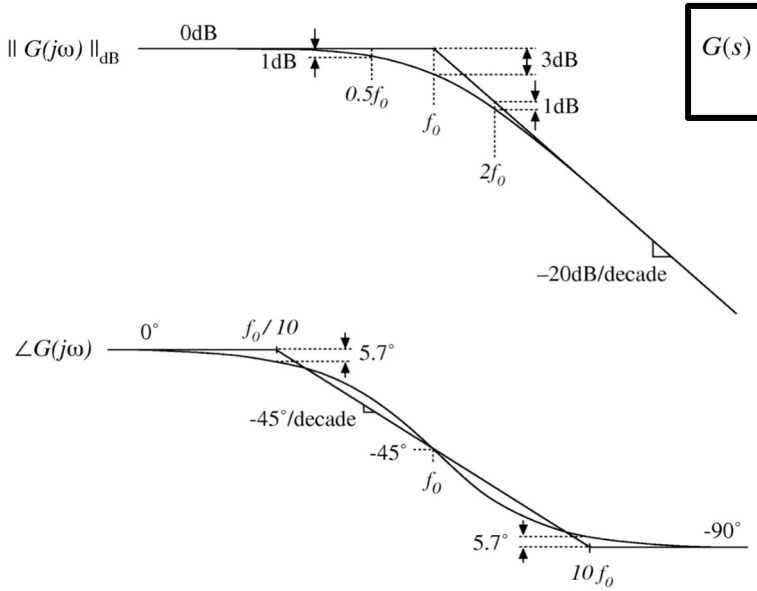
Announcements

- Exam review on Monday
- Return Analog Discovery Studio & Exp1 parts in class on Monday

- TNvoice Open
  - https://utk.campuslabs.com/eval-home/
  - Please fill out – Closes midnight May 11
  - Currently 70% response rate
  - +5 pts EC on final for 100% response rate

