CMPE-242
Applied Feedback Control

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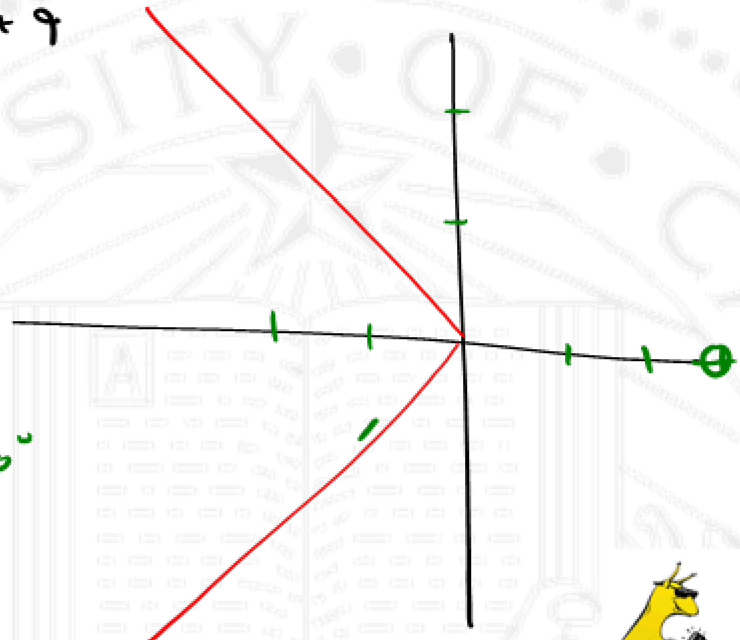
Questions

