

Integral effect

$$\dot{x} = Ax + Bu + Gv = Ax + B(Fr - Kx) + Gr$$

$$\dot{x} = 0 \Rightarrow 0 = (A - BK)x + (BF + G)r$$

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 0 \\ 0 & k_1 \\ k_2 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \quad K = \begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix} \quad G = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$$

$$(BK - A)x = (BF + G)r_0$$

$$x_{ss} = (BK - A)^{-1} (BF + G)r_0$$

$$y_{ss} = \underbrace{C(BK - A)^{-1} (BF + G)}_{\text{integral effect}} r_0$$

$$C(BK - A)^{-1} (BF + G) = I$$

$$C(BK - A)^{-1} BF + C(BK - A)^{-1} G = I$$

$$F = (C(BK - A)^{-1} B)^{-1} (I - C(BK - A)^{-1} G)$$