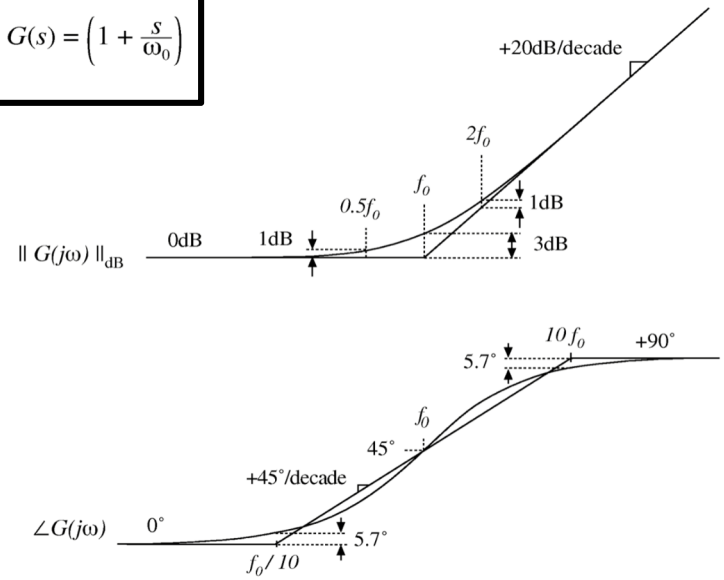
Real Pole

$$G(s) = \frac{1}{\left(1 + \frac{s}{\omega_0}\right)}$$



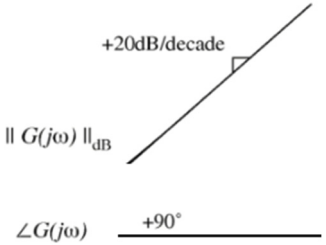
Real Zero

$$G(s) = \left(1 + \frac{s}{\omega_0}\right)$$



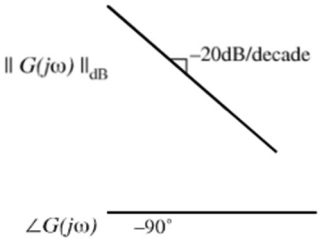
$$G(s) = s$$

LF Zero



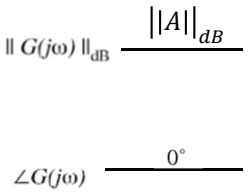
$$G(s) = \frac{1}{s}$$

LF Pole



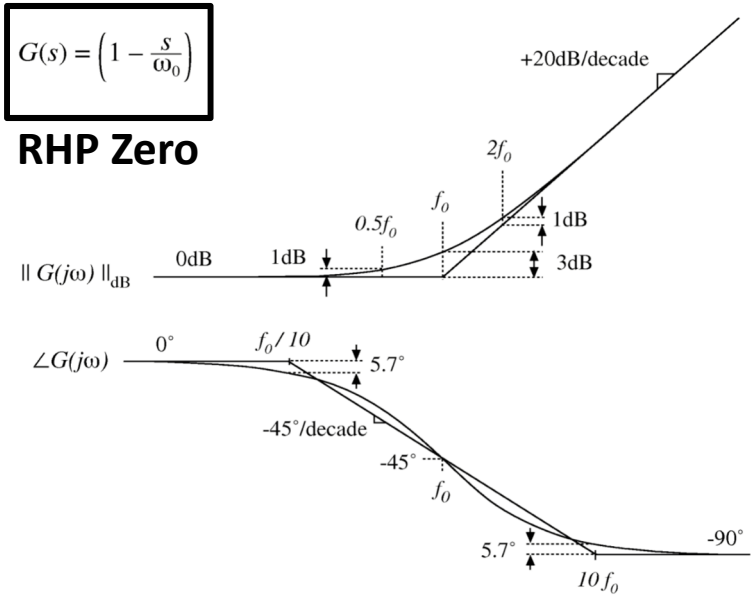
$$G(s) = A$$

Constant



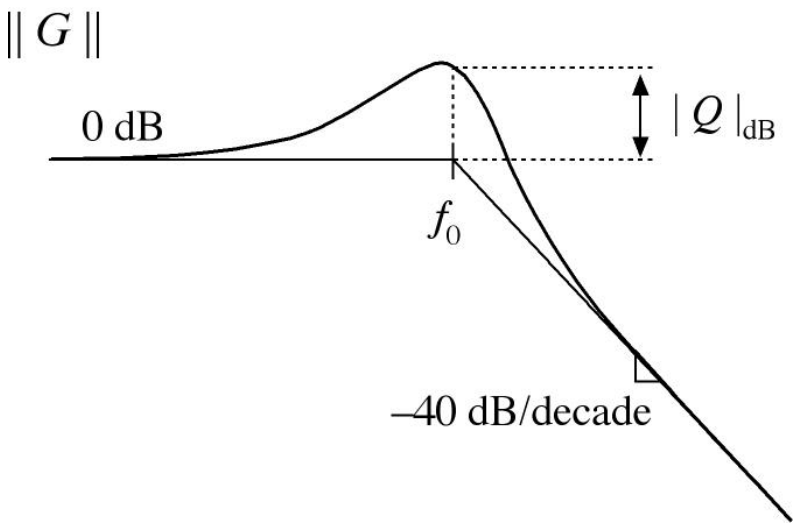
$$G(s) = \left(1 - \frac{s}{\omega_0}\right)$$

