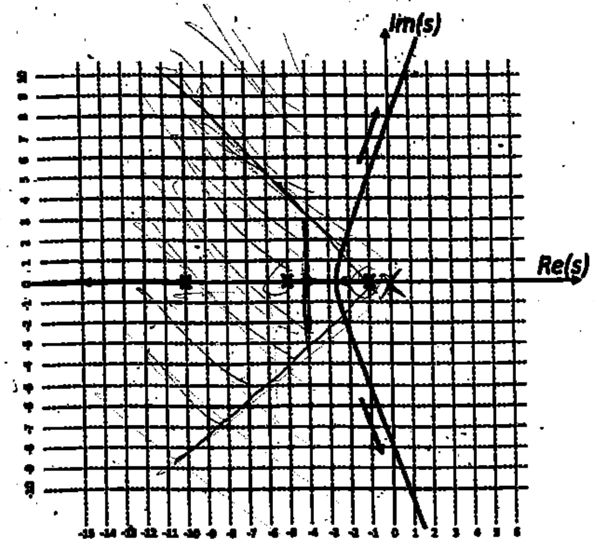
Universidad del País Vasco / Euskal Herriko Unibertsitatea		Ikasturtea: 2014/2015
	Izena ______	2015/Urtarrila/9
	1. Abizena ______	Iraupena: 2 ordu 15min
	2. Abizena ______	Taldea

1.1 irudiko Erroen Toki Geometrikoa irabazpen estatiko unitarioa duen planta bati dagokio.



1.1 irudia- Plantaren Erroen Toki Geometrikoa

1. Kontrolatu beharreko plantaren transferentzi funtzioa kalkula ezazu.
2. Maila aurrean errore nulua, egonkortze-denbora segundo bat baino txikiagoa (%2 irizpidea) eta gaindipen maximoa %4.3 izango direla ziurtatzen duen kontrolagailurik sinpleena, zein den adierazi ezazu, kalkulu zehatzik egin gabe. Justifika ezazu zure erantzuna Erroen Kokapen Geometrikoa erabiliz.
3. Aurreko atalean adierazitako eskakizunak betetzen dituen kontrolagailuaren parametroak kalkula itzazu.

a)

$$G(s)=\frac{50}{(s+10)(s+5)(s+1)}$$

b)

PI kontrolagailu batek ez du betetzen, hortaz, PID:

$G_c(s)=K_c\left(1+\frac{1}{8}s+\frac{1}{1.2s}\right)$, non $K_c \in (3,6)$

$Q(S)\left[S^2+2.8S+400\right]=T(S)\left[56.25S+4\right.$

5.

	[redacted]	Ikasturtea: 2014/2015 2015/Urtarrila/9
	Izena ______________	Iraupena: 2 ordu 15min
	1. Abizena ______________	
	2. Abizena ______________	Taldea

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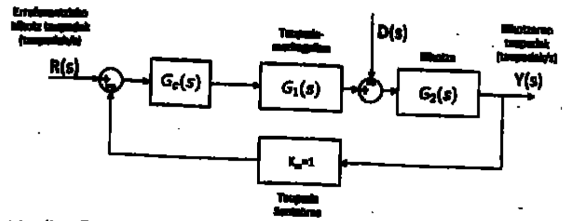
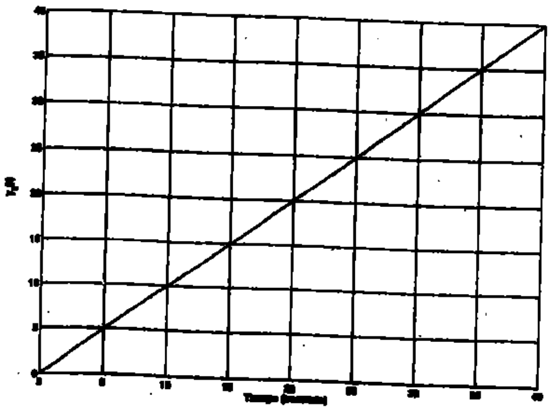
Taupada-markagailu elektronikoek bihotzaren odol-ponpaketa erregulatzen dute. 2.1 irudiak taupada-markagailuaren eta bihotzaren dinamika hurbilduan oinarritutako kontrol sistema bat adierazten du.

