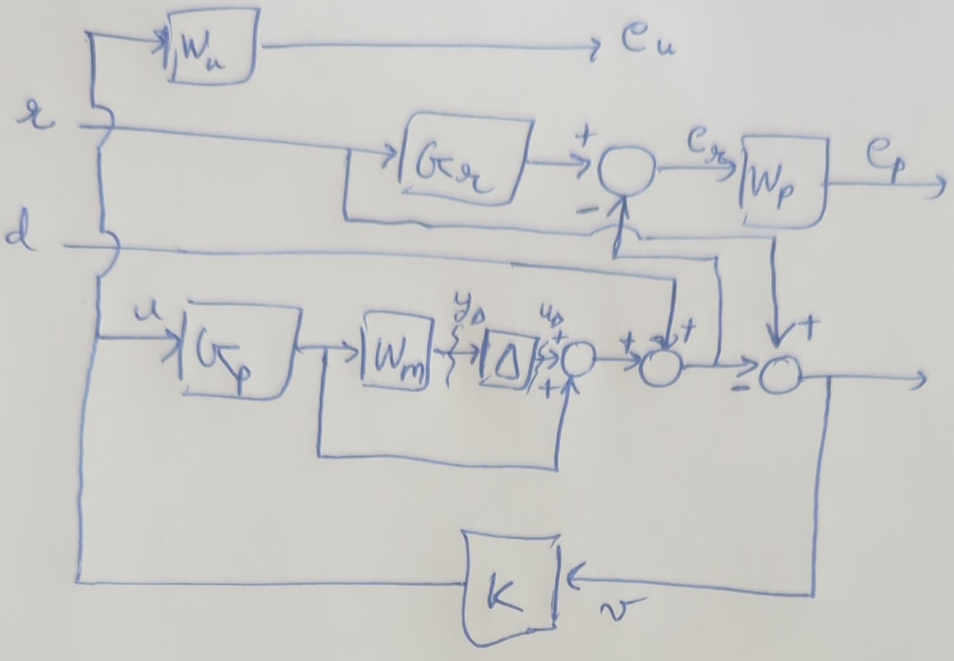
Q3



$$y_\Delta = W_m C_p u \qquad w = \begin{bmatrix} r \\ d \end{bmatrix}$$

$$z = \begin{bmatrix} e_u \\ e_p \end{bmatrix} \Rightarrow e_u = W_u u$$

$$e_p = W_p\left(C_r r - (d + u_\Delta + C_p u)\right)$$

$$= W_p(C_r r - d - u_\Delta - C_p u)$$

$$= W_p C_r r - W_p d - W_p u_\Delta - W_p C_p u$$

$$v = r - (d + u_\Delta + C_p u)$$

$$= r - d - u_\Delta - C_p u$$

$$\begin{bmatrix} y_\Delta \\ z \\ v \end{bmatrix} = \begin{bmatrix} y_\Delta \\ e_u \\ e_p \\ v \end{bmatrix} = \left[\begin{array}{ccc|c} 0 & 0 & 0 & W_m C_p \\ 0 & 0 & 0 & W_u \\ -W_p & W_p C_r & -W_p & -W_p C_p \\ -I & I & -I & -C_p \end{array}\right] \begin{bmatrix} u_\Delta \\ r \\ d \\ u \end{bmatrix}$$

P

$$N = F_l(P,k) = P_{11} + P_{12}k(I - P_{22}k)^{-1}P_{21}$$

$$\Rightarrow N = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -W_p & W_p G_{cr} & -W_p \end{bmatrix} + \begin{bmatrix} W_m G_{cp} \\ W_u \\ -W_p G_{cp} \end{bmatrix} k \left(1 - (-G_{cp})k\right)^{-1} \begin{bmatrix} -1 & 1 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -W_p & W_p G_{cr} & -W_p \end{bmatrix} + \begin{bmatrix} W_m G_{cp} k \\ W_u k \\ -W_p G_{cp} k \end{bmatrix} \left[(1 + G_{cp}k)^{-1} \right] \begin{bmatrix} -1 & 1 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -W_p & W_p G_{cr} & -W_p \end{bmatrix} + \begin{bmatrix} W_m G_{cp} k/(1+G_{cp}k) \\ W_u k/(1+G_{cp}k) \\ -W_p G_{cp} k/(1+G_{cp}k) \end{bmatrix} \begin{bmatrix} -1 & 1 & -1 \end{bmatrix}$$

Let $T = G_{cp}k/(1+G_{cp}k)$, $T = 1 - S \Rightarrow S = 1 - T$

$$\Rightarrow S = \frac{1}{1+G_{cp}k}$$

$$\Rightarrow N = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -W_p & W_p G_{cr} & -W_p \end{bmatrix} + \begin{bmatrix} W_m T \\ W_u k S \\ -W_p T \end{bmatrix} \begin{bmatrix} -1 & 1 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -W_p & W_p G_{cr} & -W_p \end{bmatrix} + \begin{bmatrix} -W_m T & W_m T & -W_m T \\ -W_u k S & W_u k S & -W_u k S \\ W_p T & -W_p T & W_p T \end{bmatrix}$$

$$N = \begin{bmatrix} -W_m T & W_m T & -W_m T \\ -W_u k S & W_u k S & -W_u k S \\ -W_p(1-T) & W_p G_{cr} - W_p T & -W_p(1-T) \end{bmatrix} = \begin{bmatrix} -W_m T & W_m T & -W_m T \\ -W_u k S & W_u k S & -W_u k S \\ -W_p S & W_p(G_{cr} - T) & -W_p S \end{bmatrix}$$