1. $U = K_U G \sqrt{H}$

U_0, G_0, H_0 cumplen $U_0 = K_U G_0 \sqrt{H_0}$

los incrementos:

$$\Delta U = K_U \Delta G \sqrt{H_0} + K_U G_0 \frac{\Delta H}{2\sqrt{H_0}}$$

$$\Rightarrow u = \frac{\Delta U}{U_0} = \frac{K_U \sqrt{H_0}}{K_U \sqrt{H_0}\, G_0} \Delta G + \frac{K_U G_0 \Delta H}{2\sqrt{H_0}\, K_U G_0 \sqrt{H_0}} = \boxed{g + \frac{h}{2} = u} \quad (1)$$

$P = K_P H U \quad , \quad P_0 = K_P H_0 U_0$

$$\frac{\Delta P}{K_P H_0 U_0} = \frac{K_P \Delta H U_0}{K_P H_0 U_0} + \frac{K_P H_0 \Delta U}{K_P H_0 U_0} \Rightarrow \boxed{p = h + u} \quad (2)$$

2. $\begin{cases} u = g + h/2 \\ p = h + u \\ K_M \dot{u} = -h \end{cases}$

$$g \longrightarrow \boxed{T(s)} \longrightarrow p$$

$$\begin{cases} K_M \, \dot{\overline{(g + h/2)}} = -h \\ p = h + g + h/2 = \frac{3}{2} h + g \Rightarrow h = \frac{2}{3}(p - g) \end{cases}$$

$$\Rightarrow K_M\left(\dot{g} + \frac{\dot{p} - \dot{g}}{3}\right) = -\frac{2}{3}(p - g)$$

$$\Rightarrow K_M(2\dot{g} + \dot{p}) = -2p + 2g$$

EN LAPLACE, con C.I. nulas:

$$[2K_M s - 2]\, g(s) = -(K_M s + 2)\, P(s)$$

$$\Rightarrow \frac{p(s)}{g(s)} = -2\frac{K_M s - 1}{K_M s + 2} = \frac{1 - K_M s}{1 + \frac{K_M}{2} s} \Rightarrow \boxed{T(s) = \frac{1 - K_M s}{1 + \frac{K_M}{2} s}}$$

3. $$T(s) = \frac{1 - T_w s}{1 + \frac{T_w}{2} s}$$

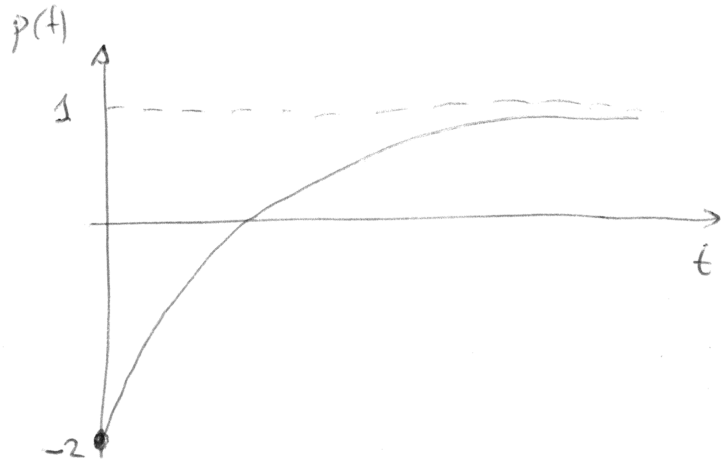
$$g \longrightarrow \boxed{T(s)} \longrightarrow p$$

