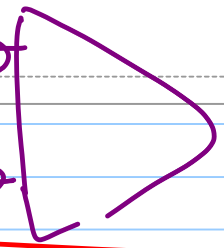
Note Title 01-08-2018

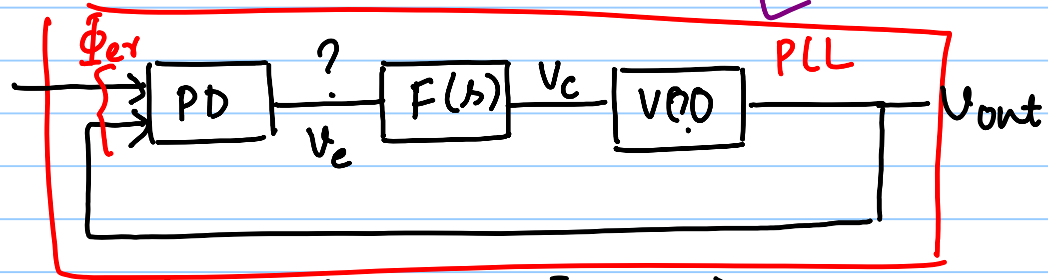
# Lecture #2

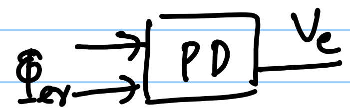



Vin ✗ Vout

$\Phi_{in} - \Phi_{out}$

## Basic operation of PLL




$K_{pd} = \dfrac{dV_e}{d\Phi_{er}}$ [V/rad]

$V_{in} = A_{in} \sin(\omega_{in} t + \Phi_{ino}(t)) \longrightarrow \Phi_{in}(t) = \omega_{in} t + \Phi_{ino}(t)$

$V_{out} = A_{out} \sin(\underbrace{\omega_{out} t + \Phi_{outo}(t)}) \longrightarrow \Phi_{out}(t) = \omega_{out} t + \Phi_{outo}(t)$

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

$\Phi_{er}(t) = \Phi_{in}(t) - \Phi_{out}(t)$

$= (\omega_{in} - \omega_{out}) t + (\underbrace{\Phi_{ino}(t) - \Phi_{outo}(t)}) = \Phi_{ino}(t) - \Phi_{outo}(t)$

$\dfrac{d(\Phi_{er}(t))}{dt} = 0$ ✓ $\not\Rightarrow$ $\Phi_{er}(t) = 0$

$\omega_{out} = 2\pi f_{free} + 2\pi K_{vco} \cdot V_c$

$V_c \rightarrow$ [VCO] $\rightarrow V_{out} = A_{out} \sin(\Phi_{out}(t))$

VCO: Voltage controlled Oscillator

$$\Phi_{out}(t) = \int 2\pi f_{out} \cdot dt$$

$$= 2\pi \int (f_{free} + K_{VCO} \cdot V_c)\, dt$$

$$= 2\pi f_{free} t + 2\pi K_{VCO} \cdot \int V_c \cdot dt$$

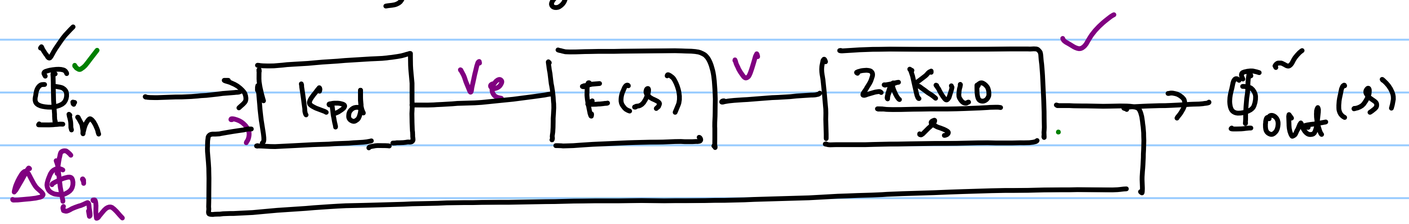
$$\Phi_{out}(t) = 2\pi K_{VCO} \int V_c \cdot dt$$

