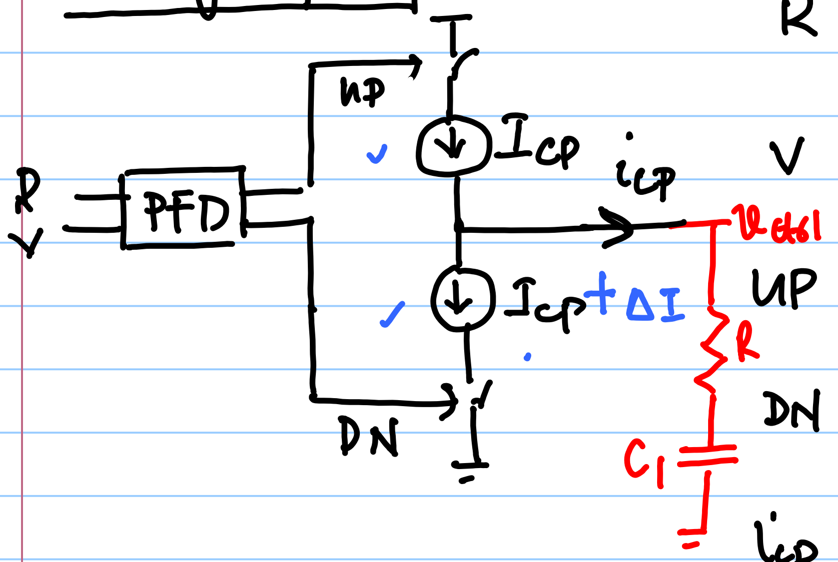
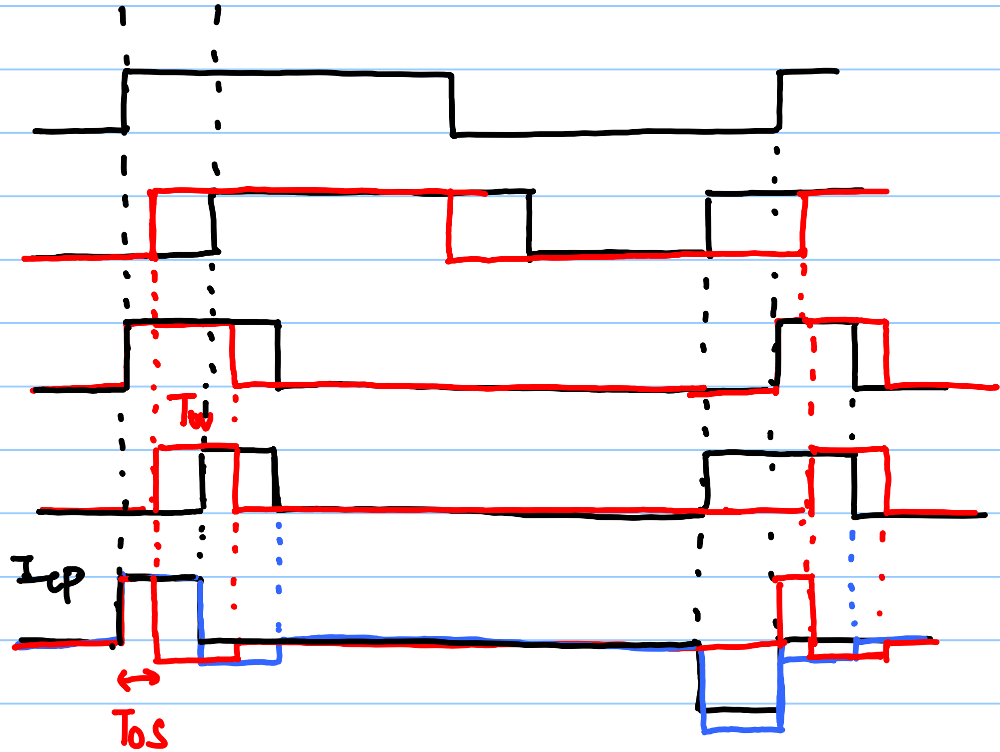
Note Title: Lecture # 38 — 23-11-2020

Charge-pump.