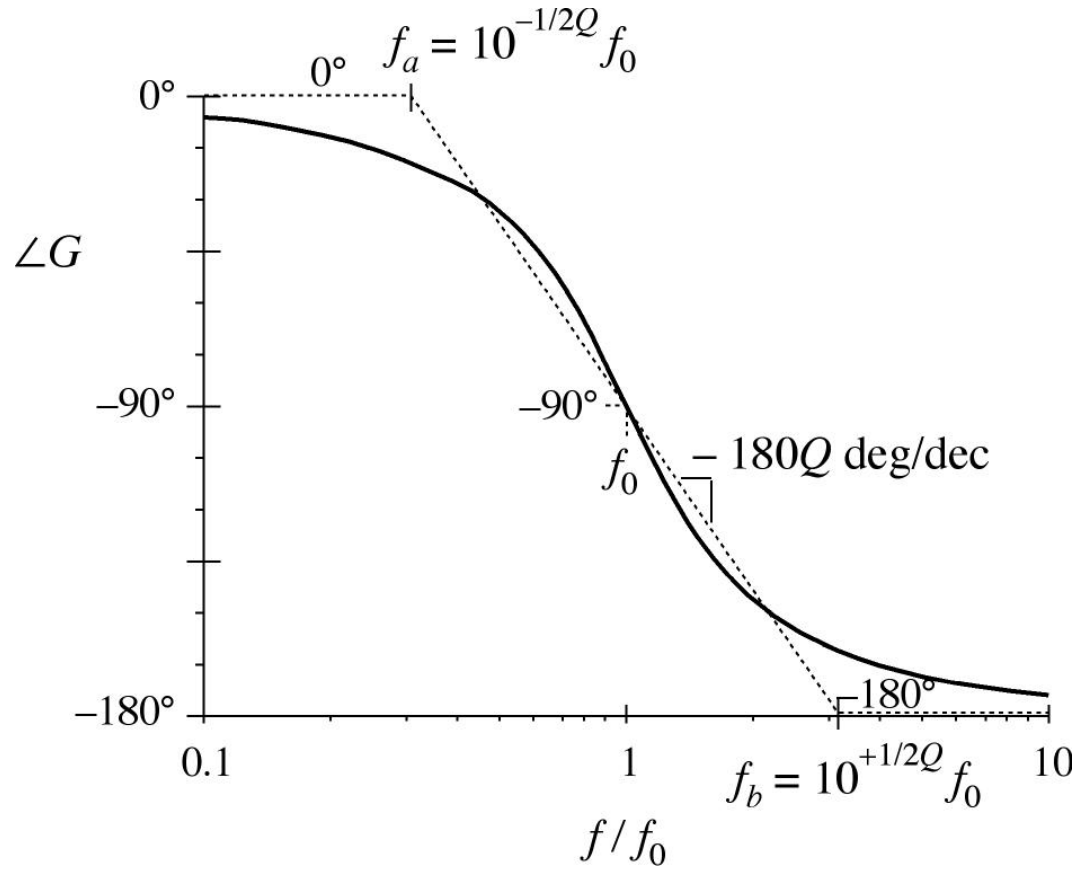
RHP Zero



Complex Poles

$$H(s) = \frac{1}{\left(\frac{s}{\omega_0}\right)^2 + \frac{s}{Q\omega_0} + 1}$$





The Low-Q Approximation

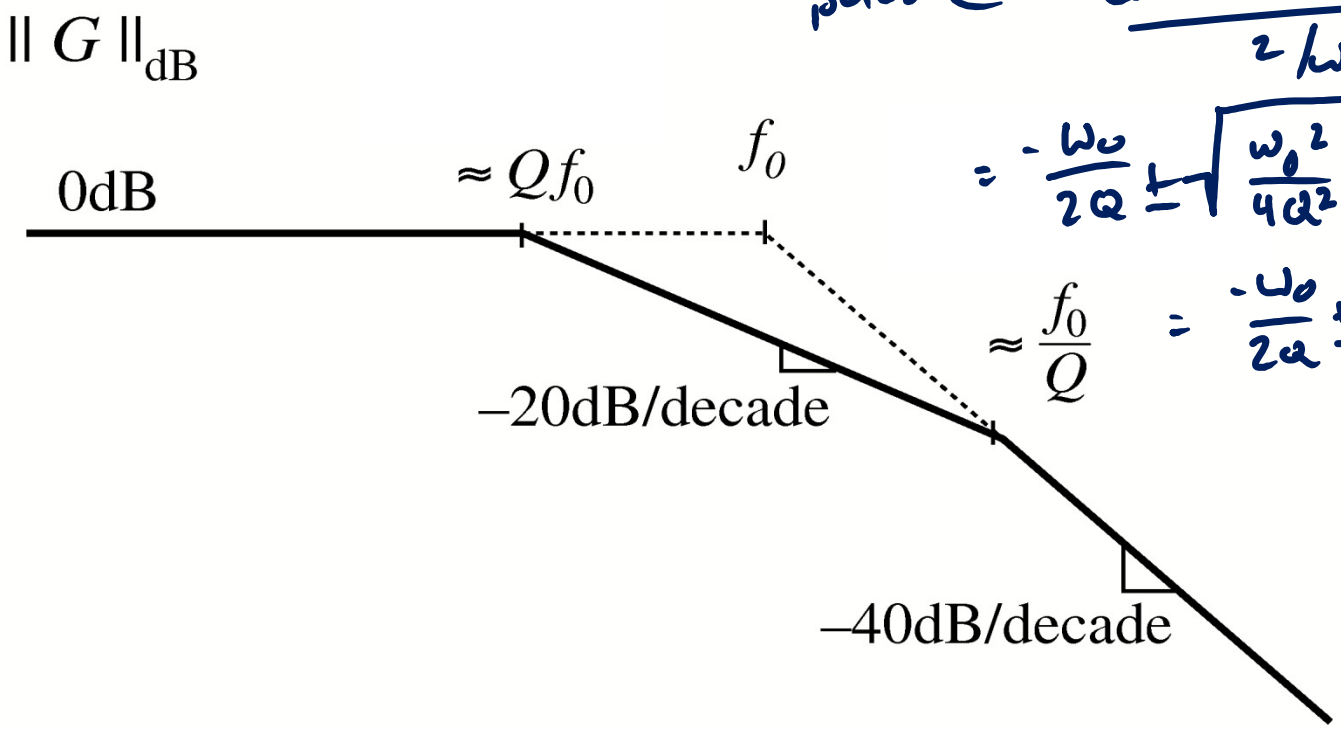
for $Q \ll 0.5$

$$\frac{1}{\left(\frac{s}{\omega_0}\right)^2 + \frac{s}{Q\omega_0} + 1}$$

poles @ $\dfrac{-\frac{1}{Q\omega_0} \pm \sqrt{\left(\frac{1}{Q\omega_0}\right)^2 - 4\frac{1}{\omega_0^2}}}{2/\omega_0^2}$

