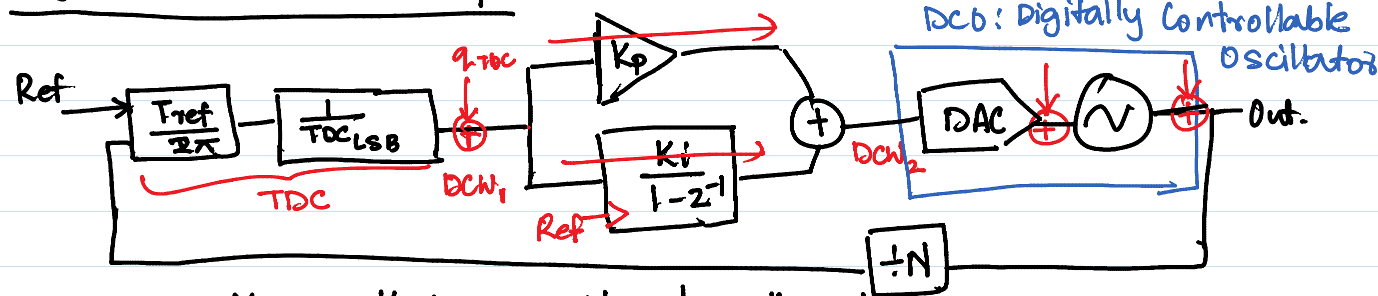
Lecture 35
Tuesday, April 4, 2017
3:52 PM

Digital Phase Locked-Loop



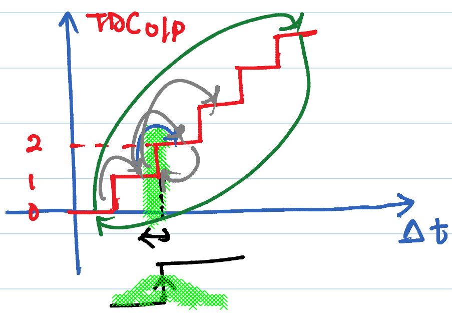
$\alpha \rightarrow K_p$ $\quad K_p$: proportional path gain

$\beta \rightarrow K_i$ $\quad K_i$: integral path gain

DAC : Digital-to-Analog converter.

K_{VCO} [Hz/V]

K_{DCO} [Hz/LSB]



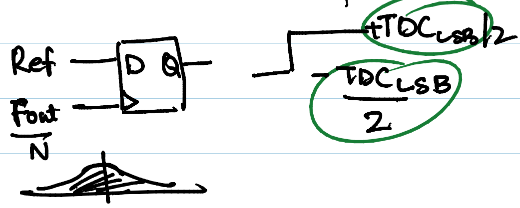
$$DCW_1 = \Delta\phi_{err} \times \frac{1}{2\pi} \times \frac{T_{ref}}{TDC_{LSB}}$$

Eg: T_{ref} : 8ns

TDC_{LSB} : 400 ps

$$\Delta\phi_{err} = \frac{2\pi}{T_{ref}} \cdot \Delta t$$

$\Delta\phi_{err}(t)$	0.4ns	0.8ns	0ns	1.2ns	—	1
DCW_1	1	2	0	3		



$$K_{pd} = \frac{d\bar{V}_{pd}}{d(\Delta T)} = \frac{2}{\sqrt{2\pi}} \frac{1}{\sigma_j} \exp\left(-\frac{\Delta t^2}{2\sigma_j^2}\right)$$

D-flip flop based phase error detector

$$LG(z) = \frac{1}{2\pi} \frac{T_{ref}}{TDC_{LSB}} \left[K_p + \frac{K_i}{1-z^{-1}}\right] \frac{K_{DCO}}{s}$$

$$LG(s) \approx \underbrace{\frac{T_{ref}}{2\pi\, TDC_{LSB}}}_{DCW} \underbrace{\left[K_p + \frac{K_i f_{ref}}{s}\right]}_{DCW} \underbrace{\frac{K_{DCO}}{s}}_{Phase}$$

$$1-z^{-1} = 1 - e^{-sT} \approx 1 - (1 - sT) = sT = s/f_{ref}$$

x — ADC — y $\qquad y = \underset{\sqcup}{k}x + q$

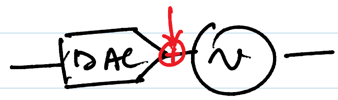
Noise sources in DPLL

1) Quantization noise in TDC , $q_{TDC} \pm \frac{TDC_{LSB}}{2}$

Quantization noise (power spectral density) $S_{q_{tdc}} = \frac{\Delta^2}{12} \frac{1}{f_{ref}}$

$NTF_{q_{tdc}}$ = low pass filter.

2) DAC quantization noise



Gain of current DAC = x A/LSB

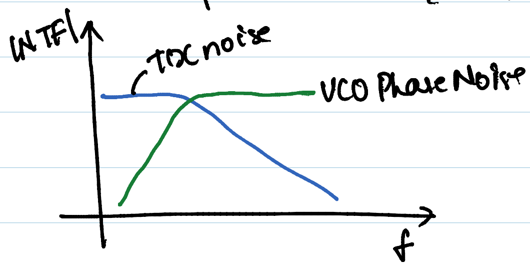
Gain of current controlled osc. = ΔF Hz/A.

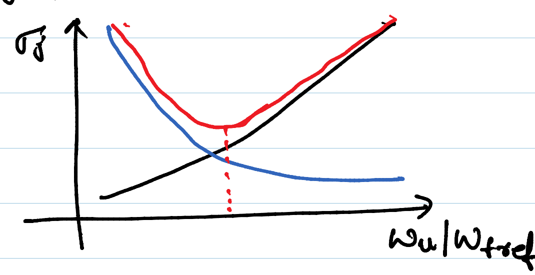
$S_{q_i DAC} =$

NTF = band pass

3) Coefficient quantization in digital loop filter.

4) VCO phase noise , NTF = high pass



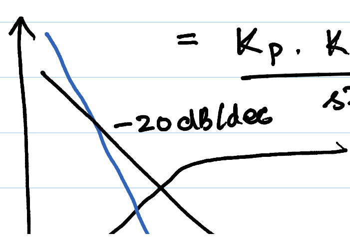


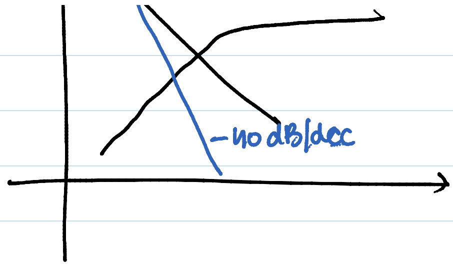
$$NTF_{TDC} = \frac{\left(K_p + \frac{K_i f_{ref}}{s}\right) \cdot \frac{K_{DCO}}{s}}{1 + LG} = \frac{K_p \cdot K_{DCO}}{s} \frac{1}{1+LG} + \frac{K_i K_{DCO} f_{ref}}{s^2} \times \frac{1}{1+LG}$$

$$= \frac{K_{DCO}}{s^2} \left(\frac{s \cdot K_p + K_i f_{ref}}{1+LG} \right)$$

$$= \frac{K_p \cdot K_{DCO}}{s^2} \frac{\left(s + \frac{K_i f_{ref}}{K_p}\right)}{1+LG}.$$

$$\Phi_m = \tan^{-1} \left(\frac{\omega K_p}{K_i f_{ref}} \right)$$





<u>Remark</u> : While reducing capacitor area in integral path we added quantization noise in proportional path