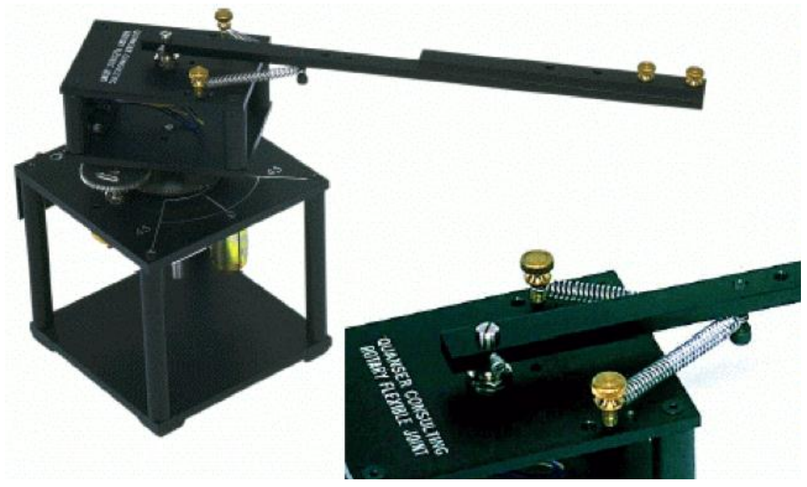
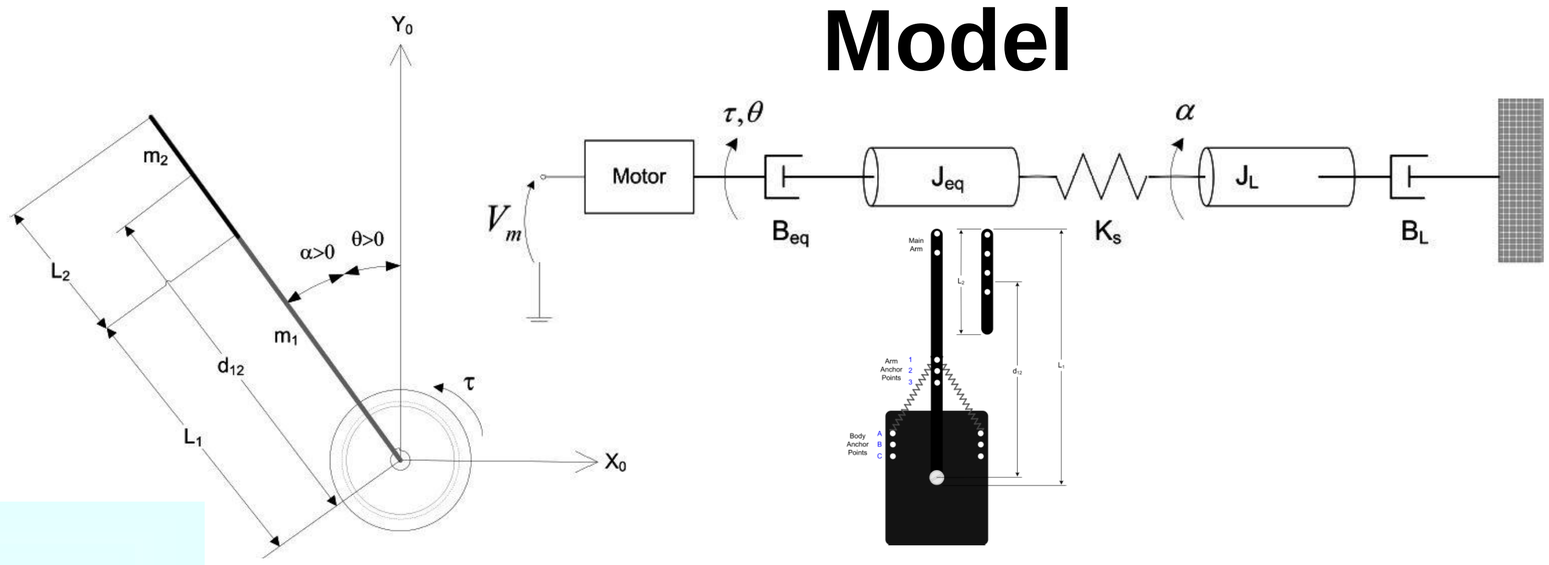
Rotary Flexible Joint