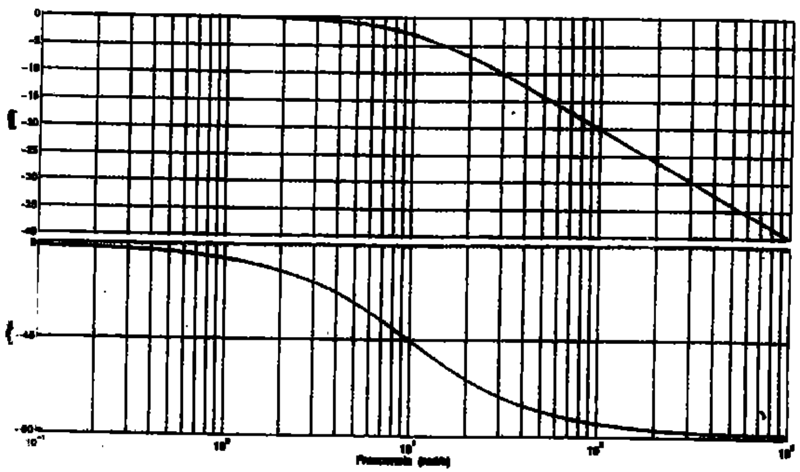


2.1 Irudia – Taupada-markagailuaren bidezko bihotz taupaden kontrol sistema

$G_2(s)$ bihotzaren erantzuna maila sarrera unitarioaren aurrean (2.2. irudia) ezaguna da, baita $G_1(s)$ taupada-markagailuaren Bode diagrama ere (2.3. irudia).



2.2 Irudia- $G_2(s)$ sistemaren erantzuna maila unitarioari.



2.3 Irudia - $G_1(s)$ sistemaren Bode diagrama

1. $G_1(s)$ eta $G_2(s)$ transferentzi funtzioak kalkula itzazu.

2. Diseina ezazu ondorengo eskakizunak betetzen dituen $G_c(s)$ kontrolagailurik sinpleena, aukeraketa justifikatuz:

   - Sistema berrelikatuaren gaindipen maximoa %10-a baino txikiagoa erreferentzia aldaketen aurrean.
   - Erreferentzia maila sarrera denean egonkortze denbora 6s baino txikiagoa (%5-ko irizpidea).
   - %20ko errore maximoa perturbazioa maila sarrera denean.

3. Aurreko ataleko baldintzak mantenduz (gaindipena eta errorea), begizta itxiko sistemaren egonkortze denbora txikitu nahi da, gehienez 0.25 segundo izanez. Justifika ezazu ea aurreko atalean diseinatutako kontrolagailuak baldintza berri hauek betetzeko gai den edo ez. Ezin bada, aurreko eta atal honetako eskakizunak beteko dituen kontrolagailu berri bat diseina ezazu.

1)

$$G_1(s) = \frac{10}{s+10}$$

$$G_2(s) = \frac{1}{s}$$

2)

$G_c(s) = K_c$, non $K_c \in (5{,}7.19)$

3)

$G_c(s) = K_c(1 + T_d s)$, non $K_c > 12$ eta $T_d = 0.1$

	Izena ______________	Ikasturtea: 2014/2015 2015/Urtarrila/9
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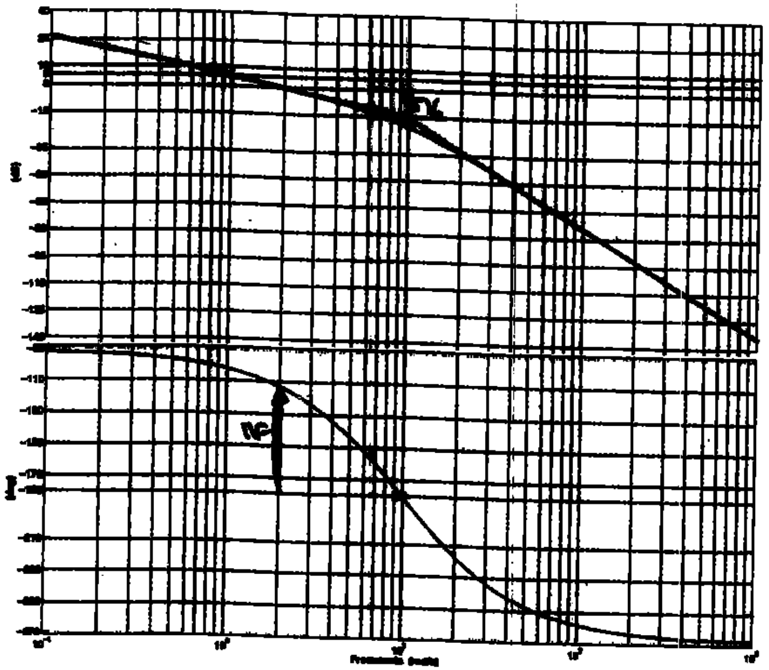
3.1 Irudian begizta irekiko sistema baten maiztasun-erantzuna adierazten da.



