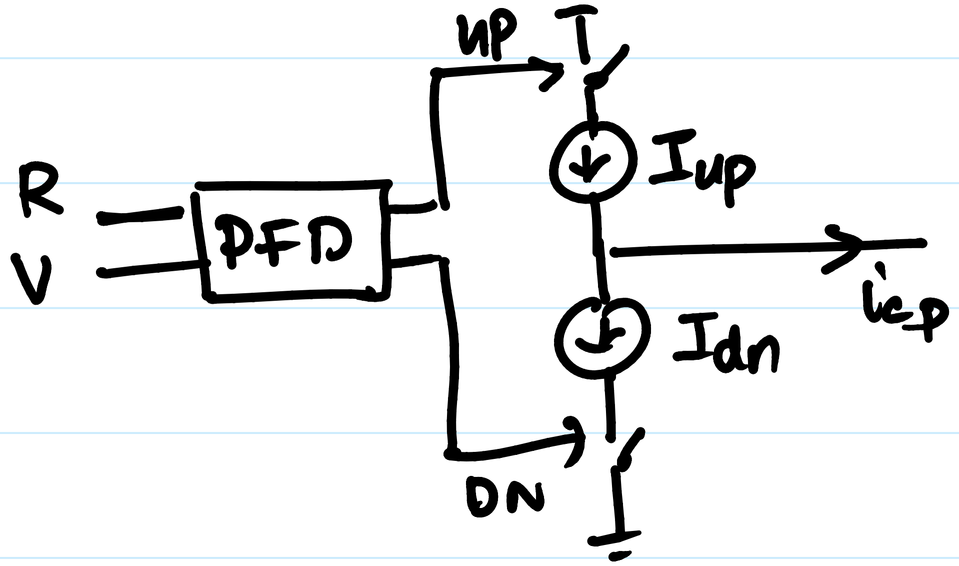
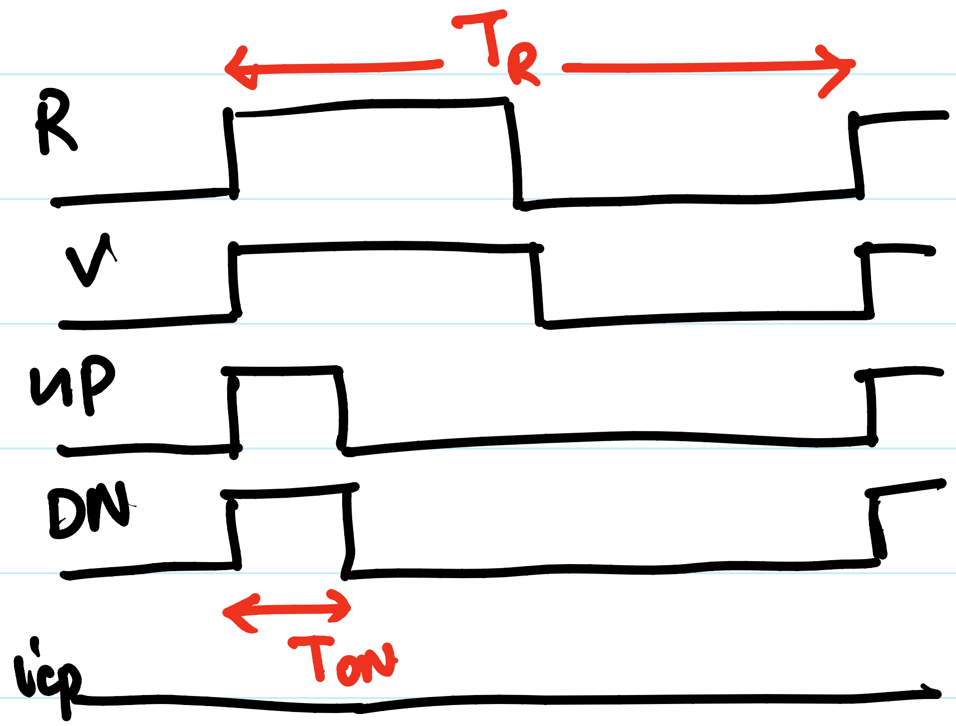
Lecture 17

