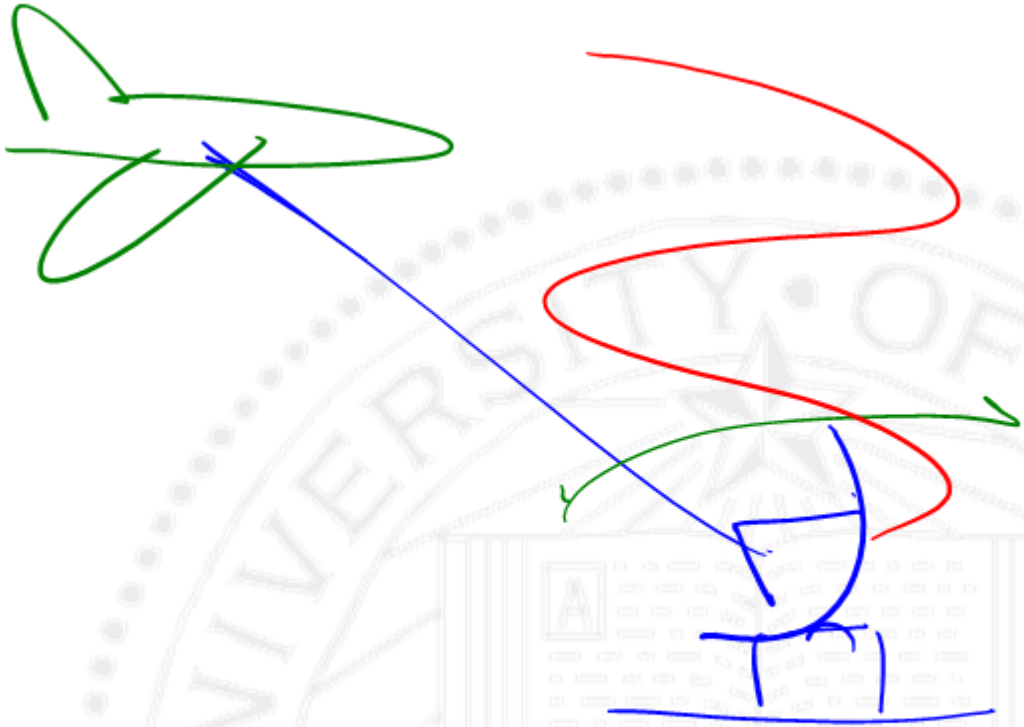
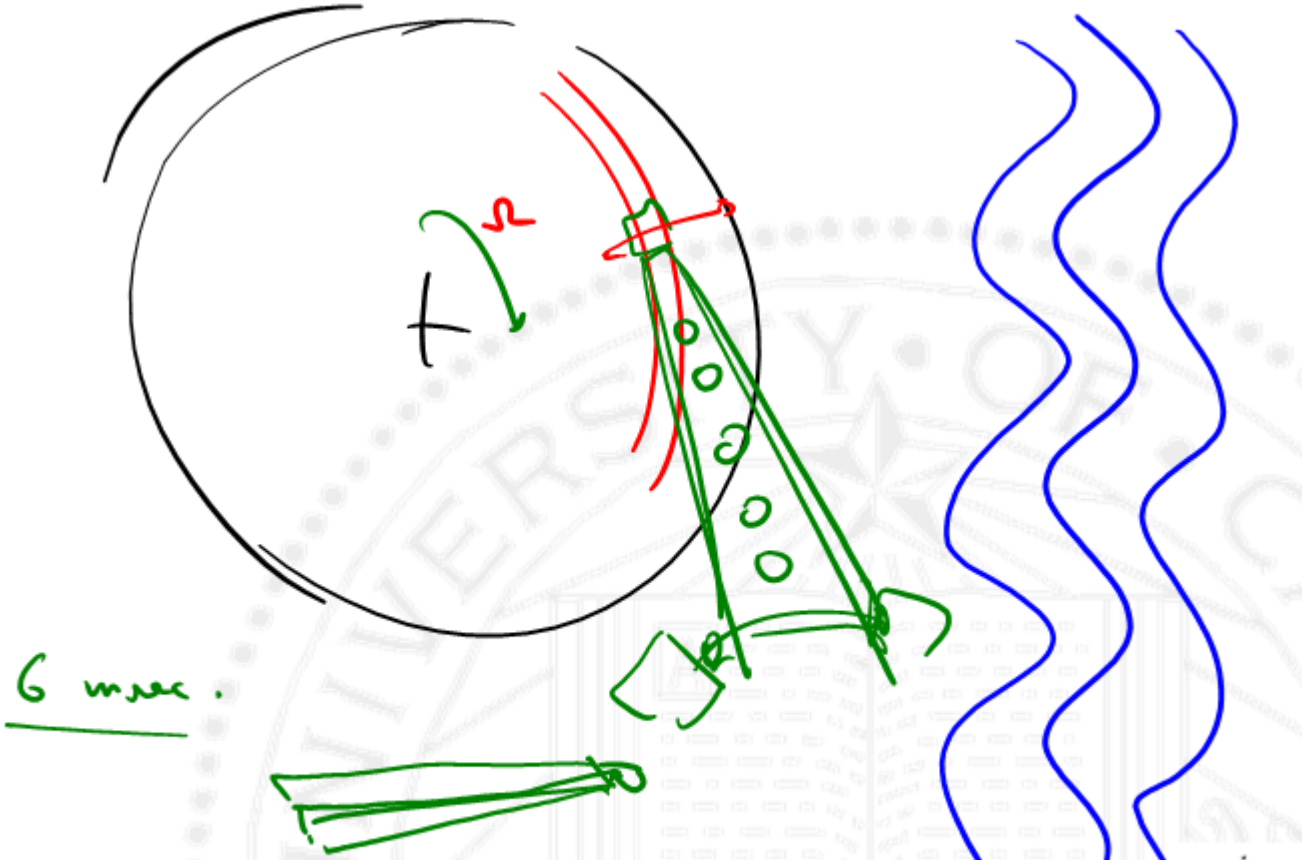
CMPE-242
Applied Feedback Control

