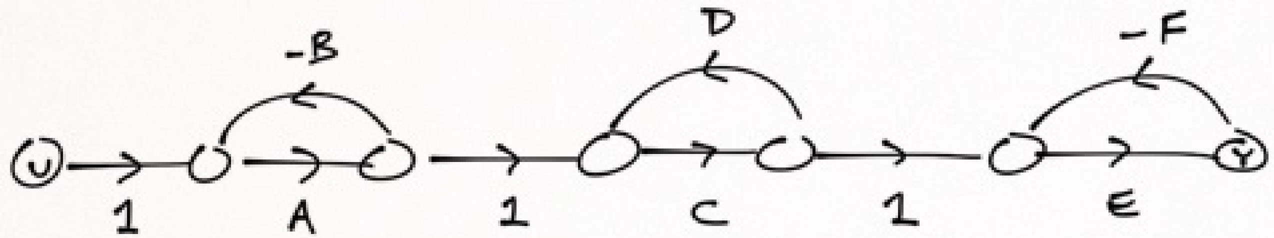
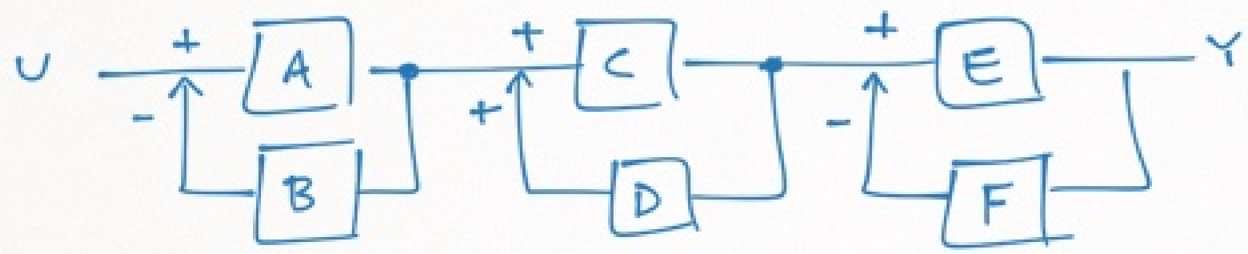
EECE 360 QUIZ #1

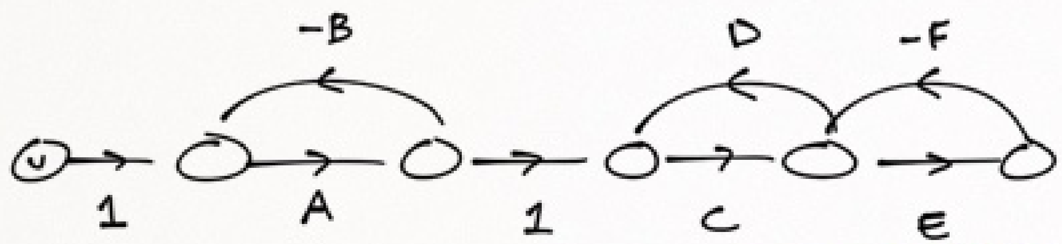
convert signal flow diagram to block diagram & find transfer function

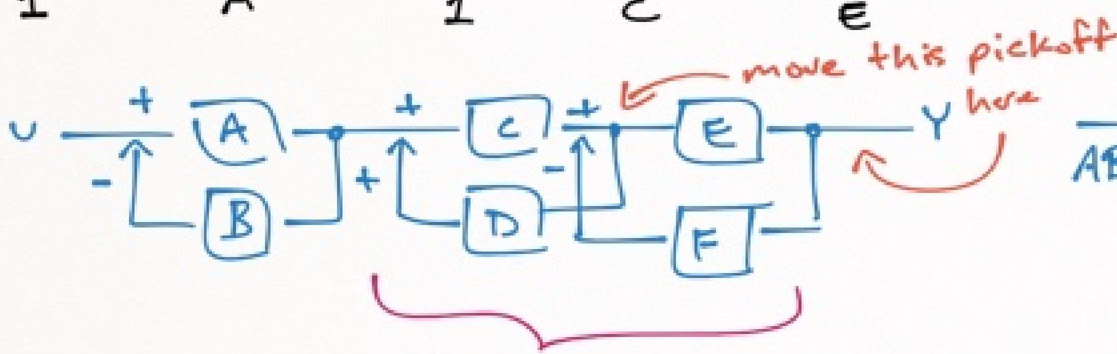




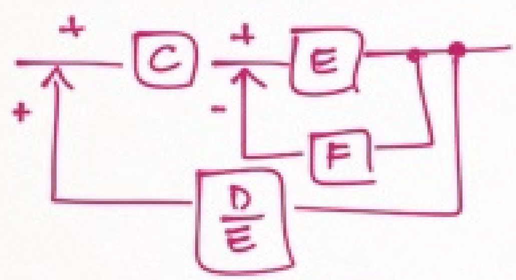
$$\frac{A}{AB+1}\cdot\cancel{\frac{C}{CD+1}}\cdot\frac{E}{EF+1}=\frac{Y}{U}$$

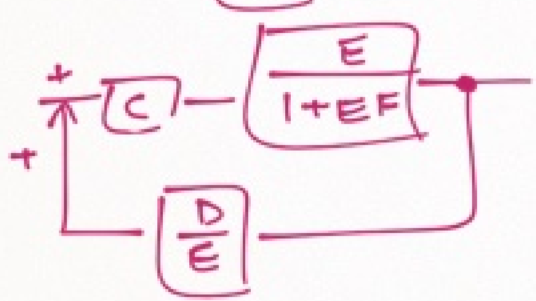
$$\frac{C}{1-CD}$$





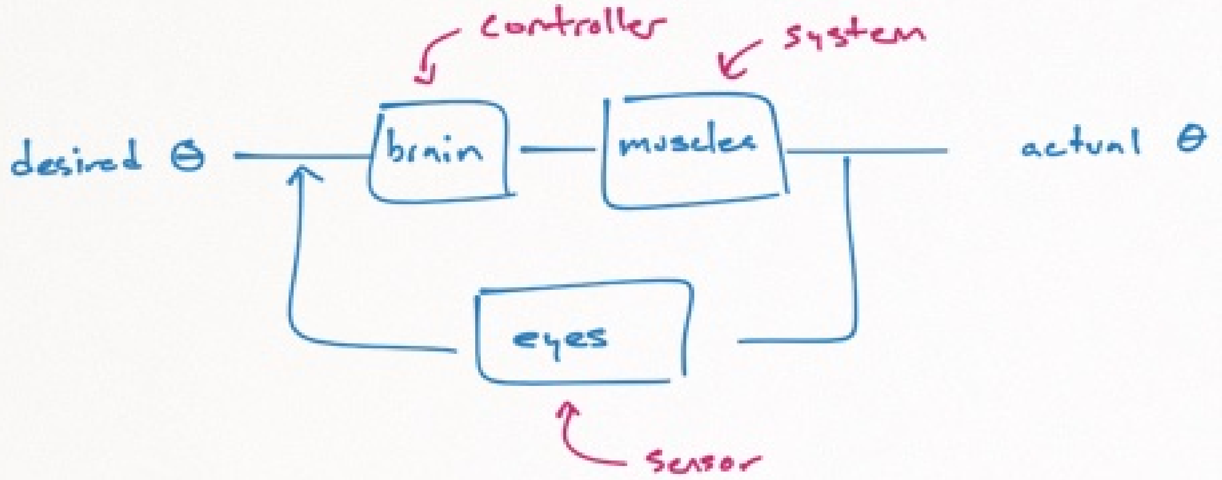
$$\frac{A}{AB+1}\cdot\frac{EC}{1+EF-CD}$$



