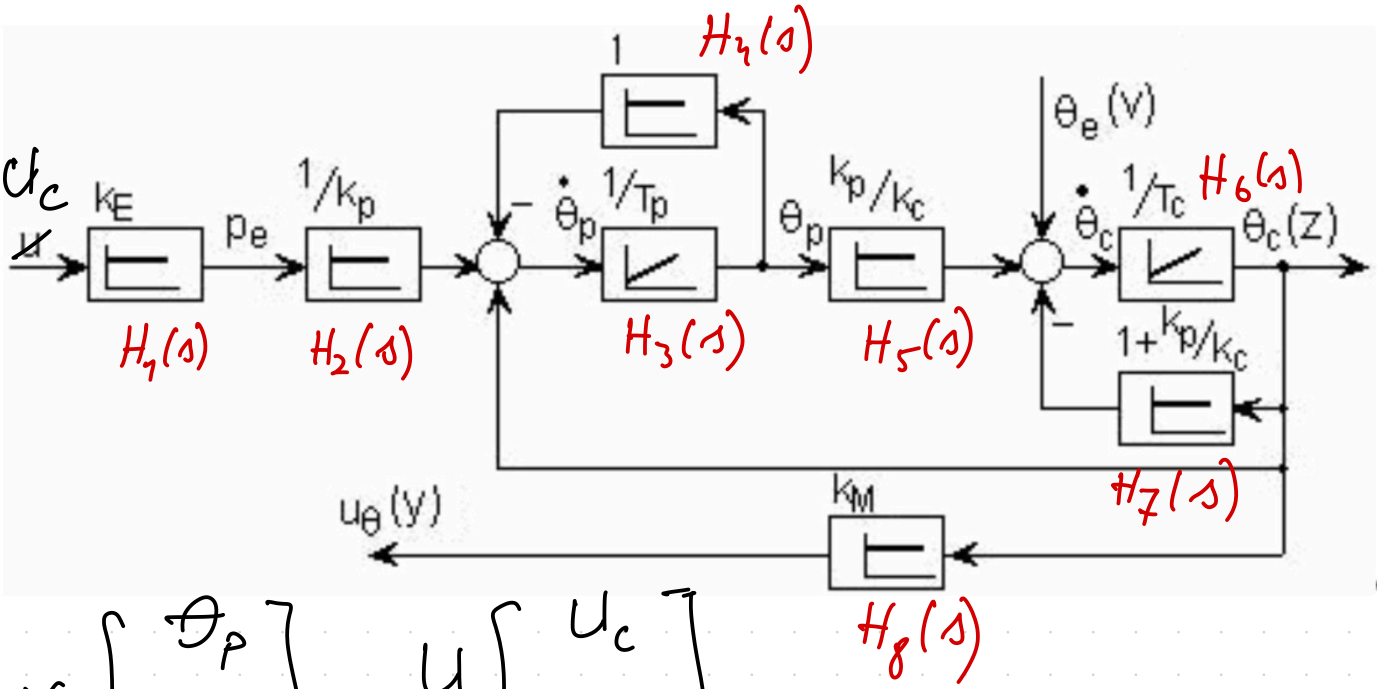
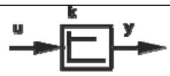
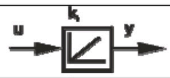
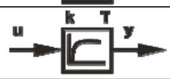
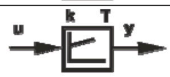


$$x \begin{bmatrix} \theta_p \\ \theta_c \end{bmatrix} \qquad u \begin{bmatrix} u_c \\ \theta_e \end{bmatrix}$$

Tipul ET	Simbolizare	Funcția de transfer în timp continuu
P		$H(s) = \mathrm{k}$
I		$H(s) = \frac{\mathrm{k_i}}{s}$
D		$H(s) = s\mathrm{k_D}$
PT1		$H(s) = \frac{\mathrm{k}}{s\mathrm{T}+1}$
PI		$H(s) = \frac{\mathrm{k}}{s\mathrm{T}}(s\mathrm{T}+1)$

$$H_1(s) = k_E$$

$$H_2(s) = \frac{1}{k_p}$$

$$H_3(s) = \frac{1}{sT_p}$$

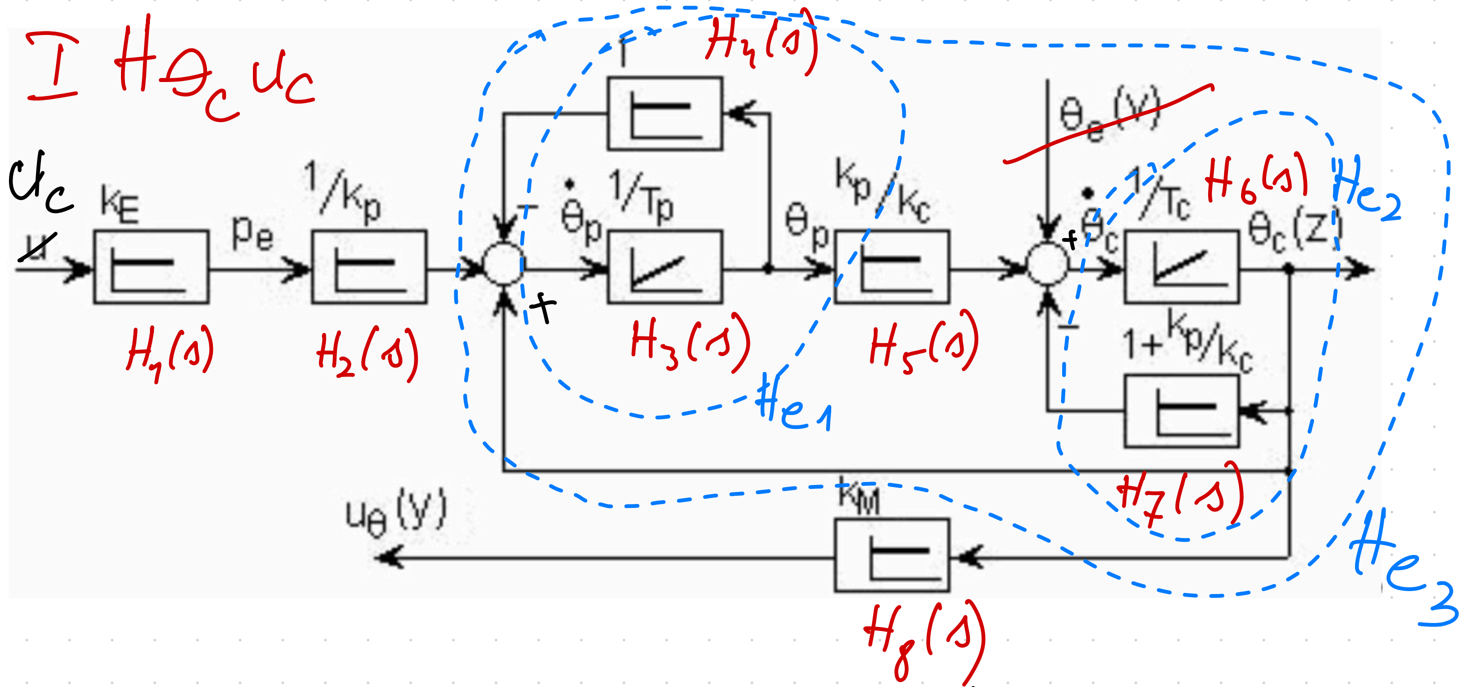
$$H_4(s) = 1$$

$$H_5(s) = k_p/k_c$$

$$H_6(s) = \frac{1}{sT_c}$$

$$H_7(s) = 1 + k_p/k_c$$

$$H_8(s) = k_M$$



$$H_{e_1} = \frac{H_3(s)}{1+H_3(s)\,H_4(s)} = \frac{\frac{1}{sT_p}}{1+\frac{1}{sT_p}\cdot 1} = \frac{1}{\cancel{sT_p}}\cdot\frac{\cancel{sT_p}}{sT_p+1} = \frac{1}{sT_p+1}$$

