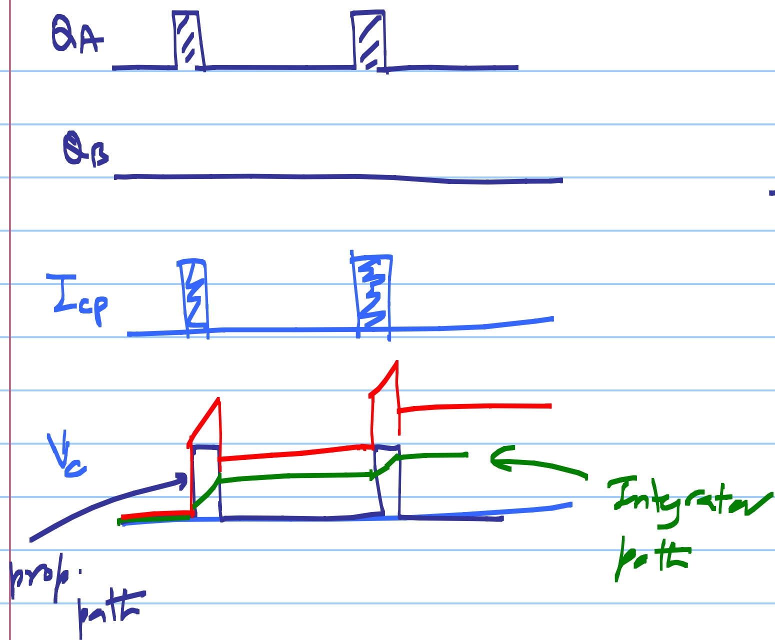
circuit-level schematic

Type-II PLL

$$K_{PD,I} = \frac{I_o}{2\pi C}$$

$$Z(s) = R + \frac{1}{sC}$$

$$K_{PD} = \frac{I_o R}{2\pi}$$



$\Delta\phi \Rightarrow$ jump in the o/p frequency

$$\Delta\phi \cdot \frac{I_0 R}{\cancel{2\pi}} \cdot \cancel{2\pi} K_{VCO}.$$

$\Rightarrow$ jump in the divider frequency

$$\Delta\phi \underbrace{\left[\left(\frac{I_0 R K_{VCO}}{N}\right)\right]}_{\omega_{u,loop}}$$

