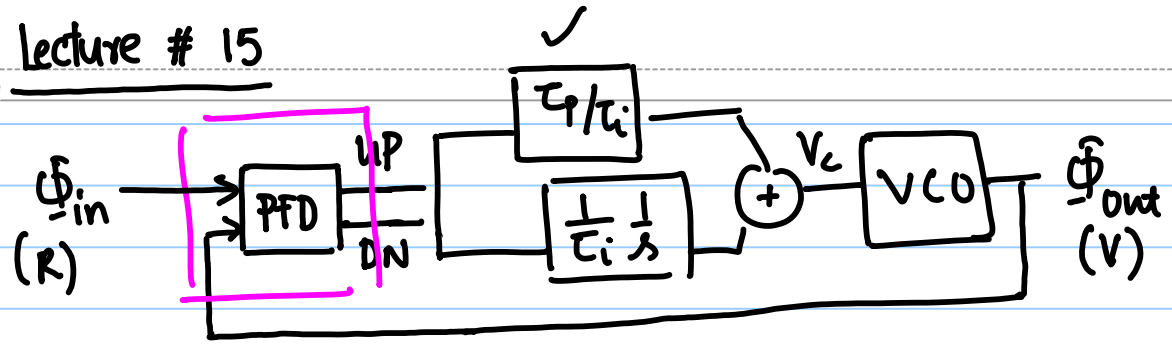
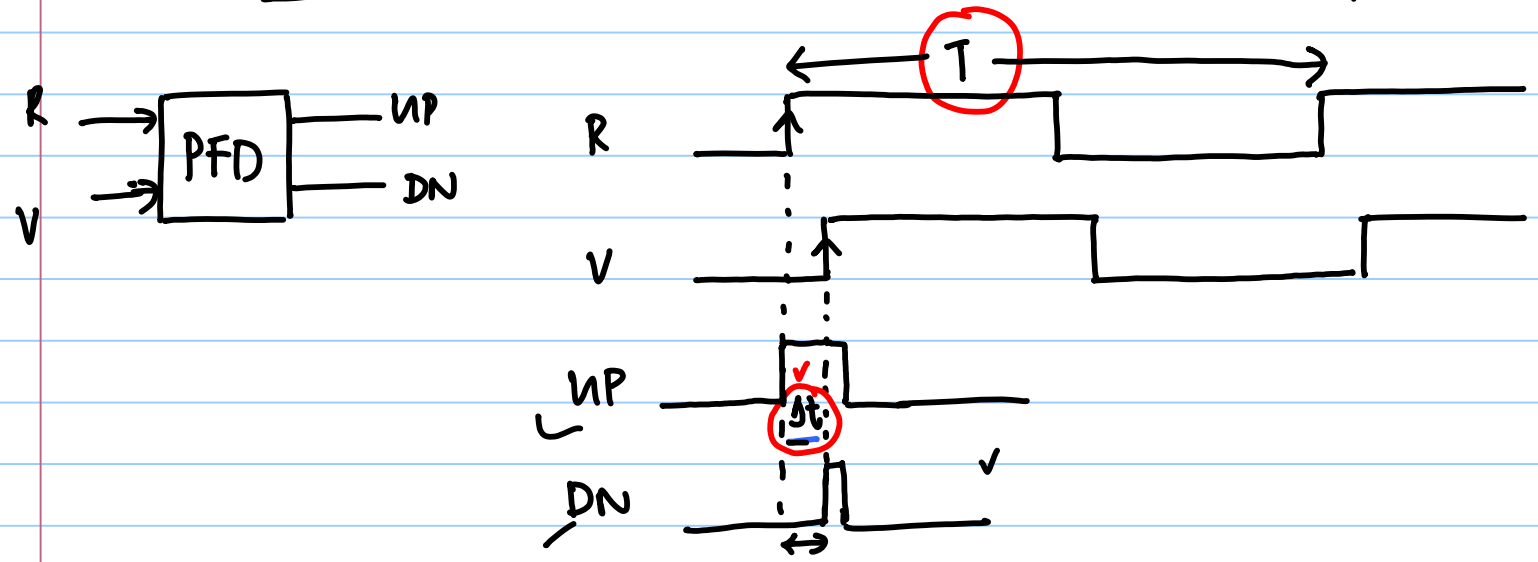
Lecture # 15