$$H_{e_2}(s) = \frac{H_6(s)}{1+H_6(s)H_7(s)} = \frac{\frac{1}{\cancel{sT_c}}}{\frac{sT_c}{1}+\frac{1}{\cancel{sT_c}}\left(1+k_p/k_c\right)} = \frac{1}{sT_c+k_p/k_c+1}$$

$$H_{e_3}(s) = \frac{H_{e_1}(s)\cdot H_5(s)\cdot H_{e_2}(s)}{1-H_{e_1}(s)\,H_5(s)\cdot H_{e_2}(s)} =$$

$$\frac{1}{sT_p+1}\cdot\frac{k_p}{k_c}\cdot\frac{1}{sT_c+k_p/k_c+1} =$$

$$= \frac{k_p/k_c}{s^2T_pT_c + sT_pk_p/k_c + sT_p + sT_c + k_p/k_c + 1}$$

$$H_{e_3}(s) = \frac{\frac{k_p/k_c}{(\,)}}{1-\frac{k_p/k_c}{(\,)}} = \frac{k_p/k_c}{(\,)-k_p/k_c} = \frac{k_p/k_c}{s^2T_pT_c + s\left(T_pk_p/k_c+T_p+T_c\right)+1}$$

$$H_{\vartheta_c u_c}(s) = H_1(s) \cdot H_2(s) \cdot H_{e_3}(s)$$

$$H_{e_3}(s) = \frac{H_{e_1}(s) \cdot H_5(s) \cdot H_{e_2}(s)}{1 - H_{e_1}(s) H_5(s) \cdot H_{e_2}(s)}$$

$$H_{e_2}(s) = \frac{H_6(s)}{1 + H_6(s) H_7(s)}$$

$$H_{e_1}(s) = \frac{H_3(s)}{1 + H_3(s) H_4(s)}$$

$$H_{e_3}(s) = \frac{\frac{H_3(s)}{1+H_3(s)H_4(s)} \cdot H_5(s) \cdot \frac{H_6(s)}{1+H_6(s)H_7(s)}}{1 - \frac{H_3(s)}{1+H_3(s)H_4(s)} \cdot H_5(s) \cdot \frac{H_6(s)}{1+H_6(s)H_7(s)}}$$

$$\frac{H_3(s)}{1+H_3(s)H_4(s)} \; H_5(s) \; \frac{H_6(s)}{1+H_6(s)H_7(s)} = \frac{H_3(s)H_5(s)H_6(s)}{1 + H_3(s)H_4(s) + H_6(s)H_7(s) + H_3(s)H_4(s)H_6 H_7}$$

$$u_c \longrightarrow H_1 \longrightarrow H_2 \rightarrow H_{e_3} \longrightarrow \vartheta_c$$

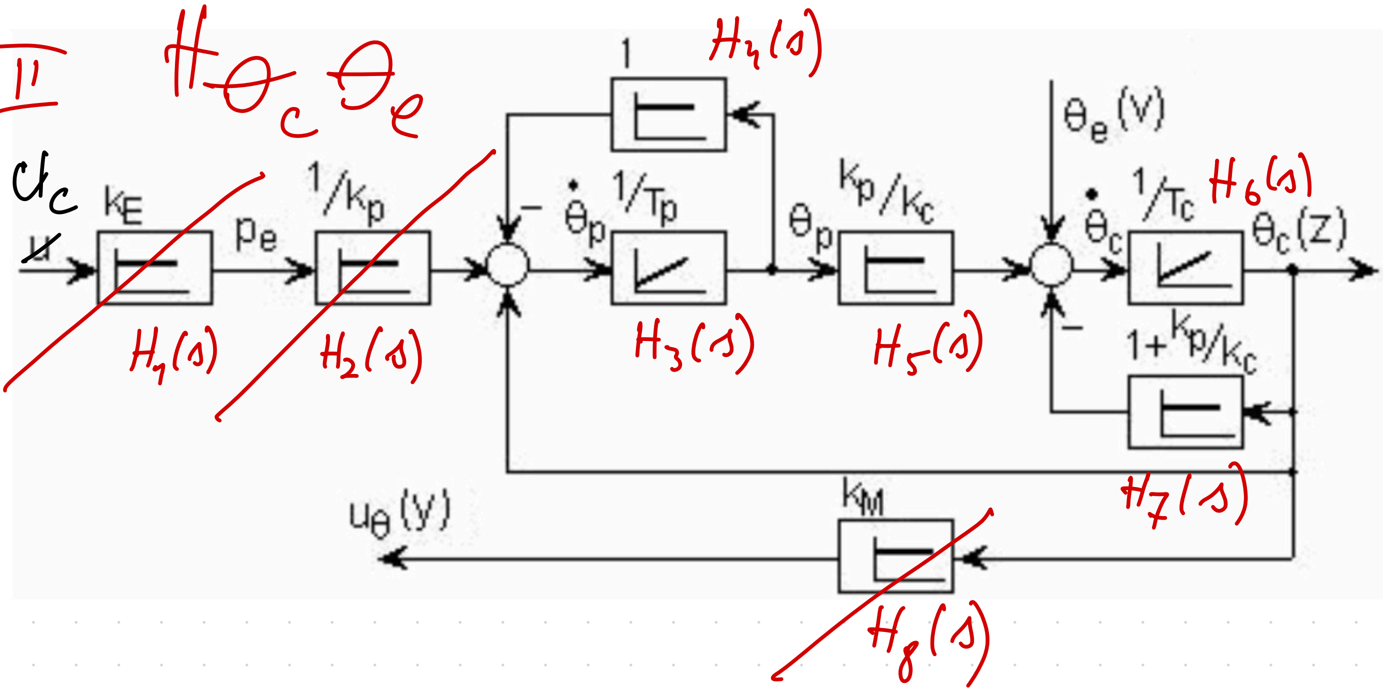
$$H_{\theta_c, u_c}(s) = \frac{H_1(s) H_2(s) H_3(s) H_4(s) H_6(s)}{1 + H_3(s) H_4(s) + H_6(s) H_7(s) + H_3(s) H_4(s) H_6(s) H_7(s)}$$

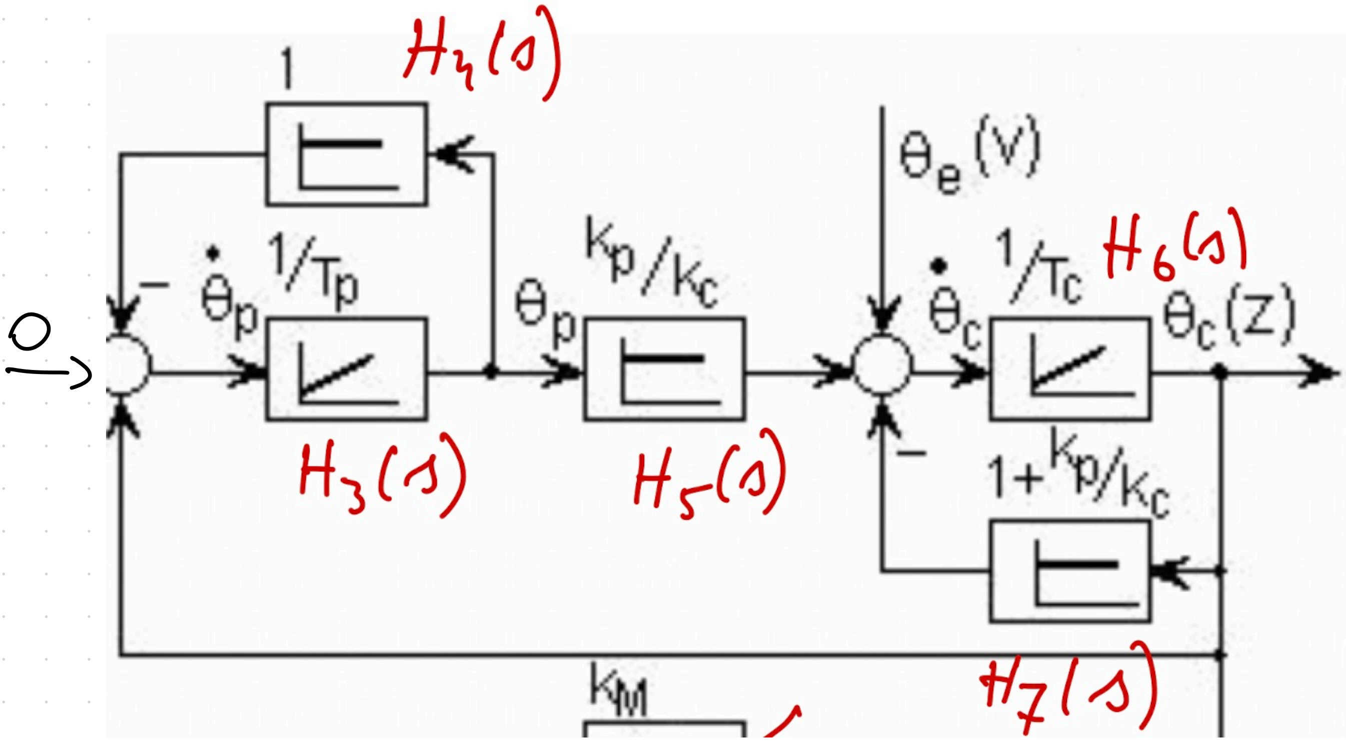
$$H_{\theta_c, u_c}(s) = H_1(s) H_2(s) \cdot H_{e_3}(s)$$

