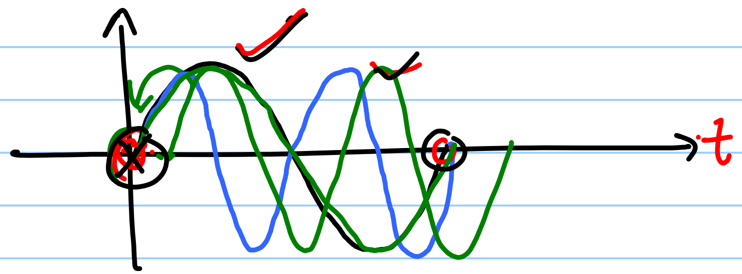
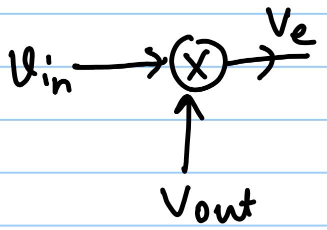
lecture #3

Phase error measurement for different freq?



Eg. $W_{in} = 2\pi 100\ MHz$

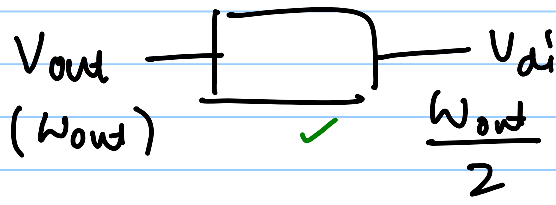
$W_{out} = 200\ MHz \times 2\pi = 150\ MHz$



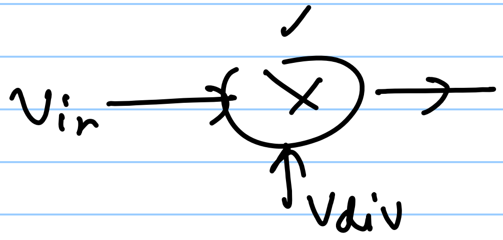
$V_e = V_{in} \times V_{out}$

$$V_e = -\frac{1}{2}\left[\cos(\underbrace{\overset{3\omega_{in}}{\overline{W_{in}+W_{out}}}}\ t) - \cos(\underbrace{\overset{-W_{in}}{\overline{W_{in}-W_{out}}}\ t})\right]$$

