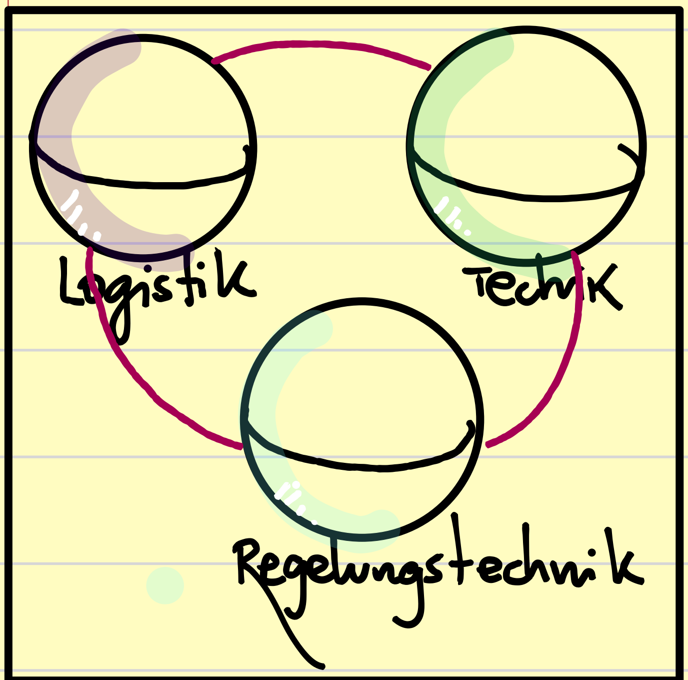
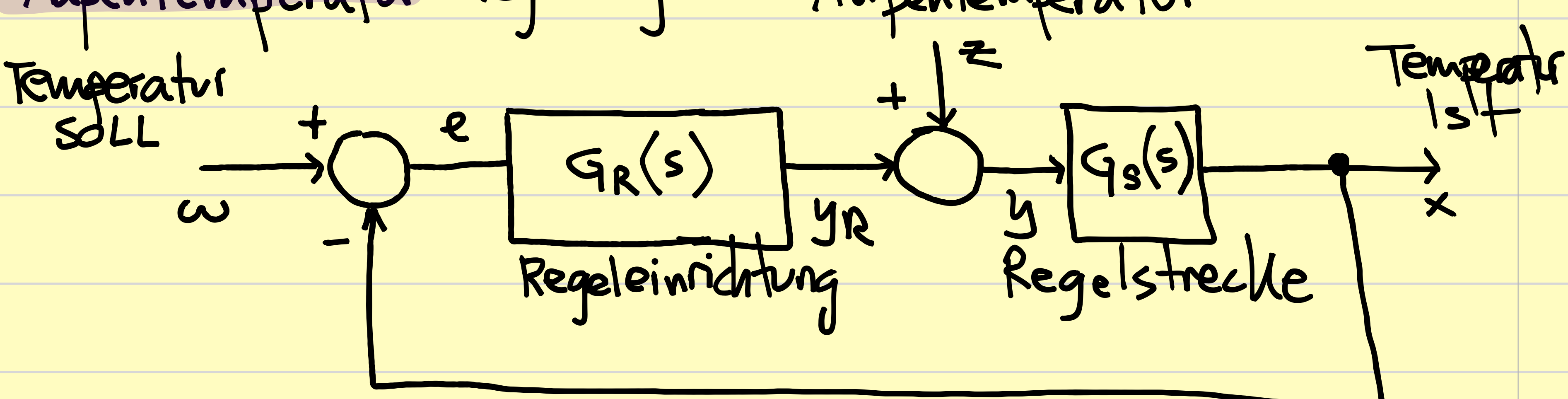
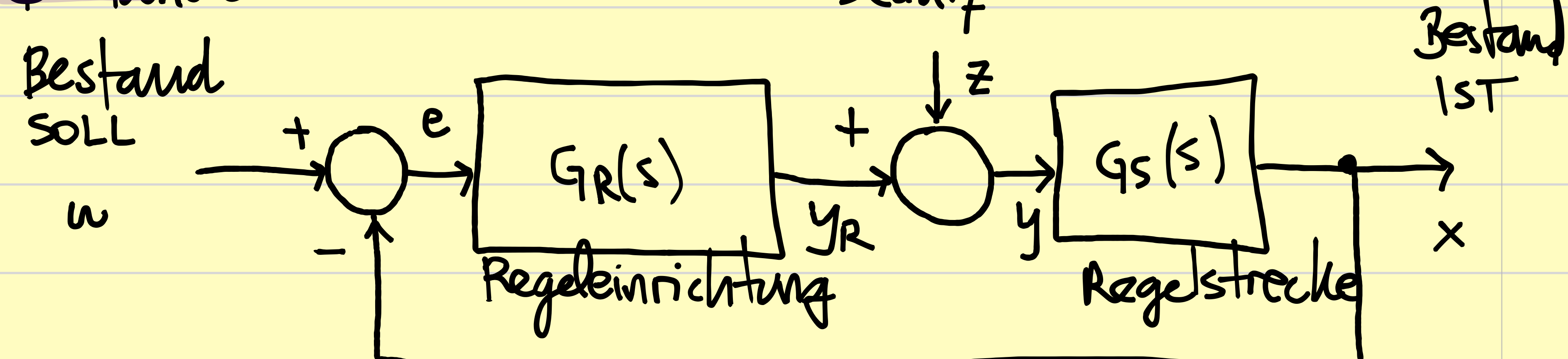
20231121_Regelungstechnik_BEL4