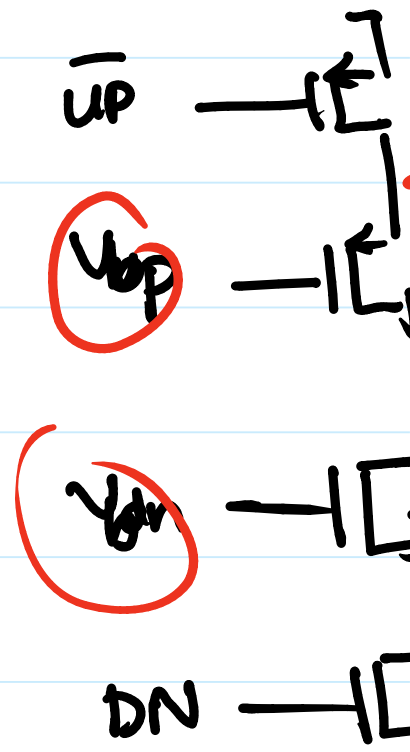
Monday, February 13, 2017 9:43 AM

PLL building blocks.

Charge-pump:





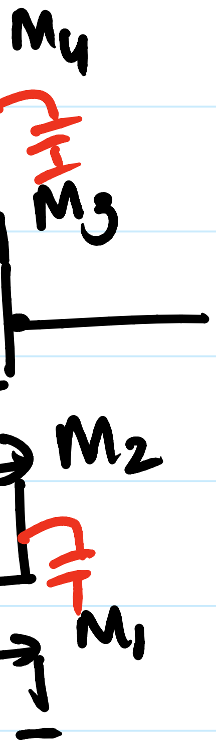


$$i_{cp} = I_{up} - I_{dn}$$

M_1, M_4 are

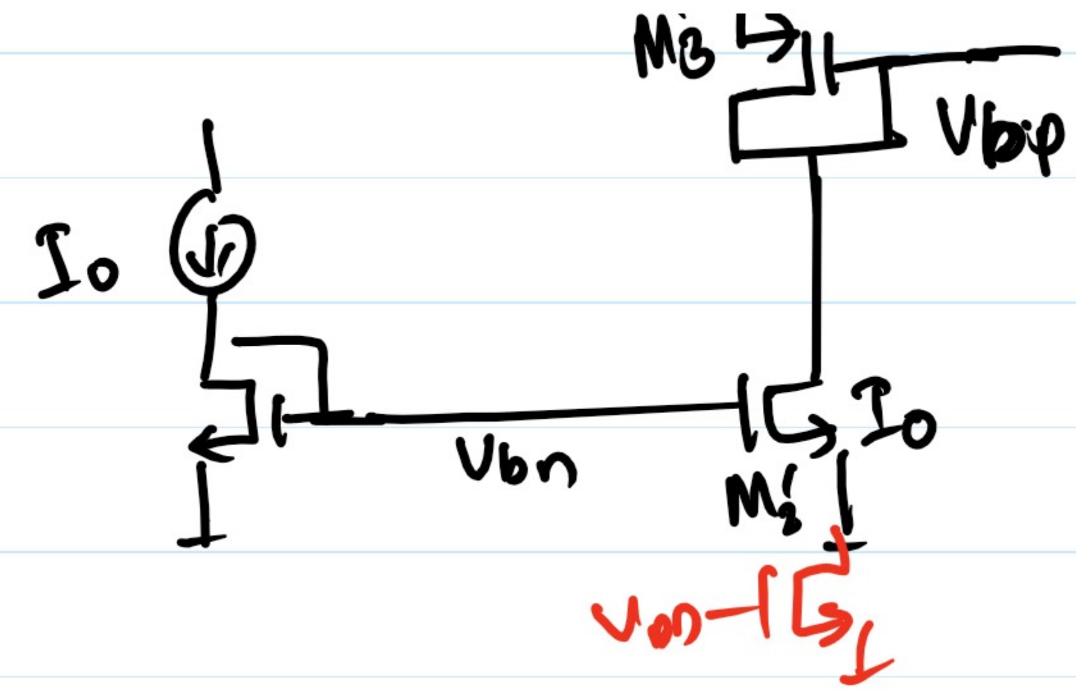
M_2, M_3 are

- Mismatch between I_{up} & I_{dn}, $I_{up} \neq I_{dn}$ (Static errors)
- Dynamic error: Charge-sharing during transient clock f



