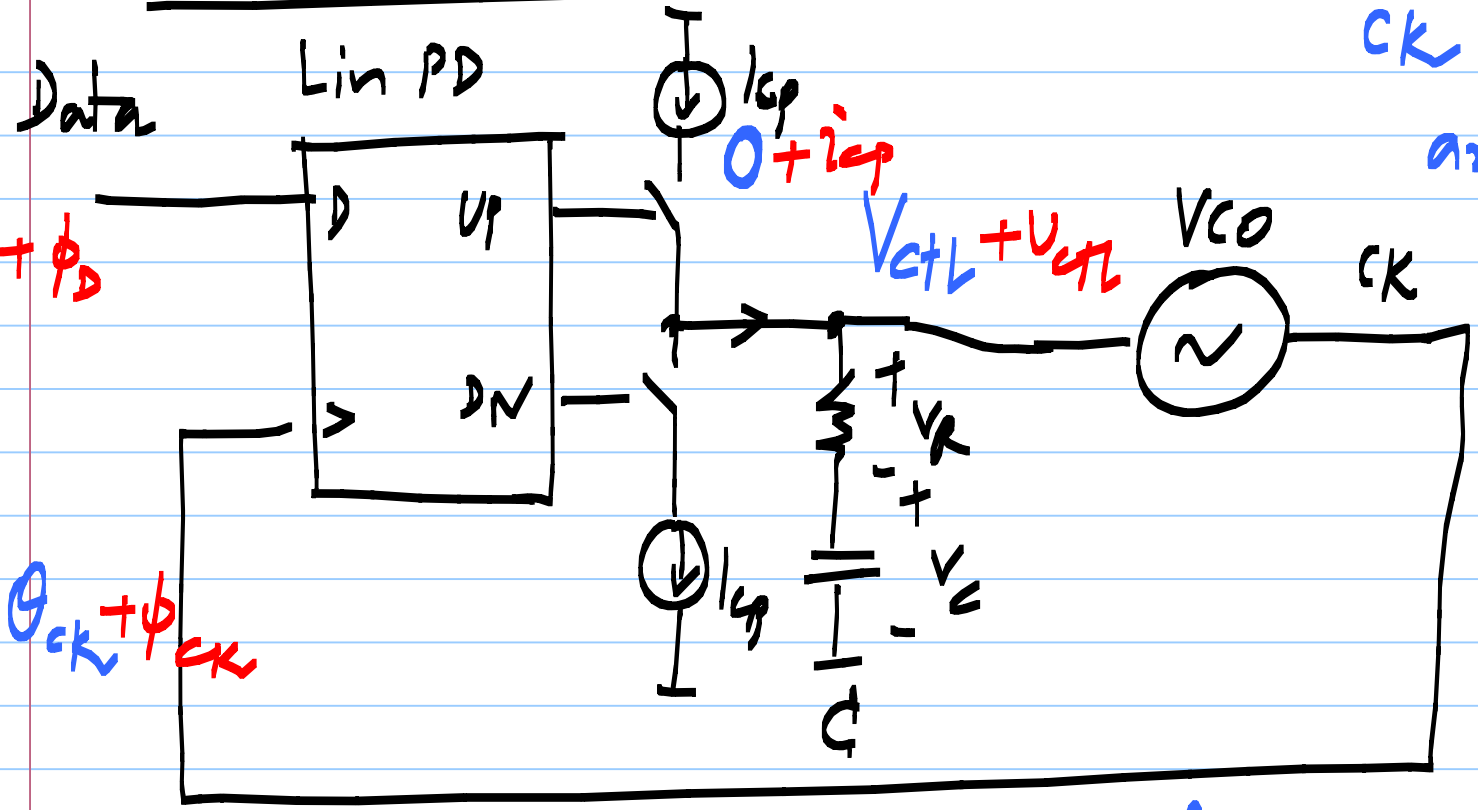
CDR w/o forwarded clock

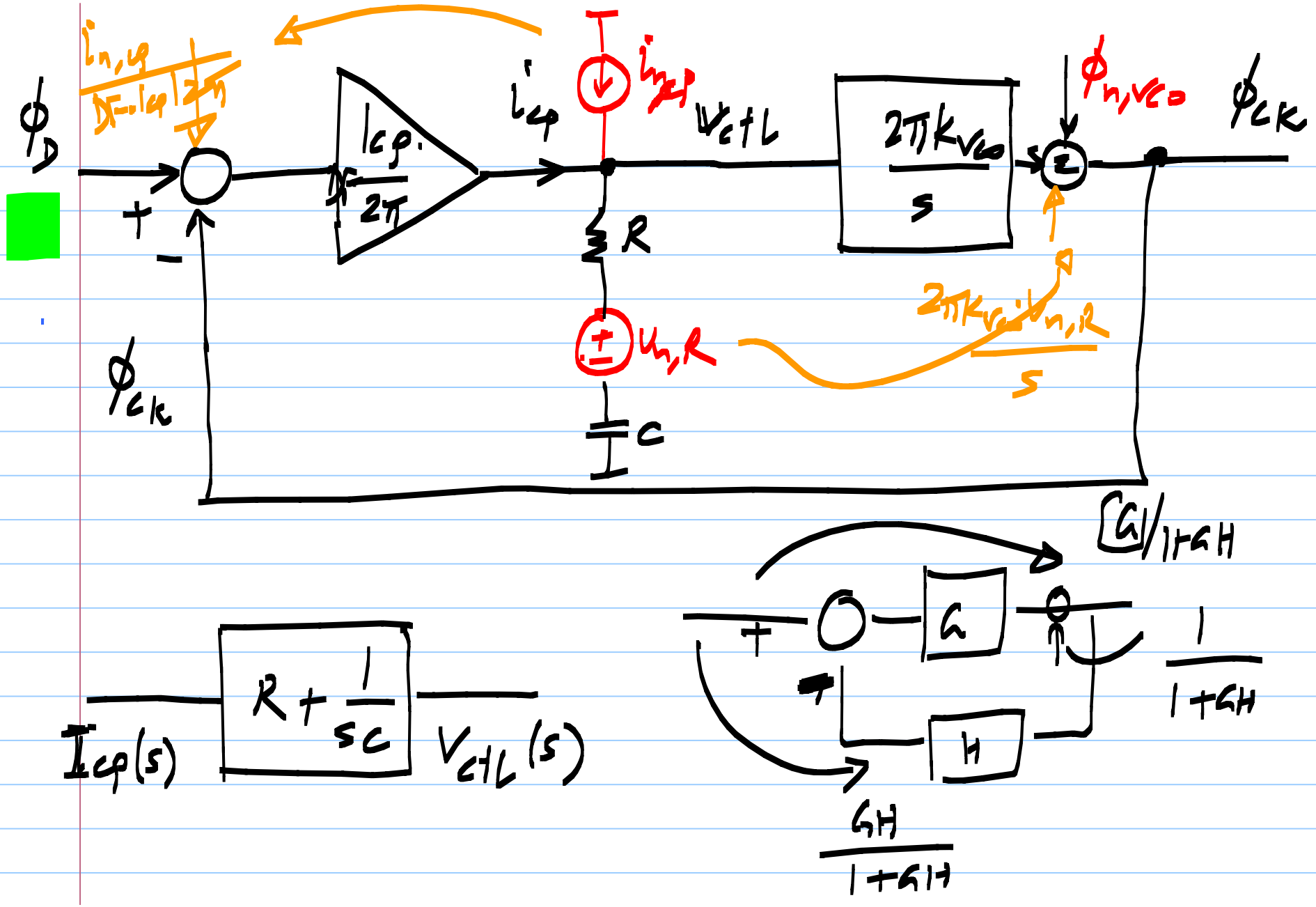


OP. POINT:

CK rising edges are @ center of the Data

$$\theta_{ck} = 2\pi f_0 t + 2\pi K_{vco} \int v_{ctl} \cdot dt$$

$$\theta_{ck} + \phi_{ck} = 2\pi f_0 t + 2\pi K_{vco} \int v_{ctl}\, dt + 2\pi K_{vco} \int v_{ctl}\, dt$$


ϕ_D
$i_{n,cp}$
$\frac{I_{cp}}{2\pi}$
i_{cp}
$i_{n,cp}$
V_{ctl}
$2\pi K_{VCO}$
s
$\phi_{n,VCO}$
ϕ_{CK}
R
$v_{n,R}$
$2\pi K_{VCO} i_{n,R}$
s
C
ϕ_{CK}
$I_{cp}(s)$
$R + \frac{1}{sC}$
$V_{ctl}(s)$
G
H
$\frac{G}{1+GH}$
$\frac{1}{1+GH}$
$\frac{GH}{1+GH}$

$$\frac{\phi_{ck}(s)}{\phi_D(s)} = \frac{\frac{s}{\omega_z} + 1}{\frac{s^2}{\omega_n \omega_z} + \frac{s}{\omega_z} + 1} \cdot \frac{1}{DF\left(\frac{I_{cp} R}{2\pi}\right)}$$

