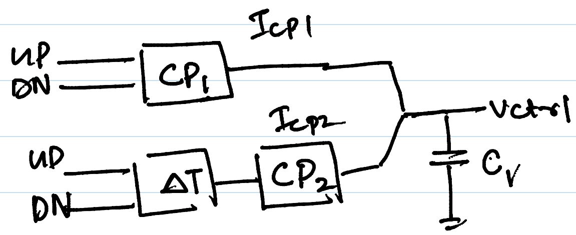
Lecture 34

Tuesday, April 4, 2017
9:58 AM

Loop Filter.



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

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

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

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

$I_{cp1} - I_{cp2} > 0$,

For +ve $\Delta\Phi_{err}$, CP_1 pushes current into cap.

CP_2 drains current from cap.

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

$$\omega_z = \frac{1}{\frac{I_{cp2}}{I_{cp}} \cdot \Delta T}$$

Eg: $\Delta T = \frac{1}{2\pi \times 10^6} \approx 0.16\ \mu s$

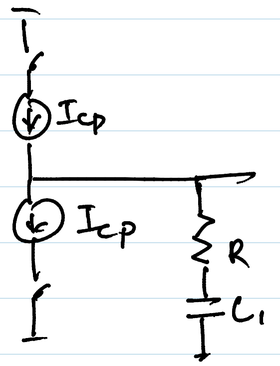
Digital Phase-Locked Loop (DPLL)

1.) Loop filter occupies a lot of area

- large area for passive cap.
- large area for active cap. + leakage current.

2) Mismatch in CP UP/DN current sources

3) Digital logic is invariant to PVT variations.



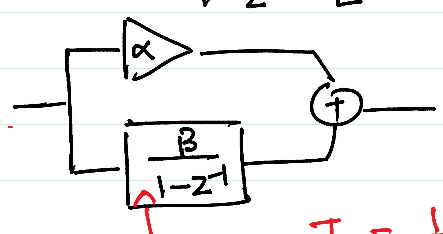
$$I_{cp}\left(R+\frac{1}{sC_1}\right) \Rightarrow I_{cp}\left[R+\frac{1}{C_1}\,\frac{T_s}{2}\,\frac{(1+z^{-1})}{1-z^{-1}}\right]$$

Bilinear trans. $s = \frac{2}{T_s}\,\frac{1-z^{-1}}{1+z^{-1}}$

T_s is sampling freq.)

$$LF(z) = I_{cp}\left[\underbrace{R}_{} + \underbrace{\frac{\frac{T_s}{2C}(1+z^{-1})}{1-z^{-1}}}_{}\right]$$

$$= \frac{I_{cp}}{1-z^{-1}}\left[\left(R+\frac{T_s}{2C}\right)+\left(\frac{T_s}{2C}-R\right)z^{-1}\right] \checkmark$$



$$LF(z) = \alpha + \frac{\beta}{1-z^{-1}}$$

$$= \frac{(\alpha+\beta)-\alpha . z^{-1}}{1-z^{-1}}$$

$T_s = \frac{1}{F_{ref}}$

$$\alpha+\beta = I_{cp}.\left(R+\frac{T_s}{2C}\right)$$

$$\alpha = I_{cp}\left(R-\frac{T_s}{2C}\right)$$

$$\Rightarrow \beta = I_{cp}.\frac{T_s}{C}$$

$$\frac{\alpha}{\beta} = \frac{R-\frac{T_s}{2C}}{T_s/C} = \frac{RC}{T_s} - \frac{1}{2}$$

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

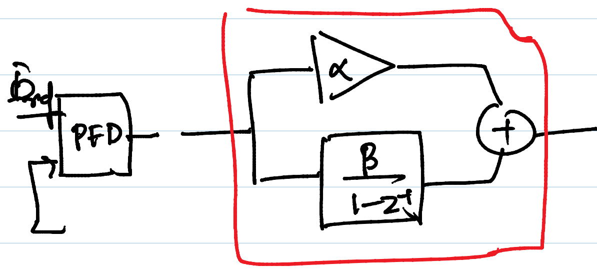
$$= \frac{I_{cp}}{2\pi s^2 C}\,(1+sRC) . K_{vco}$$

$$\Phi_m = \tan^{-1}(\omega_u \cdot RC) = \tan^{-1}\left(\frac{\omega_u}{\omega_z}\right) \Rightarrow \frac{1}{\omega_z} = \frac{1}{\omega_u}\tan(\Phi_m)$$

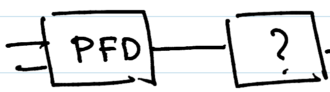
$$|LG| = 1 \Rightarrow \omega_u = \frac{I_{cp} \cdot K_{vco} \cdot R}{2\pi}$$

$$\frac{\alpha}{\beta} = \frac{F_{ref}}{\omega_z} - \frac{1}{2} = \frac{F_{ref}}{\omega_u} \cdot \tan(\Phi_m) - \frac{1}{2}$$