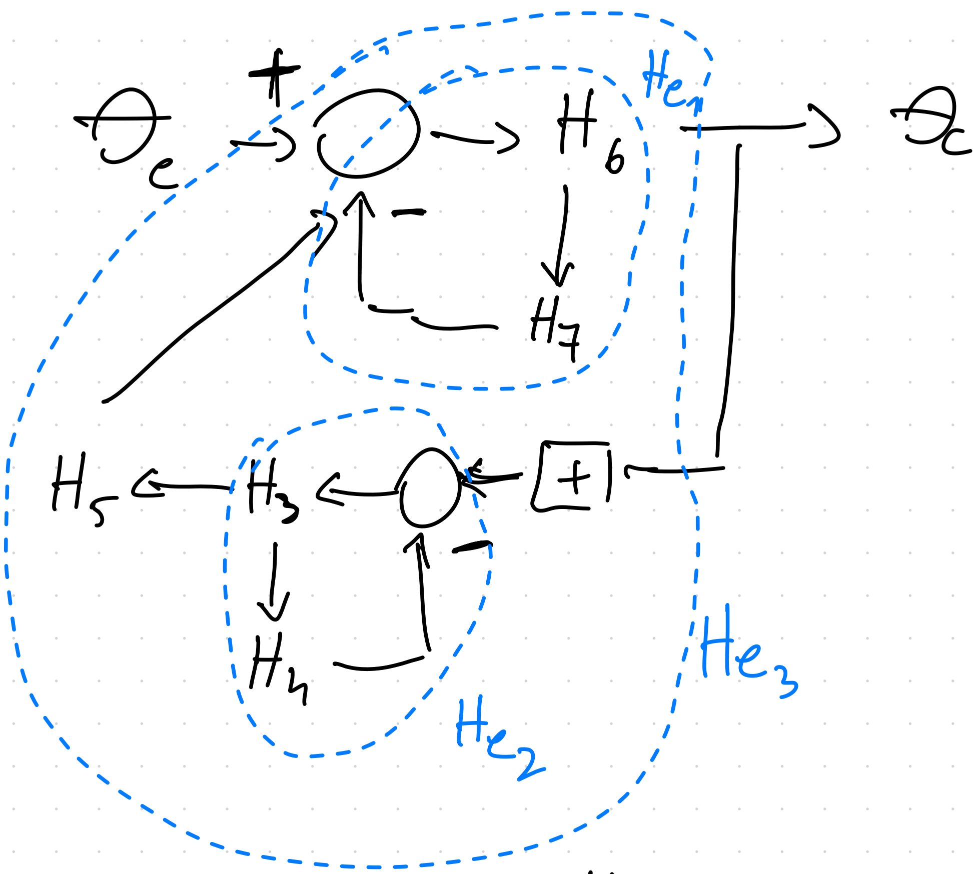
$$= k_E / \cancel{k_p} \cdot \frac{\cancel{k_p}/k_c}{s^2 T_p T_c + s(T_p k_p/k_c + T_p + T_c) + 1} = \frac{k_E / k_c}{s^2 T_p T_c + s(T_p k_p/k_c + T_p + T_c) + 1}$$

$$\boxed{H_{\theta_c u_c}(s) = \frac{k_E / k_c}{s^2 T_p T_c + s(T_p k_p/k_c + T_p + T_c) + 1}}$$

II $H_{\theta_c \theta_e}$

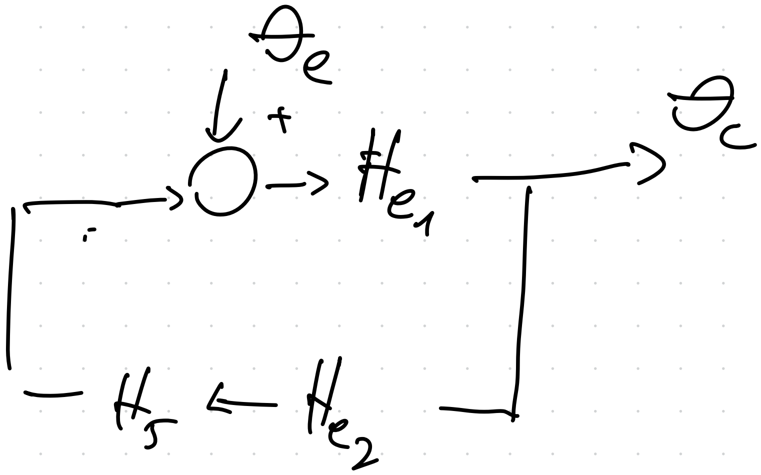






$$H_{e_1}(s) = \frac{H_6(s)}{1 + H_6(s)\,H_7(s)} = \frac{1}{sT_c + k_p/k_c + 1}$$

$$H_{e_2}(s) = \frac{H_3(s)}{1 + H_3(s)\,H_4(s)} = \frac{1}{sT_p + 1}$$



$J \quad \frac{k_p}{k_c}$

$e_1 \quad \frac{1}{sT_c + k_p/k_c + 1}$

$e_2 \quad \frac{1}{sT_p + 1}$

$$H_{\vartheta_{c},\vartheta_e}(s) = \frac{H_{e_1}(s)}{1 - H_{e_1}(s)\, H_{e_2}(s)\, H_J}$$

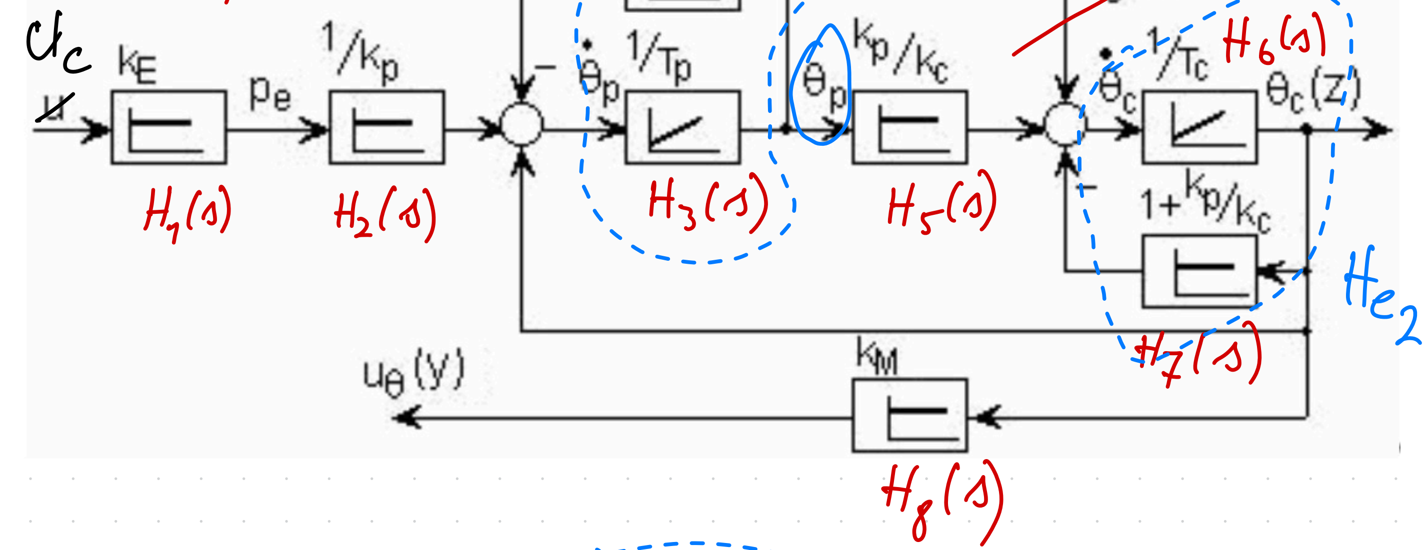
$$H_{\vartheta_{c},\vartheta_e}(s) = \frac{\frac{1}{sT_c + k_p/k_c + 1}}{1 - \frac{1}{sT_c + k_p/k_c + 1} \cdot \frac{1}{sT_p + 1} \cdot \frac{k_p}{k_c}} =$$

