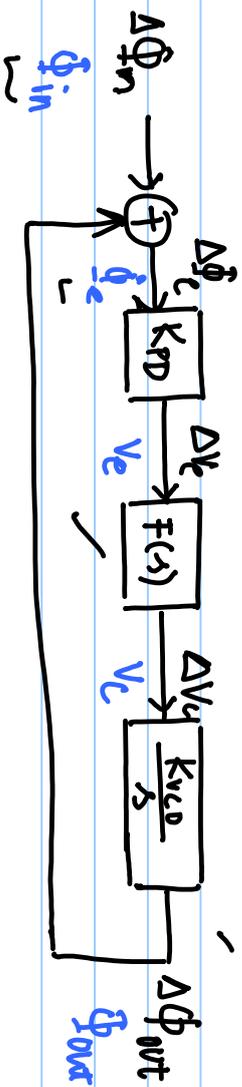


Lecture #5



$$LG(s) = \frac{K_{PD} F(s) K_{VCO}}{s}$$

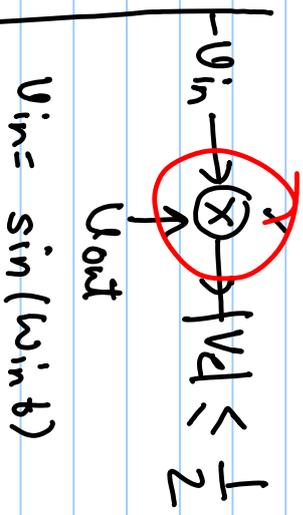
$$\Phi_{in} = \frac{\Delta \omega(t)}{\lambda^2}$$

$$\lim_{t \rightarrow \infty} \Phi_e(t) = \lim_{\lambda \rightarrow 0} \lambda \cdot \Phi_e(s)$$

$$= \lim_{\lambda \rightarrow 0} \lambda \cdot \frac{\Delta \omega(0)}{\lambda^2} \cdot \frac{1}{1 + L\lambda}$$

$$= \lim_{\lambda \rightarrow 0} \frac{\Delta \omega(0)}{\lambda} \cdot \frac{\lambda}{1 + K_{PD} F(s) K_{VCO}}$$

$$\lim_{t \rightarrow \infty} \Phi_e(t) = \frac{\Delta \omega(0)}{K_{PD} F(0) K_{VCO}}$$