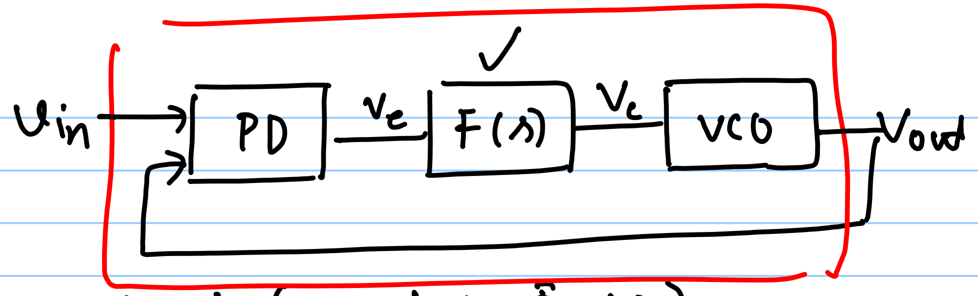
$V_e \propto \Phi_e$

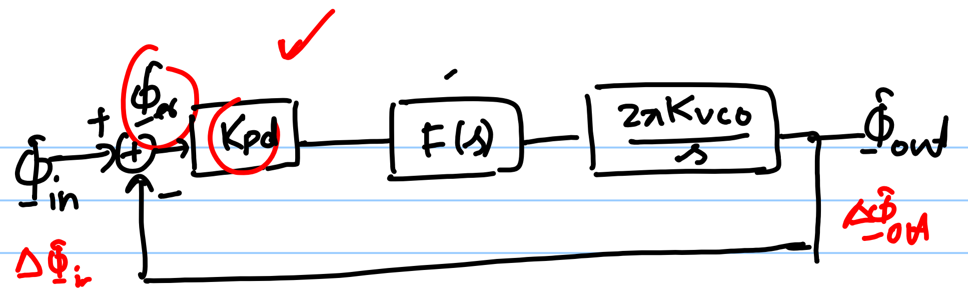


$V_{div} = \sin(\frac{W_{out}}{2} t.)$



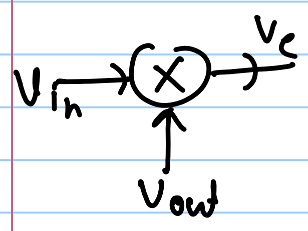
$$V_e' = -\frac{1}{2}\left[\cos(2\omega_{in} \cdot t) - \underbrace{\cos(\pi/2)}\right]$$





$V_{in} = 1. \sin(\underline{\omega_{in}.t + \Phi_{in}(0)})$

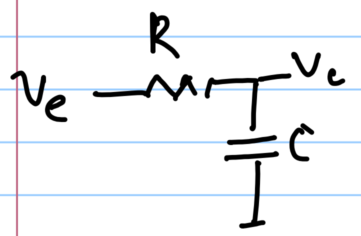
$V_{out} = 1. \sin(\underline{\omega_{out}.t + \Phi_{out}(0)})$



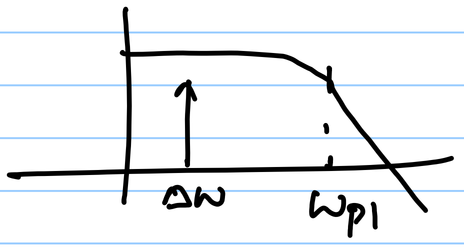
$$V_e = -\frac{1}{2}\Big[\cos(\overline{\omega_{in}+\omega_{out}}t + \Phi_{in}(0) + \Phi_{out}(0)) - \cos(\overline{\omega_{in}-\omega_{out}}\,t + \Phi_{in}(0) - \Phi_{out}(0))\Big]$$

$\omega_{in} - \omega_{out} = \Delta\omega$

$$V_e(t) = -\frac{1}{2}\Big[\cos(\overline{\omega_{in}+\omega_{out}}\,t + \qquad) - \cos(\Delta\omega.t + \Phi_{in}(0) - \Phi_{out}(0))\Big]$$



$$\frac{V_c(s)}{V_e(s)} = \frac{1}{1+sRC} = \frac{1}{1+s/\omega_{p1}}$$



$$\acute{V}_e = \boxed{\frac{1}{2}} \cos\left(\underbrace{\overset{=0}{\Delta\omega} . t + \Phi_{in}(0) - \Phi_{out}(0)}_{} \right)$$

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

ω_{free} : free running freq.

$V_c = 0$

$$V_{out} = \sin\left(\int (\omega_{free} + 2\pi K_{vco} . V_c) \, dt \right)$$

$$✓ = \sin\left(\underbrace{\omega_{free} . t + \int 2\pi K_{vco} . Kpd \cos(\underset{=0}{\Delta\omega . t} + \Phi_{er}(0)) \, dt}_{} \right)$$

$$= \sin(\underbrace{\omega_{in} . t + 2\pi K_{vco} Kpd \cos(\Phi_{er}(0)}_{}) \, t)$$

