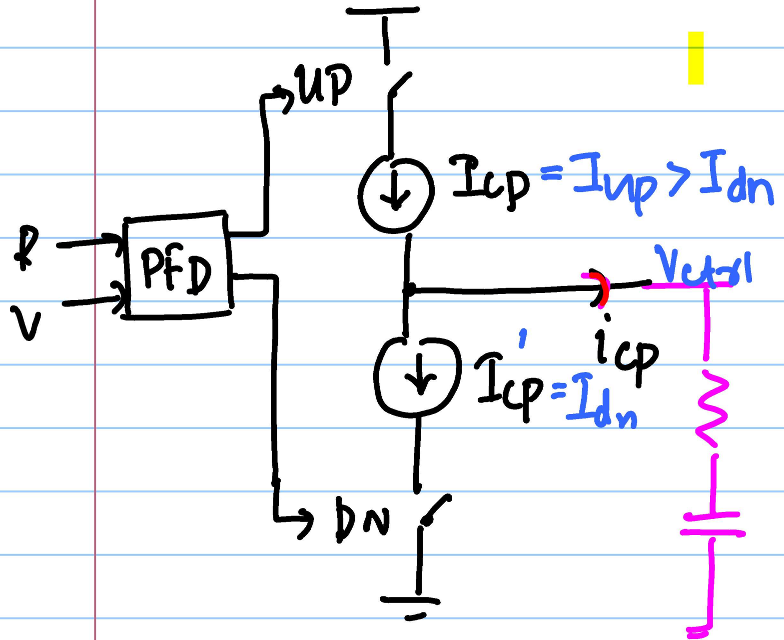
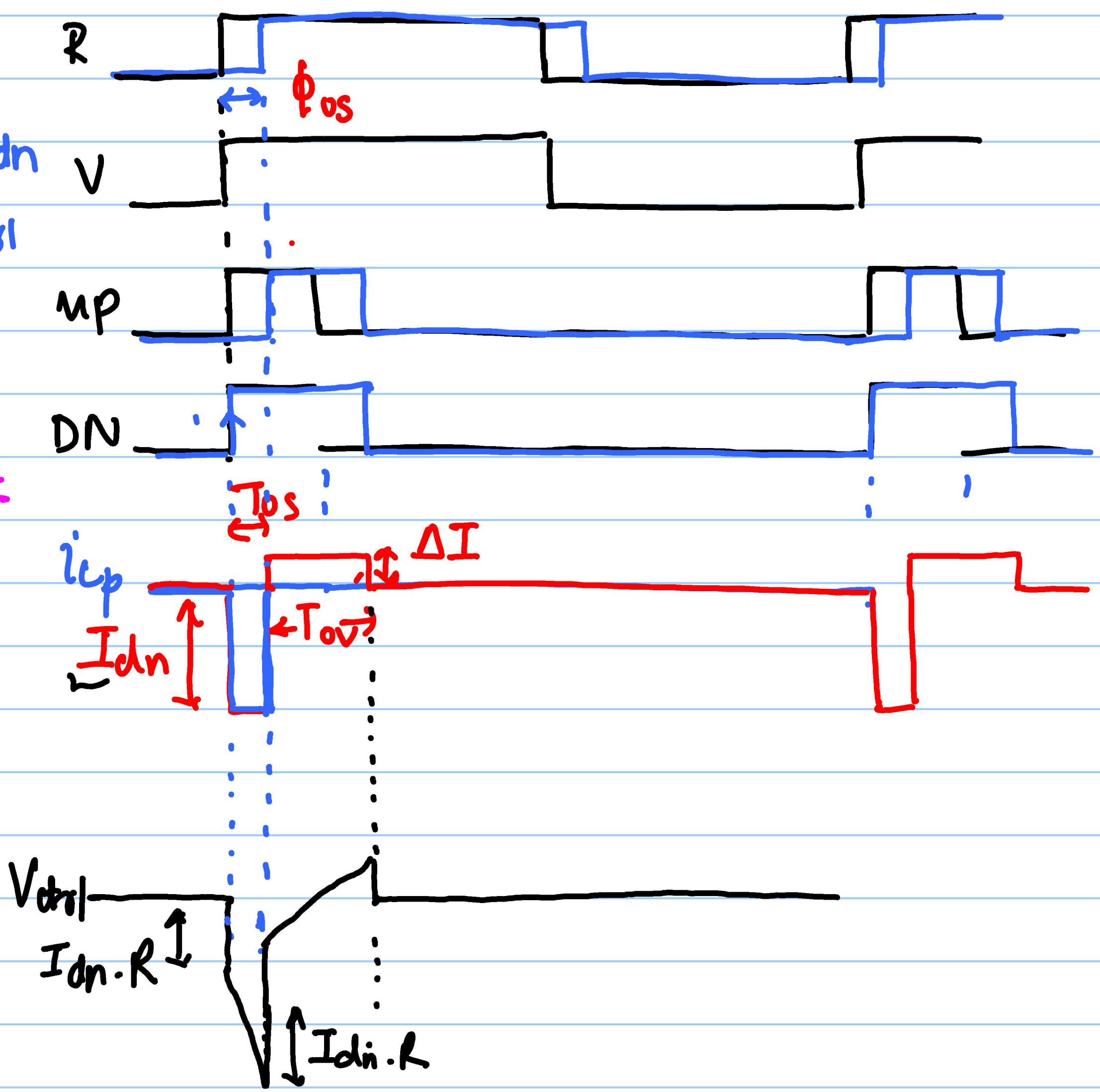
Lecture # 30

