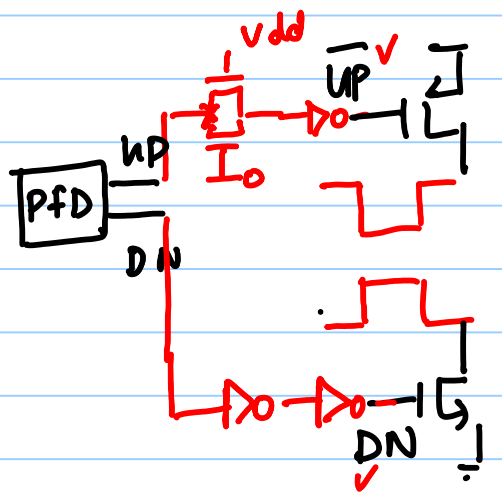
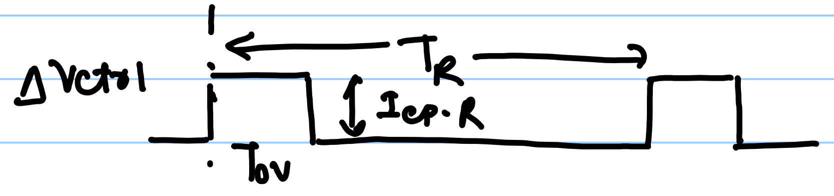
Note Title 13-08-2020

Lecture # 33





$$\Delta V_{ctrl} = a_0 + \sum a_n \cos(n\omega_R t) + b_n \sin(n\omega_R t)$$

$\neq 0$

$$a_n = \frac{1}{n\pi} I_{cp} R \sin\left(n\pi \frac{T_{os}}{T_R}\right)$$

$$b_n = \frac{1}{n\pi} I_{cp} R \cos\left(n\pi \frac{T_{os}}{T_R}\right)$$

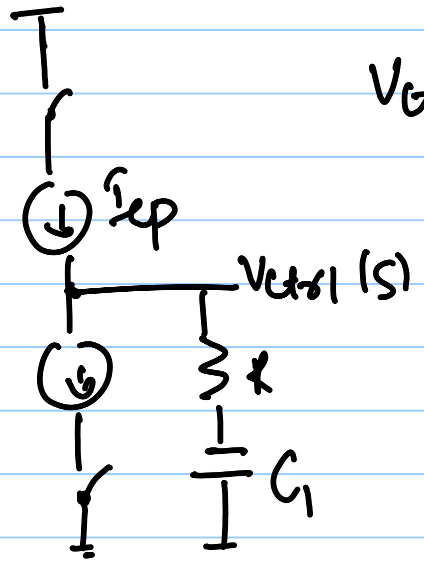
$$\Delta V_{ctrl} = a_0 + I_{cp} R \sum \frac{1}{n\pi} \left\{ \sin\Big(\underbrace{n\pi \frac{T_{os}}{T_R}}_{\theta}\Big) \cos(n\omega_R t) + \cos\left(n\pi \frac{T_{os}}{T_R}\right) \sin(n\omega_R t) \right\}$$

$$V_{out} = \sin\left(\omega_0 t + K_{vco} \int \Delta V_{ctrl} \cdot dt\right)$$

$$= \sin\left(\omega_0 t + \frac{K_{vco} I_{cp} R}{\pi} \int \sin(\theta) \cos(\omega_R t) + \cos(\theta) \sin(\omega_R t)\, dt\right)$$

$$= \sin\left(\omega_0 t + \frac{K_{vco} I_{cp} R}{\pi \omega_R} \left\{ \sin\theta \sin(\omega_R t) - \cos(\theta) \cos(\omega_R t) \right\}\right)$$

$$\sin(\omega_R t + \phi)$$



$$V_{ctrl}(s) = I_{cp} \cdot R + \frac{I_{cp}}{sC_1} = V_{prop} + V_{int}$$

$$= I_{cp1} \cdot R + \frac{I_{cp2}}{sC_1}$$

$$= I_{cp}\left(\frac{I_{cp1}}{I_{cp}} \cdot R + \frac{I_{cp2}/I_{cp}}{sC_1}\right)$$