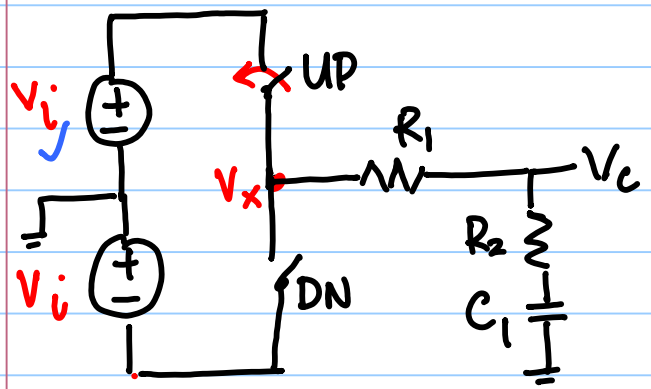
Note Title 19-06-2020

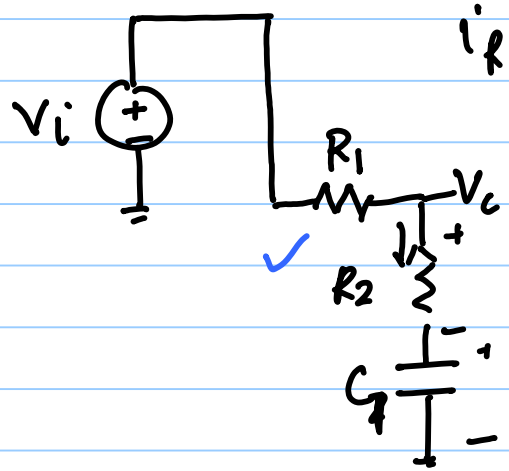


$$V_c = \left(\frac{\tau_p}{\tau_i} + \frac{1}{\tau_i}\frac{1}{s}\right)\Phi_e$$



$$\Phi_e = 2\pi \cdot \frac{\Delta t}{T}$$



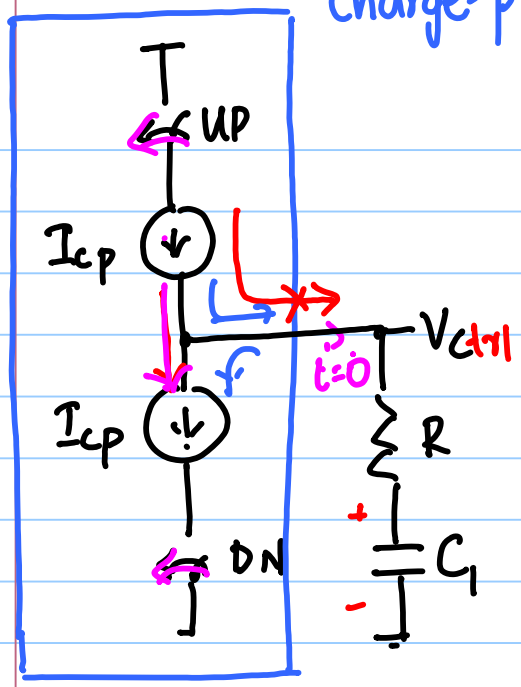


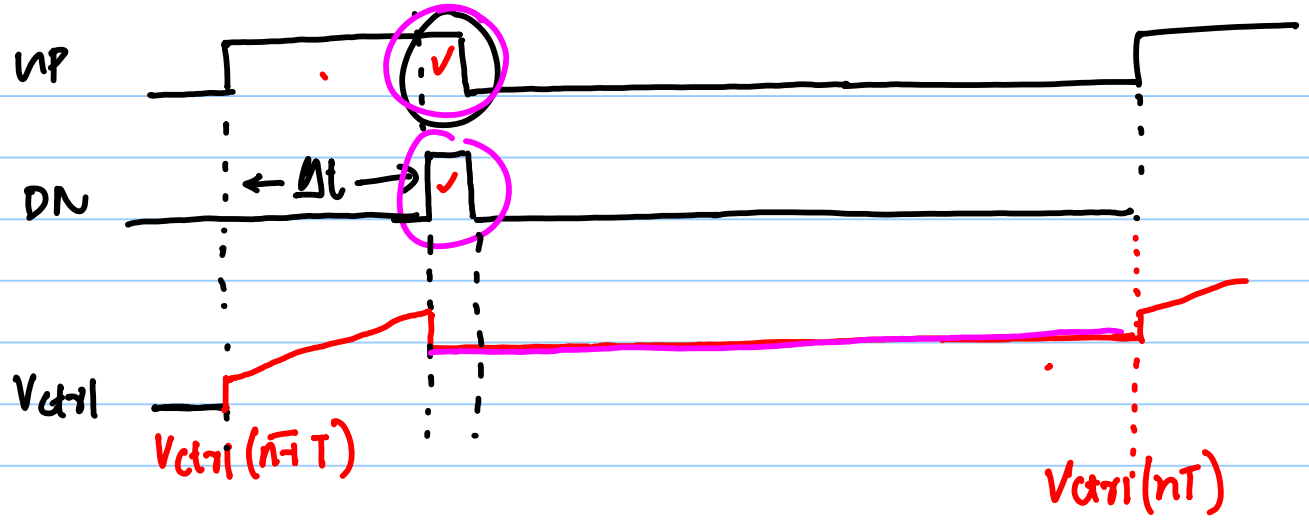
$$i_R = \frac{V_i(t) - V_c(t)}{R_1}$$

$$V_c(t) = i_R \cdot R_2 + \frac{1}{C_1}\int i_R \cdot dt$$