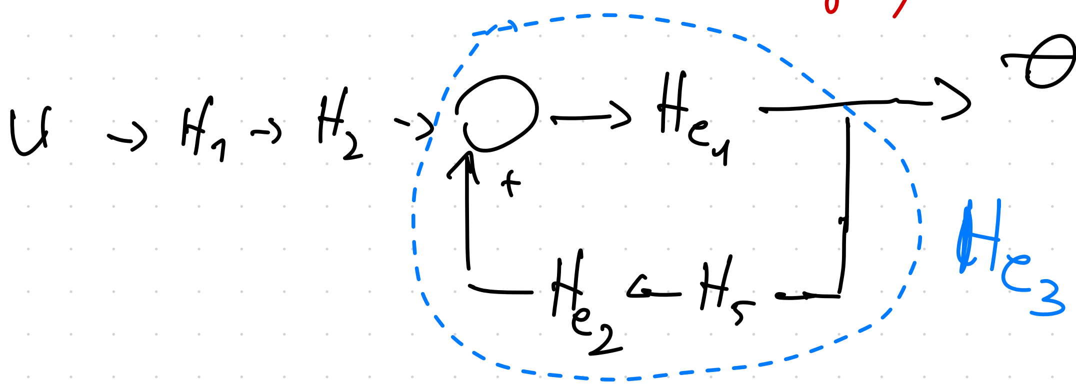
$$= \frac{1}{\cancel{sT_c + k_p/k_c + 1}} \cdot \frac{1}{\frac{(sT_c + k_p/k_c + 1)(sT_p + 1)k_c - k_p}{(\cancel{sT_c + k_p/k_c + 1})(sT_p + 1)\, k_c}}$$

$$H_{\vartheta_c \vartheta_e}(s) = \frac{(sT_p + 1)\, k_c}{s^2 k_c T_p T_c + s k_c T_p + s k_p T_p + s k_c T_c + k_c}$$

$$\boxed{H_{\vartheta_{c},\vartheta_e}(s) = \frac{s\,T_p + 1}{s^2 T_p T_c + s T_p + T_p k_p/k_c + sT_c + 1}}$$

III H_{θ_p, u_c}





$$H_{e3}(s) = \frac{H_{e1}(s)}{1 - H_{e1}(s)\, H_{e2}(s)\, H_5(s)}$$

$$H_{e1}(s) = \frac{1}{sT+1} \qquad H_{e2}(s) = \frac{1}{sT_c + k_p/k_c + 1}$$

$$H_{e3}(s) = \frac{\frac{1}{sT+1}}{1 - \left(\frac{1}{sT+1}\right)\left(\frac{1}{sT_c + k_p/k_c + 1}\right) \cdot \frac{k_p}{k_c}}$$

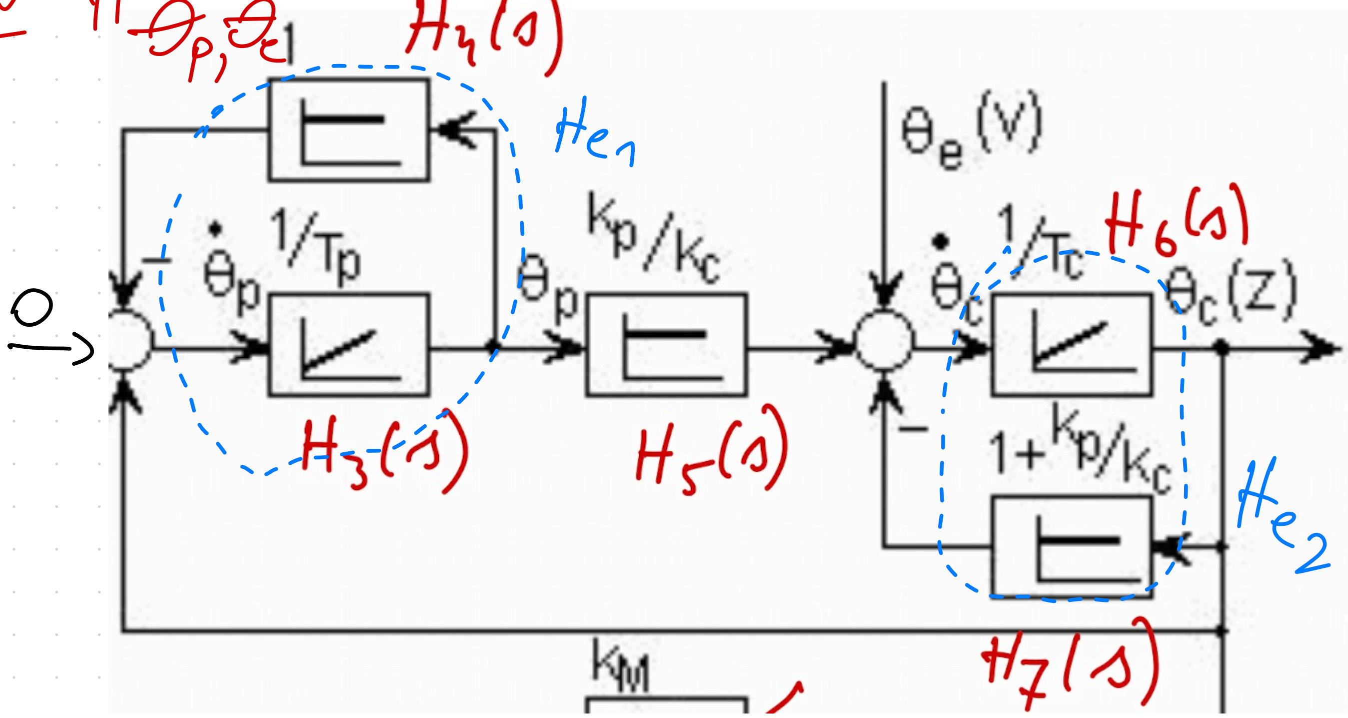
$$H_{e3}(s) = \cancel{\frac{1}{sT+1}} \cdot \frac{\cancel{(sT+1)}(sT_c + k_p/k_c + 1)\, k_c}{(sT+1)(sT_c + k_p/k_c + 1)k_c - k_p}$$

