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$$1) (I+GH)^{-1} \cdot G = G(I+HG)^{-1} \Rightarrow I \cdot G = (I+GH) \cdot G \cdot (I+HG)^{-1} \Rightarrow$$

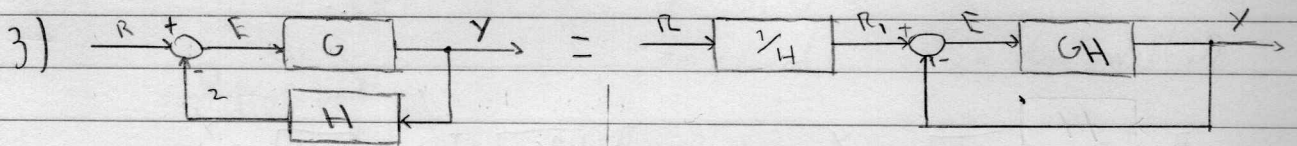
$$\Rightarrow G(I+HG) = (I+GH) \cdot G \Rightarrow$$

$$\Rightarrow G + GHG = G + GHG \quad \therefore$$

$$2) HG(I+GH)^{-1} = (I+HG)^{-1}HG \Rightarrow HG = (I+HG)^{-1}HG(I+GH) \Rightarrow$$

$$\Rightarrow (I+HG) \cdot HG = HG(I+GH) \Rightarrow$$

$$\Rightarrow HG + HGHG = HG + HGHG \quad \therefore$$



$$\bullet Y = GE = G(R - HY) \Rightarrow$$

$$\Rightarrow Y = GR - GHY \Rightarrow$$

$$\Rightarrow Y(1+GH) = GR \Rightarrow$$

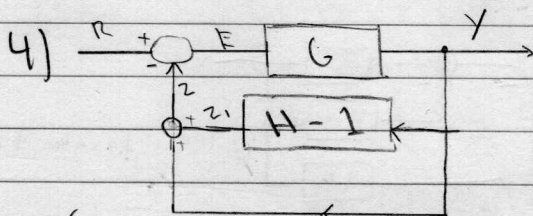
$$\Rightarrow Y = \frac{G}{1+GH} R$$

$$\bullet Y = GH \cdot E = GH \cdot (R_1 - Y) \Rightarrow$$

$$\Rightarrow GH \cdot \left(\frac{R}{H} - Y\right) = GR - GHY \Rightarrow$$

$$\Rightarrow Y(1+GH) = GR \Rightarrow$$

$$\Rightarrow Y = \frac{G}{1+GH} R$$



$$\bullet Y = GE = G \cdot (R - (Z_1 + Y)) =$$

$$= GR - GY - G(H-1) \cdot Y =$$

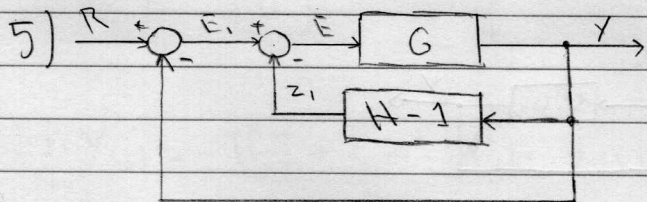
$$= GR - GY - GHY + GY = GR - GHY \Rightarrow$$

$$\Rightarrow Y(1+GH) = GR \Rightarrow Y = \frac{G}{1+GH} R$$

Cond. diretto: G

FTMA:  $(H-1) \cdot G = L$

Blocco con feedback unitario:  $\frac{\text{cond. diretto}}{1+L} = \frac{G}{1+G(H-1)}$



$$\bullet Y = GE = G \cdot (E_1 - Z_1) =$$

$$= G((R-Y) - (H-1) \cdot Y) =$$

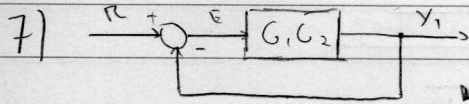
$$= G(R - Y - HY + Y) =$$

$$= G(R - HY) = GR - GHY \Rightarrow$$

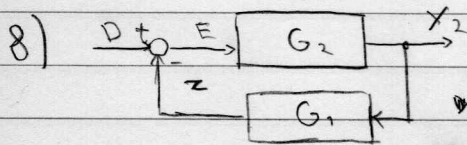
$$\Rightarrow Y(1+GH) = GR \Rightarrow Y = \frac{G}{1+GH} R$$

6) Inventando os ramos:

$$\begin{aligned} \rightarrow Y &= GE = G(E_1 - Z_1) = G((R - (H-1)y) - Y) = \\ &= G(R - HY + Y - Y) = GR - GHY = 0 \\ \Rightarrow Y(1+GH) &= GR \Rightarrow \frac{Y}{R} = \frac{G}{1+GH} \end{aligned}$$



$$\begin{aligned} \bullet Y_1 &= G_1 G_2 \cdot E = G_1 G_2 (R - Y_1) = G_1 G_2 R - G_1 G_2 Y_1 = 0 \\ \Rightarrow Y_1 (1 + G_1 G_2) &= G_1 G_2 R \Rightarrow \frac{Y_1}{R} = \frac{G_1 G_2}{1 + G_1 G_2} \end{aligned}$$

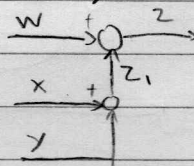
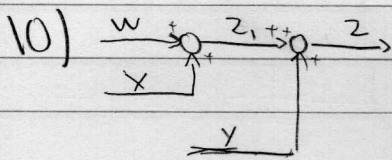


$$\begin{aligned} \bullet Y_2 &= G_2 E = G_2 \cdot E = G_2 (D - Z) = 0 \\ \Rightarrow Y_2 &= G_2 (D - G_1 Y_2) = G_2 D - G_2 G_1 Y_2 = 0 \\ \Rightarrow Y_2 (1 + G_2 G_1) &= G_2 D \Rightarrow \frac{Y_2}{D} = \frac{G_2}{1 + G_2 G_1} \end{aligned}$$

