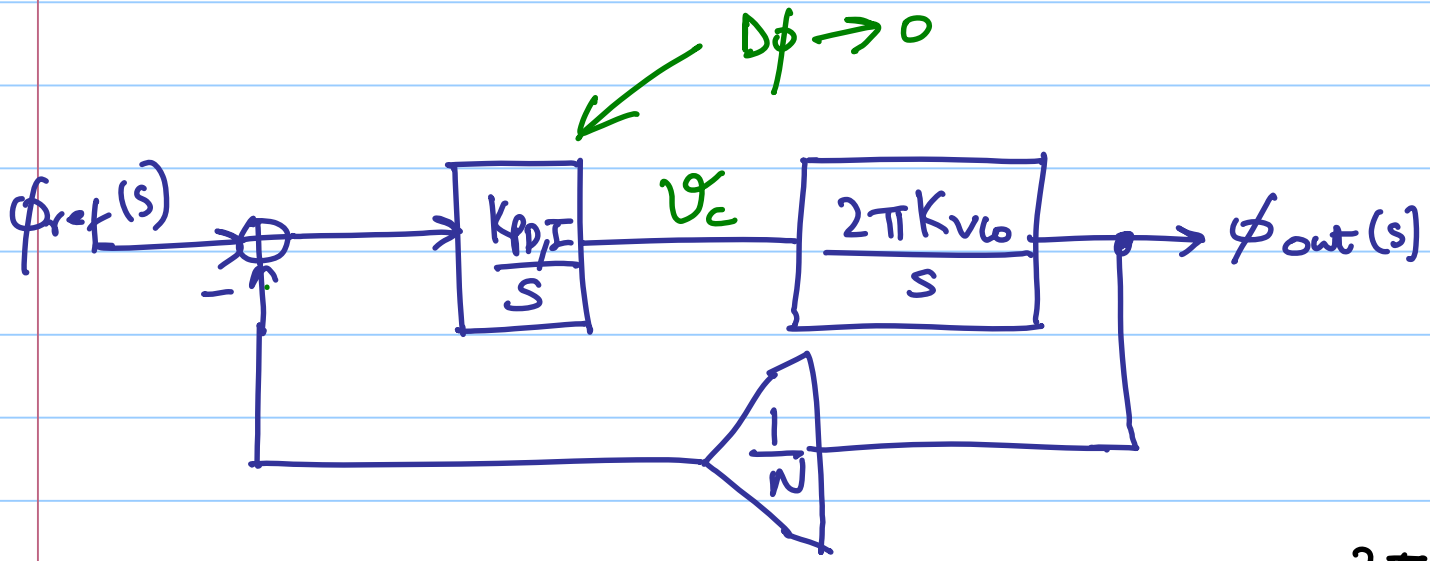
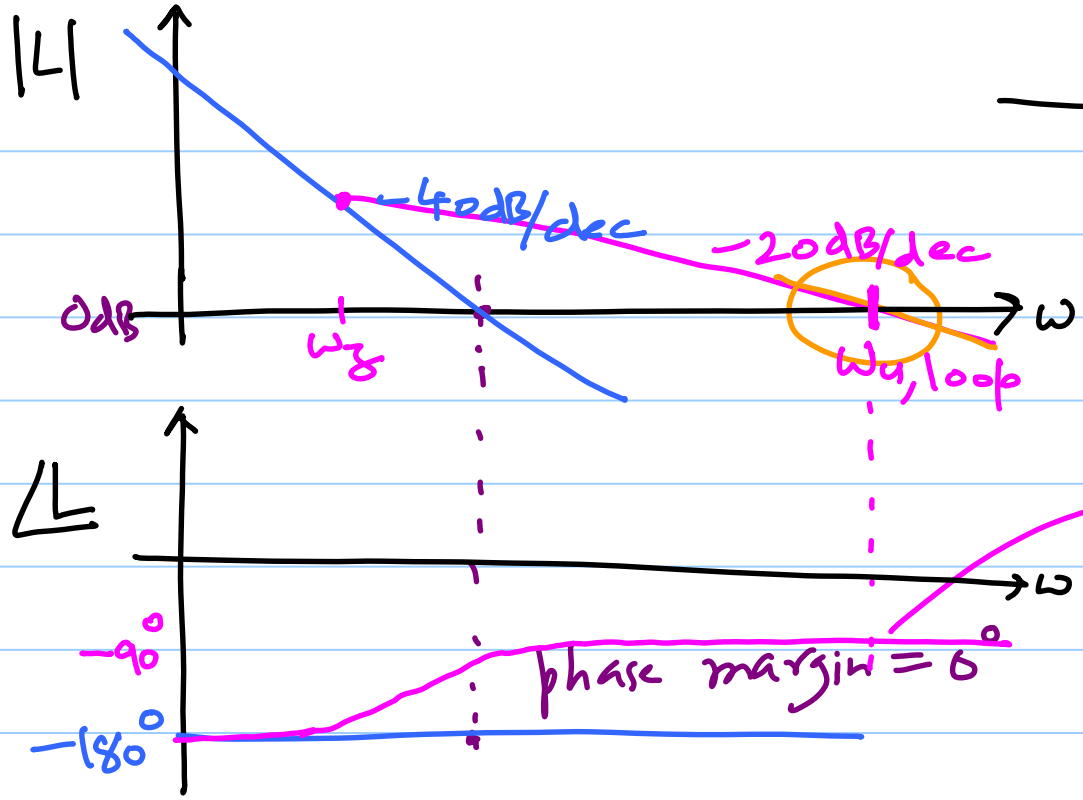
ECE 518 - Lecture 6

