

Frequency Acq. in Type-II PLL.

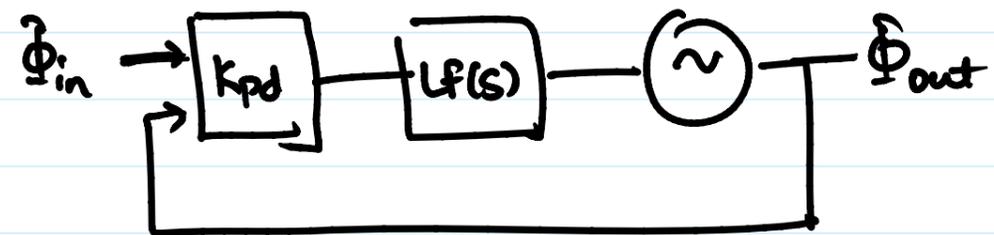
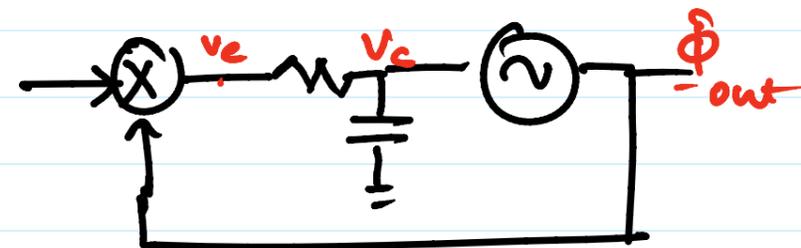
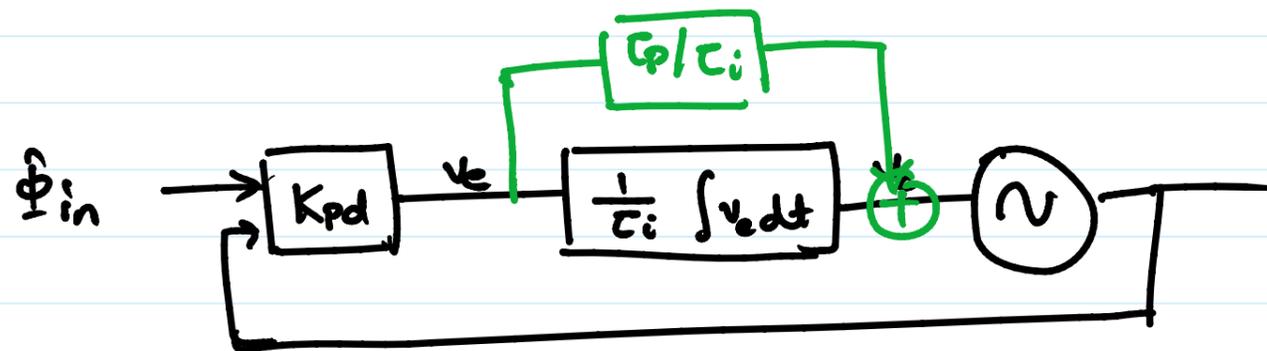
Type-I PLL : Lock in range, hold-in range, pull in range $\Delta\omega \leq K = K_{vco} \cdot K_{pd}$

$\frac{\Delta\omega}{k} \leq 1$ Increase $\Delta\omega \Rightarrow k \uparrow$

To increase $\Delta\omega$

1.) Infinite DC gain for PLL

$LF(s) = \frac{1}{s} \times \frac{1}{\tau_i}$



at $t=0, V_c=0$
 $\omega_0 = \omega_{free} < \omega_{in}$ at $t=0$

$\Phi_{err}(t) = (\omega_{in} - \omega_0)t$
 $= (\Delta\omega) \cdot t$

$V_{out} = A \sin(K_{vco} \int V_c dt + \omega_{free} t)$

ω_{free} is VCO freq. at $V_c=0$

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

$\Phi_{out} = \omega_{free} t + \int K_{vco} \cdot V_c dt$

ph of $V_c(t) = \sin(\omega t)$

o/p of PD, $v_e(t) = \sin(\Phi_{err}(t))$ ✓

o/p of integ, $v_c(t) = \frac{1}{T_i} \int v_e(t) dt$
 $= \frac{1}{T_i} \int \sin(\Delta\omega \cdot t) dt = \frac{1}{T_i \Delta\omega} \cos(\Delta\omega \cdot t)$