Note Title 04-08-2020

Charge Pump.



- In steady stade, $\phi_{er} = 0$



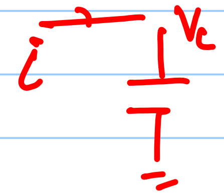
$\Delta I = I_{up} - I_{dn}$

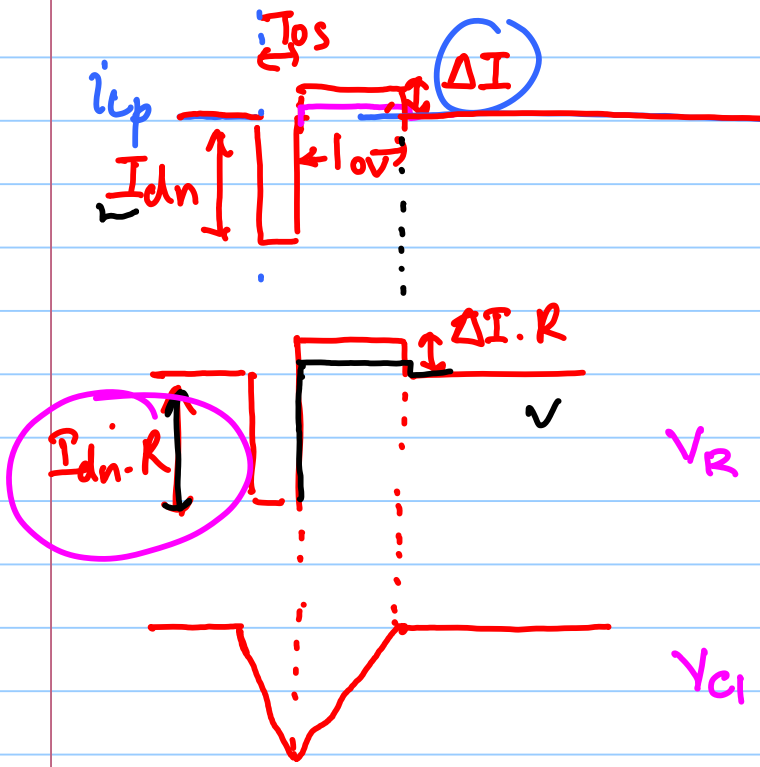
$I_{dn} . T_{os} = \Delta I . T_{ov}$

$T_{os} = \frac{\Delta I}{I_{dn}} . T_{ov}$

$$2\pi \frac{T_{os}}{T_R} = \frac{\Delta I}{I_{cp}} \quad 2\pi \cdot \frac{T_{ov}}{T_R}$$

