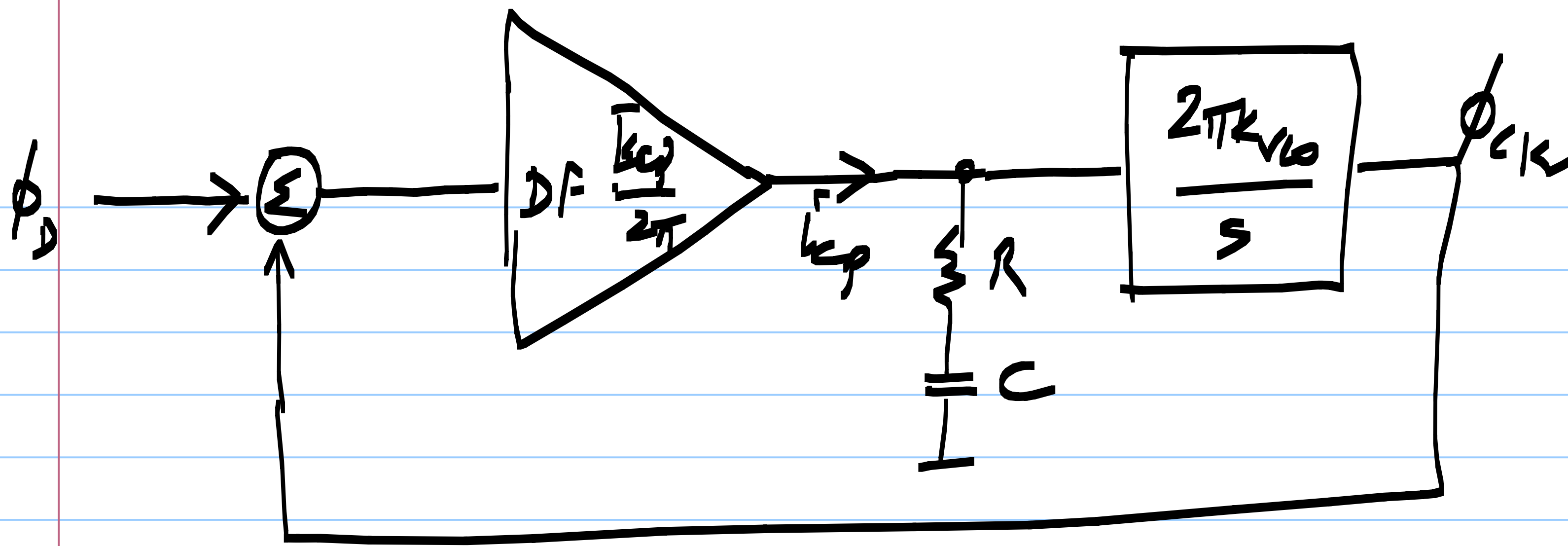


$$L(s) = DF \cdot \frac{I_{cp}}{2\pi}\left(R + \frac{1}{sC}\right) \cdot \frac{2\pi K_{vco}}{s}$$

$$= \underbrace{\frac{DF \cdot I_{cp} R K_{vco}}{s}}_{} \cdot \frac{1 + sCR}{sCR} = \frac{\omega_u}{s} \cdot \left(\frac{\omega_z}{s} + 1\right)$$