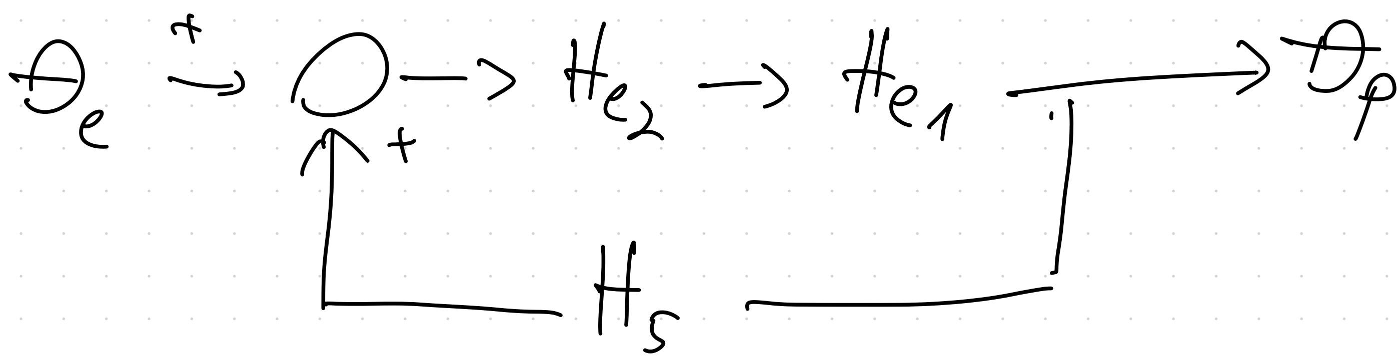
$$H_{\theta_p,u_c}(s) = H_1(s) \cdot H_2(s) \cdot H_{e_3}(s)$$

$$= \frac{k_E}{k_p} \cdot \frac{s T_c + k_p/k_c + 1}{s^2 k_c T_p T_c + s k_c T_p + s k_p T_p + s k_c T_c + k_c}$$

$$\boxed{H_{\theta_p u_c}(s) = \frac{s T_c k_E/k_p + k_E/k_c + k_E/k_p}{s^2 k_c T_p T_c + s k_c T_p + s k_p T_p + s k_c T_c + k_c}}$$

IV H_{θ_p,θ_e}





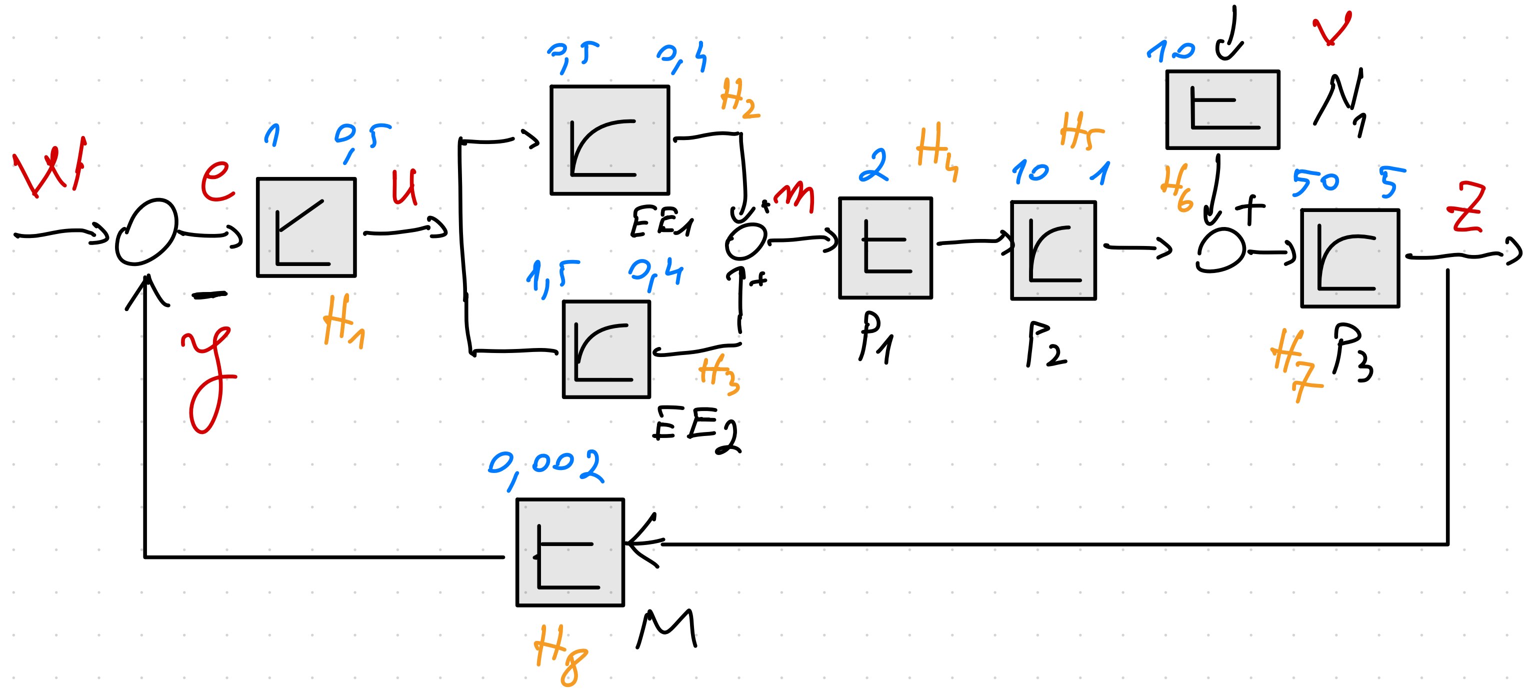
$$H_{\theta_p \theta_e}(s) = \frac{H_{e_1}(s) H_{e_2}(s)}{1 - H_{e_1}(s) H_{e_2}(s) H_s(s)}$$

$$H_{e_1}(s) = \frac{1}{sT_p + 1} \qquad H_{e_2}(s) = \frac{1}{sT_c + k_p/k_c + 1}$$

$$H_{\theta_p \theta_e}(s) = \frac{H_{e_1}(s)\, H_{e_2}(s)}{1 - \left(\frac{1}{sT_p+1}\right)\left(\frac{1}{sT_c + k_p/k_c + 1}\right) \cdot \frac{k_p}{k_c}}$$

$$H_{\theta_p \theta_e}(s) = \frac{\cancel{\frac{1}{sT_p+1}} \cdot \cancel{\frac{1}{sT_c + k_p/k_c + 1}}}{\frac{(sT_p+1)(sT_c + k_p/k_c + 1)k_c - k_p}{\cancel{(sT_p+1)}\,\cancel{(sT_c + k_p/k_c + 1)}\,k_c}}$$

$$\boxed{H_{\theta_p \theta_e}(s) = \frac{1}{s^2 T_p T_c + sT_p k_p/k_c + sT_p + sT_c + k_p/k_c + 1}}$$



$$H_1(s) = \frac{k}{sT}(sT+1) = \frac{1}{s\cdot\frac{1}{2}}\left(s\frac{1}{2}+1\right) = \frac{\frac{s}{2}+1}{\frac{s}{2}} = \frac{s+2}{s}$$

$$H_2(s) = \frac{k}{sT+1} = \frac{0,5}{s(0,4)+1} = \frac{\frac{1}{2}}{\frac{4s}{10}+1} = \frac{\frac{1}{\cancel{2}}}{\frac{4s+10}{\cancel{10}_5}} = \frac{5}{4s+10}$$

$$H_3(s) = \frac{1,5}{s(0,4)+1} = \frac{\frac{3}{\cancel{2}}}{\frac{4s+10}{\cancel{10}_5}} = \frac{15}{4s+10}$$