$g(t) = Y(t)$

$g(s) = \frac{1}{s} \Rightarrow p(s) = \frac{1 - T_w s}{1 + \frac{T_w}{2} s} \frac{1}{s} = \frac{1}{s} + \frac{-\frac{3}{2} T_w}{1 + \frac{T_w}{2} s}$

$$= \frac{1}{s} - \frac{3}{s + \frac{2}{T_w}}$$

$$\boxed{p(t) = 1 - 3 e^{-\frac{2t}{T_w}}}$$



$t_d = t_{0.5}$

$t_r = t_{0.9} - t_{0.1}$

Calculemos t_x genérico

$p(t) = x = 1 - 3 e^{-\frac{2t_x}{T_w}}$

$\Rightarrow 3 e^{-\frac{2t_x}{T_w}} = 1 - x \Rightarrow e^{-2\frac{t_x}{T_w}} = \frac{1-x}{3}$

$\Rightarrow -2 \frac{t_x}{T_w} = \ln \frac{1-x}{3} \Rightarrow t_x = -\frac{1}{2} \ln \frac{1-x}{3} \cdot T_w$

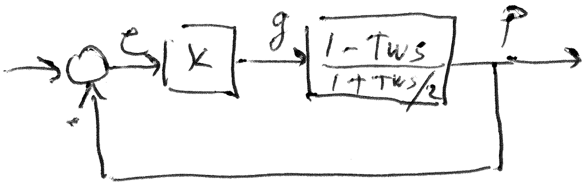
$\Rightarrow t_x = \frac{\ln \frac{3}{1-x}}{2} \cdot T_w$

$\Rightarrow t_d = \frac{\ln \frac{3}{0.5}}{2} T_w = \boxed{\frac{\ln 6}{2} T_w = t_d}$

$t_{0.9} - t_{0.1} = \frac{\ln \frac{3}{0.1} - \ln \frac{3}{0.9}}{2} T_w = \frac{\ln \frac{0.9}{0.1}}{2} T_w = \frac{\ln 9}{2} T_w$

$= \boxed{t_r = \ln 3 \, T_w}$

4.



$$T_{ce}(s) = \frac{KT}{1+KT} = \frac{K(1-T_w s)}{1+\frac{T_w s}{2}+K(1-T_w s)} = \frac{K(1-T_w s)}{\left[\frac{1}{2}-K\right]T_w s + 1 + K}$$

⇒ EL SISTEMA REALIMENTADO ES ESTABLE SI

$$\boxed{0 < K < 1/2}$$

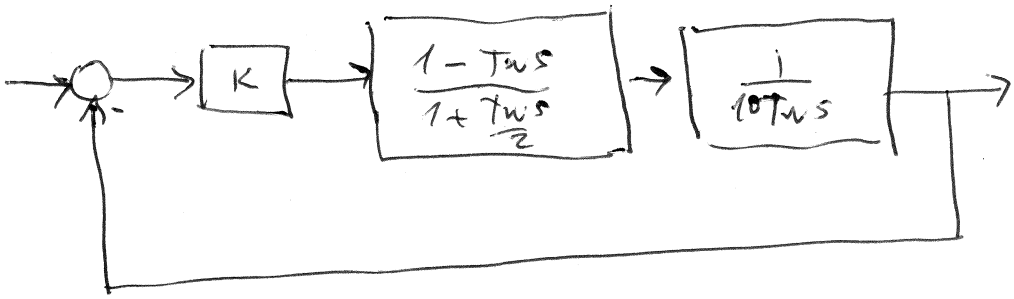
HAY VALORES DE K negativos que asegura la estabilidad.

$$e_\infty = \lim_{s \to 0} \frac{1}{1+KT(s)} = \frac{1}{1+K} \quad \forall K \mid 0<K<1/2$$