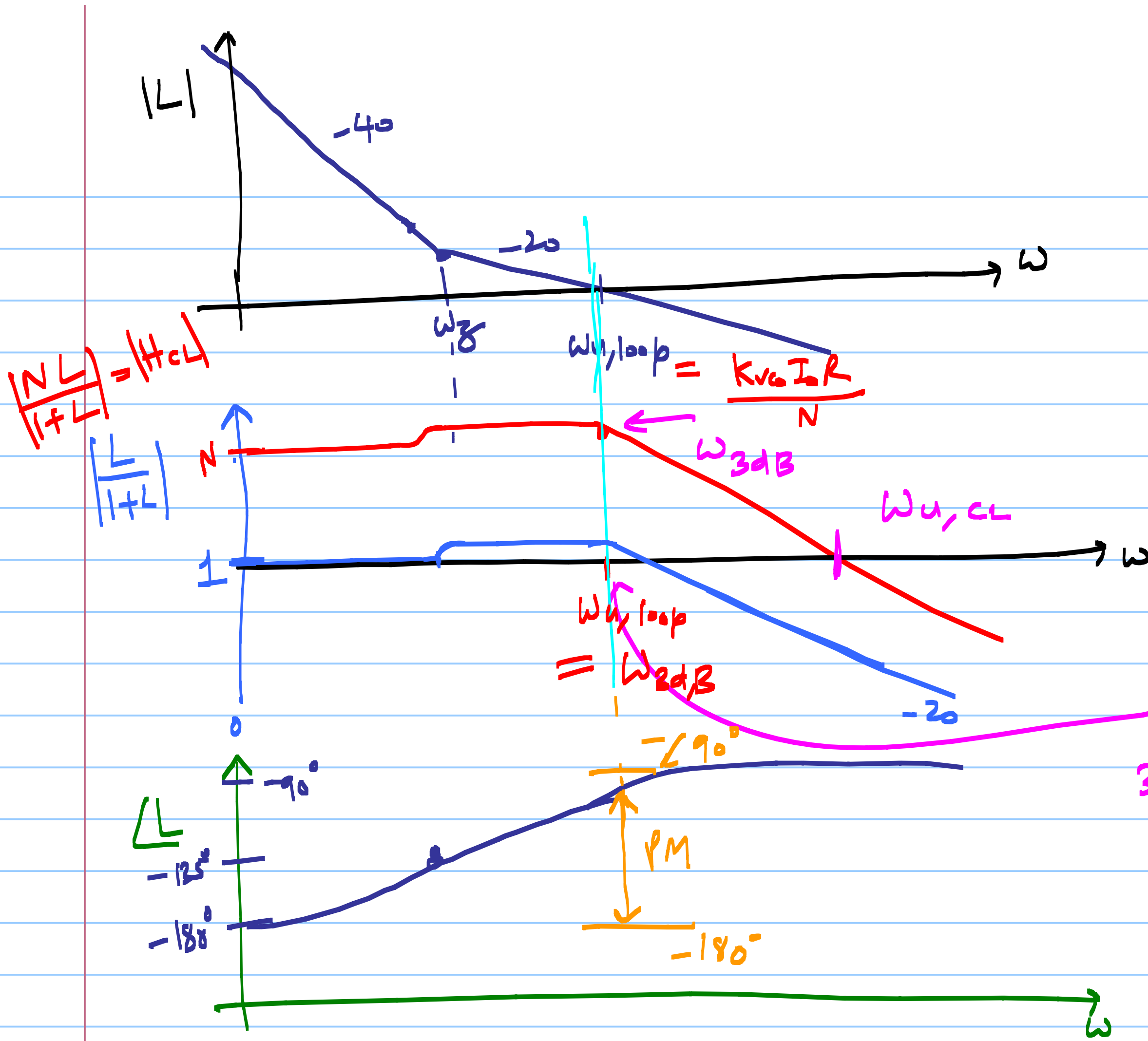
$$\omega_{u,loop} = \frac{2\pi K_{VCO} \cdot K_{PD}}{N} \qquad K_{PD} = \frac{I_0 R}{2\pi}$$

$$= \frac{\cancel{2\pi} K_{VCO} I_0 R}{\cancel{2\pi} N}$$

$$\boxed{\omega_{u,loop} = \frac{K_{VCO} \cdot I_0 R}{N}}$$

"Note 2π factor cancellation"