$$G(s) = \frac{-2(s-2)}{s^2+s+9}$$

$\zeta = .707$



$$1 + KG = 0$$

$$1 - KG = 0$$

$$KG = 1$$

$0, 360^\circ$

$1 \cdot 1 = 1$

$-\phi_d - 90 + 135 = -180$

ϕ_d

x → 0

real axis

asymptotes

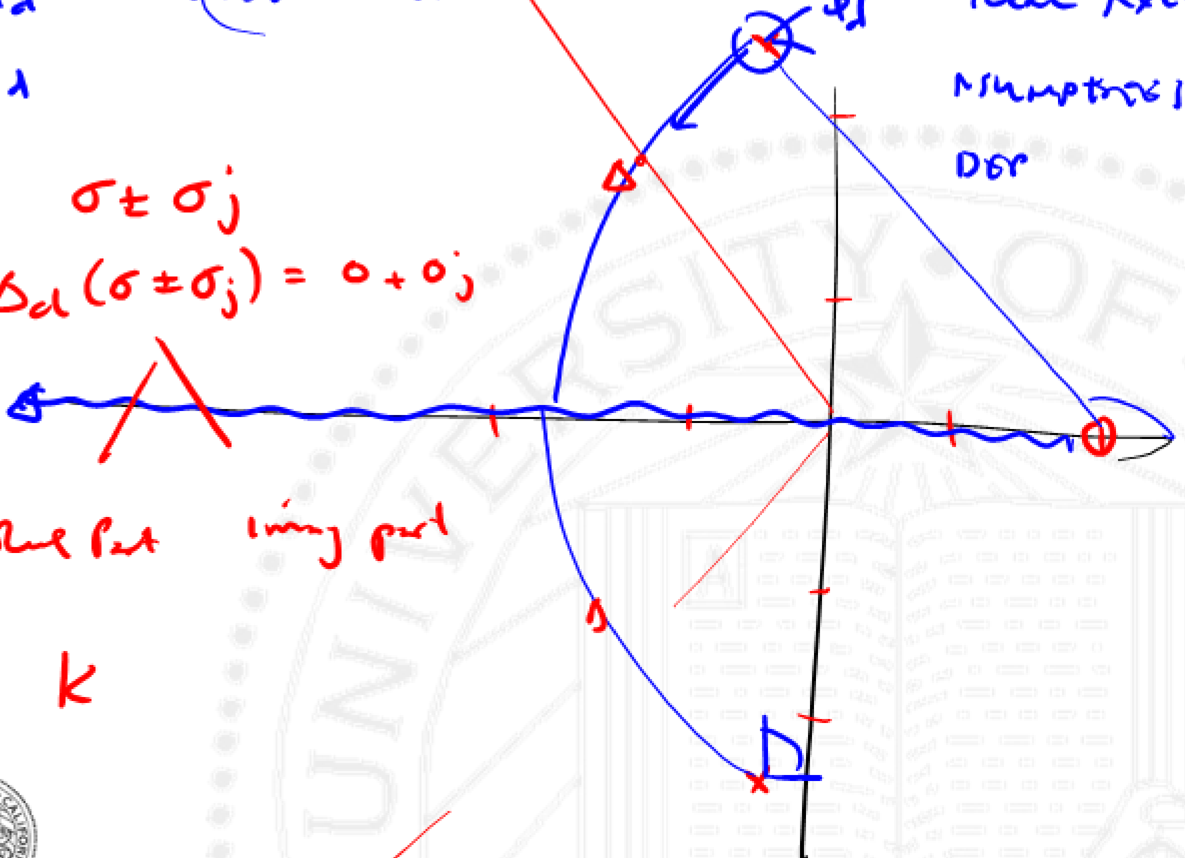
DOF

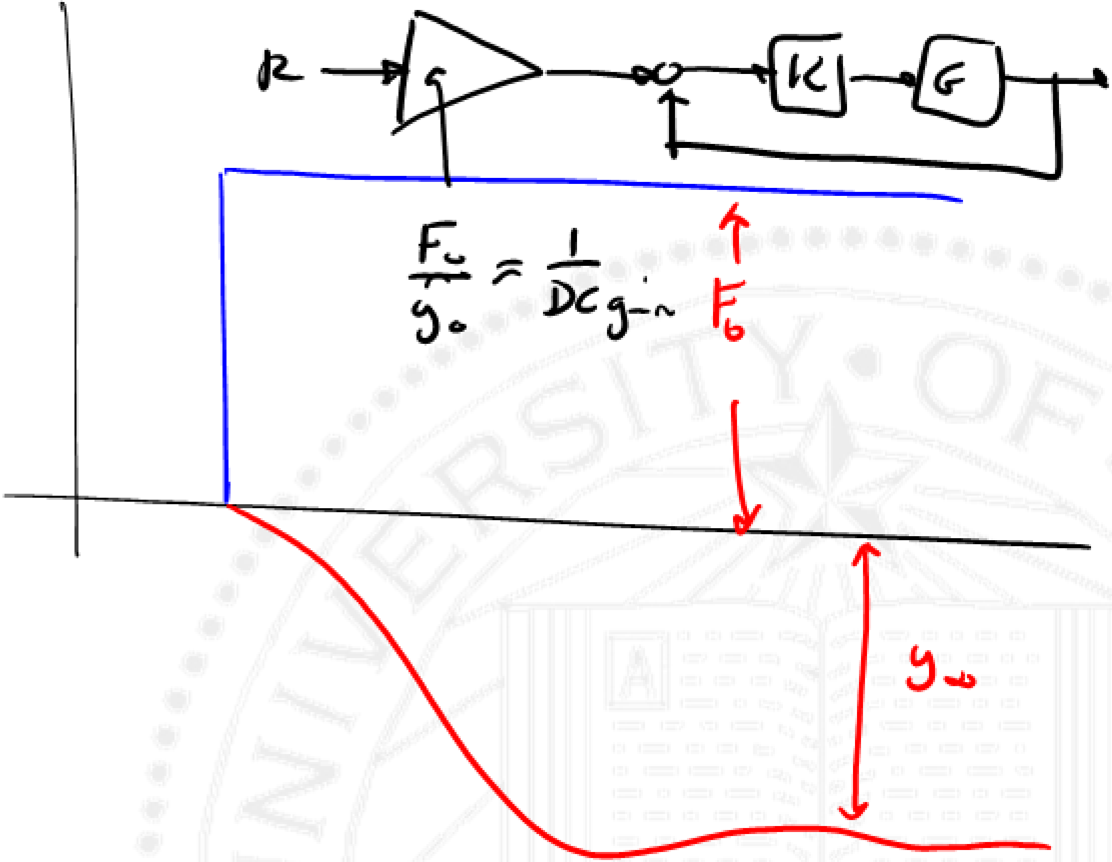
$\sigma \pm \sigma j$

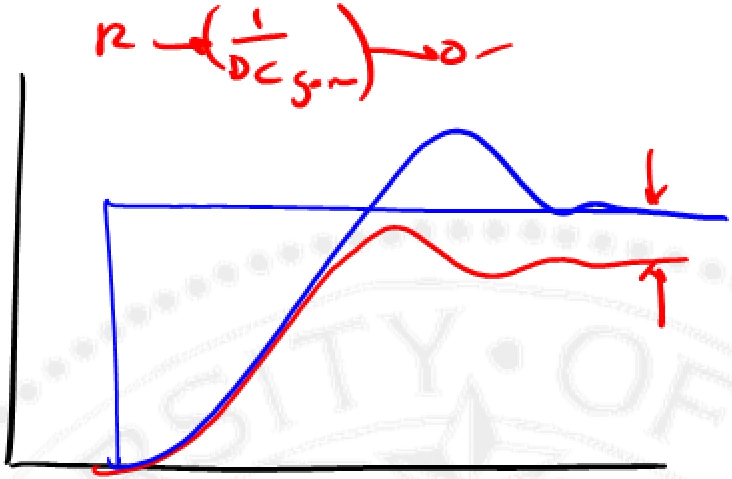
$\Delta_d(\sigma \pm \sigma j) = 0 + 0j$

Real Part imag part

K



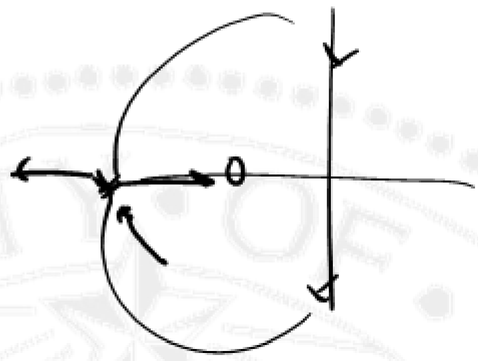

R
K
G
$\frac{F_\omega}{y_0} \approx \frac{1}{DC_{gain}}$
F_0
y_ω


R
1
DC gain

~~Rule #6~~

Break-in / Break out points

$$\Delta_{cl} = 1 + K\frac{b(s)}{a(s)}$$



$$b(s)\frac{da}{ds} - a(s)\frac{db}{ds} = \phi$$

solve for s.

MATLAB

Root locus

$$\boxed{\frac{KN}{D} = -1}$$ Evan's form

(1) $x \to o$

(2) REAL AXIS : TO LEFT OF AN ODD # x's, o's

(3) ASYMPTOTES : $\alpha = \dfrac{\Sigma p_i - \Sigma z_i}{n-m}$ $\otimes$ Divide 360 evenly

(4) Arrival/Departure : use test point θ_d

(5) $j\omega$-axis crossing : $\Delta_{cl}(j\omega) = 0 + 0j$, solve for K, ω

(6) Break-in/Break-out, use Matlab.

$$\frac{X}{F} = \frac{1}{ms^2 + bs + k}$$

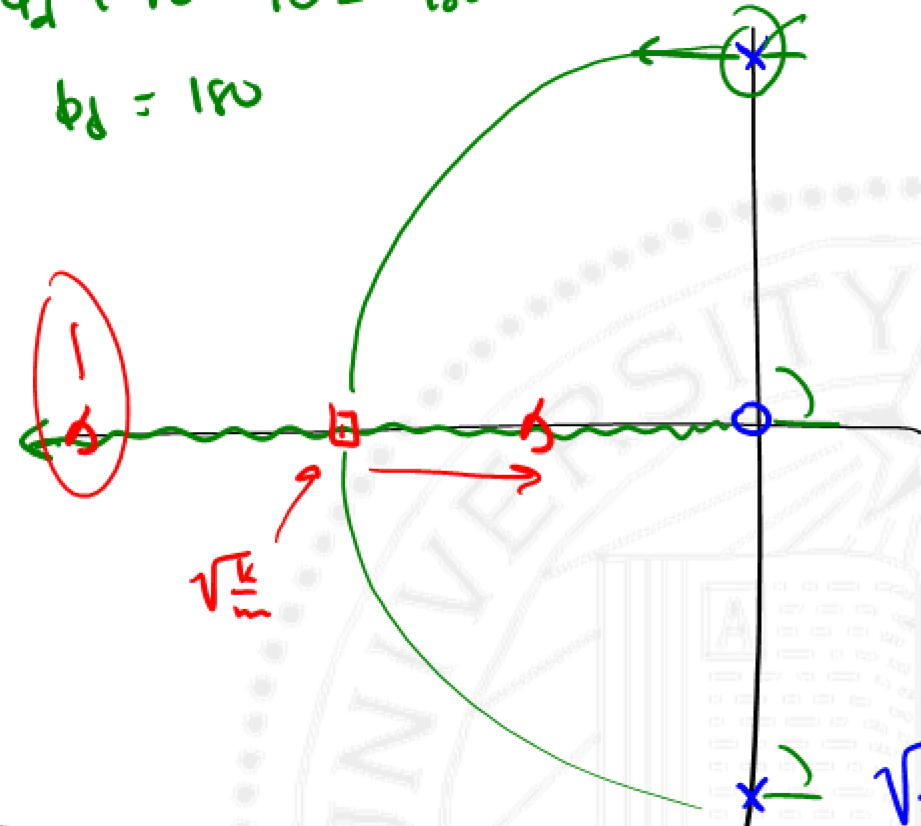
$$\frac{X}{F} = \frac{\frac{1}{m}}{\boxed{\left(s^2 + \frac{k}{m}\right) + \frac{b}{m}s}} \longrightarrow 1 + \frac{\frac{b}{m}s}{\left(s^2 + \frac{k}{m}\right)} = \phi = \delta_{cl}(s)$$

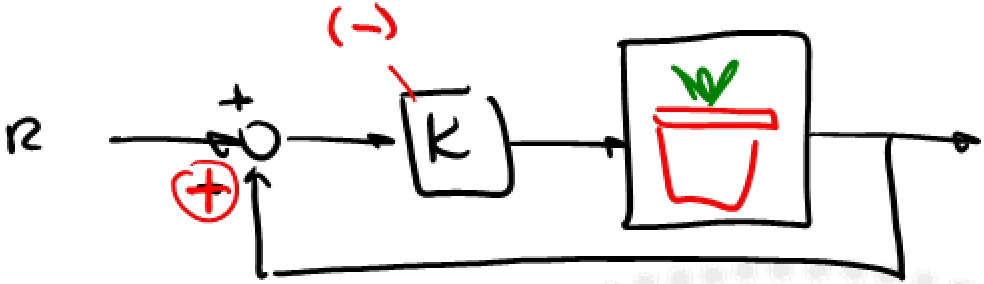
$$\boxed{\frac{b}{m}\frac{s}{\left(s^2 + \frac{k}{m}\right)} = -1}$$

$$-\phi_d + 90 - 90 = -180$$

$$\phi_d = 180$$

$$\frac{b}{m}\,\frac{s}{\left(s^2 + \frac{k}{m}\right)}$$





$\Delta_{cl}(s) = N_c N + K D_c D \longrightarrow \frac{Y}{R} = \frac{GK}{1+GK} \longleftarrow \Delta(s)$

$GK = -1 \rightarrow \angle 180^\circ$

$|\cdot| = 1$

ZERO DEGREE ROOT LOCUS

$\frac{Y}{R} = \frac{GK}{1-GK} \text{ — } \Delta(s) \Longrightarrow \boxed{GK = +1}$

$\angle 0^\circ$

360°

$|\cdot| = 1$

if $\underline{k < 0}$ $\rightarrow$ $\measuredangle\, 0^\circ$ $\quad 1 + Gk \rightarrow 1 - Gk$

(1) Rule #1: X $\rightarrow$ 0 "same"