$$V_c(t) = f(\Delta t)$$
$$= f(\Phi_e)$$

Charge-pump.





$$\Delta V_{ctrl} = \frac{I_{cp} \cdot \Delta t}{C_1} = \frac{I_{cp} \cdot T}{C_1 \cdot 2\pi}\left(2\pi \frac{\Delta t}{T}\right)$$

$$= \underbrace{\frac{I_{cp} \cdot T}{2\pi C_1}} \cdot \underbrace{\phi_e}$$

$q = CV$

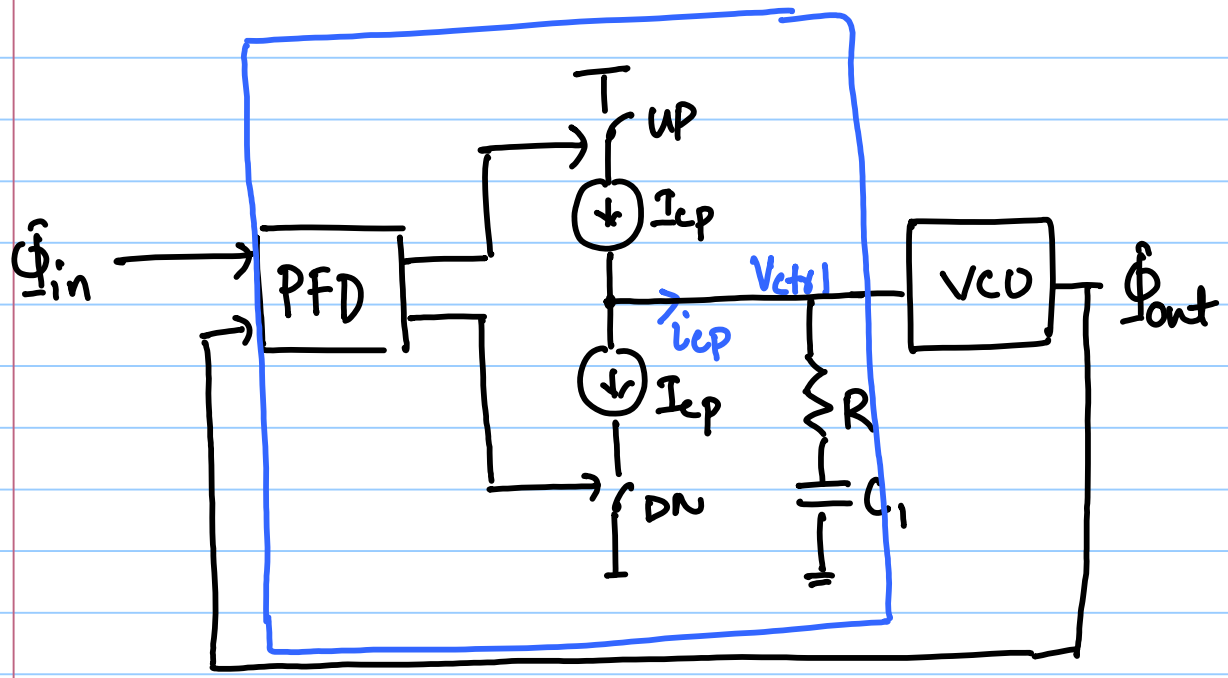
$i_{avg} = \frac{q}{T}$

Avg. charge dumped on cap. $\overline{Q_{ctrl}} = \frac{C_1 \cdot \Delta V_{ctrl}}{T}$

