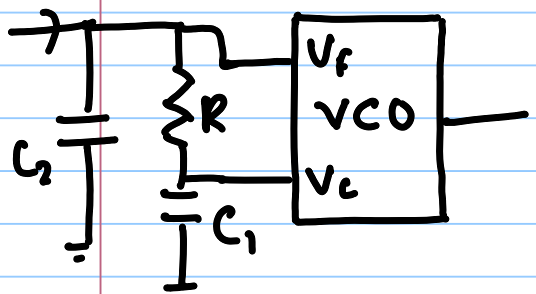
Lecture # 43

Note Title 24-10-2017

Split-tuned PLLs.



$V_f : K_{vco}^F$, $V_c : K_{vco}^C$

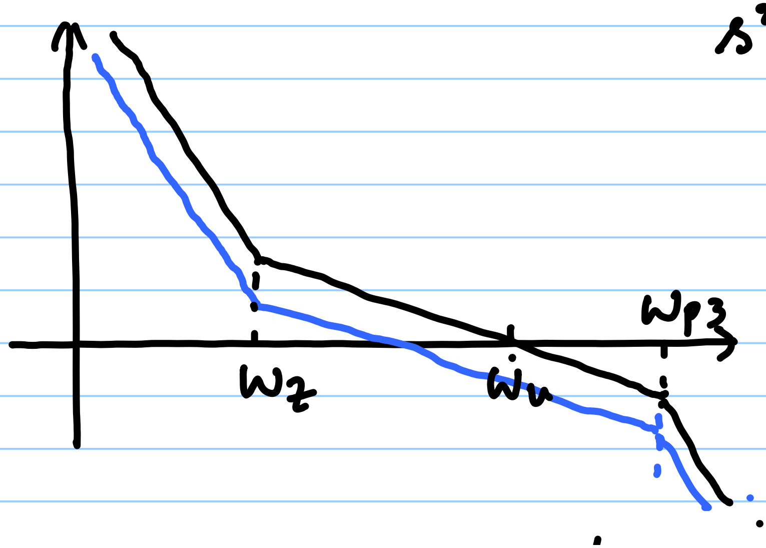
$K_{vco}^F = \frac{K_{vco}}{K}$

$K_{vco}^C = \frac{(K-1)}{K} K_{vco}$

$$LG(s) = \frac{K I_{cp} K_{vco}}{s^2 (KC_1 + C_2)} \frac{(1 + sRC_1)}{\left(1 + sR \frac{KC_1 \cdot C_2}{KC_1 + C_2}\right)}$$

$$\frac{\left(R + \frac{1}{sC_1}\right) \times \frac{1}{sC_2}}{R + \frac{C_1 + C_2}{sC_1 C_2}}$$

Old $\quad LG(s) = \frac{I_{cp}}{s^2} \frac{K_{vco}}{(C_1 + C_2)} \frac{(1 + sRC_1)}{\left(1 + sR \frac{C_1 C_2}{C_1 + C_2}\right)}$