3.1 Irudia – Begizta irekiko sistemaren Bode Diagrama

1. Polo guztiak errealak direla eta ezker plano-erdian daudela jakinik, identifika ezazu dagokion transferentzi funtzioa.
2. Planta hau aintzat hartuz, sistema berrelikatu egiten da 1 irabazpena duen sentsore batekin. Zein izango da egoera iraunkorrean sistema berrelikatuak aurkeztuko duen errorea 2 maldako arrapala baten aurrean?
3. Azter ezazu sistema berrelikatuaren egonkortasun erlatiboa.
4. Noraino handitu daiteke begizta irekiko sistemaren irabazpena sistema ezegonkortu aurretik?

1)

$$G(s) = \frac{199.5}{s(s+10)^2}$$

2)

$$e_{ssv} \approx 1$$

3)

Bode diagraman oinarrituta MG eta MF kalkula ditzakegu, gutxi gora behera, MG=15dB eta MF=70º. Biak positiboak direnez, sistema egonkorra da 1 irabazpena duen sentsorearekin berrelikatzean,

4)

$$K_{cmax} = 5.62$$

2015/urtarrila/ 09

(1) Ariketa

3) ETG-ko irudi bat . Irabazpen unitarioa !!

1) Kontrolatu beharreko plantaren trsf.-funtzioa kalkulatu.

$K_v = \lim_{s \to 0} GH = 1$

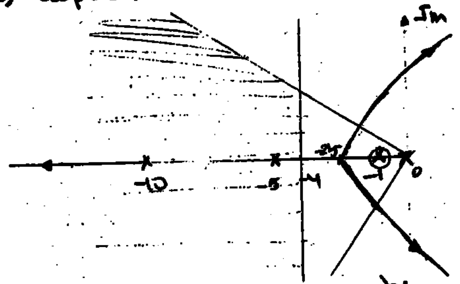
$K_v = \frac{K}{1 \cdot 5 \cdot 10} = 1 \longrightarrow \underline{K = 50}$

$$\boxed{G(s) = \frac{50}{(s+1)(s+5)(s+10)}}$$

✓

- Si queremos evitar error → PI
- Si queremos evitar la oscilación → PD

2) $e_{ssp} = 0$. $t_s(\%2) \leq 1s$. $M_p \leq \%4.3$ → kontrolagailuak sinpleena.



- $t_s(\%2) \leq 1s \rightarrow \zeta\omega_n \geq 4$

R

- $M_p \leq \%4.3 \rightarrow \zeta \geq 0.707$

$\downarrow$

$\theta \leq 45°$

- $e_{ssp} = 0$ izan behar du → ~~R~~

- PI kontrolagailua

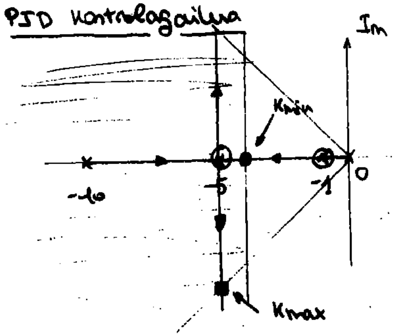
$G_c(s) = \frac{K_c(s+T_i)}{s}$ non $T_i = 1$

- $\sigma = \frac{\Sigma z - \Sigma p}{n-m} = \frac{1-10-5-1-0}{4-1} = -5$

- $\theta_k = \frac{(2k+1)\pi}{n-m}$,

- ETG-ari illusiz, ez dago gure espezifikazioen barrean.

- PID kontrolagailua



- $M_p \leq \%4'3 \rightarrow \delta \geq 0.707 \rightarrow \theta \leq 45^\circ$
- $t_s(\%2) \leq 1s \rightarrow \delta\omega_n \geq 4$

$$G_{PID}(s) = \frac{K_c\left(\frac{1}{T_i}+s\right)(1+T_d s)}{s}$$

$$G(s)H(s) = \frac{K\cancel{(s+1)}\cancel{(s+5)}}{s(s+10)\cancel{(s+5)}\cancel{(s+1)}} = \frac{K}{s(s+10)} \qquad K=(K_c\cdot T_d)\cdot 50$$

$$1+GH=0 \longrightarrow s^2+10s+K=0$$
$$s^2+2\delta\omega_n s+\omega_n^2=0$$

$$\left.\begin{array}{l} 10 = 2\delta\omega_n \\ K = \omega_n^2 \end{array}\right\} \xrightarrow{K_{min}} \left\{\begin{array}{l} \delta = 1 \\ \omega_n = 5 \\ K = 25 \end{array}\right. \rightarrow K_c = \frac{25\cdot 6}{50} = 3$$