Note Title 2/3/2015

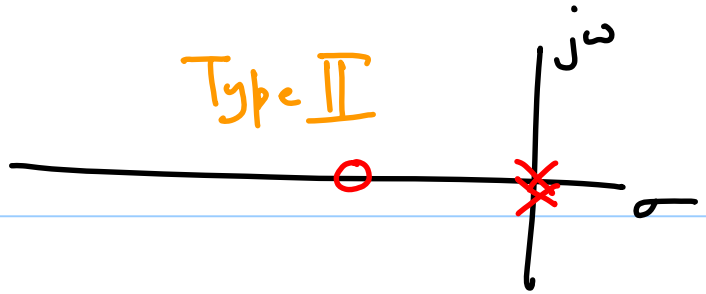


$$L(s) = \frac{2\pi K_{PD,I} \cdot K_{VCO}}{N \cdot s^2}$$

2-poles at DC

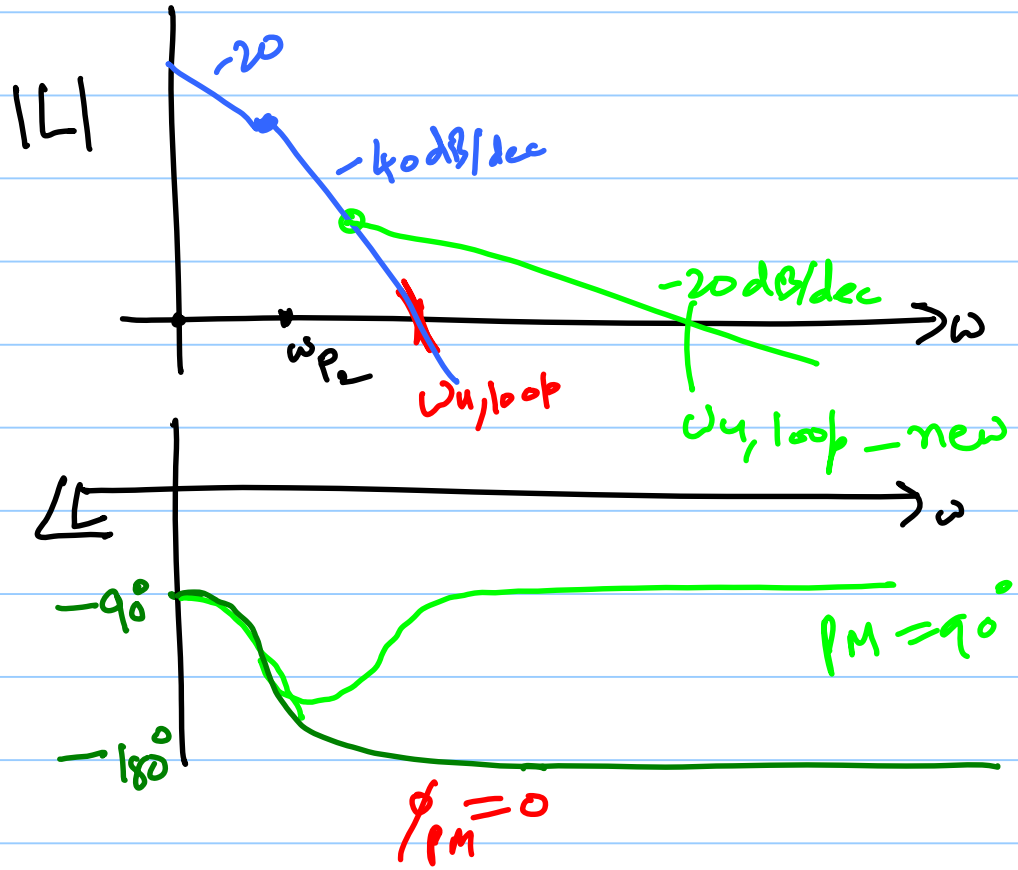


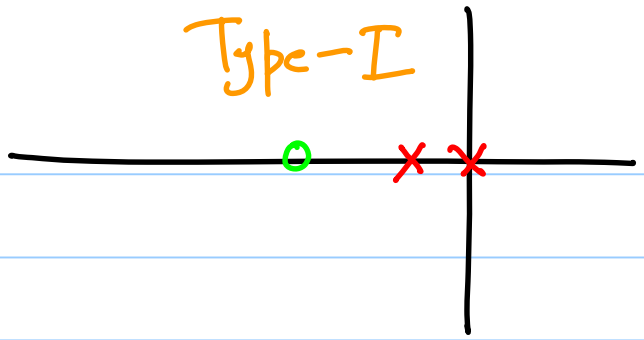
Type II



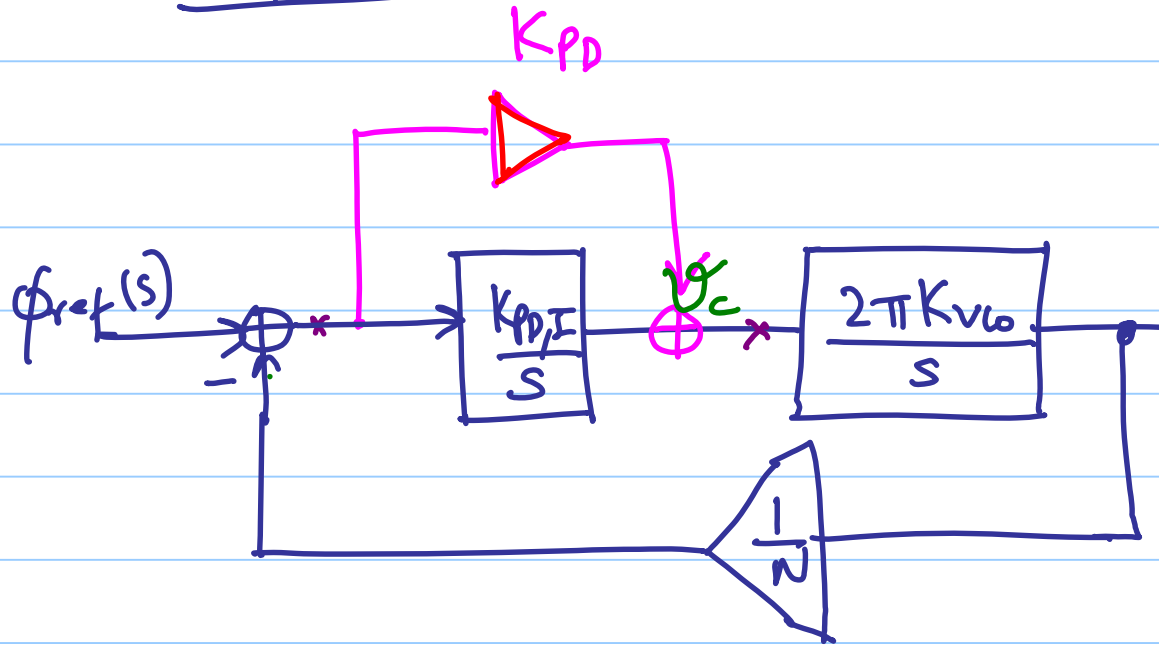
phase margin $\leq 90^\circ$

Aside


|L|
-20
-40dB/dec
-20dB/dec
ω_{p_2}
$\omega_{u,loop}$
$\omega_{u,loop\_new}$
$\angle L$
ω
-90°
-180°
$PM = 90^\circ$
$\phi_{PM} = 0$


Type-I

Type-II PLL



$$LF(s) = K_{PD} + \frac{K_{PD,I}}{s}$$

$$= \frac{(sK_{PD} + K_{PD,I})}{s}$$

$$= \left(\frac{1 + sK_{PD}/K_{PD,I}}{s/K_{PD,I}}\right)$$

$$= \frac{\left(1 + \frac{s}{\omega_z}\right)}{s/K_{PD,I}}$$

Type II $\Rightarrow$ 2 poles at DC

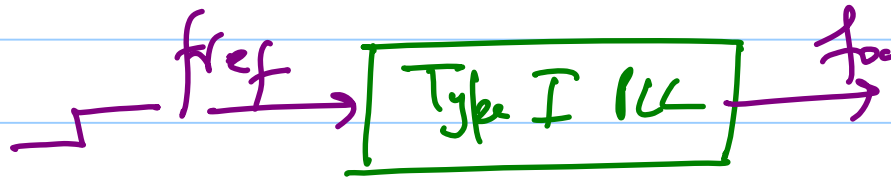
↳ not same as the order

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

Type II ⇒ 2 poles at DC

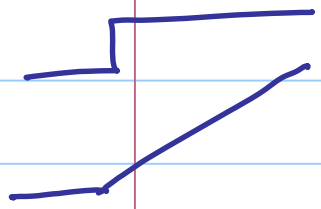
* with a Type-I system ⇒ the steady-state error to a step input = 0