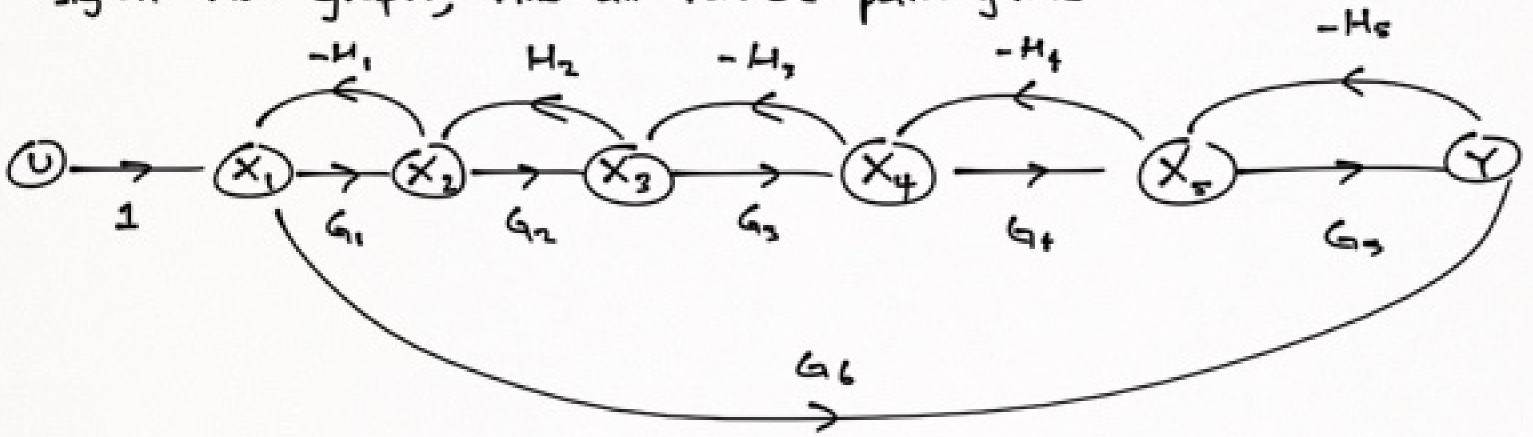


$$\frac{\frac{CE}{1+EF}}{1+\frac{CE}{1+EF}\cdot\frac{D}{E}}=\frac{-EC}{DC-FE-1}=\frac{EC}{1+FE-DC}$$

gymnast uses her eyes, brain, stomach muscles to balance body on beam.
draw feedback control system, label all blocks/signals



for signal flow graph, find all forward path gains



P_1: $G_1G_2G_3G_4G_5$

P_2: G_6

find all loop gains

L_1: $-G_1H_1$

L_2: G_2H_2

L_3: $-G_3H_3$

L_4: $-G_4H_4$

L_5: $-G_5H_5$

L_6: $G_6H_1H_2H_3H_4H_5$

compute determinant Δ in terms of L & P

$\Sigma\pi_1 = L_1 + L_2 + L_3 + L_4 + L_5 + L_6$ (all loops)

$\Sigma\pi_2 = L_1L_3 + L_1L_4 + L_1L_5 + L_2L_4 + L_2L_5 + L_3L_5$ (double loops that don't touch)

$\Sigma\pi_3 = L_1L_3L_5$

$$\Delta = 1 - \Sigma\pi_1 + \Sigma\pi_2 - \Sigma\pi_3$$

compute sub-determinant in terms of L & P

go through forward paths identifying loops that don't touch it

$P_1 = G_1 G_2 G_3 G_4 G_5$ ← touches all loops $\therefore \Delta_1 = 1$

$P_2 = G_6$ ← doesn't touch L_2, L_3, L_4, doesn't touch combo of $L_2 L_4$ which also don't touch eachother $\therefore \Delta_2 = 1 - L_2 - L_3 - L_4 - L_2 L_4$

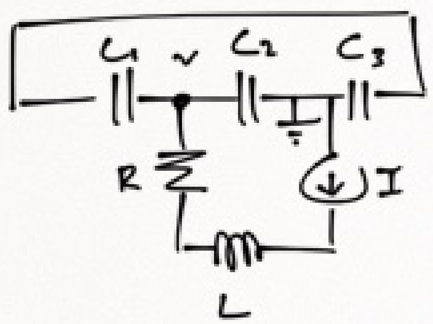
compute transfer function $\frac{Y}{U}$

$$TF = \frac{\sum P_i \Delta_i}{\Delta} = \frac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta} = \frac{G_1 G_2 G_3 G_4 G_5 + G_6 (1 - L_2 - L_3 - L_4 - L_2 L_4)}{\Delta}$$

from previous page

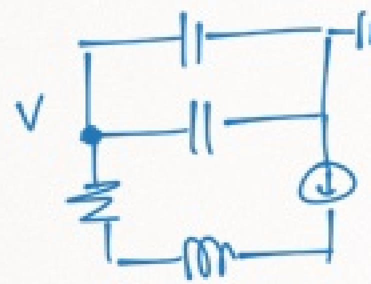
QUIZ #2

convert following system into simplest possible mechanical equivalent & label w/ mech. symbols

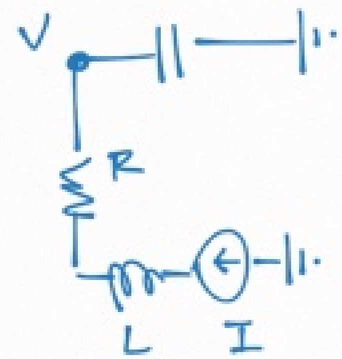


$\left(C_1^{-1} + C_3^{-1}\right)^{-1} + C_2$

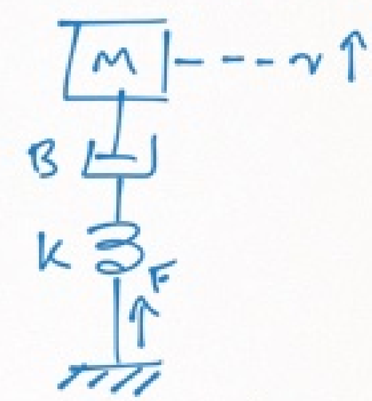
1. simplify circuit



$\longrightarrow$



2. draw mech equivalent



write formulas for mech. symbols in terms of electrical symbols

$R = \frac{1}{B}$ $\quad L = \frac{1}{K}$ $\quad M = \left(C_1^{-1} + C_3^{-1}\right)^{-1} + C_2$ $\quad v = V$ $\quad F = I$

convert following transfer function into time domain

$$\frac{Y(s)}{V(s)} = \frac{s^3 + s^2 + s + 1}{(s+1)(s+2)(s+3)}$$

partial fractions

$$1 + \frac{5}{s+2} - \frac{10}{s+3}$$

inverse-laplace

$$\delta(t) + 5e^{-2t} - 10e^{-3t}$$

apparently it's more correct to multiply these by u(t), the heaviside step function

$$= \frac{A}{s+1} + \frac{B}{s+2} + \frac{C}{s+3}$$

$$= \frac{A(s+2)(s+3) + B(s+1)(s+3) + C(s+1)(s+2)}{(s+1)(s+2)(s+3)}$$

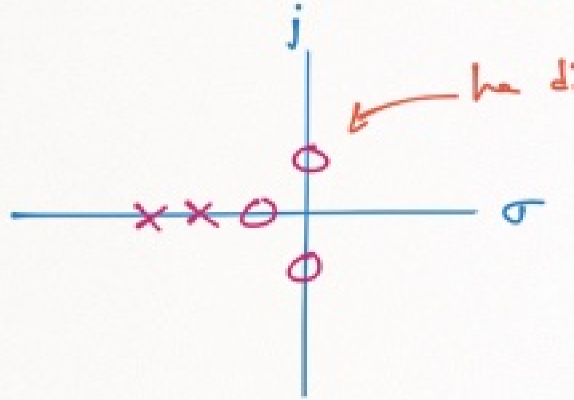
$s=-1 \qquad A(1)(2) = -1+1-1+1$

$s=-2 \qquad B(-1)(1) = -8+4-2+1=15$

sketch the previous page's T.F. poles & zeros. what's the order of the system? is it stable?