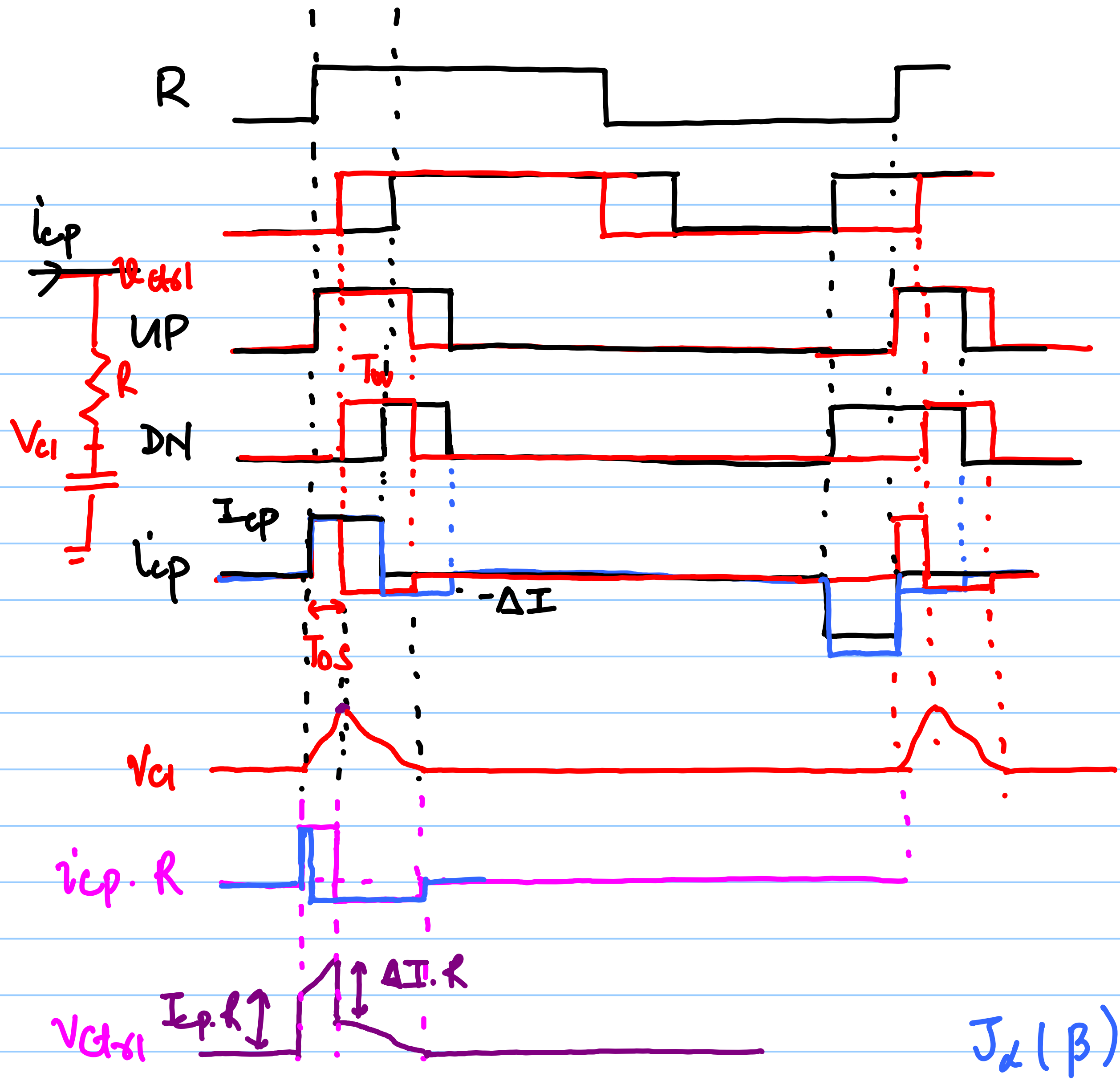


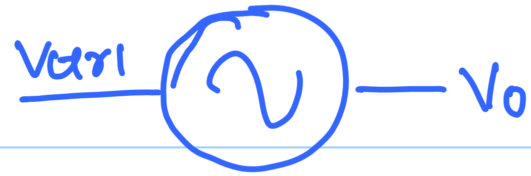
- Current mismatch $\quad I_{UP} \neq I_{DN}$ or $I_{UP} = I_{DN} - \Delta I = I_{CP}$