ss error due to a ramp input ≠ 0



$\phi = \int f_{req}$ ⇒ $\Delta\phi \neq 0$

A type II PLL ⇒ ss error with input step & input ramp = 0



$\Delta f_{req} \to 0$

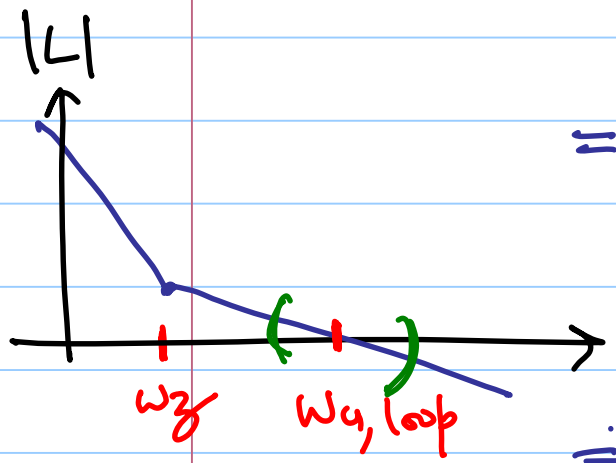
$\Delta\phi \to 0$

$L(s) = \frac{1}{s}$ ← Type I ⟷ $u(t)$

$\frac{1}{s^2}$ ← Type II ⟷ $t\,u(t)$

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

$$= \frac{2\pi K_{VCO}\,(sK_{PD} + K_{PD,I})}{N s^2}$$



$$= 2\pi K_{VCO} \cdot K_{PD_I} \frac{\left(1 + \frac{sK_{PD}}{K_{PD,I}}\right)}{N \cdot s^2}$$

$$= \frac{2\pi K_{VCO}\, K_{PDI}}{N} \cdot \frac{(1 + s/\omega_z)}{s^2}$$

$$\omega_z = \frac{K_{PDI}}{K_{PD}}$$

To find $\omega_{u,loop}$

$|L| = 1 \Rightarrow$ find $\omega = \omega_{u,loop}$

$\omega \simeq \omega_{u,loop} \gg \omega_z$

$\left(\frac{s}{\omega_z}+1\right) \simeq \frac{s}{\omega_z}$ for $\omega \gg \omega_z$

pole-zero cancellation

$$L(s) \simeq \frac{2\pi K_{VCO} \cdot K_{PD,I}}{N} \cdot \frac{1}{s^2} \cdot \omega_z$$

