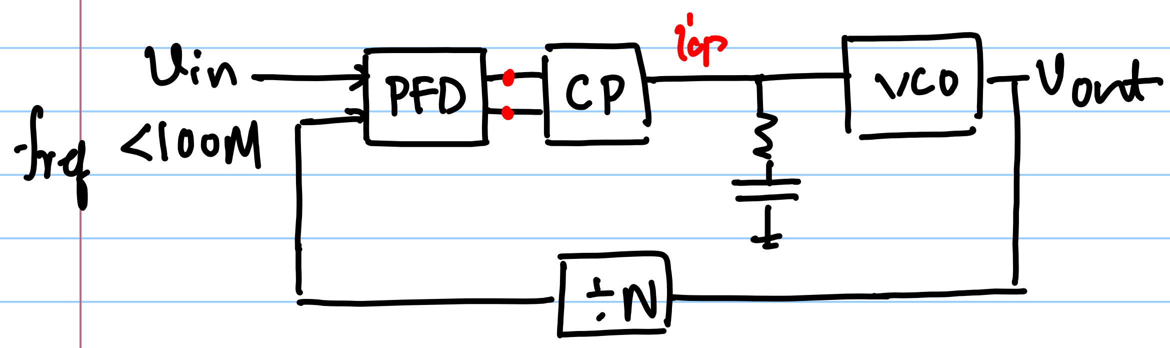
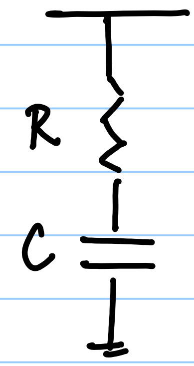
Note Title 18-08-2020

Lecture # 35



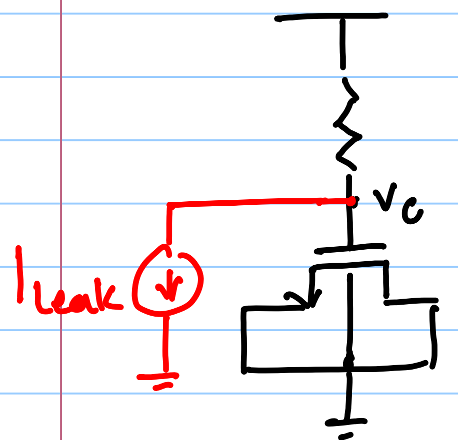


C ~ 100 pF

mim-cap : 2 fF/μm²

$$A = \frac{100\,pF}{2\,fF/\mu m^2}$$

±20% PVT variations



DPLF: $F(S) = R + \frac{1}{sC}$

$$\frac{V(s)}{I(s)} = R + \frac{1}{sC} \quad \text{or} \quad v_{ctrl}(t) = i_{cp}(t) \cdot R + \frac{1}{C}\int_0^t i_{cp}(t) \cdot dt$$

$$= K_p \, i_{cp}(t) + \ldots$$

$$V_{ctrl}(nT) = i_{cp}(nT)\cdot R + \frac{1}{C}\sum_{k=0}^{n-1} i_{cp}(kT)\cdot T \qquad T: \text{Ref. period}$$

$$i_{cp}R + \frac{i_{cp}}{sC} \Longrightarrow i_{cp}R + \frac{i_{cp}\cdot T}{C}\frac{z^{-1}}{1-z^{-1}} \quad \text{where } z = e^{sT} = e^{j\omega T} = e^{j\omega/f_{ref}}$$

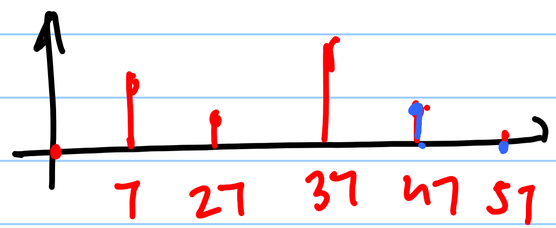
$$i_{cp}R + \frac{i_{cp}T}{C}\frac{1}{sT} \longleftarrow z = e^{sT} \approx 1+sT$$