switches

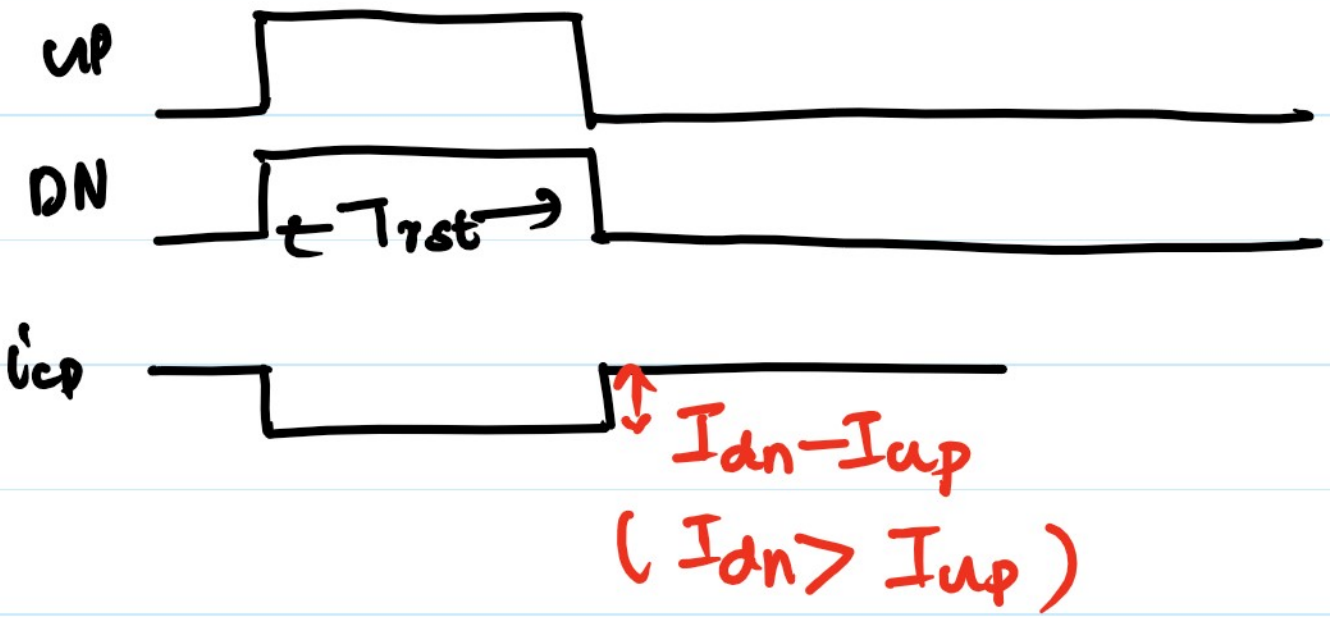
current source

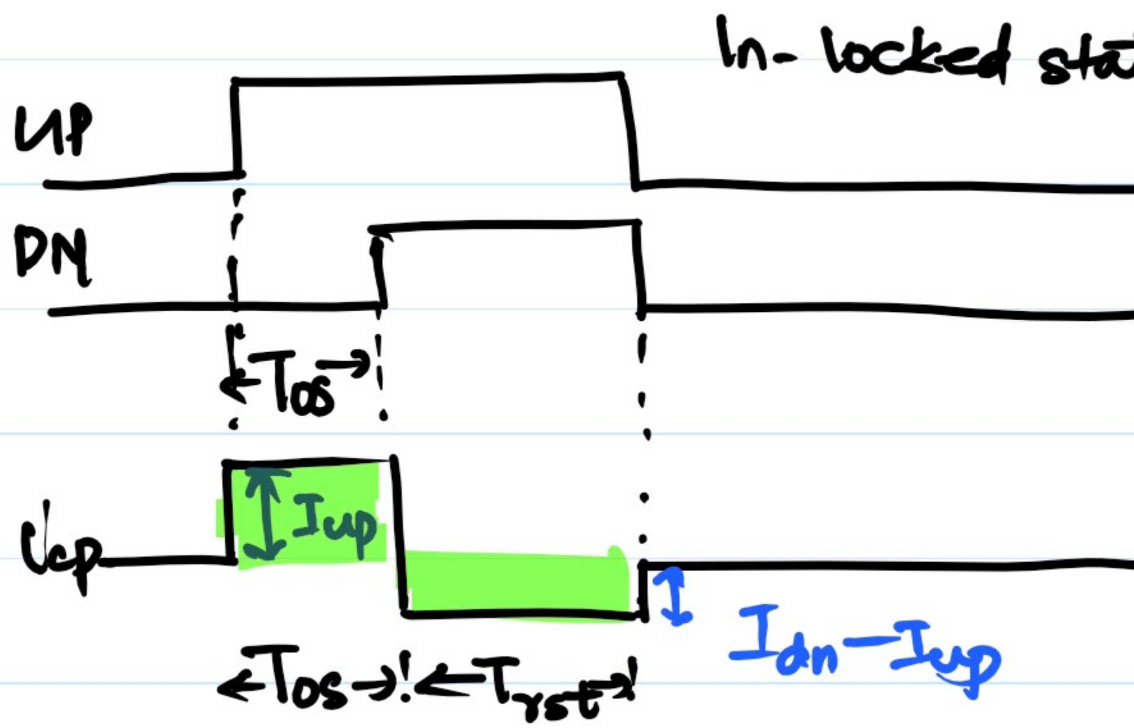


Mismatch between M_2 & M_2' ,

- $\overline{UP}$ / DN → I_{up}/I_{dn} delay

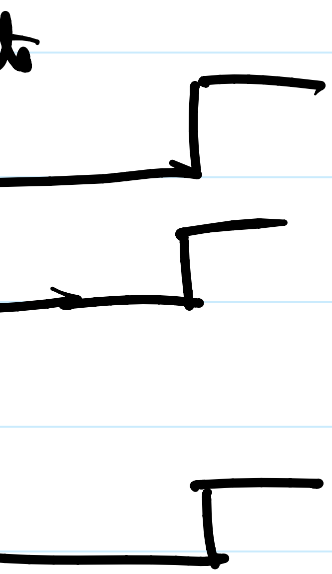
a) Mismatch between I_{up} & I_{dn}





$$I_{up} \cdot T_{os} = (I_{dn} - I_{up})\, T_{rst}$$

M_3 & M_3'