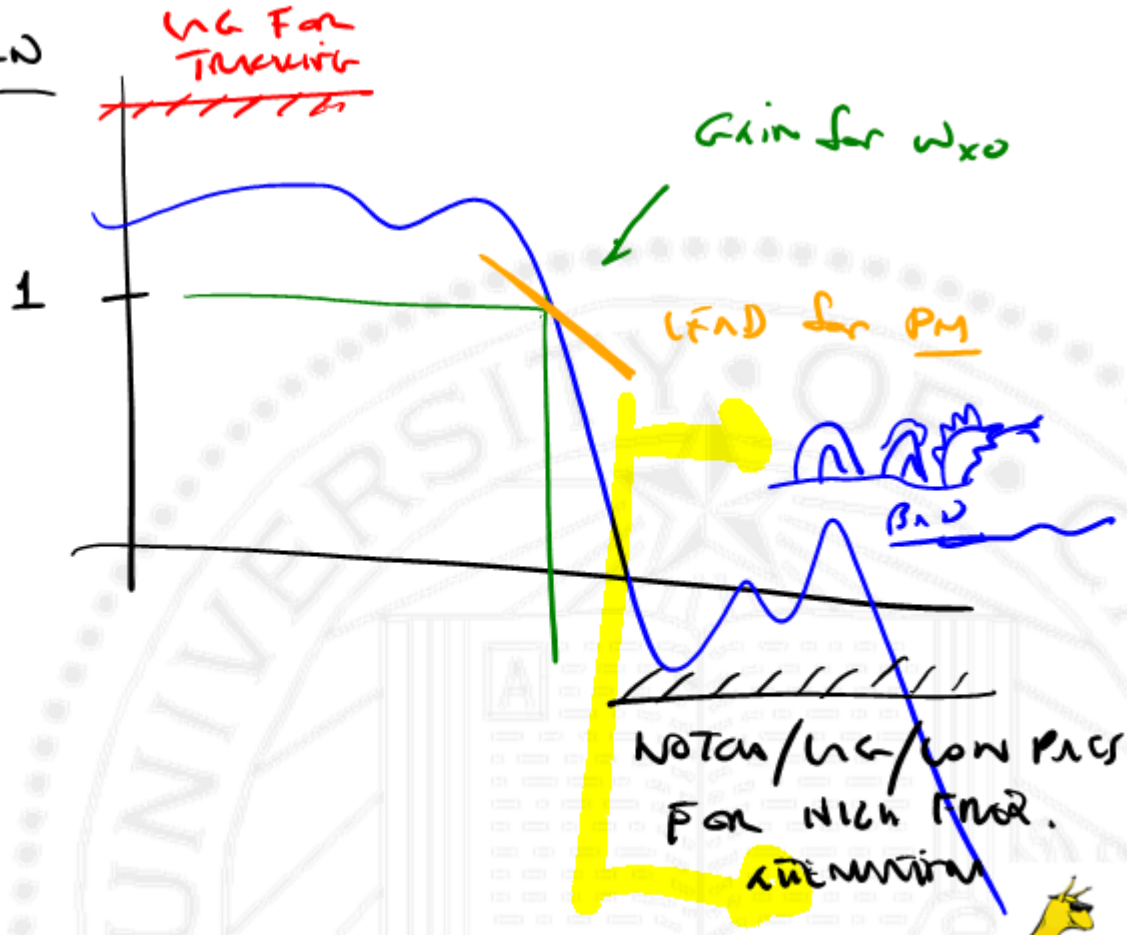
Gabriel Hugh Elkaim

Winter 2016




6 mrad.

Bode Design


LAG for Tracking
Gain for ω_{xo}
1
LEAD for PM
BW
NOTCH/LAG/LOW PASS
FOR HIGH FREQ.
ATTENUATION