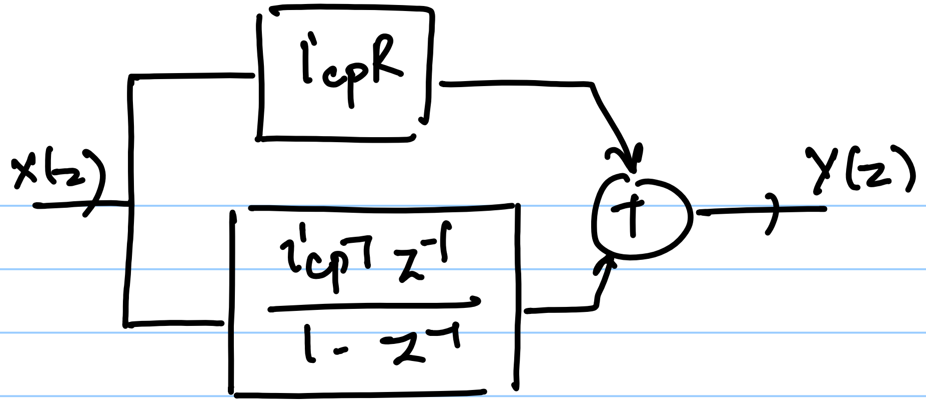
$$\frac{Y(z)}{X(z)} = i_{cp}\cdot R + \frac{i_{cp}\cdot T}{C}\frac{z^{-1}}{1-z^{-1}} \qquad \frac{\omega}{f_{ref}} = 2\pi\frac{f}{f_{ref}} \ll 1$$

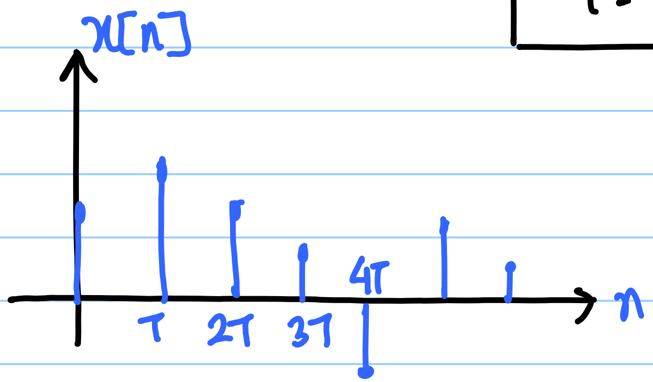
$$\frac{Y_p(z)}{X(z)} = i_{cp}R \qquad \frac{Y_i(z)}{X(z)} = \frac{i_{cp}T}{C}\frac{z^{-1}}{1-z^{-1}}$$

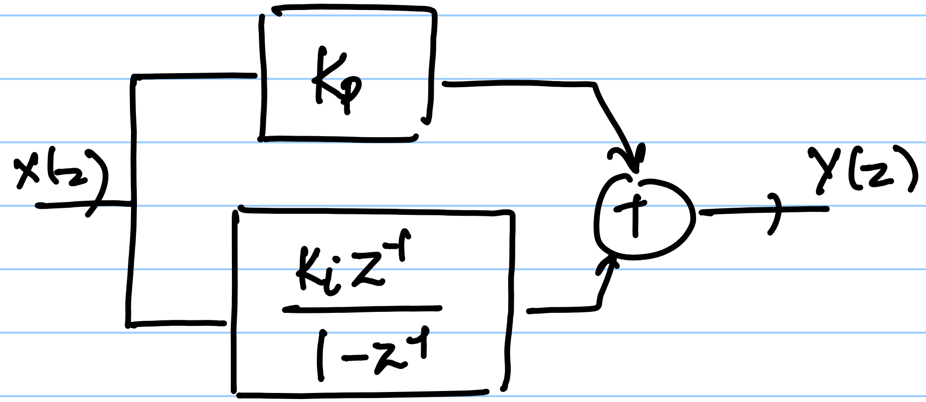
$$y[n] = i_{cp}\cdot R\, x[n] \qquad y_i[n] = y_i[n-1] + \frac{i_{cp}T}{C}x[n-1]$$

at $t = nT$,









$$\frac{Y(z)}{X(z)} = K_p + \frac{K_i z^{-1}}{1-z^{-1}} \xrightarrow{CT} K_p + \frac{K_i}{sT} = \frac{sK_pT + K_i}{sT} = \frac{sK_p + K_i/T}{s}$$