$$H_4(s) = 2$$

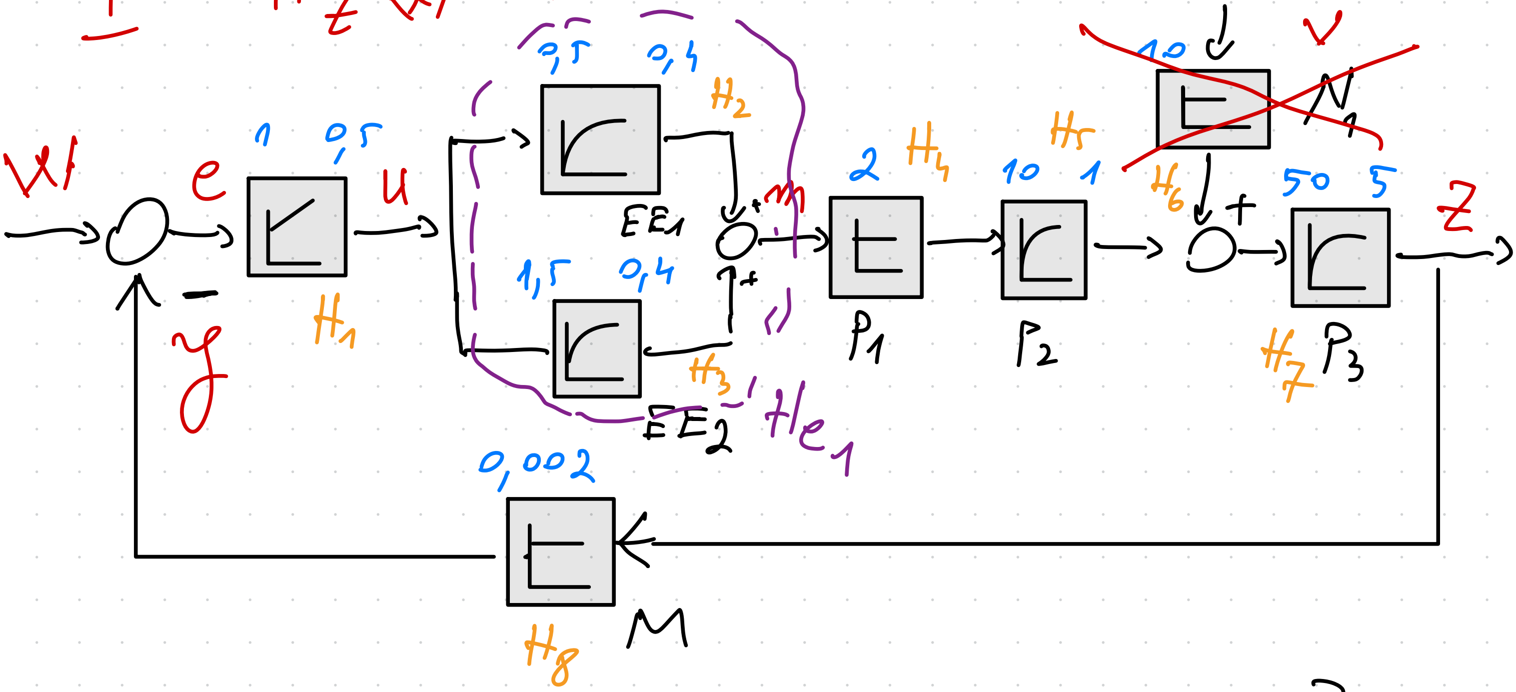
$$H_5(s) = \frac{10}{s+1}$$

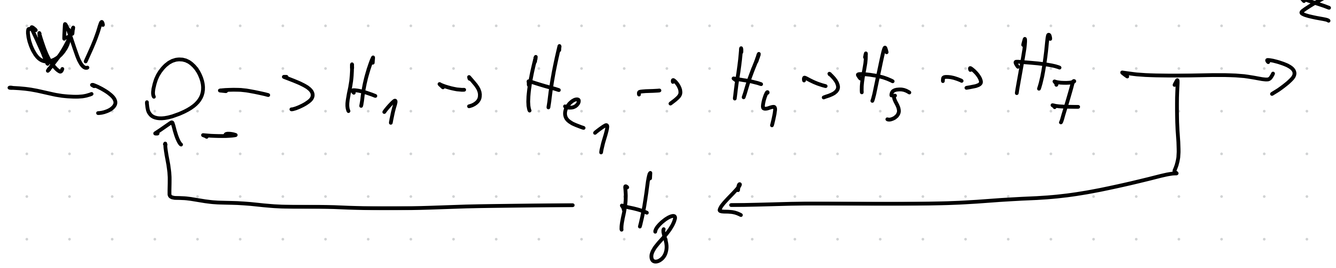
$$H_6(s) = 10$$

$$H_7(s) = \frac{50}{5s+1}$$

$$H_8(s) = 0,002 = \frac{2}{1000}$$

I $\quad H_{zw}(s)$





$$\boxed{H_{zw}(s) = \frac{H_1(s)\left(H_2(s) + H_3(s)\right) H_4(s) H_5(s) H_7(s)}{1 + H_1(s)\left(H_2(s) + H_3(s)\right) H_4(s) H_5(s) H_7(s) H_8(s)}}$$

$$H_1(s)\left(H_2(s) + H_3(s)\right) H_4(s) H_5(s) H_7(s) = \frac{s+2}{s} \cdot \frac{20}{\cancel{4s+10}\atop 2s+5} \cdot \cancel{2} \cdot \frac{10}{s+1} \cdot \frac{50}{5s+1}$$

$$= \frac{10^4 (s+2)}{s(s+1)(2s+5)(5s+1)}$$

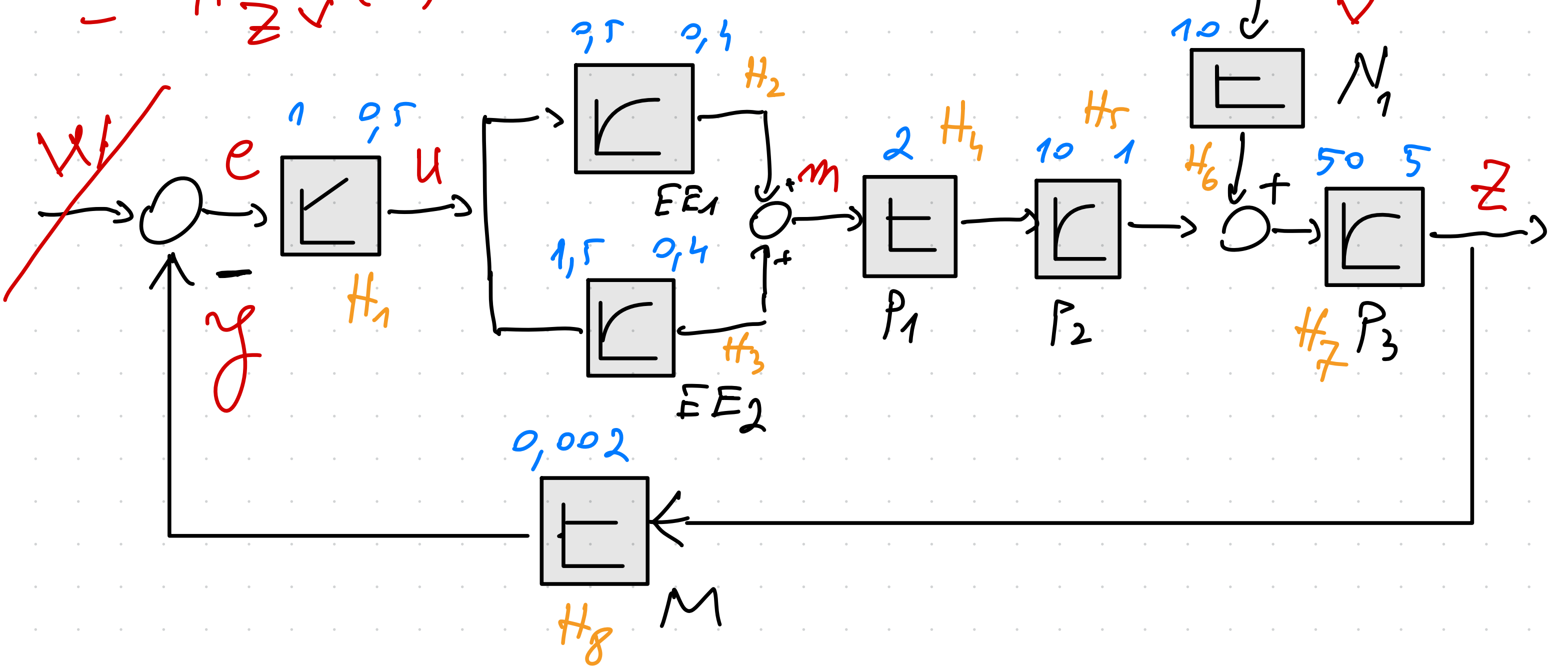
$$H_{zw}(s) = \frac{\dfrac{10^4 (s+2)}{s(s+1)(2s+5)(5s+1)}}{1 + \dfrac{20(s+2)}{s(s+1)(2s+5)(5s+1)}}$$