$= \dfrac{-\omega_0}{2Q} \pm \sqrt{\dfrac{\omega_0^2}{4Q^2} - \omega_0^2}$

$= \dfrac{-\omega_0}{2Q} \pm \omega_0\sqrt{\dfrac{1}{4Q^2} - 1}$

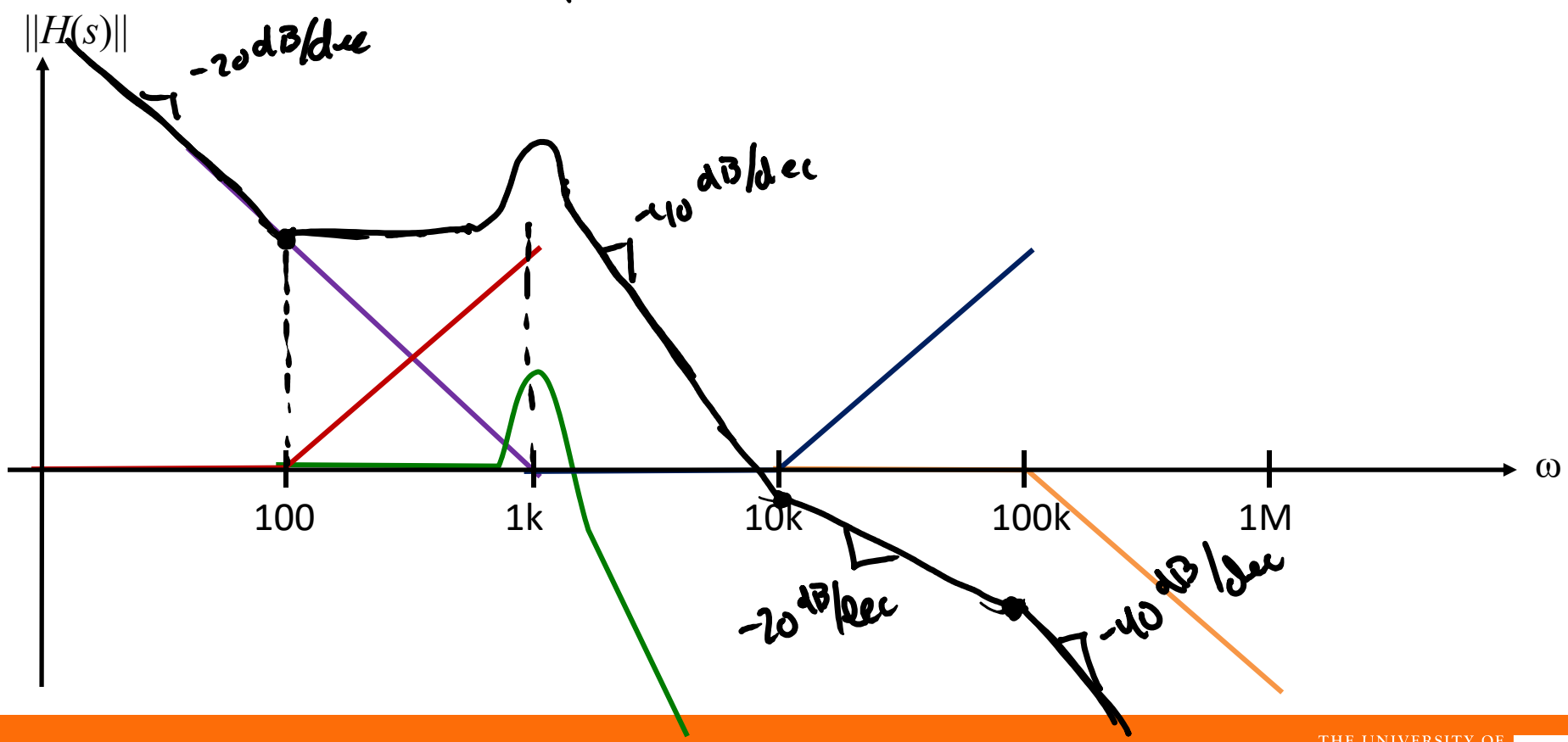


Example

$$H(s) = \frac{A}{s}\frac{\left(1+\frac{s}{w_{z1}}\right)\left(1+\frac{s}{w_{z2}}\right)}{\left(\left(\frac{s}{\omega_0}\right)^2+\frac{s}{Q\omega_0}+1\right)\left(1+\frac{s}{\omega_p}\right)}$$