(2) Real Axis: <u>Not</u> 180°

(3) Asymptotes: α ← same, $\measuredangle$ other one

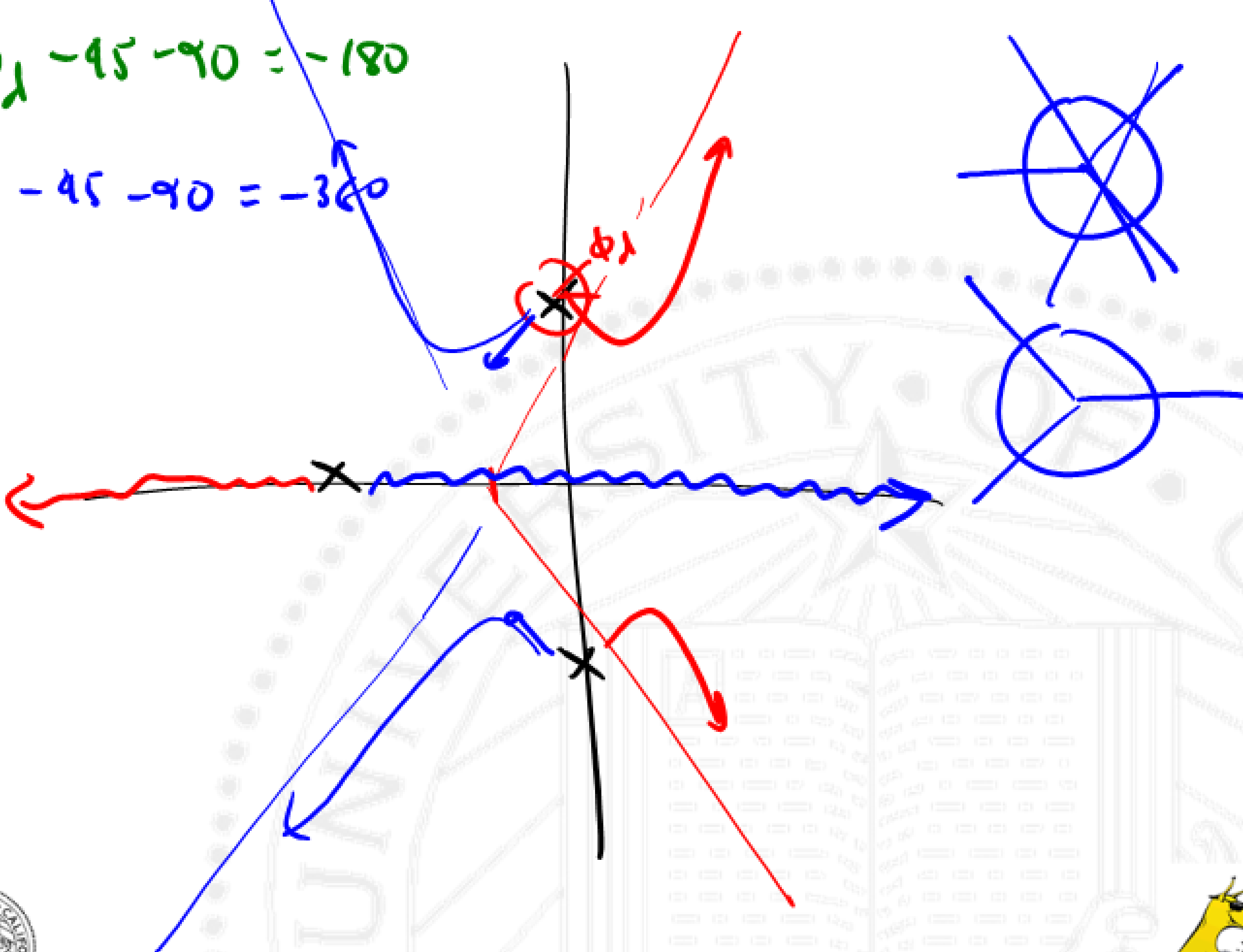
(4) Departure/Arrival: use test point. $\pm 360, 0$.

(5) $j\omega$-axis — same

(6) Break-in/Breakout — same (use Matlab)

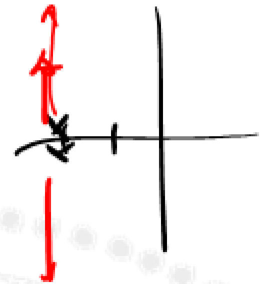
$$-\phi_\lambda - 45 - 90 = -180$$

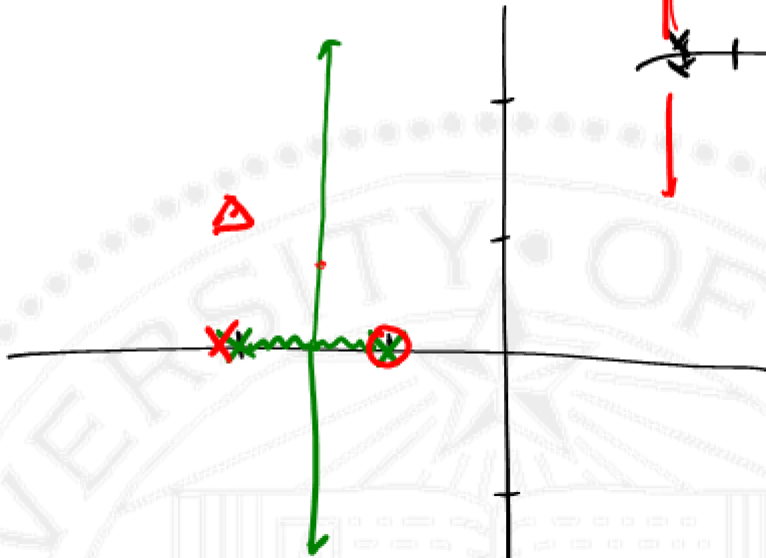
$$-\phi_\lambda - 45 - 90 = -360$$



$$G(s) = \frac{8}{(s+2)(s+1)}$$

$$x_{des} = -2 \pm j$$



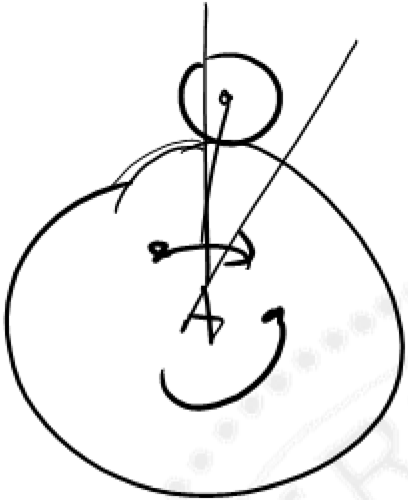


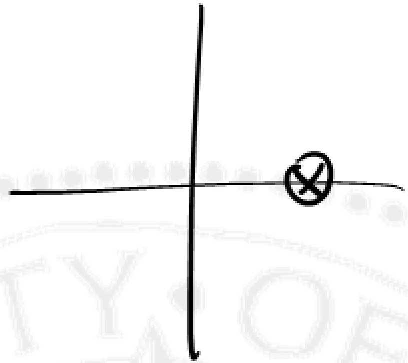
$$K(s) = K_0 \frac{s+1}{s+2}$$

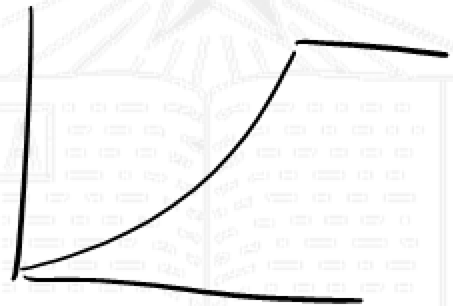
$$\boxed{\frac{1}{8}}$$

$$GK(s) = \frac{\cancel{8}(s+1)}{8\cancel{(s+1)}(s+2)^2} = \frac{1}{(s+2)^2}$$

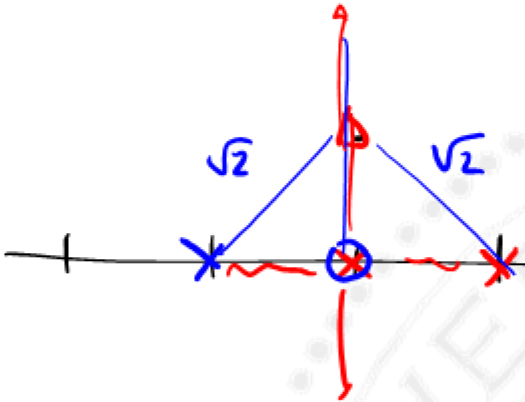
$$\boxed{\text{DC gain} = \frac{1}{4}}$$







$$K(s) = K_0 \frac{s+2}{s+3}$$



$$K_0 = \frac{1}{4} \leftarrow GK = \frac{8}{\sqrt{2}\cdot 1} \cdot \frac{K_0 \cdot 1}{\sqrt{2}}$$