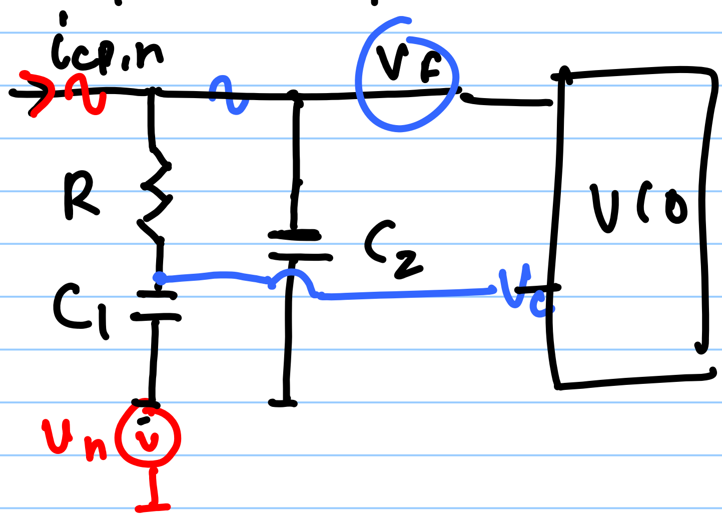


$$\omega_{z,new} = \omega_{z,old} = \frac{1}{RC_1}$$

$$\omega_{p3,new} = \omega_{p3,old} = \frac{1}{RC_1C_2/C_1+C_2}$$

$$LG(s) \approx \frac{I_{cp} K_{vco}}{s^2 C_1} \frac{(1+s/\omega_z)}{(1+s/\omega_{p3})}$$

- $K_{vco} \rightarrow K_{vco}/K$
- $C_1 \rightarrow KC_1$
- $I_{cp} \rightarrow KI_{cp}$



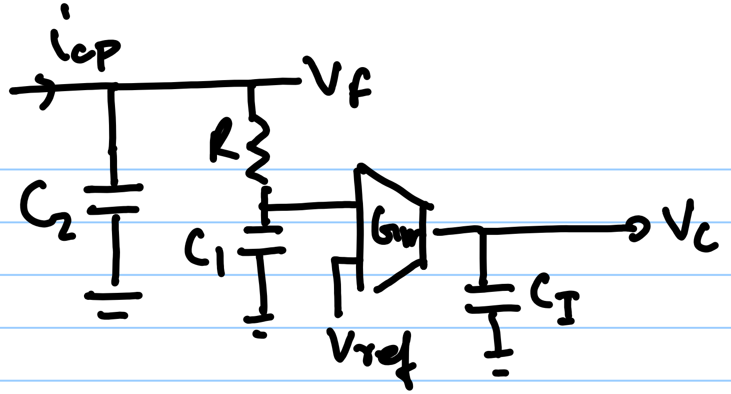
K_{vco}

$$NTF_R = \frac{K_{vco}}{s} \frac{1}{1+LG}$$

K_{vco}/K

$$\frac{V_F}{i_{cp}}$$

$$\frac{V_c}{i_{cp}} = \frac{V_F}{i_{cp}} \times \frac{1}{1+sRC_1}$$



$$\frac{V_f}{I_{cp}} = F(s)$$

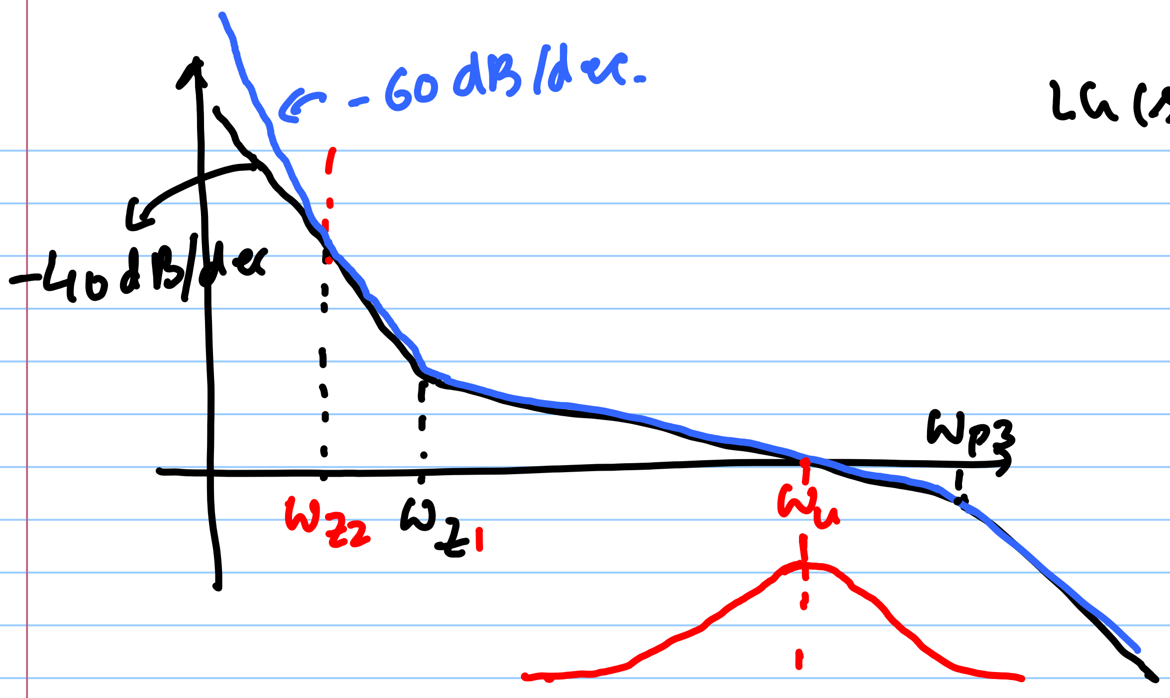
$$\frac{V_c}{I_{cp}} = F(s) \times \frac{1}{1+sRC_1} \times \frac{G_m}{sC_I}$$