$\downarrow K_{max}$

$$\left\{\begin{array}{l} \delta = 0.707 \\ \omega_n = 7.07 \\ K = 50 \end{array}\right. \rightarrow K_c = \frac{50\cdot 6}{50} = 6$$

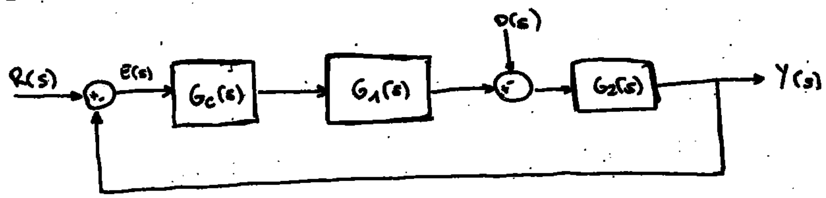
$$\Rightarrow K_c \in (3, 6)$$

$$\rightarrow K_c\left(1+\frac{1}{T_i s}+T_d s\right) = K_c\cdot T_d\,\frac{s^2+\frac{1}{T_d}s+\frac{1}{T_i T_d}}{s} = \frac{K}{50}\cdot\frac{\overbrace{(s+1)(s+5)}^{s^2+6s+5}}{s}$$

$$\left\{\begin{array}{l} K_c\cdot T_d = \frac{K}{50} \\ \frac{1}{T_d} = 6 \\ \frac{1}{T_i T_d} = 5 \end{array}\right. \rightarrow \left\{\begin{array}{l} T_d = \frac{1}{6} \\ T_i = \frac{6}{5} \\ K_c = \frac{6}{50} \end{array}\right.$$

$$\Rightarrow \boxed{G_{PID}(s) = K_c\left(1+\frac{1}{1.2s}+\frac{1}{6}s\right)}$$

② Ariketa



(*) $G_2(s)$ -en erantzuna maila sarrera unitario

(*) $G_1(s)$ -en BODE Diagrama.

1) $G_1(s)$ eta $G_2(s)$ transferentzi funtzioak kalkulatzea.

• $\boxed{\text{BODE}}$

$0 = 20 \log K \rightarrow \underline{K=1}$

$$\underline{G_1(s)} = \frac{1}{(0.1s+1)} = \underline{\frac{10}{(s+10)}}$$

•

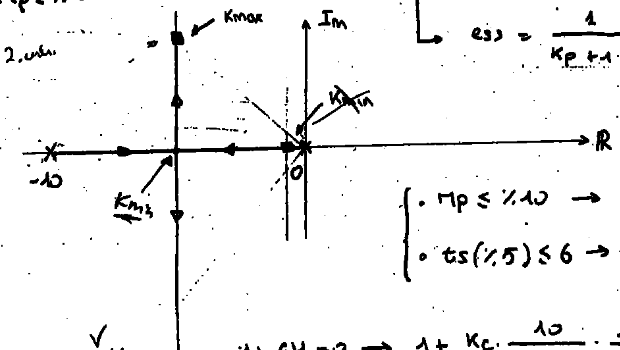
$y_2(t) = t$

$$Y_2(s) = \frac{1}{s^2} = G_2(s)\cdot\frac{1}{s} \rightarrow \underline{G_2(s) = \frac{1}{s}}$$

2) $M_p \le \%10$. $t_s(\%5) \le 6s$. $e_{ss_m} \le \%20$

Aplikatu 2.ordena

$$e_{ss} = \frac{1}{K_p+1} = 0.2 \rightarrow \underline{K_p = 4}$$



• $M_p \le \%10 \rightarrow \xi \ge 0.591 \rightarrow \theta \le 53.76°$

• $t_s(\%5) \le 6 \rightarrow \xi\omega_n \ge 0.5$

→ P kontrolagailua

$G_c(s) = K_c$

$1+GH=0 \rightarrow 1+K_c\cdot\frac{10}{s+10}\cdot\frac{1}{s} = s^2+10s+10K_c = 0$ $(K_c>0)$

$$\bullet\, E(s) = \frac{R(s)}{1+G_cG_1G_2} - \frac{G_2\cdot D(s)}{1+G_cG_1G_2} = \frac{s(s+10)}{s^2+10s+10K_c}\,\overset{1/s}{R(s)} - \frac{s+10}{s^2+10s+10K_c}\,\overset{1/s}{D(s)}$$

$$e_{ss} = \lim_{s\to 0} s\cdot E(s) = \left|0 - \frac{10}{10K_c}\right| \le 0.2 \rightarrow \underline{K_c \ge 5}$$??

