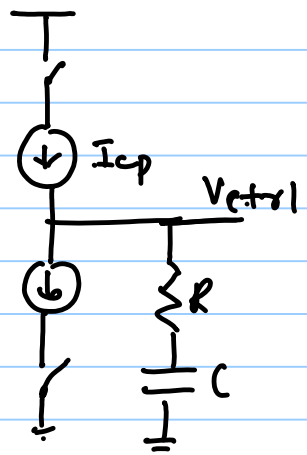
Lecture #42

Note Title 30-10-2018

Digital PLLs



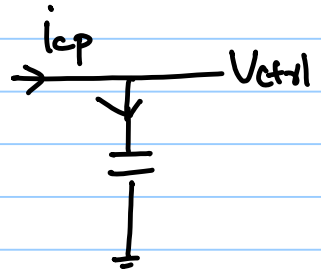
Large size of cap.

$\frac{V_{ctrl}}{I_{cp}} = R + \frac{1}{sC}$ — Split-tuned PLL

— Capacitor multiplication

process variation.

$V_{ctrl}(s) = \frac{1}{sC} I_{cp}(s)$



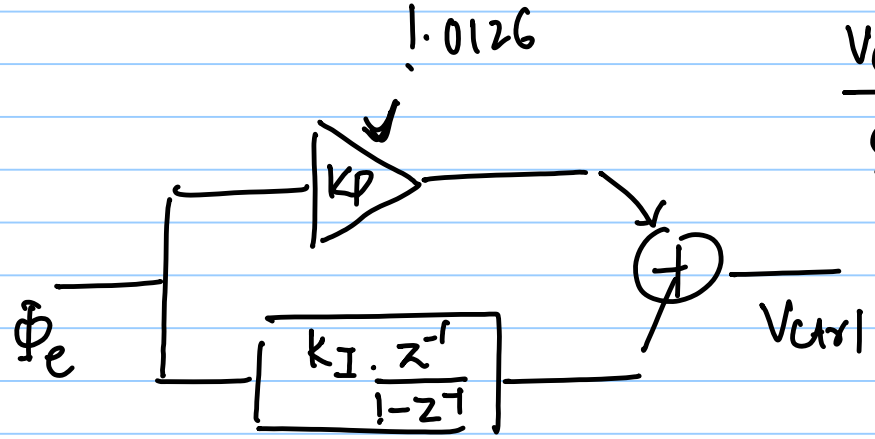
$V_{ctrl}(\overline{n+1}\,T) = V_{ctrl}(nT) + \frac{1}{C}\int_0^{\Delta t} i_{cp}\,dt$ ✓

$V_{ctrl}(\overline{n+1}\,T) = V_{ctrl}(nT) + \frac{i_{cp}}{C}\cdot\Delta t(n)$

$\therefore + \frac{i_{cp}}{C}\,2\pi\cdot\frac{\Delta t(n)}{T}\cdot\frac{T}{2\pi}$

✓ $V_{ctrl}(\overline{n+1}\,T) = V_{ctrl}(nT) + \frac{i_{cp}}{C}\cdot\frac{T}{2\pi}\,\phi_e(nT)$ ✓

$$z\ V_{Ctrl}(z) = V_{ctrl}(z) + \frac{I_{cp} \cdot T}{C \cdot 2\pi} \Phi_e(z)$$

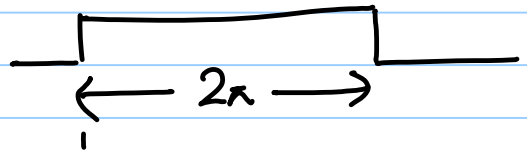


$$\frac{V_{Ctrl}(z)}{\Phi_e(z)} = \frac{I_{cp} \cdot T}{C \cdot 2\pi} \cdot \frac{1}{z-1}$$