$$\omega_n = DF \cdot \frac{I_{cp} R}{2\pi} \cdot 2\pi K_{vco}$$

$$\left[\frac{\phi_{ck}(s)}{V_{n,R}(s)} = \left[\frac{2\pi K_{vco}}{\omega_n}\right] \frac{s/\omega_z}{1 + s/\omega_z + s^2/\omega_n \omega_z}\right] = \left[\frac{1}{DF \cdot \left(I_{cp} R/2\pi\right)}\right]$$

$$\frac{\phi_{ck}(s)}{I_{n,cp}(s)} = \frac{1}{DF \cdot \left(I_{cp}/2\pi\right)} \cdot \frac{1 + s/\omega_z}{1 + s/\omega_z + s^2/\omega_n \omega_z} \qquad \omega_z \ll \omega_n$$

$$\frac{\phi_{ck}(s)}{\phi_{n,vo}(s)} = \frac{\frac{s^2}{\omega_n \omega_z}}{1 + \frac{s}{\omega_z} + \frac{s^2}{\omega_n \omega_z}}$$

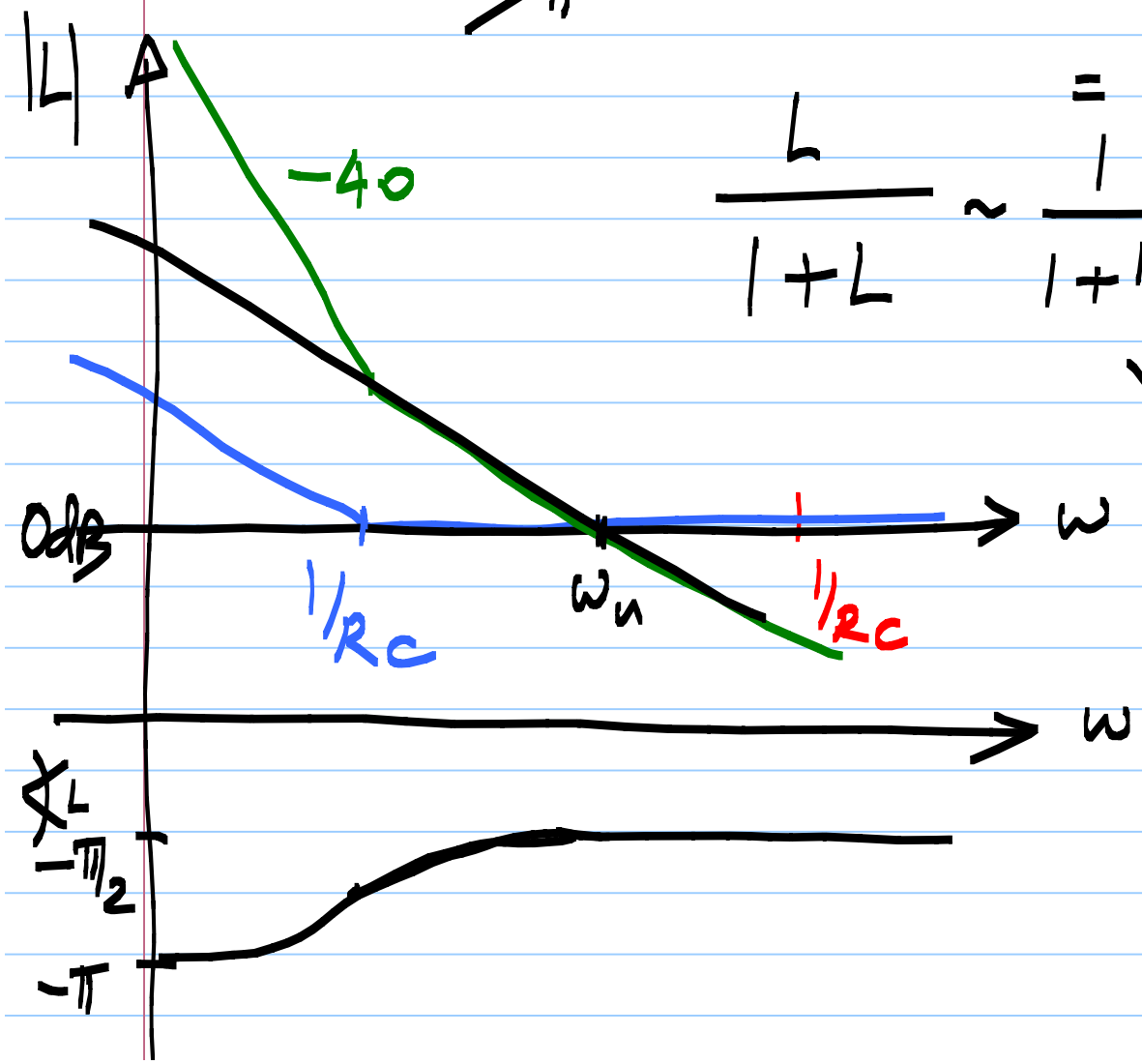
$$L(s) = DF \cdot \frac{I_{cp}}{2\pi} \cdot \left(R + \frac{1}{sC}\right) \cdot \frac{2\pi K_{vco}}{s}$$