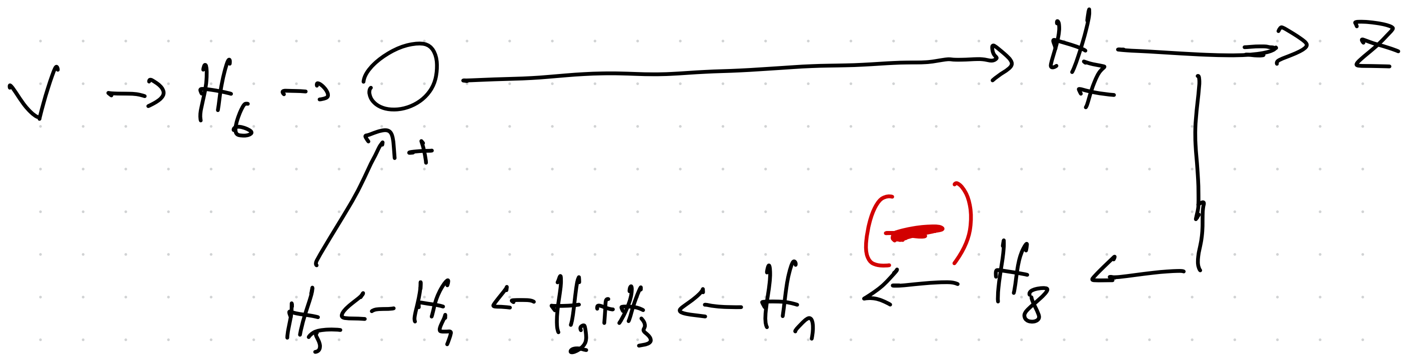
$$H_{ZW}(s) = \frac{\dfrac{10^4 (s+2)}{s(s+1)(2s+5)(5s+1)}}{1 + \dfrac{20(s+2)}{s(s+1)(2s+5)(5s+1)}} =$$

$$= \frac{10^4 (s+2)}{\cancel{(\;)}} \cdot \frac{\cancel{(\;)}}{(\;) + 20(s+2)} = \frac{10^4 (s+2)}{(\;) + 20(s+2)}$$

$$\boxed{H_{ZW}(s) = \frac{10^4 (s+2)}{s(s+1)(2s+5)(5s+1) + 20(s+2)}}$$

II $H_{ZV}(s)$





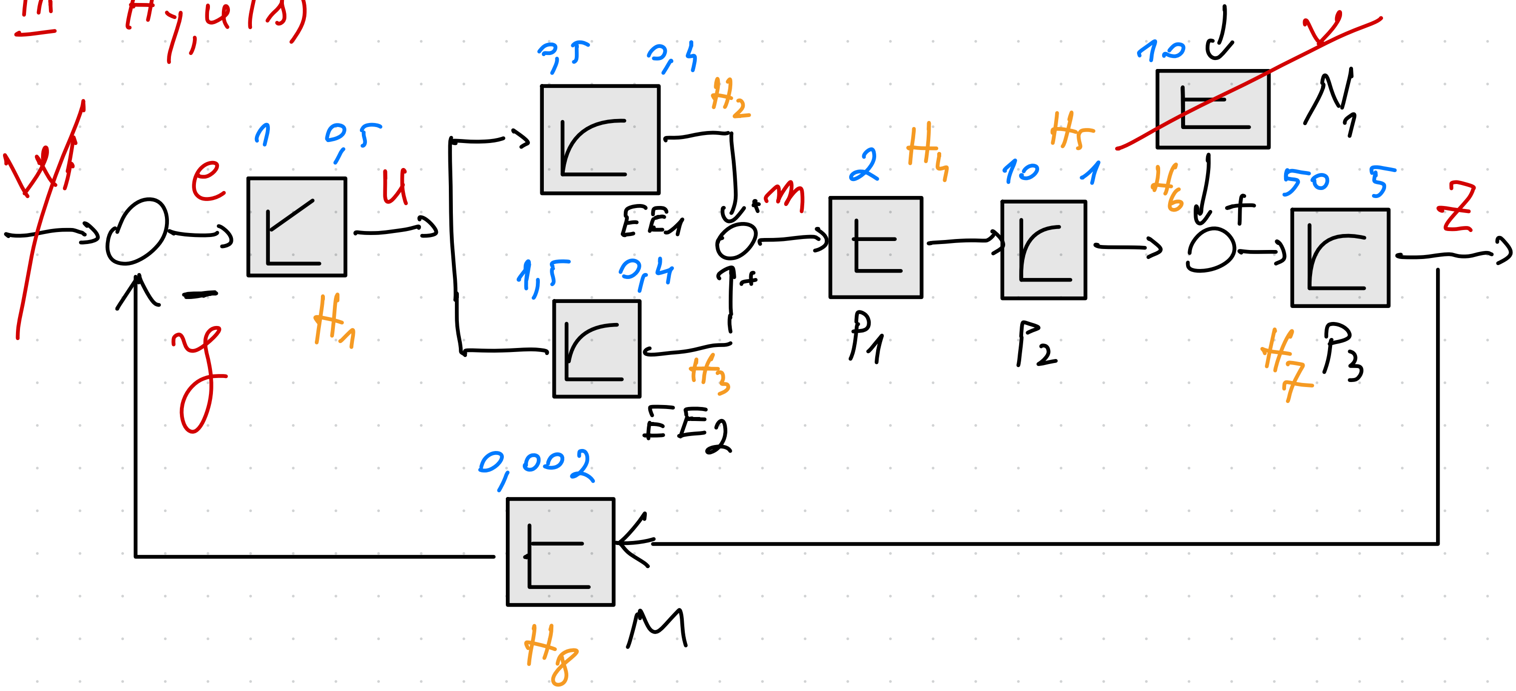
$$\boxed{H_{z,v}(s) = H_6(s) \cdot \frac{H_7(s)}{1 + H_1(s)\left[H_2(s) + H_3(s)\right] H_4(s)\, H_5(s)\, H_7(s)\, H_8(s)}}$$

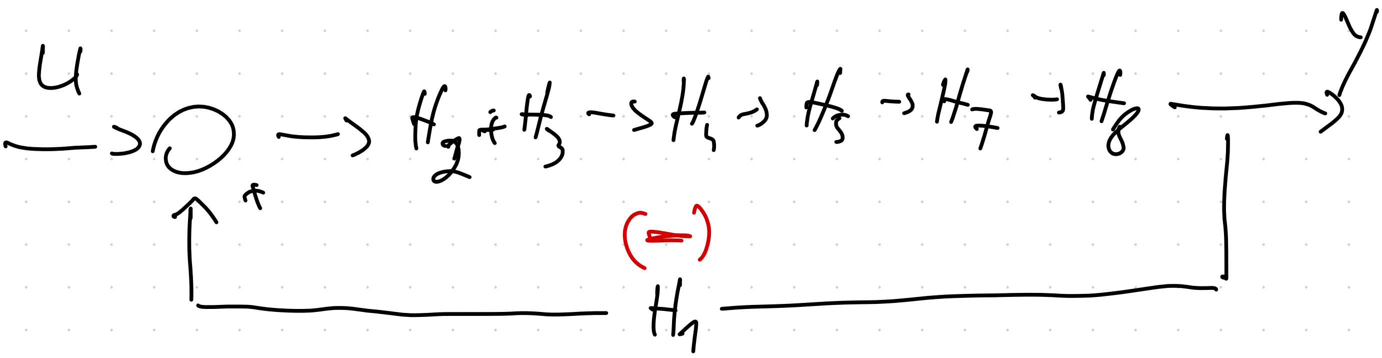
$$H_{z,v}(s) = 10 \cdot \frac{\dfrac{50}{5s+1}}{1 + \dfrac{20(s+2)}{s(s+1)(2s+5)(5s+1)}} =$$