$$: \quad \frac{10^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$$

$\omega_n = 10$

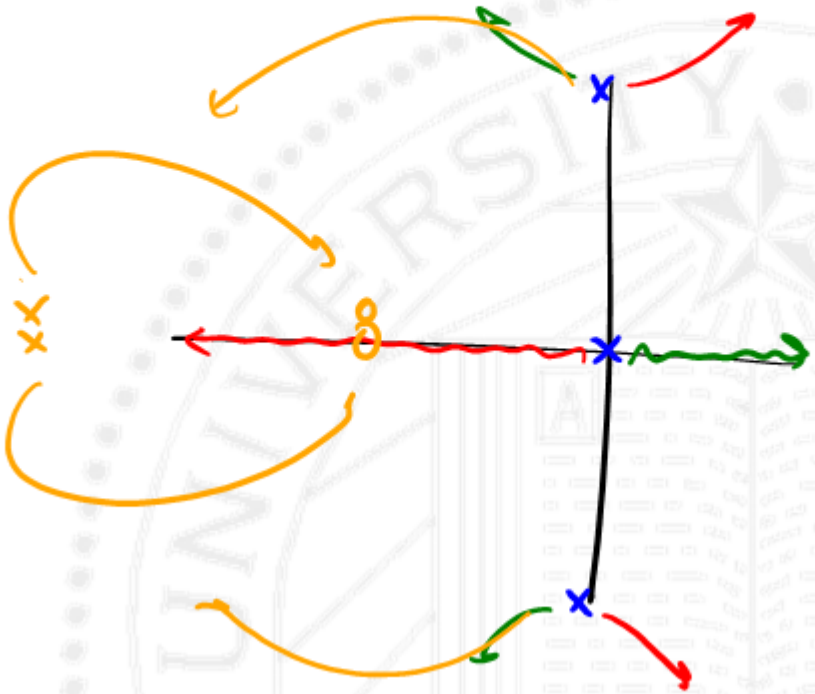
$\zeta = 0.05$

$\frac{1}{2\zeta} = 10$

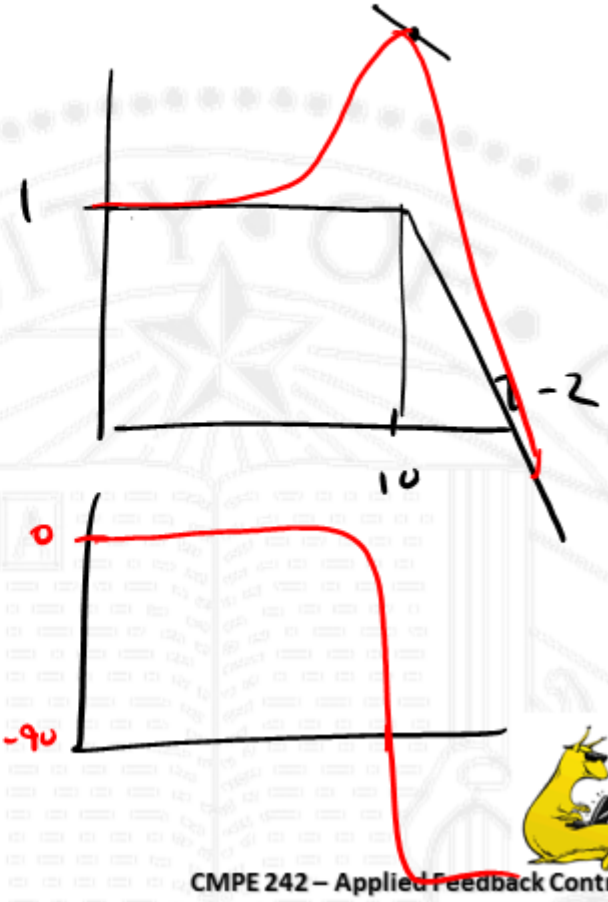
$\left|\frac{\varepsilon}{R}\right| < 0.01$