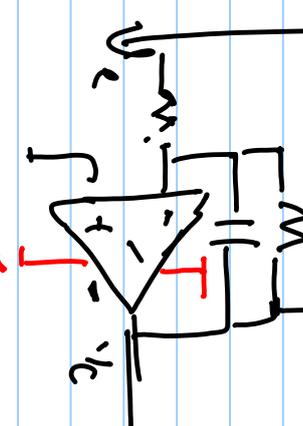
$$|V_{in}| \leq \frac{1}{2}$$

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

$$K_{PD} = \frac{dV_e}{d\Phi_e}$$

$$V_e = K_{PD} \cdot \Phi_e \leq \frac{1}{2}$$

$$V_e = K_{PD} \cdot \frac{V_c}{V_e} = \frac{1}{1 + sRC}$$



At $t \rightarrow \infty$ $V_c(t) = K_{PD} \cdot \mathcal{E}_e$

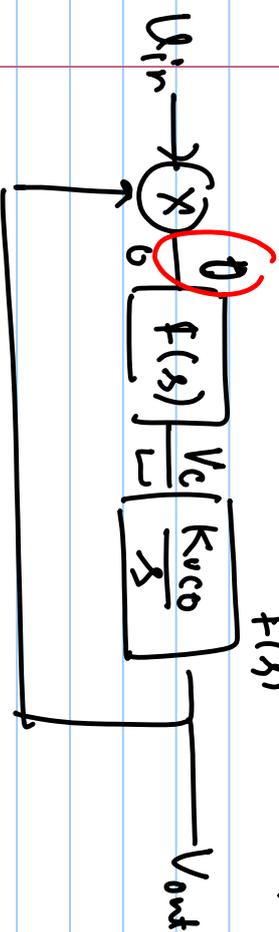
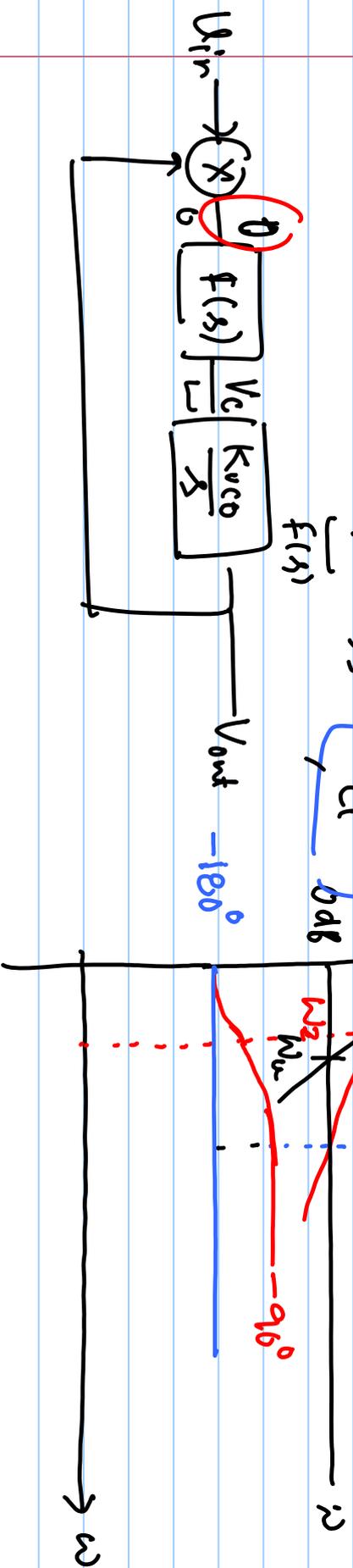
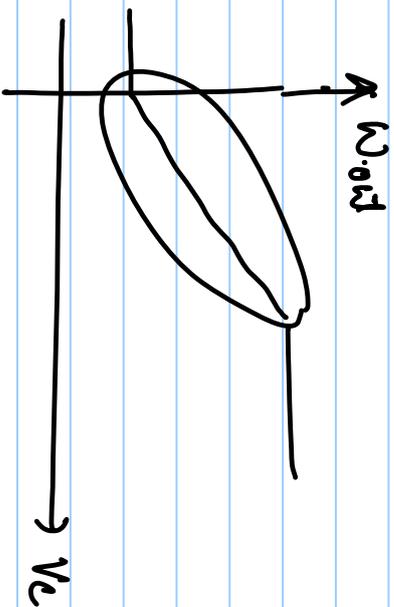
$\underline{V}_c \rightarrow \boxed{VCD} \rightarrow i_{out} = \omega_{free} + K_{VCO} \cdot \underline{V}_c$

At $t \rightarrow \infty$ $V_c(t) = F(0) \cdot V_e$

$F(0) \rightarrow \infty$

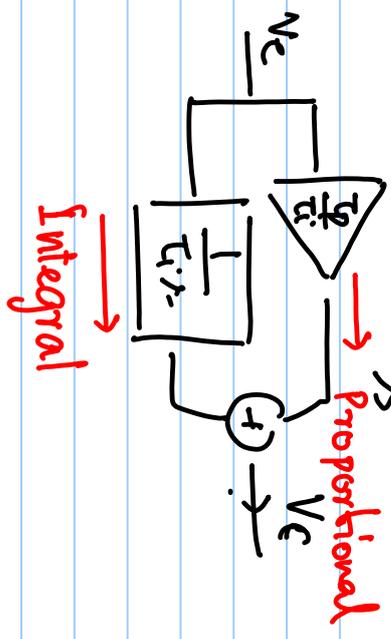
$\Rightarrow \underline{F(s)} = \frac{1}{s}$

LC: $(s) = K_{PD} \cdot \frac{1}{s} \cdot \frac{K_{VCO}}{s} \cdot \underbrace{\left[\frac{(\Delta T_p + 1)}{\tau_i} \right]}_{0 \text{ dB}}$



$$F(s) = \frac{(1+s/\omega_z)}{(1+s/\omega_p)} = \frac{1}{\omega_z} + \frac{1}{s} = \frac{T_p}{T_i} + \frac{1}{s}$$

Φ_{erst}



$$\int \Phi_e(s) = \frac{\Delta\omega(s)}{K_{PD} F(s) K_{VIO}} = 0$$

Frequency ramp, $\Delta\omega = k \cdot t \cdot \omega(t)$

$$\Delta\Phi = \frac{k}{s^3}$$

$$\int \Phi_e(s) = \int \frac{k}{s \cdot K_{PD} K_{VIO} (1+s/\omega_z)} =$$

$F(s)$	$\Delta\Phi_r(t)$	$\Delta\omega_r(t)$	$\Delta\omega_r'(t)$
$\frac{1}{1+s/\omega_p}$	0	-	-
$\frac{1}{s}$	0	0	0
$\frac{1+s/\omega_z}{s}$	0	0	0