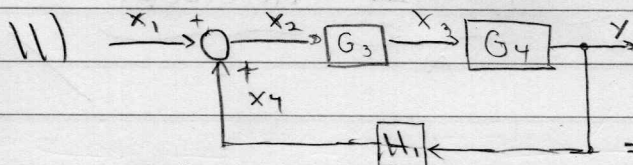
$$9) Y_1 + Y_2 = \frac{G_1 G_2 R}{1 + G_1 G_2} + \frac{G_2 D}{1 + G_2 G_1}$$

→ Memos equações características

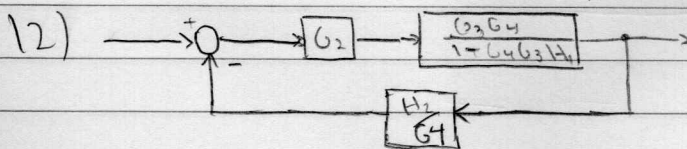
$$\Rightarrow Y_1 + Y_2 = \frac{G_1 G_2 R + G_2 D}{1 + G_1 G_2}$$



$$\bullet Z = Z_1 + Y = W + X + Y \quad \bullet Z = W + Z_1 = W + X + Y$$

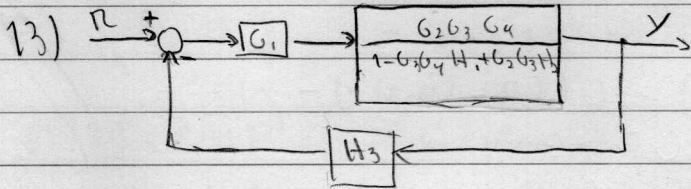


$$\begin{aligned} \bullet Y &= G_4 \cdot X_3 = G_4 \cdot G_3 \cdot X_2 = \\ &= G_4 G_3 \cdot (X_1 + X_4) = 0 \\ \Rightarrow Y &= G_4 G_3 (X_1 + H_1 Y) \Rightarrow Y(1 + G_4 G_3 H_1) = G_4 G_3 X_1 \Rightarrow \frac{Y}{X_1} = \frac{G_4 G_3}{1 + G_4 G_3 H_1} \end{aligned}$$



$$\bullet T_2 = \frac{\text{canal direto}}{1 + \text{RTMA}} = \frac{G_2 G_3 G_4}{1 + G_4 G_3 H_1} = \frac{G_2 G_3 G_4}{1 + G_4 G_3 H_1} \cdot \frac{1 + G_4 G_3 H_1}{1 + G_4 G_3 H_1} = \frac{G_2 G_3 G_4}{1 + G_4 G_3 H_1 + G_2 G_3 H_2}$$

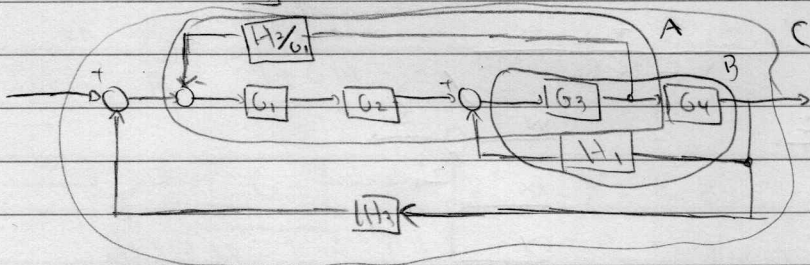
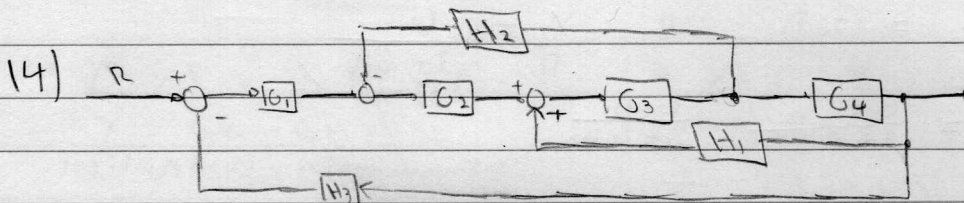
$$\bullet T_2 = \frac{G_2 G_3 G_4}{1 - G_4 G_3 H_1 + G_2 G_3 H_2}$$



$$T = \frac{\text{Cand. Directo}}{1 + L} = \frac{G_1 \cdot G_2 \cdot G_3 \cdot G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2} \cdot \frac{1}{1 + \frac{H_3 \cdot G_2 G_3 G_4 \cdot G_1}{1 - G_3 G_4 H_1 + G_2 G_3 H_2}} = \frac{N}{D}$$

$$\Rightarrow T = \frac{N}{D} = \frac{N}{D + H_3 N} \Rightarrow T = \frac{N}{1 + \frac{H_3 N}{D}}$$

$$\Rightarrow T = \frac{G_1 G_2 G_3 G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2 + H_3 G_1 G_2 G_3 G_4}$$



$$T = \frac{\text{Cand. Directo}}{1 + \sum L} = \frac{G_1 G_2 G_3 G_4}{1 - \underbrace{G_3 G_4 H_1}_B + \underbrace{G_1 G_2 G_3 \frac{H_2}{G_1}}_A + \underbrace{G_1 G_2 G_3 G_4 H_3}_C}$$