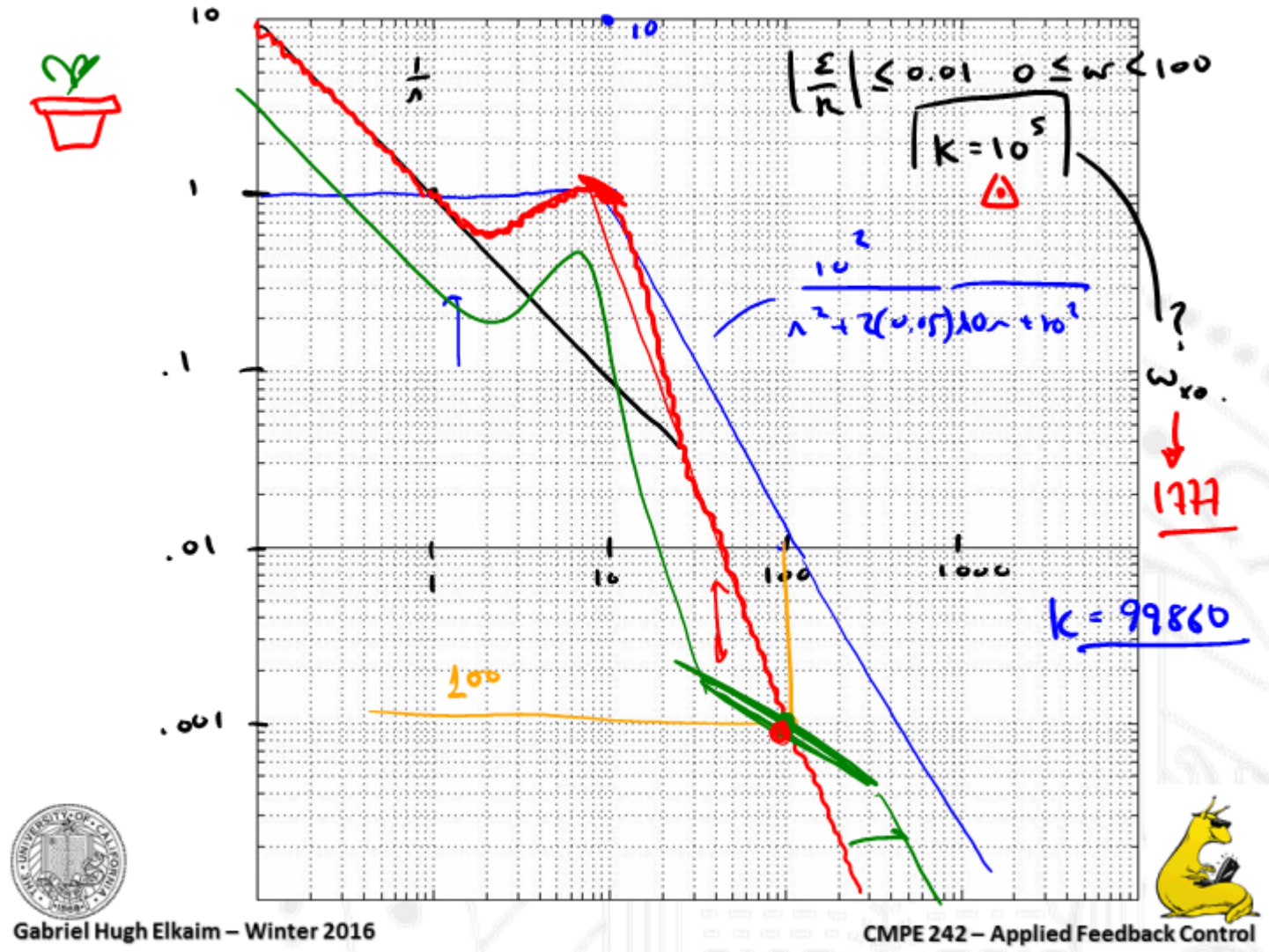
$0 \le \omega < 100$

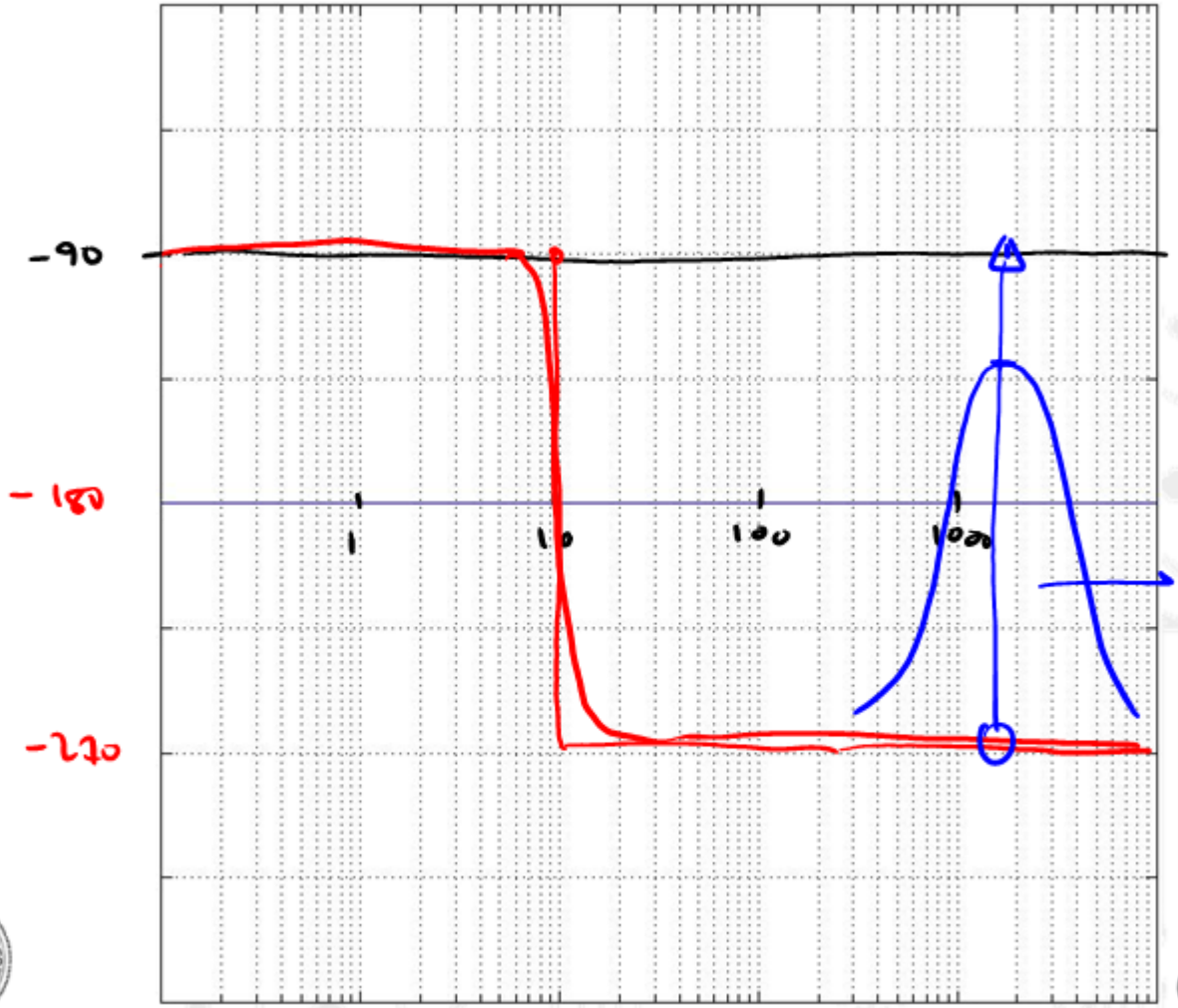
$PM \ge 50^\circ$



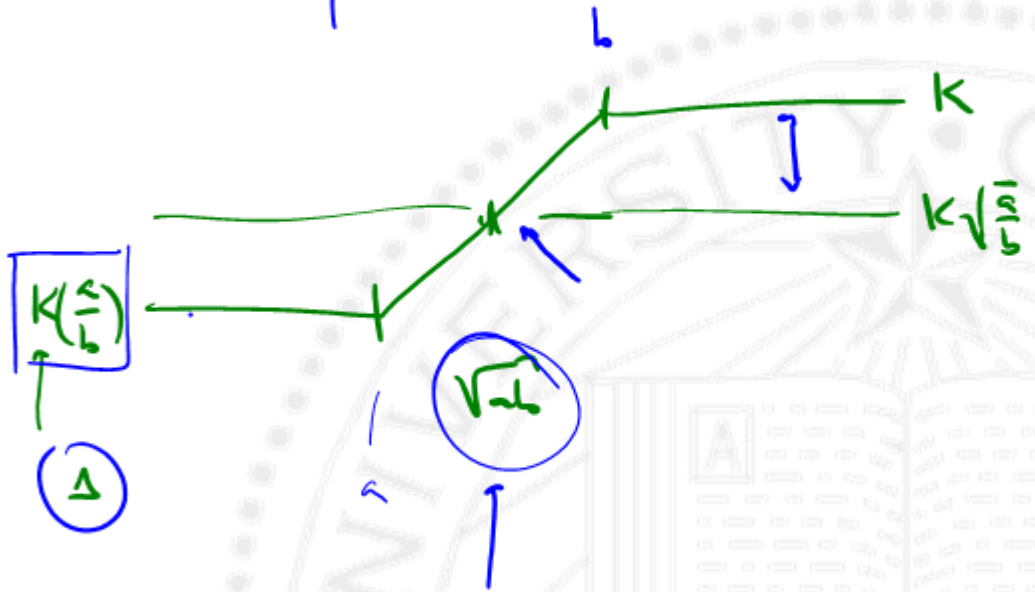
$: \frac{1}{s} \qquad \frac{10^2}{s^2 + 2(0.05)10s + 10^2}$