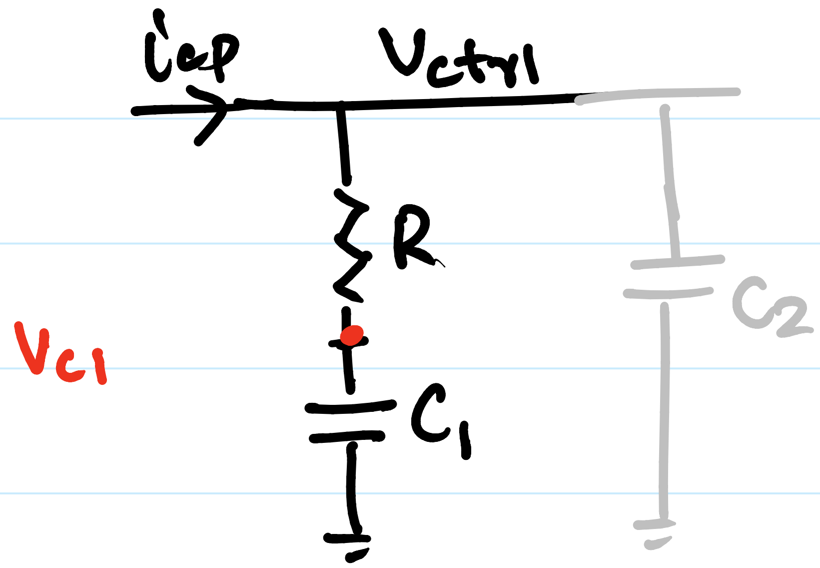


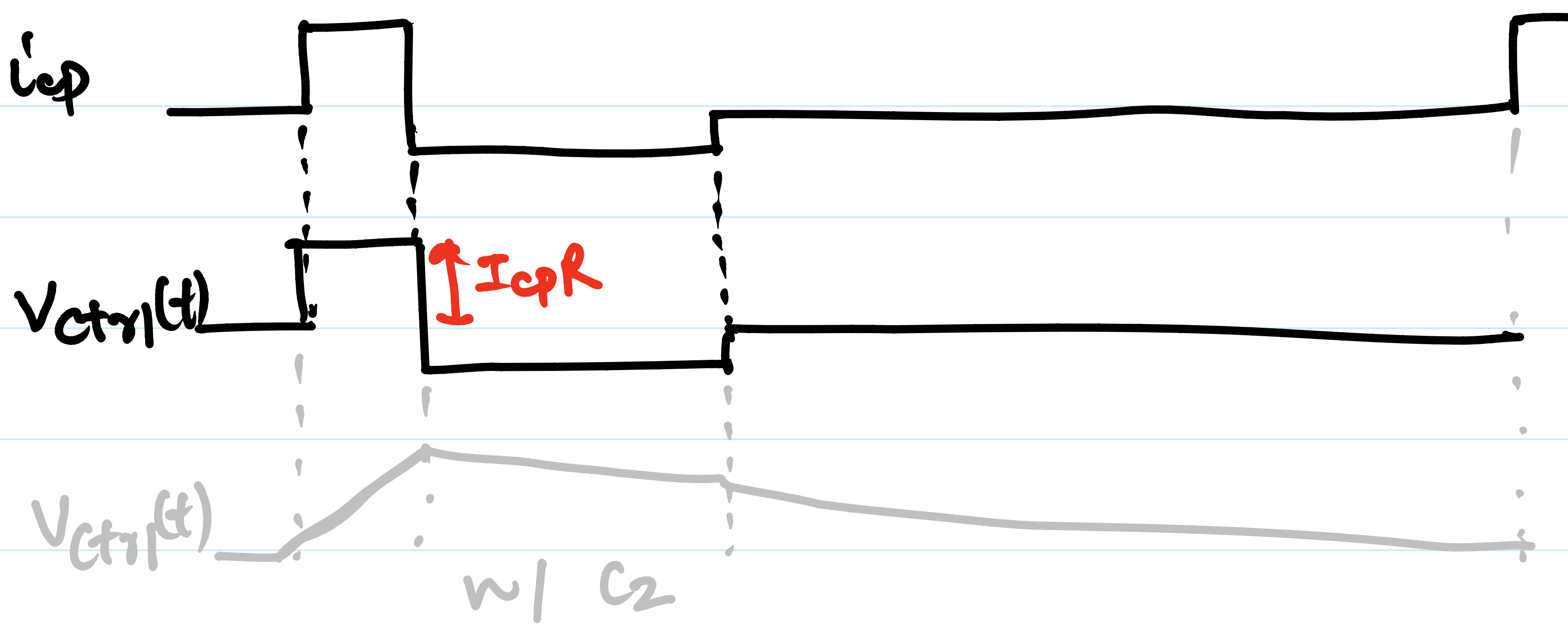
$$I_{up} \cdot T_{os} = (I_{dn} - I_{up})\, T_{rst}$$

$$\frac{T_{os}}{T_{rst}} = \frac{I_{dn} - I_{up}}{I_{up}} = \frac{\Delta I}{I}$$

$$T_{os} = \frac{\Delta I}{I}\, T_{rst}$$

$$\Delta\Phi_{os} = 2\pi \cdot \frac{T_{os}}{T_R} = 2\pi \cdot \frac{\Delta I}{I}\, \frac{T_{rst}}{T_R}$$; T_R — Ref. pe