$$= I_{cp}\left(K \cdot R + \frac{1}{sC_1}\right)$$

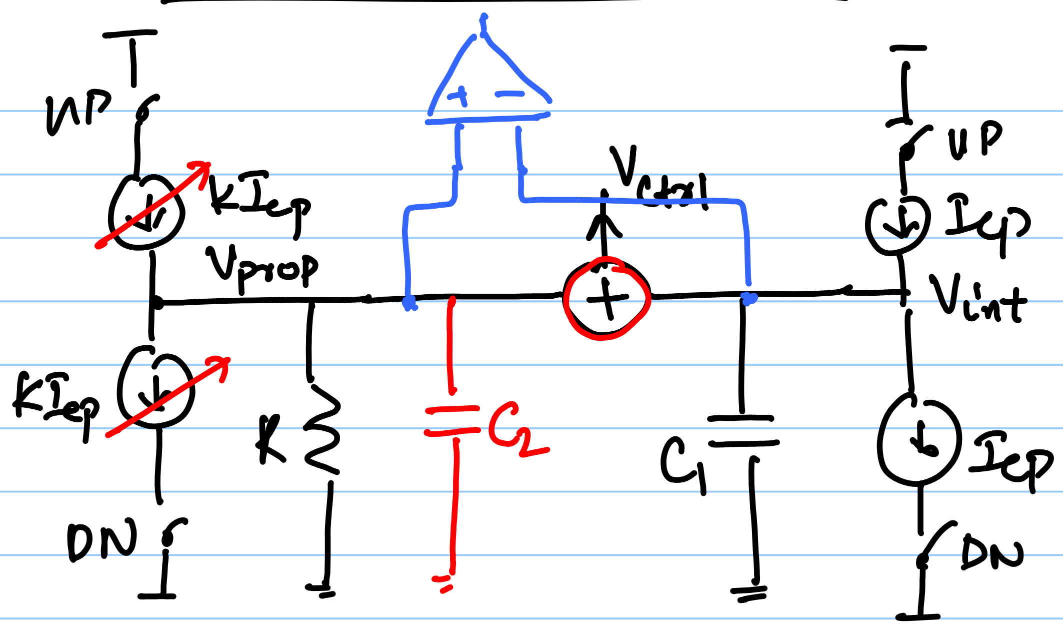
$$\frac{I_{cp1}}{I_{cp}} = K$$

$$\frac{I_{cp2}}{I_{cp}} = 1$$

$$\Rightarrow \omega_z = \frac{1}{K \cdot RC_1} = \frac{1}{R(KC_1)} = \frac{1}{RC_1'}$$

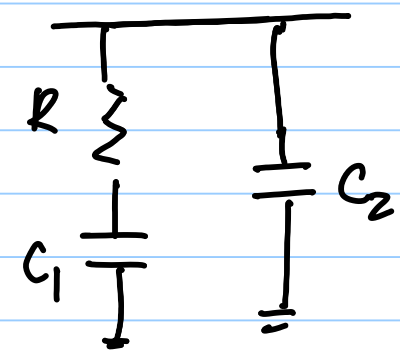
$\omega_z = 1/KRC_1$	$\omega_z = 1/KRC_1$
R, KC_1, I_{cp}	$R, C_1, I_R = KI_{cp}$
	$I_C = I_{cp}$

Dual-path loop filter (DPLF)



$$V_{ctrl} = I_{cp}\left(kR_1 + \frac{1}{sC_1}\right)$$

- Opamp.

- 

$$V_{ctrl}(s) = kI_{cp}\frac{R}{1+sRC_2} + I_{cp}\frac{1}{sC_1}$$

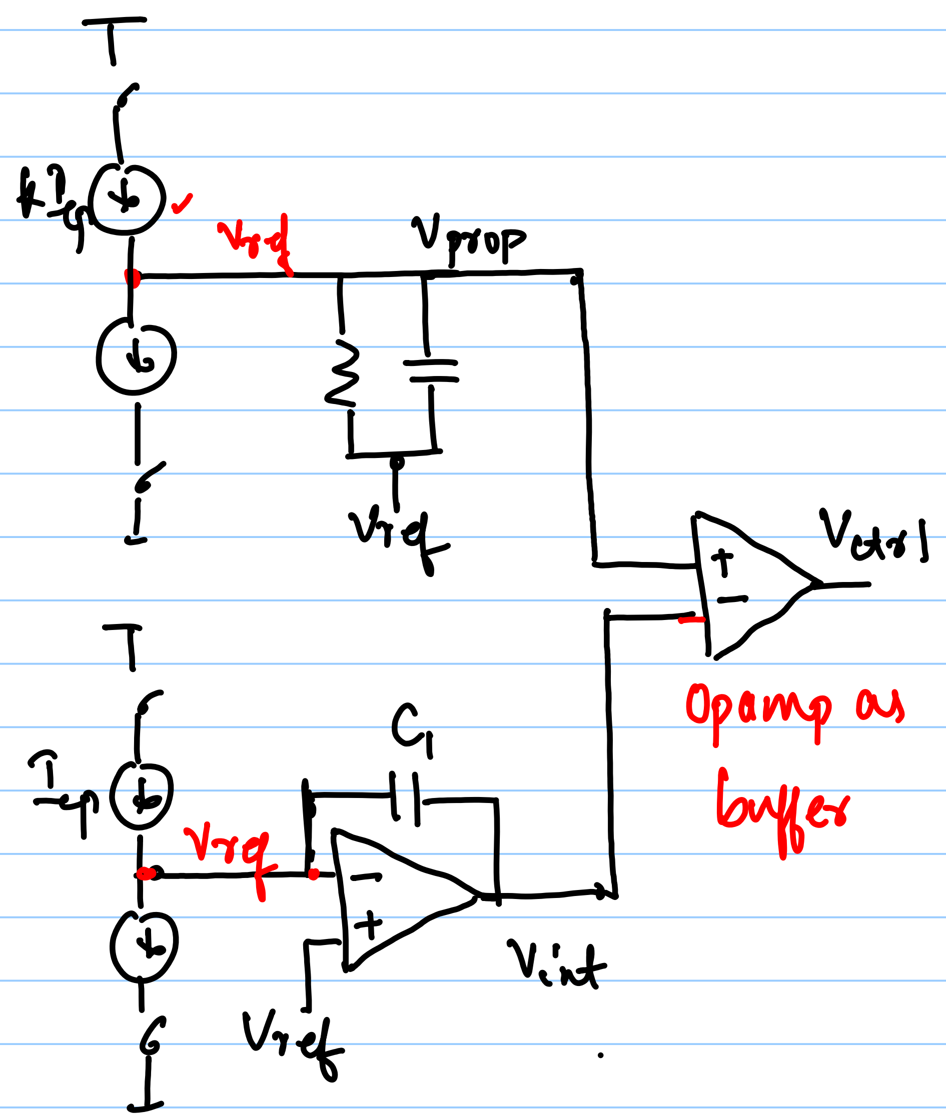
$$= \frac{I_{cp}}{1+sRC_2}\left(\frac{1+s(C_2+kC_1)R}{sC_1}\right)$$

