Rotary Flexible Link

The Flexible Link experiment consists of a flexible metal ruler (link) with a strain gauge attached mounted on top of the SRV02 load gear shaft and fastened with screws. The strain gauge measures the link tip displacement based on a known stiffness and the torque measured at the gear shaft.

This experiment explores the use of partial-state and full-state feedback to control the movement of the end of the flexible link as a torque is applied to the base of the link. By adjusting the parameters of the compensator design the student can achieve the most rapid system response with the least amount of unwanted oscillation.

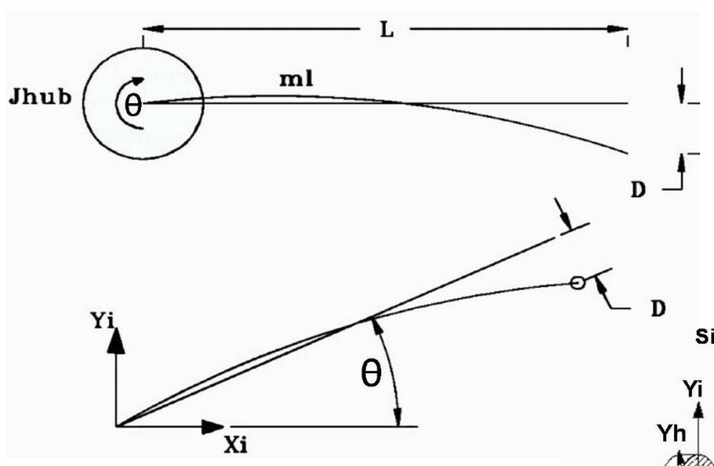
State-space model

$$\dot{\mathbf{x}} = A\mathbf{x} + Bu \qquad \mathbf{y} = C\mathbf{x} + Du \qquad \mathbf{x} = \begin{bmatrix} \theta \\ \alpha \\ \dot{\theta} \\ \dot{\alpha} \end{bmatrix} \qquad \mathbf{y} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

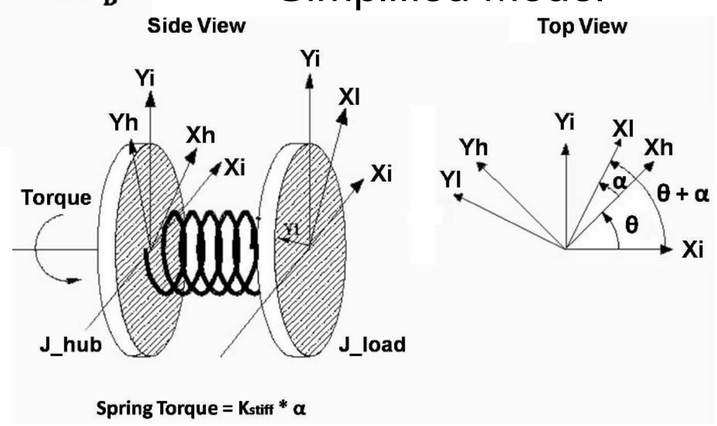
$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \dfrac{K_{stiff}}{J_{eq}} & \dfrac{-\eta_m\eta_g K_t K_m K_g^2 + B_{eq}R_m}{J_{eq}R_m} & 0 \\ 0 & \dfrac{K_{stiff}\left(J_{eq}+J_{link}\right)}{J_{eq}J_{link}} & \dfrac{\eta_m\eta_g K_t K_m K_g^2 + B_{eq}R_m}{J_{eq}R_m} & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 0 \\ \dfrac{\eta_m\eta_g K_t K_g}{J_{eq}R_m} \\ \dfrac{-\eta_m\eta_g K_t K_g}{J_{eq}R_m} \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Free-body diagram