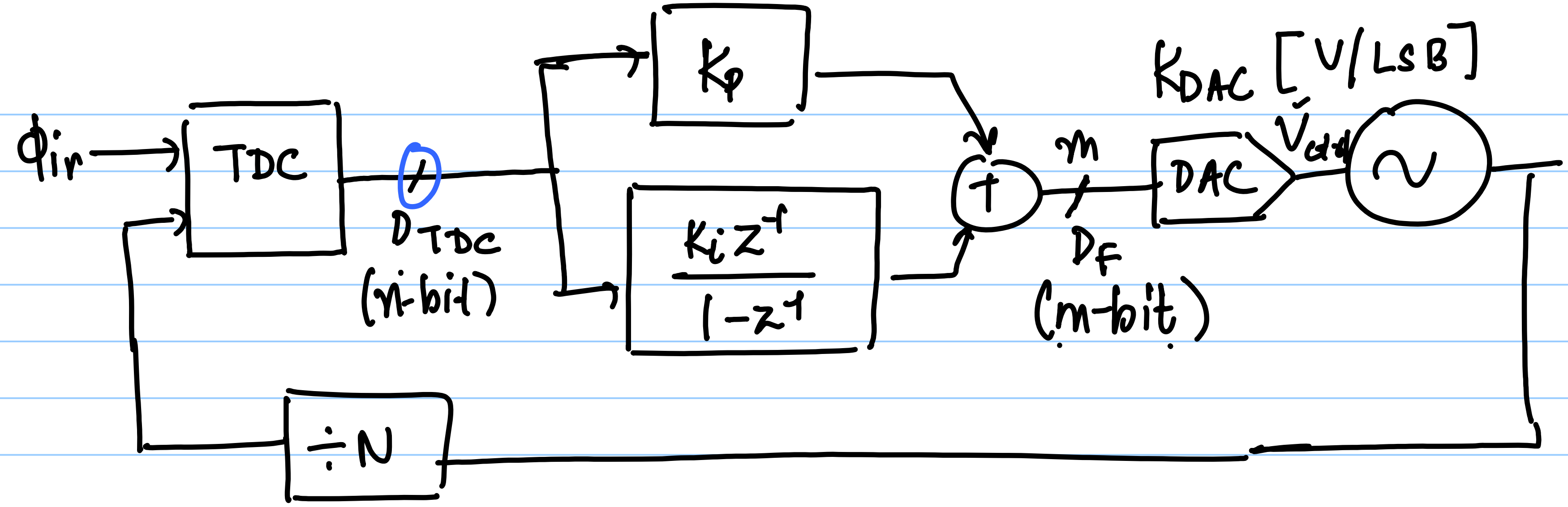
$$= K_p + \frac{K_i}{z-1}$$

$$= \frac{z.K_p - K_p + K_i}{z-1}$$

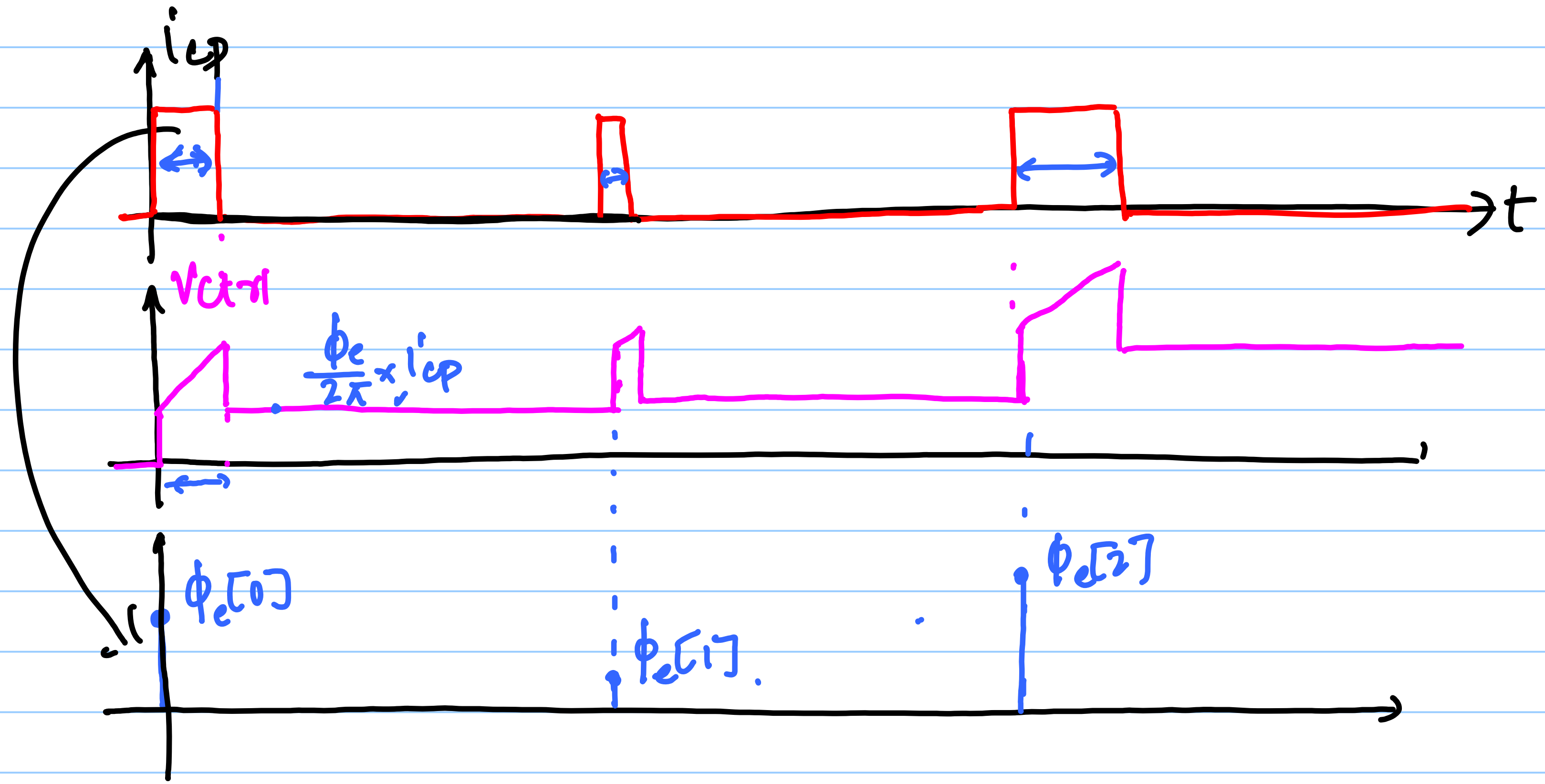
$$\omega_z = \frac{K_i}{K_pT}$$

$$z_p = 1$$

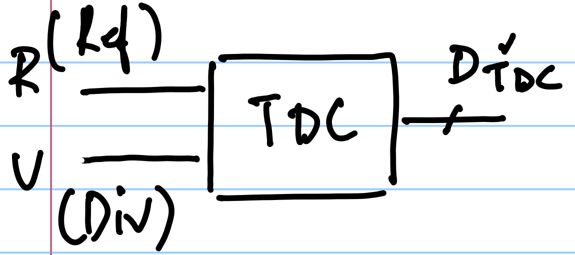
$$z_z = \frac{K_p - K_i}{K_p} = 1 - \frac{K_i}{K_p}$$