A	w_{z1}	w_{z2}	ω_0	Q	ω_p
1000	100	10k	1k	10	100k

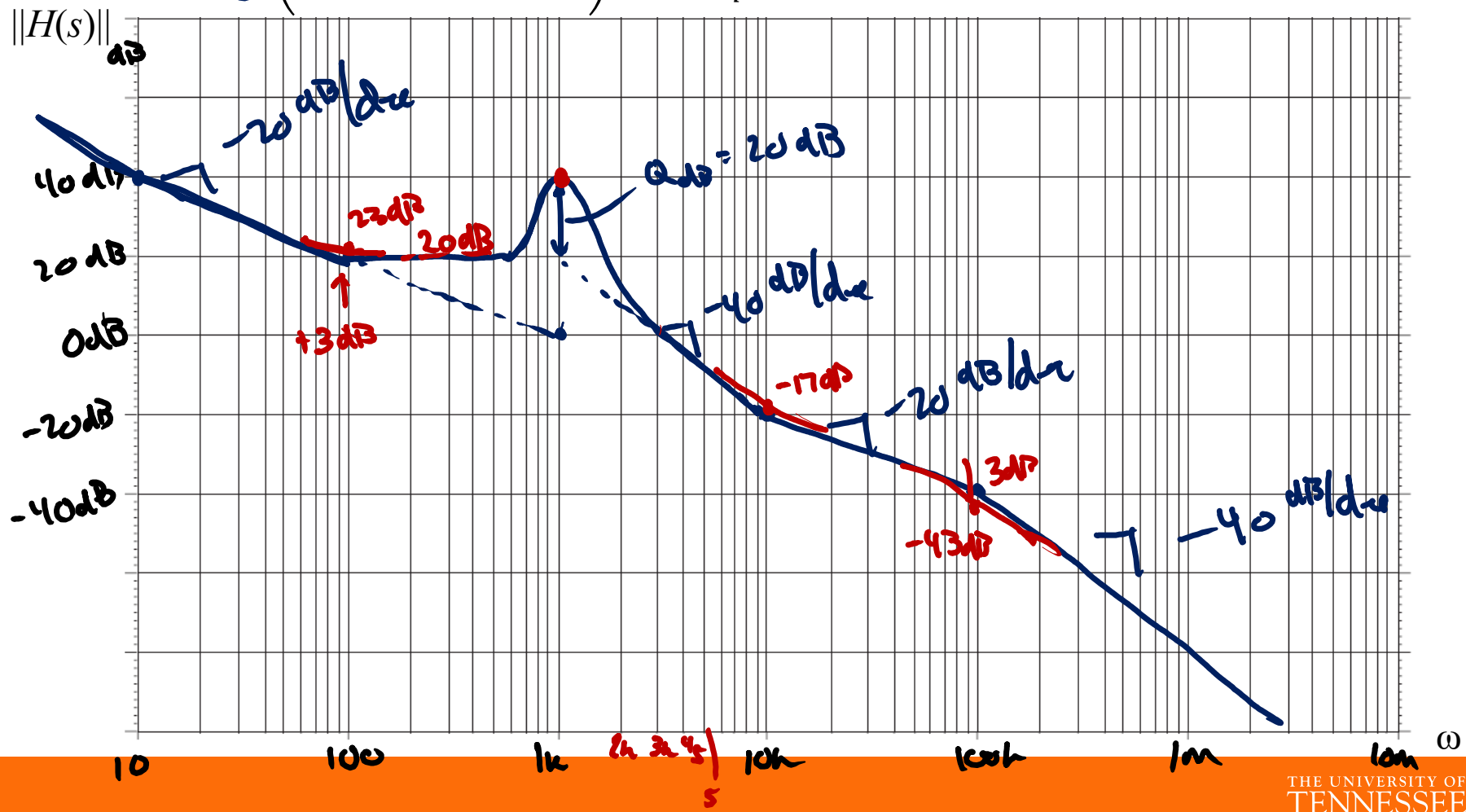
$$= \frac{A}{s\omega_{z1}} \frac{(\omega_{z1}+s)(\ -\ -\ )}{(\ -\ \ -\ )}$$



Example

A	w_{z1}	w_{z2}	ω_0	Q	ω_p
1000	100	10k	1k	10	100k

$$H(s) = A\frac{\left(1+\frac{s}{w_{z1}}\right)\left(1+\frac{s}{w_{z2}}\right)}{s\left(\left(\frac{s}{\omega_0}\right)^2+\frac{s}{Q\omega_0}+1\right)\left(1+\frac{s}{\omega_p}\right)}$$



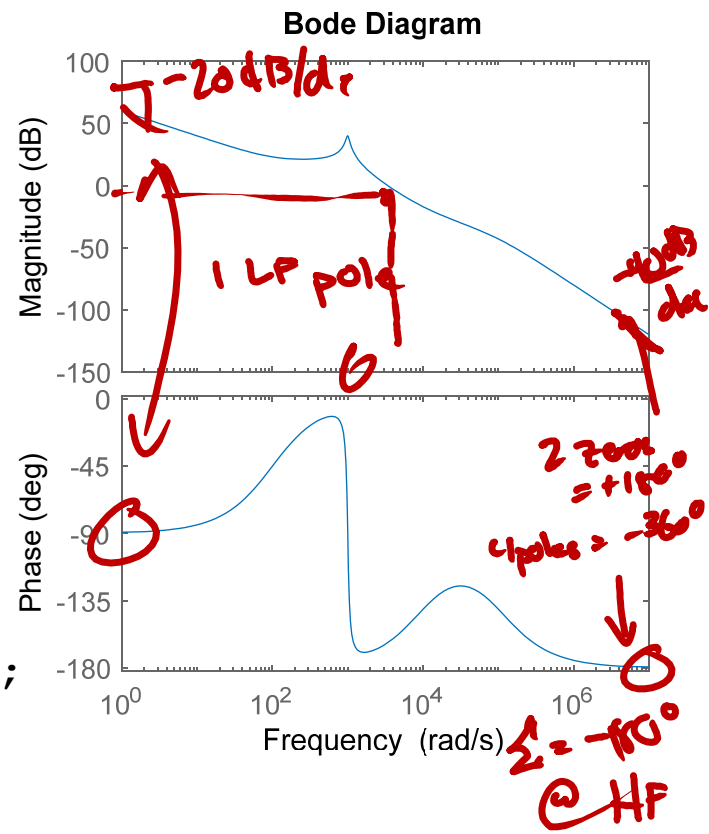
MATLAB

```
A = 1000;
wz1 = 100;
wz2 = 10e3;
w0 = 1e3;
Q = 10;
wp = 100e3;

s = tf('s');

H = A*(1+s/wz1)*(1+s/wz2)/…
        (s*(1+s/wp)*((s/w0)^2+s/Q/w0+1));

bode(H)
```