$$i_{avg} = \frac{I_{cp}}{2\pi} \cdot \phi_e$$

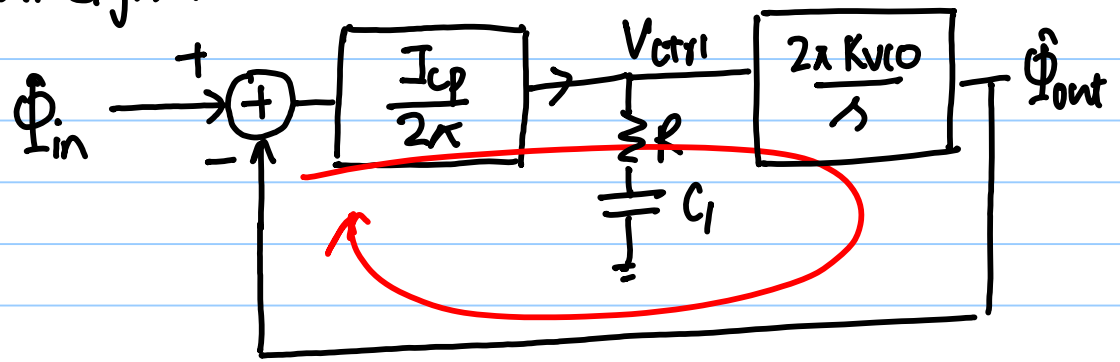
$$V_{ctrl}(s) = I_{avg}(s) \times \left(R + \frac{1}{sC_1}\right) \checkmark$$

$$V_{ctrl}(s) = \hat{\Phi}_e \times \frac{I_{cp}}{2\pi}\left(R + \frac{1}{sC_1}\right) \checkmark$$



charge-pump PLL.

Small-signal Model



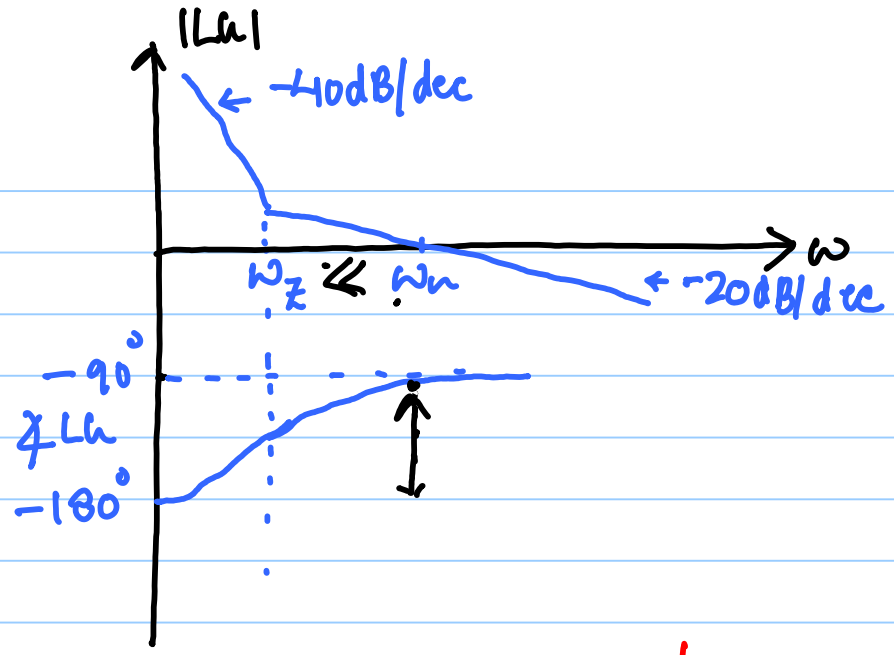
$[K_{VCO}] = Hz/V$

$$L(s) = \frac{I_{cp}}{2\pi}\left(R + \frac{1}{sC_1}\right)\frac{2\pi K_{VCO}}{s}$$

$$L(s) = \frac{I_{cp}\cdot K_{VCO}}{s^2 C_1}\underbrace{(1+sRC_1)}_{\gg 1}\ \underbrace{(1+s/\omega_z)}$$

$$\omega_{p1} = \omega_{p2} = 0$$

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



Unity gain frequency. $\omega_n\big|_{|L(s)|=1} \approx I_{cp}\cdot K_{VCO}\cdot R$