$\omega_z < \omega_u$
for good phase margin

$\omega_z \ll \omega_n$

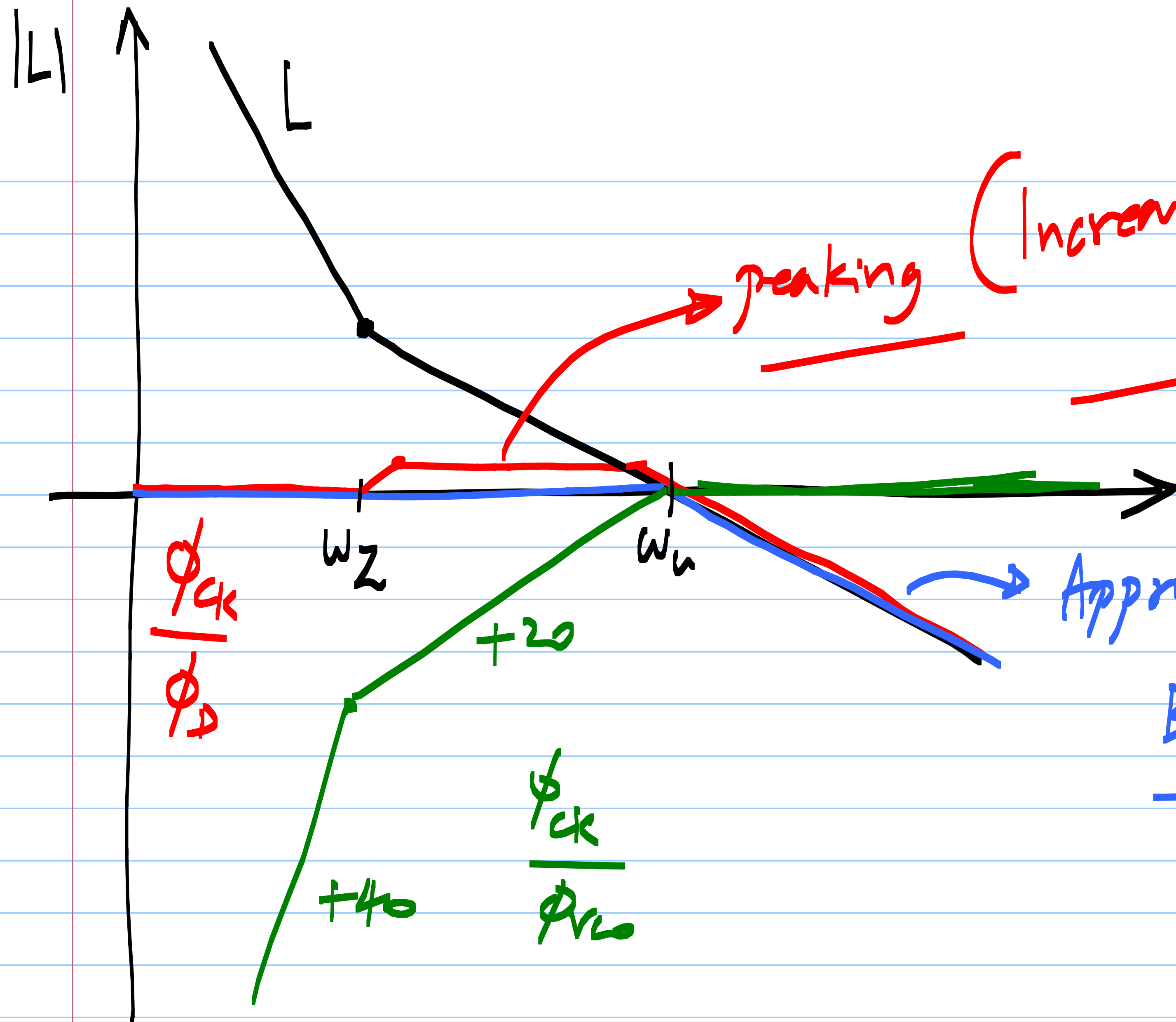
$$\frac{\phi_{ck}}{\phi_D} = \boxed{\frac{1 + s/\omega_z}{1 + \frac{s}{\omega_z} + \frac{s^2}{\omega_n \omega_z}}} \simeq \frac{\left(1+\frac{s}{\omega_z}\right)\left(1+\frac{s}{\omega_n}\right)}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$

$$\simeq \frac{1}{1 + s/\omega_n}$$

$p_1 > \omega_z \qquad p_2 \simeq \omega_n$

Peaking is small if $\omega_z \ll \omega_n$ (highly overdamped)

$$\frac{1 + s/\omega_z}{\underbrace{(1 + s/p_1)\,(1 + s/p_2)}_{p_2 = \omega_n}}$$



peaking (Increases if ω_z approaches ω_u)

Approximate $\frac{\phi_{ck}}{\phi_D}$.