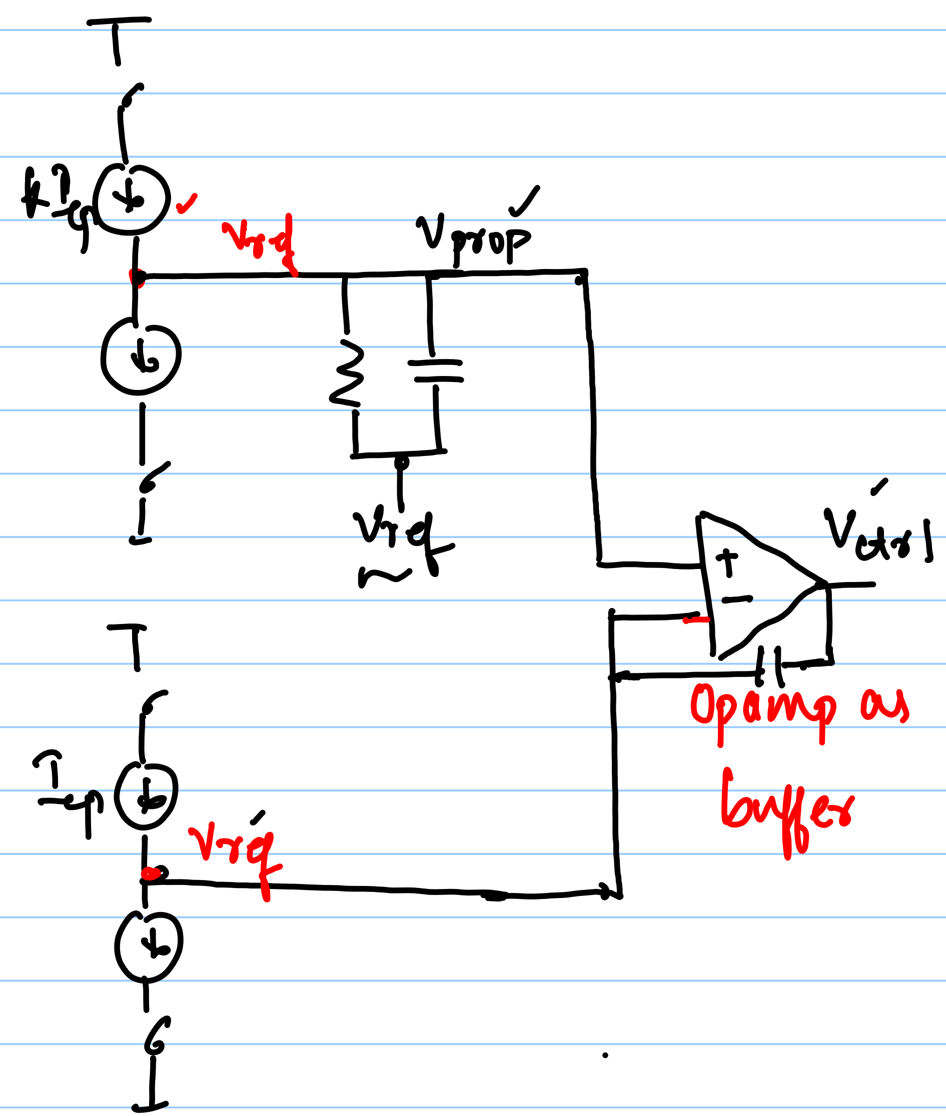
$$\omega_z = \frac{1}{R(C_2+kC_1)} \approx \frac{1}{kC_1}, \quad \omega_{p1} = 0,\ \omega_{p2} = \frac{1}{kC_2}$$

