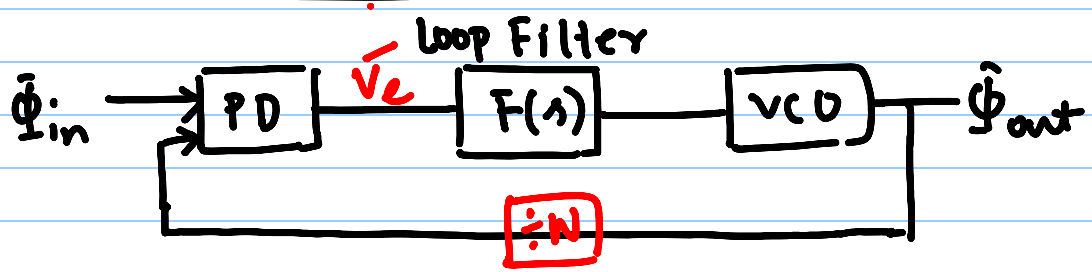
Note Title 21-08-2017

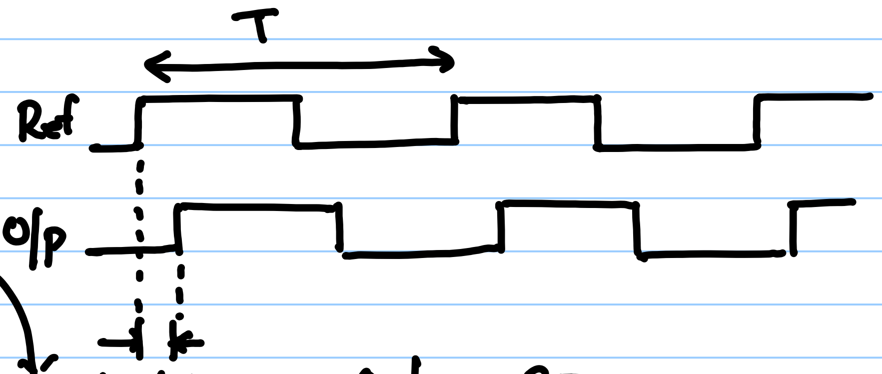
# Lecture #12



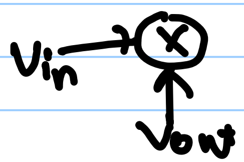

* Input / Output signals are voltage/current
* PLL enforces a relationship b/w i/p & o/p phase & frequency

## Phase Error Detector (PD)

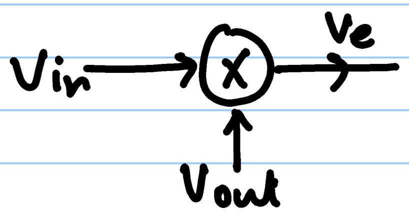
- Analog
  - Multiplier based PD
  - Sample & Hold
- Digital
  - EXOR
  - SR latch
  - DFF based
  - 3-state PFD




$\underbrace{\Delta t}_{\text{Const.}} \rightarrow \Delta\phi = \frac{2\pi}{\underbrace{T}} \cdot \Delta t$



# Multiplier-based PD




$V_{in} = a_{in} \cdot \sin(\omega_{in} t)$

$V_{out} = a_{out} \cdot \sin(\omega_{out} t - \hat{\Phi}_e)$

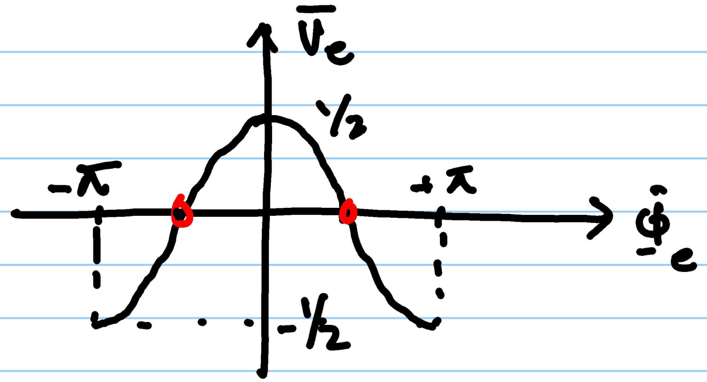
$\omega_{in} = \omega_{out}$, $a_{in} = a_{out} = 1$