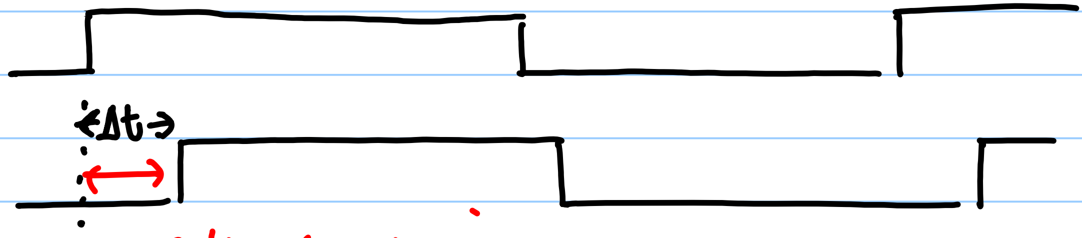
ϕ_{ir}
TDC
D_{TDC}
(n-bit)
K_p
$\frac{K_i z^{-1}}{1-z^{-1}}$
+
m
D_F
(m-bit)
K_{DAC} [V/LSB]
DAC
V_{ctrl}
÷N



i_{cp}
t
V_{ctrl}
$\frac{\phi_e}{2\pi} \times i_{cp}$
$\phi_e[0]$
$\phi_e[1]$
$\phi_e[2]$