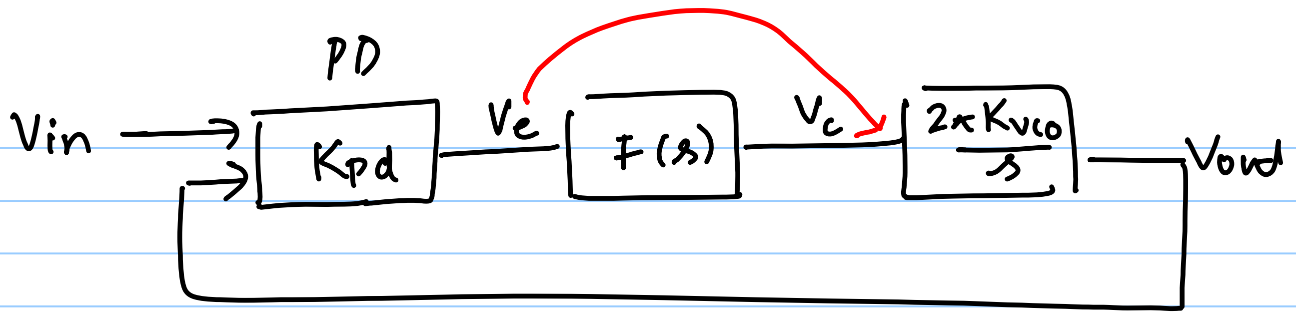
$$[K_{VCO}] = Hz/V$$


$$\omega_{out} = 2\pi K_{VCO} \cdot V_c$$

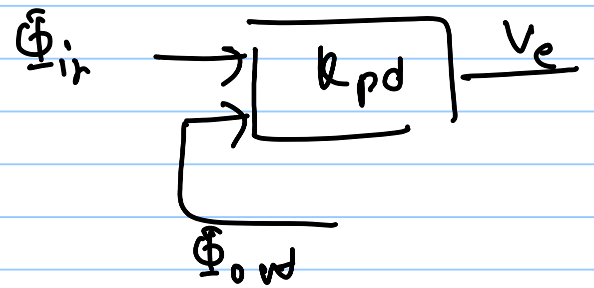
$$\omega_{out}(s) = 2\pi K_{VCO} \cdot V_c(s)$$

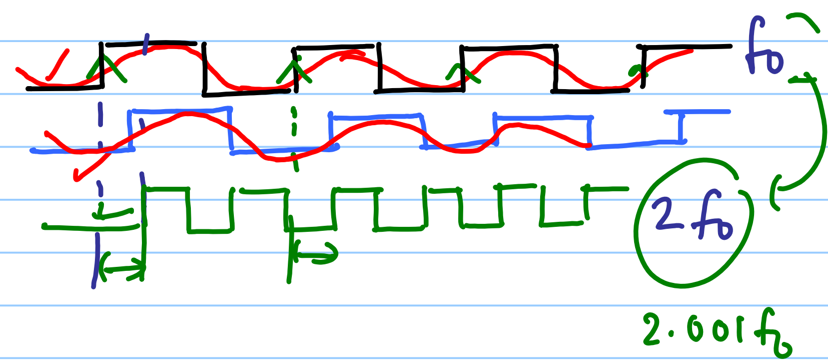
$$\Phi_{out}(s) = 2\pi K_{VCO} \cdot \frac{V_c(s)}{s}$$





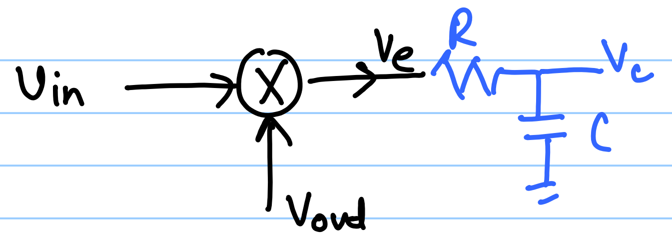

$$V_e = K_{pd}\,(\Phi_{in} - \Phi_{out})$$




$$LG(s) = K_{pd} \times F(s) \times \frac{2\pi K_{vco}}{s} = K_{pd} \times \frac{1}{1+sRC} \times \frac{2\pi K_{vco}}{s}$$

$$\frac{\Phi_{out}(s)}{\Phi_{in}(s)} = \frac{LG}{1+LG}$$




$\Delta\omega = 0.1\,\omega_{\phi n}$

$F(s) = \frac{1}{1+sRC}$

$$V_e = \frac{A_{in} \cdot A_{out}}{2}\left[2 \cdot \sin(\omega_{in}t + \Phi_{in0}) \cdot \sin(\omega_{out}t + \Phi_{out0})\right]$$

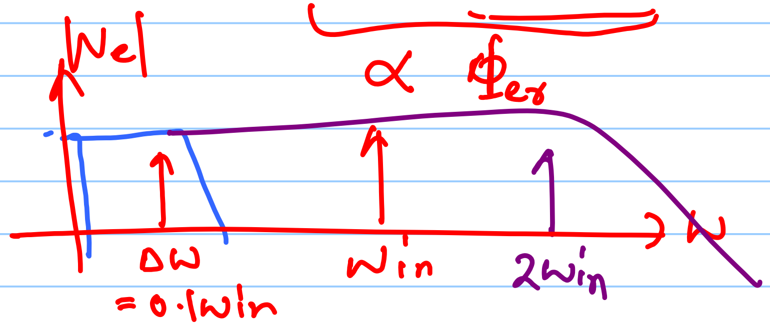
$$= -\frac{A_{in}A_{out}}{2}\Big[\cos(\omega_{in}t\,\omega_{out}t + \Phi_{in}(0) + \Phi_{out0}) - \cos(\omega_{in} - \omega_{out}t + \Phi_{in0} - \Phi_{out0})\Big]$$

$$\doteq A_{pd}\cos(\Delta\omega\, t + \Phi_{in0} - \Phi_{out0}) - A_{pd}\cos(\omega_{out} + \omega_{in}t + \_\_\_)$$

$\Delta\omega = 0$

$$= A_{pd}\cos(\Phi_{in0} - \Phi_{out0}) - A_{pd}(\cos(2\omega_0 t + \_))$$

$\propto \Phi_{er}$




$$K_{pd} = \frac{dV_e}{d\Phi_{er}} = -A_{pd}\sin(\Phi_{er}) = A_{pd}$$