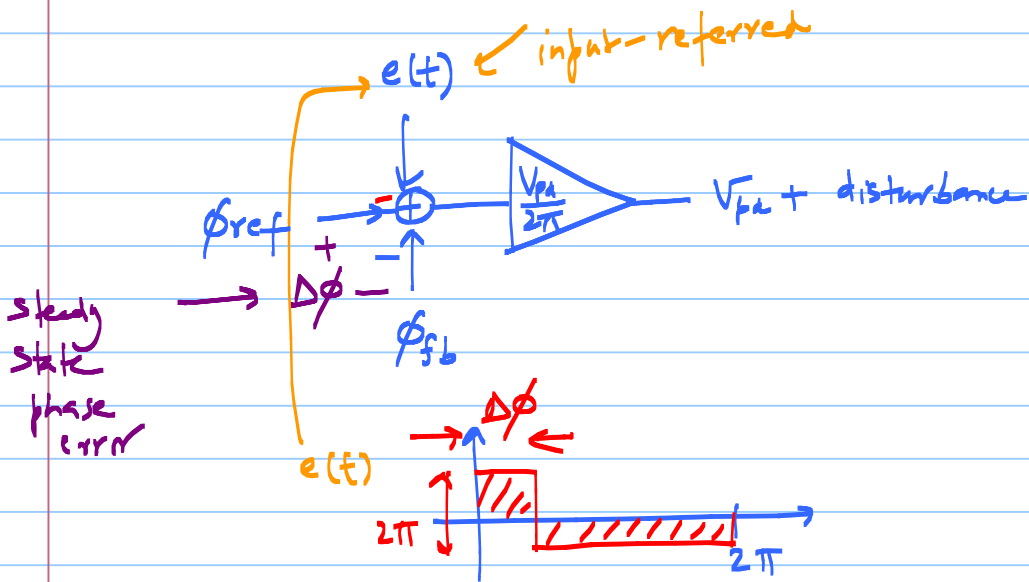
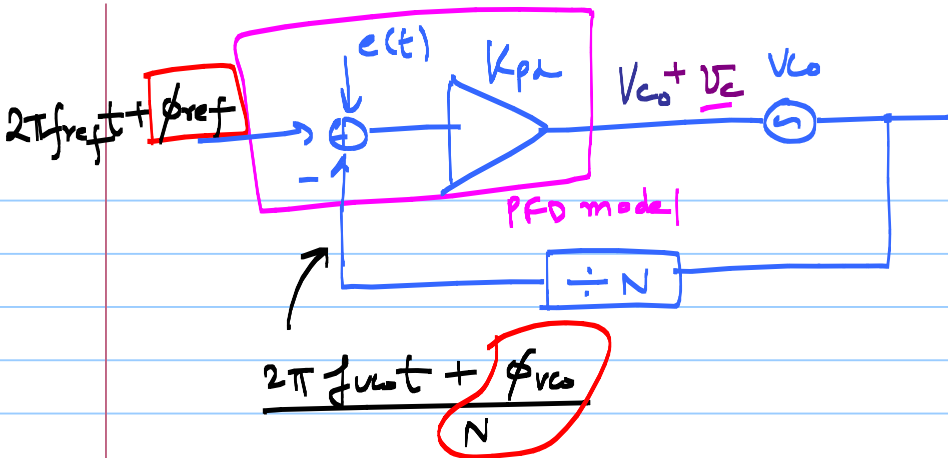
ECE 518 - Lecture 12

Note Title 2/28/2013

$\boxed{\text{Skip dc}}$

in transient sims





$$\underbrace{2\pi f_0 t + \Phi_{vco} + \phi_{vco}(t)}_{\text{output phase}}$$

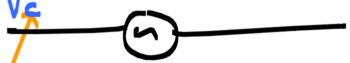
* The loop has been operating in steady-state around an operating point

$\Rightarrow$ Draw the incremental (small-signal) phase equivalent circuit for this PLL

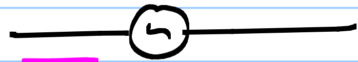
Incremental VCO Model

$V_{co} + V_c$

small DC voltage



$$\cos\left(2\pi f_o t + 2\pi k_{vco}\int V_c\, dt\right)$$



$V_{co} + V_c + \boxed{\underbrace{\Delta V}_{ac}}$

$$\cos\left(2\pi f_o t + 2\pi k_{vco}\int V_c\, dt + \boxed{2\pi k_{vco}\int \Delta V\, dt}\right)$$