40MHz ⇒ 25ns



0.94362157
− 0.94325

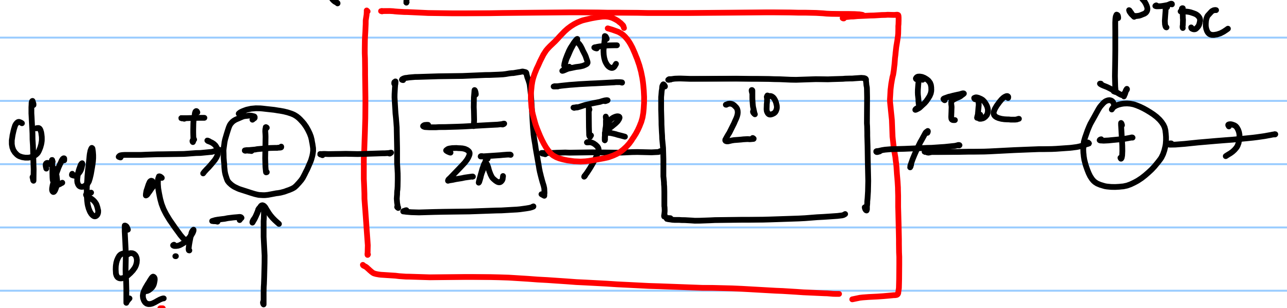
10-bit TDC

Resolution $= \frac{T_R}{2^{10}}$

$D_{TDC} = 10'b\,00000\,00000 \Rightarrow \Delta t = 0,\ \phi_e = 0$

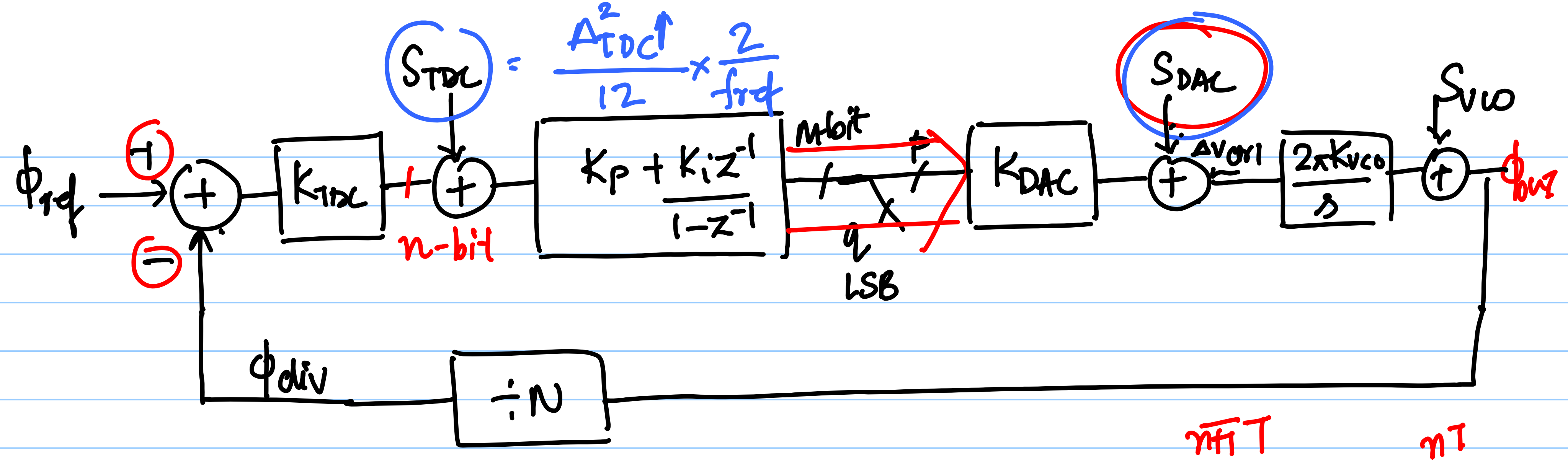
$\frac{\Delta t}{(T_R/2^{10})} \Rightarrow D_{TDC}$

$D_{TDC} = 10'b\,11111\,11111 \Rightarrow \Delta t \approx T_R,\ \phi_e \approx 2\pi$