BW of ω_u

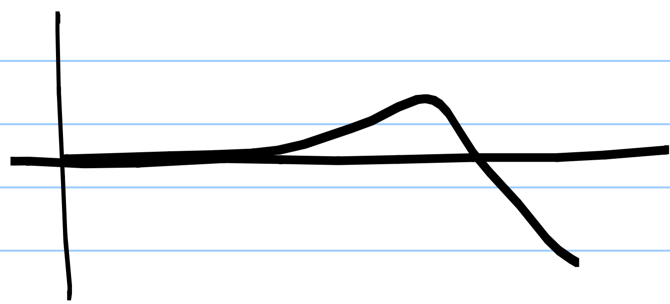
$$H(s) = \frac{1 + s/\omega_z}{1 + s/\omega_z + s^2/\omega_z\omega_n}$$

$$H_1(s) = \left[\frac{1}{1 + s/\omega_z + s^2/\omega_z\omega_n} \right]$$

complex conjugate poles if $\omega_z > \frac{\omega_n}{4}$

$$Q = \sqrt{\frac{\omega_z}{\omega_n}}$$

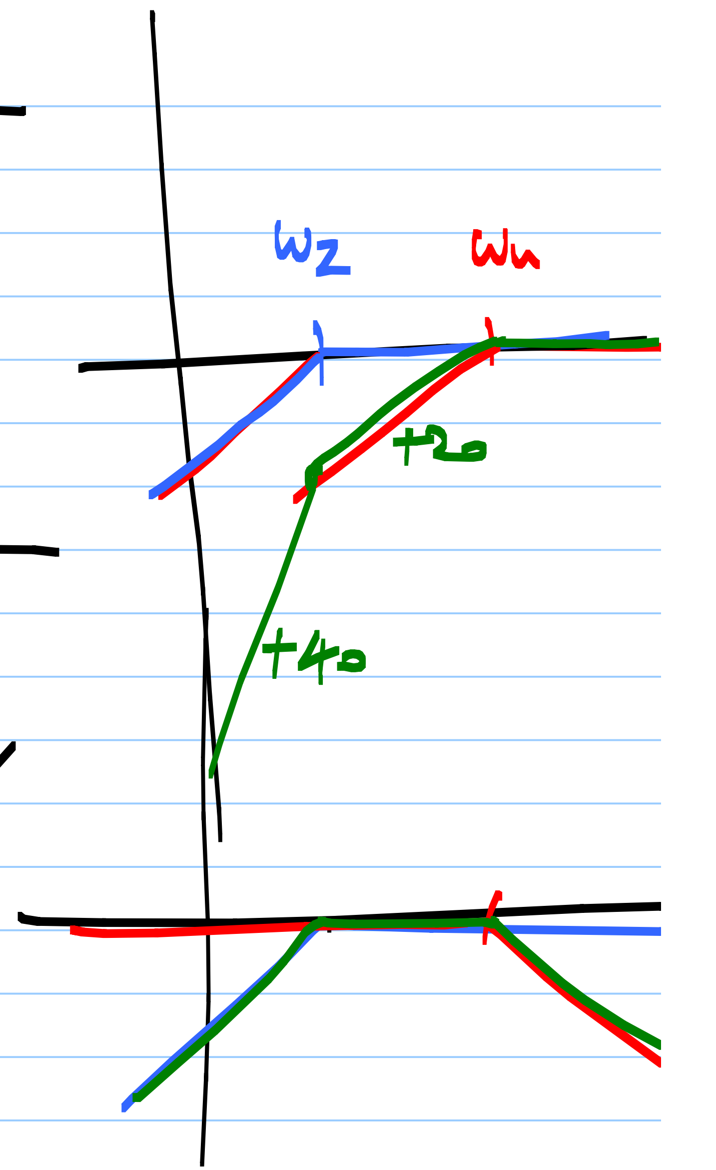
$$\zeta = \frac{1}{2}\sqrt{\frac{\omega_n}{\omega_z}}$$