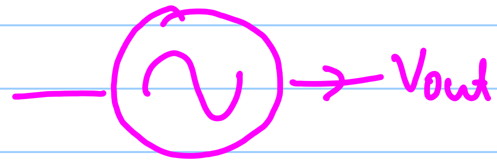
$$\phi_{os} = \frac{\Delta I}{I_{cp}} \cdot \frac{2\pi \cdot T_{ov}}{T_R}$$





$$V_{ctrl} = i_{cp}R + \frac{1}{C} \int i_{cp} . dt$$

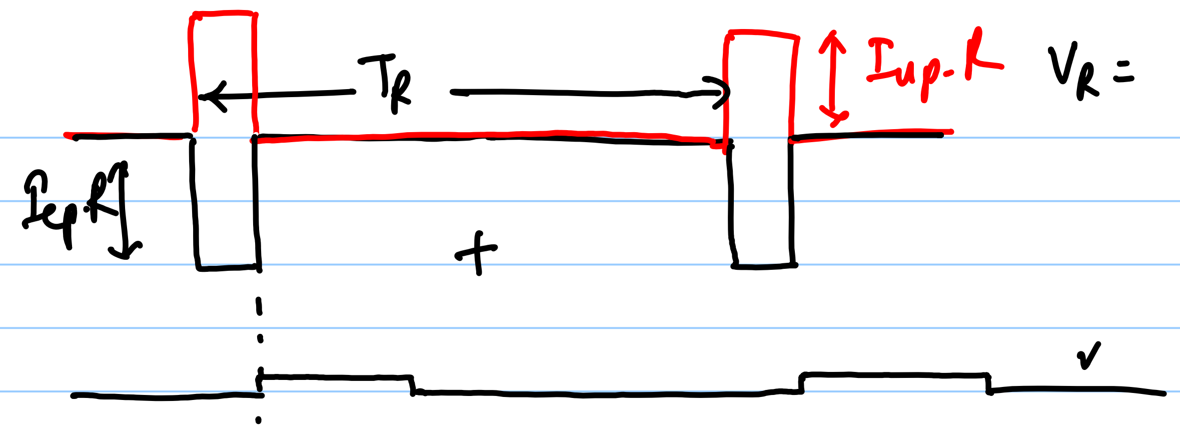
$$\frac{1}{C} \int_0^{T_{os}} I_{dn} . dt = \frac{1}{C} \int_0^{T_{ov}} \Delta I . dt$$



$$f_{vco} = f_0 + K_{vco} . V_c$$

$$V_{out} = \sin\left(w_0 t + \int K_{vco} . V_c . dt \right)$$

V_R:



$$V_R = a_0 + \sum_n a_n \cos(n\omega_R t) + b_n \sin(n\omega_R t)$$

$$a_0 \simeq -I_{dn}R \frac{T_{os}}{T_R}$$

$$a_n = -\frac{2I_{dn} \cdot R}{n\pi} \sin\left(n\pi \frac{T_{os}}{T_R}\right)$$

$$V_{ctrl}(t) \approx -I_{dn}R \frac{T_{os}}{T_R} \underbrace{- \frac{2I_{dn} \cdot R}{\pi} \sin\left(\frac{\pi T_{os}}{T_R}\right) \cos(\omega_R t)}$$

$$V_{out} = \sin\left(\omega_0 t + \int \frac{2I_{up} \cdot R}{\pi} \sin\left(\frac{\pi T_{os}}{T_R}\right) K_{vco} \cdot \cos(\omega_R t)\, dt\right)$$

$$= \sin\left(\omega_0 t + \frac{2I_{up} \cdot R\, K_{vco}}{\pi} \sin\left(\frac{\pi T_{os}}{T_R}\right) \int \cos(\omega_R t)\, dt\right)$$

$$: \sin\left(\omega_0 t + \frac{\beta}{2}\, 2\sin\left(\frac{\pi T_{os}}{T_R}\right) \frac{\sin(\omega_R t)}{\omega_R}\right)$$

$$= \sin\left(\omega_0 t + \frac{\beta'}{2}\, 2\sin\left(\pi \frac{T_{os}}{T_R}\right) \sin(\omega_R t)\right)$$