$$= \frac{2\pi K_{VCO} K_{PD,I}}{NS} \left(\frac{K_{PD}}{K_{PD,I}}\right)$$

$$= \frac{2\pi K_{VCO} K_{PD}}{NS}$$

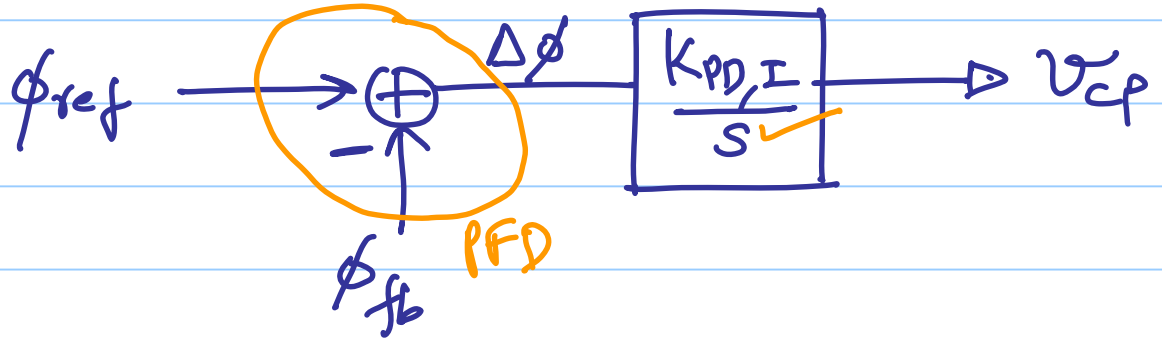
for $|L|=1$

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

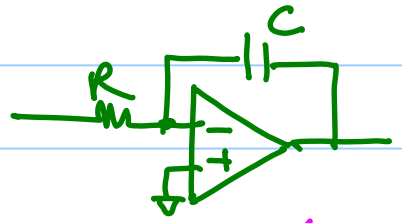
* Σ^n looks the same as the Type-I PLL

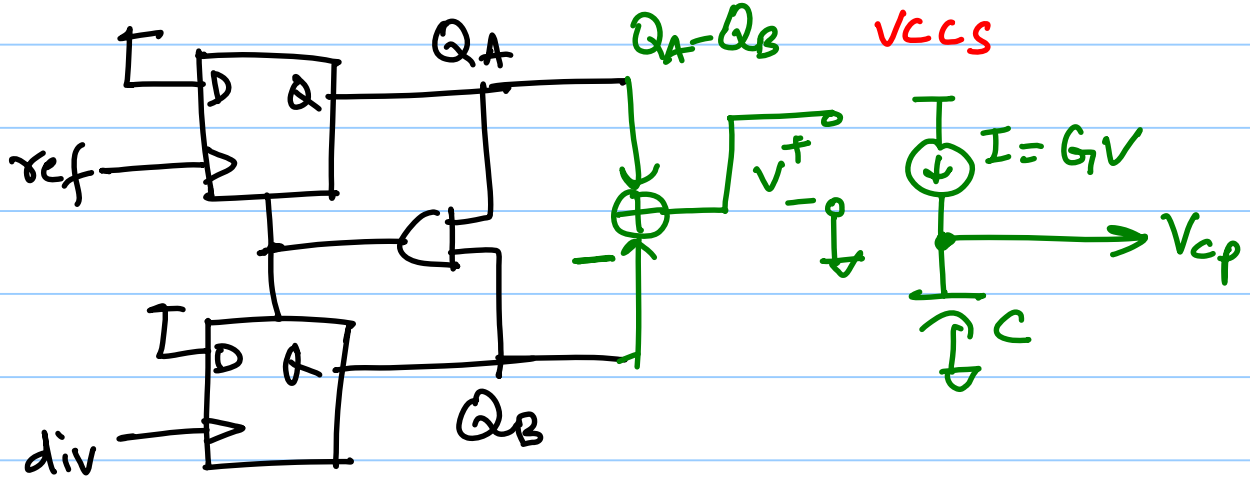
But, $\Delta\phi \to 0$

* Need to construct the integrating loop-filter