$$\frac{s^3+s^2+s+1}{(s+1)(s+2)(s+3)} = \frac{\cancel{(s+1)}(s+j)(s-j)}{\cancel{(s+1)}(s+2)(s+3)} = \frac{(s+j)(s-j)}{(s+2)(s+3)}$$

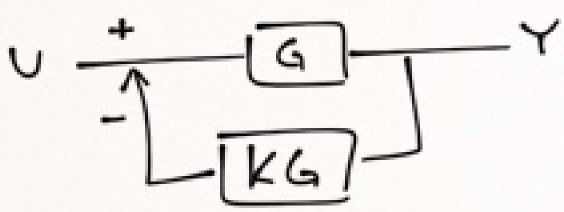
IT'S 2nd ORDER



he didn't label the complex poles for some reason

no poles in RHP ∴ stable

compute ζ & ω_n as a function of K of following system



$$G = \frac{1}{s+1}$$

$$\frac{Y}{U} = \frac{G}{1+KG^2} = \frac{s+1}{K+s^2+2s+1}$$

$$\zeta = \frac{a}{\sqrt{a^2+\omega^2}} \qquad \omega_n = \sqrt{a^2+\omega^2}$$

$$\text{CE: } s^2+2s+1+K = s^2+2\zeta\omega_n s+\omega_n^2$$

$$\omega_n^2 = 1+K \rightarrow \omega_n = \sqrt{1+K}$$

$$\cancel{2}\cancel{s} = \cancel{2}\zeta\omega_n\cancel{s} \rightarrow \zeta = \frac{1}{\omega_n} = \frac{1}{\sqrt{1+K}}$$

what value of K results in critical damping?

critically damped @ $\zeta = 1$ $\qquad 1 = \frac{1}{\sqrt{1+K}} \qquad K = \emptyset$

note that when $K<\emptyset$ the system turns into a positive feedback system.
sketch the natural response when $K=-0.5$

@ $K=-0.5$ $\qquad \zeta=\frac{1}{\sqrt{1-0.5}}=1.41$

$\zeta>1 \therefore$ overdamped

NATURAL RESPONSE?

use Routh-Hurwitz criteria to determine values of K for which system is stable

$$\frac{Y}{U}=\frac{s+1}{s^2+2s+(1+k)}$$

s^2	1	$1+k$
s^1	2	$\emptyset$
s^0	m_1	

$$m_1=\frac{-1}{b}\det\begin{vmatrix} a & c \\ b & d \end{vmatrix}=-\frac{1}{2}\left(\emptyset-2(1+k)\right)=1+k$$

$1+k>0$ to remain stable

$\therefore k>-1$

compute rise & settle time for the following system $\frac{Y}{U}=\frac{s+45}{s^2+3s+9}$

CE: s^2+3s+9

$3s=2\zeta\omega_n s$ $\qquad \omega_n^2=9 \rightarrow \omega_n=3$

$\frac{3}{2}=\zeta\omega_n \rightarrow \zeta=\frac{3}{6}=\frac{1}{2}$

$0.3<\zeta<0.8 \therefore \cancel{T_r \simeq \frac{2.16\zeta+0.6}{\omega_n}} = 0.560$

?

$T_s \simeq \frac{4}{\zeta\omega_n}=\frac{4}{3/2}=2.67s$

$T_r=\frac{1}{\omega_n\sqrt{1-\zeta^2}}\left(\pi-\tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right)\right)$

$=0.806s$

compute the DC gain, final value of impulse response, & percentage overshoot

$$PO = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}} \times 100\% = \underline{16.3\%}$$

Final value theorem $\lim_{s \to \emptyset} sF(s) = FV$

$$TF(s) = K_{DC} \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$FV = \lim_{s \to 0} s \frac{s+45}{s^2+3s+9} = \underline{\emptyset}$$

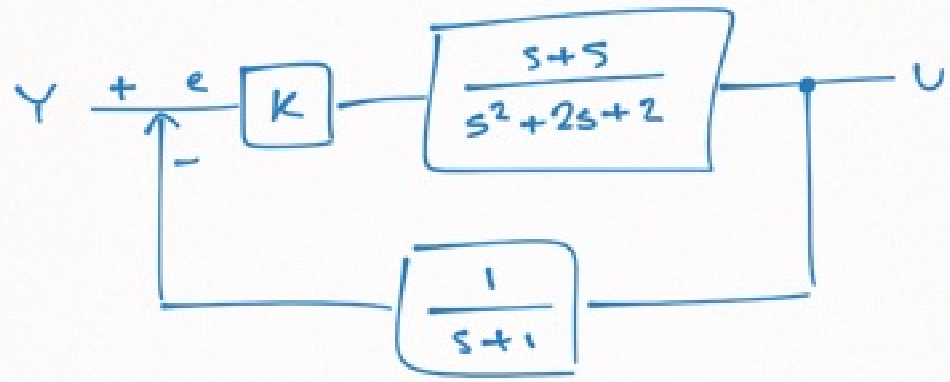
$$TF(0) = K_{DC} = \frac{\emptyset + 45}{\emptyset + \emptyset + 9} = \underline{5}$$

s = frequency, so frequency = $\emptyset$ therefore <u>DC</u>

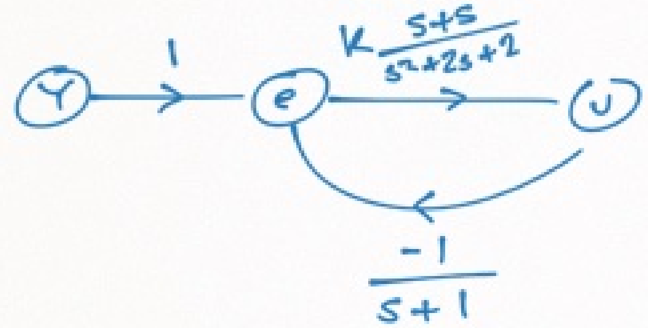
QUIZ #3

$$\frac{Y}{U} = \frac{\dfrac{K(s+5)}{s^2+2s+2}}{1 + \dfrac{K(s+5)}{(s+1)(s^2+2s+2)}}$$