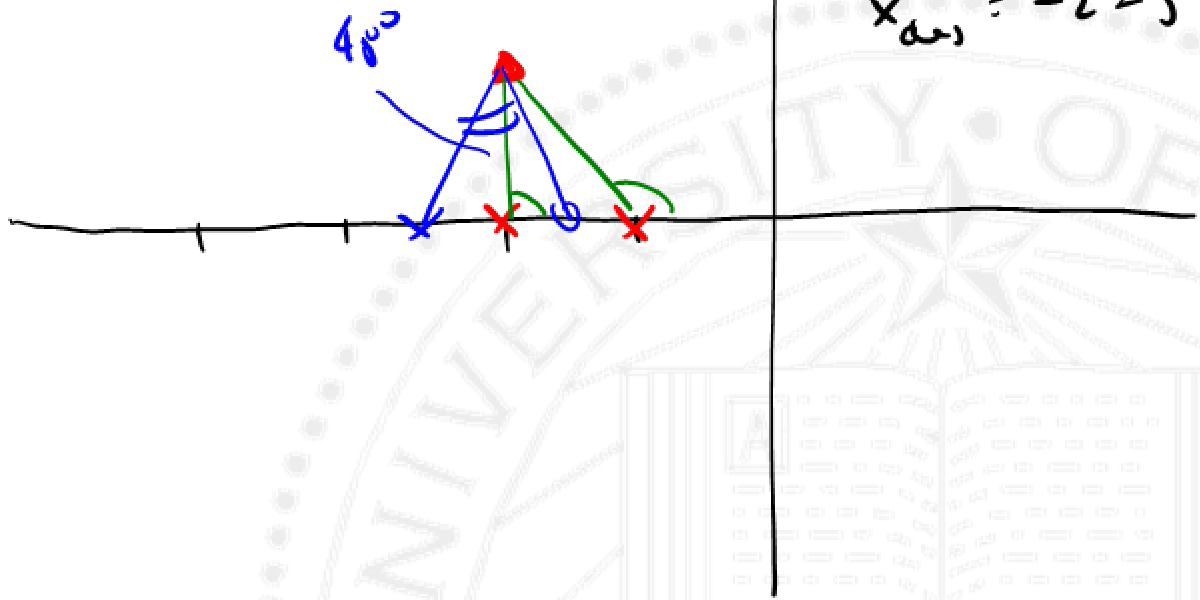
$$\text{DC gain: } \frac{8 \cdot \frac{1}{4}\cancel{(s+2)}}{(s+1)\cancel{(s+2)}(s+3)}$$

$$\boxed{= \frac{2}{3}}$$

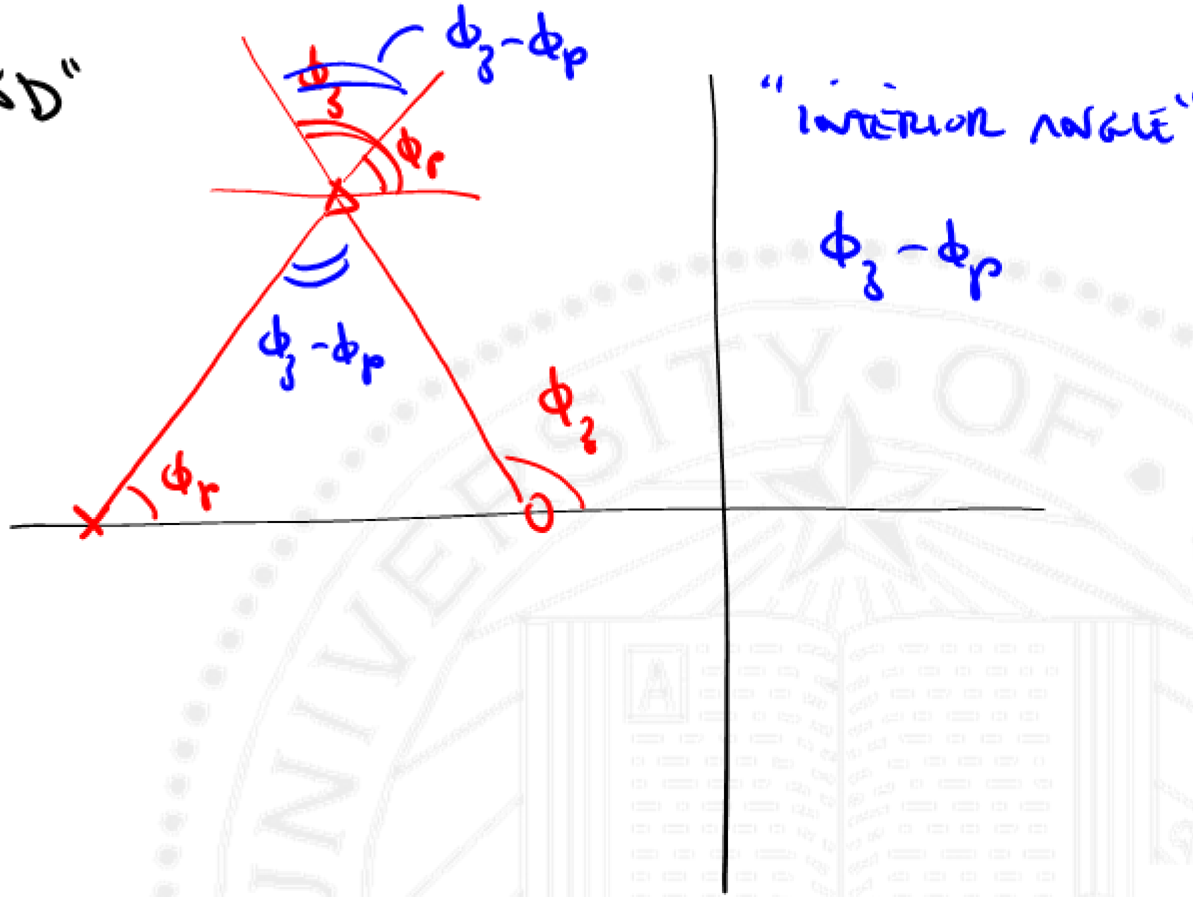
$\phi_0 = -135 - 90 = \underline{-225} \quad \underline{+45^\circ} = -180^\circ$