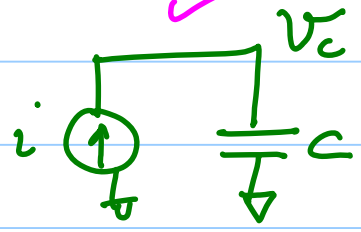


→ to the VCO





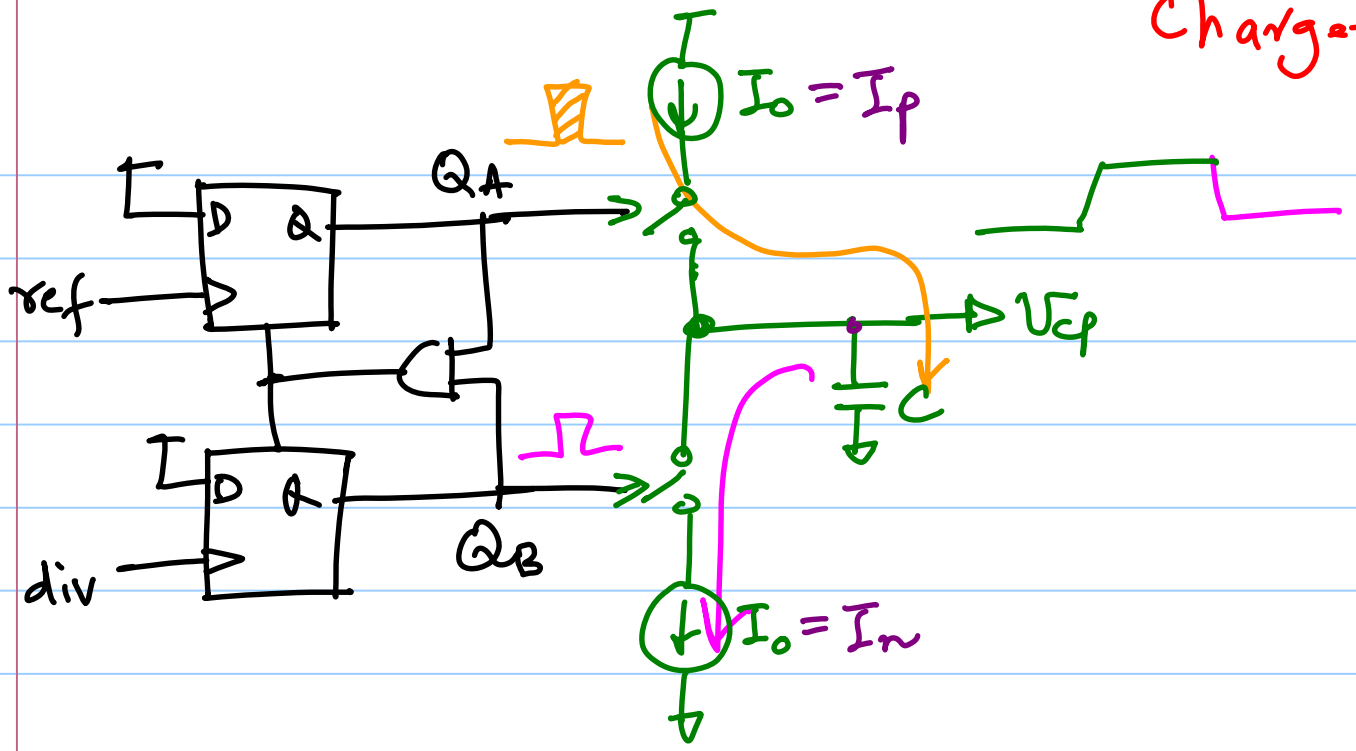
VCCS



$$v_c = \frac{1}{C}\int i\,dt$$

$$= \frac{I}{sC}$$

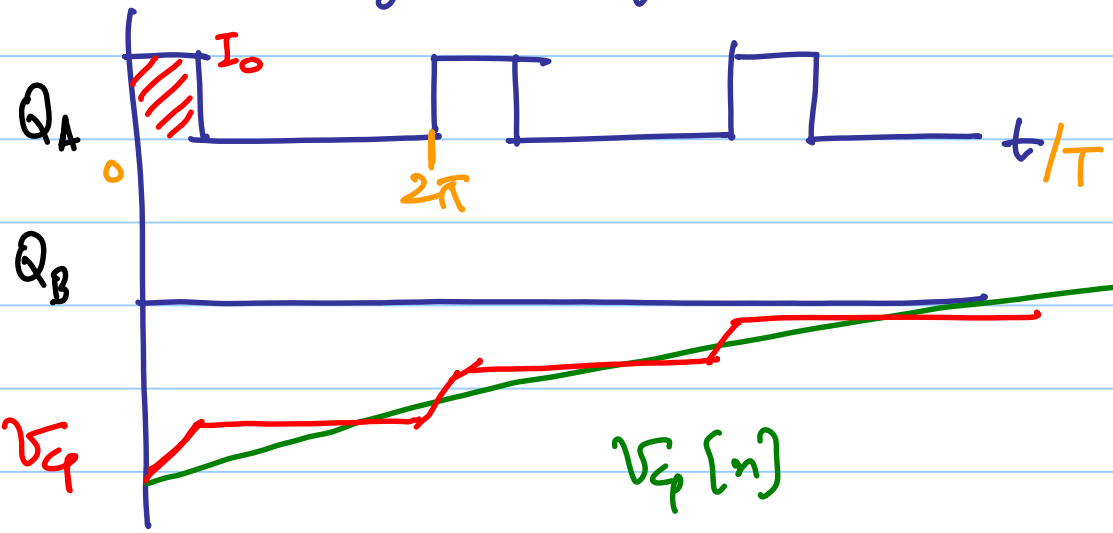
Charge-pump PLL



push current $Q_A > 0$

pull current $Q_B > 0$

* Let's say the ref clock is leading div



DT operation of the PLL

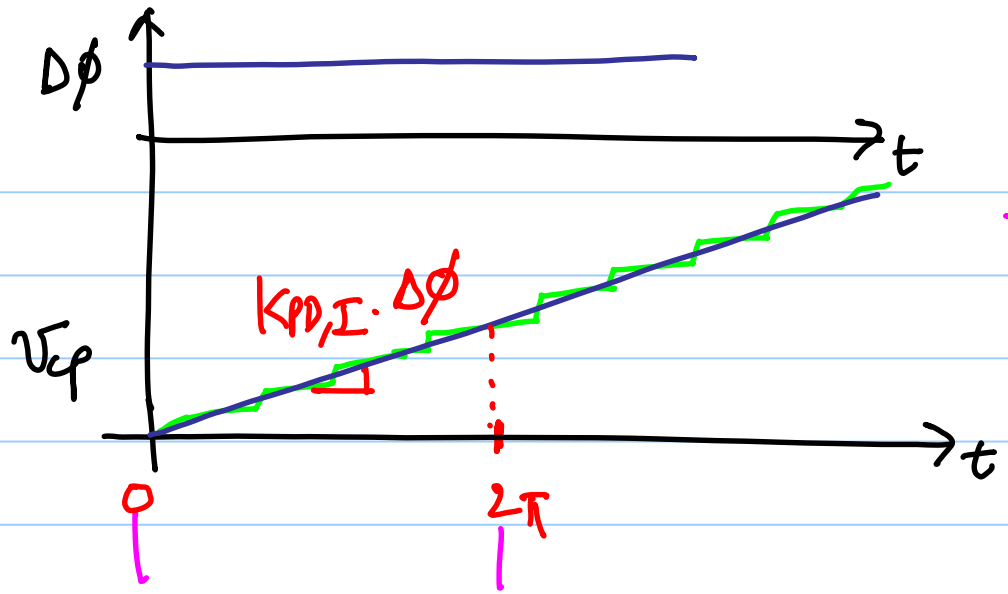
CT approximation for $\omega_{u,loop} \ll \omega_{ref}$