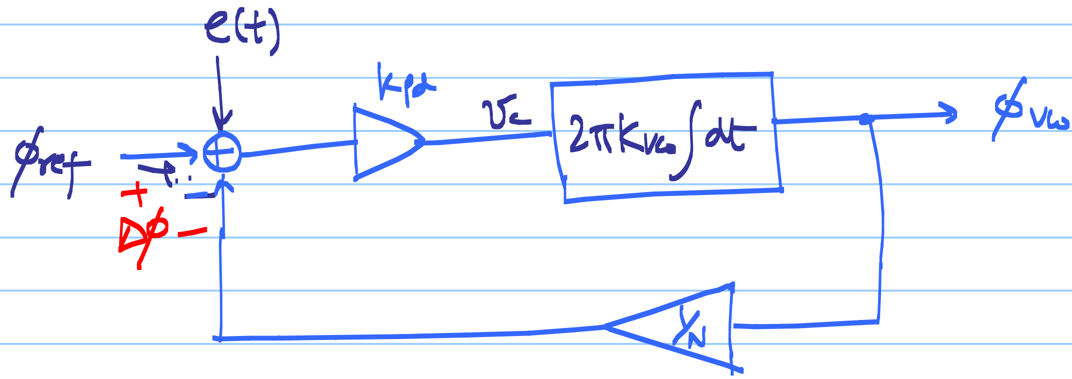
incremental VCO model

$$\underbrace{\Delta V}_{\text{incremental input voltage}} \longrightarrow \boxed{\underbrace{2\pi k_{vco}}_{\frac{Hz}{V}}\int dt} \longrightarrow \underbrace{2\pi k_{vco}\int \Delta V \cdot dt}_{\text{phase}}$$

Laplace

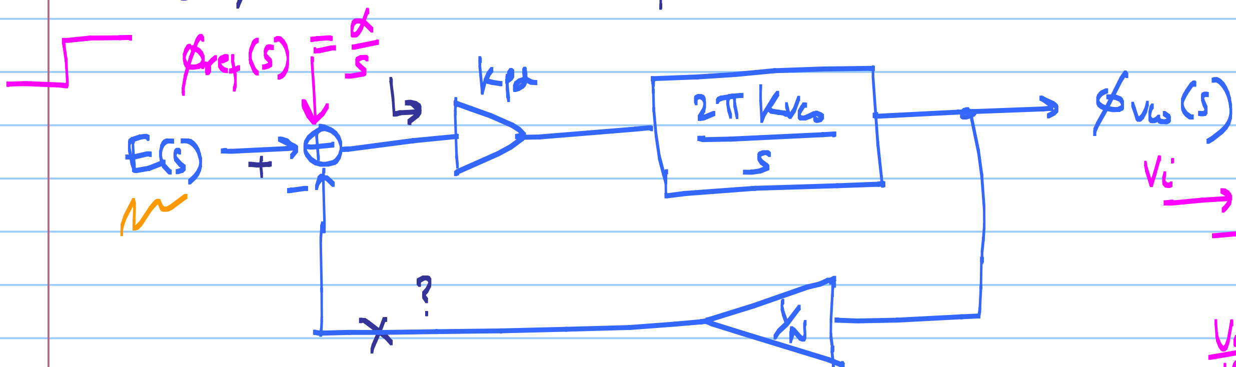
$$\Delta V(s) \longrightarrow \boxed{\frac{2\pi k_{vco}}{s}} \longrightarrow \phi_{vco}(s)$$

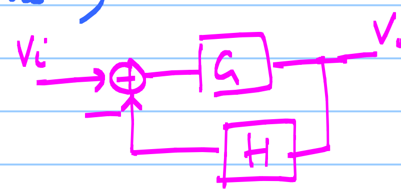
Incremental Model for the Type-I PLL



e(t) depends on $\Delta\phi$

Laplace domain Model





$$\frac{V_o}{V_i}(s) = \frac{G}{1+GH}$$

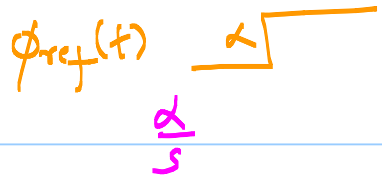
L(s)