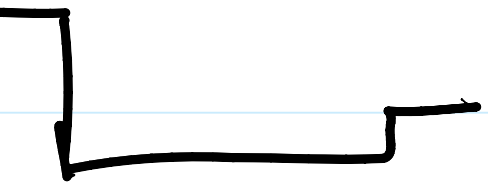




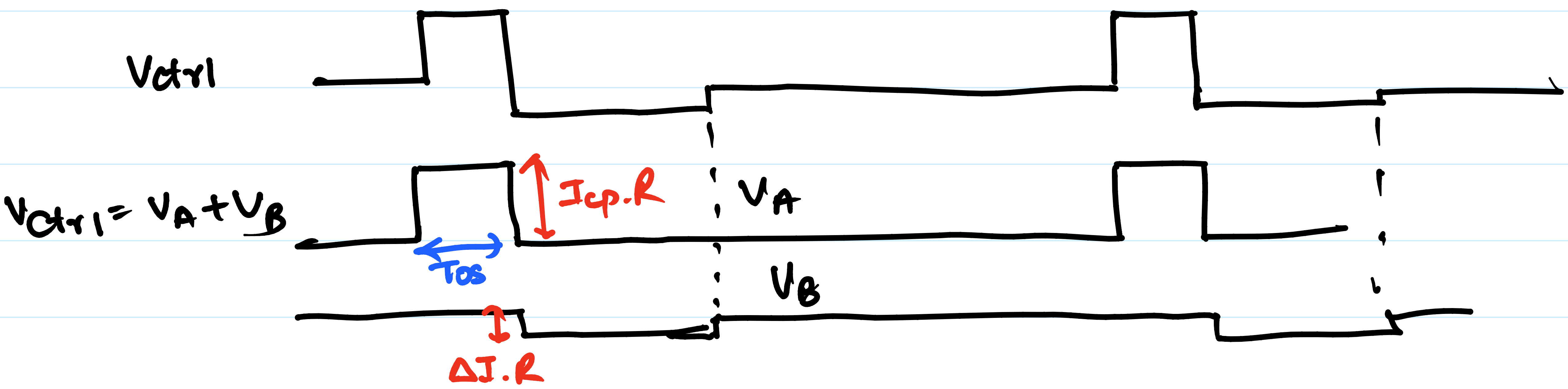
$$i_{cp} = C_1 \frac{dV_{c1}}{dt}$$

$$V_{c1} = \frac{1}{C_1}\, i_{cp}\, t$$

riod



$$V_{ctrl} = \frac{1}{C_1} i_{cp} t + i_{cp} \cdot R$$



$$V_{ctrl} = V_A + V_B \approx V_A = a_0 + \sum_n a_n \cos(n\omega_R t)$$

ω_R: ref. fr

$$a_0 = I_{cp} \frac{T_{os}}{T_R}$$

For $n=1$

$$V_{ctrl} = \frac{2 I_{cp} \cdot R}{\omega_R T_R} \sin\left(2\pi \cdot \frac{T_{os}}{T_R}\right) \cos(\omega_R t)$$

$$\approx \frac{2 I_{cp} R}{\omega_R T_R} \underbrace{\left(2\pi \cdot \frac{T_{os}}{T_R}\right)}\cos(\omega_R t)$$