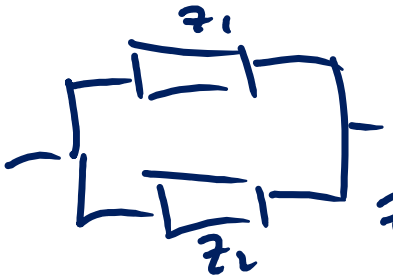
Approximate Graphical Analysis

- $\|H_1 \cdot H_2\|_{dB} = \|H_1\|_{dB} + \|H_2\|_{dB}$ multiply (linear) → add (log)
- $\|\omega^n\|_{dB} \rightarrow 20(n)\log(\omega) \rightarrow 20(n)$ dB/dec line
- $\|1 + jx\|_{dB} = \begin{cases} \|x\|_{dB}, & x \gg 1 \\ \sqrt{2} = 3dB, & x = 1 \\ 1, & x \ll 1 \end{cases}$ Addition (linear) → max() (log) + look at where they're equal closer

---

$Z_{eq} = Z_1 + Z_2$

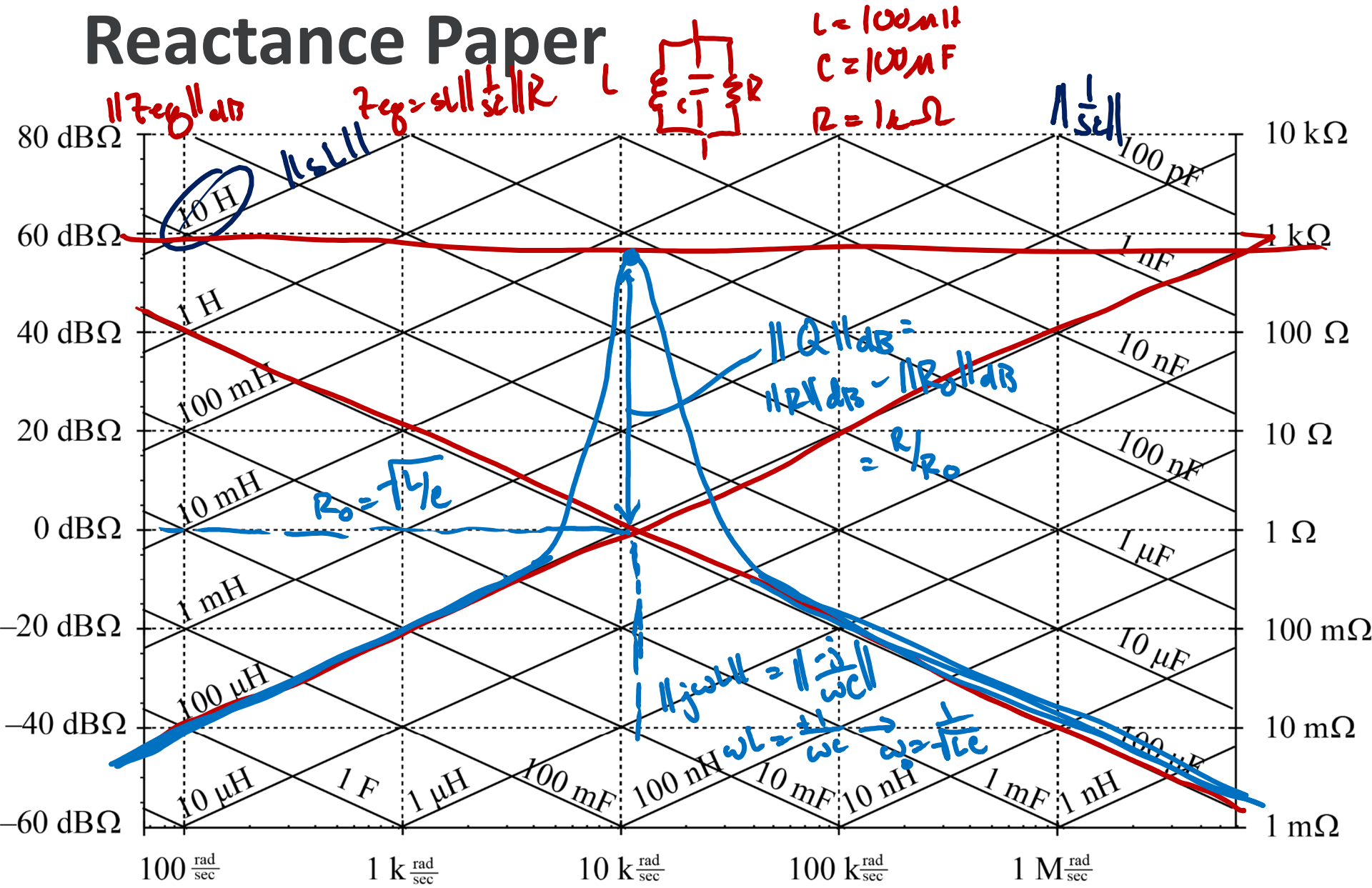
$\|Z_{eq}\|_{dB} = \|Z_1 + Z_2\|_{dB} = \begin{cases} \|Z_1\|_{dB}, & Z_1 \gg Z_2 \\ \text{look closer}, & Z_1 \simeq Z_2 \\ \|Z_2\|_{dB}, & Z_2 \gg Z_1 \end{cases}$