$$I_{UP} = I_{CP}$$

$$I_{DN} = I_{cp} + \Delta I$$

$$I_{cp} \cdot T_{os} = \Delta I \times T_{ov} \Rightarrow \boxed{T_{os} = \frac{\Delta I}{I_{cp}} \cdot T_{ov}}$$





$$V_o = 1.\cos\left(w_{free} \cdot t + K_{vco} \int V_{ctrl} \cdot dt\right)$$

$$= \cos\left(w_o \cdot t + \int K_{vco} \cdot V_{ctrl}\, dt\right)$$

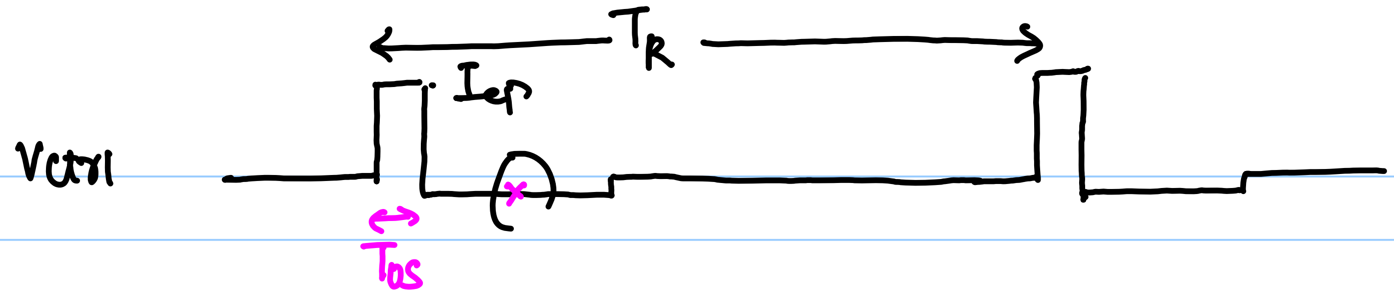
$$V_o = \cos(w_o t + \beta \sin(w_m t))$$

$$= J_0(\beta)\cos(w_o t)$$

$$+ J_1(\beta)\big(\cos(w_o + w_m)t - \cos(w_o - w_m)t\big)$$

$$+ J_2(\beta) \cdot \quad .$$

$$J_\alpha(\beta) = \frac{1}{2\pi}\int_0^{2\pi} \cos(\alpha\tau - \beta\sin(\tau))\, d\tau$$



$$V_{ctrl}(t) = \sum a_n \cos(n\omega_R t) + b_n \sin(n\omega_R t) \approx \sum \frac{1}{n\pi} I_{cp} R \sin(n\phi_{os}) \cos(n\omega_R t)$$

$$= \sum_n c_n \cos(n\omega_R t + \phi_n)$$

$$\int_0^{T_R} V_{ctrl} \cdot \cos(m\omega_R t) \cdot dt = a_m \int_0^{T_R} \cos^2(m\omega_R t) \cdot dt$$

$$I_{cp} \cdot R \left. \frac{\sin(m\omega_R t)}{m\omega_R} \right|_0^{T_{os}} = \frac{a_m}{2} \int_0^{T_R} 1 - \cos(2m\omega_R t) \cdot dt$$

$$\frac{I_{cp} \cdot R}{m\omega_R} \sin(m\omega_R \cdot T_{os}) = \frac{a_m}{2} \cdot T_R$$

$$a_m = \frac{2}{T_R} \frac{I_{cp} \cdot R}{m \cdot \omega_R} \sin\left(m \cdot \frac{2\pi}{T_R} \cdot T_{os}\right) = \frac{1}{m\pi} I_{cp} \cdot R \cdot \sin(m \cdot \phi_{os})$$