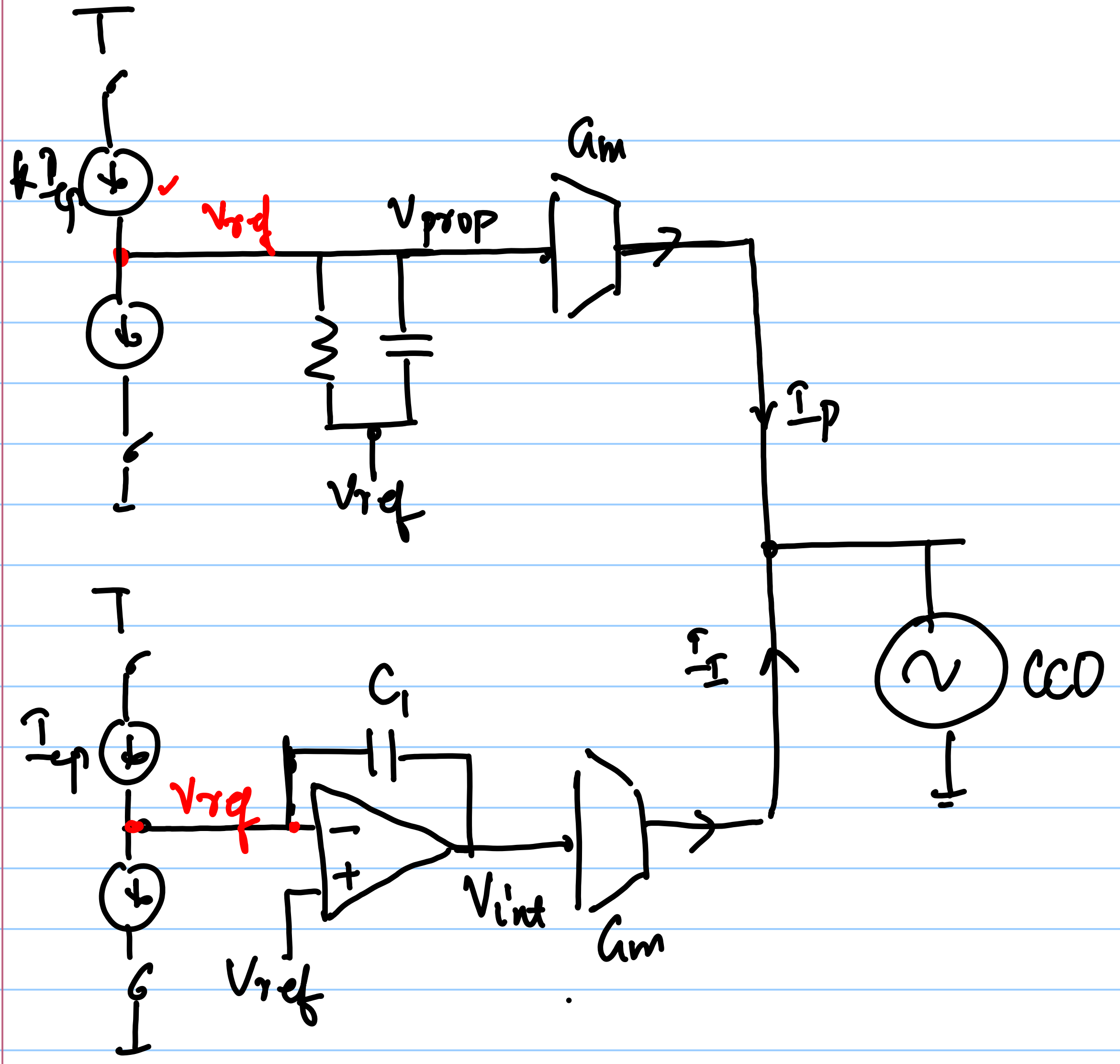
$$\omega_z = \frac{1}{RC_1}$$

$$\omega_{p1} = 0$$

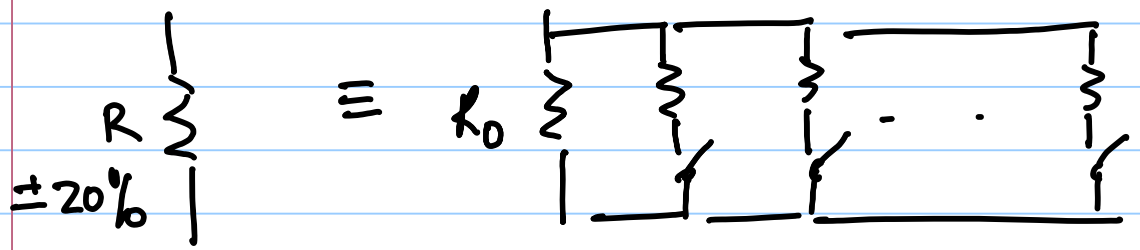
$$\omega_{p2} = \frac{1}{\frac{RC_1C_2}{C_1+C_2}} \approx \frac{1}{RC_2}$$

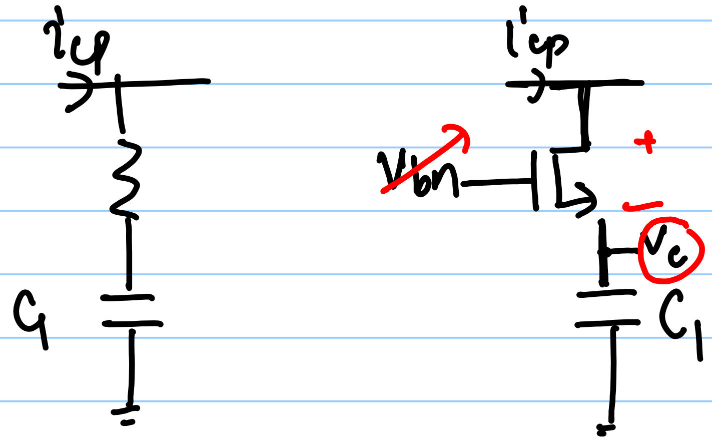

T
kI_{cp}
Vref
Vprop
Vref
Vctrl
T
I_{cp}
Vref
C1
Vref
Vint
Opamp as
buffer

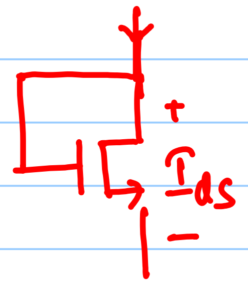

T
kI_{cp}
Vref
Vprop'
Vref
Vctrl'
T
I_{cp}
Vref'
Opamp as
buffer



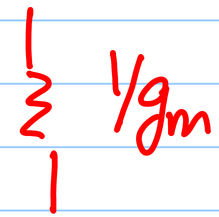
kI_{cp}
V_{ref}
V_{prop}
G_m
I_P
V_{ref}
I_{cp}
V_{ref}
C_1
I_I
CCO
V_{int}
G_m
V_{ref}