$\rightarrow \; s^2 + 10s + (10+K_c) = s^2 + 2\delta w_n s + w_n^2$

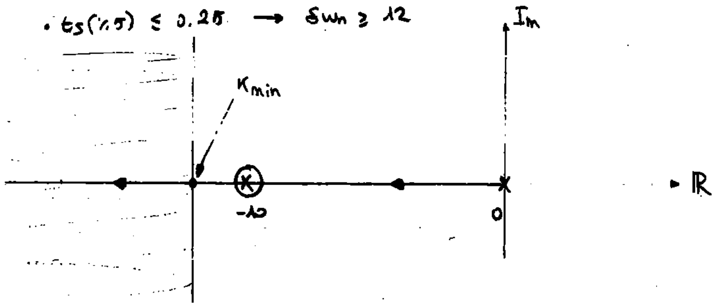
$$\left\{\begin{array}{l} 10 = 2\delta w_n \\ 10+K_c = w_n^2 \end{array}\right. \xrightarrow{K_{max}} \left\{\begin{array}{l} \delta = 0.591 \\ w_n = 8.46 \text{ rad/s} \\ K_c = 7.16 \end{array}\right.$$

$\downarrow K_m$

$$\left\{\begin{array}{l} \delta = 1 \\ w_n = 5 \\ K = 2.5 \end{array}\right. \Rightarrow \boxed{K_c \in (5,\; 7.16)}$$

3) $ts(\%5) \leq 0.25\,s \rightarrow$ Kontrolagailua ?

- $ts(\%5) \leq 0.25 \rightarrow \delta w_n \geq 12$



- P kontrolagailua eskeraka ez dagolako gure gureo $\rightarrow$ PD erabili:

$G_c(s) = K_c\,(1 + Td\cdot s) \rightarrow$ non $\underline{Td = 0.1}$

$1 + GH = 1 + K_c\,(\cancel{1+0.1\cdot s})\,\dfrac{1}{(\cancel{0.1s+1})\,s} = s + K_c = 0$

1go. ordenakoa dres $\longrightarrow \tau = \dfrac{1}{12}$ eta $\boxed{\tau s + 1 = \dfrac{s}{K_c} + 1}$

$\Rightarrow \boxed{K_c > 12}$

(3.) Ariketa

① Begiratu irudiko BODE DIAGRAMA

1) Trasf. funtzioa?

$$\underline{G_{BA}(s)} = \frac{2}{s\cdot\left(\frac{s}{10}+1\right)^2} = \underline{\frac{200}{s(s+10)^2}}$$

2) Berelikatu irabaz. 1 izanda.

Egoera iraunkorrean edukiko duen errorea 2 maldako arrapala baten aurrean?

$$K_v = \lim_{s\to 0} s\cdot GH = 2$$

$$e_{ssv} = \frac{2}{K_v} \longrightarrow \underline{e_{ss_v} = 1}$$

3) Aztertu esazu sistema berelikatuaren egonkortasun erlatiboa.

Diagramatik lortu $\longrightarrow \begin{cases} MG = 15\,dB \\ MF = 70^\circ \end{cases} \Rightarrow$ <u>EGONKORRA</u>

4) Noraino handitu daiteke BA-ren irabazpena sistema ezegonkortu aurretik?

$$1 + GH = 0 \longrightarrow 1 + \frac{200\,K_c}{s(s+10)^2} = 0 \longrightarrow s^3 + 20s^2 + 100s + 200\,K_c = 0$$

$\downarrow$

$K_c > 0$

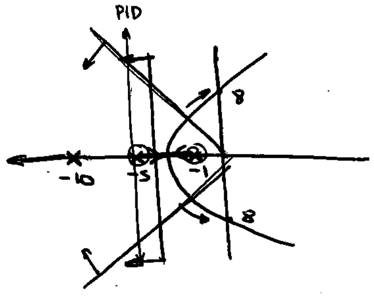
s^3	1	100
s^2	20	$200K_c$
s^1	$100-10K_c$	0
s^0	$200K_c$	0

$\longrightarrow K_c < 10$

$$\rightarrow MG = 20\log K_{cr} \longrightarrow 15 = 20\log K_{cr} \Rightarrow \underline{\underline{K_{cr} = 5.62}}$$