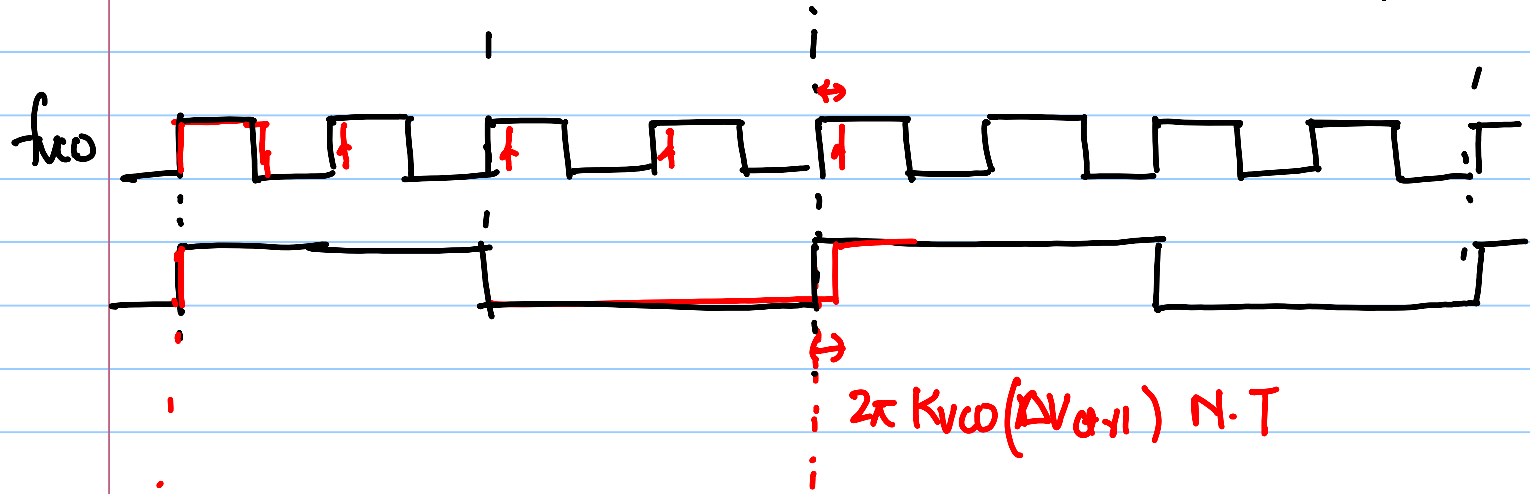
$\phi_e = 2\pi \cdot \frac{\Delta t}{T_R}$

$K_{TDC} = \frac{d(D_{TDC})}{d\phi_e} = \frac{2^{10}}{2\pi}$ [LSB/rad]



$(n+1)T$ $\quad$ nT

$$G(z) = K_{TDC}\left(K_p + \frac{K_i}{z-1}\right) K_{DAC} \frac{2\pi K_{vco}}{s}$$



$$G(s) = K_{TDC}\left(K_p + \frac{K_i}{\frac{s}{f_{ref}}}\right) K_{DAC} \frac{2\pi K_{vco}}{s}$$

$$\phi_{div}[n+1] = \phi_{div}[n] + 2\pi K_{vco} V_{ctrl}[n] \cdot NT$$

$$\phi_{div}[n+1] - \phi_{div}[n]$$

$$= 2\pi K_{vco} V_{ctrl}[n]\ N T_{out}$$

$$(z-1)\,\phi_{div}(z)$$

$$= 2\pi K_{vco} \cdot V_{ctrl}(z) \cdot T_R$$

$$\phi_{div}(z) = \frac{2\pi K_{vco} V_{ctrl}(z)}{z-1} \cdot T_R$$

$$\phi_{out} = \int 2\pi K_{vco} \cdot V_c \cdot dt$$

$\phi_{div} =$

$\phi_{div} \leftarrow \boxed{\div N} \leftarrow \phi_{vco}$

$$2\pi \cdot \frac{\Delta t'}{T_R}$$

$$2\pi \cdot \frac{\Delta t}{T_{out}} = \Delta\phi_{vco}$$

$$\Delta t = \frac{\Delta\phi_{vco}}{2\pi} \cdot T_{out}$$

$$\Delta\phi_{div} = \frac{2\pi}{T_R} \cdot \frac{\Delta\phi_{vco}}{2\pi} \cdot T_{out}$$

$$\Delta\phi_{div} = \Delta\phi_{vco} \cdot \frac{T_{out}}{T_R}$$

$$\frac{\Delta\phi_{div}}{\Delta\phi_{out}} = \frac{T_{out}}{T_R} = \frac{1}{N}$$