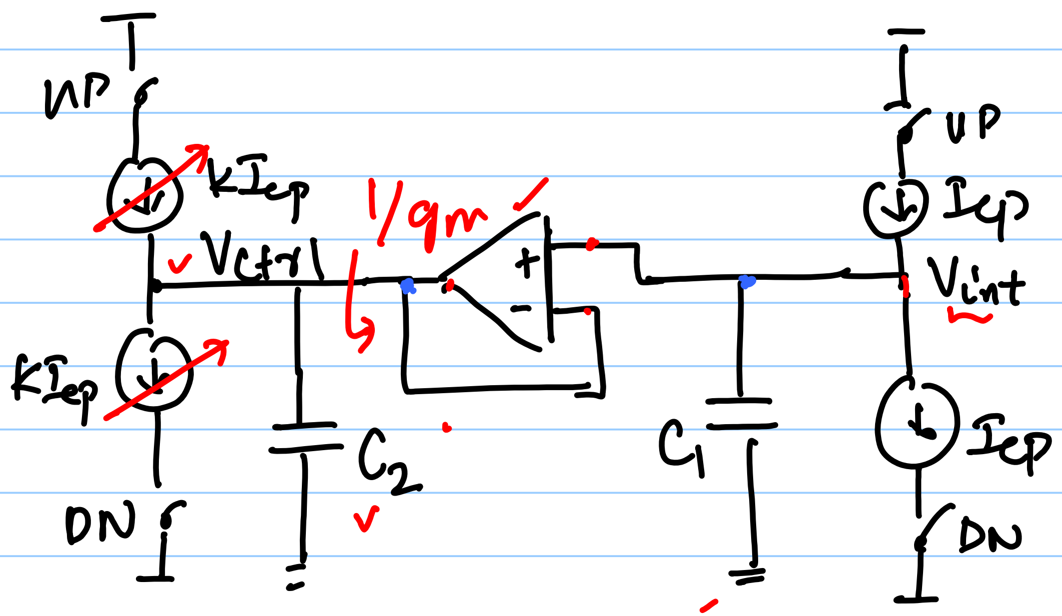






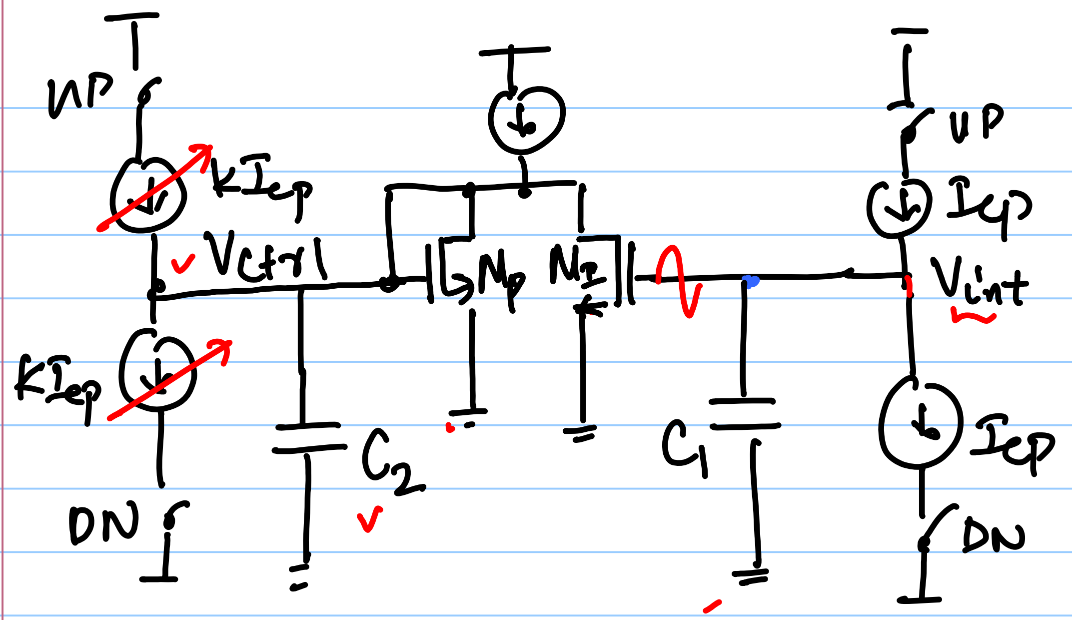
saturation ≡





$$V_{ctrl}(s) = \frac{I_{cp}}{sC_1} + \frac{K I_{cp}\, 1/G_m}{1 + \frac{sC_2}{G_m}}$$

$$\frac{V_{ctrl}}{I_{cp}} = \frac{1 + \frac{KC_1 + C_2}{G_m} s}{sC_1\left(1 + s\frac{C_2}{G_m}\right)}$$



$$V_{ctrl}(s) = \left[\frac{I_{cp}}{sC_1} g_{m2} + K I_{cp}\right]\frac{1}{g_{mp}}$$