$$= \frac{K_I\ z^{-1}}{1-z^{-1}} \checkmark$$

$$\frac{V_{ctrl}(z)}{\Phi_e} = K_p + \frac{K_I \cdot z^{-1}}{1-z^{-1}}$$

Φ_e : # of bits 4-bits



$\Phi_e = 0$ rad/s ⟶ 0000

-2π rad/s ⟶ 1111 ✓

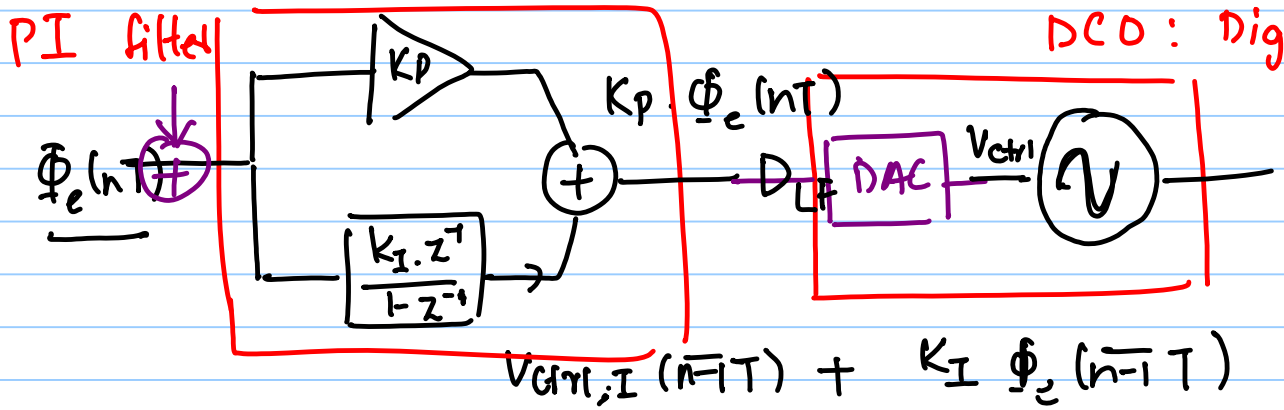
Kp : 2 bits 00, 01, 10, 11

1111 x 10 = 1110

K_I :

$V_{ctrl}(nT) =$ 1. $K_p \cdot \Phi_e(nT) + K_I$

PI filter



$V_{ctrl,I}(n-1T) + K_I \Phi_e(n-1T)$

DCO: Digital Controlled oscillator.

K_{VCO}: $V_{ctrl} \rightarrow f_{out}$

K_{DCO}: $D_{LF} \rightarrow f_{out}$

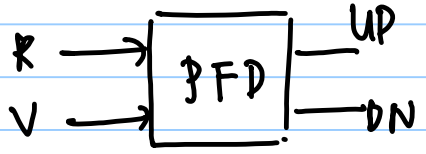
$$\frac{V_{ctrl}}{\Phi_e} = K_p + \frac{K_I \cdot z^{-1}}{1-z^{-1}} = K_p + \frac{K_I}{z-1} = K_p + \frac{K_I}{e^{sT}-1} = K_p + \frac{K_I f_{ref}}{s}$$

$$= \frac{1}{s}\left[sK_p + K_I f_{ref}\right]$$

$$= \frac{K_I \cdot f_{ref}}{s}\left[1 + \frac{sK_I}{K_I f_{ref}}\right] \qquad \omega_z = \frac{K_I \cdot f_{ref}}{K_p}$$

$\Phi_e \rightarrow$ fast

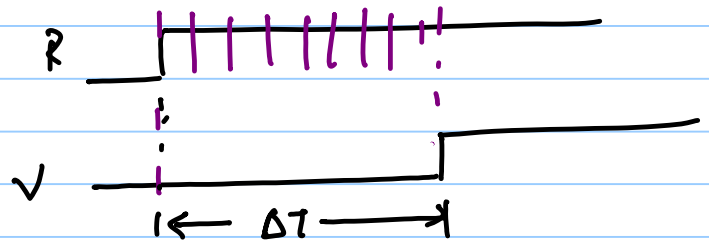
$$LF = \left[K_p + \frac{k \cdot z^{-1}}{1 - z^{-1}} \right] \frac{2\pi K_{DCO}}{s} \times \frac{1}{N}$$



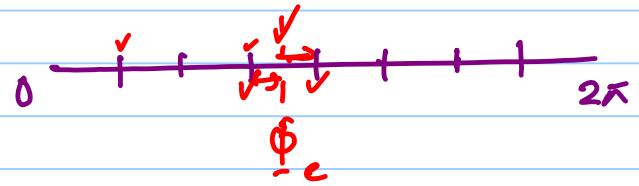
Phase error $[-2\pi, 2\pi]$ → Digital → 4'bxxxx