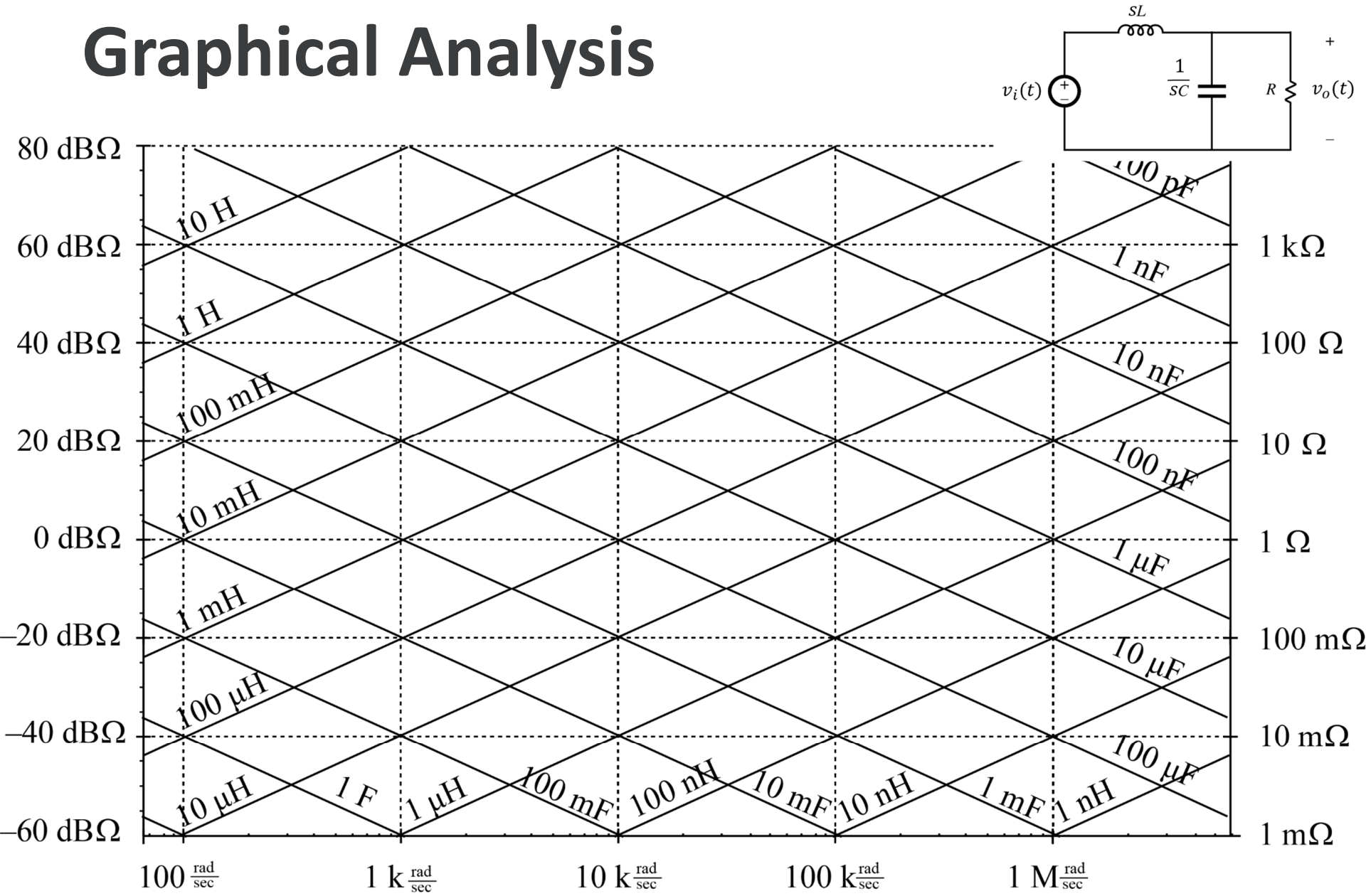
$Z_{eq} = \frac{Z_1 Z_2}{Z_1 + Z_2}$

$\|Z_{eq}\|_{dB} = \left\| \frac{Z_1 Z_2}{Z_1 + Z_2} \right\|_{dB} = \begin{cases} \|Z_2\|_{dB} & Z_1 \gg Z_2 \\ \text{look closer}, & Z_1 \simeq Z_2 \\ \|Z_1\|_{dB}, & Z_2 \gg Z_1 \end{cases}$