$G(s) = \frac{8}{(s+1)(s+2)}$

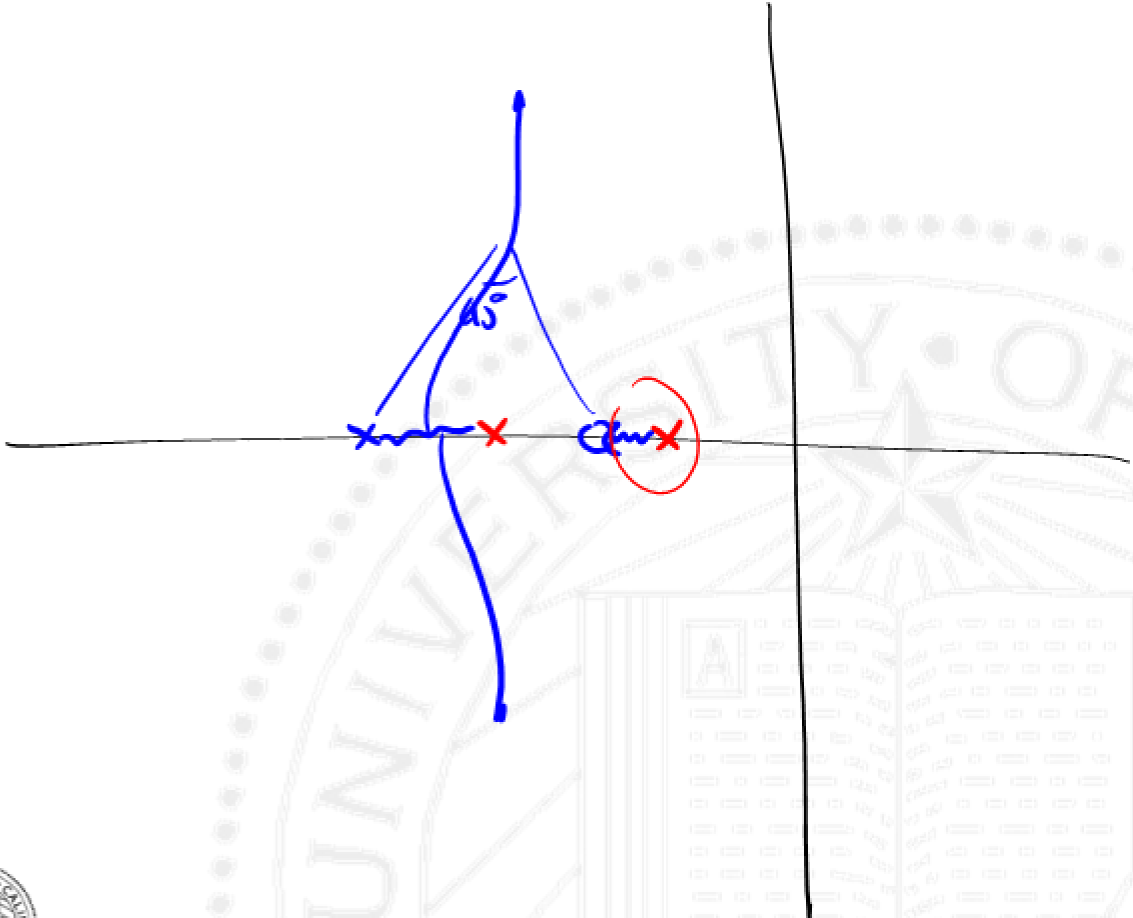
$x_{des} = -2 \pm j$



"LEAD"

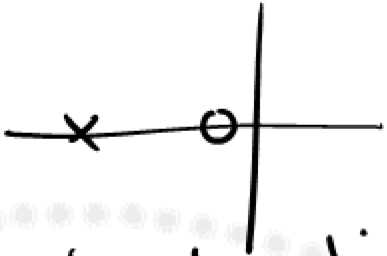


$\phi_z - \phi_p$
ϕ_z
ϕ_p
$\phi_z - \phi_p$
ϕ_p
ϕ_z
"INTERIOR ANGLE"
$\phi_z - \phi_p$