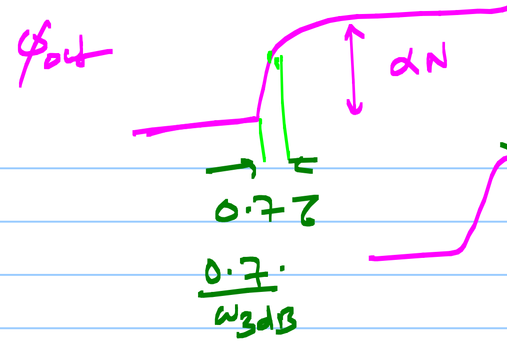
(open) Loop response $= L(s) = \frac{2\pi K_{pd} K_{VCO}}{N} \cdot \frac{1}{s}$

$$= \frac{\omega_{u,loop}}{s}$$

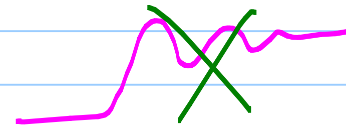
$$\frac{\phi_{VCO}(s)}{E(s)} = \frac{N}{1 + \frac{s \cdot N}{2\pi K_{VCO} \cdot K_{PD}}}$$

first-order response





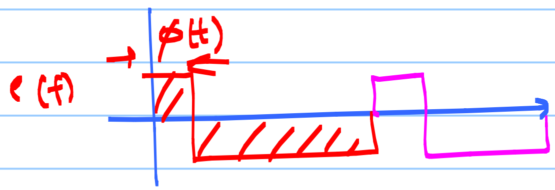
$$\tau = \frac{1}{\omega_{3dB}}$$



\#

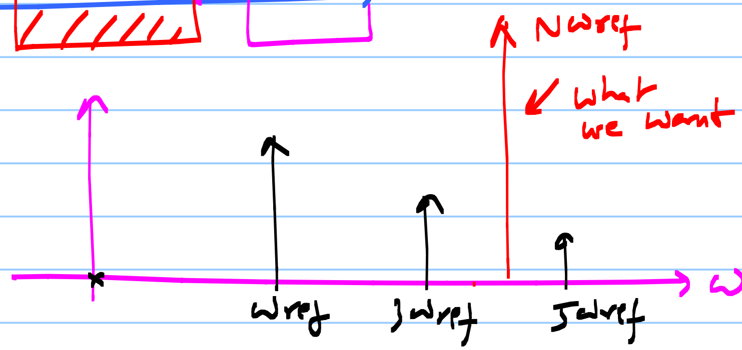
Type$_n$ of a system

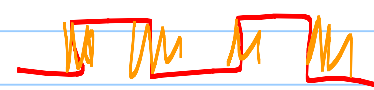
$\Rightarrow$ Loop response has # poles at DC



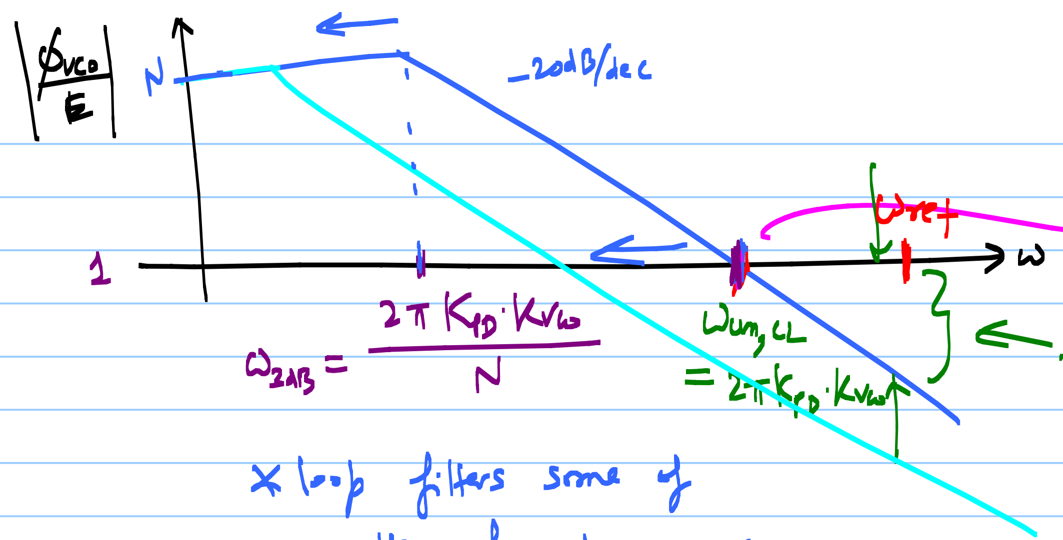
periodic $\Rightarrow 2\pi \cdot f_{ref} \Rightarrow \omega_{ref}$