$$LG(s) = \frac{I_{cp}F(s)}{2\pi}\left[K_{vco}^{f} + \frac{K_{vco}^{c}}{(1+sRC_1)} \times \frac{G_m}{sC_I}\right] \times \frac{2\pi}{s}$$

$$= \frac{I_{cp}}{2\pi}\,\frac{2\pi F(s)/s}{(1+sRC_1)} \cdot \left[K_{vco}^{f}\, sC_I(1+sRC_1) + K_{vco}^{c}.G_m\right] \times \frac{1}{sC_I}$$

$$\overbrace{s^2 RC_1C_I K_{vco}^{f} + sC_I K_{vco}^{f}} \hspace{-5.5em} \underbrace{\phantom{sC_I K_{vco}^{f}} + K_{vco}^{c} G_m} = 0$$

$$s \approx \frac{K_{vco}^{c}.G_m}{K_{vco}^{f}\,C_I} = \omega_{z2}, \quad s \approx \frac{1}{RC_1} = \omega_{z1}$$



$$LG(s) \propto \frac{I_{cp}\,(s+\omega_{z1})(s+\omega_{z2})}{s^3 C_I (C_1+C_2)\,(s+\omega_{p3})}$$

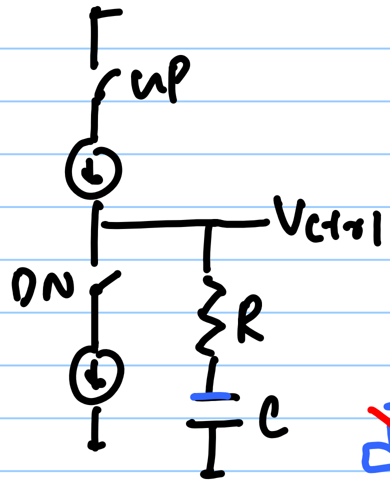
$$\omega_{z2} \ll \omega_{z1}$$

$$\frac{K_{VCO}^{c}\, G_m}{K_{VCO}^{f}\, C_I} \ll \frac{1}{RC_1}$$

- G_m contributes noise

$$\boxed{PFD} \xrightarrow{\phi_{err}} \boxed{I_{cp}} - \boxed{LF} -$$

Digital PLL.