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

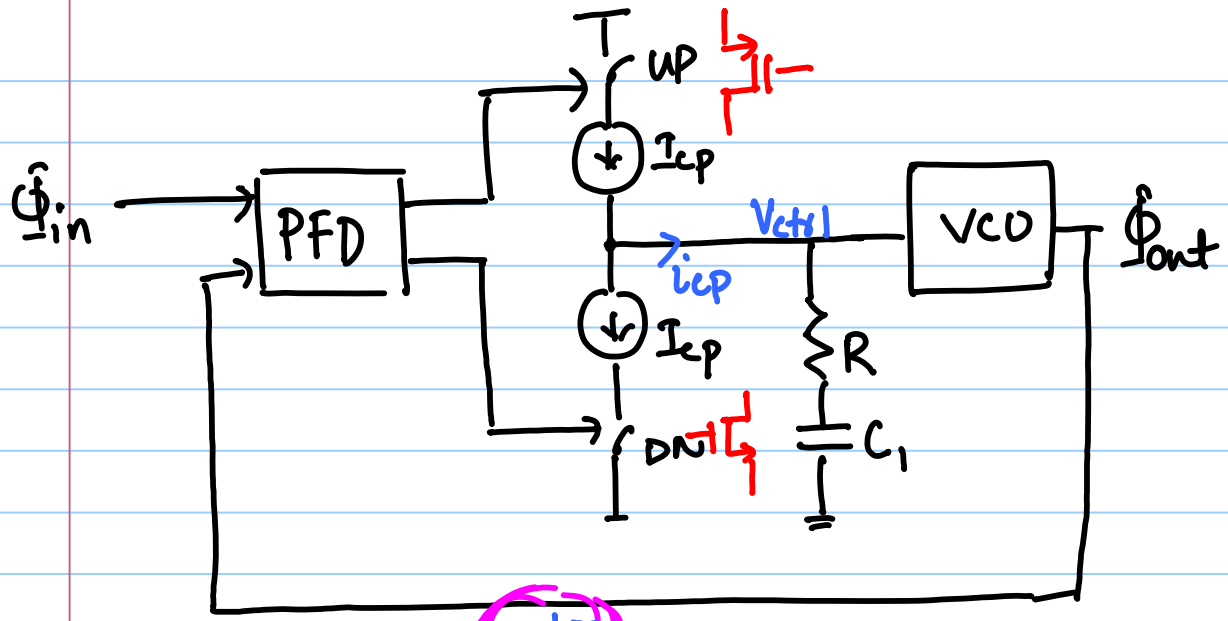
$$\text{Phase Margin} = \tan^{-1}\left(\frac{\omega_n}{\omega_z}\right)$$

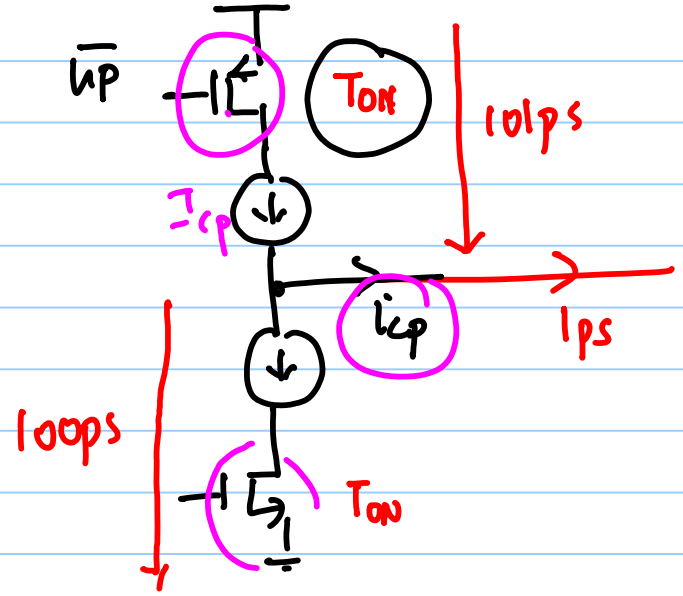
$$L(s) = \frac{I_{cp}K_{VCO}}{s^2 C_1}(1+s/\omega_z)$$