$$T_{ref} = \frac{1}{f_{ref}}$$





" reference feedthrough "
↳ undesirable



* loop filters some of the periodic error

* To reduce disturbances in the o/p due to the periodic nature of the phase error

$$\boxed{\omega_{ref} \gg 2\pi K_{PD} \cdot K_{VCO}} \rightarrow (2)$$

* Constraint on the range

$$2\pi |N f_{ref} - f_0| < 2\pi K_{PD} \cdot K_{VCO} \longrightarrow ①$$

Linear regim of the PFD

$$f_{ref} >> K_{PD} \cdot K_{VCO} \longrightarrow ②$$

$$|N f_{ref} - f_0| < K_{PD} \cdot K_{VCO} << f_{ref}$$

$$|\underbrace{N f_{ref}}_{f_{out}} - f_0| << f_{ref}$$

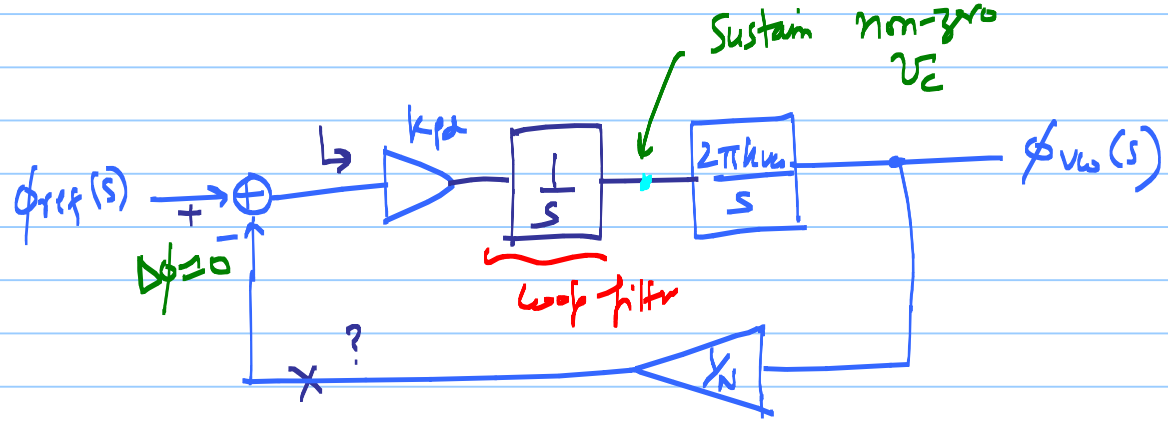
$$|N f_{ref} - f_0| < \frac{f_{ref}}{10}$$

$$f_0 - \frac{f_{ref}}{10} \le f_{out} \le f_0 + \frac{f_{ref}}{10}$$

<u>Very small</u> tuning range

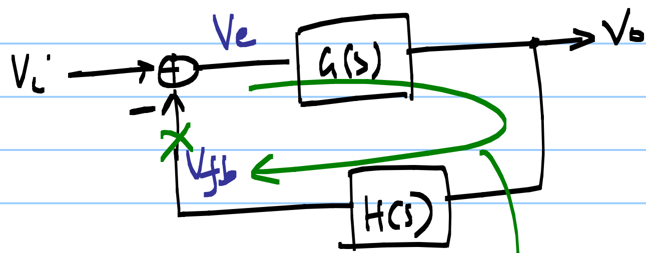
"Type-I is totally useless."

Solution ⇒ Type-II PLL ⇒ Add a loop filter "integrating controller"



⇒ 2^{nd}-order system (Type-II)

Feedback System Review contd.



$L(s) = G(s)\,H(s)$

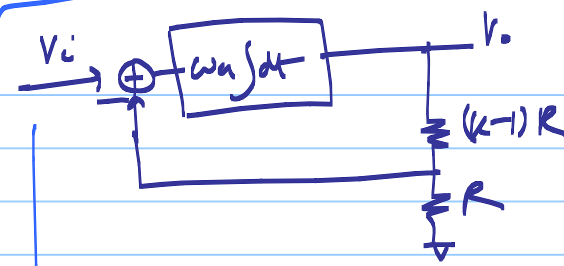
$$\frac{V_o(s)}{V_i(s)} = \frac{G(s)}{1 + G(s)\,H(s)}$$