$-2 \sin A \cdot \sin B$

$= \cos(A+B) - \cos(A-B)$

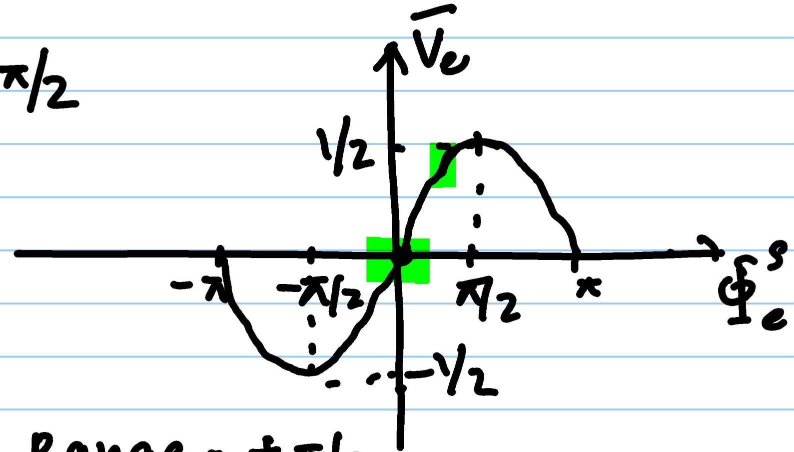
$$V_e = \frac{-1}{2}\left[\cos(2\omega_{in} t - \hat{\Phi}_e) - \cos(\hat{\Phi}_e)\right]$$

$$\bar{V}_e = \frac{1}{2}\cos(\hat{\Phi}_e)$$




$$\Phi_e^s = \hat{\Phi}_e + \pi/2$$

$-\pi/2$



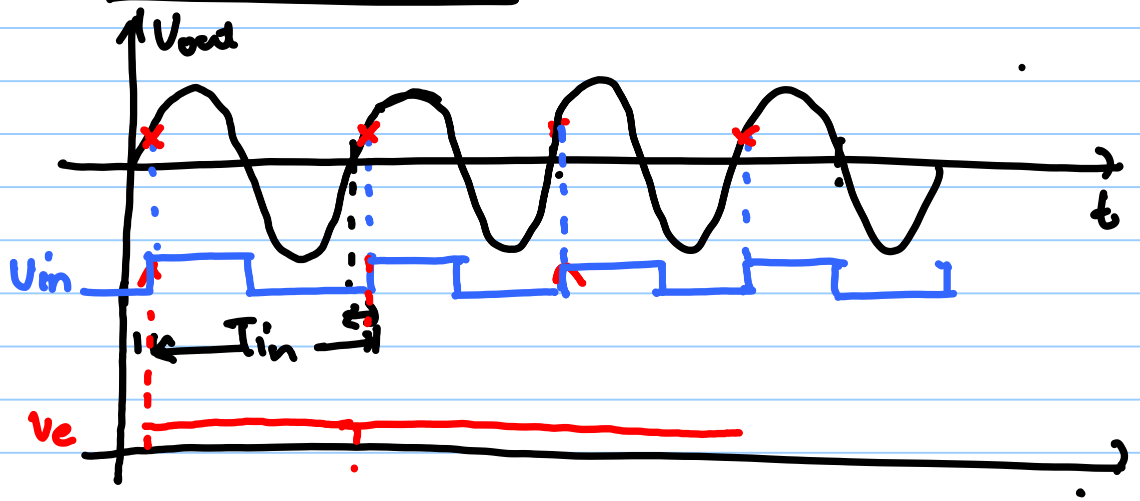

Range: $\pm\pi/2$

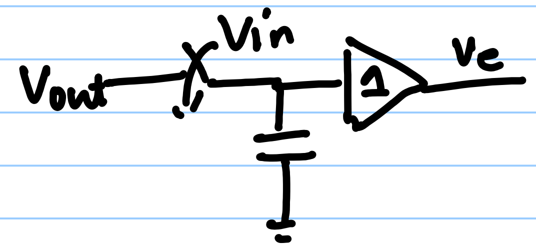
$\hat{\Phi}_e^s \longrightarrow \bar{V}_e$

$\bar{V}_e = \underline{K_{pd}} \cdot \hat{\Phi}_e^s \qquad K_{pd} = \dfrac{d\bar{V}_e}{d\hat{\Phi}_e^s} = \dfrac{1}{2}\cos(\hat{\Phi}_e^s)$

$\bar{V}_e$ is a non-linear function of $\Phi_e$.