Simplified Model

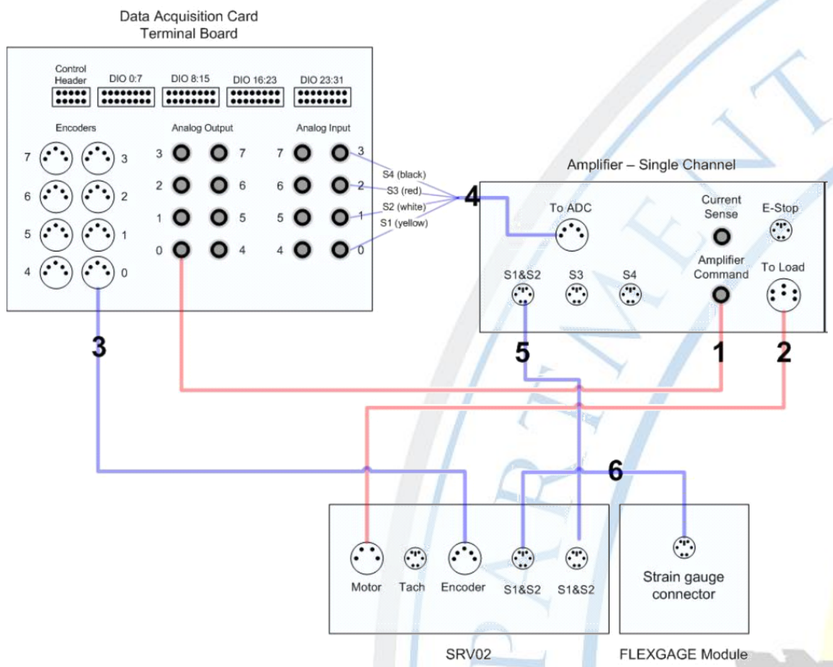


LQR controller design

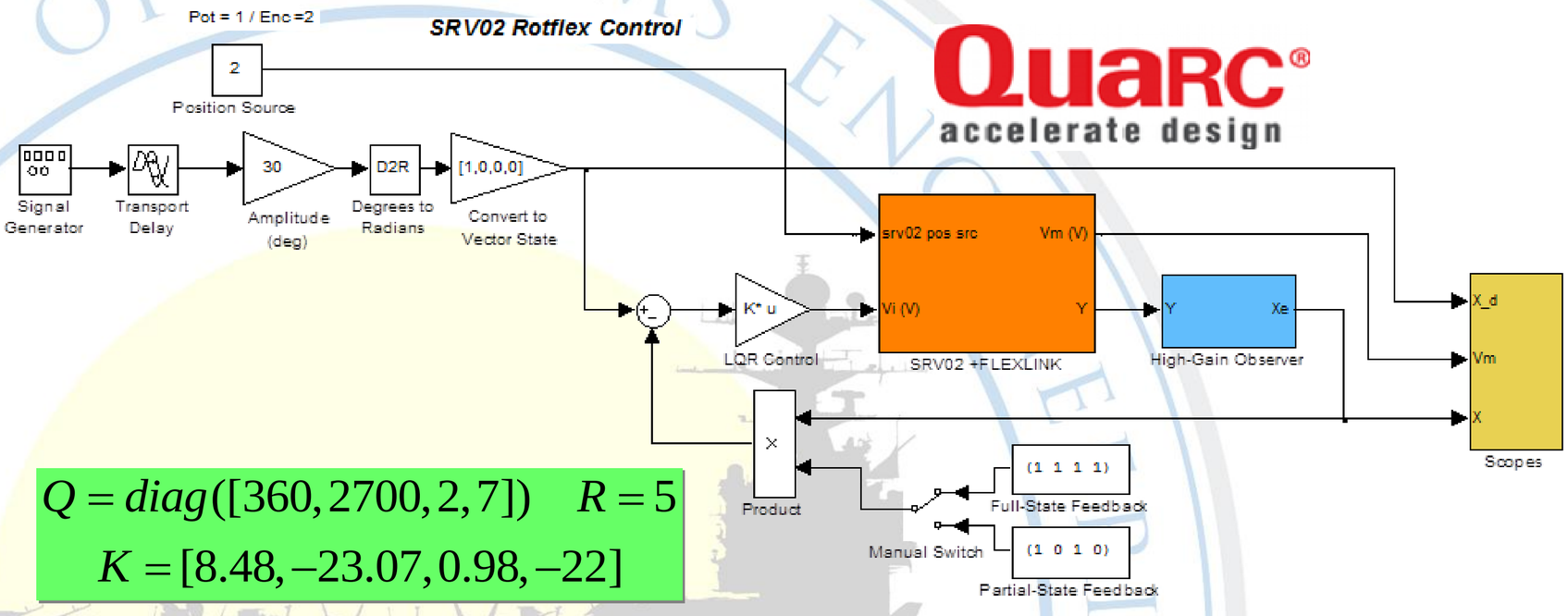
$$\dot{\mathbf{x}} = A\mathbf{x} + Bu \qquad J = \int_0^\infty (\mathbf{x}^T Q\mathbf{x} + uRu)dt$$

$$A^T P + PA - PBR^{-1}B^T P + Q = 0 \qquad K = R^{-1}B^T P \qquad u = -K\mathbf{x}$$

Wiring diagram



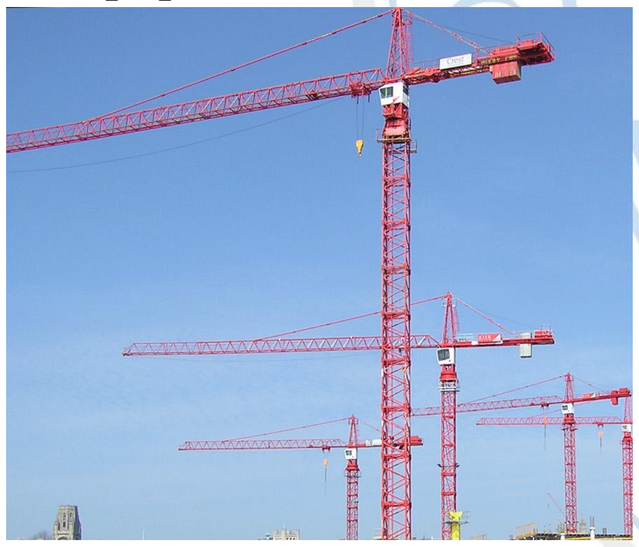
Simulink block diagram



$$Q = diag([360, 2700, 2, 7]) \qquad R = 5$$

$$K = [8.48, -23.07, 0.98, -22]$$

Applications



PoC: Prof. **Oleg Yakimenko**, Bu-223
oayakime@nps.edu, (831) 656-2826

NPS PRAESTANTIA PER SCIENTIAM 1909

CRUSER
Consortium for Robotics and Unmanned Systems Education and Research

SYSTEMS ENGINEERING
ESTABLISHED 2002