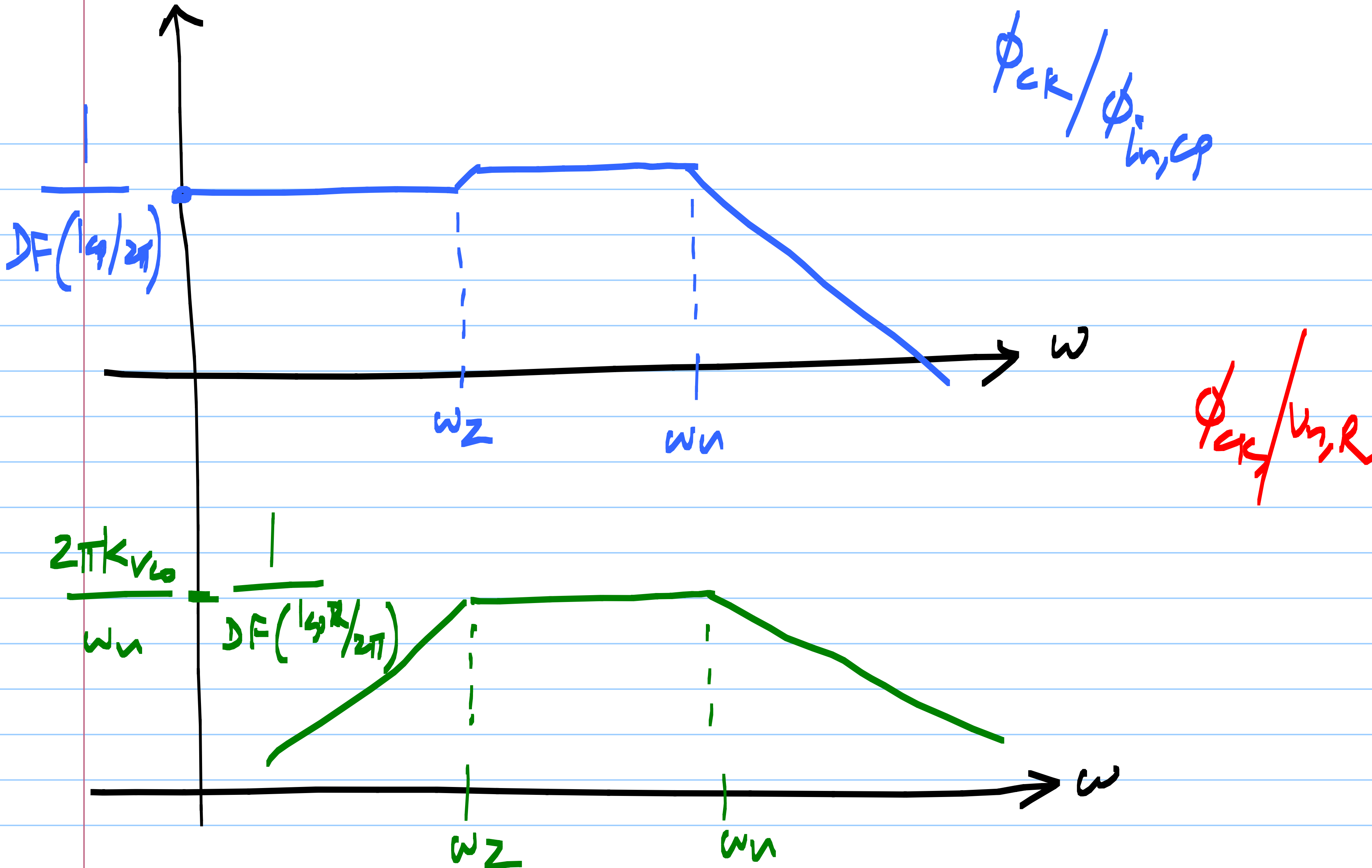


$$\frac{\phi_{ck}}{\phi_{v_{io}}} = \frac{s^2/\omega_u \omega_z}{1 + \frac{s}{\omega_z} + \frac{s^2}{\omega_u \omega_z}}$$