2015 URT

[redacted] ETG kest unitario duen planta bati dagokio



a) ~~ks~~ Plantaren trasf funtzio?

b) $\lrcorner$ ess=0 kontrolagailu?
ts(%2) < 1s
Mp < %4,3

ETG erabili

a) 3 polo $\rightarrow$ $\dfrac{k}{(s+1)(s+5)(s+10)}$ $\rightarrow$ $\boxed{G(s) = \dfrac{50}{(s+1)(s+5)(s+10)}}$

$$K_{est} = 1 = \lim_{s\to 0} \frac{k}{(s+1)(s+5)(s+10)} \Rightarrow \frac{k}{50} = 1 \rightarrow k = 50$$

b) ① ESKAKIZUNAK

- $Mp < \%4,3 \rightarrow \delta \geq \sqrt{\dfrac{\ln Mp^2}{\ln Mp^2 + \pi^2}} \geq 0{,}707 \rightarrow \boxed{\theta \leq 45^\circ}$
- $ts_s(\%2) < 1s \rightarrow \dfrac{4}{\delta \cdot w_n} < 1 \rightarrow \boxed{\delta \cdot w_n > 4}$

② KONT AUK

$\lrcorner$ ess=0 izateko 1 mota behar $\rightarrow$ PI Ez da betetzen

$\boxed{PID}$ $\quad G_c(s) = \dfrac{K_c\, T_d(s^2 + s/T_d + 1/T_iT_d)}{s}$

$$G_{BA} = G_c(s)\cdot G(s) = \frac{K_cT_d(s^2 + \overbrace{s/T_d}^{z_1} + \overbrace{1/T_iT_d}^{z_2})\,50}{s\,(s+1)(s+5)(s+10)}$$

$$= \frac{50K_cT_d\,(s+\overset{1}{z_1})(s+\overset{5}{z_2})}{s\,\cancel{(s+1)}\cancel{(s+5)}(s+10)} \underset{\substack{z_1=1\\ z_2=5}}{=} \frac{50K_cT_d}{s(s+10)}$$

$$G_{BC}(s) = \frac{G_{BA}(s)}{1+G_{BA}(s)} = \frac{50K_cT_d/s(s+10)}{1+} = \frac{50K_cT_d}{s(s+10)+50K_cT_d}$$

$$\longrightarrow \quad (s+1)(s+5) = s^2+6s+5 = s^2 + \frac{s}{T_d} + \frac{1}{T_dT_i} \qquad \begin{cases} 6 = \frac{1}{T_d} \rightarrow \boxed{T_d = 1/6} \\ 5 = \frac{6}{T_i} \rightarrow \boxed{T_i = 6/5} \end{cases}$$

$$G_{BC}(s) = \frac{50/6\, K_c}{s(s+10) + \frac{50}{6}K_c}$$

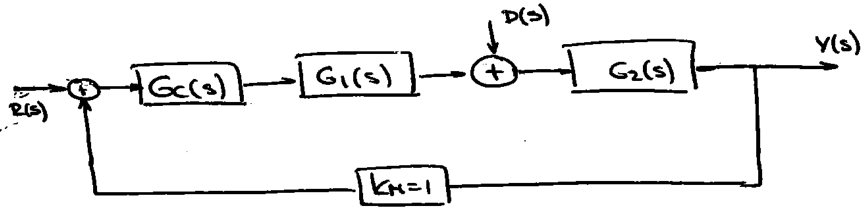
- $K_{c\,MAX} \longrightarrow \quad \xi = 0{,}707$

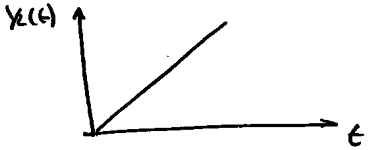
$$G_{BC}(s) = \frac{50/6\, K_c}{s^2+10s+\frac{50}{6}K_c} = \frac{K\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2} \qquad \begin{cases} 10 = 2\cdot 0{,}707\cdot\omega_n \\ \quad \hookrightarrow \omega_n = 7{,}07 \\ \frac{50}{6}K_c = \omega_n^2 \rightarrow \boxed{K_c = 6} \end{cases}$$