for the following closed loop transfer function create a block-diagram



redraw system as a signal flow graph



for above system, compute the open-loop poles & zeros

OPEN LOOP: KGH

zeros : -5

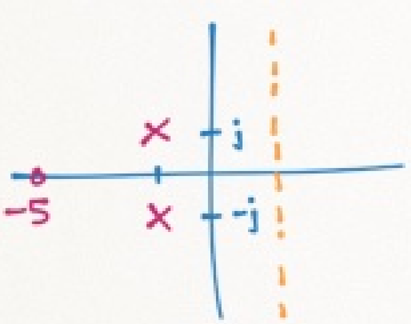
poles : $-1-j$, $-1+j$, -1

compute assymptotes of root locus

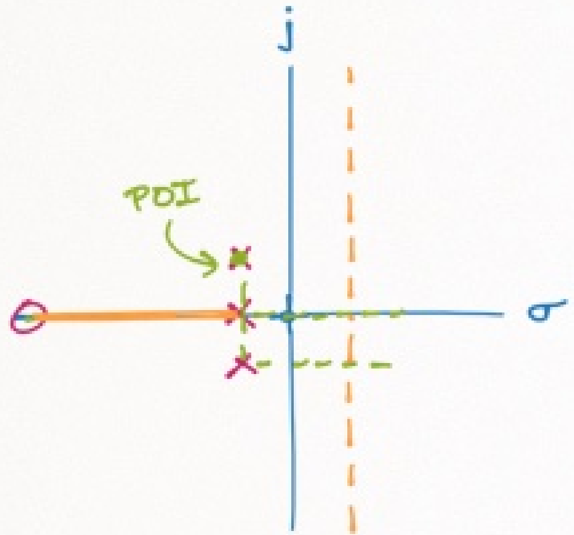
determine using angle criteria, $XS = \#p - \#z = 3 - 1 = 2$ $\qquad \sigma_A = \dfrac{\Sigma p - \Sigma z}{XS} = \dfrac{-1 + (-1-j) + (-1+j) - (-5)}{2}$

\# assymptotes

2 ASSYMPTOTES $\therefore \pm 90^\circ$ $\qquad \sigma_A = 1$



for all complex poles & zeros, compute departure / arrival angles



ANGLE CRITERIUM

$\theta = \tan^{-1}\frac{1}{4}$

DEPARTURE ANGLE OF COMPLEX POLES

$$\sum P - \sum Z = 180$$

$$90 + 90 + \theta - \tan^{-1}\frac{1}{4} = 180$$

$$\theta = \tan^{-1}\frac{1}{4} = 14.03^\circ$$

ARRIVAL ANGLE FOR COMPLEX POLES

there aren't any for some reason

compute breakpoints

$$\frac{d}{ds}\frac{1}{GH} = \emptyset$$

$$\frac{d}{ds}\frac{s^2+2s+2}{s+5} = \emptyset$$

$$\frac{d}{ds}(s+5)^{-1}(s^2+2s+2)$$

$$(s^2+2s+2)\frac{d}{ds}(s+5)^{-1} + (s+5)^{-1}\frac{d}{ds}(s^2+2s+2)$$

$$(s^2+2s+2)(-1(s+5)^{-2}\cdot 1) + (s+5)^{-1}(2s+2)$$

$$\frac{-s^2-2s-2}{(s+5)^2} \quad \frac{2s+2}{s+5}$$

is system stable for all positive values of K? If so, compute max K value.

$s^3 \quad 1 \quad 4$
$s^2 \quad 3 \quad 2+k$
s^1
0^0

$\cancel{-\frac{1}{3}(2+k-12) > \phi}$
$\cancel{k > 10}$

$(s^2+2s+2)(1+s)$

$s^2+2s+2+s^3+2s^2+2s$

$s^3+3s^2+4s+2+K$

GH

$s^2 \quad 1 \quad 2+k$
$s^1 \quad 2 \quad 0$
s^0

$\cancel{-\frac{1}{2}(-2(2+k)) > 0}$
$\cancel{2+k > 0}$
$\cancel{k > 2}$

G

$$\frac{G}{1+GH} = \frac{\dfrac{k(s+5)}{s^2+2s+2}}{1+\dfrac{k(s+5)}{(s^2+2s+2)(s+1)}} = \frac{\sim\!\sim}{(s+1)(s^2+2s+2)+k(s+5)}$$

$\cancel{s^2}+\cancel{2s}+2+\cancel{s^3}+\cancel{2s^2}+\cancel{2s}+\cancel{ks}+k5$

$s^3+3s^2+(4+k)s+2+k5$

$1 \quad 4+k$
$3 \quad 2+k5$

$-\frac{1}{3}(2+k5-12-3k) > 0$

$-\frac{1}{3}(-10+2k) > 0$

$2k > 10$

$k > 5$

compute the frequency when the system is marginally stable

$K = 5$

$s^3 + 3s^2 + (4+K)s + 2 + 5K$

$s^3 + 3s^2 + 9s + 27$

$(s+3)\underbrace{(s^2+9)}_{s \pm 3j}$

$\underline{s \pm 3j}$

frequency is $3 \frac{rad}{s}$

using ziegler nichols compute PID gains

$K_p = 0.6 K_u = 0.6(5) = \underline{3}$

$K_I = 1.2 \, K_u / T_u = 1.2 \, \frac{5}{\frac{2\pi}{3}} = \underline{2.86}$

$K_D = 0.075 K_u T_u = 0.075 \cdot \frac{2\pi}{3} \cdot 5 = \underline{0.785}$

$T_u = \frac{2\pi}{f} = \frac{2\pi}{3}$

QUIZ #4

$$KGH = \frac{10^8(s+100)}{(s+10)^2(s^2+1600s+10^6)}$$

write in correct form for drawing bode plot

$$K_{DC} = 10^8 10^2 \frac{1}{10^1 10^1 10^3 10^3}$$

$$= \frac{10^{10}}{10^8} = 10^2$$

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

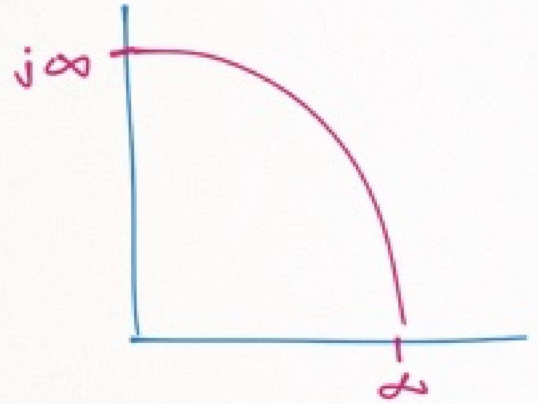
$$= \frac{-1600}{2} \pm \frac{\sqrt{1600^2 - 4(10^6)}}{2}$$

$$= -800 \pm 600$$

$$10^2 \frac{1+\frac{s}{100}}{\left(\frac{s}{10}+1\right)^2\left(\frac{s}{-800,600}+1\right)\left(\frac{s}{-800,-600}+1\right)}$$

draw associated Nyquist contour in s-domain, transform any points that do not appear on the bode plot into the u+jv domain