$$\frac{\beta'}{2} = \frac{2 I_{up} \cdot R\, K_{VCO}}{2\omega_R}$$

$$\sin\left(\frac{\pi \cdot T_{os}}{T_R}\right)$$

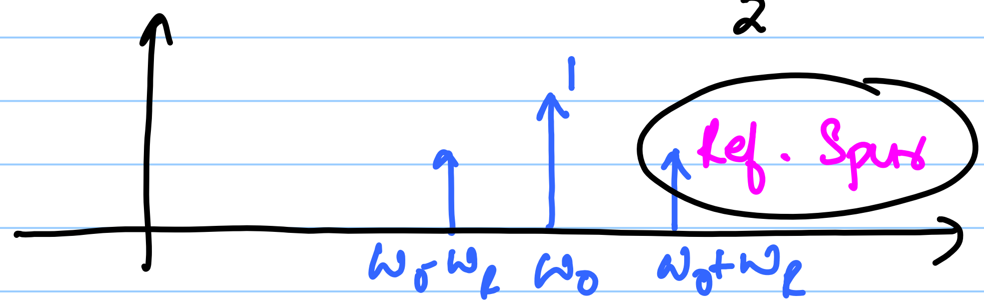
$$= \sin(\omega_0 t) \cdot \cos\left(\frac{\beta'}{2}\, 2\sin\left(\frac{\pi T_{os}}{T_R}\right) \sin(\omega_R t)\right)$$

$$+ \cos(\omega_0 t)\, \sin\left(\frac{\beta'}{2} \cdot 2\sin\left(\frac{\pi T_{os}}{T_R}\right) \sin(\omega_R t)\right)$$

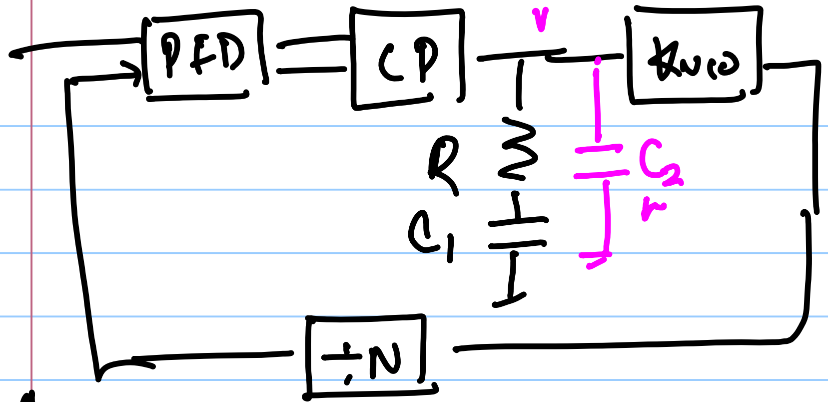
$$\theta \Rightarrow \sin(\theta) \approx \theta,\ \cos(\theta) = 1$$

$$\approx \sin(\omega_0 t) \cdot 1 + \cos(\omega_0 t) \cdot \frac{\beta'}{2}\, 2\sin\left(\frac{\pi T_{os}}{T_R}\right) \sin(\omega_R t)$$

$$= \sin(\omega_0 t) + \frac{\beta'}{2} \cdot \frac{\pi \cdot T_{os}}{T_R}\left[\sin(\omega_0 + \omega_R t) - \sin(\omega_0 - \omega_R t)\right]$$



$$\frac{\beta'}{2} \cdot \frac{\pi \cdot T_{os}}{T_R} = \frac{2 I_{up} \cdot R\, K_{VCO}}{2\omega_R} \cdot \frac{\pi \cdot T_{os}}{T_R}$$



$$= \frac{2 I_{up} \cdot R \cdot K_{vco}}{2 \cdot 2\pi f_R} \cdot \frac{\phi_{os}}{2}$$

$$= \frac{1}{2}\left(\frac{2 I_{up} \cdot R \cdot K_{vco}}{2\pi \cdot f_R} \cdot \phi_{os}\right)$$

$$= \frac{1}{2}\left(\frac{2 \cdot f_{BW} \cdot N \phi_{os}}{2\pi f_R}\right)$$

Rel. Spur $\propto f_{BW}$

$\propto \phi_{os}$.