$$= \frac{1}{H(s)} \cdot \frac{1}{1 + \frac{1}{G(s) \cdot H(s)}}$$

$$= \begin{cases} \frac{1}{H(s)} & \text{for } |GH| \gg 1 \\ G(s) & \text{for } |GH| \ll 1 \end{cases}$$

feedback breaks down

feedback amplifier



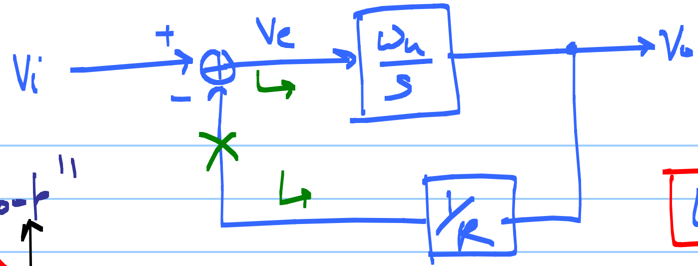
$G(s) = \frac{\omega_u}{s}$

$H(s) = 1/k$

$$\frac{V_o}{V_i}(s) = k \cdot \frac{1}{1 + \frac{1}{\frac{\omega_u}{sk}}}$$

(open) Loop-gain $= L(s) = G(s)H(s)$

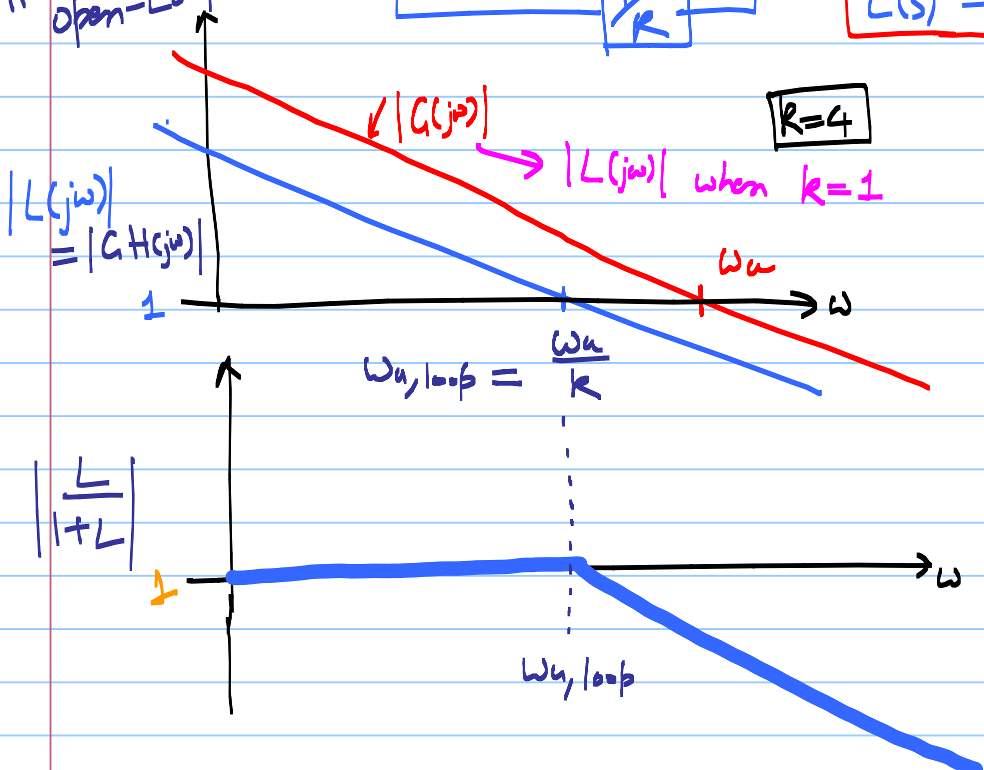
$\omega_u \Rightarrow$ unity gain frequency for the integrator