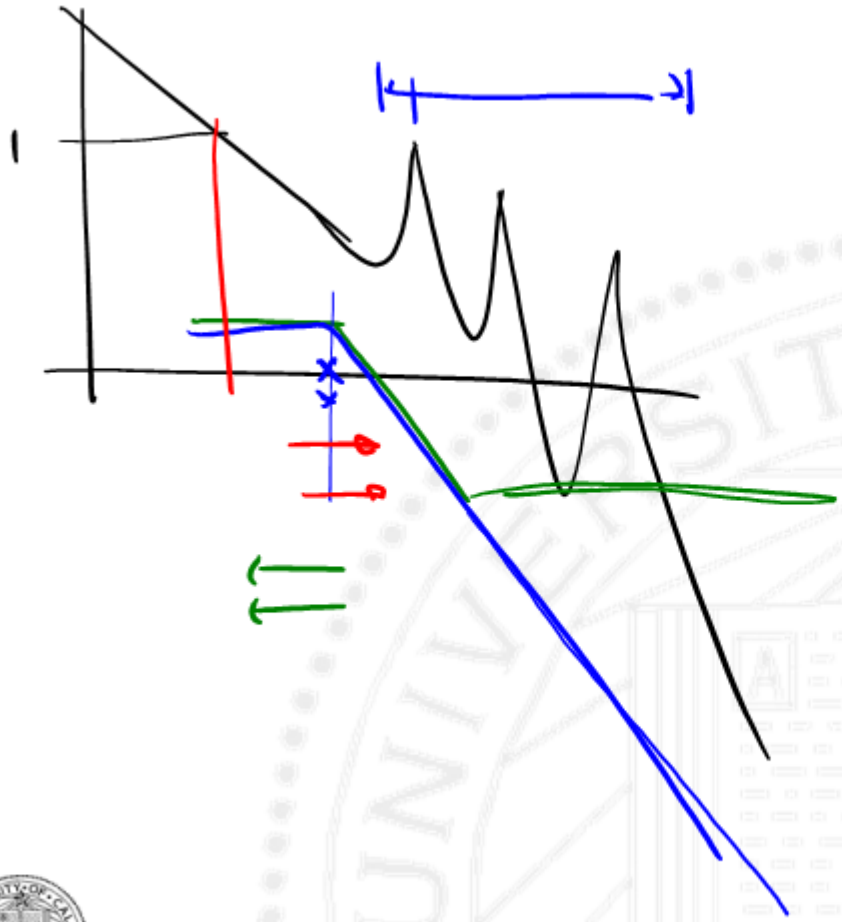



10
1
.1
.01
.001
1
10
100
1000
$\frac{1}{s}$
$\left|\frac{\varepsilon}{R}\right| \le 0.01 \quad 0 \le \omega \le 100$
$K = 10^5$
$\frac{10^2}{s^2 + 2(0.15)10s + 10^2}$
ω_{x0}
177
$K = 99860$
100


-90
-180
-270
1/s
1
1
10
100
10a

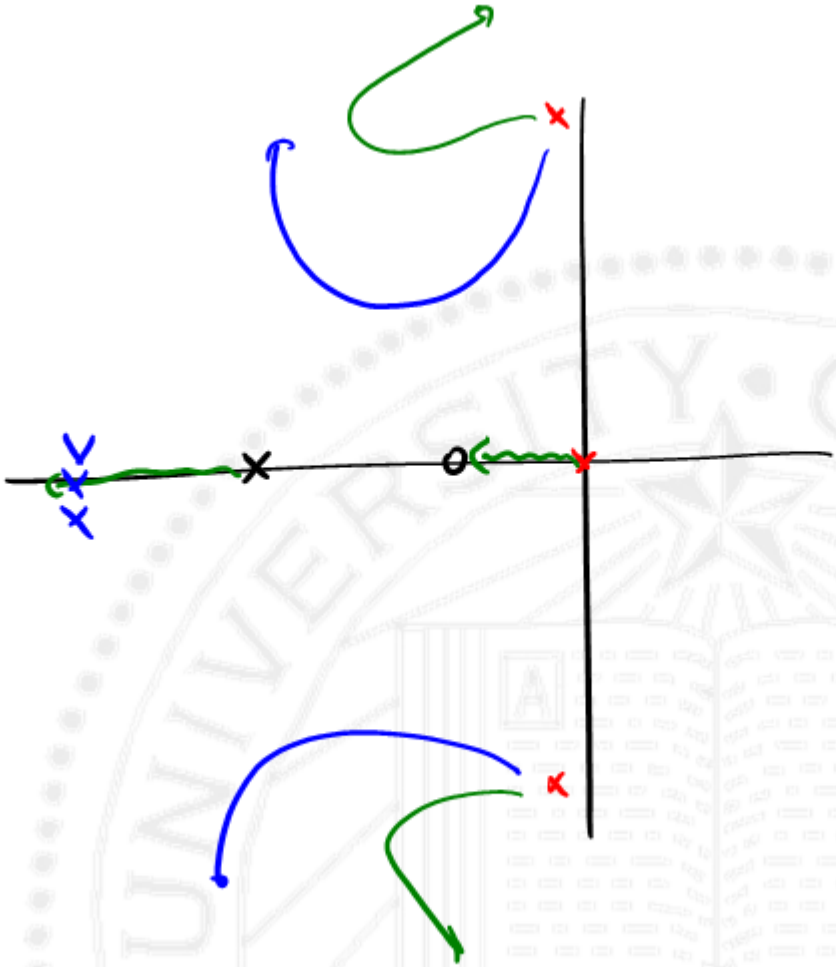
$$K(s) = 10^5 \left(\frac{s+562}{s+5620} \right)^2 \longrightarrow \omega_{x0}$$