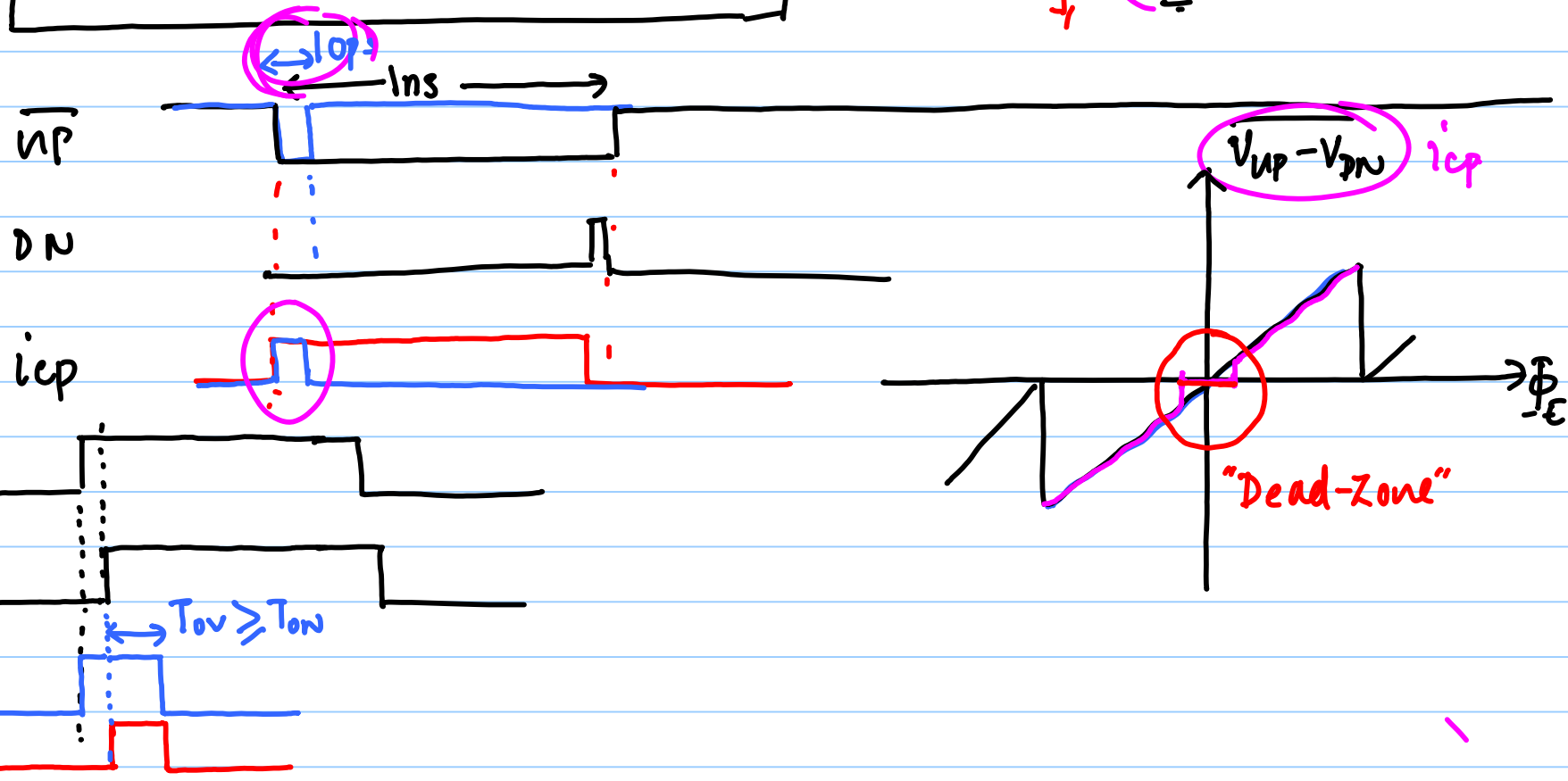
$$|L(s)| = 1$$

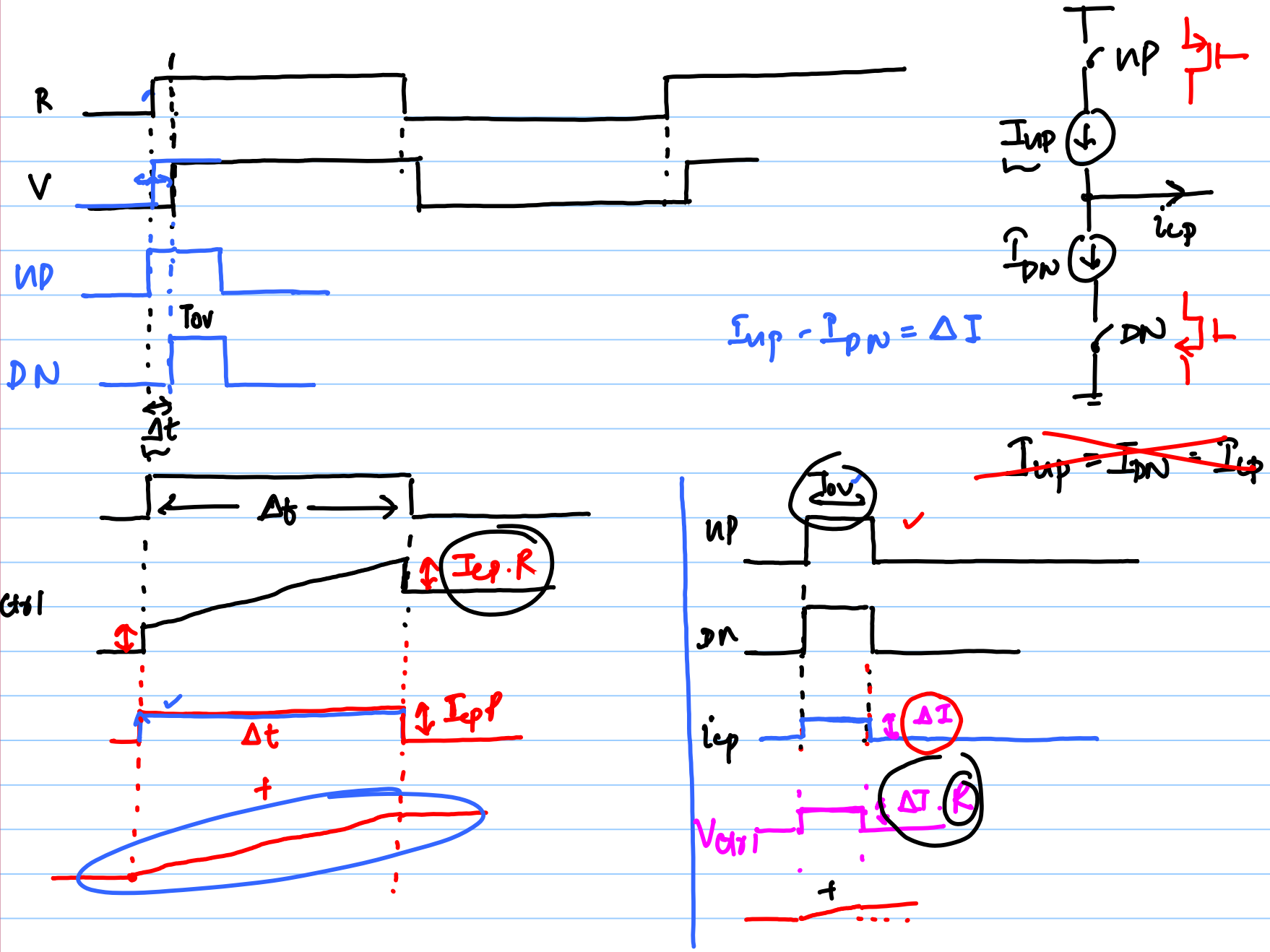
$$\frac{I_{cp}\cdot K_{VCO}\sqrt{1+\omega_n^2/\omega_z^2}}{\omega_n^2 C_1} = 1$$