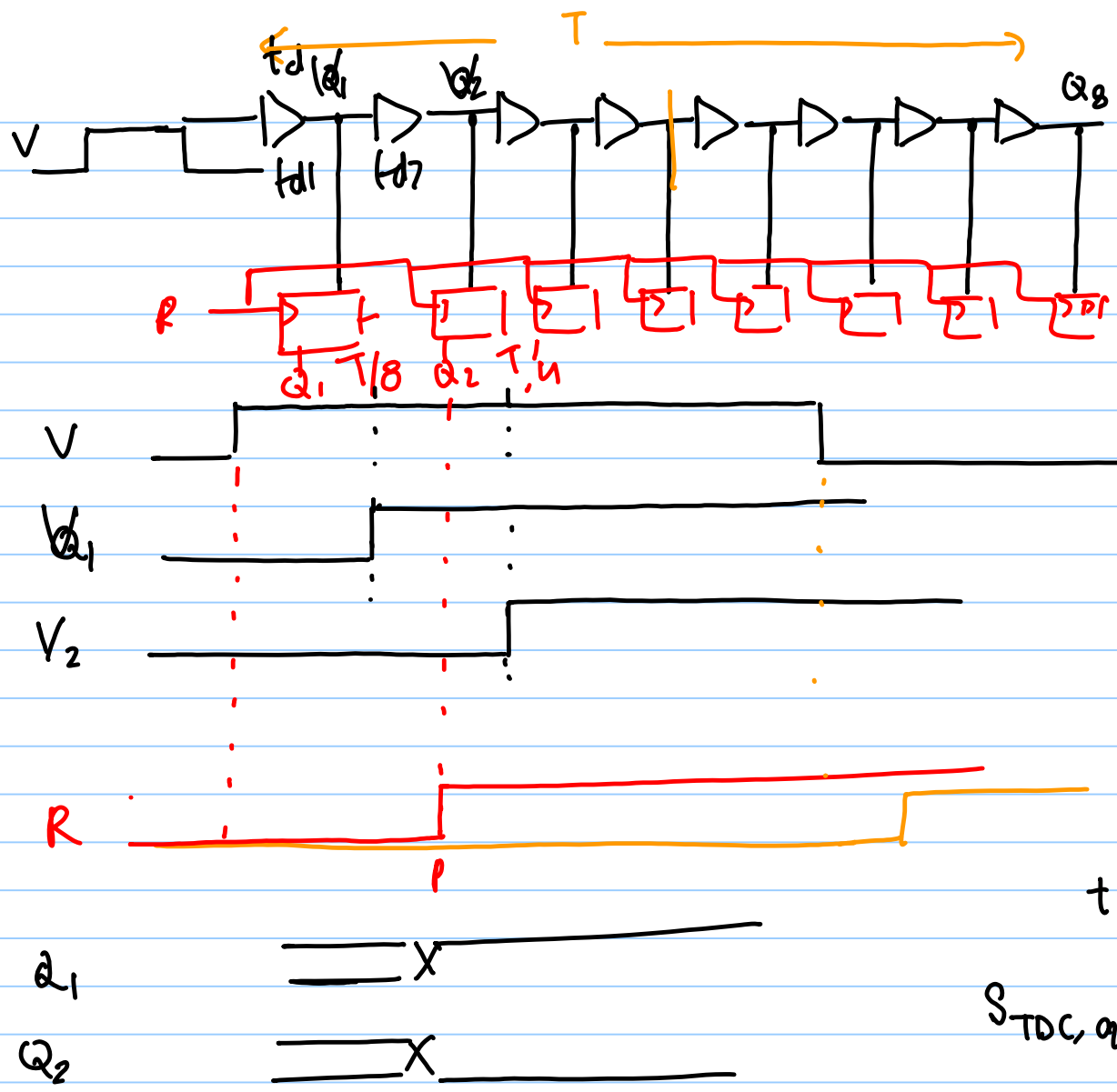
$-2\pi \leftarrow 0 \rightarrow 2\pi$

1111 0000 0111



2π





$$t_d = \frac{T}{8}$$

$Q_1 - Q_8$ | 3 bit

TDC : Time-to-Digital Conv

Quantization Error

$$-\frac{t_d}{2} < \Delta < \frac{t_d}{2}$$

$t_d \downarrow \rightarrow$ # of delay cells.

$t_d \uparrow \rightarrow$ large quantization.

$$t_d \rightarrow 2\pi \cdot \frac{t_d}{T}$$

$$S_{TDC,q} = \frac{(2\pi \cdot t_d/T)^2}{12 \cdot f_{ref}} = \frac{(2\pi t_d)^2}{12 \cdot T}$$

TDC Quantization Noise ⟶ ↓ BW

VCO Noise ⟶ ↑ BW