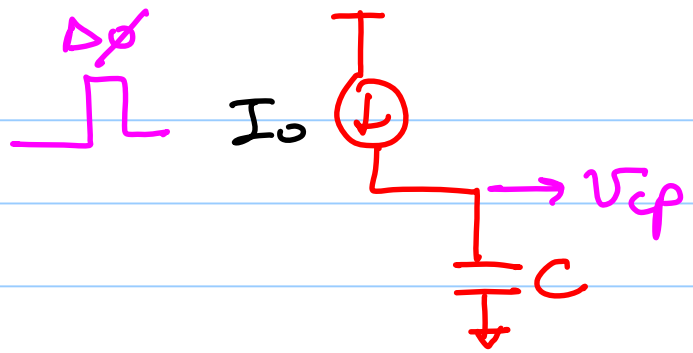
$\omega_{u,loop} \leq \frac{\omega_{ref}}{10}$

We can approximate this system as a CT for analysis

as long as $\omega_{c,loop} \leq \frac{\omega_{ref}}{10}$

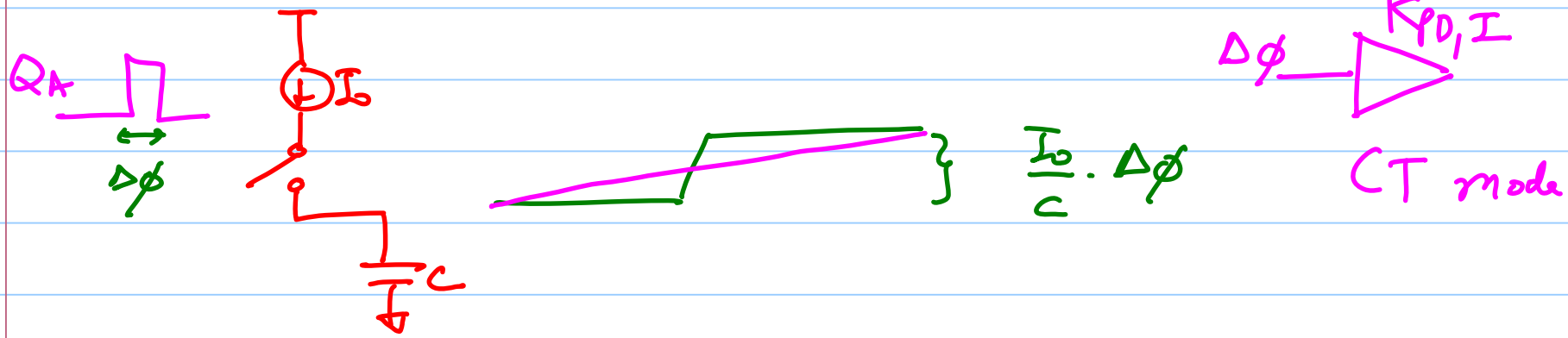
$\Rightarrow$ PLL response is much slower than the frequency of phase detection (sampling)