$K_{VCO} \rightarrow \frac{Hz}{V}$

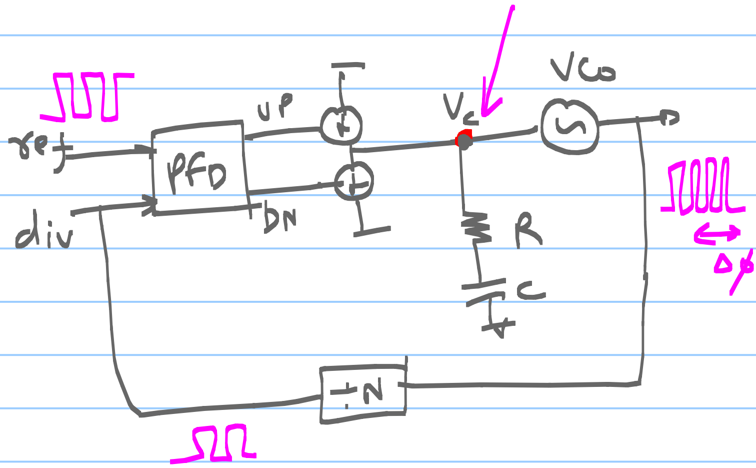


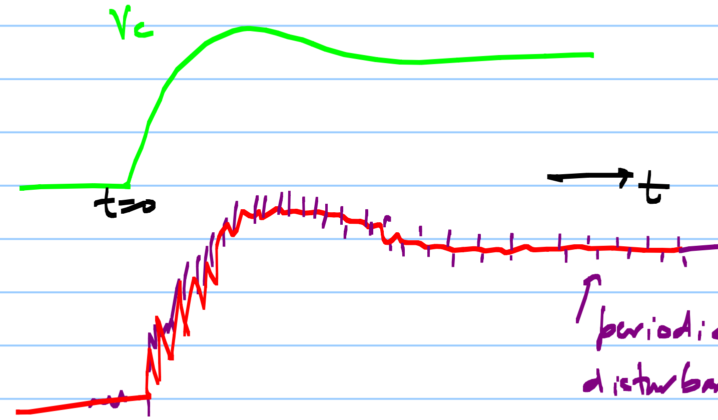
$$\left|\frac{L}{1+L}\right| = \begin{cases} 1, & |L| \gg 1 \\ |L|, & |L| \ll 1 \end{cases}$$

loop bandwidth
3dB BW of the closed-loop

$$\omega_z = \frac{K_{PD,I}}{K_{PD}} = \frac{\frac{I_0}{2\pi C}}{\frac{I_0 R}{2\pi}} = \frac{1}{RC}$$

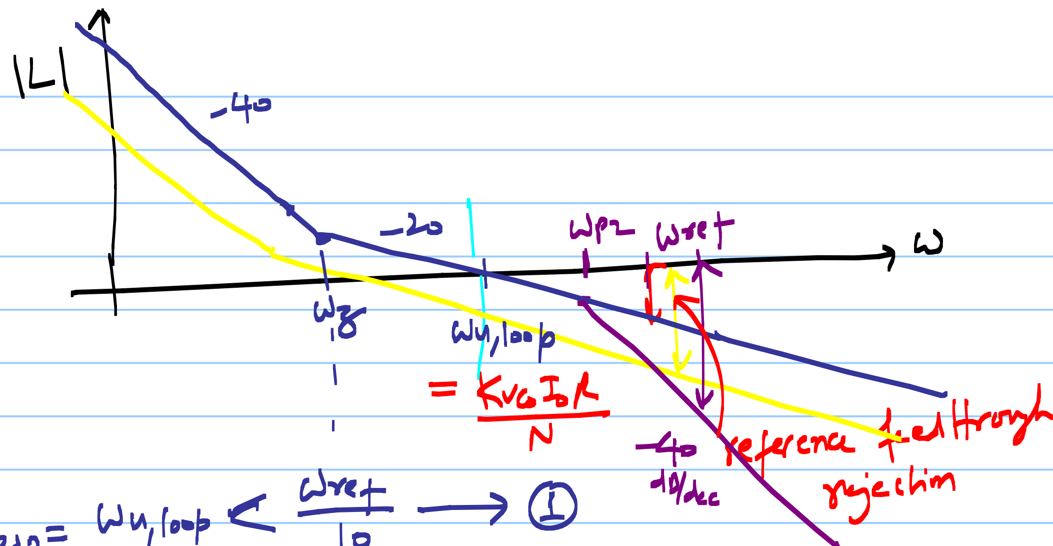
LNA





periodic disturbance

⇒ ripples in V_c



$\omega_{3dB} = \omega_{u,loop} < \frac{\omega_{ref}}{10} \longrightarrow$ (1)

CT approximation $\longrightarrow$ (2)

