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① $Y = (I+GH)^{-1} GR \Rightarrow Y = TR \rightarrow T = (I+GH)^{-1} G$

$\underbrace{\phantom{(I+GH)^{-1}}}_{T}$

Pelo diagrama de blocos: $Z = HY \Rightarrow R - E = HY \Rightarrow R - G^{-1}Y = HY \Rightarrow R = (G^{-1}+H)Y \Rightarrow$

$R = (I + HG)G^{-1}Y \Rightarrow (I+HG)^{-1}R = G^{-1}Y \Rightarrow Y = \underbrace{G(I+HG)^{-1}}_{T} R \Rightarrow \boxed{T = G(I+HG)^{-1}}$
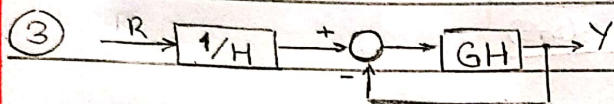
$\therefore (I+GH)^{-1}G = G(I+HG)^{-1} = G(I+L)^{-1}$, com $L = HG$

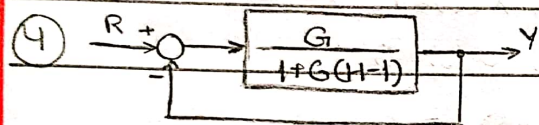② $Z = HY \Rightarrow Z = HGE = HG(R-Z) \Rightarrow HGR = (I+HG)Z \Rightarrow \boxed{ZR^{-1} = (I+HG)^{-1}HG}$

$Y = GE \Rightarrow H^{-1}Z = G(R-Z) \Rightarrow GR = (H^{-1}+G)Z = (I+GH)H^{-1}Z \Rightarrow \boxed{ZR^{-1} = H(I+GH)^{-1}G}$

Para $L = HG = GH$: $\dfrac{Z}{R} = \dfrac{HG}{I+HG} = \dfrac{GH}{I+GH} = \dfrac{L}{I+L}$
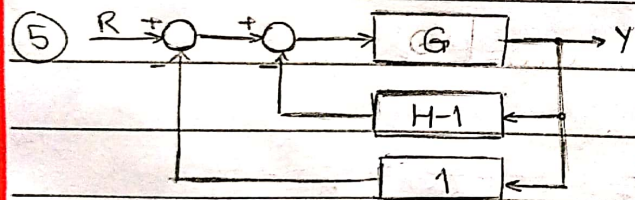
$Z = HY \Rightarrow Z = HG(R-Z) \Rightarrow \boxed{\dfrac{Z}{R} = \dfrac{HG}{I+HG}}$
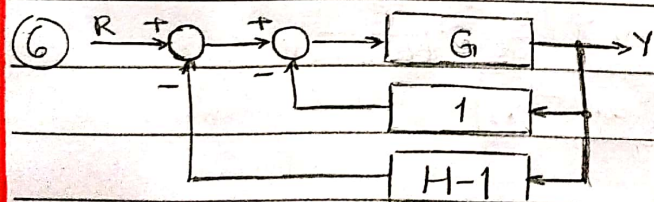
③

$Y = \left(\dfrac{R}{H} - Y\right)GH = GR - YGH \Rightarrow \boxed{Y = \dfrac{GR}{1+GH}}$
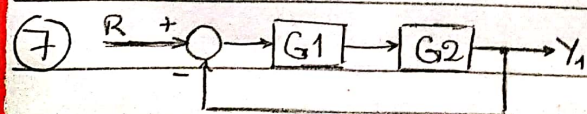
④

$Y = \dfrac{G}{1+G(H-1)}(R-Y) \Rightarrow Y\left(1+\dfrac{G}{1+G(H-1)}\right) = \dfrac{GR}{1+G(H-1)} \Rightarrow \boxed{Y = \dfrac{GR}{1+GH}}$
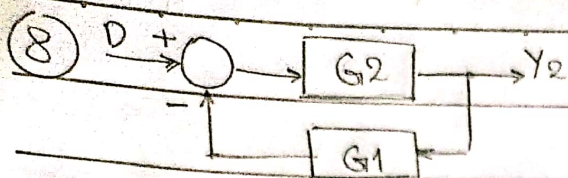
⑤