no zeros or poles @ $\sigma = \emptyset$



draw the magnitude & frequency bode plots

entry point $= 20\log K_{DC} = 20\log 100 = 20 \cdot 2 = 40\,dB$

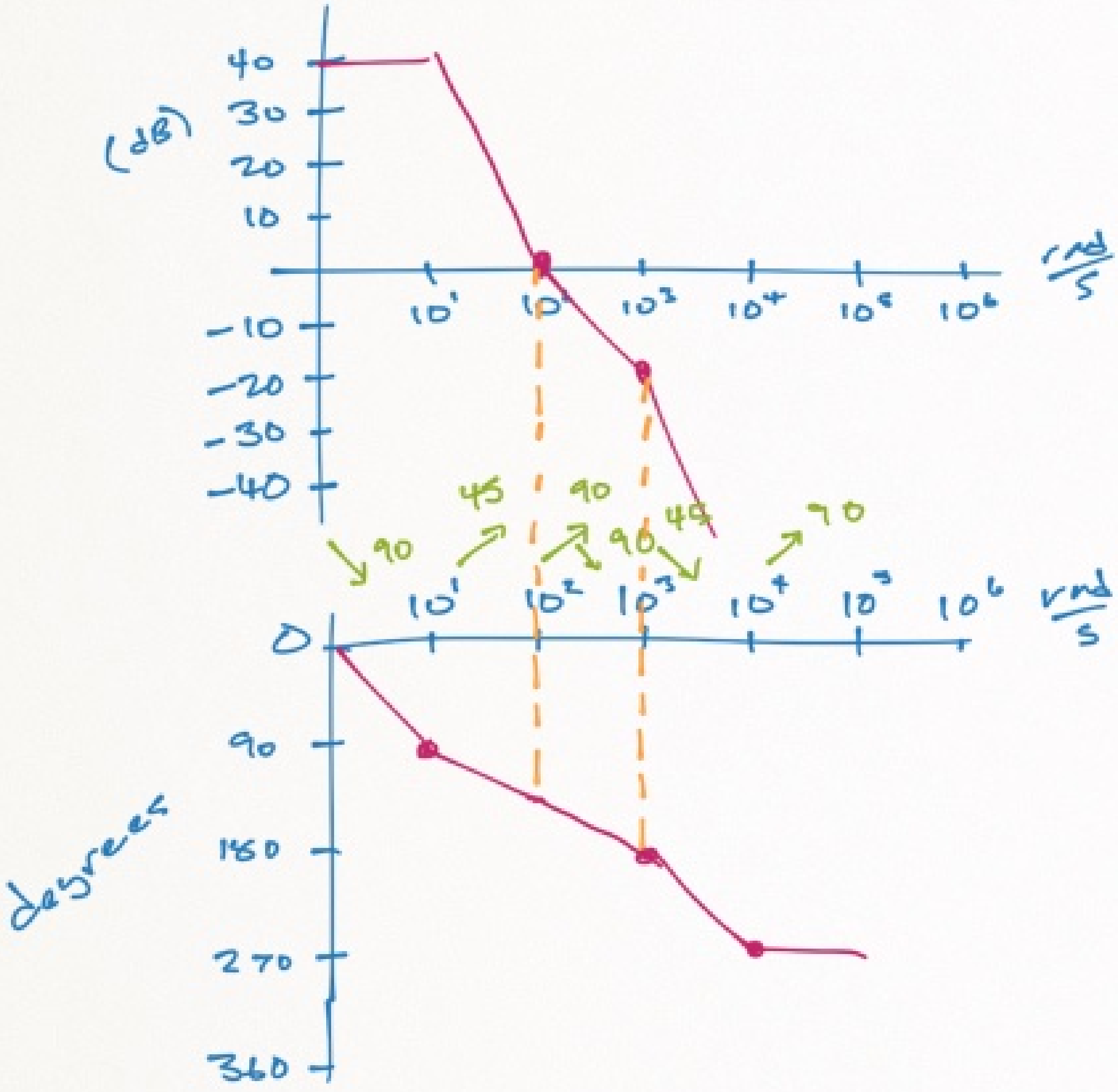
no pole or zero @ $\emptyset$ so it's slope coming in is @ $0\frac{dB}{dec}$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \det \begin{vmatrix} d & -b \\ -c & a \end{vmatrix}$$

@ 10^1 2 poles so slope $= -40\frac{dB}{dec}$

@ 10^2 1 zero so slope $= -20\frac{dB}{dec}$

@ 10^3 2 pole so slope $= -60\frac{dB}{dec}$



if magnitude entering at $0\frac{dB}{dec}$ phase enters @ $0°$

if mag enters @ $20\frac{dB}{dec}$ phase enters @ $90°$

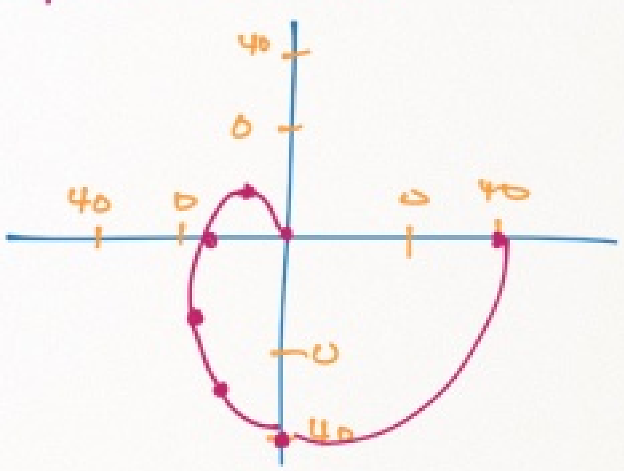
if mag enters @ $40\frac{dB}{dec}$ place enters @ $180°$

determine gain margin, phase margin, crossover frequency

gain margin (gain @ 180° + 180°)

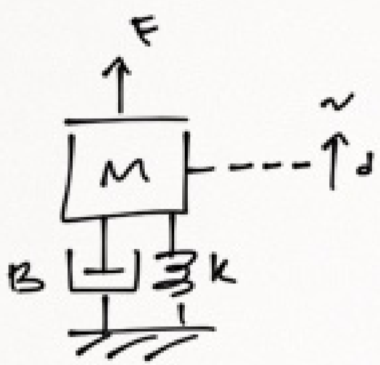
phase margin ($\emptyset$ - phase @ 0dB)

draw nyquist



STATE SPACE REVIEW

Ex)

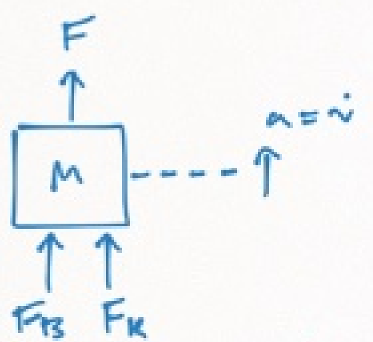


define states

independent values that define energy in the system

states: v & d

do free body diagram



always choose forces in the same direction

$$F_B + F_K + F = m\dot{v}$$
$$Bv + Kd + F = m\dot{v}$$

these are (-)ive WHY?

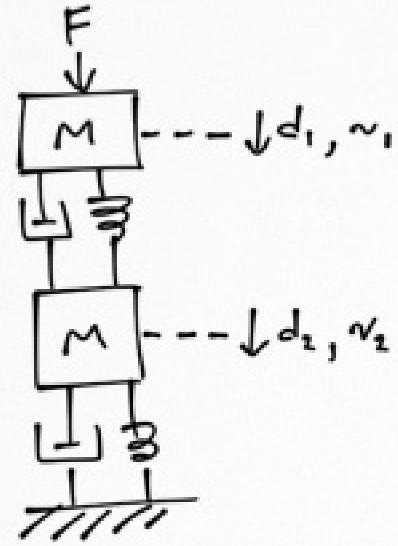
put in the form $\dot{\bar{x}} = \bar{\bar{A}}\bar{x} + \bar{\bar{B}}\bar{u}$

$$\dot{\bar{x}} = \begin{vmatrix} \dot{d} \\ \dot{v} \end{vmatrix} \qquad \bar{x} = \begin{vmatrix} d \\ v \end{vmatrix} \qquad \bar{u} = \begin{vmatrix} F \end{vmatrix}$$

$$\dot{d} = A_{11}d + A_{12}v + B_1F \longrightarrow \dot{d} = v \ \therefore \ A_{11} = B_1 = \emptyset,\ A_{12} = 1$$
$$\dot{v} = A_{21}d + A_{22}v + B_2F \longrightarrow \dot{v} = \frac{Bv}{m} + \frac{Kd}{m} + \frac{F}{m}$$

$$\underline{\begin{bmatrix} \dot{d} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} \emptyset & 1 \\ \frac{k}{m} & \frac{B}{m} \end{bmatrix} \begin{bmatrix} d \\ v \end{bmatrix} + \begin{bmatrix} \emptyset \\ \frac{1}{m} \end{bmatrix} F}$$