Small loop BW

Type-II PLL

$\Rightarrow \Delta\phi = 0$

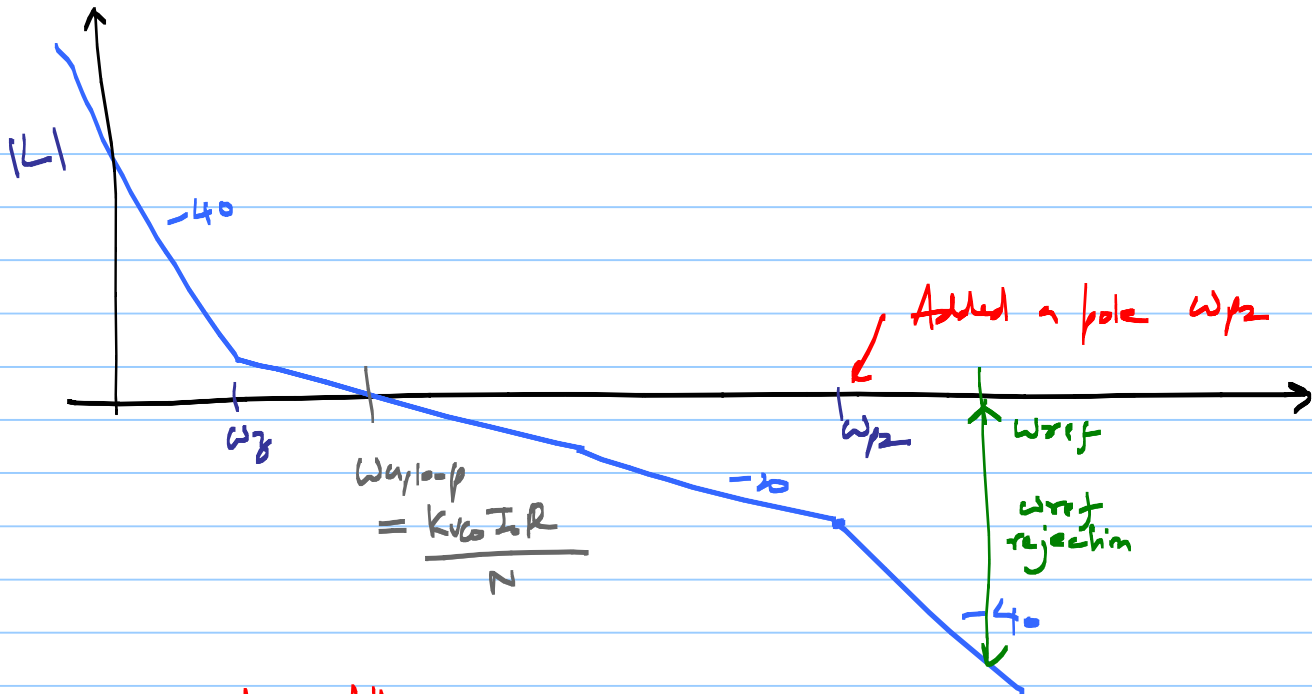
* mismatch in charge pump
* Q_A & Q_B mismatch

* Add another pole for ω_{ref} rejection
* PM reduced

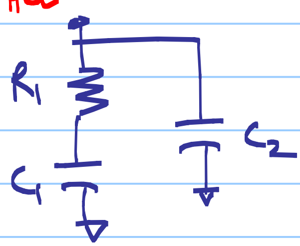
$\omega_{u,loop}$ $\Rightarrow$ larger loop BW $\longrightarrow$ (+) fast response
wider tracking/locking range