$$\int_0^{T_R} (I_{cp} \cdot R) \cos(m\omega_R t) \cdot d$$

$$= \int_0^{T_R} \sum_n a_n \cos(n\omega_R t).$$

$$\frac{I_{cp} R \times}{m\omega_R} \sin(m\omega_R t)\Big|_0^{T_{os}}$$

$$= \frac{a_m}{2} \int^{T_R} 1 - \cos(2m$$

eq

t

$\cos(n\omega_R t)$ dt

$n\omega_R t)$ .dt

$$= \frac{2 I_{cp} R}{\omega_R T_R} \Delta\phi_{os} \cdot \cos(\omega_R t)$$

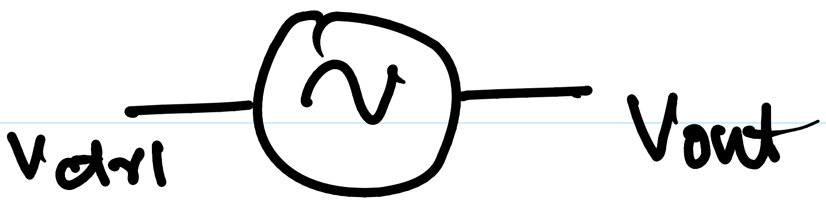
$$= \frac{I_{cp} R}{\pi} \Delta\phi_{os} \cos(\omega_R t)$$

$$= \frac{a_m}{2} \int_0 1 - \cos(2n$$

$$\Rightarrow \quad a_n = \frac{2 I_{cp} . R}{n \omega_R T_R}$$

$$a_n = \frac{2 I_{cp} . R}{n \omega_R T_R} \sin(2$$

$$= \frac{I_{cp} R}{n\pi} \sin(2n\pi$$



$$V_{out} = A \cos(\cdot \; K_{vco} . \int V_{ctrl} . dt)$$

$$= A \cos(\; K_{vco} \int V_o + \frac{2 I_{cp} . R}{\omega_R T_R} . \Delta\phi_{os} . \cos(\omega_R t) \; dt)$$

$$= A \cos(\omega_o t + \underbrace{\frac{2 I_{cp} . R}{\omega_R T_R} . \Delta\phi_{os} . K_{vco}}_{\beta .} \int \cos(\omega_R t) \, dt$$

$$= A \cos(\omega_o t . + \frac{\beta}{\omega_R} \sin(\omega_R t))$$

$n\omega_R t)\ .dt$

$\sin\left(n\omega_R T_{os}\right)$

$2n\pi \frac{T_{os}}{T_R}\Big)$

$\frac{T_{os}}{T_R}\Big)$ ✓

$t\ \Big)$

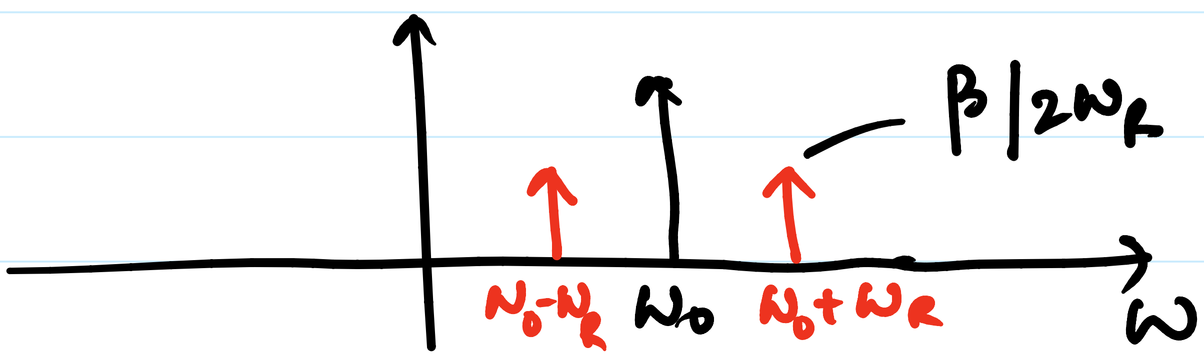
ω_R

$$= A\cos(\omega_0 t)\cos\left(\underbrace{\frac{\beta}{\omega_R}\sin(\omega_R t)}_{\approx 0}\right) - A\sin(\omega_0 t)\cdot\sin\Big($$