The Flexible Joint experiment consists of the Flexible Joint Module mounted on top of the SRV02 load gear. The module is attached to the load gear by two thumbscrews. The flexible joint itself consists of two identical springs mounted to the top of the joint module and the Main Arm. The Arm deflection is measured using a sensor. Three types of springs result in a total of nine possible stiffness constants. The link is also adjustable in length thus allowing for variations in inertia. The experiment is intended to model control problems that are encountered in large geared robot and spacecraft joints. The purpose of the experiment is to design a controller that will place the tip of the Main Arm at a specified angle.

Model



Equations of motion

$$(J_{eq} + J_L)\ddot{\theta} + J_L\ddot{\alpha} + B_{eq}\dot{\theta} = \tau \qquad B_L = 0$$

$$J_L\ddot{\theta} + J_L\ddot{\alpha} + B_L\dot{\theta} + K_s\alpha = \tau \qquad \tau = \frac{\eta_g K_g \eta_m k_t (V_m - K_g k_m \dot{\theta})}{R_m}$$

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

$$\mathbf{y} = C\mathbf{x} + Du \qquad C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

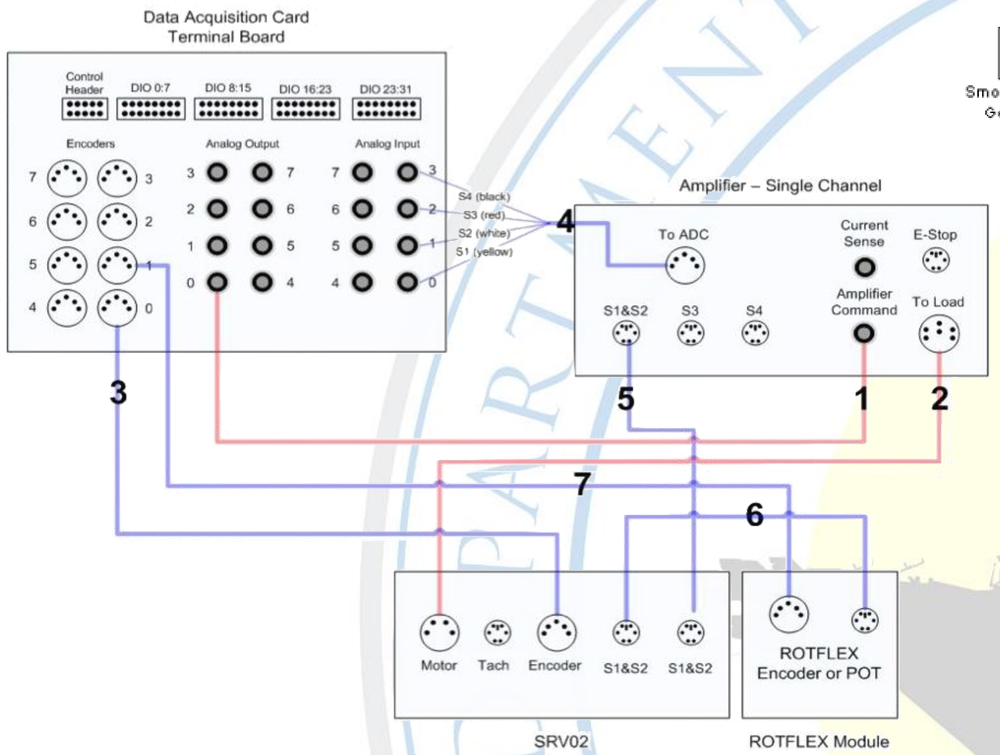
$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{K_s}{J_{eq}} & \frac{-\eta_g \eta_m k_t k_m K_g^2 - B_{eq} R_m}{J_{eq} R_m} & 0 \\ 0 & \frac{K_s (J_{eq} + J_L)}{J_{eq} J_L} & \frac{-\eta_g \eta_m k_t k_m K_g^2 + B_{eq} R_m}{J_{eq} R_m} & 0 \end{bmatrix} \qquad B = \frac{\eta_g K_g \eta_m k_t}{J_{eq} R_m} \begin{bmatrix} 0 \\ 0 \\ 1 \\ -1 \end{bmatrix}$$