- $K_{c\,MIN} \longrightarrow \quad \xi = 1 \qquad \begin{cases} 10 = 2\omega_n \rightarrow \omega_n = 5 \\ \frac{50}{6}K_c = 25 \rightarrow \boxed{K_c = 3} \end{cases}$

$$G_c(s) = K_c\left(1 + T_d\cdot s + \frac{1}{T_i s}\right) \qquad \begin{cases} T_d = 1/6 \\ T_i = 6/5 \end{cases} \qquad K_c \in (3,6)$$

[redacted]





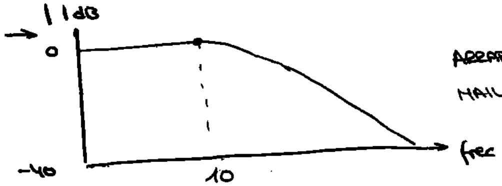
$G_2(s)$ → Maila sarrera unitarioa

Erantzuna →

ARRAPALA IRT $Y(s) = \frac{1}{s^2}$

MAILA UNIT SAR $U(s) = 1/s$

$G_1(s)$ →



a) $G_1(s)$ eta $G_2(s)$?

Wn	Malda hat.	Malda Amaiera	Polo/Zero
10	-20 dB	-20 dB	→ 1 Polo : $\frac{1}{s+10} = \frac{1}{0,1s+1}$

$20\log K = 0$ → $\boxed{K=1}$

$$\boxed{G_1(s) = \frac{1}{0,1s+1} = \frac{10}{s+10}}$$

$$\boxed{G_p(s) = \frac{10}{s(s+10)}}$$

- $\boxed{G_2(s) = \frac{Y(s)}{R(s)} = \frac{1/s^2}{1/s} = \frac{s}{s^2} = \frac{1}{s}}$

b) $G_c(s)$?

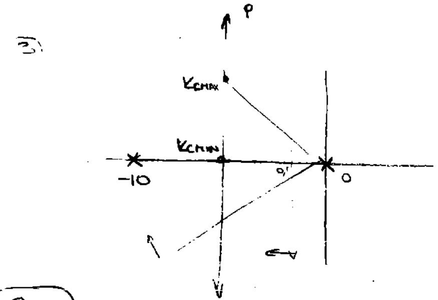
- Sist berelikatzen $M_p \leq \%10$
- $R(s)$ ⎍ denean $t_s(\%5) \leq 6$
- $D(s)$ ⎍ denean $e_{sds} = \%20$

Bi sorrera
↓
GAINAZARMEN PRINTZ

①

- $M_p \leq 10 \rightarrow \delta = \sqrt{\frac{\ln 0{,}1^2}{\ln 0{,}1^2 + \pi^2}} = 0{,}6 \rightarrow \boxed{\theta \leq 53{,}77^\circ}$
- $t_s(\%5) \leq 6 \rightarrow \frac{3}{\delta \cdot \omega_n} \leq 6 \rightarrow \boxed{\delta \cdot \omega_n > 0'5}$
- $e_{sd} \leq \%20 \rightarrow e_{sd} = \frac{1}{1+k_p} \leq 0{,}2 \rightarrow 1 \leq 0{,}2 + 0{,}2k_p \rightarrow \boxed{k_p \geq 4}$

② Ⓟ bdekin $G_c = k_c$



$G_{BA} = \frac{10}{s(s+10)}$

$G_{BCI}\Big|_{D(s)=0} = \frac{10k_c}{s(s+10) + 10k_c} = \frac{10k_c}{s^2 + 10s + 10k_c}$

G_{BCI}

- **K_{cMAX}** $\rightarrow \delta \cdot \omega_n = 0{,}5 \quad \delta = 0{,}6$

$$\frac{10k_c}{s^2 + 10s + 10k_c} = \frac{K\omega_n^2}{s^2 + 2\delta\omega_n s + \omega_n^2} \qquad \begin{cases} 10 = 2 \cdot 0{,}6 \cdot \omega_n \rightarrow \omega_n = 8{,}33 \\ 10k_c = \omega_n^2 \rightarrow \boxed{K_c = 6{,}94} \end{cases}$$

- **K_{cMIN}** $\rightarrow \delta \cdot \omega_n = 0{,}5 \quad \delta = 1$

$$\begin{cases} 10 = 2 \cdot \omega_n \rightarrow \omega_n = 5 \\ 10k_c = 25 \rightarrow \boxed{K_c = 2{,}5} \end{cases}$$