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

$$\frac{L}{1+L} \sim \frac{1}{1+1/L}$$

$$\omega_u = DF \cdot I_{cp} R K_{vco}$$

$$\omega_z = \frac{1}{RC} < \omega_u$$



$|L| \gg 1$ → 1

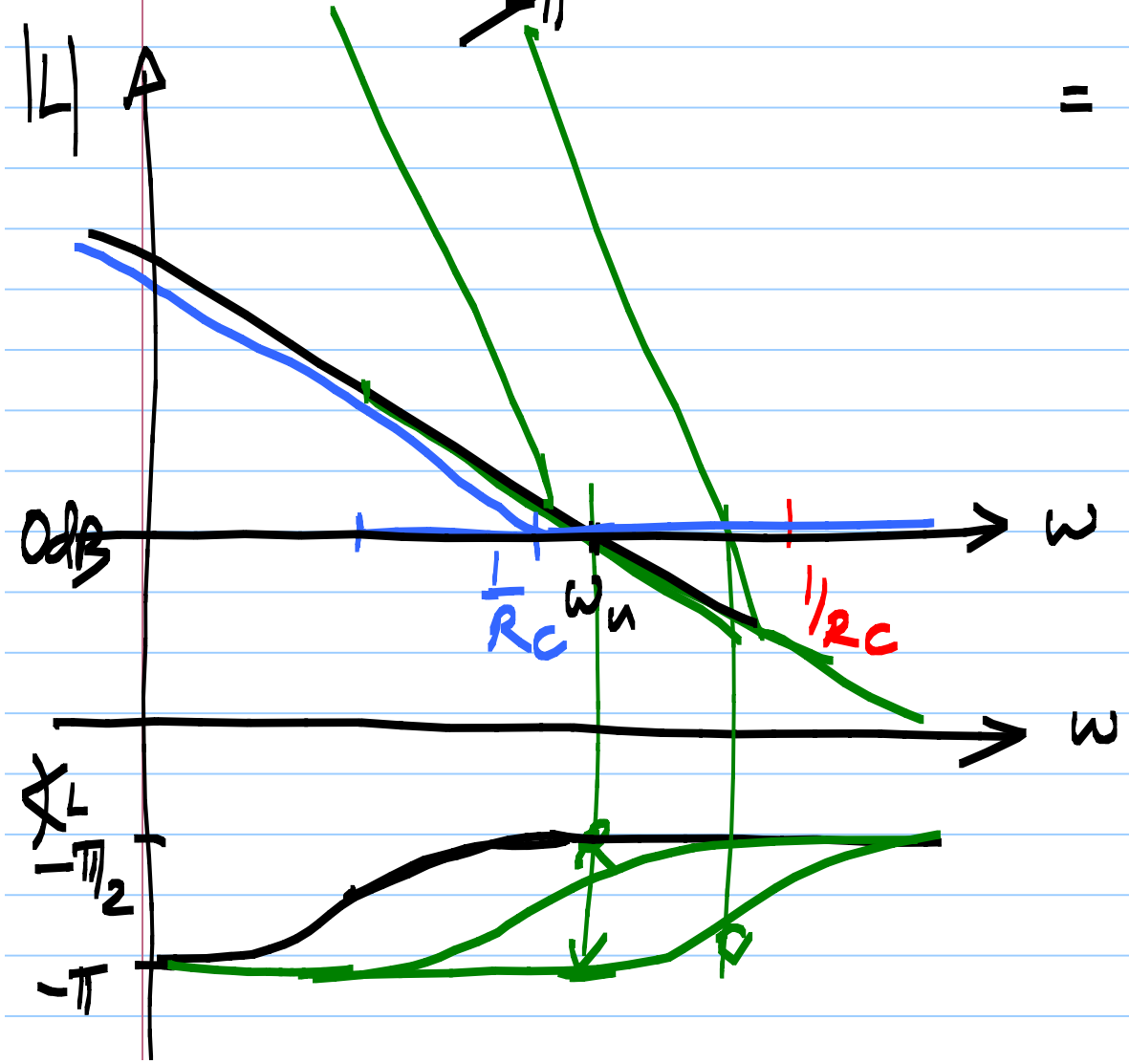
$|L| \ll 1$ → L

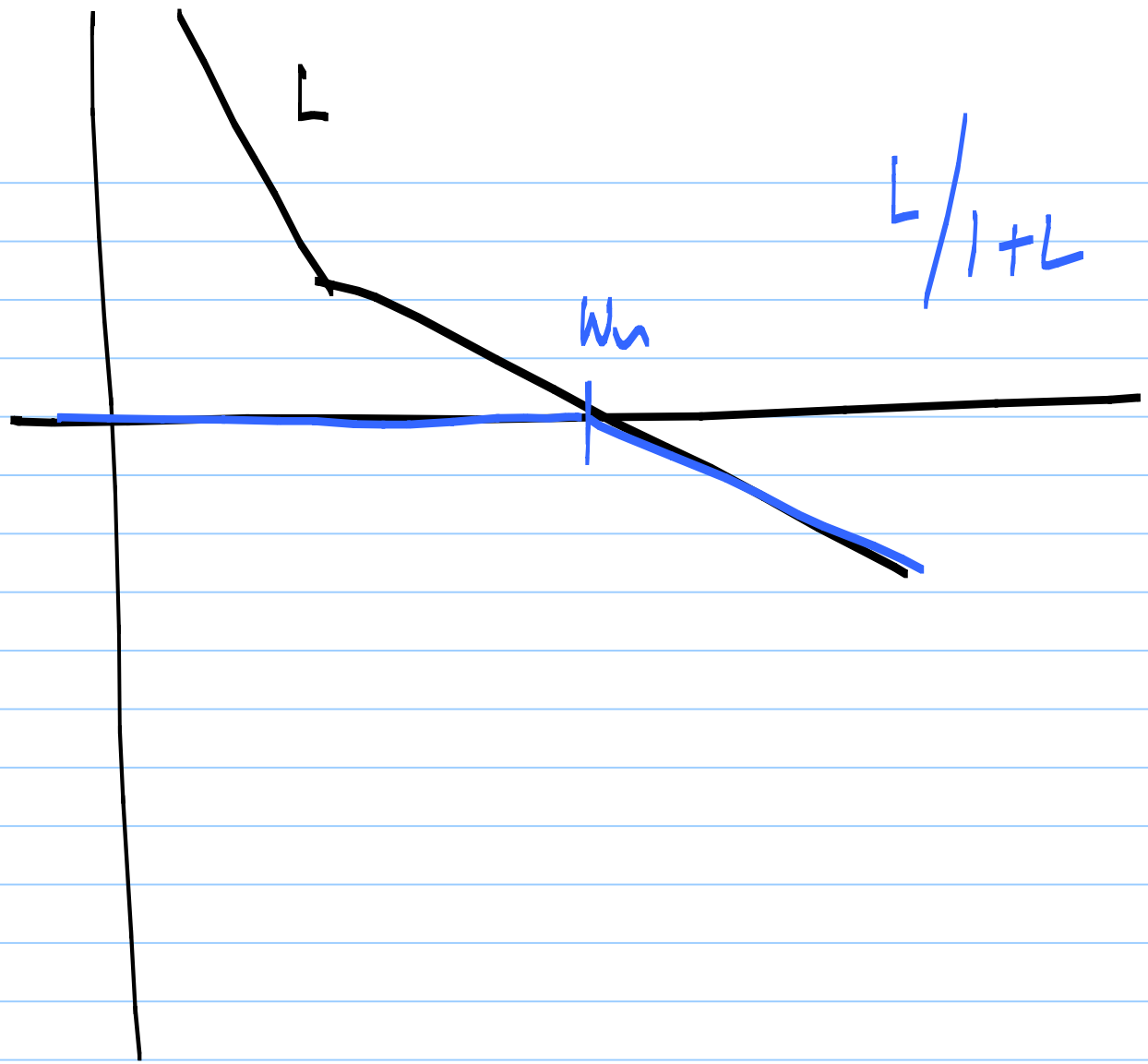
$$L(s) = DF \cdot \frac{I_{cp}}{2\pi} \cdot \left(R + \frac{1}{sC}\right) \cdot \frac{2\pi k_{vco}}{s}$$

$$= \underbrace{DF \cdot \frac{I_{cp} R k_{vco}}{s}} \left[\frac{(1+sCR)}{sCR}\right]$$

$$\omega_u = DF \cdot I_{cp} R k_{vco}$$

$$L(s) = \frac{\omega_u}{s}\left(\frac{\omega_z}{s} + 1\right)$$




L
L/1+L
Wu