Außentemperatur Regelung

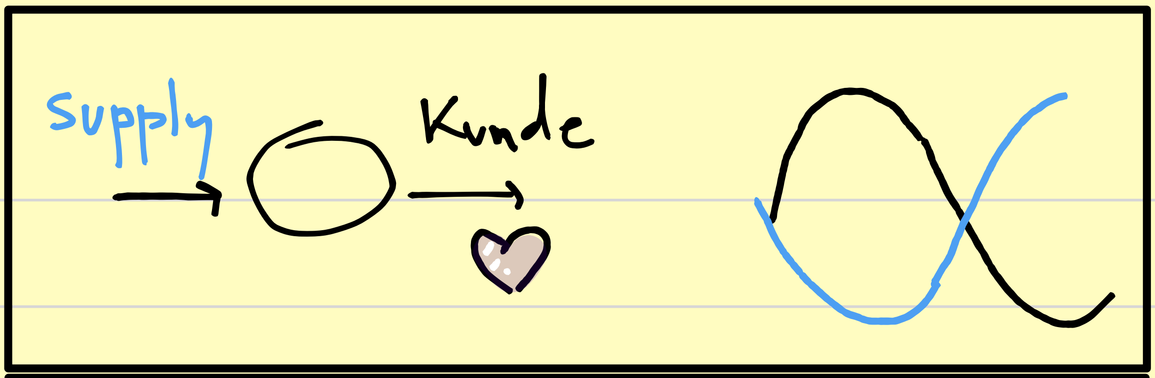


Bestände



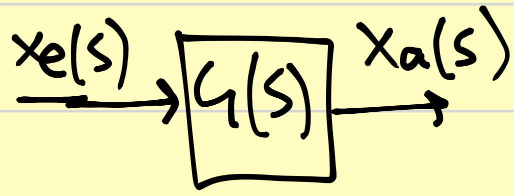
Bei der Beurteilung eines Regelkreises interessieren u.a.:

a) das dynamische Verhalten der Regelgröße „x" auf eine Sollwertänderung, das so genannte FÜHRUNGSVERHALTEN



Der Logistiker will Demand und Supply zusammen bringen.