PLL

Type	Order
Case 1	2
Case 2	2

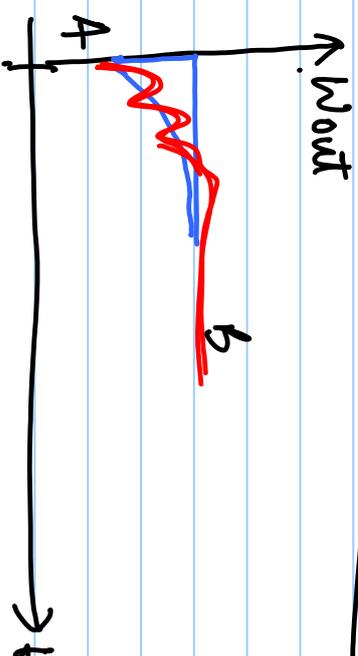
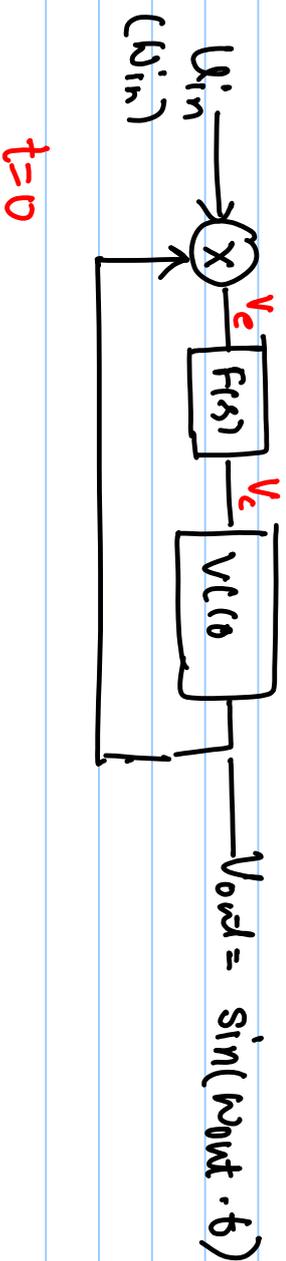
Type: # of integrators in the loop

Order: # of poles

Case 1	1	2
Case 2	2	2

Case 1. $L_u = K_{PD} \frac{1}{1+s/\omega_p} \frac{K_{VCO}}{s}$

Case 2. $L_u = K_{PD} \frac{1+s/\omega_z}{s} \frac{K_{VCO}}{s}$



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

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

$$\Delta \omega(t) = \omega_{in} - (\omega_{out}(t))$$

$$= (\omega_{in} - \omega_{free}) + K_{VCO} \cdot 0$$

$$\Delta \omega(t) = (\omega_{in} - \omega_{free}) \quad \checkmark$$

$$V_e = V_{in} \times V_{out}$$

$$= \sin(\omega_{in} \cdot t) \times \sin(\omega_{out} \cdot t)$$

$$= \frac{1}{2} \left[\cos(\Delta \omega(t) \cdot t) - \cos(\overbrace{\omega_{in} + \omega_{out}} \cdot t) \right]$$

$$\approx \frac{1}{2} \cos(\Delta \omega(t) \cdot t)$$

$$= \frac{1}{2} \cos(\Delta \omega(t) \cdot t + \underbrace{K_{VCO} \cdot V_e \cdot dt})$$

$$\omega_{in} = 100 \text{ Mrad/s}$$

$$\omega_{out} = 99 \text{ Mrad/s}$$

$$K_{VCO} = 100 \text{ Mrad/s/V}$$

In steady state:

$$V_e = \frac{\Delta \omega(t)}{K_{VCO}} = \frac{1 \text{ Mrad/s}}{100 \text{ Mrad/s/V}} = 10 \text{ mV}$$

$$F(s) = \frac{1}{1+s/\omega_{BP}} \Rightarrow V_e = 10 \text{ mV}$$

$$V_e = \frac{1}{2} \cos(\phi_e)$$

$$\phi_e = \cos^{-1}(0.02)$$

$t=0$

$$\checkmark \Phi_e(t) = \Delta\omega(0) \cdot t + K_{VCO} \int_{t_1}^t V_e \cdot dt$$

$$V_e(t) = \frac{1}{2} \sin(\Phi_e(t))$$

$$V_e(t) = \sin(\Delta\omega(0) \cdot t + K_{VCO} \cdot \int \sin(\Phi_e(t)) \cdot dt)$$

at $t=t_1$

$$\cdot V_e \int_{t=t_1}^{t_1+\Delta t} = \sin(\Phi_e(t_1))$$

$$t=t_1+\Delta t, \quad \Phi_e(t_1+\Delta t) =$$

$$y(z)$$

$$x(z) = \frac{1}{1-z^{-1}}$$

$$y[n] = y[n-1] + x[n]$$

$$n=0, \quad y[n-1] = 0$$

$$y[0] = x[0]$$

$$y[n] = y[n-1] + x[n]$$

$$\frac{d\Phi_e(t)}{dt} = 0$$

$$\Phi_e' = \Delta\omega(0) + K_{VCO} \cdot V_e$$

$$= \Delta\omega(0) + \frac{K_{VCO}}{2} \cdot \sin(\Phi_e) = 0$$

$$\cos(\Phi_e) = \frac{-\Delta\omega(0)}{K_{VCO}} = \frac{-\Delta\omega(0)}{K_{VCO} \cdot K_{PD}}$$



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