$$\Phi_{out} = \omega_{free} t + \int K_{vco} \cdot v_c dt$$

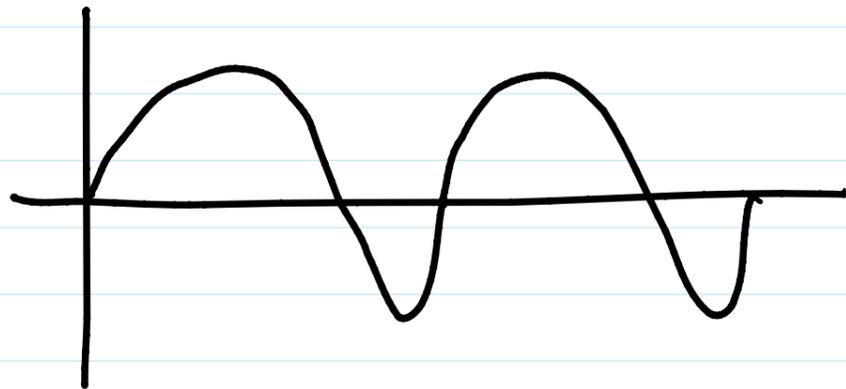
$$\omega_{in} = 5 \omega_{free}$$

$$\omega_{out} = 5 \omega_{free}, \Rightarrow v_c = \frac{4 \omega_{free}}{K_{vco}}$$