$$\omega_{inst} = \frac{d(\Phi_{out})}{dt}$$

$t = 0 \quad \Delta\omega = \omega_{in} - \omega_{out}$

$t > 0$

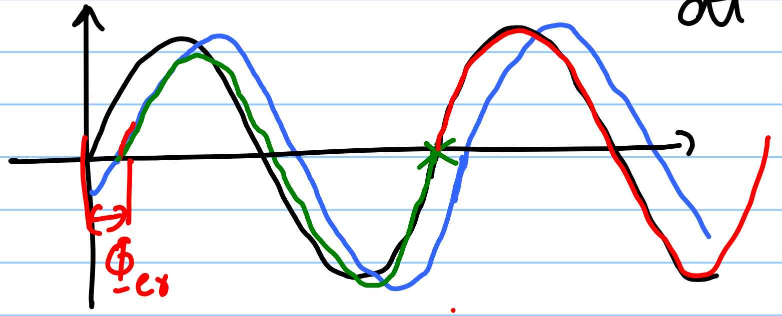
Φ_{in}

$\Phi_{er} = 0$

Φ_{out}

$\Phi_{er} \neq 0 \quad \omega_{in} = \omega_{out}$

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



at $t=0$, $\Delta\Phi_{in}(t) = \cdot\,\Phi(0)\ u(t)$

$$\underset{t\to\infty}{\mathrm{lt}}\ \Delta\Phi_{out}(t) =$$

$$LG(s) = K_{pd}\cdot\frac{1}{1+s/\omega_{p1}}\ \frac{2\pi K_{vco}}{s}$$

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

$$\Phi_{er} = \Phi_{in} - \Phi_{out} = \frac{1}{1+LG}\cdot\Phi_{in}$$

$$= \frac{1}{1+K_{pd}F(s)\frac{2\pi K_{vco}}{s}}\qquad\frac{\Phi(0).}{s}$$

$$\underset{t\to\infty}{\mathrm{lt}}\ \Phi_{er}(t) = \underset{s\to 0}{\mathrm{lt}}\ s\cdot\Phi_{er}(s) = 0$$

$\checkmark$

$t<0$, $\omega_{out} = \omega_{in}$

$t=0$, $\Delta\omega_{in} = \omega_{in}(0).\,u(t)$

$$\underset{t\to\infty}{\mathrm{lt}}\ \Delta\omega_{out}(t) = \quad\Big|\quad \underset{t\to\infty}{\mathrm{lt}}\ \Phi_{out}(t) =$$

$$\omega_r = \frac{d\Phi}{dt}$$

$$\Phi_i = \int\omega\,dt$$

$$\Phi_{in}(s) = \frac{\omega_{in}(s)}{s}$$

$$= \frac{\Delta\omega(0)}{s^2}$$

$$\underset{t\to\infty}{\mathrm{lt}}\ \Phi_{er}(t) = \underset{s\to 0}{\mathrm{lt}}\ s\cdot\Phi_{er}(s)$$

$$= \frac{\omega_{in}(0)}{s\left(1+K_{pd}F(s).\frac{2\pi K_{vco}}{s}\right)}.$$

$$\lim_{t\to\infty} \Phi_{er}(t) = \frac{W_{in}(0)}{s + K_{pd}\cdot F(s)\ K_{vco}\times 2\pi}$$

$$\Phi_{er}(\infty) = \underbrace{\frac{\omega_{in}(0)}{K_{pd} F(0).\ K_{vco}\times 2\pi}}$$ ✓

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

$$V_c = V_e = \frac{1}{2} \sin\left(\frac{\Delta\omega}{2\pi K_{pd} K_{vco}}\right)$$

$$\omega'_{out} = \omega_{free} \cancel{+} \underbrace{2\pi K_{vco} \times \frac{1}{2}\cos\left(\frac{\Delta\omega}{2\pi K_{pd}.K_{vco}}\right)}$$ ✓

$$= \omega_{in} + \underline{\Delta\omega}$$

$$\Rightarrow \Delta\omega = 2\pi K_{vco}\cdot\frac{1}{2}\cos\left(\overbrace{\frac{\Delta\omega}{2\pi K_{pd} K_{vco}}}^{\Phi_e(\infty)}\right)$$

$$\omega_{out}(s) = \frac{LG}{1+LG}\,\omega_{in}(s)$$ ✓

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

if. $\omega_{free} = \omega_{in}$ ✓

$$\omega_{out} = \omega_{in} + 2\pi K_{vco}.V_e$$

$\omega_{out} = \omega_{in}$ w/ $V_c = c$

$$\cos(\underline{\Phi}_e(\infty)) = \frac{\Delta\omega}{2\pi K_{vco} \times \frac{1}{2}}$$

$$\underline{\cos(\underline{\Phi}_e(0))} = \frac{\Delta\omega}{2\pi K_{vco} \cdot K_{pd} \cdot \boxed{F(0)}} \quad \checkmark \quad < 1$$

$$\Delta\omega < 2\pi K_{vco} \cdot K_{pd} \cdot F(0)$$