(−) more reference feedthrough

$\Rightarrow$ smaller loop BW $\longrightarrow$ (−) slow changes frequencies



Loop-filter



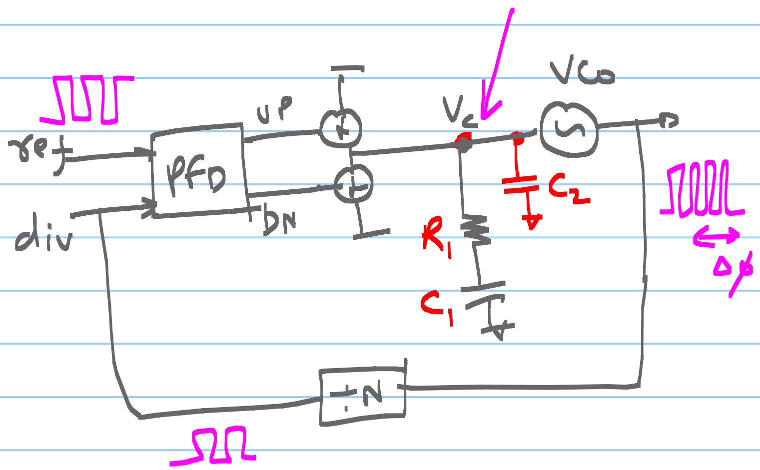
2^{nd}-order loop filter

$s_p = 0, -\omega_{p2}$

Type-II

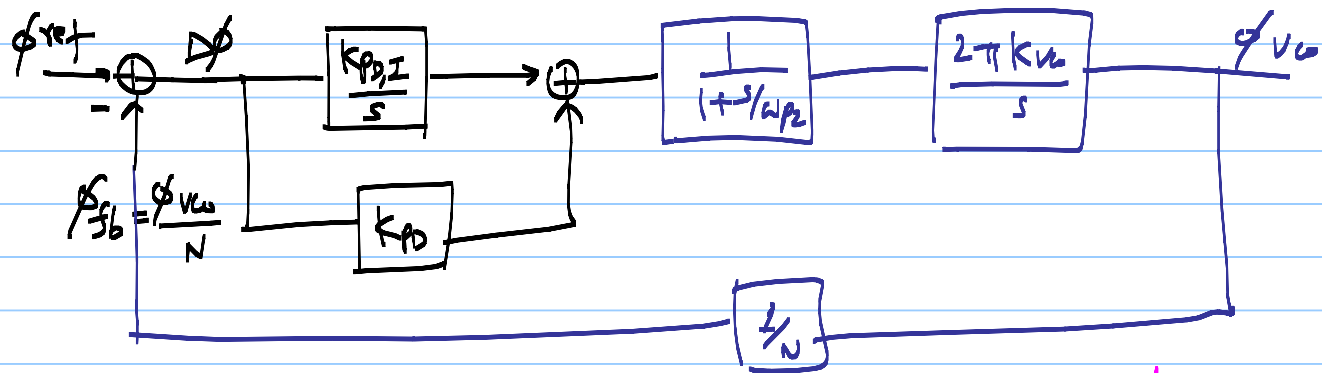
↳ order → 3rd order system

Loop filter → 2nd order



* Type-II PLL with a third pole

phase domain model



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

$$\omega_{p_2} = \frac{1}{R_1 (C_1 \| C_2)}$$

$$\frac{C_1 C_2}{C_1 + C_2}$$

$$L(s) = \frac{K_{vco} I_0}{s^2 (C_1 + C_2) N} \frac{(1 + sR_1C_1)}{(1 + sR_1\, C_1\|C_2)}$$

PLL Design Example:

Spec. $f_{out} = 1\ GHz$

$f_{ref} = 10\ MHz$

$\Rightarrow N = 100$

VCO $\Rightarrow$ $K_{VCO} = 100\ \frac{MHz}{V}$

$V_q = 0.9V$

$V_{DD} = 1.8V$

loop-BW: $f_{BW,loop} = \frac{f_{ref}}{25} = 400\ kHz$ "chosen arbitrarily"

$\Rightarrow \omega_{BW,loop} = 2\pi \times 400\ kHz$

$$\frac{K_{VCO}(I_0 R)}{N} = 2\pi \times 400\ kHz$$

$$\frac{100\ \frac{MHz}{V} \cdot (I_0 R)}{100} = 2\pi \times 400\ kHz$$

$\Rightarrow \quad \boxed{I_0 R \simeq 2.4\ V}$

$I_0 = 1mA \Rightarrow R = 2.4k$

$\omega_z < \omega_{n,loop}$

$\times \quad \omega_z = \frac{1}{RC} = \frac{\omega_{n,loop}}{2} = 2\pi \times 200kHz$

$\Rightarrow \quad \frac{1}{RC} = 2\pi \times 200k$

$\Rightarrow \quad C = \frac{1}{2\pi \times 200k \times 2.4k}$

$= 332\ pf$

$@ \frac{1fF}{\mu m^2} \Rightarrow \boxed{332\ mm^2}$

$\Rightarrow \quad 1\ mm^2 \Rightarrow \$60k$

$C_1 < 20pF$