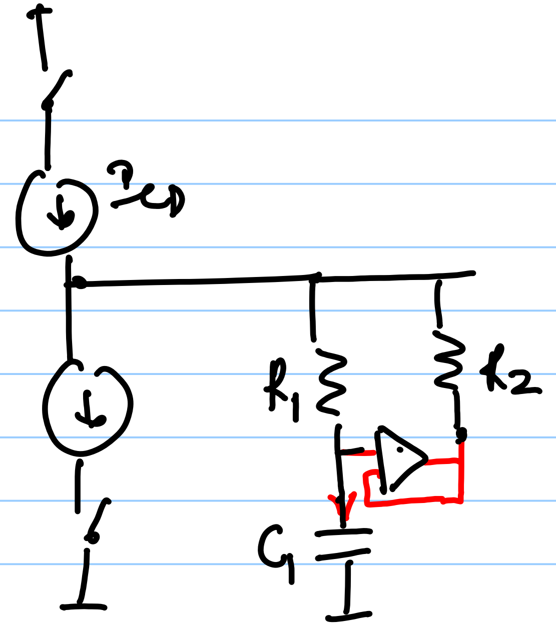
w/o C_2

$$V_{ctrl} = K I_{cp} \cdot R + \frac{I_{cp}}{sC_1} \Rightarrow \frac{V_{ctrl}}{I_{cp}}$$

$$\cancel{\frac{V_{ctrl}}{K I_{cp}}}$$

$$= I_{cp} \cdot R + \frac{(I_{cp}/K)}{sC_1}$$

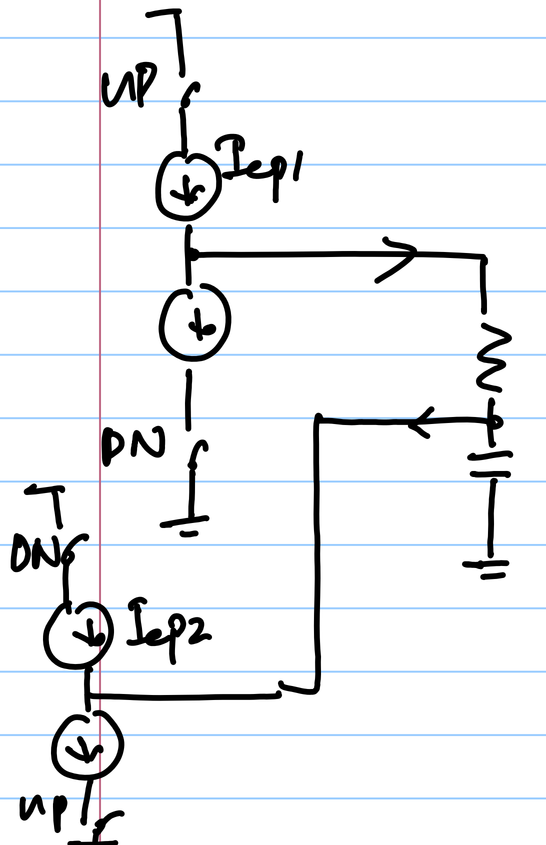
$$= I_{cp}\left(\frac{1+sKC_1R}{sC_1K}\right)$$



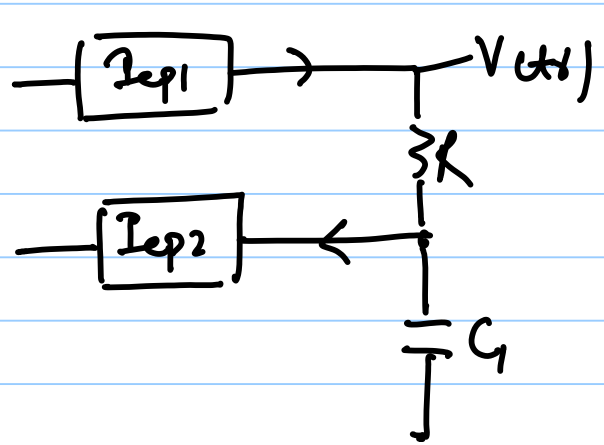
$$V_{ctrl} = I_{cp} \cdot \frac{R_2}{R_1+R_2} \times \frac{1}{sC_1} + I_{cp}(R_1 \| R_2)$$