Ex)



define states

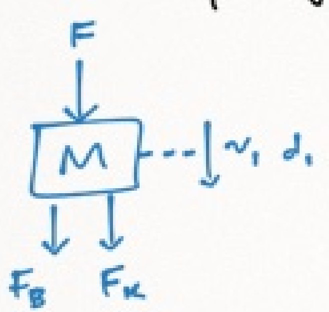
$v_1 \quad v_2 \quad d_1 \quad d_2$

define vectors

$$\bar{x} = \begin{vmatrix} d_1 \\ d_2 \\ v_1 \\ v_2 \end{vmatrix} \qquad \dot{\bar{x}} = \begin{vmatrix} \dot{d}_1 \\ \dot{d}_2 \\ \dot{v}_1 \\ \dot{v}_2 \end{vmatrix} \qquad \bar{u} = \begin{vmatrix} F \end{vmatrix}$$

still don't get signs

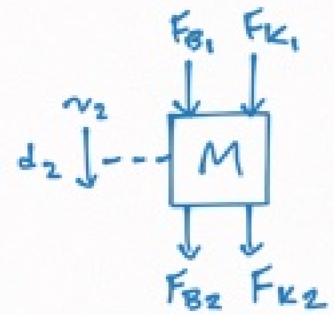
do free body diagrams



$$F_B + F_K + F = m\dot{v}_1$$

$$F_B = B(v_2 - v_1)$$

$$F_K = K(d_2 - d_1)$$



$$F_{B1} + F_{K1} + F_{B2} + F_{K2} = m\dot{v}_2$$

$$F_{B1} = B(v_1 - v_2) \qquad F_{B2} = -Bv_2$$

$$F_{K1} = K(d_1 - d_2) \qquad F_{K2} = -Kd_2$$

$v_2 > v_1$ **WHY?**

define matrices

$$\dot{d}_1 = v_1$$
$$\dot{d}_2 = v_2$$

$$\dot{v}_1 = \frac{Bv_2}{M} + \frac{-Bv_1}{m} + \frac{Kd_2}{m} + \frac{-Kd_1}{m} + \frac{F}{M}$$

$$\dot{v}_2 = \frac{Bv_1}{m} + \frac{-Bv_2}{m} + \frac{-Bv_2}{m} + \frac{kd_1}{m} + \frac{-Kd_2}{m} + \frac{-Kd_2}{m}$$

$$\begin{vmatrix} \dot{d}_1 \\ \dot{d}_2 \\ \dot{v}_1 \\ \dot{v}_2 \end{vmatrix} = \begin{vmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ \frac{-K}{m} & \frac{K}{m} & \frac{-B}{m} & \frac{B}{M} \\ \frac{K}{m} & \frac{-2K}{m} & \frac{B}{m} & \frac{-2B}{M} \end{vmatrix} \begin{vmatrix} d_1 \\ d_2 \\ v_1 \\ v_2 \end{vmatrix} + \begin{vmatrix} 0 \\ 0 \\ 1/M \\ 0 \end{vmatrix} F$$

define output equation

$\bar{y} = \bar{\bar{C}}\bar{x} + \bar{\bar{D}}\bar{u}$, outputs v_1, v_2, d_1, d_2 : Δv, Δd

$$\bar{y} = \begin{vmatrix} \Delta d \\ \Delta v \end{vmatrix} = \begin{vmatrix} -1 & 1 & \emptyset & \emptyset \\ \emptyset & \emptyset & -1 & 1 \end{vmatrix} \begin{vmatrix} d_1 \\ d_2 \\ v_1 \\ v_2 \end{vmatrix} + \begin{vmatrix} \emptyset \\ \emptyset \end{vmatrix} F$$

transform into s-domain using laplace

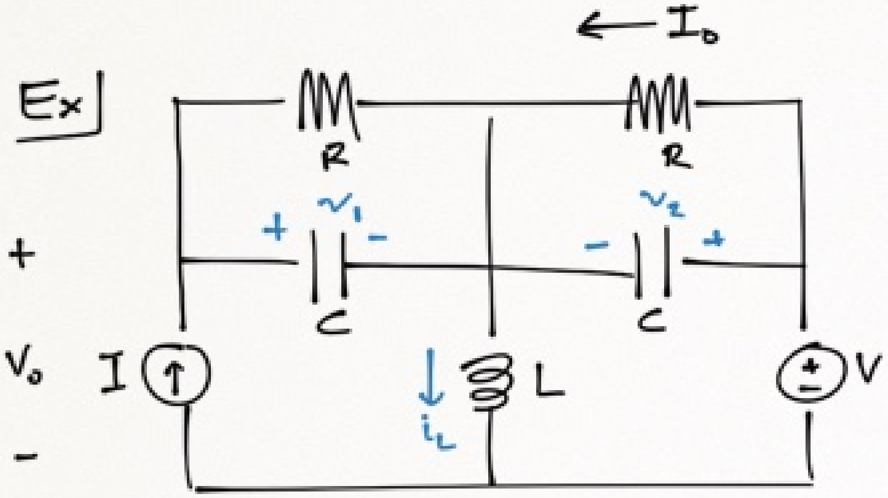
$$\dot{\bar{x}} = \bar{\bar{A}}\bar{x} + \bar{\bar{B}}\bar{u} \xrightarrow{\mathcal{L}} s\bar{x} - \bar{x}_0 = \bar{\bar{A}}\bar{x} + \bar{\bar{B}}\bar{u}$$

$$s\bar{x} - \bar{\bar{A}}\bar{x} = \bar{x}_0 + \bar{\bar{B}}\bar{u}$$

$$\bar{x}\underbrace{(s\bar{\bar{I}} - \bar{\bar{A}})}_{= \bar{\bar{\phi}}} = \bar{x}_0 + \bar{\bar{B}}\bar{u}$$

$$\bar{x} = \underbrace{\bar{\bar{\phi}}\bar{x}_0}_{\text{response to initial conditions}} + \underbrace{\bar{\bar{\phi}}\bar{\bar{B}}\bar{u}}_{\text{response to forcing function}}$$

Ex



define state vectors

$$x = \begin{vmatrix} v_1 \\ v_2 \\ i_L \end{vmatrix} \qquad \dot{x} = \begin{vmatrix} v_1' \\ v_2' \\ i_L' \end{vmatrix} \qquad u = \begin{vmatrix} V \\ I \end{vmatrix}$$

define matrices

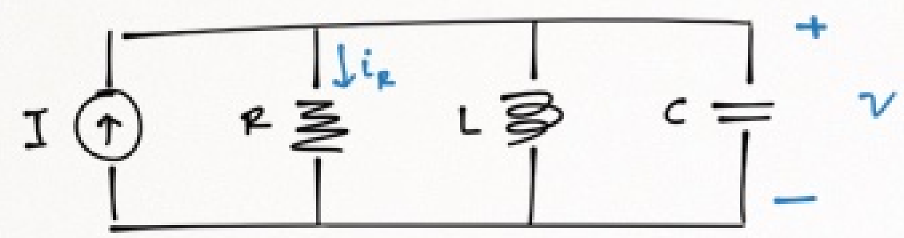
$$i_L = \overbrace{C\dot{v}_1 + \frac{1}{R}v_1}^{I} + C\dot{v}_2 + \frac{1}{R}v_2 \longrightarrow \dot{v}_2 = \frac{i_L}{C} + \frac{-I}{C} + \frac{-1}{RC}v_2$$

$$I = C\dot{v}_1 + \frac{1}{R}v_1 \longrightarrow \dot{v}_1 = \frac{I}{C} + \frac{-1}{RC}v_1$$

$$V - v_2 - L i_L' = 0 \longrightarrow i_L' = \frac{V}{L} - \frac{v_2}{L}$$

$$\begin{vmatrix} \dot{v}_1 \\ \dot{v}_2 \\ i_L' \end{vmatrix} = \begin{vmatrix} \frac{-1}{RC} & 0 & 0 \\ 0 & \frac{-1}{RC} & \frac{1}{C} \\ 0 & \frac{-1}{L} & 0 \end{vmatrix} \begin{vmatrix} v_1 \\ v_2 \\ i_L \end{vmatrix} + \begin{vmatrix} 0 & \frac{1}{C} \\ 0 & -\frac{1}{C} \\ \frac{1}{L} & 0 \end{vmatrix} \begin{vmatrix} V \\ I \end{vmatrix}$$