45°

LEAD

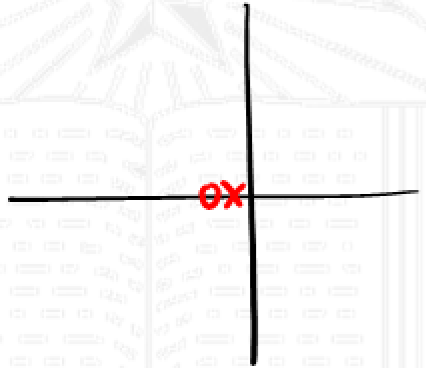
$$K(s) = K_0 \frac{s+z}{s+p}$$



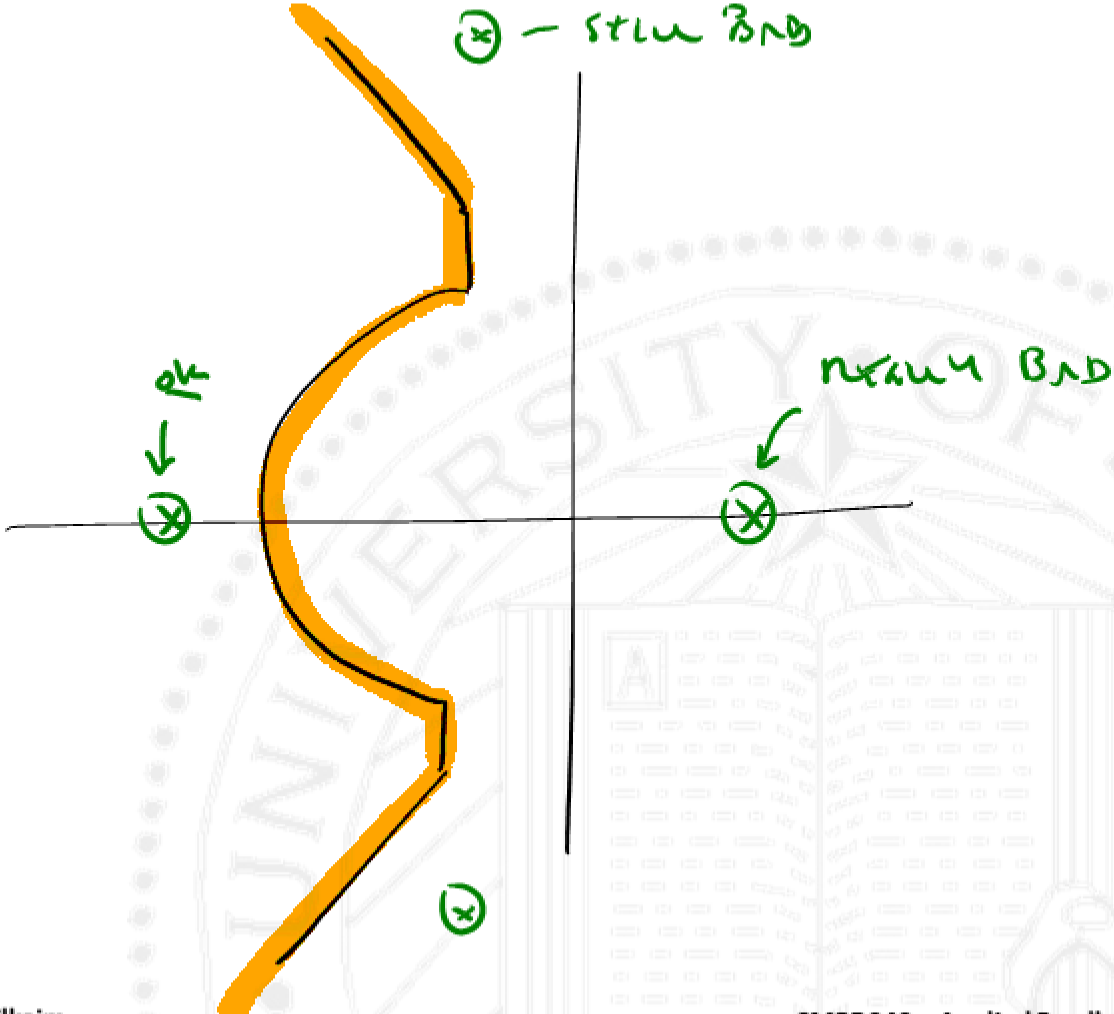
put branch through desired location

LAG

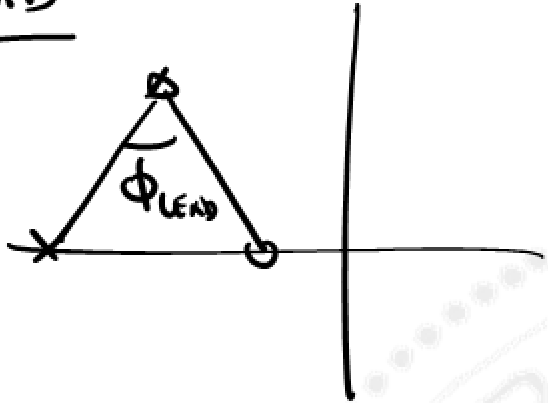
$$K(s) = K_0 \frac{s+z}{s+p}$$



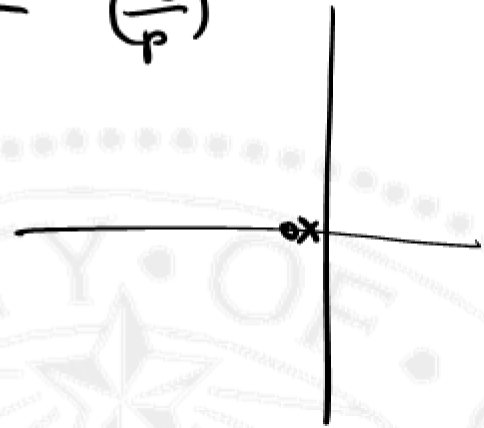
Gain $\left(\frac{z}{p}\right)$


– still bad
ok
really bad

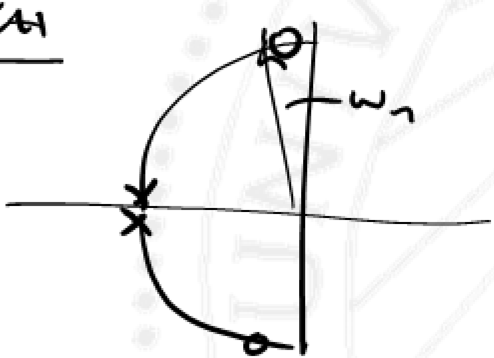
LEAD



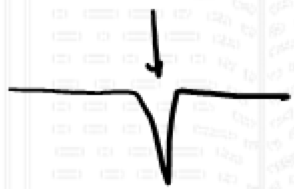
LAG $\left(\frac{3}{P}\right)$

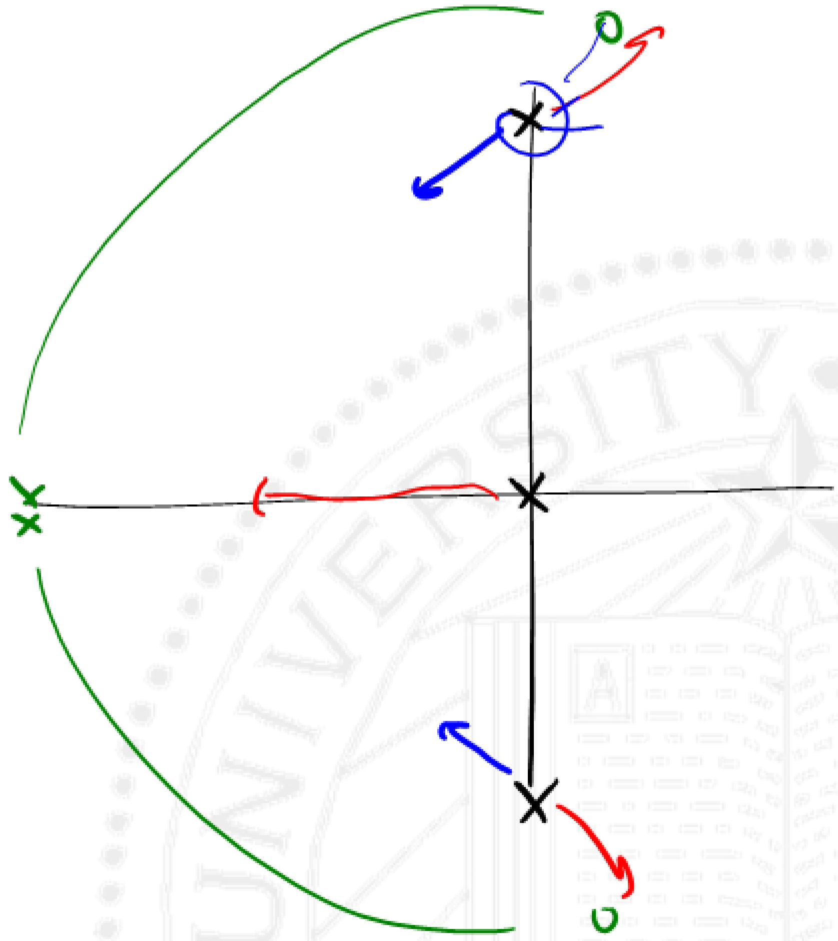


NOTCH

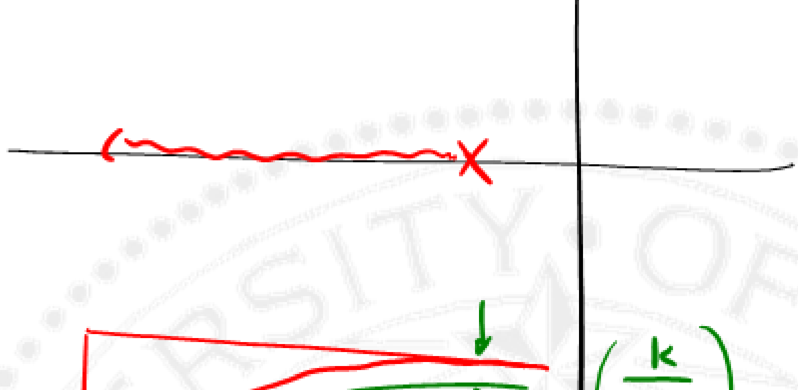


$$K(s) = \frac{K(s^2 + 2\zeta\omega s + \omega^2)}{(s+\omega)^2}$$

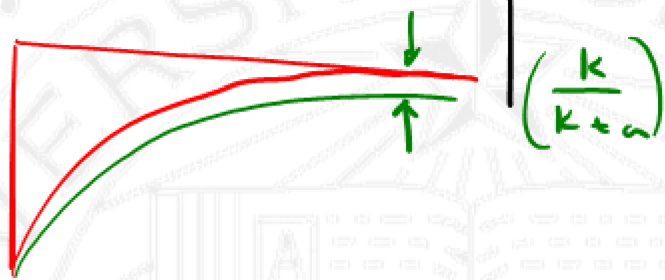




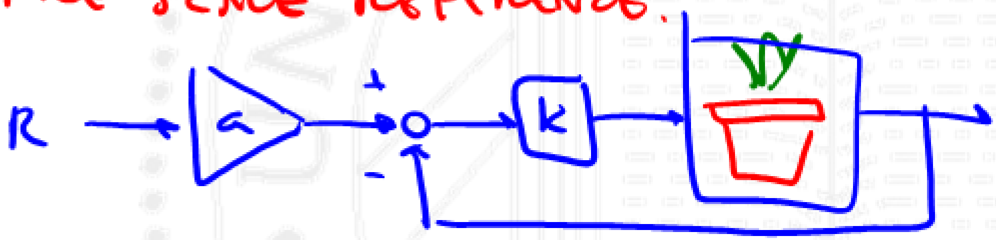
$$G(s) = \frac{1}{s+a} \longrightarrow K(s) = K \qquad \frac{GK}{1+GK} = \frac{K}{K+a}$$