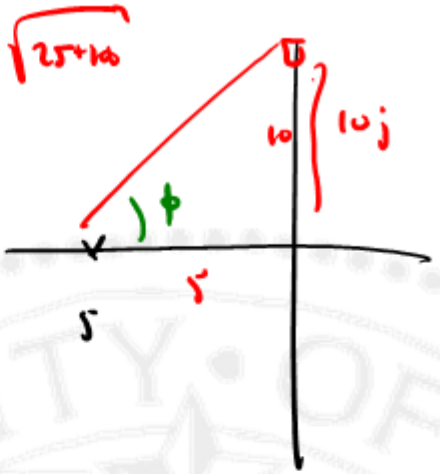


$$K(s) = \left(\frac{s}{s+a}\right)^n$$

$$\frac{a}{5} \sim -12^\circ n$$



$$K_{lag}(s) = \left(\frac{s}{s+5}\right)\Bigg|_{s=10j}$$



$$\left|K_{lag}(s)\right| = \frac{1}{\sqrt{125}} \approx .09$$

$$\frac{(s+2)}{s(s+3)(s+5)}$$

DC gain $= \left.\frac{2}{15}\right|_{s=0}$

$j\omega$

σ

-5 -3 -2 0

$\angle: -90 + \tan^{-1}\left(\frac{\omega}{2}\right) - \tan^{-1}\left(\frac{\omega}{3}\right) - \tan^{-1}\left(\frac{\omega}{5}\right)$