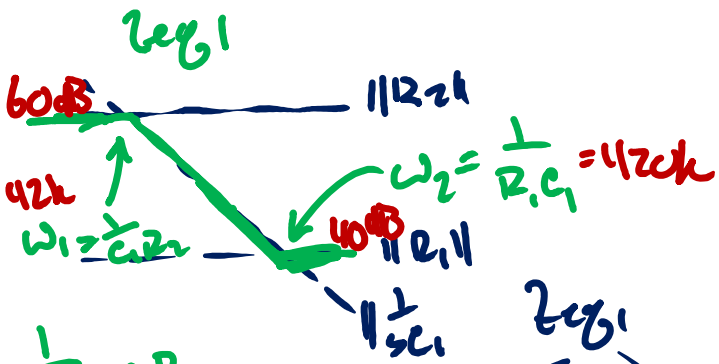
Reactance Paper



Graphical Analysis

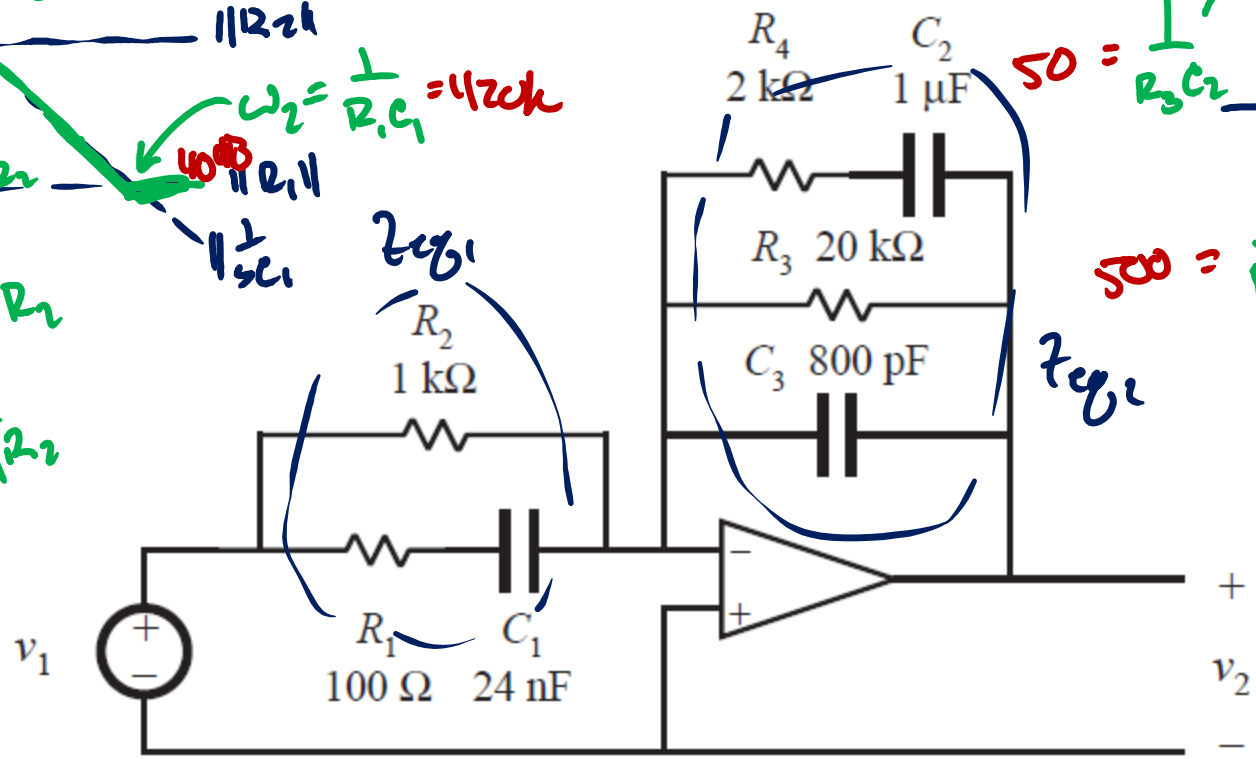


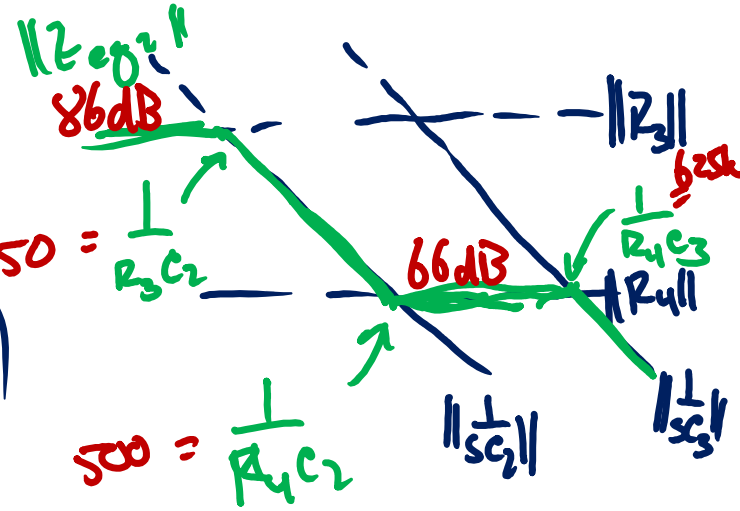
Graphical Analysis



$\frac{1}{\omega C_1} = R_2$

$\omega = \frac{1}{C_1 R_2}$





$$H = \frac{V_2(s)}{V_1(s)} = -\frac{Z_{eq2}}{Z_{eq1}}$$

Impedance/Reactance Paper