$$v_c = v_e = \frac{1}{K_{pd}} \sin(\Phi_{err}) \ll 1$$

$$\Rightarrow \frac{\Delta\omega}{K_{pd} K_{vco}} \ll 1$$

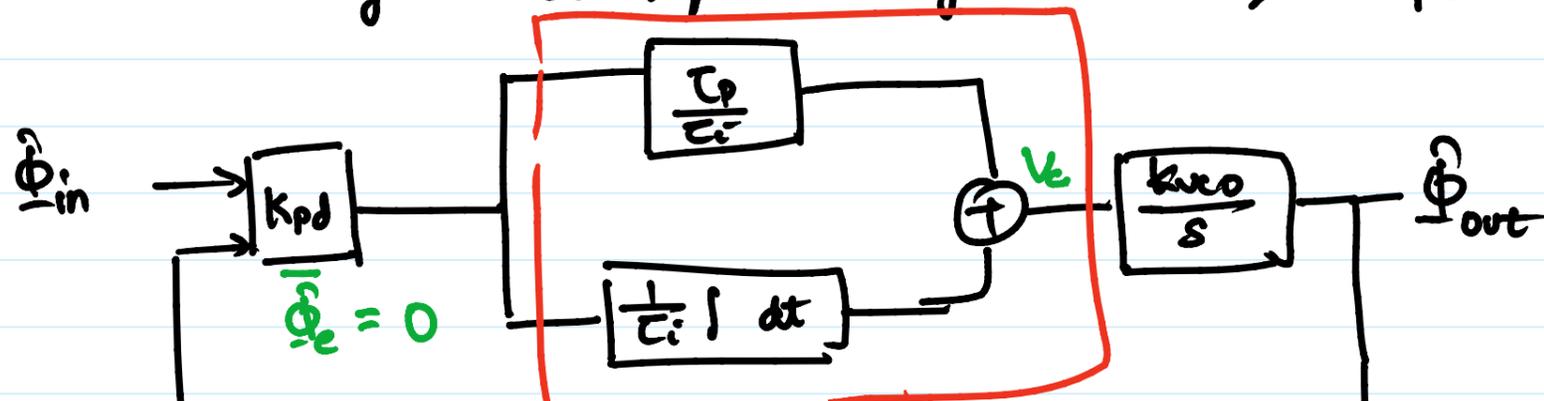
in Type-I PLL

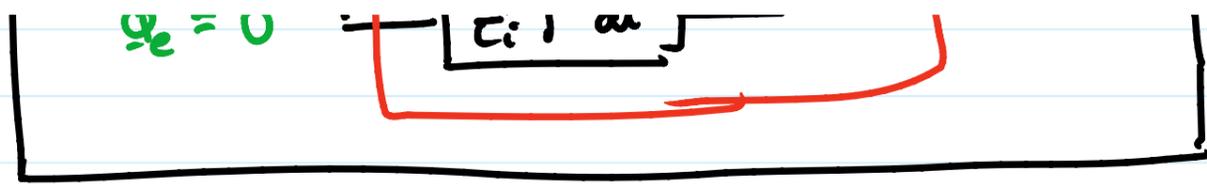


at $t=0$, $v_c=0$, $v_e = \sin(\theta)$

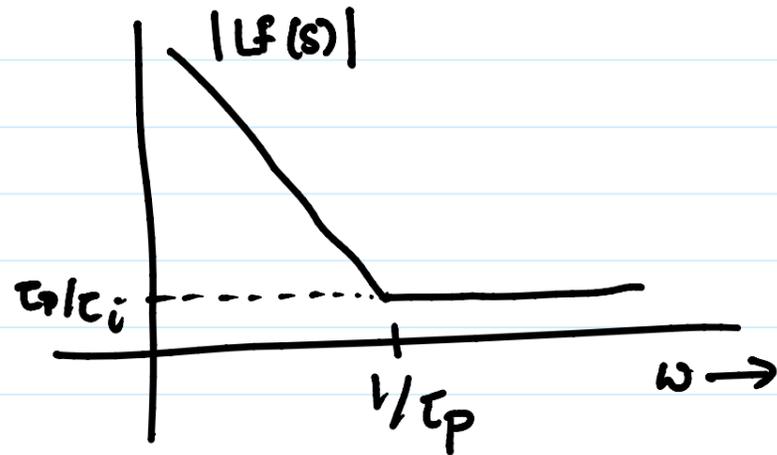
at $t = \infty$, $v_c = \frac{\Delta\omega}{K_{vco}}$, $v_e = \sin(\theta)$

2) Stability of PLL w/ 2-integrators \Rightarrow Proportional path,





$$LF(s) = \frac{\tau_p}{\tau_i} + \frac{1}{\tau_i} \frac{1}{s} = \frac{1}{\tau_i} \frac{(1+s\tau_p)}{s}$$



$$LF(0) = \infty$$

$$LF(\infty) = \tau_p/\tau_i$$

1) Hold-in range of Type-II PLL

$$|LF(0)| = \infty \Rightarrow \Delta\omega_H = \infty$$

2) Lock-in range of Type-II PLL

$$\hat{\Phi}_{err}(t) = \Delta\omega \cdot t - K_{vco} \int v_e \cdot dt$$

$$= \Delta\omega \cdot t - K_{vco} \int \left[\frac{\tau_p}{\tau_i} v_e + \int \frac{1}{\tau_i} v_e(\tau) \cdot d\tau \right] dt$$

$$= \Delta\omega \cdot t - \frac{K_{vco} \cdot K_{pd}}{\tau_i} \left[\int \tau_p \cdot v_e(t) \cdot dt + \int \left(\int v_e(\tau) \cdot d\tau \right) dt \right]$$

$$\frac{d\hat{\Phi}_{err}(t)}{dt} = \Delta\omega - \frac{K_{vco} \cdot K_{pd}}{\tau_i} \left[\tau_p \sin(\hat{\Phi}_{err}) + \int^t \sin(\hat{\Phi}_{err}(\tau)) \cdot d\tau \right]$$

$$\frac{d}{dt} = \Delta\omega - \frac{K_{vco} \cdot K_{pd}}{\tau_i} \left[\tau_p \sin(\hat{\Phi}_{err}) + \int_0^t \sin(\hat{\Phi}_{err}(t)) dt \right]$$