$$G(s) = \frac{x_a(s)}{x_e(s)}$$

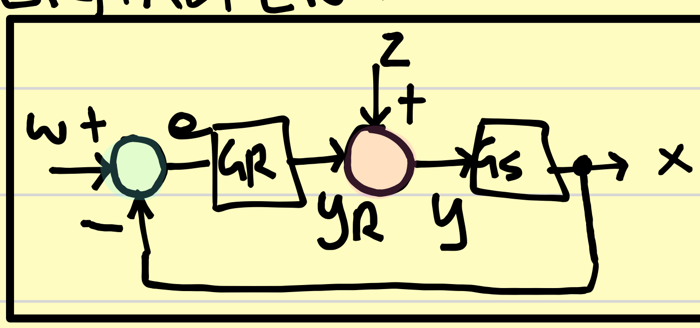


$$G_L(s) = \frac{Supply(s)}{Demand(s)}$$

$$\boxed{\text{Führungsverhalten} = \frac{x(s)}{w(s)}}$$

b) die dynamische Reaktion der Regelgröße „x" auf eine Störung, s.g. STÖRVERHALTEN.

$$\text{Störverhalten} = \frac{x(s)}{z(s)}$$



Führungsübertragungsfunktion

$$\left.\begin{aligned} y_R(s) &= [\underbrace{w(s)-x(s)}_{e(s)}]\cdot G_R(s) \\ x(s) &= [y_R(s)+z(s)]\cdot G_S(s) \end{aligned}\right\}$$

$$x(s) = \left[\left(\left[w(s) - x(s)\right] \cdot G_R(s) + z(s)\right] G_S(s)$$

$$x(s) + x(s) \cdot G_R(s) G_S(s) = w(s) G_R(s) G_S(s) + z(s) G_S(s)$$

$$\boxed{x(s)\left[1 + G_R(s) G_S(s)\right] = w(s) G_R(s) G_S(s) + z(s) G_S(s)}$$

$z(s) = \text{KONSTANT}$

$$x = x_1, w = w_1 \rightarrow x_1(s)\left[1 + G_R(s) G_S(s)\right] = w_1(s) G_R(s) G_S(s) + z(s) G_S(s)$$

$$x_2 = x_2, w = w_2 \rightarrow x_2(s)\left[1 + G_R(s) G_S(s)\right] = w_2(s) G_R(s) G_S(s) + z(s) G_S(s)$$

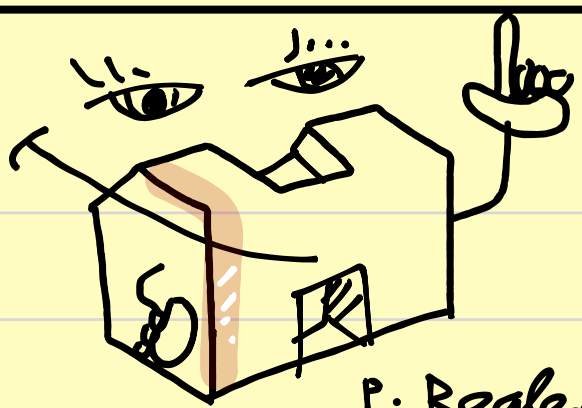
$$\underbrace{\left[x_1(s) - x_2(s)\right]}_{x(s)}\left[1 + G_R(s) G_S(s)\right] = \underbrace{\left[w_1(s) - w_2(s)\right]}_{w(s)} G_R(s) G_S(s)$$

FÜHRUNGSÜBERTRAGUNGSFUNKTION:

$$G_w(s) = \frac{x(s)}{w(s)} = \frac{G_R(s) G_S(s)}{1 + G_R(s) G_S(s)}$$

STÖRÜBERTRAGUNGSFUNKTION

$$G_z(s) = \frac{x(s)}{z(s)} = \frac{1}{\frac{1}{G_S(s)} + G_R(s)} = \frac{G_S}{1 + G_R(s) G_S(s)}$$