$$\frac{V_{ctrl}(s)}{\phi_{err}} = I_{cp}\left(\underbrace{R}_{\text{Prop.}} + \underbrace{\frac{1}{sC}}_{\text{Integral}}\right)$$

$$s \to \frac{2}{T}\,\frac{1-z^{-1}}{1+z^{-1}} \qquad I_{cp}, C$$

$$V_{ctrl}(z) = I_{cp}\left(R + \frac{T}{2C}\,\frac{1+z^{-1}}{1-z^{-1}}\right)$$

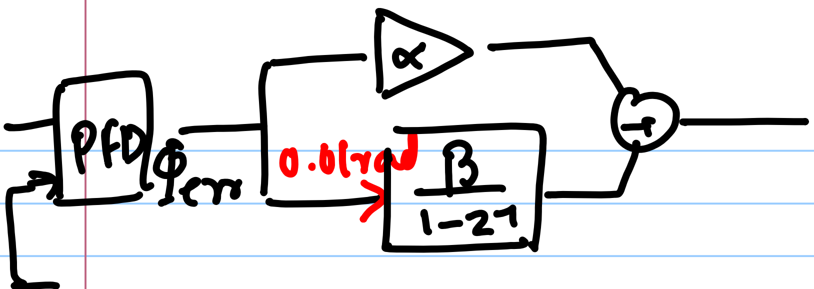
$$= \frac{I_{cp}}{2C}\,\frac{2CR(1-z^{-1}) + T(1+z^{-1})}{1-z^{-1}}$$

$$= \frac{I_{cp}}{2C}\,\frac{(2RC+T) + (T-2RC)z^{-1}}{1-z^{-1}} \quad \text{—(1)}$$

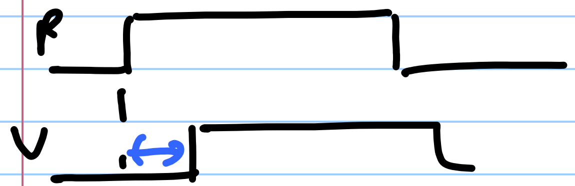
$$\frac{V_{ctrl}(z)}{\phi_{err}(z)} = \alpha + \frac{\beta}{1-z^{-1}}$$

$$V_{ctrl}(n) = \alpha\,\phi_{err}(n)$$

$$+$$



$$\frac{V_{ctrl}(z)}{\Phi_{err}(z)} = \frac{(\alpha+\beta) - \alpha z^{-1}}{1-z^{-1}} \quad -(2)$$