$$= \frac{500}{\cancel{5s+1}} \cdot \frac{s(s+1)(2s+5)\cancel{(5s+1)}}{s(s+1)(2s+5)(5s+1) + 20(s+2)}$$

$$\boxed{H_{z,v}(s) = \frac{500\, s(s+1)(2s+5)}{s(s+1)(2s+5)(5s+1) + 20(s+2)}}$$

III $H_{y,u}(s)$





$$\boxed{H_{y,u}(s) = \frac{\left(H_2(s)+H_3(s)\right)H_4(s)H_5(s)H_7(s)H_8(s)}{1-\left(-H_1(s)\right)\left(H_2(s)+H_3(s)\right)H_4(s)H_5(s)H_7(s)H_8(s)}}$$

$$H_{y,u}(s) = \frac{\frac{\cancel{10}}{2s+5}\cdot 2\cdot\frac{\cancel{10}}{s+1}\,\frac{\cancel{50}^{\,5}}{5s+1}\,\frac{2}{\cancel{1000}}}{1+\frac{s+2}{s}\,\frac{\cancel{10}}{2s+5}\cdot 2\cdot\frac{\cancel{10}}{s+1}\cdot\frac{\cancel{50}^{\,5}}{5s+1}\cdot\frac{2}{\cancel{1000}}}$$

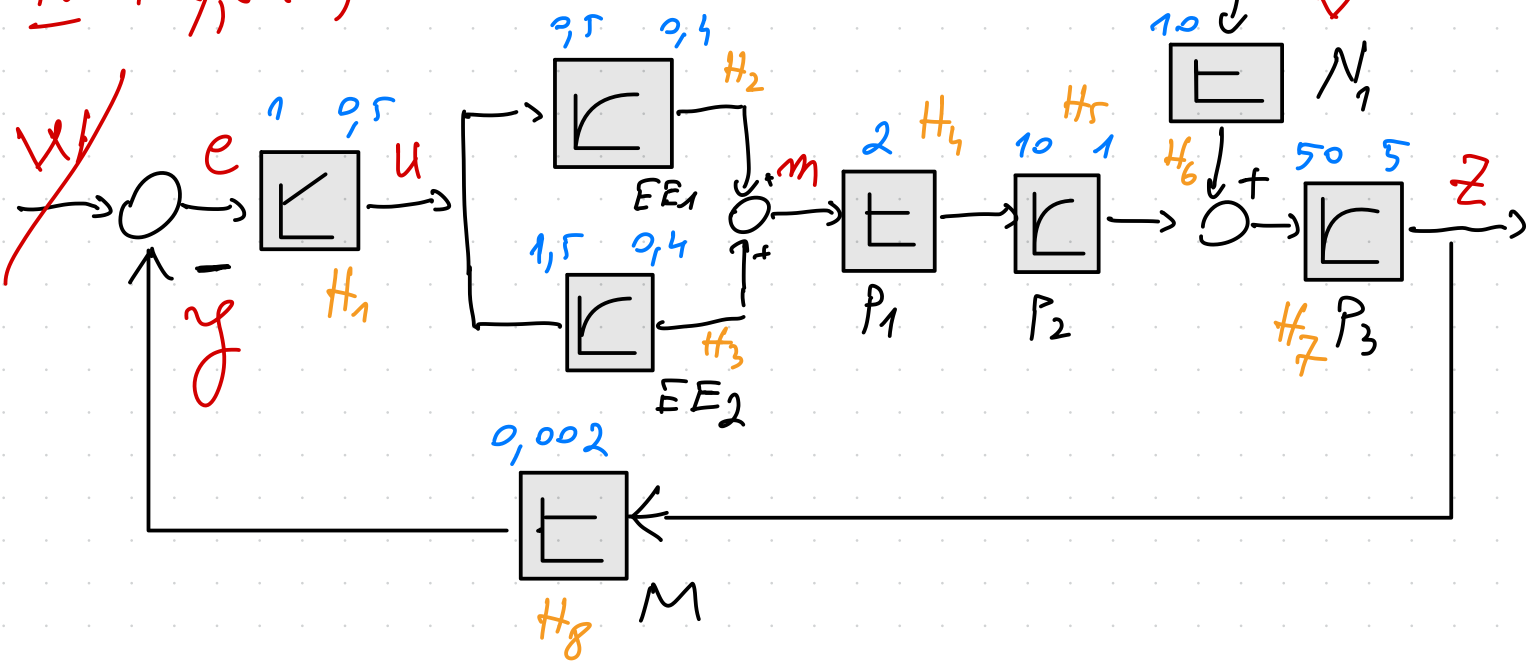
$$H_{y,u}(s) = \frac{\frac{20}{(s+1)(5s+1)(2s+5)}}{1+\frac{20(s+2)}{s(2s+5)(s+1)(5s+1)}}$$

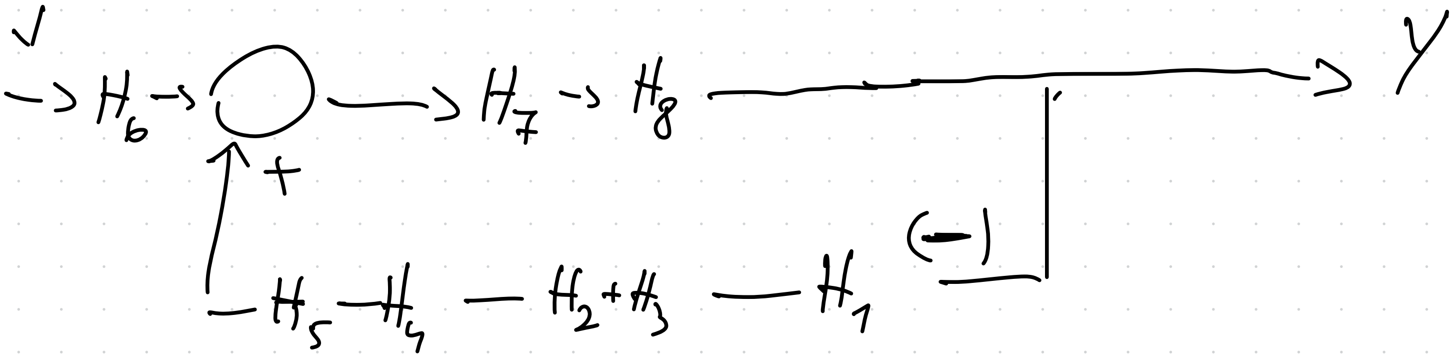
$$H_{y,u}(s) = \frac{\dfrac{20}{(s+1)(5s+1)(2s+5)}}{1 + \dfrac{20(s+2)}{s(2s+5)(s+1)(5s+1)}}$$

$$H_{y,u}(s) = \frac{20}{\cancel{(\,)}} \cdot \frac{s\,\cancel{(\,)}}{s(\,) + 20(s+2)}$$

$$\boxed{H_{y,u}(s) = \frac{20\,s}{s(2s+5)(s+1)(5s+1) + 20(s+2)}}$$

IV $H_{y,v}(s)$





$$\boxed{H_{y,v}(s) = H_6(s)\,\frac{H_7(s)\,H_8(s)}{1-\left(-H_1(s)\right)\left(H_2(s)+H_3(s)\right)H_4(s)H_5(s)H_7(s)\,H_8}}$$

$$H_{y,v}(s) = \frac{\cancel{10}\cdot\frac{\cancel{50}}{5s+1}\cdot\frac{\cancel{2}}{\cancel{1000}}}{1+\frac{20(s+2)}{s(2s+5)(s+1)(5s+1)}}$$

$$H_{y,v}(s) = \frac{1}{\cancel{5s+1}}\;\frac{s(2s+5)(s+1)\cancel{(5s+1)}}{s(2s+5)(s+1)(5s+1)+20(s+2)}$$

$$\boxed{H_{y,v}(s) = \frac{s(2s+5)(s+1)}{s(2s+5)(s+1)(5s+1)+20(s+2)}}$$