P. Regler

$P \cdot T_1$ Strecke

Qualitätsquote $0 \le k_P \le 1$

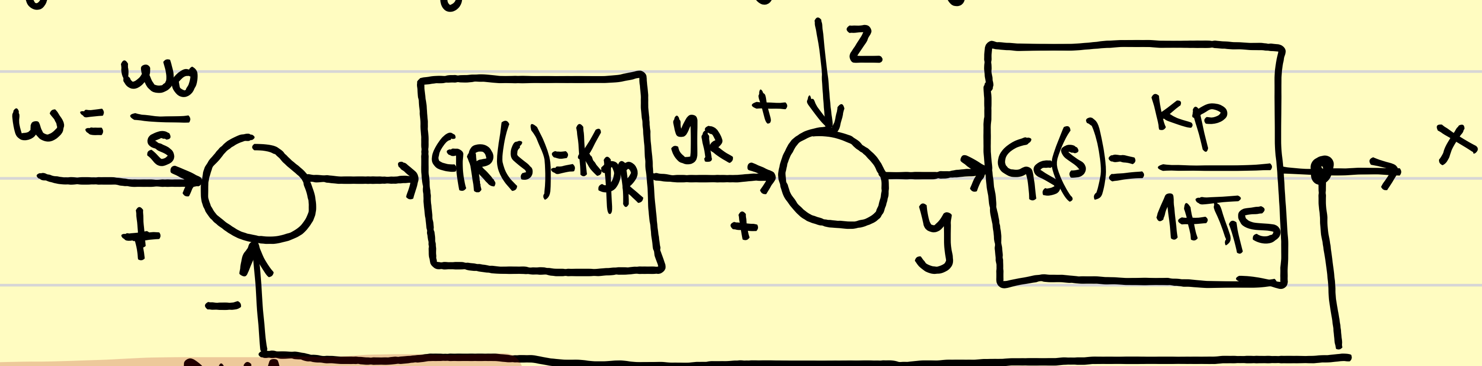
0% gute Teile — 100% gute Teile

$[k_P]$

Verzögerung (Rüstzeit, Reinigung, ...)

$[T_1]$

Regeleinrichtung zur Regelung der H4. Maschine ...



FÜHRUNGSVERHALTEN

$$G_w = \frac{x(s)}{w(s)} = \frac{G_R(s)G_S(s)}{1+G_R(s)G_S(s)} = \frac{K_{PR}\cdot K_P\cdot\frac{1}{1+T_1 s}}{1+K_{PR}K_P\cdot\frac{1}{1+T_1 s}} =$$

$$= \frac{\frac{K_{PR}\cdot K_P}{\cancel{1+T_1 s}}}{\frac{1+T_1 s+K_{PR}\cdot k_P}{\cancel{1+T_1 s}}} = \frac{K_{PR}\cdot k_P}{1+K_{PR}\cdot k_P+T_1 s}$$

$$G_w(s) = \frac{x(s)}{w(s)} \longrightarrow x(s) = \frac{K_{PR}\cdot k_P\cdot w_0}{s\left(1+K_{PR}\cdot k_P+T_1 s\right)} =$$

$$= \frac{A}{s} + \frac{B}{1+k_{PR}\cdot k_P+T_1 s} =$$

$$= \frac{A}{s} + \frac{B}{\frac{1+k_{PR}\cdot k_P}{T_1}+s}$$

$$K_{PR} \cdot K_P \cdot w_0 = A\left(s + \frac{1+K_{PR}K_P}{T_1}\right) + Bs$$

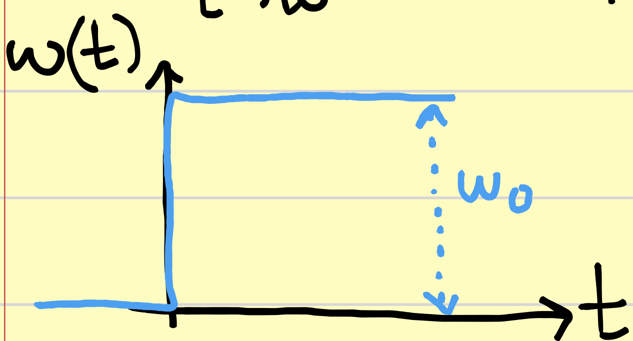
$$s=0 \rightarrow A = \frac{K_{PR}K_P w_0}{\frac{1+K_{PR}\cdot K_P}{T_1}} = \frac{K_{PR}K_P T_1}{1+K_{PR}\cdot K_P} w_0$$