$\omega_R = \frac{2\pi}{T_R}$, $\frac{2\pi}{T_R} \cdot T_{os} = \phi_{os}$

$$\frac{I_{cp}\cdot R}{m\omega_R} \times -\cos(m\omega_R t)\Big|_0^{T_{os}} = \frac{b_m}{2}\cdot T_R$$

$$\frac{I_{cp}\cdot R}{m\omega_R}\left(1-\cos(m\cdot\phi_{os})\right) = \frac{b_m}{2}\cdot T_R$$

$$LG = \frac{I_{cp}}{2\pi}\cdot\frac{(1+sRC_1)}{s^2 C_1}\frac{K_{vco}}{N}$$

$$|LG| = 1 = \frac{I_{cp}\cdot\omega_u R C_1 \, K_{vco}}{2\pi\,\omega_u^2 C_1 \, N}$$

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

$$b_m = \frac{I_{cp}\cdot R}{m\pi}\left(1-\cos(m\phi_{os})\right)$$

$$V_0 = \cos\left(\omega_0 t + \frac{K_{vco}}{\pi} I_{cp}\cdot R\sin(\phi_{os})\int\cos(\omega_R t)\,dt\right)$$

$$= \cos\left(\omega_0 t + \underbrace{\frac{K_{vco} I_{cp} R\sin(\phi_{os})}{\pi\omega_R}}_{=\beta}\sin(\omega_R t)\right) = \cos(\omega_0 t + \beta\sin(\omega_R t))$$

$$= \cos\left(\omega_0 t + \frac{2\pi K_{vco}' I_{cp}\cdot R\sin(\phi_{os})}{\pi\, 2\pi f_R}\sin(\omega_R t)\right)$$

$$= \cos\left(\omega_0 t + \frac{2\pi N\omega_u\sin(\phi_{os})}{\pi\omega_R}\sin(\omega_R t)\right)$$

$$= \cos\left(\omega_0 t + \frac{2N\omega_u}{\omega_R} \sin(\phi_{os}) \sin(\omega_R t) \right)$$

$$= \cos(\omega_0 t) \cdot \cos(\beta \sin(\omega_R t)) - \sin(\omega_0 t) \cdot \sin(\beta \cdot \sin(\omega_R t))$$

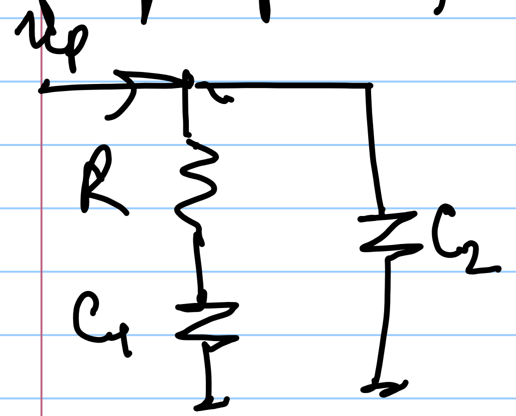
$\beta \ll 1$, $\theta \approx 0$

$$\approx \cos(\omega_0 t) \cdot \cos(0) - \beta \sin(\omega_0 t) \cdot \sin(\omega_R t)$$

$$= \cos(\omega_0 t) + \frac{\beta}{2} \left[\cos(\overline{\omega_0 + \omega_R}\, t) - \cos(\overline{\omega_0 - \omega_R}\, t) \right]$$

$$\frac{\beta}{2} = \frac{N \cdot \omega_u}{\omega_R} \sin(\phi_{os}) \, . = \text{Spur Magnitude}$$

Spur power, $P_{spur} \approx 20 \log_{10} \left(\frac{\omega_u}{\omega_R} N \sin(\phi_{os}) \right) - 20\log_{10} \left(\frac{f_R}{f_{P3}} \right)$



$$2\pi f_{P3} = \frac{1}{\frac{R C_1 C_2}{C_1 + C_2}}$$

$\frac{f_u}{\uparrow f_R} \Downarrow$

$\frac{f_R}{f_{P3}}$,