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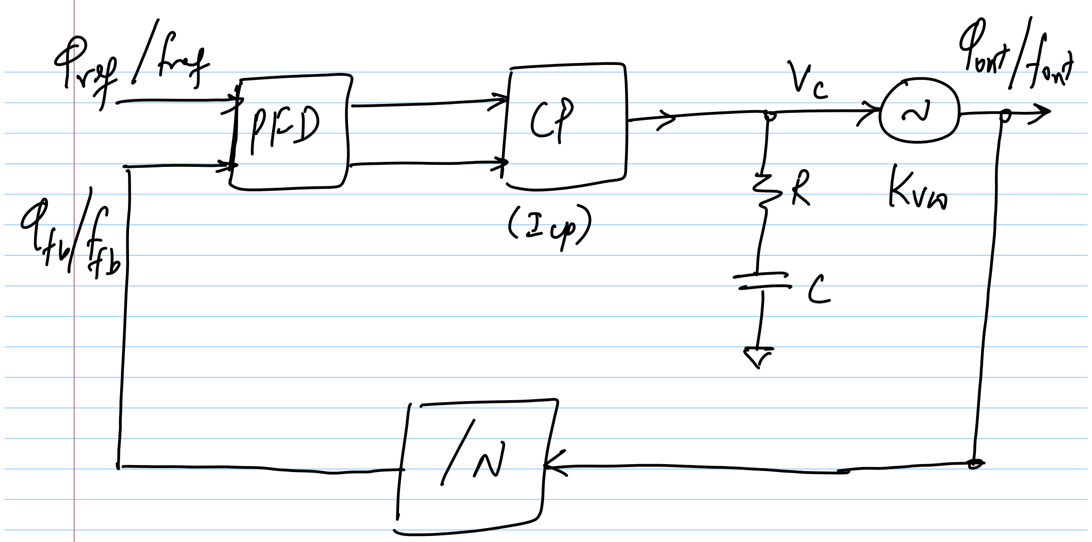
Lec 41

PLL Design Example

* Type-II 2^{nd} order Charge Pump PLL

Given: $f_{ref} = 10\,kHz$, $f_{out} = 1\,MHz$,
loop BW $= 500\,Hz$, $\zeta = \frac{1}{\sqrt{2}} = 0.707$
$K_{vco} = 500\,kHz/V$

* $Q = \frac{1}{2\zeta} = 0.707$
* ζ or Q are specified based on loop locking transient



LG for $\varphi_{out}/\varphi_{ref}$:

$$L(s) = \frac{1}{2\pi} \cdot I_{cp} \cdot \left[R + \frac{1}{sC}\right] \cdot \frac{2\pi K_{vco}}{s} \cdot \frac{1}{N}$$

$$= \frac{I_{cp} \cdot K_{vco}(1+sCR)}{s^2 NC}$$

CLG $\quad H(s) = N \cdot \frac{L(s)}{1+L(s)}$

$$= N \cdot \frac{I_{cp}K_{vco}(1+sCR)/s^2NC}{1 + I_{cp}K_{vco}(1+sCR)/s^2NC}$$

$$= N \cdot \frac{\frac{I_{cp}K_{vco}}{NC}(1+sCR)}{s^2 + \frac{I_{cp}K_{vco}R}{N} \cdot s + \frac{I_{cp}K_{vco}}{NC}}$$

compare with std. form $\quad s^2 + 2\zeta\omega_n s + \omega_n^2$

$$\omega_n = \sqrt{\frac{I_{cp}K_{vco}}{NC}}\ ; \quad \zeta = \frac{R}{2}\sqrt{\frac{I_{cp}CK_{vco}}{N}}$$

Step 1: Design VCO and get K_{vco}
(here K_{vco} is given); $N = \frac{f_{out}}{f_{ref}}$

Step 2 : Use relation between ω_{-3dB} and ω_n (can be derived based on CLG expression)*

$$\omega_{-3dB}^2 = \omega_n^2 \cdot \left[(2\zeta^2+1) + \sqrt{(2\zeta^2+1)^2+1}\right]$$

↳ $f_{-3dB} = \omega_{-3dB}/2\pi$ = loop BW

* Refer to F.M. Gardner, "Phaselock Techniques", Second ed., Wiley, 1979

Step 3 : Choose I_{cp}

→ based on noise and area considerations

Step 4 : Set ζ and calculate R & C

Step 5 : Iterate if required based on noise and area considerations

Here : $f_{-3dB} = 500\,Hz$, $\zeta = \frac{1}{\sqrt{2}}$

$\Rightarrow \omega_{-3dB} = 3140$ rad/s , $\zeta^2 = 0.5$

$$(3140)^2 = \omega_n^2\left[2+\sqrt{5}\right]$$

$\omega_n = 1525.6$ rad/s

Choose $\boxed{I_{cp} = 10\,\mu A}$

$$N = \frac{f_{out}}{f_{ref}} = 100$$

$$\omega_n = \sqrt{\frac{I_{cp}K_{vco}}{NC}}$$

$$(1525.6)^2 = \frac{10e^{-6} \times 500e^{3}}{100\,C}$$

$\Rightarrow \boxed{C = 21.48\,nF}$

$$\zeta = \frac{R}{2}\sqrt{\frac{I_{cp}K_{vco}C}{N}}$$

$\Rightarrow \boxed{R = 43.15\,k\Omega}$

Notes

1) zero is located @ $z = \frac{1}{2\pi RC} = 171.8\,Hz$

2) $f_n = \frac{K_{pd} K_{vco}}{N}$

3) $K_{pd} = \frac{I_{cp} \cdot R}{2\pi}$

4) $K_{pd_I} = \frac{I_{cp}}{2\pi C}$

5) Spec. can be in terms of phase margin, i.e., relative values of K_{pd} & K_{pd_I} (position of zero) and f_n.

F. M. Gardner, "Phaselock Techniques," Second Edition, Wiley

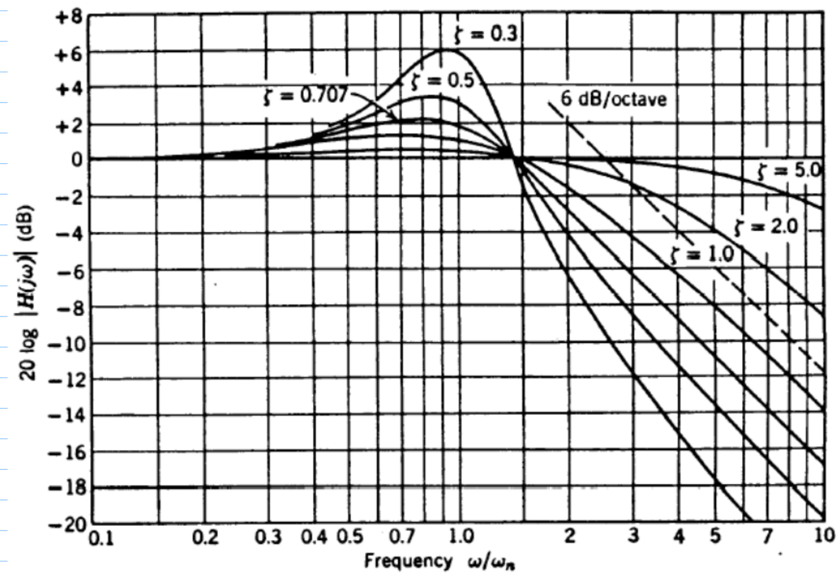


Figure 2.3 Frequency response of a high-gain second-order loop.