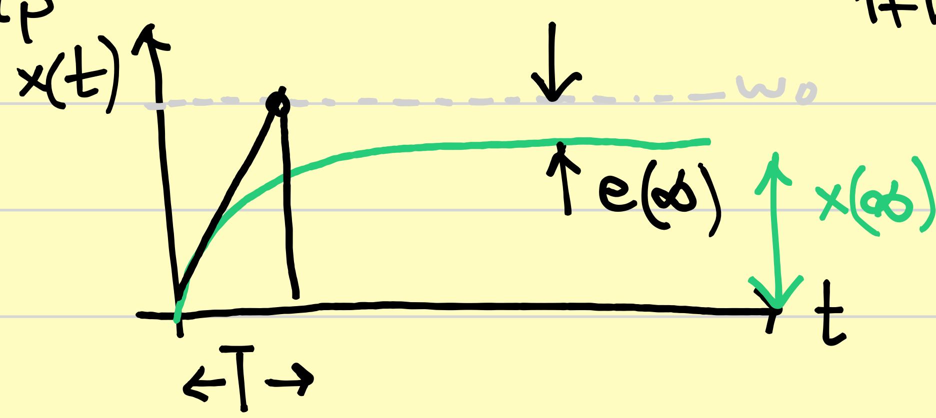
$$s = -\frac{1+K_{PR}K_P}{T_1} \rightarrow B = \frac{-K_{PR}K_P T_1}{1+K_{PR}K_P}$$

Nach Rücktransformation in den Zeitbereich ...

$$x(t) = \frac{K_{PR}K_P}{1+K_{PR}K_P}\left(1-e^{-t\cdot\frac{1+K_{PR}K_P}{T_1}}\right) w_0 \quad < w_0 \; !$$

$$\lim_{t\to\infty} x(t) = \frac{K_{PR}K_P}{1+K_{PR}K_P}\cdot w_0 \; ; \; e(\infty) = w_0 - x(\infty) = \frac{1}{1+K_{PR}K_P}\cdot w_0$$





STÖRVERHALTEN

$$G_Z(s) = \frac{X(s)}{Z(s)} = \frac{G_S(s)}{1+G_R(s)G_S(s)} = \frac{K_P}{1+K_{PR}K_P + T_1 s}$$

KONSTANTER DEMAND: $Z(s) = \frac{Z_0}{s}$

$$x(s) = G_Z(s) \cdot Z(s) = \frac{K_p \cdot z_0}{s\left(1 + K_{PR}K_p + T_1 s\right)}$$

$$= \frac{A}{s} + \frac{B}{s + \frac{1 + K_{PR}K_p}{T_1}}$$

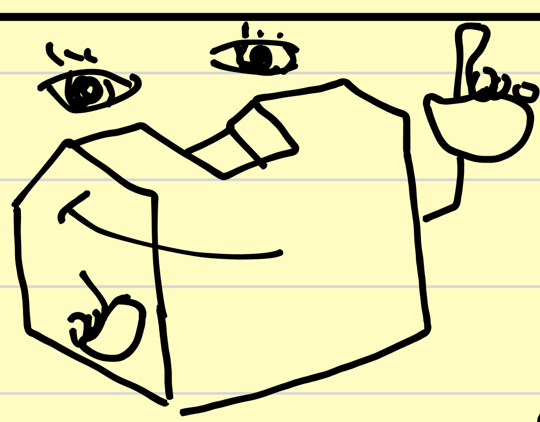
$$K_p \cdot z_0 = A\left(s + \frac{1 + K_{PR}K_p}{T_1}\right) + Bs$$

$$s = 0 \rightarrow A = \frac{K_p T_1}{1 + K_{PR}K_p} \cdot z_0$$

$$s = -\frac{1 + K_{PR}K_p}{T_1} \rightarrow B = -\frac{K_p T_1}{1 + K_{PR}K_p} z_0$$