EL MÍNIMO SE LOGRA PARA $K = \frac{1}{2} - \varepsilon \quad \varepsilon \ll 1$

$$\boxed{e_\infty \text{ óptimo} \cong \frac{1}{1+1/2} = \frac{2}{3}}$$

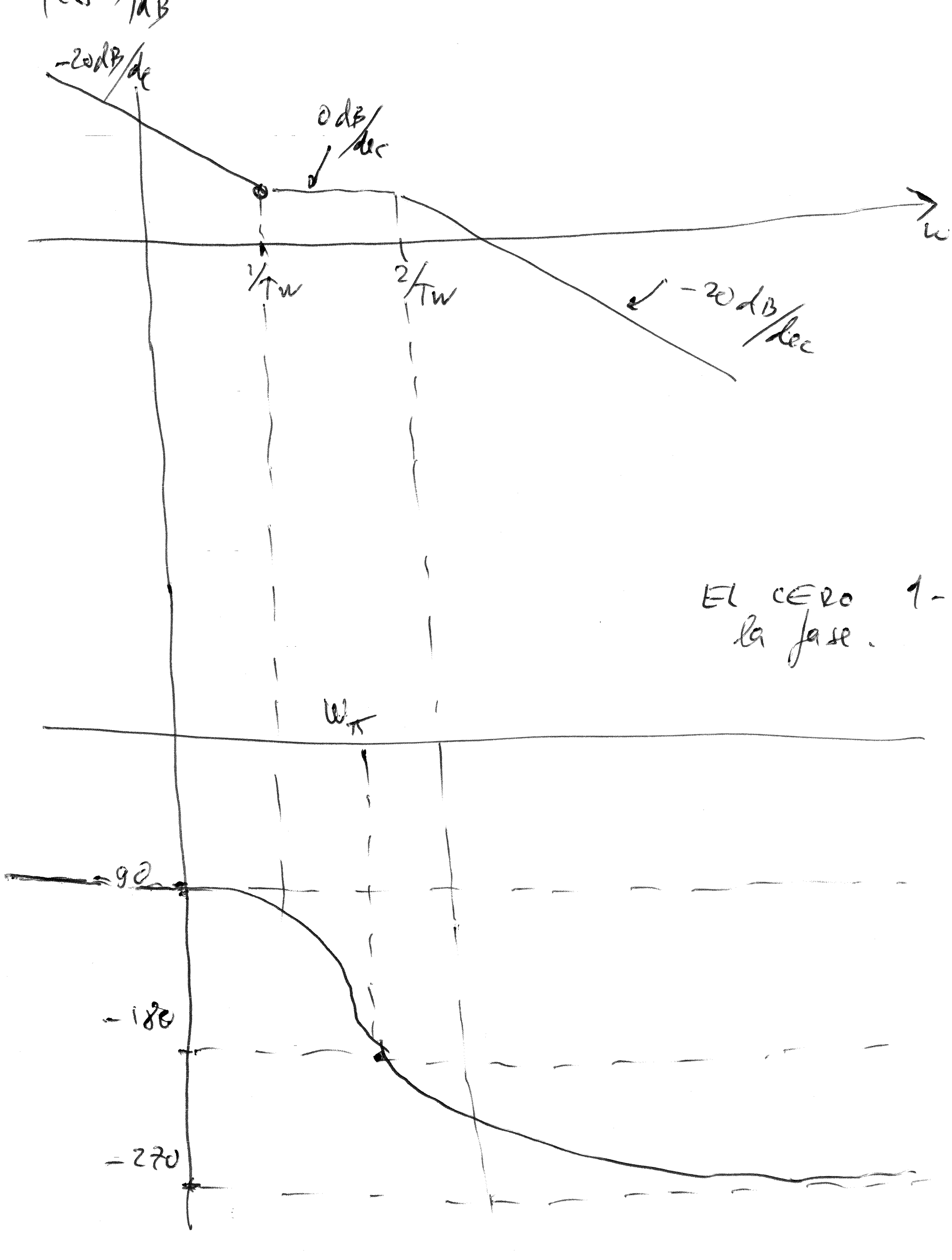
5.