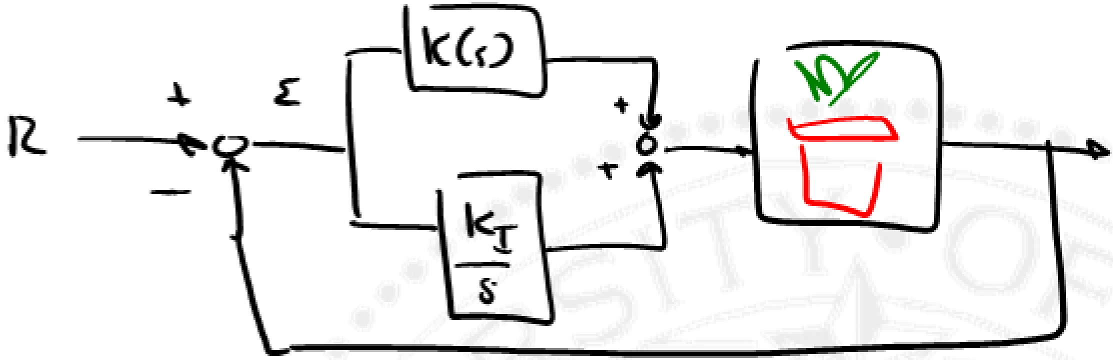
DC gain $= \left(\frac{1}{a}\right)$



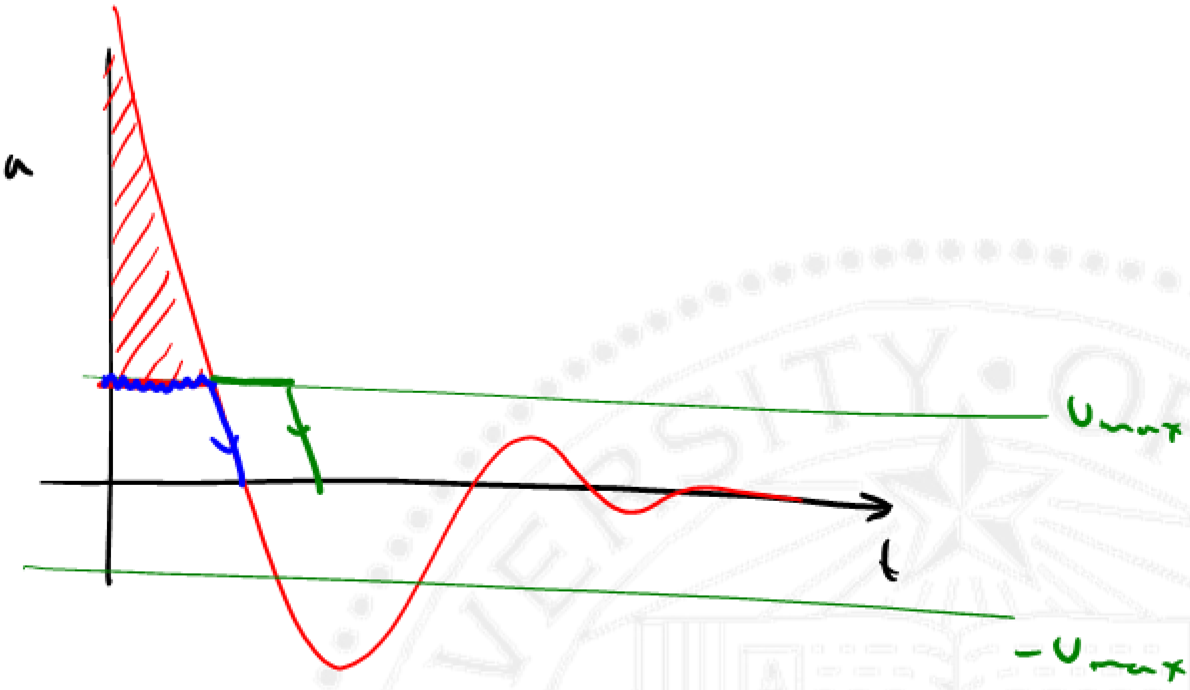
PRE-SCALE REFERENCE.



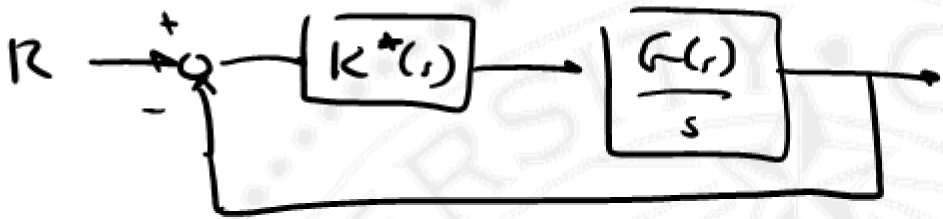
Integral Control



- Anti-windup
- Reset


u
t
u_{max}
$-u_{max}$

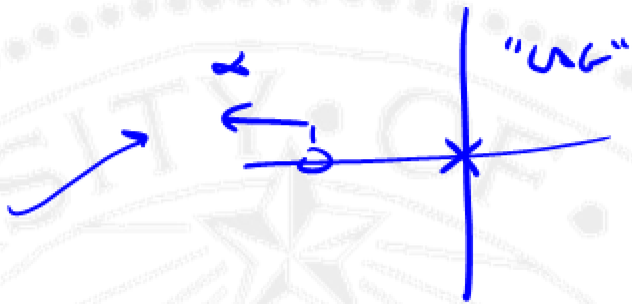
$$K^*(s) + \frac{K_I}{s} = \frac{K_I + s K^*(s)}{s} = \frac{K(s)}{s}$$



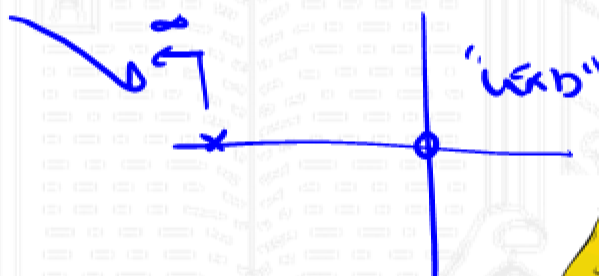
PID – Proportional, Integral, Derivative

$K_p \longrightarrow K(s) = K$

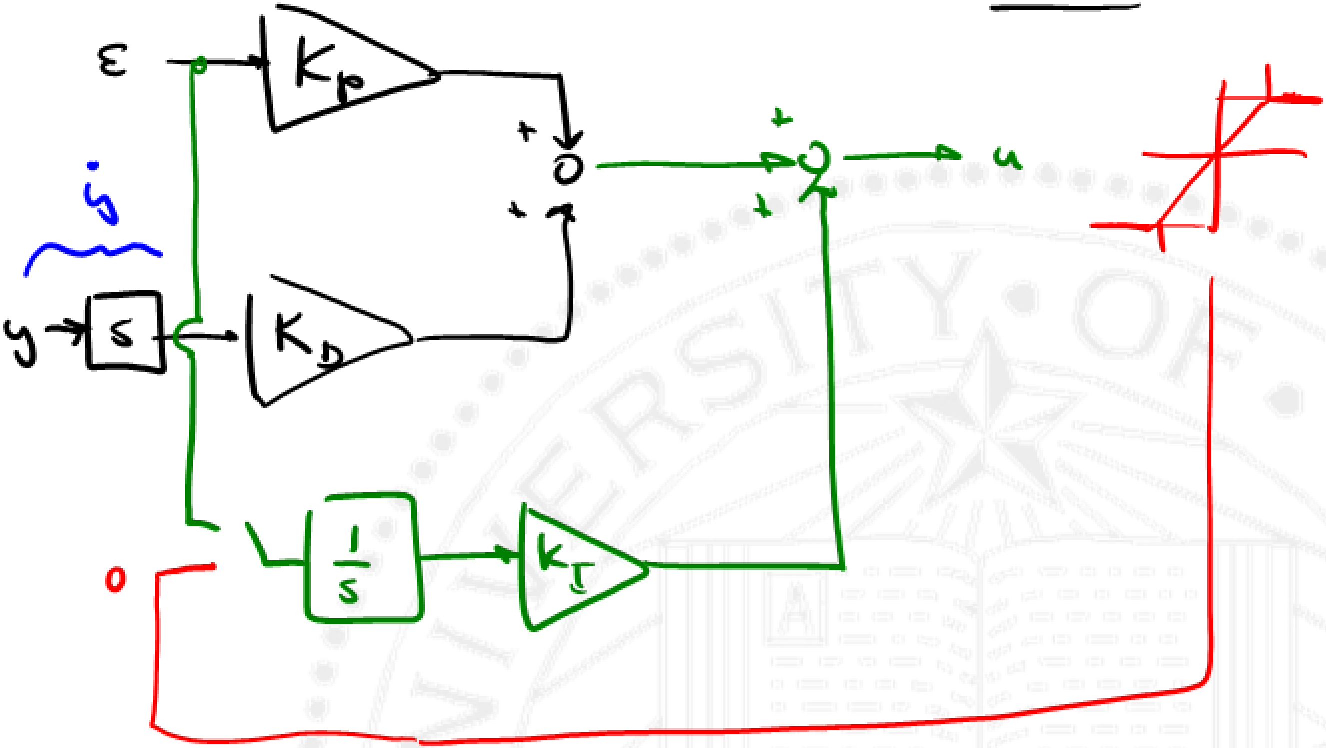
$K_I \longrightarrow K(s) = \frac{K_I}{s}$