## Sample & Hold PD




$\omega_{in} = \omega_{out}$

$V_e = \sin(\omega_{in} \cdot \Delta t)$

$V_{out} = \sin(\omega_{out} t)$

$V_e = \sin(\omega_{out} \times (n.T_{in} + \Delta t))$

$= \sin(n.\omega_{out}.T_{in} + \omega_{out}.\Delta t)$

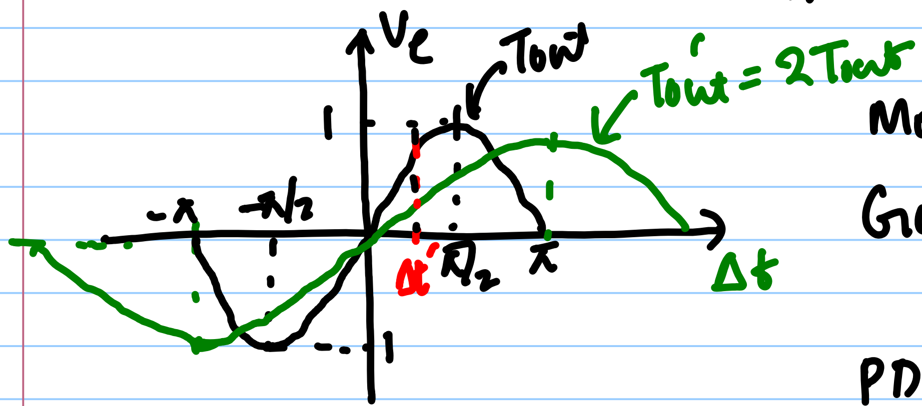
if $\omega_{out} = \omega_{in} \Rightarrow \omega_{out}.T_{in} = 2\pi \Rightarrow V_e = \sin(\omega_{out}.\Delta t) = \sin(\phi_e)$

if $\omega_{out} = N\omega_{in} \Rightarrow \omega_{out}.T_{in} = 2N\pi$

$\omega_{out}.\frac{2\pi}{\omega_{in}} = 2N\pi.$

$V_e = \sin(2N\pi + \omega_{out}.\Delta t)$

$= \sin(\Phi_e) = \sin(\frac{2\pi}{T_{out}}.\Delta t)$




Montonous Range = $-\pi/2$ to $+\pi/2$

Gain, $K_{pd} = \frac{dV_e}{d\Phi_e} = \cos(\phi_e)$

PD is non-linear.

Case: $\omega_{out} = N\omega_{in}$ ; $\Phi_e$ is w.r.t. $\omega_{in}$ or $\omega_{out}$ ✓ ?

$\Phi_e$ range $-\pi/2$ to $+\pi/2$ $\Rightarrow$ $-\frac{T_{out}}{4}$ to $+\frac{T_{out}}{4}$

$\Phi_e$ range $-\pi/2$ to $+\pi/2$ w.r.t ref. $T_{in}$ $\Rightarrow$ $-\frac{T_{in}}{4}$ to $+\frac{T_{in}}{4}$

Vin( Fin ) Vout(Fout)

$F_{in}$ $\xleftrightarrow{F_{out}}$ Normalizing phase error w.r.t $f_{in}$.

if Normalizing " w.r.t $f_{out}$.

$V_{out} = \sin(\omega_{out} t)$ $\omega_{out} = N\omega_{in}$.

$V_e = V_{out} \times \underbrace{\sum \delta(t - nT_{in})}$

$V_e(s) = V_{out}(s) * \frac{1}{T} \sum \delta(f - kf_{in})$