$$\cong \frac{\left(s/\omega_z\right)\left(s/\omega_u\right)}{\underbrace{\left(1 + s/\omega_z\right)}\underbrace{\left(1 + s/\omega_u\right)}}$$

$$\left[\frac{s/\omega_z}{\left(1 + s/\omega_z\right)}\right]\left[\frac{1}{\left(1 + s/\omega_u\right)}\right]$$





φck/φin,cp
1 / DF(Icp/2π)
ω
ωz
ωn
φck/in,R
2πKvco / ωn
1 / DF(IcpR/2π)
ω
ωz
ωn

Phase noise due to R:

$$L(f) = 2kTR \left[\frac{1}{DF\left(\frac{I_{cp}R}{2\pi}\right)} \right]^2 \cdot \left| \frac{s/\omega_z}{1 + s/\omega_z + s^2/\omega_z\omega_u} \right|^2_{s=j2\pi f}$$

$$2\int_0^\infty L(f)\cdot df$$

$$= 4kTR \frac{1}{\left(DF \frac{I_{cp}R}{2\pi}\right)^2} \cdot \frac{DF \cdot I_{cp}R \cdot K_{vco}}{4}$$

Integrated jitter due to R

$$= 4kT\cancel{R} \, \frac{\cancel{4}\pi^2}{\left(DF \cdot I_{cp}\cancel{R}\right)^{\cancel{2}}} \cdot \frac{\cancel{DF \cdot I_{cp} R} \cdot K_{vco}}{\cancel{4}}$$