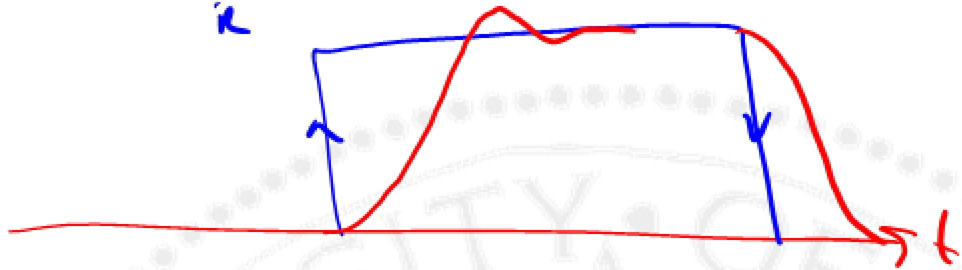
$K_d \longrightarrow K(s) = s K_D$



RIGHT WAY TO DO PID

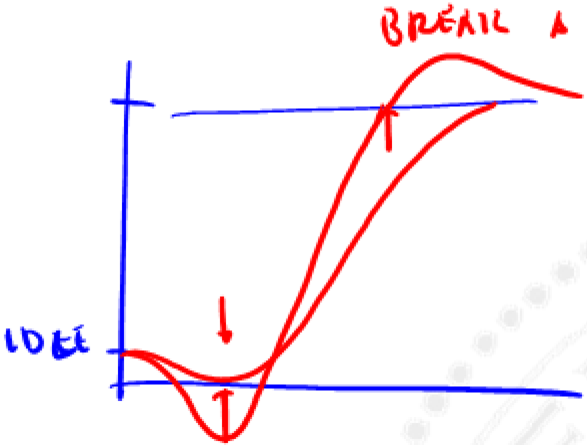


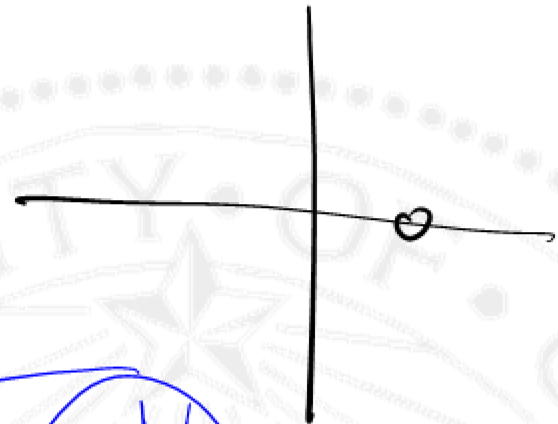
BUMPLESS TRANSFER



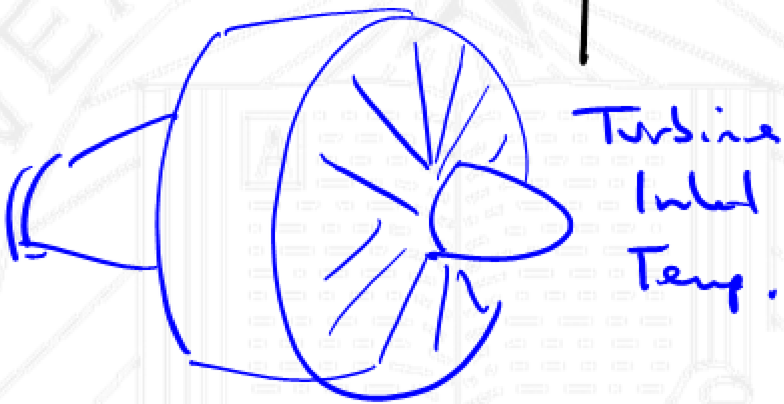
$$\frac{dE}{dt} = \frac{dR}{dt} - \frac{dY}{dt}$$

NON-MINIMUM PHASE ZERO



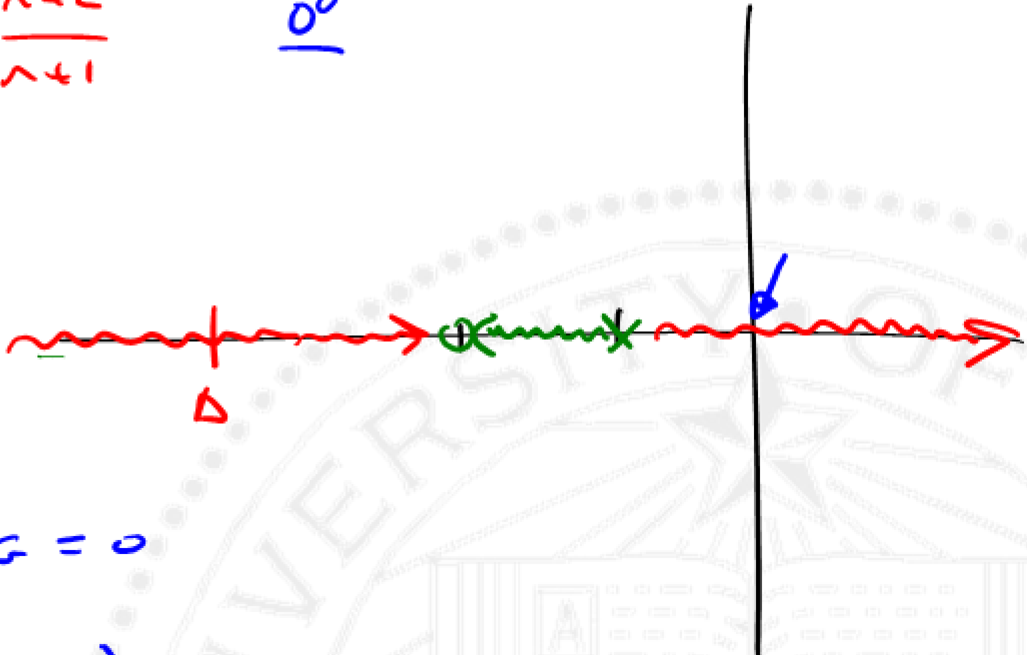


$f_{FUEL} \simeq$ THRUST



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

$\underline{0^\circ}$



$$1 + KG = 0$$

$$1 + \frac{K(s+2)}{s+1} = 0$$

$$(s+1) + K(s+2) = 0 + 0j \Big|_{s=j\omega}$$

$$(s+1)+k(s+2)=0\Big|_{s=j\omega}$$

$$(j\omega+1)+k(j\omega+2)=0+0j$$

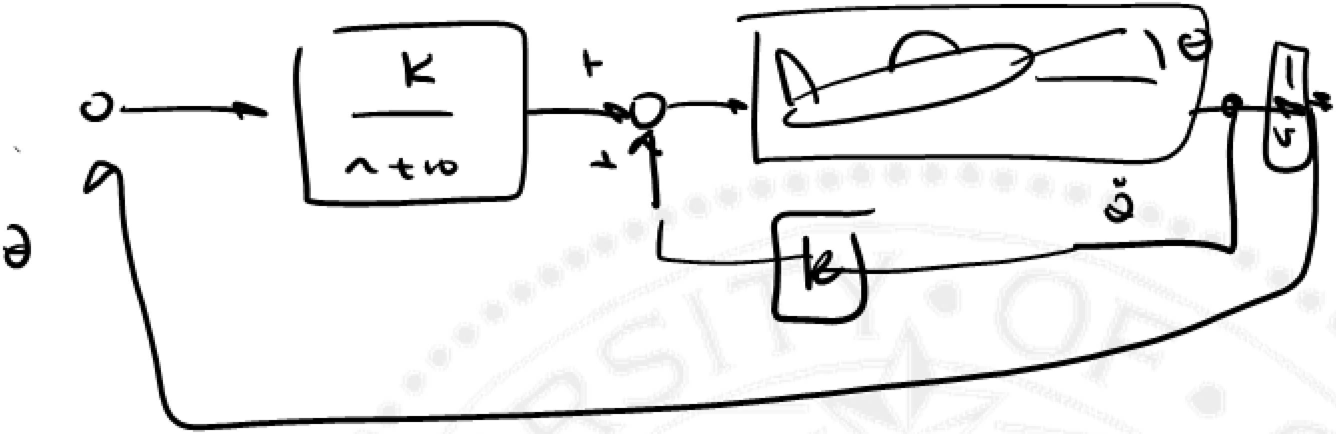
$$[k+1]j\omega+[1+2k]=0+0j$$

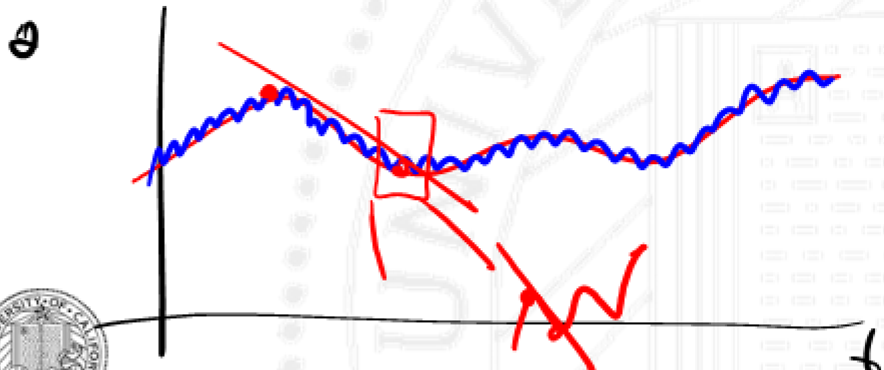
$$k=-\frac{1}{2},\ \omega=\phi$$

Analysis – what happens when I bump the system.

Synthesis – place things where I want them

place $D_c(s)$.





$\dot{\theta}$ – NUMERICAL

$\dot{\theta}$ – PHYSICAL