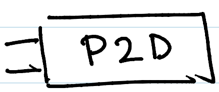
$$\boxed{\frac{\alpha}{\beta} = \frac{F_{ref}}{\omega_u} \cdot \tan(\Phi_m) - \frac{1}{2}}$$



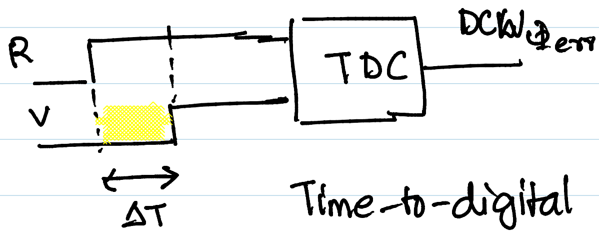
Loop-filter



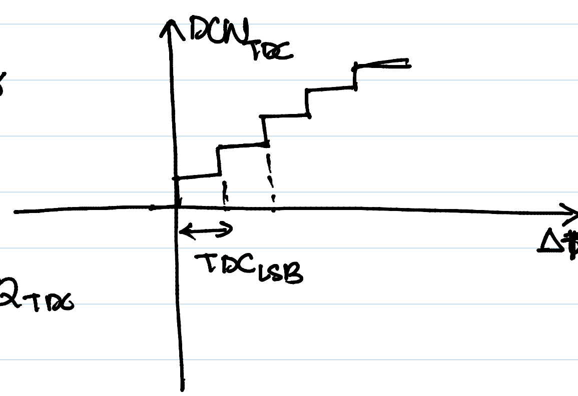
Digital Control Word



Phase-to-digital converter

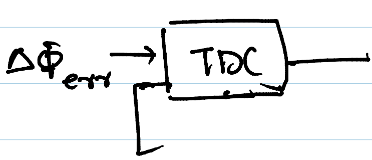


Time-to-digital converter



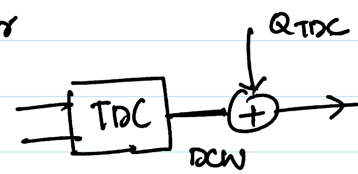
$$\Delta\Phi_{err} = 2\pi \cdot \frac{\Delta T}{T_{ref}}$$

$$\Delta T = \underbrace{\left\lfloor \frac{\Delta T}{TDC_{LSB}} \right\rfloor}_{DCW} \cdot TDC_{LSB} + Q_{TDC}$$

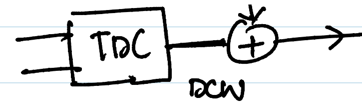


$$\underbrace{\Delta T} = \frac{\Delta\Phi_{err}}{2\pi} \cdot T_{ref} = \underbrace{\frac{T_{ref}}{2\pi}} \cdot \Delta\Phi_{err}$$

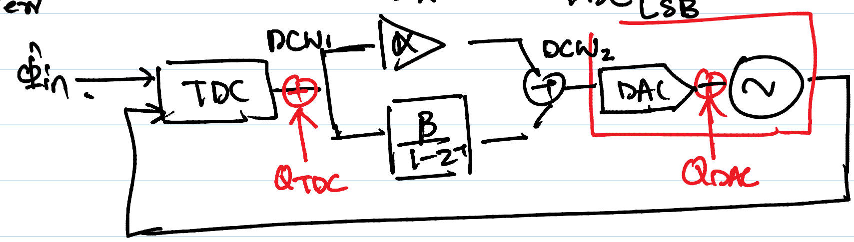
$$= \left\lfloor \frac{\Delta T}{\quad} \right\rfloor \cdot TDC_{LSB}$$

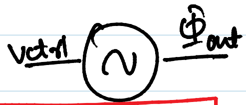


$$= \left\lfloor \frac{\Delta T}{TDC_{LSB}} \right\rfloor \cdot TDC_{LSB}$$

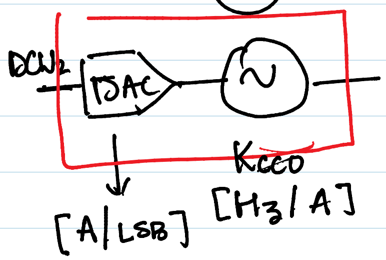


$$\frac{\Phi_{out}}{\Phi_{err}} = LG(z) = \frac{T_{ref}}{2\pi} \times \frac{1}{TDC_{LSB}} \times \left(\alpha + \frac{\beta}{1-z^{-1}}\right) \frac{K_{DCO}}{s}$$





$$= \frac{K_{VCO}}{s}$$



K_{DCO}

$[Hz / LSB]$