Ex



state vectors

output : i_R

input : I

$x = \begin{vmatrix} v_c \\ i_L \end{vmatrix}$ $\quad \dot{x} = \begin{vmatrix} \dot{v}_c \\ i_L' \end{vmatrix}$ $\quad I = i_R + i_L + i_c$ $\quad v_L = i_L s L$ $\quad u = |I|$

$I = \frac{v}{R} + i_L + Csv$ $\quad \rightarrow s i_L = i_L' = \frac{v}{L}$

state matrices $\quad \rightarrow sv = v' = \frac{-v}{RC} + \frac{I}{C} + \frac{-i_L}{C}$

$$\begin{vmatrix} v_c' \\ i_L' \end{vmatrix} = \begin{vmatrix} -\frac{1}{RC} & -\frac{1}{C} \\ \frac{1}{L} & \emptyset \end{vmatrix} \begin{vmatrix} v_c \\ i_L \end{vmatrix} + \begin{vmatrix} \frac{1}{C} \\ \emptyset \end{vmatrix} |I|$$

output equation

$$\bar{y} = \bar{C}\bar{x} + \bar{D}\bar{u}$$

$$|i_R| = \begin{vmatrix} \frac{1}{R} & \emptyset \end{vmatrix} \begin{vmatrix} v_c \\ i_L \end{vmatrix} + |\emptyset| I$$

ϕ, **WHAT DOES THIS EVEN MEAN?**

$$\phi = [sI - A]^{-1}$$

$$= \left(\begin{vmatrix} s & \emptyset \\ \emptyset & s \end{vmatrix} - \begin{vmatrix} \frac{-1}{RC} & \frac{-1}{C} \\ \frac{1}{L} & \emptyset \end{vmatrix} \right)^{-1}$$

$$= \begin{vmatrix} s + \frac{1}{RC} & \frac{1}{C} \\ -\frac{1}{L} & s \end{vmatrix}^{-1}$$

$$\phi = \frac{1}{s^2 + \frac{s}{RC} - \frac{1}{LC}} \begin{vmatrix} s & -\frac{1}{C} \\ \frac{1}{L} & s + \frac{1}{RC} \end{vmatrix}$$

get transfer function

$$T(s) = \frac{Y}{U} = \bar{\bar{C}}\,\bar{\bar{\phi}}\,\bar{\bar{B}} + \bar{\bar{D}}$$

$$\frac{Y}{U} = \begin{bmatrix} \frac{1}{R} & \varnothing \end{bmatrix} \frac{1}{s^2 + \frac{s}{RC} + \frac{1}{LC}} \begin{bmatrix} s & \frac{-1}{C} \\ \frac{1}{L} & s + \frac{1}{RC} \end{bmatrix} \begin{bmatrix} \frac{1}{C} \\ \varnothing \end{bmatrix} + \begin{bmatrix} \varnothing \end{bmatrix}$$

$$= \frac{1}{s^2 + \frac{s}{RC} + \frac{1}{LC}} \begin{bmatrix} \frac{s}{R} & \frac{-1}{RC} \end{bmatrix} \begin{bmatrix} 1/C \\ \varnothing \end{bmatrix}$$

$$= \frac{\frac{s}{RC}}{s^2 + \frac{s}{RC} + \frac{1}{LC}}$$ ← CHARACTERISTIC EQUATION

get roots of CE

$$\det(\bar{\bar{A}}) = \det(\lambda \bar{\bar{I}} - \bar{\bar{A}}) = \varnothing$$

$$\text{CE:} \quad s^2 + \frac{1}{RC}s + \frac{1}{LC} = \varnothing$$

$$s = \frac{\frac{-1}{RC} \pm \sqrt{\frac{1}{R^2C^2} - \frac{4}{LC}}}{2}$$

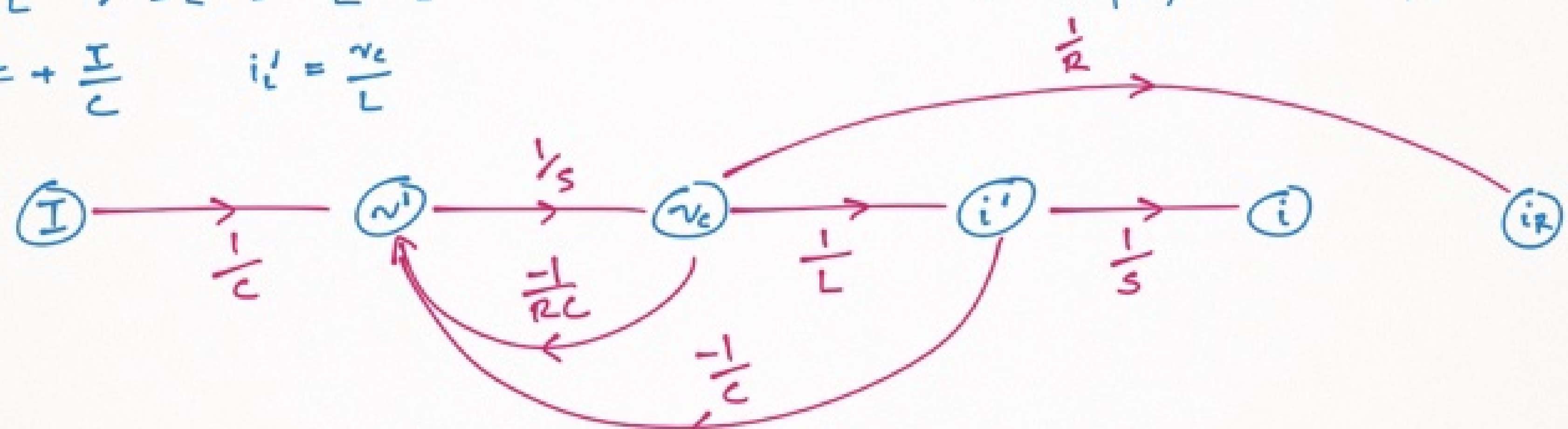
draw signal flow diagram

$$\begin{bmatrix} v_c' \\ i_L' \end{bmatrix} = \begin{bmatrix} \frac{-1}{RC} & \frac{-1}{C} \\ \frac{1}{L} & \varnothing \end{bmatrix} \begin{bmatrix} v_c \\ i_L \end{bmatrix} + \begin{bmatrix} 1/C \\ \varnothing \end{bmatrix} I$$

inputs: I

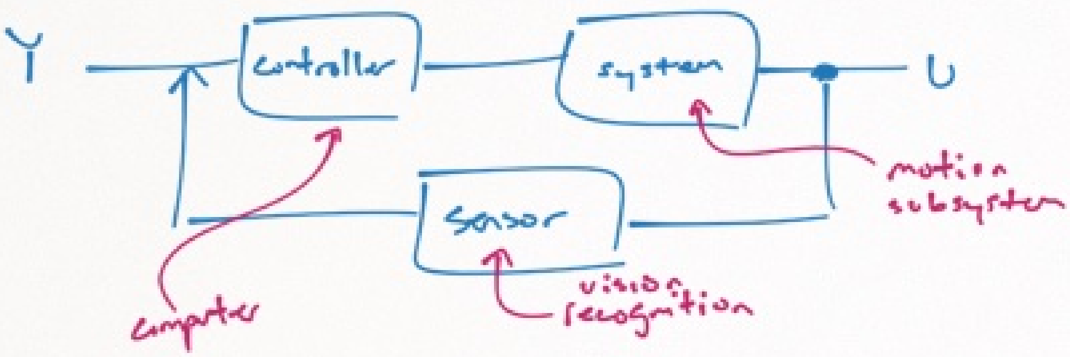
$$i_R = \begin{vmatrix} 1/R & \varnothing \end{vmatrix} \begin{vmatrix} v \\ i \end{vmatrix} + \varnothing I = \frac{v}{R}$$

$$v' = \frac{-v}{RC} + \frac{-i_L}{C} + \frac{I}{C} \qquad i_L' = \frac{v_c}{L}$$