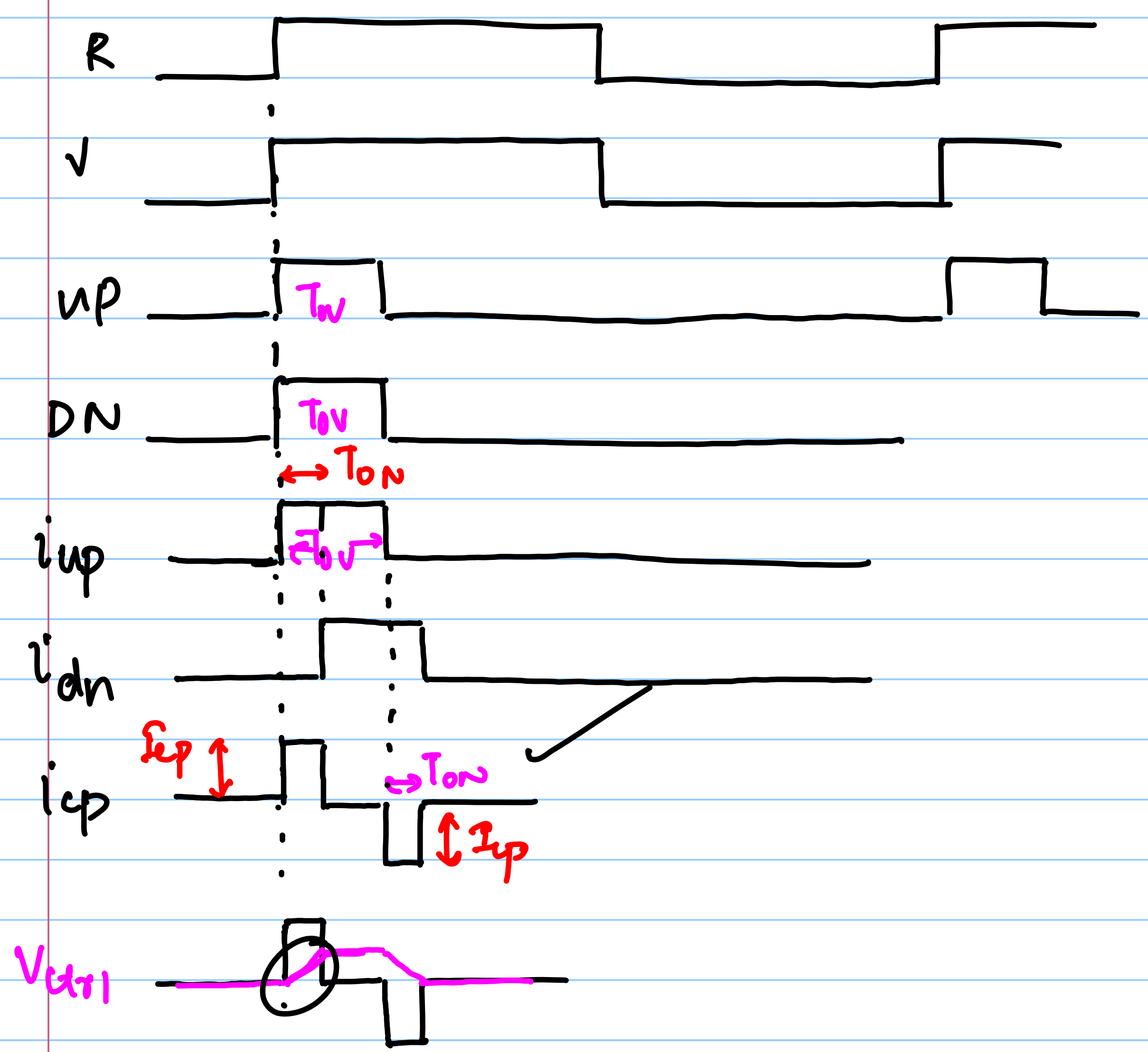
$\propto \frac{1}{f_R}$

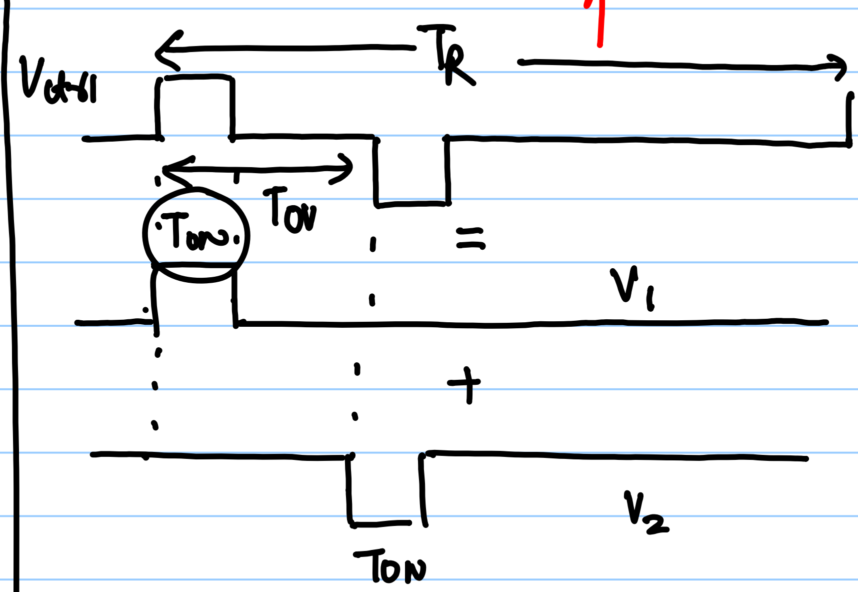
$$H_G = \frac{1}{2\pi} \cdot I_{cp} \cdot \left(R + \frac{1}{sC_1}\right) \frac{2\pi K_{vco}}{s} \frac{1}{N} \times$$

$$= \frac{I_{cp}(1 + sRC_1) K_{vco}}{s^2 C_1 N} \times \frac{1}{\left(1 + \frac{sRC_1C_2}{C_1 + C_2}\right)}$$

$$|H_G(\omega_n)| \approx 1 \Rightarrow \frac{I_{cp} \cdot (\omega_n \cdot