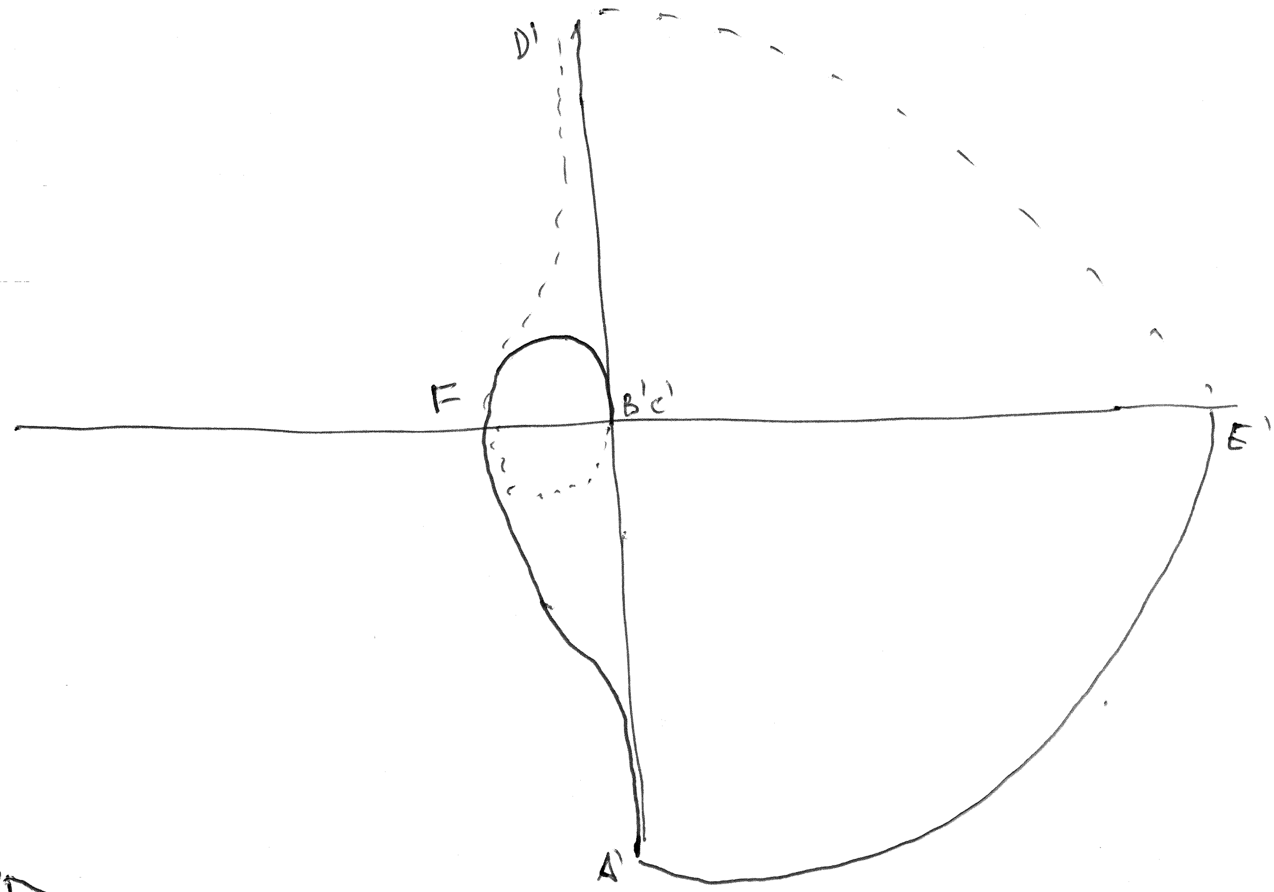
$$L(s) := \frac{K}{10T_w}\,\frac{1-T_w s}{1+\frac{T_w s}{2}}\,\frac{1}{s}$$