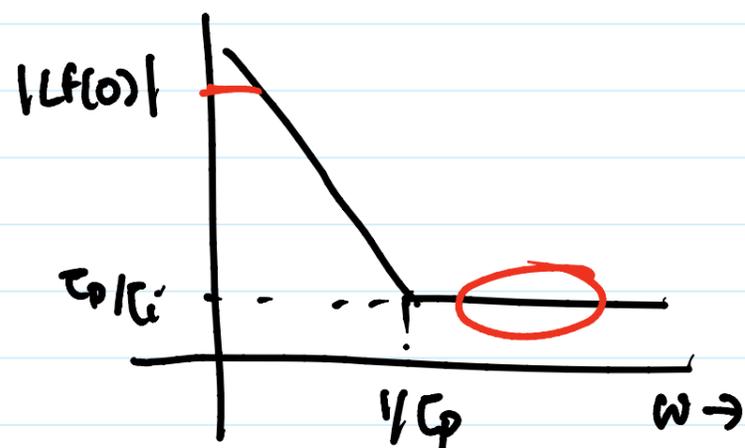
$$= \Delta\omega - \frac{K_{vco} \cdot K_{pd} \cdot \tau_p}{\tau_i} \sin(\hat{\Phi}_{err}) - \frac{K_{vco} \cdot K_{pd}}{\tau_i} \int_0^t \sin(\Delta\omega \cdot t) dt$$

in locked state, $\frac{d\hat{\Phi}_{err}(t)}{dt} = 0$

$$\frac{\Delta\omega}{K_{vco} \cdot K_{pd} \cdot \frac{\tau_p}{\tau_i}} = \sin(\hat{\Phi}_{err}) < 1$$

$$\Delta\omega_L \leq \underbrace{K_{vco} \cdot K_{pd} \cdot \frac{\tau_p}{\tau_i}}_K = K \times |LF(\infty)|$$

3) Pull-in range



DC gain in prop. path = $\tau_p/\tau_i = |LF(\infty)|$

DC gain of combined filter = $|LF(0)| = K_{dc,prop} + K_{dc,int}$

DC gain in integ. path = $|LF(0)| - |LF(\infty)|$

$$\hat{\Phi}_{err}(t) = \Delta\omega \cdot t - K_{vco} \int V_e dt$$

$$= \Delta\omega \cdot t - K_{vco} \int K_{dc,int} V_e dt$$

$$= \Delta\omega \cdot t - K_{vco} [|L_f(0)| - |L_f(\infty)|] \int v_e dt$$

$$\Delta\Omega = \frac{d\hat{\phi}_{err}(t)}{dt} = \Delta\omega - K_{vco} [|L_f(0)| - |L_f(\infty)|] v_e$$

$$= \Delta\omega - K_{vco} [|L_f(0)| - |L_f(\infty)|] K_{pd} \left[\frac{\Delta\Omega}{K} - \sqrt{\left(\frac{\Delta\Omega}{K}\right)^2 - 1} \right]$$

$\Delta\Omega =$ frequency error

$$\frac{d\hat{\phi}_{err}(t)}{dt} = \Delta\omega - K_{vco} \cdot K_{pd} \sin(\hat{\phi}_{err}(t))$$

$$\Delta\Omega = \Delta\omega - [K - K_{dc}] \left[\frac{\Delta\Omega}{K} - \sqrt{\left(\frac{\Delta\Omega}{K}\right)^2 - 1} \right]$$

in case, $\Delta\Omega$ has real roots \Rightarrow Unable to pull in. $\Delta\omega \geq K \sqrt{\frac{2K_{dc}}{K} - 1}$

$\Delta\Omega$ has complex roots $\Rightarrow \Delta\omega < K \sqrt{\frac{2K_{dc}}{K} - 1}$

$$\Delta\omega_p < \sqrt{2K_{dc} \cdot K} \quad , \text{if } K_{dc} > K$$

$$= \sqrt{2(K_{vco} \cdot K_{pd})^2 (|L_f(0)| |L_f(\infty)|)}$$

$$\Delta\omega_p = K_{vco} \cdot K_{pd} \sqrt{2 \cdot |L_f(0)| |L_f(\infty)|}$$