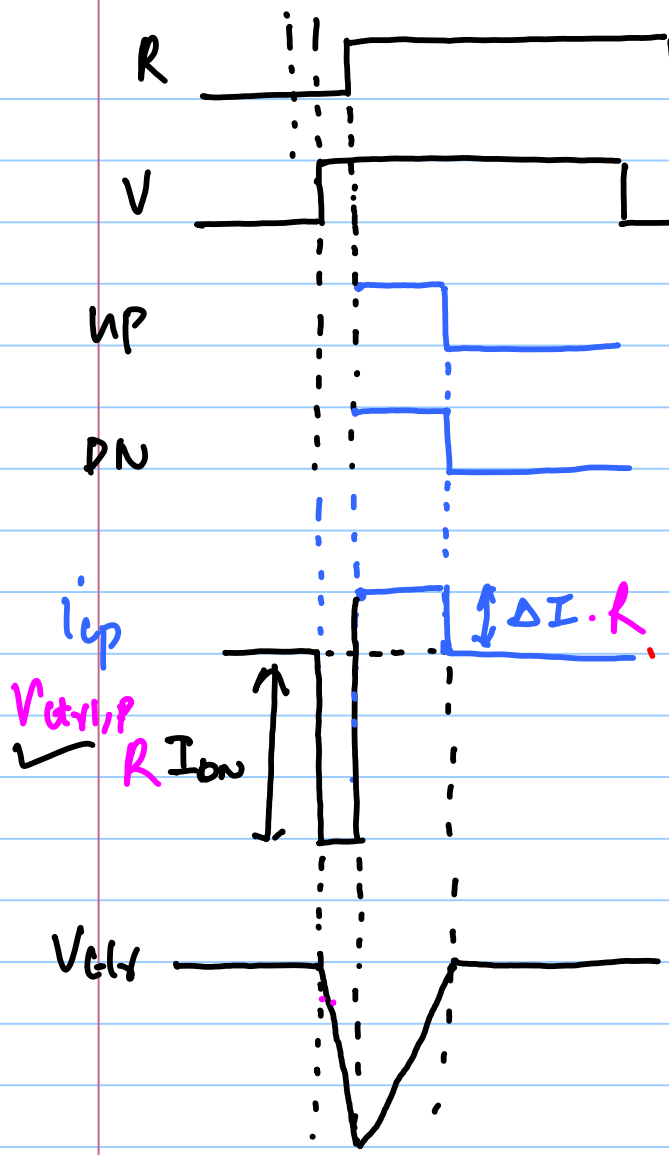
$$\frac{I_{cp}K_{VCO}\cdot \omega_n/\omega_z}{\omega_n^2 C_1} = 1$$


UP
I_{cp}
ϕ_{in}
PFD
V_{ctrl}
VCO
ϕ_{out}
i_{cp}
I_{cp}
R
DN
C_1


$\overline{UP}$
T_{ON}
10ps
I_{cp}
i_{cp}
1ps
100ps
T_{ON}


10ps
1ns
$\overline{UP}$
DN
i_{cp}
R
V
$T_{ov} \geq T_{ON}$
UP
DN
$V_{UP} - V_{DN}$
i_{cp}
ϕ_E
"Dead-Zone"


R
V
UP
DN
Tov
Δt
Δt
Icp·R
VCtrl
Icp
Δt
t
UP
DN
Iup
Idn
icp
Iup - Idn = ΔI
Iup = Idn = Icp
Tov
UP
DN
icp
ΔI
ΔI·R
VCtrl
t



- Control voltage will have a ripple periodic w/ reference period.

- w/ periodic voltage ripple at control voltage $\Longrightarrow$ periodic frequency ripple.

$$\Delta V_{ctrl,R}(t) = \sum a_n \cos(n\omega_R t) + b_n \sin(n\omega_R t)$$

$n = 1$

$$a_n = f\left(\overline{I}_{CP}, R\right)$$

$$f_{VCO} = f_{free} + K_{VCO}\left(V_{C,st} + \Delta V_{ctrl,R}(t)\right)$$

$$V_{out} = \sin\left(2\pi \int f_{VCO}\, dt\right)$$

$\Longrightarrow$ $f_{VCO,0} \pm f_R$

Oscillator.