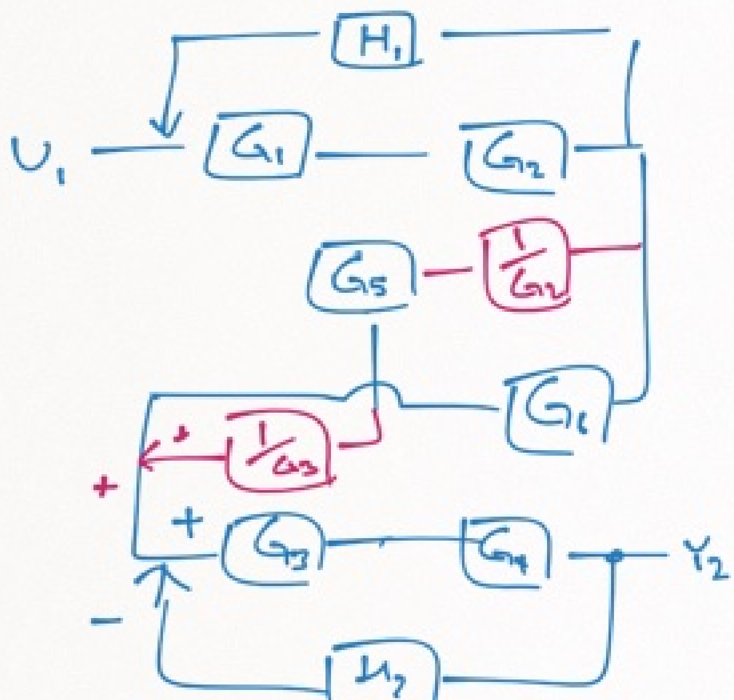


QUIZ #1

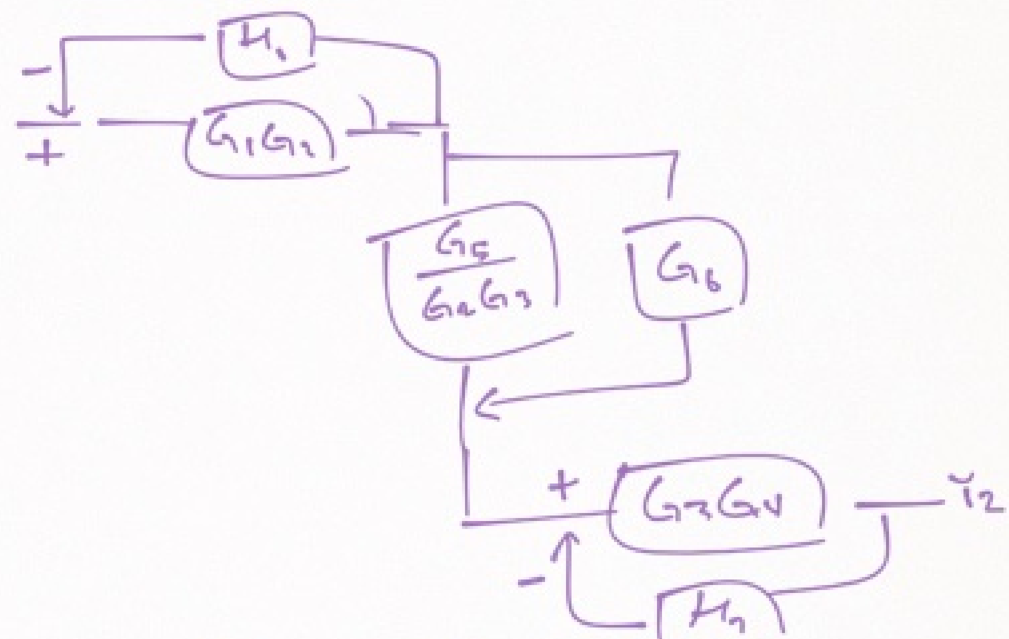
sketch block diagram of control whatever



determine $\frac{Y_2}{U_1}$



superposition $U_2 = \emptyset$, $Y_1 = \emptyset$



$$\frac{Y_2}{U_1} = \left(\frac{G_1G_2}{1+H_1G_1G_2}\right)\left(\underbrace{\frac{G_5}{G_2G_3} + \frac{G_6 G_2G_3}{G_2G_3}}_{\frac{G_5 + G_6G_2G_3}{\quad}}\right)\left(\frac{G_3G_4}{1+H_2G_3G_4}\right)$$

$G_5 = -G_6G_2G_3$

QUIZ #3

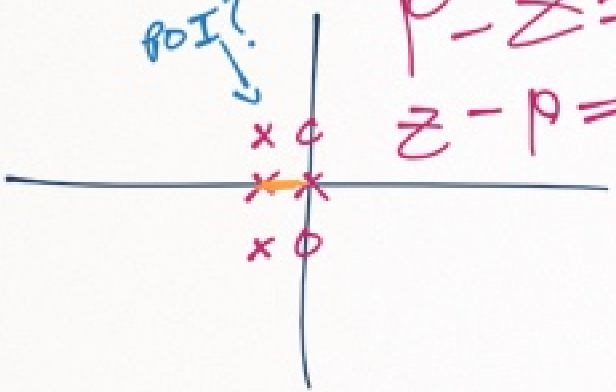
$$\frac{\pi}{\omega_n\beta} = \frac{4}{\zeta\omega_n} = \frac{\pi}{\sqrt{1-\zeta^2}\,\omega_n}$$

root locus of $\frac{k(s^2+1)}{s(s+1)(s^2+2s+2)} = KGH$

zeros @ $\pm j$

poles @ $-1, -1+j, -1-j, 0$

$$\frac{-2 \pm \sqrt{4-4\cdot 2}}{2}$$



$P - Z = 180$

$Z - P = 180$

$$\frac{-1 \pm \sqrt{-4}}{2} = -1 \pm j$$

$\#P - \#Z = XS = 4 - 2 = 2$

$$\frac{-1-1-1}{XS} = \frac{-3}{2} = \frac{-3}{2}$$

$\phi_A = \pm 90°$

$\sigma_A = \frac{-3}{2}$

$(s^2+s)(s^2+2s+2) + k(s^2+1)$

$(s^4 + 2s^3 + 2s^2 + s^3 + 2s^2 + 2s) + k(s^2+1)$

$(s^4 + 3s^3 + 4s^2 + 2s) + k(s^2+1)$

$\Sigma P_\theta - \Sigma Z_\theta = \pm 180$

$90 + 90 + 45 + \theta - 180 - 90 - 27 = 180$