change in V_{cp} in one cycle of V_{cp} $= \frac{I_o}{C} \cdot \Delta\phi$

$= K_{PD,I} \cdot \Delta\phi \cdot 2\pi$

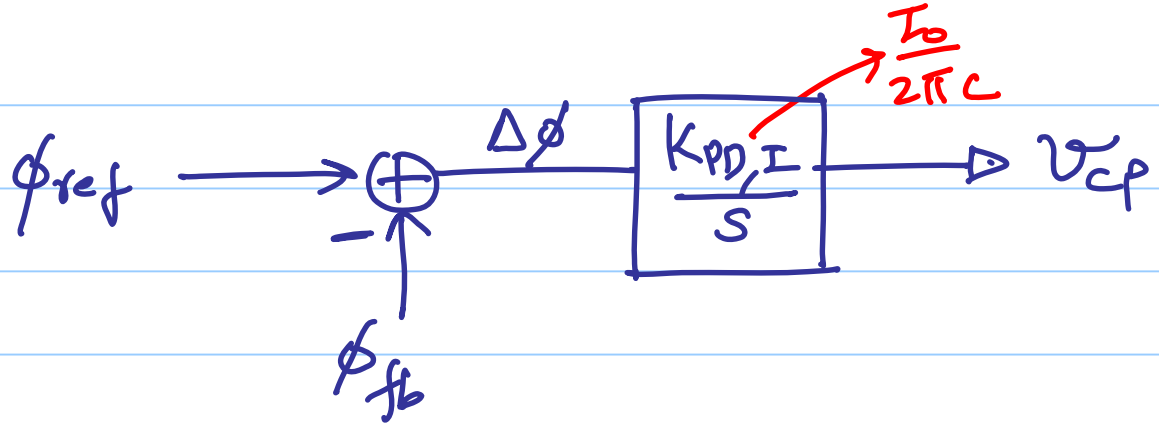


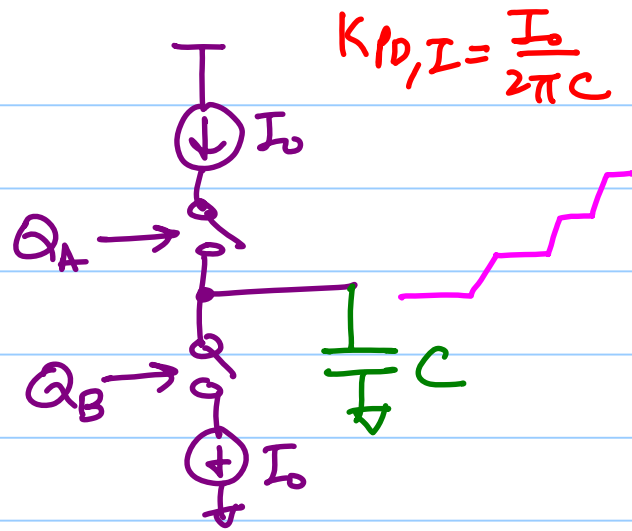
matching the DT step = CT ϕ by a $\frac{K_{PD,I}}{s}$ block

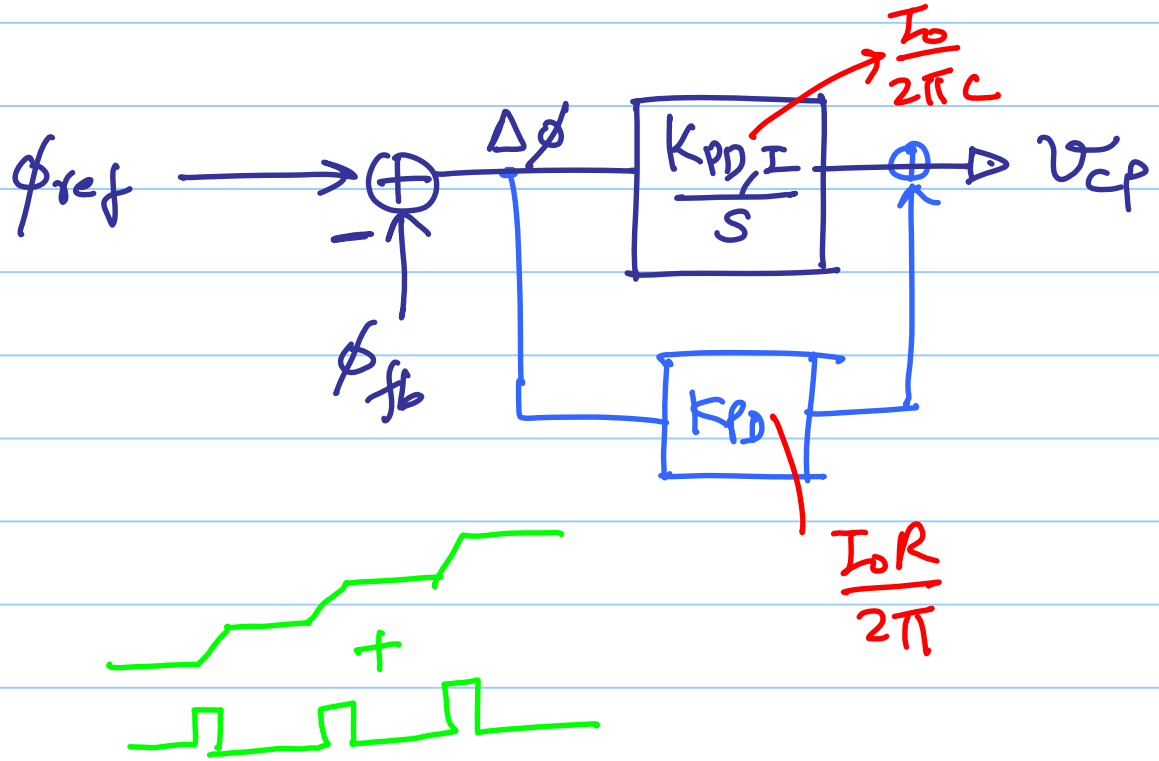
$$\frac{I_0}{C} \cdot \Delta\phi = K_{PD,I} \cdot \Delta\phi \cdot 2\pi$$

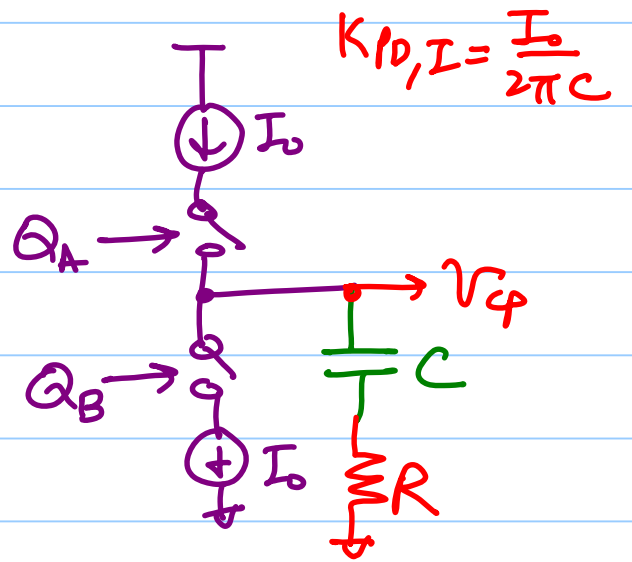
$$\boxed{K_{PD,I} = \frac{I_0}{2\pi C}}$$