$$= A\cos(\omega_0 t) - A\sin(\omega_0 t)\cdot\frac{\beta}{\omega_R}\sin(\omega_R t)$$

$$= A\cos(\omega_0 t) + \frac{A}{2}\,\frac{\beta}{\omega_R}\Big(\cos(\overline{\omega_0+\omega_R}\,t) - \cos(\omega$$

$$= A\cos(\omega_0 t) + A \times \frac{\beta}{2\omega_R}\Big[\cos(\overline{\omega_0+\omega_R}\,t) - \cos(\omega_0-$$



$$\frac{\beta}{2\omega_R} = \frac{2 I_{cp}\cdot R}{\omega_R T_R}\cdot\Delta\Phi_{os}\cdot K_{vco}\cdot\frac{1}{2\omega_R}$$

$$\frac{\beta}{\omega_R T_R} \cdot \sin(\omega_R t) \Big)$$

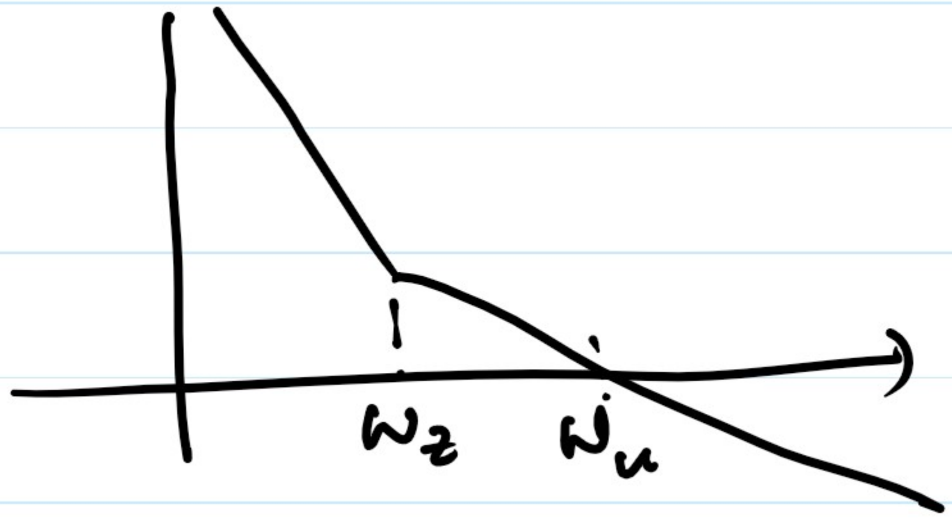
$$\omega_0 - \omega_R)t \Big)$$

$$\omega_R)t \Big]$$

$$= \frac{2 I_{cp} \cdot R}{\omega_R T_R} \cdot 2\pi \cdot \frac{T_{os}}{T_R} \times \frac{K_{vco}}{2 \cdot \frac{2\pi}{T_R}}$$

$$= \frac{I_{cp} \cdot R}{2 \omega_R T_R} T_{os} \cdot K_{vco} = \frac{I_{cp} \cdot R \cdot K_{vco}}{2\pi} \cdot \frac{T_{os}}{(2/T_R) T_R} =$$

$$LG = \frac{I_{cp}}{2\pi}\left(R + \frac{1}{sC_1}\right)\frac{K_{vco}}{s} = \frac{I_{cp}}{2\pi} \frac{K_{vco}}{sC_1} \frac{(1+sRC_1)}{s}$$



$$|LG(\omega_u)| = \frac{I_{cp}}{2\pi} \frac{K_{vco}}{\omega_u C_1} RC_1 =$$

$$\omega_u = \frac{I_{cp} R \cdot K_{vco}}{2\pi}$$

$$\text{Spur magnitude} = \frac{F_{BW}}{2 F_R} \Delta\Phi_{os}$$

$$\frac{2\pi F_{BW}}{2 \cdot F_R} \cdot \frac{T_{OS}}{T_R} = \frac{F_{BW}}{2F_R} \Delta\Phi_{OS}$$

$= 1$