$$= \frac{I_{cp}}{s\, C_1\left(1+\frac{R_1}{R_2}\right)} + I_{cp} R_{eff}.$$

$$\omega_z = R_{eff}\, C_1 \left(1+\frac{R_1}{R_2}\right) = R_1 C_1$$



$\equiv$



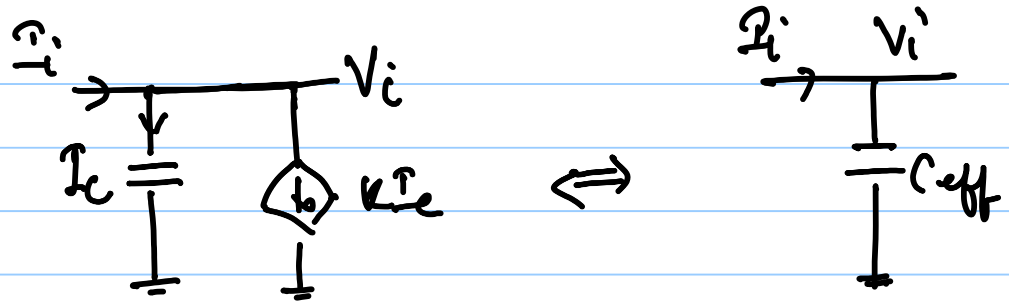
$$V_{ctrl}(s)$$

$$= I_{cp1} \cdot R + \frac{(I_{cp1} - I_{cp2})}{sC_1}$$

$$= I_{cp1}\left[R + \frac{\left(1-\frac{I_{cp2}}{I_{cp1}}\right)}{sC_1}\right]$$

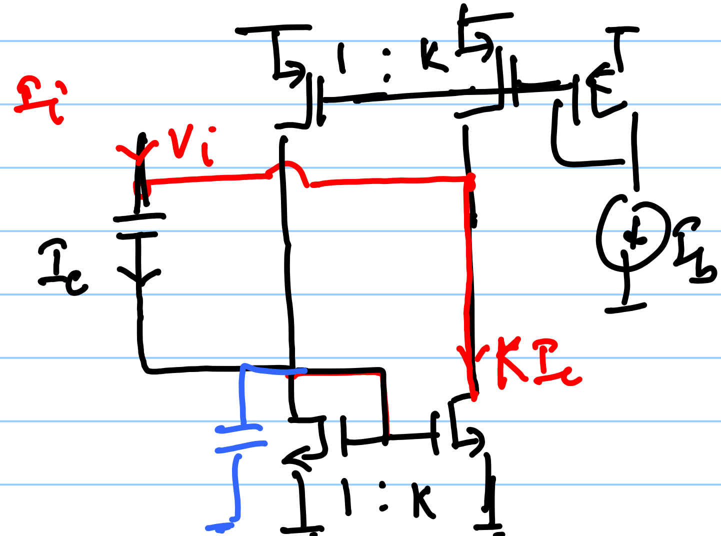
$$= I_{cp}\left[R + \frac{(1-\alpha)}{sC_1}\right]$$