5.1^2

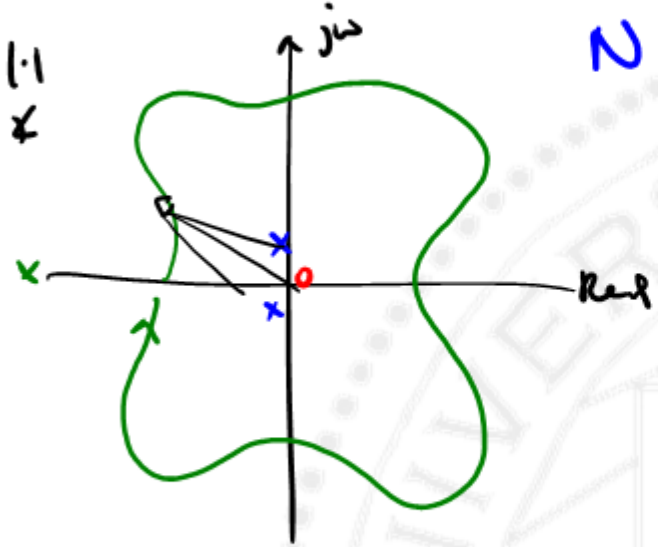
1

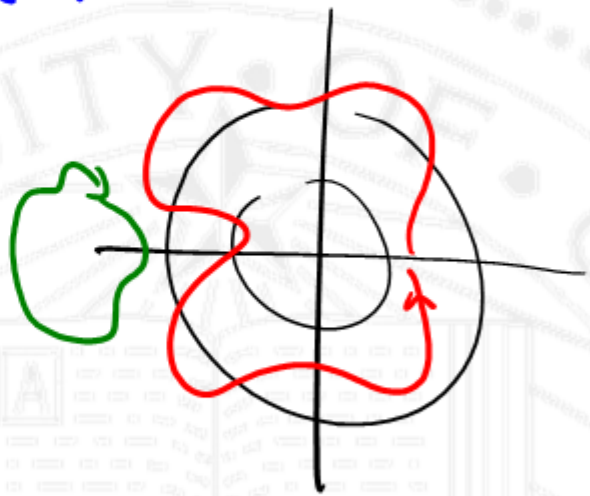
$1 \; e \; \omega : 1$

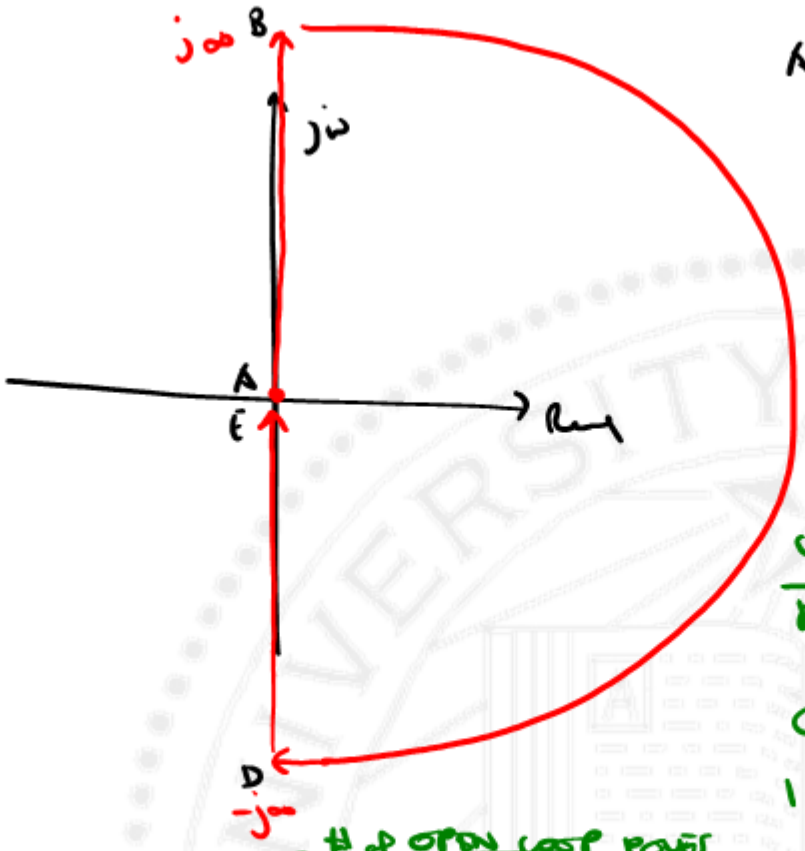
Nyquist

Cauchy's Principle of the Argument

$N = Z - P$







A → B : BODE PLOT

POLE — ENCIRCLEMENT

ZERO + ENCIRCLEMENT

$$\frac{Y}{R} = \frac{GK}{1+GK}$$

$GK = -1$

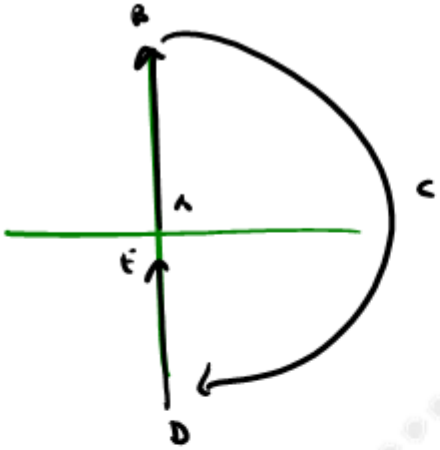
$1 + GK = 0 \leftarrow \Delta$

$1 + K\frac{N}{D} = 0$ $\quad D + KN = 0$

$N = Z - P$

Z = # of CLOSED LOOP POLES IN RHP

P = # of OPEN LOOP POLES IN RHP

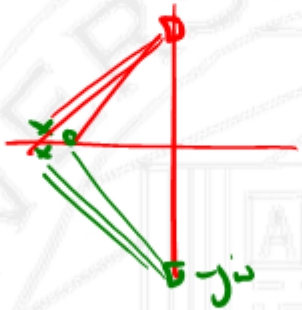


A → B : BODE PLOT

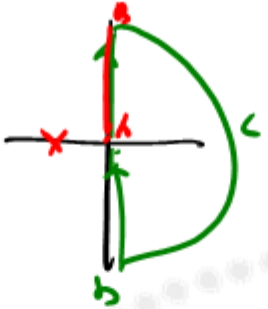
TRAVERSE B-C-D @ ∞

D → E : BODE PLOT 1:1 SAME AS $-\alpha$ OF ORIGIN

$$\tan^{-1}(-\phi) = -\tan^{-1}(\phi).$$

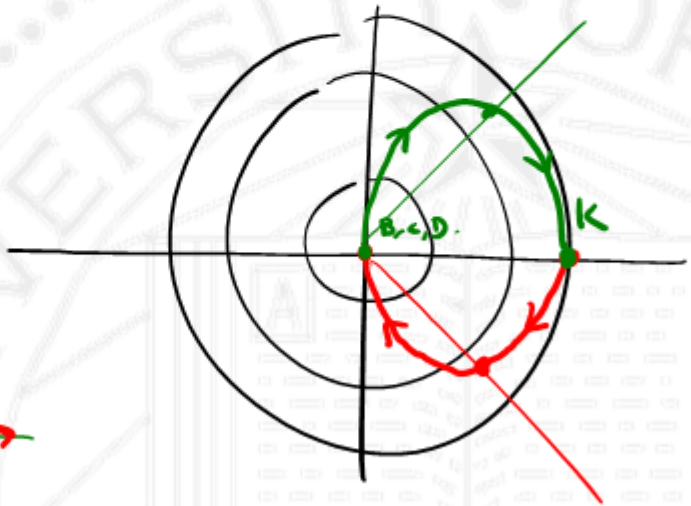


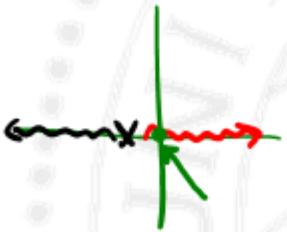
$G(s) = \frac{k}{s+1}$



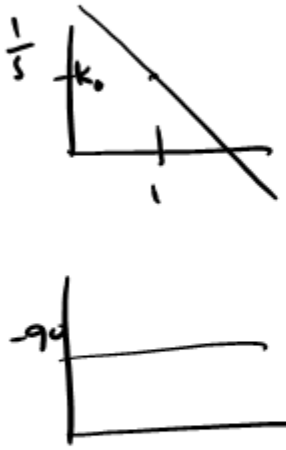
$Z = N + P$ (1, 0 ← open loop poles)