RC_1) K_{vco}}{\omega_n^2 C_1 N} = 1 \Rightarrow \omega_n = \frac{I_{cp} K_{vco} \cdot R}{N}$$

Spur $P_{spur} = 20\log_{10}\left(\frac{f_{BW}}{F_R} \cdot N \cdot \phi_{os}\right) - 20\log_{10}\left(\frac{f_R}{f_{P3}}\right)$





$V_1(t) = a_0 + \sum a_n \cos(n\omega_R t) + b_n -$

$V_2 = -V_1(t - T_{ov})$

$V_1(t) \longrightarrow V_1(s)$

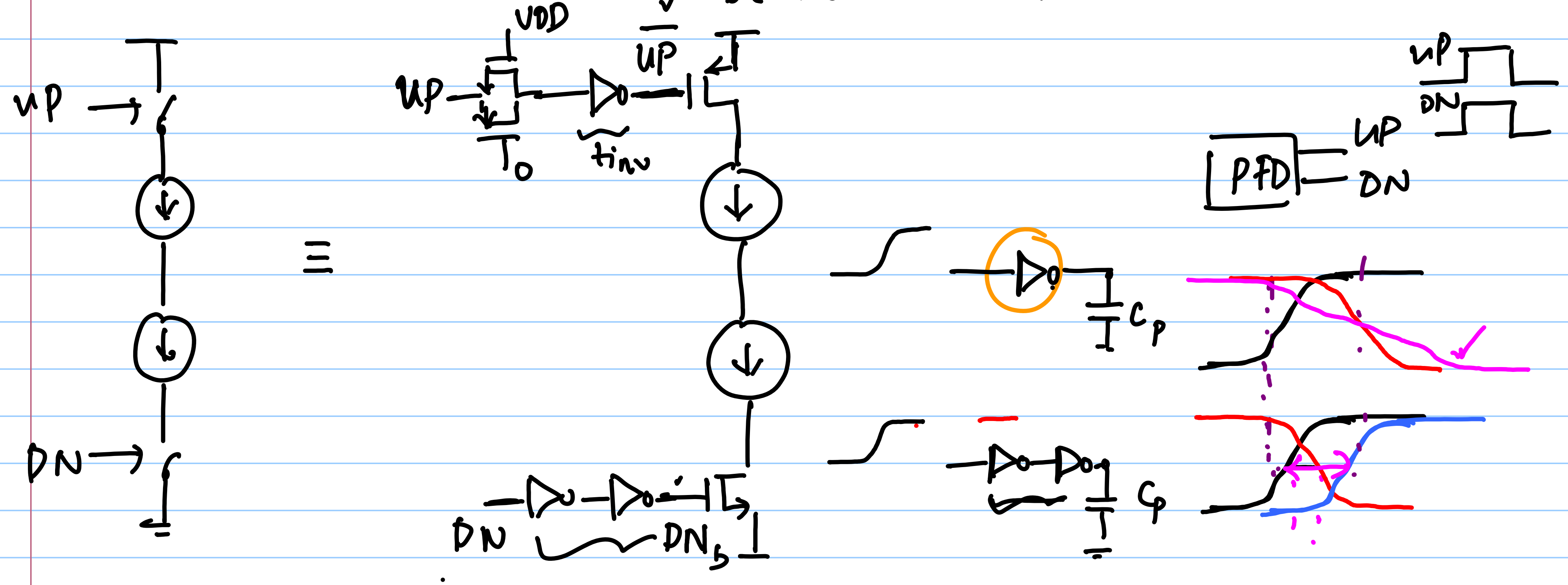
$V_2(t) \longrightarrow -V_1(s)\, e^{-sT_{ov}}$

