

$$\tau = K_p e + K_d \dot{e} + G(q) \quad (1)$$

$$K_p = \begin{bmatrix} 1000 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1000 & 0 & 0 & 0 & 0 \\ 0 & 0 & 100 & 0 & 0 & 0 \\ 0 & 0 & 0 & 100 & 0 & 0 \\ 0 & 0 & 0 & 0 & 100 & 0 \\ 0 & 0 & 0 & 0 & 0 & 10 \end{bmatrix} \quad (2)$$

$$K_d = \begin{bmatrix} 10 & 0 & 0 & 0 & 0 & 0 \\ 0 & 100 & 0 & 0 & 0 & 0 \\ 0 & 0 & 10 & 0 & 0 & 0 \\ 0 & 0 & 0 & 10 & 0 & 0 \\ 0 & 0 & 0 & 0 & 10 & 0 \\ 0 & 0 & 0 & 0 & 0 & 10 \end{bmatrix} \quad (3)$$

$$\tau = B(q)[\ddot{q}_d + K_p e + K_d \dot{e}] + C(q, \dot{q})\dot{q} + G(q) \quad (4)$$

$$K_p = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$K_d = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

$$\tau = Y\hat{\pi} + K_d \dot{e} + K_p e \quad (7)$$

$$u_\pi = R^{-1}Y^T M^{-T} B^T P x \quad (8)$$

$$K_p = \begin{bmatrix} 1000 & 00 & 0 & 0 & 0 & 0 \\ 0 & 100000 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1000000 & 0 & 0 & 0 \\ 0 & 0 & 0 & 10000 & 0 & 0 \\ 0 & 0 & 0 & 0 & 10000 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1000 \end{bmatrix} \quad (9)$$

$$K_d = \begin{bmatrix} 100 & 00 & 0 & 0 & 0 & 0 \\ 0 & 1000 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1000 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1000 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1000 & 0 \\ 0 & 0 & 0 & 0 & 0 & 100 \end{bmatrix} \quad (10)$$

$$R = 10 * I_2 \quad (11)$$

$$A = \begin{bmatrix} 0_6 & I_6 \\ -K_p & -K_d \end{bmatrix} \quad (12)$$

$$B = \begin{bmatrix} 0_6 \\ I_6 \end{bmatrix} \tag{13}$$

$$Q = I_{12} \tag{14}$$

$$A^T P + P A = -Q \tag{15}$$