$$\boxed{L(s) = \frac{\omega_u}{s/k}}$$

$\boxed{k=4}$

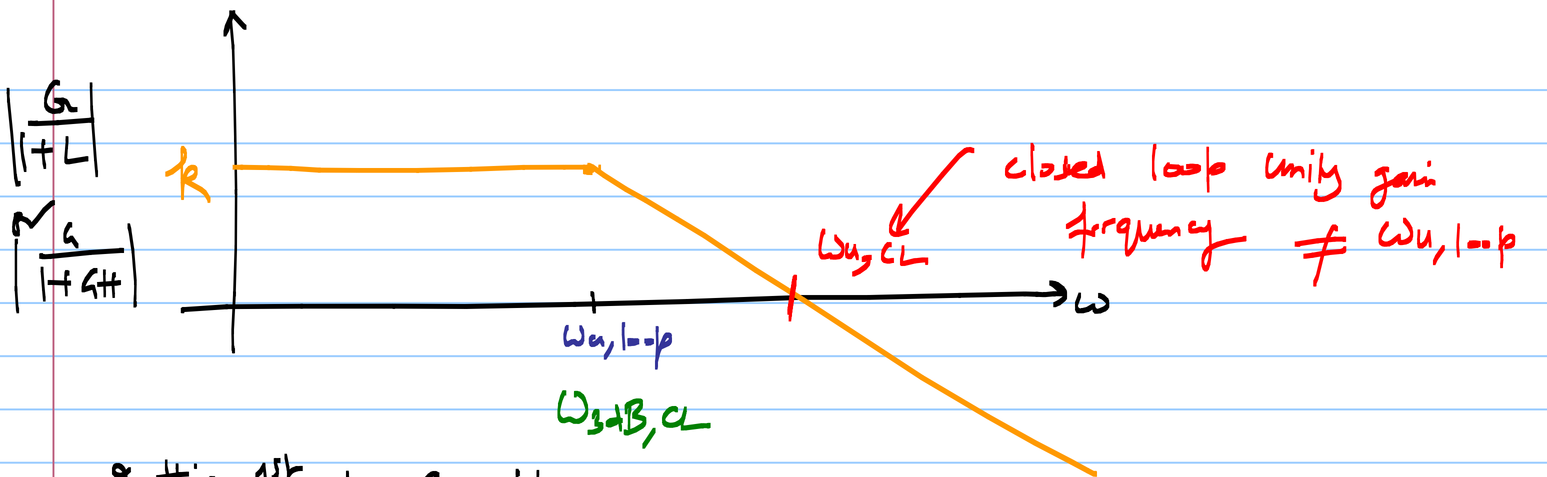
$\boxed{\omega_{u,loop}} \Rightarrow$ UGF of the open loop



← divide by $H(s)$

$\Rightarrow$ multiply be 'k'

"Closed-loop response"



In this 1st order example

* $\omega_{u,loop} = \frac{\omega_u}{k}$

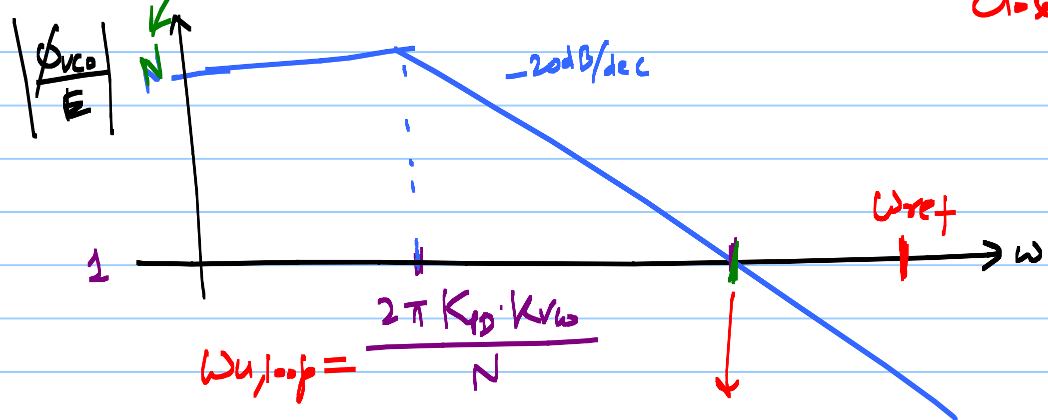
* $\omega_{3dB} = \omega_{u,loop} = \frac{\omega_u}{k}$

is the UGF of $G(s)H(s)$

* NOT $G(s)$

Closed-loop response

Closed-loop gain ($\triangleq K$)



$$\omega_{u,loop} = \frac{2\pi K_{PD} \cdot K_{VCO}}{N}$$

$$\omega_{u,CL} = 2\pi K_{PD} \cdot K_{VCO}$$

To filter ω_{ref} periodic disturbance

$\Rightarrow$ Need very small loop-bandwidth

↳ poor tuning range.