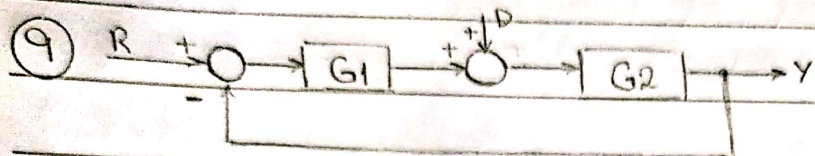$Y = (R-Y-Y(H-1))G \Rightarrow Y = (R-YH)G \Rightarrow Y(1+GH) = GR \Rightarrow \boxed{Y = \dfrac{GR}{1+GH}}$

⑥

$Y = (R-Y(H-1)-Y)G \Rightarrow Y = (R-HY)G \Rightarrow Y = GR - GHY \Rightarrow \boxed{Y = \dfrac{G}{1+GH}}$

⑦

$Y_1 = (R-Y_1)G_1 G_2 \Rightarrow Y_1(1+G_1 G_2) = G_1 G_2 R \Rightarrow \boxed{Y_1 = \dfrac{G_1 G_2 R}{1+G_1 G_2}}$
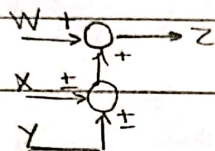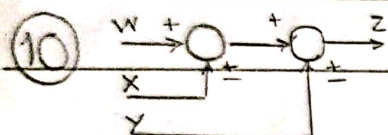
⑧

$$Y_2 = (D - Y_2 G_1) G_2 \Rightarrow Y_2(1 + G_1 G_2) = G_2 D \Rightarrow \boxed{Y_2 = \frac{G_2 D}{1 + G_1 G_2}}$$

⑨

$$Y = \left[(R - Y)G_1 + D\right]G_2 \Rightarrow Y(1 + G_1 G_2) = G_1 G_2 R + G_2 D \Rightarrow \boxed{Y = \underbrace{\frac{G_1 G_2 R}{1 + G_1 G_2}}_{Y_1} + \underbrace{\frac{G_2 D}{1 + G_1 G_2}}_{Y_2}}$$
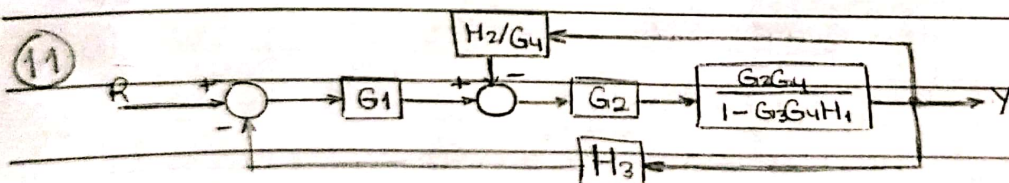
$$Y = Y_1 + Y_2$$

As três funções terão os mesmos polos

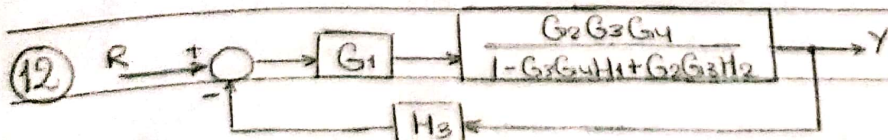**⑩**

$$Z = (W \pm X) \pm Y = W \pm X \pm Y \qquad \qquad Z = W + (\pm X \pm Y) = W \pm X \pm Y$$
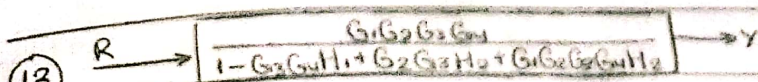
∴ Diagramas equivalentes

⑪

$$Y = G_2 \left[G_1(R - H_3 Y) - \frac{H_2 Y}{G_4} \right] \frac{G_3 G_4}{1 - G_3 G_4 H_1}$$

$$\boxed{Y = \frac{R G_1 G_2 G_3 G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2 + G_1 G_2 G_3 G_4 H_3}}$$

⑫

$$Y = G_1(R - H_3 Y) \frac{G_2 G_3 G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2}$$

$$\boxed{Y = \frac{R G_1 G_2 G_3 G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2 + G_1 G_2 G_3 G_4 H_3}}$$

⑬

$$\boxed{Y = \frac{R G_1 G_2 G_3 G_4}{1 - G_3 G_4 H_1 + G_2 G_3 H_2 + G_1 G_2 G_3 G_4 H_3}}$$