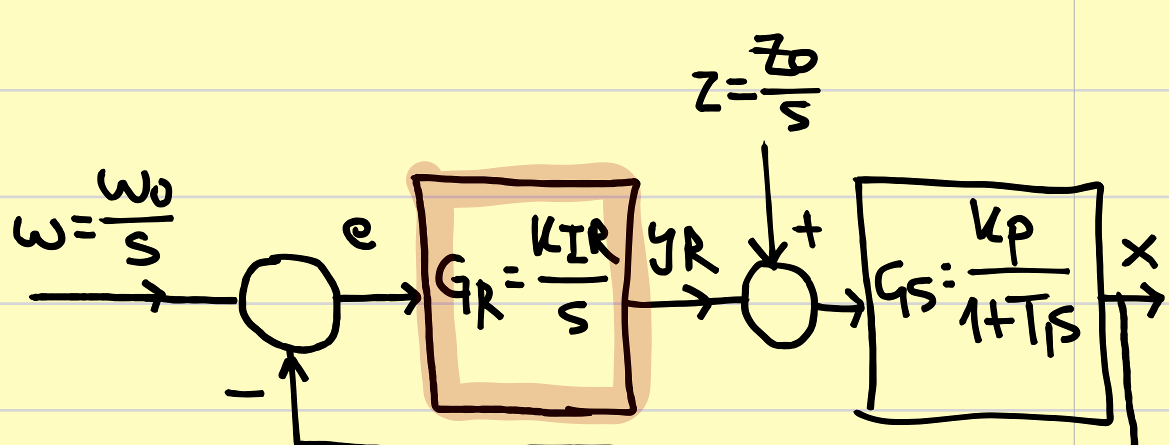
$$x(t) = \frac{K_p}{1 + K_{PR}K_p}\left(1 - e^{-t \cdot \frac{1 + K_{PR}K_p}{T_1}}\right) z_0$$

$$\lim_{t \to \infty} x(t) = \frac{K_p}{1 + K_{PR}K_p} \cdot z_0 < z_0 \quad !$$



1. Regler

$P \cdot T_1$ Strecke



FÜHRUNGSVERHALTEN

$$G_w(s) = \frac{x(s)}{w(s)} = \frac{G_R(s)\,G_S(s)}{1+G_R(s)\,G_S(s)} = \frac{\frac{K_{IR}}{s}\cdot\frac{K_P}{1+T_1 s}}{1+\frac{K_{IR}}{s}\cdot\frac{K_P}{1+T_1 s}} =$$

$$= \frac{K_{IR}\cdot K_P}{s(1+T_1 s)+K_{IR}K_P}$$

$$x(s) = \frac{K_{IR}\cdot K_P}{s^2(1+T_1 s)+s K_{IR}K_P}\,w_0 =$$

$$= \frac{K_{IR}\cdot K_P}{s\left(s+T_1 s^2+K_{IR}K_P\right)}\,w_0 = \frac{A}{s}+\frac{B}{s-s_1}+\frac{C}{s-s_2}$$

$$s^* = \frac{-1\pm\sqrt{1-4K_{IR}K_P T_1}}{2T_1} = \begin{cases} s_1 = -0{,}1 \\ s_2 = -0{,}9 \end{cases}$$

Beispiel:

$K_{IR} = 0{,}1\ s^{-1}$

$K_P = 0{,}9$

$T_1 = 1\ s$

$$\rightarrow\quad x(s) = \frac{0{,}09}{s(s+s^2+0{,}09)} = \frac{A}{s}+\frac{B}{s+0{,}1}+\frac{C}{s+0{,}9}$$

$$0{,}09 = A(s+0{,}1)(s+0{,}9)+B\,s(s+0{,}9)+C\,s(s+0{,}1)$$

$s=0 \rightarrow A=1$

$s=-0{,}1 \rightarrow C=-1{,}125$

$s=-0{,}9 \rightarrow B=+0{,}125$

$$x(s) = \frac{1}{s} + 0{,}125\,\frac{1}{s+0{,}1} - 1{,}125\,\frac{1}{s+0{,}9}$$

$$x(t) = 1 + 0{,}125\,e^{-0{,}1t} - 1{,}125\,e^{-0{,}9t}$$

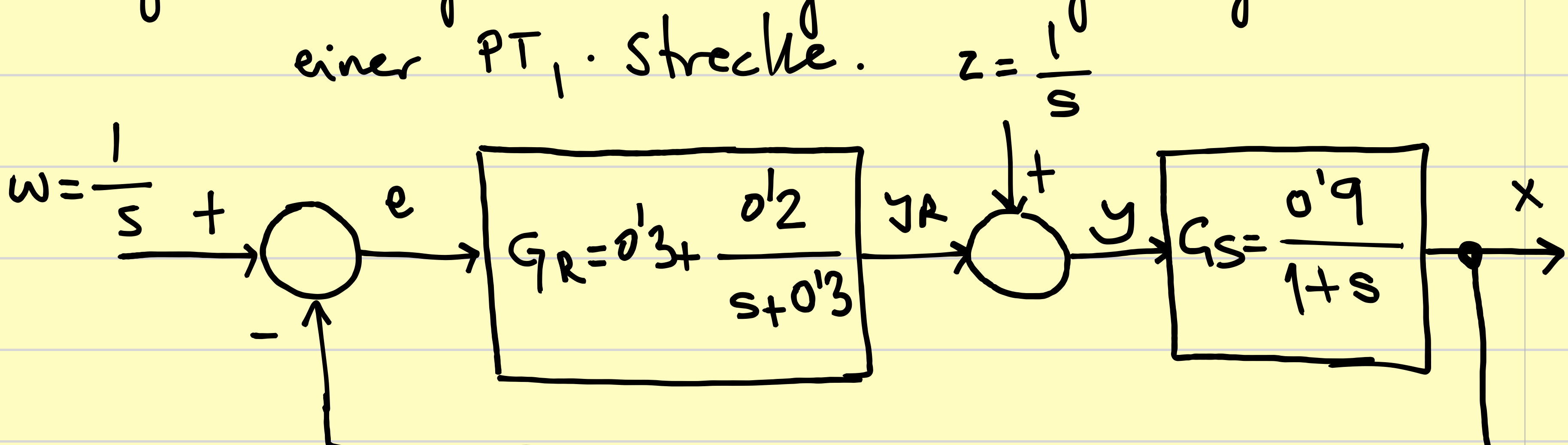
Generell: $$x(s) = G_w(s)\cdot w(s) = \frac{\frac{K_{IR}K_P}{T_1}}{s^2 + s\frac{1}{T_1} + \frac{K_{IR}K_P}{T_1}}\,\frac{w_0}{s}$$

$$x(t) = \left[1 - e^{-\frac{1}{2T_1}}\left(\cos\omega_E t + \frac{1}{2T_1\omega_E}\sin\omega_E t\right)\right]w_0$$

$$\omega_E = \sqrt{\frac{K_{IR}K_P}{T_1} - \frac{1}{(2T_1)^2}}$$

Qualitativ verstehen

Übung. PI. Regeleinrichtung zur Regelung einer PT_1. Strecke.



a) FÜHRUNGSVERHALTEN   b) STÖRVERHALTEN

Übung. PI-Regeleinrichtung zur Regelung einer I-Strecke.