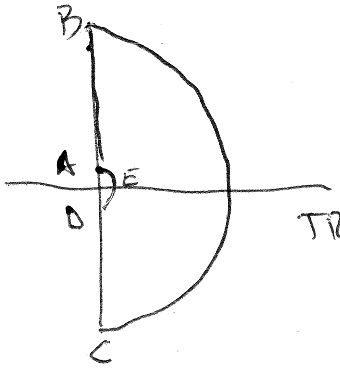
$$\boxed{\ell(s) = \frac{1}{10}\,\frac{1-T_w s}{1+\frac{T_w s}{2}}\,\frac{1}{T_w s} = \frac{L(s)}{K}}$$

5. $$\ell(s) = \frac{1}{10}\,\frac{1 - T_w s}{1 + \frac{T_w s}{2}}\,\frac{1}{T_w s}$$



El cero $1 - T_w s$ atrasa la fase.





TRAMO E → A
$s = r e^{j\theta}$
$\theta : 0 \to \pi/2$

$$l(s) = \frac{1}{10} \cdot 1 \cdot \frac{1}{T_w r} e^{-j\theta} \quad (0 \to -\pi/2)$$

PRECISAMOS CONOCER F.

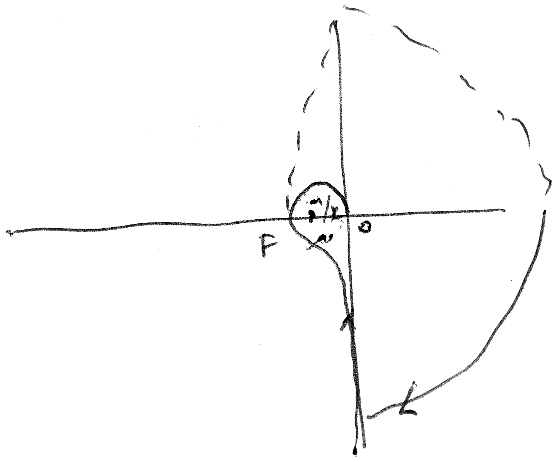
Se da en la frecuencia $\omega_\pi = \sqrt{\frac{1}{T_w} \cdot \frac{2}{T_w}} = \frac{\sqrt{2}}{T_w}$

$$l(j\omega_\pi) = \frac{1}{10} \frac{1 - j T_w \frac{\sqrt{2}}{T_w}}{1 + j \frac{T_w}{2} \frac{\sqrt{2}}{T_w}} \cdot \frac{1}{j T_w \frac{\sqrt{2}}{T_w}} = \frac{1}{10} \frac{1 - j\sqrt{2}}{1 + j\frac{\sqrt{2}}{2}} \cdot \frac{1}{j\sqrt{2}} =$$

$$= \frac{1}{10} \frac{(1 - j\sqrt{2})(1 - j\sqrt{2}/2)}{\left[1^2 + \left(\frac{\sqrt{2}}{2}\right)^2\right]} \frac{1}{j\sqrt{2}} = \frac{1}{10} \frac{1 - j\sqrt{2} - j\sqrt{2}/2 - 1}{1 + 1/2} \frac{1}{j\sqrt{2}} =$$

$$= \frac{1}{10} \frac{-j\sqrt{2}\, 3/2}{3/2} \frac{1}{j\sqrt{2}} = -\frac{1}{10}$$

$$\boxed{F = -1/10 \,,\ \text{fase} -\pi}$$



Si $F < -1/K$, $N = -2$. Como $P = 0$, $\underline{Z = 2}$

$\Rightarrow$ INESTABLE

$-\frac{1}{10} < -1/K$

$\Rightarrow \frac{1}{10} > \frac{1}{K} \Rightarrow$ $\boxed{K \geq 10 \quad \text{INESTABLE}}$

Si $-1/K < -\frac{1}{10}$ $N = 0 \Rightarrow Z = 0$

$\boxed{0 < K < 10 \quad \text{ESTABLE}}$

$$\boxed{e_\infty = \lim_{s \to 0} \frac{1}{1 + K\,G(s)} = \frac{1}{\infty} = 0 = e_\infty \quad \forall\, 0 < K < 10}$$