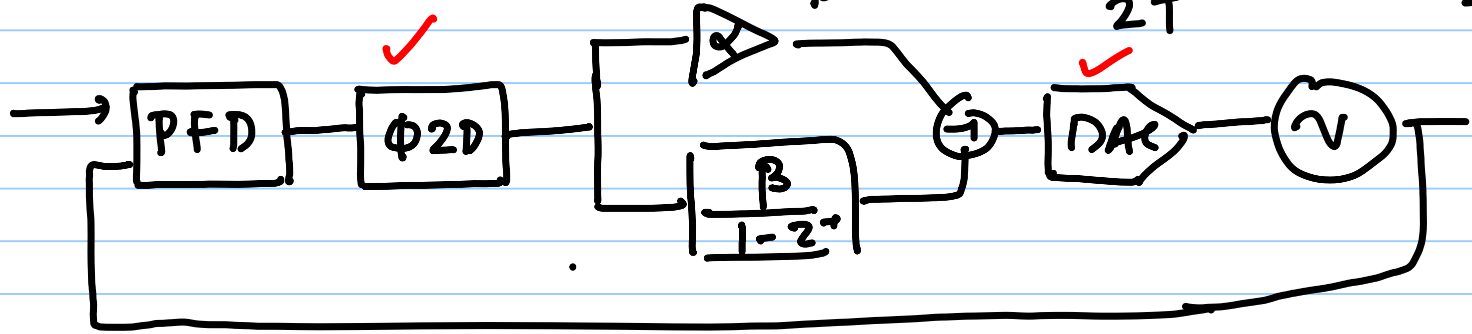
$\Phi_{err} = 0.01\,rad$

$$\alpha+\beta = \frac{I_{cp}}{2C}(T+2RC)$$

$$\alpha = \frac{I_{cp}}{2C}(2RC-T)$$

$$\beta = \frac{I_{cp}}{2C} \times 2T$$

$$\frac{\alpha}{\beta} = \frac{(2RC-T)}{2T} = \frac{RC}{T} - \frac{1}{2}$$



$$LG(s) = \frac{I_{cp}}{2\pi} \times \frac{2\pi K_{vco}}{s} \frac{(1+sRC)}{sC}$$

$$\angle LG = -180^{\circ} + \tan^{-1}(\omega/\omega_z)$$

$$\Phi_m = \tan^{-1}(\omega_u/\omega_z)$$

$$\frac{1}{RC} = \omega_z = \frac{\omega_u}{\tan(\Phi_m)}$$

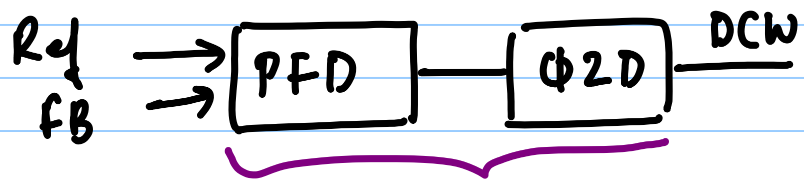
ω_z

$$\frac{\alpha}{\beta} = \frac{RC}{T} - \frac{1}{2}$$

$$= \frac{f_{ref}}{\omega_z} - \frac{1}{2}$$

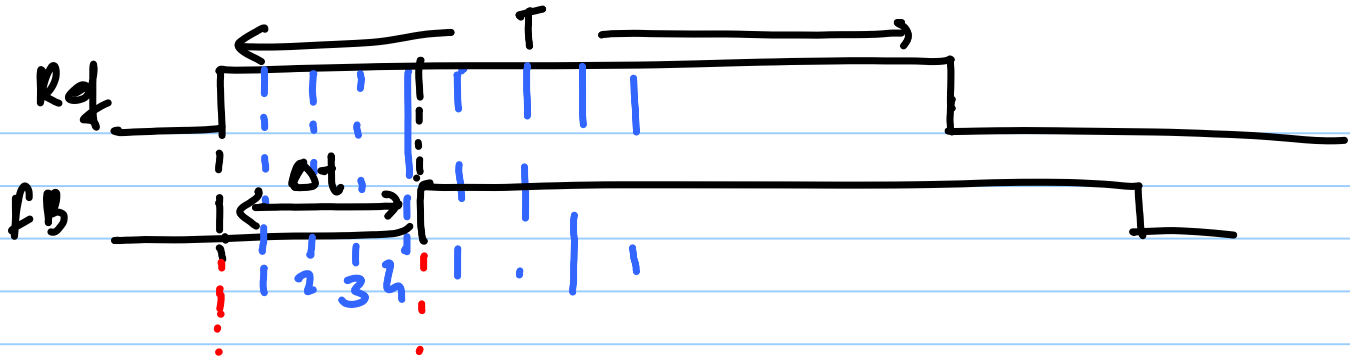
$$\frac{\alpha}{\beta} \approx \frac{f_{ref}}{\omega_u} \cdot \tan(\Phi_m) - \frac{1}{2}$$

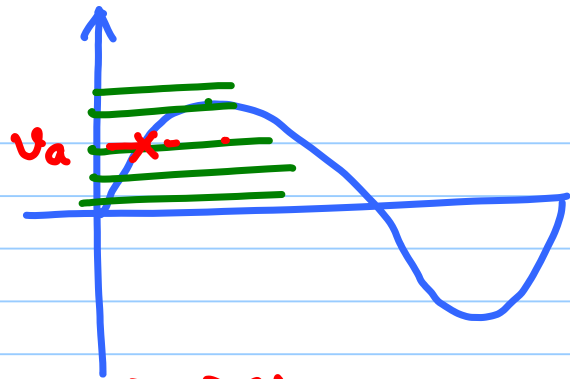
Large $\Phi_m \Rightarrow \alpha \quad \beta$



DCW: Digital Control Word.

TDC : Time to Digital Converter.





$V_a \rightarrow$ DCW.