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# Espaço de Estados

$$\bar{x} = \frac{M_1 x_1 + M_2 x_2}{M_1 + M_2} \Rightarrow \bar{x} = \frac{M_1 x_1 + M_2 x_2}{M}$$

$$\delta = x_1 - x_2$$

$$\ddot{\bar{x}} = \frac{u_1 + u_2}{M}$$

$$\ddot{\delta} = -\frac{kM}{M_1 M_2}\delta + \frac{u_1}{M_1} - \frac{u_2}{M_2}$$

$$z = [\bar{x} \quad \delta \quad \dot{\bar{x}} \quad \dot{\delta}]^T \Rightarrow \dot{z} = [\dot{\bar{x}} \quad \dot{\delta} \quad \ddot{\bar{x}} \quad \ddot{\delta}]^T \Rightarrow \dot{z} = [\dot{\bar{x}}_1 \quad \dot{\bar{x}}_2 \quad \dot{\bar{x}}_3 \quad \dot{\bar{x}}_4]^T$$

$$\begin{cases} \dot{z} = \bar{A}z + \bar{B}u \\ y = \bar{C}z + \bar{D}u \end{cases}$$

$$\begin{bmatrix} \dot{\bar{x}}_1 \\ \dot{\bar{x}}_2 \\ \dot{\bar{x}}_3 \\ \dot{\bar{x}}_4 \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & -kM/M_1M_2 & 0 & 0 \end{bmatrix}}_{\bar{A}} \begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \\ \bar{x}_3 \\ \bar{x}_4 \end{bmatrix} + \underbrace{\begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1/M & 1/M \\ 1/M_1 & -1/M_2 \end{bmatrix}}_{\bar{B}} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

$$y = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1 & M_2/M & 0 & 0 \\ 1 & -M_1/M & 0 & 0 \end{bmatrix} z$$

$$x_1 = \bar{x} + \delta\frac{M_2}{M} \Rightarrow x_1 = \frac{M_1}{M}x_1 + \cancel{\frac{M_2}{M}x_2} + \frac{M_2}{M}x_1 - \cancel{\frac{M_2}{M}x_2} \Rightarrow x_1 = x_1\frac{M}{M} \Rightarrow x_1 = x_1$$

$$x_2 = \bar{x} - \delta\frac{M_1}{M} \Rightarrow x_2 = \cancel{\frac{M_1}{M}x_1} + \frac{M_2}{M}x_2 - \cancel{\frac{M_2}{M}x_1} + \frac{M_2}{M}x_2 \Rightarrow x_2 = x_2\frac{M}{M} \Rightarrow x_2 = x_2$$