Specifications

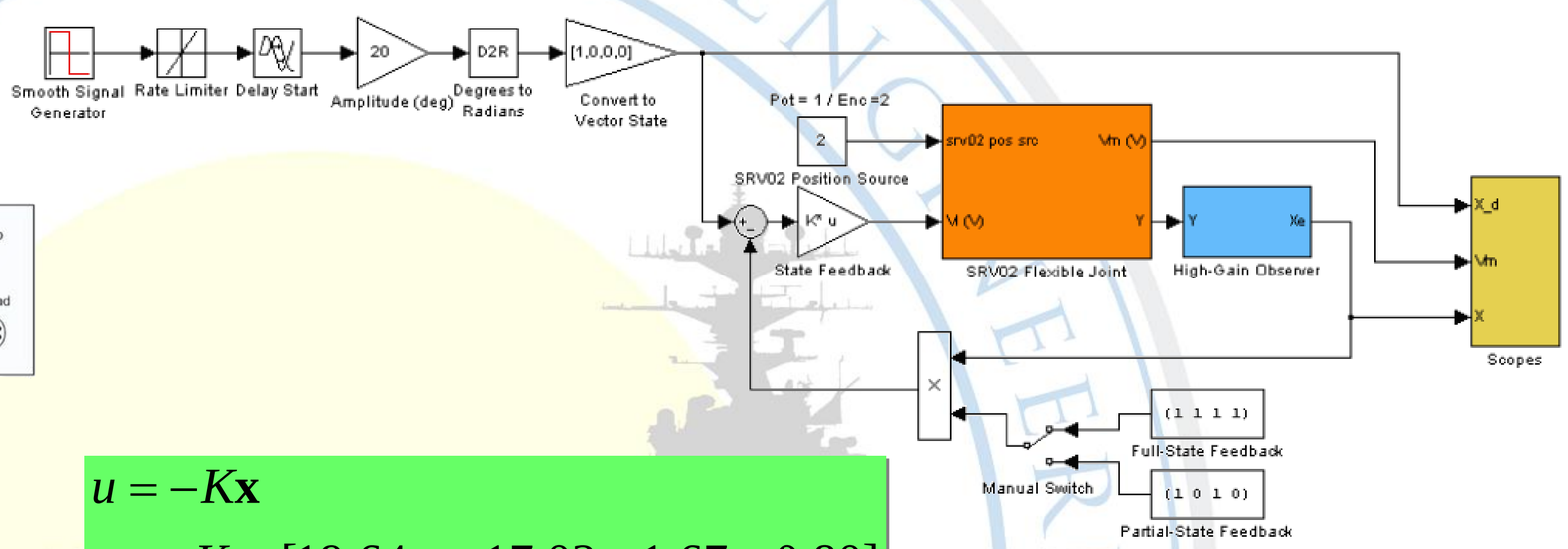
Servo angle 4% settling time:	t_s= 0.5s
Servo angle percentage overshoot:	M_p< 5%
Maximum link angle deflection:	$\lvert\alpha\rvert$ < 12.5°
Maximum control effort / voltage:	$\lvert V_m\rvert$ < 10V

Damping ratio:	ζ = 0.6
Natural frequency:	ω_n = 20 *rad/s*

Wiring diagram



Simulink block diagram



$$u = -K\mathbf{x}$$

$$K = [19.64 \quad -17.02 \quad 1.67 \quad 0.80]$$

Applications

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SYSTEMS ENGINEERING
ESTABLISHED 2002