$V_1 + V_2 = V_1(s)\left(1 - e^{-sT_{ov}}\right)$

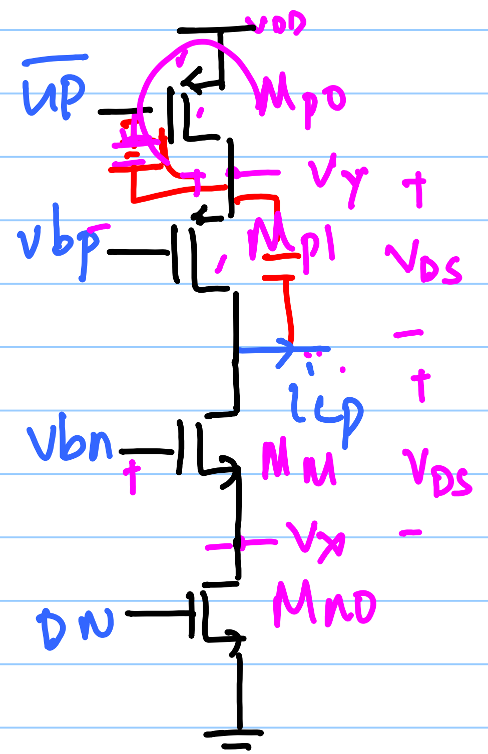
$\approx V_1(s) \cdot s \cdot T_{ov}$

$V_1'(\quad) \times \frac{2\pi T_{ov}}{T_R}$

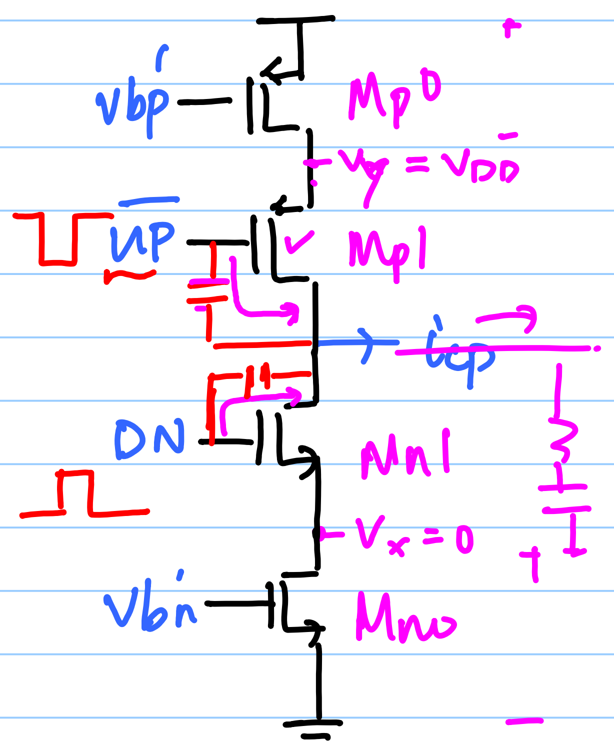
- Mismatch b/w up/dn current source should be minimized.
- Mismatch b/w ON time of top/bottom current sources should be minimized.



Source-switched CP



Drain-switched CP



Gate-switched CP