- $K_p = 4 \rightarrow K_p = \lim_{s \to 0} \frac{10k_c}{s(s+10)} = \infty$

$$K_c \in (2'5\,,\ 6'94)$$

$$G_{BC_1}(s) = \frac{K_c}{s+K_c} = \frac{1}{\frac{s}{K_c}+1}$$

$$G_{BC2}(s) = \frac{1}{s+K_c}$$

$$G_{BC\ TOT}(s) = \frac{K_c}{s+K_c} + \frac{1}{s+K_c} = \frac{K_c+1}{s+K_c} + \frac{\frac{K_c+1}{K_c}}{\underbrace{\frac{s}{K_c}}+1}$$

$$\frac{1}{K_c} = \frac{1}{12} \longrightarrow \boxed{K_c \in (12,\infty)}$$

1 MAILA $\quad e_{ss} = 3\tau < 0'25 \rightarrow \tau < \frac{1}{12}$

G_{BC2}

$$G_{BC2}(s)\Big|_{R(s)=0} = \frac{G_2}{1+G_1\cdot G_2\cdot G_c} = \frac{10+s}{s(s+10)+10K_c}$$

$$e_{ss} = e_{ssR} + e_{ssD}$$

- $e_{ssR} \longrightarrow G_{BC2}$: 1 mota $\longrightarrow \boxed{e_{ssR}=0}$
- $e_{ssD} \longrightarrow E(s) = R(s) - Y(s)\cdot H(s) = -G_D(s)\cdot D(s)$

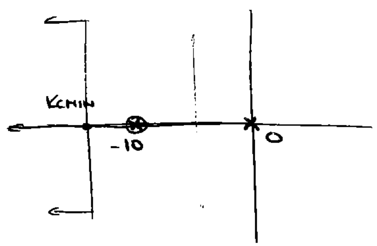
$$\left\{\begin{array}{l} G_D(s) = \dfrac{1/s}{1+\dfrac{G_1 G_c}{s}} = \dots \dfrac{s+10}{s^2+10s+10K_c} \\ D(s) = \dfrac{1}{s} \end{array}\right\} \quad E(s) = \frac{-(s+10)}{s(s^2+10s+10K_c)}$$

$$\boxed{e_{ssD} = \lim_{s\to 0} \cancel{s}\cdot\frac{-(s+10)}{\cancel{s}(s^2+10s+10K_c)} = \frac{-10}{10K_c} = -\frac{1}{K_c}}$$

$$e_{ss} = -\frac{1}{K_c} = \%20 \longrightarrow \boxed{K_c = 5}$$

$$\boxed{K_c \in (5,\ 6{,}94)}$$

c) $t_s \le 0{,}25s \longrightarrow \dfrac{3}{\xi\cdot\omega_n} \le 0{,}25 \longrightarrow \xi\cdot\omega_n \ge 12$



Ez du balio, PD

$$G_c(s) = K_c\cdot T_d\,(s + \overbrace{1/T_d}^{z_d}) \longrightarrow z_d = 10$$
$$T_d = 0{,}1$$

$$G_c(s) = 0{,}1K_c\,(s+10)$$

$$G_{BA}(s) = \frac{0{,}1K_c\,\cancel{(s+10)}\cdot 10}{s\,\cancel{(s+10)}} = \frac{K_c}{s}$$

Empieza $-90 \rightarrow$ Jaitsi POLO

[redacted]

a)

Wn	Mald tot	Malda aldak	Polo /zero
0.	-20 dB	-20 dB	$\frac{1}{s}$
10	-60'dB	-40 dB	$\frac{1}{(s+10)^2}$

$$20\log k = 6 \rightarrow k = 10^{\frac{6}{20}} = 1{,}995$$

$$\frac{1{,}995}{(s+10)^2 s} = \frac{1{,}995}{\frac{1}{100}(s+1)^2 s} \rightarrow \boxed{\frac{199{,}5}{s(s+10)^2}}$$

Para sacar el verdadero valor de $K \rightarrow$ PONER EN $\frac{s}{z}s+1$

b) essv ? 2 maldako arrapala baten aurrean?

$$e_{ssv} = \frac{2}{K_v} \qquad K_v = \lim_{s\to 0} s \cdot G_{BA}(s) = \cancel{s}\,\frac{199{,}5}{\cancel{s}(s+10)^2} = \frac{199{,}5}{100} = 1{,}995$$

$$\boxed{e_{ssv} = \frac{2}{1{,}995} \simeq 1}$$

c)

$MG = 0-(-15) = 15$

$MF = -110-(-180) = 70$

EGONKOR

d) Noraino handitu daiteke k? sist ezegonkortzeko.

MG $\rightarrow$ 15 dB/h mugitu daiteke.

$$20\log K = 15 \rightarrow \boxed{K = 10^{\frac{15}{20}} = 5{,}62}$$