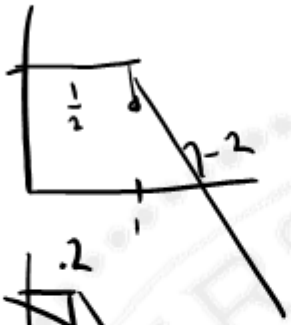
closed loop poles ← # of encirclements

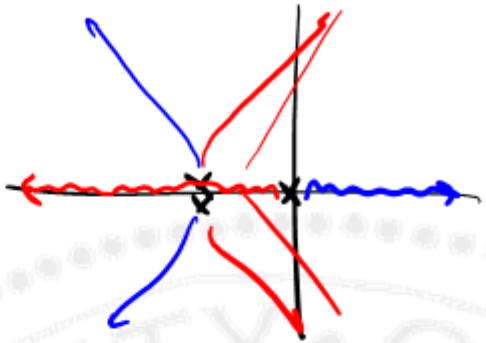


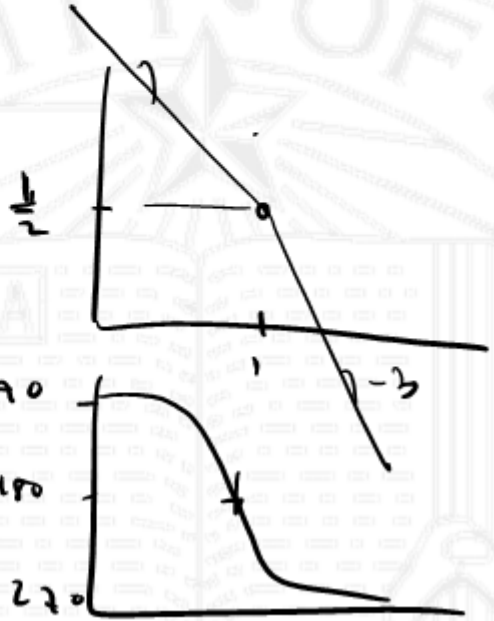


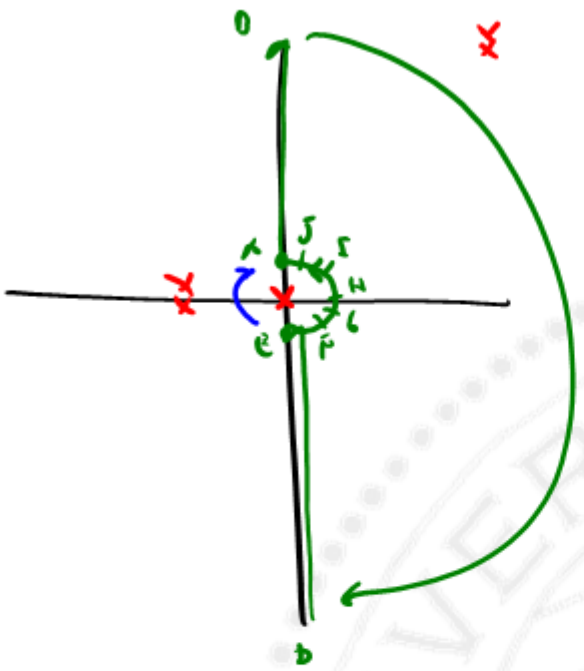
$$= \frac{K_0}{s(s+1)^2}$$





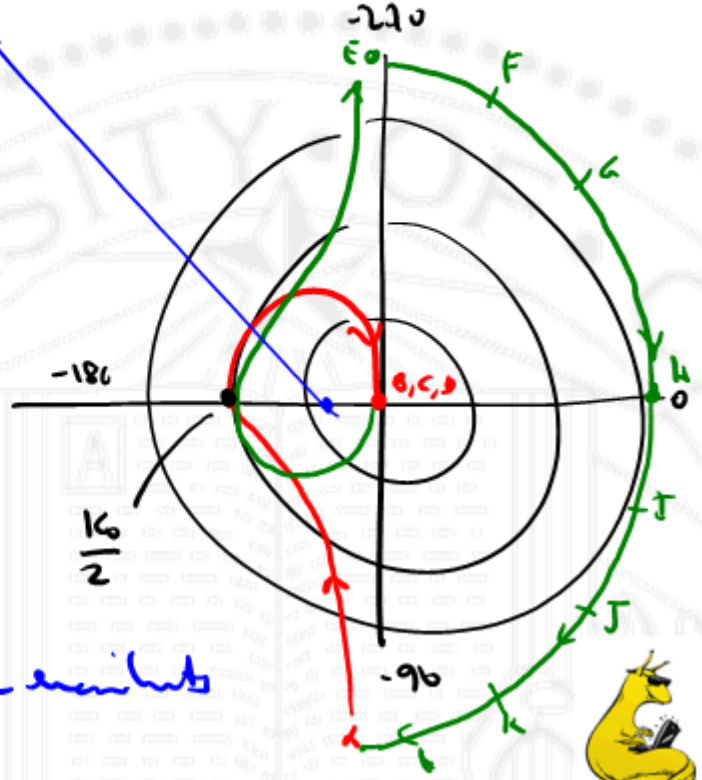






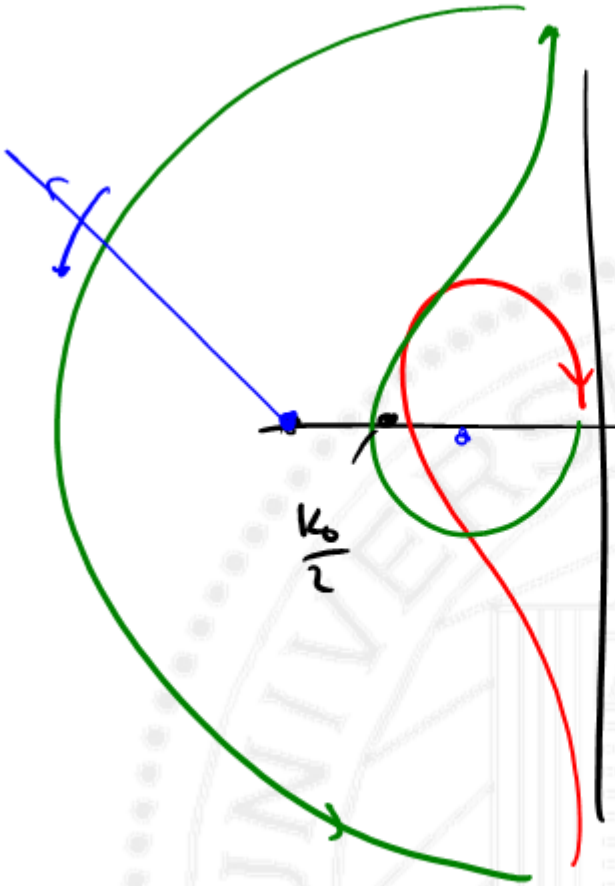
For 0° M

1 pole in RHP



180° M

$K_0 > 2$ → 2 unstable



$P = 1$

Q' $N = 0$

$Z = 1$

$N = -1$
$P = 1$ $\Rightarrow Z = 4$

$N = 1$ $Z = 2$
$P = 1$

2 poles in RHP