$$= \underbrace{\frac{4\pi^2 kT}{DF} \cdot \frac{K_{vco}}{I_{cp}}}$$

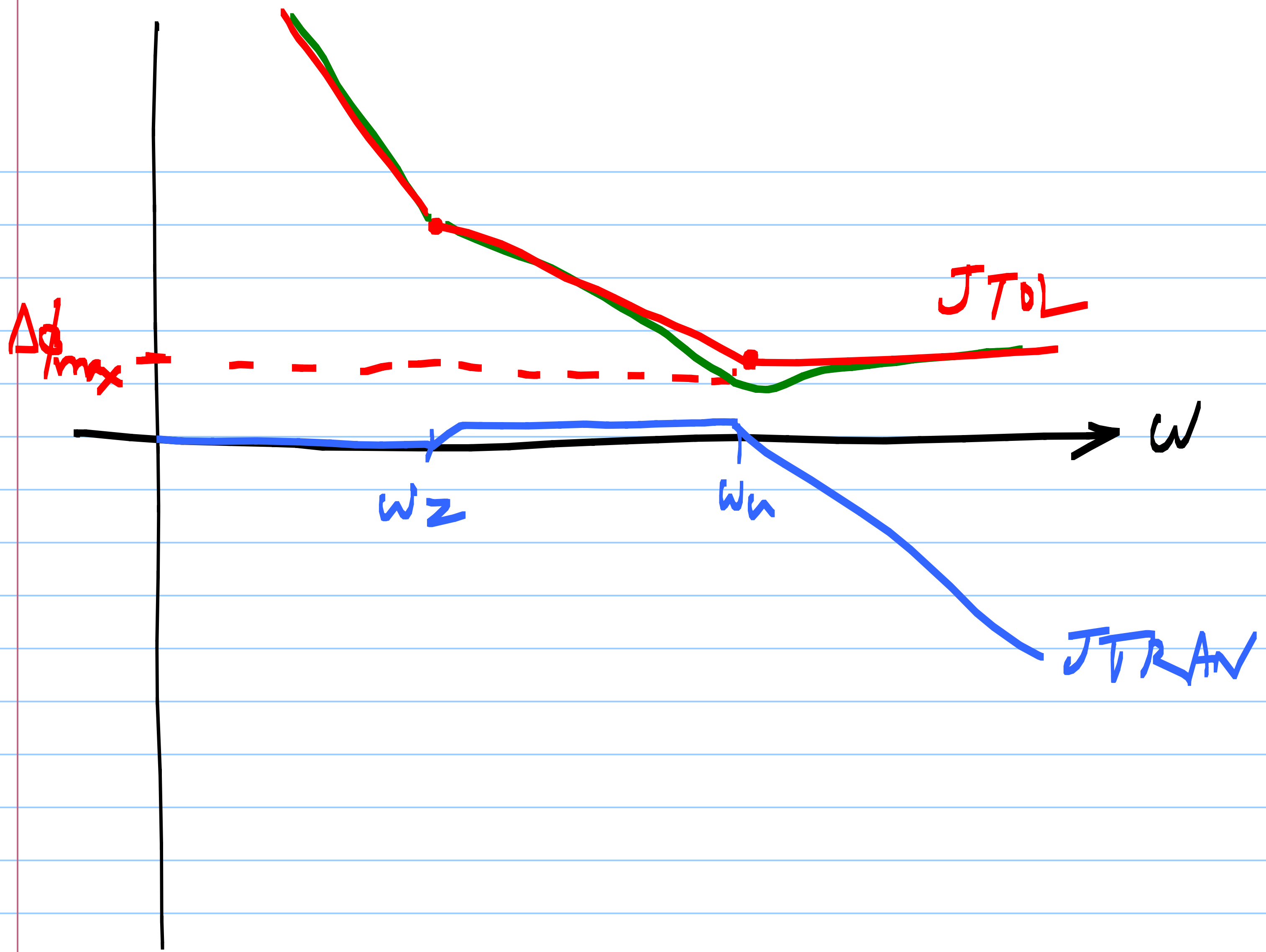
Performance metrics of a CDR

$|\phi_D - \phi_{CK}| < \phi_p$

Jitter tolerance (JTOL): Input jitter amplitude at which BER $\{|\phi_D - \phi_{ck}|$ for calculations$\}$ goes above a certain value.

Jitter transfer (JTRAN): $\left|\dfrac{\phi_{CK}}{\phi_D}\right|$

Jitter generation (JGEN): Amount of jitter generated when the input data is jitter free.


JTOL
$\Delta\phi_{max}$
ω
ωz
ωn
JTRAN

$$|\phi_D - \phi_{ck}| < \Delta\phi_{max}$$

$$|\phi_D| \left|1 - \frac{\phi_{ck}}{\phi_D}\right| < \Delta\phi_{max}$$

$$|\phi_D| < \frac{\Delta\phi_{max}}{\left[1 - \frac{\phi_{ck}}{\phi_D}\right]} = \Delta\phi_{max} \cdot \frac{1 + s/\omega_z + s^2/\omega_n\omega_z}{s^2/\omega_n\omega_z}$$

$$= \Delta\phi_{max} \left(\frac{1 + s/\omega_z}{s/\omega_z}\right)\left(\frac{1 + s/\omega_n}{s/\omega_n}\right)$$

$$\frac{s^2/\omega_n\omega_z}{1 + s/\omega_z + s^2/\omega_n\omega_z}$$

JGEN:

Twosided spectral densities

$$L(f) = S_{i_n,cp} \cdot \left| \frac{\phi_{ck}}{i_{n,cp}} \right|^2 + S_R \cdot \left| \frac{\phi_{ck}}{v_{n,R}} \right|^2$$

$$+ L(f) \cdot \left| \frac{\phi_{ck}}{\phi_{n,vco}} \right|^2$$

$$\int_0^\infty 2L(f)\, df = \sigma_T^2$$