$$\omega_z = \frac{RC_1}{1-\alpha} = R\left(\frac{C_1}{1-\alpha}\right)$$

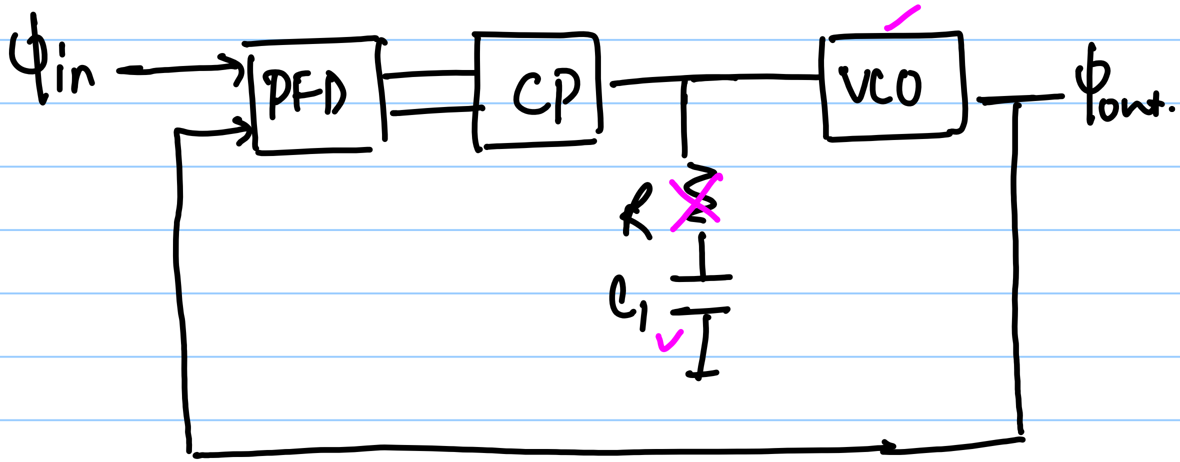


i_i
V_i
I_c
KI_c
i_i
V_i
C_{eff}

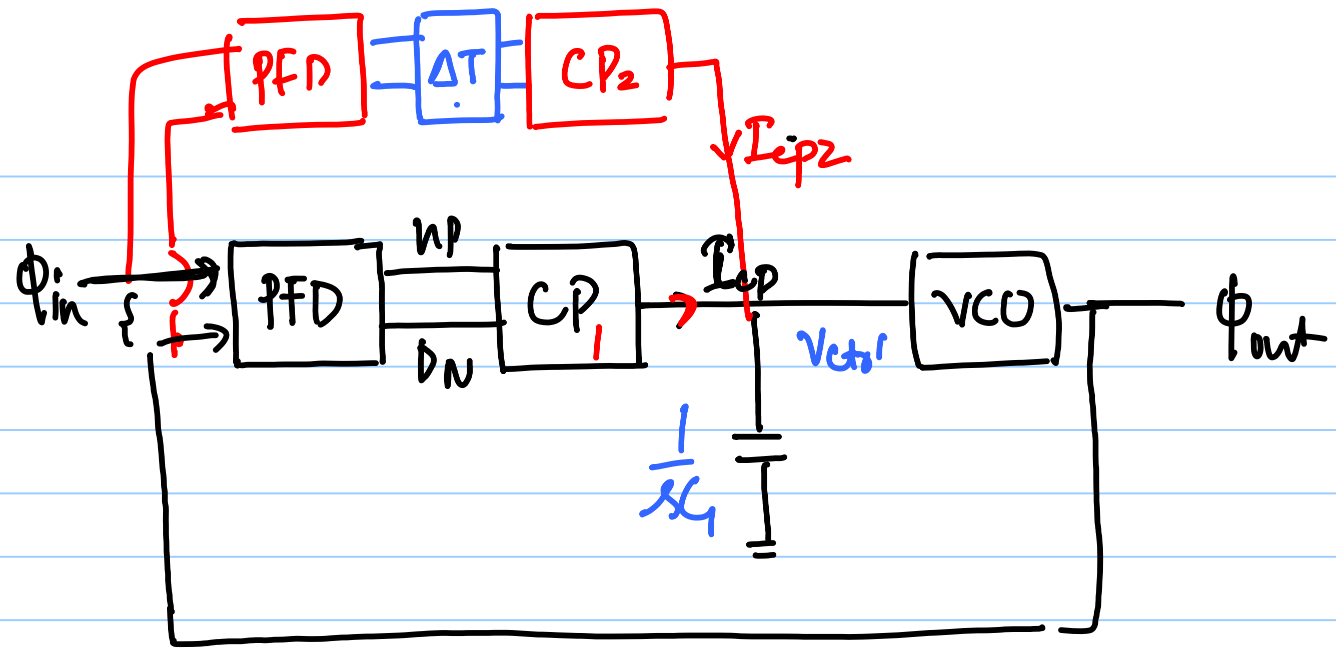
$C_{eff} = (K+1)C$



i_i
V_i
I_c
KI_c
I_b
1 : K
1 : K



ϕ_{in}
PFD
CP
VCO
ϕ_{out}
R
C_1



$$\frac{\phi_{out}}{\phi_{in}} \propto (1+s/\omega_z)$$

$$V_{ctrl}(s) = I_{cp1} \times \frac{1}{sC_1} + I_{cp} e^{-s\Delta T} \frac{1}{sC_1}$$

$$I_{cp1} = I_{cp} = -\frac{I_{cp2}}{\alpha}$$

$$= \frac{1}{sC_1}\left[I_{cp1} + I_{cp2} e^{-s\Delta T} \right]$$

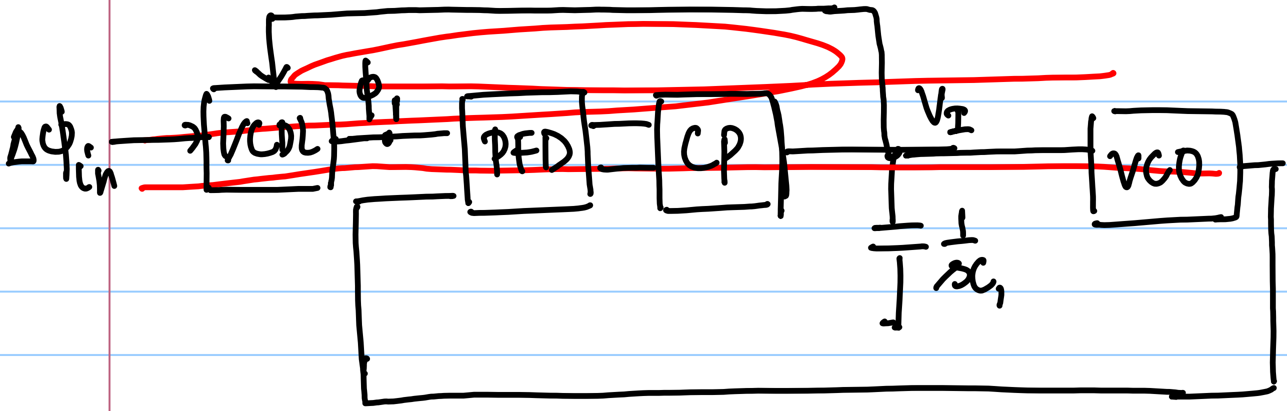
$$1\,\mathrm{Mrad/s} \approx \frac{0.75}{0.25} \times \frac{1}{\Delta T}$$

$$= \frac{1}{sC_1}\left[I_{cp1} + I_{cp2}(1 - s\Delta T) \right]$$

$$= \frac{1}{sC_1}\left[(I_{cp1} + I_{cp2}) - I_{cp2} \cdot s\Delta T \right]$$

$$= \frac{1}{sC_1}\left[I_{cp}(1-\alpha) + \alpha I_{cp}\, s\, \Delta T \right]$$

$$\omega_z = \frac{1-\alpha}{\alpha} \frac{1}{\Delta T}$$



$$\phi_1 = \Delta\phi_{in} + K_{VCDL} \cdot V_I$$

$$[K_{VCDL}] = \frac{rad}{V}$$