* assuming a CT system
* in reality the system is DT and NL

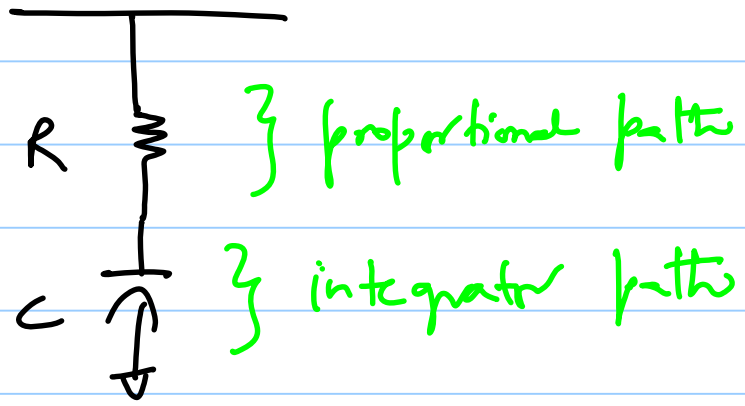

ϕ_{ref}
$\Delta\phi$
$K_{PD,I}$
$\frac{I_0}{2\pi C}$
$\frac{K_{PD,I}}{s}$
v_{cp}
ϕ_{fb}


$K_{PD,I} = \frac{I_0}{2\pi C}$
I_0
Q_A
Q_B
C
I_0


ϕ_{ref}
$\Delta\phi$
$K_{PD,I}$
$\frac{I_0}{2\pi C}$
$\frac{K_{PD,I}}{s}$
v_{cp}
ϕ_{fb}
K_{PD}
$\frac{I_0 R}{2\pi}$
+

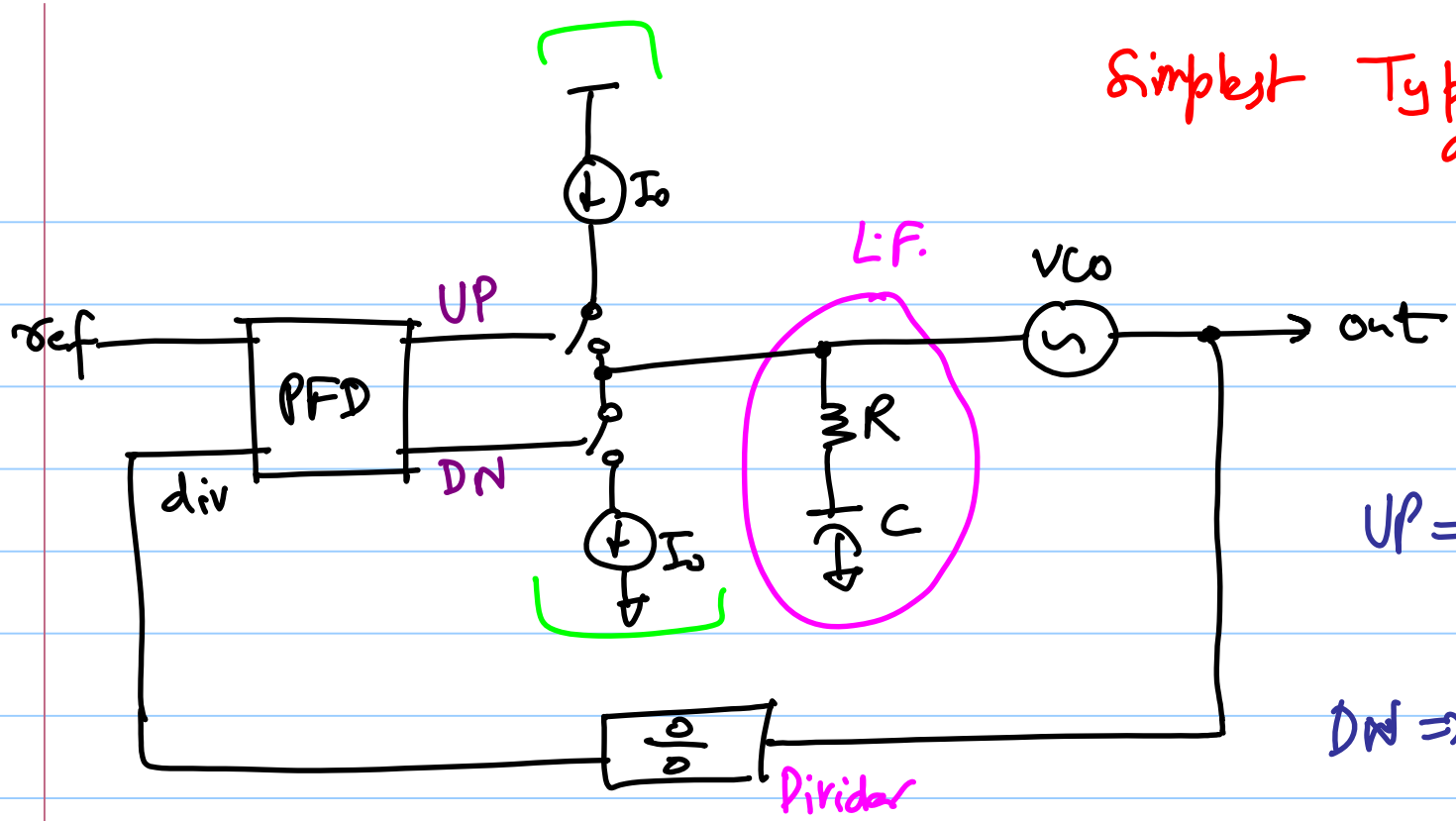

$K_{PD,I} = \frac{I_0}{2\pi C}$
I_0
Q_A
v_{cp}
C
Q_B
I_0
R

Same logic before



$$K_{PD} = \frac{I_0 R}{2\pi}$$

Simplest Type-II CP PLL architecture



UP ⇒ increment VCO frequency

DN ⇒ decrement VCO frequency