Interaction Dynamics and Control for Orbital Assembly

Very simplistic models. Good starting point. Should be further along at 3rd annual review.

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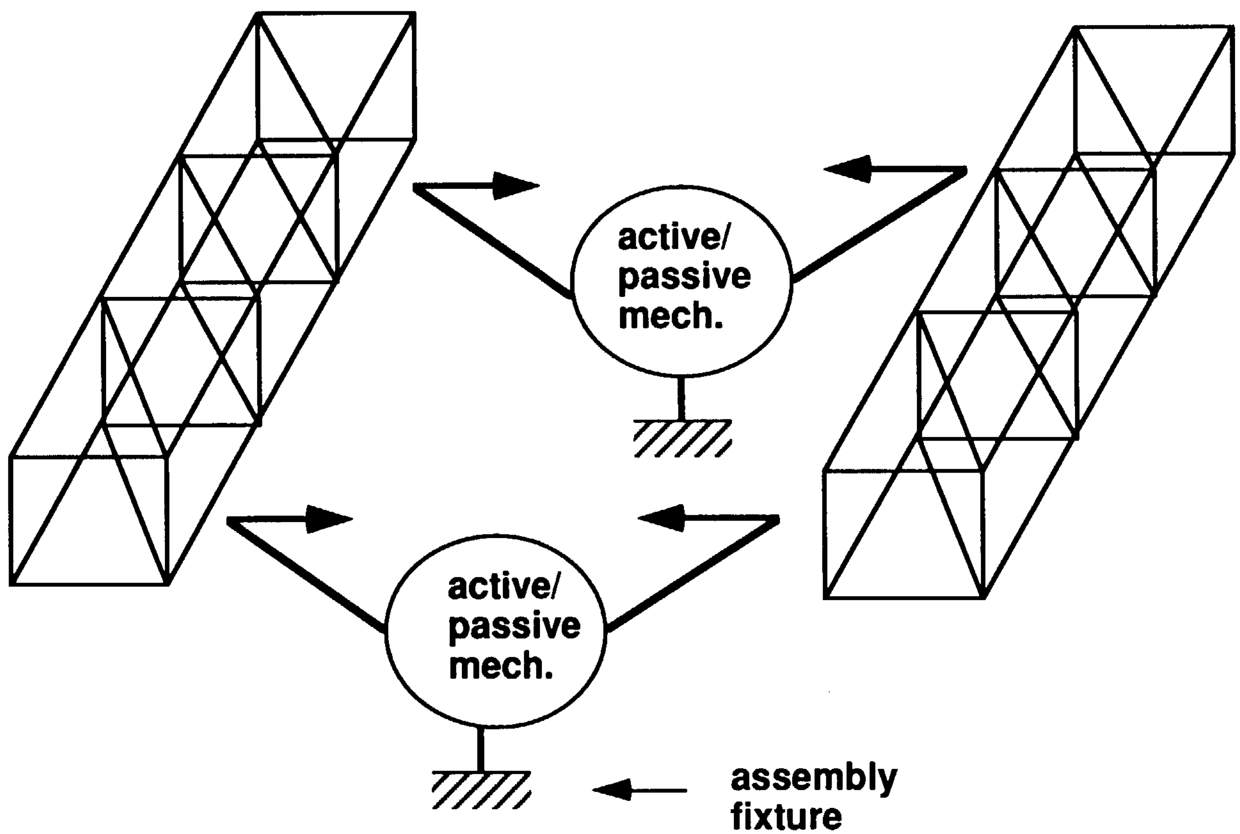
Third Annual Symposium
November 21 & 22, 1991

Dynamics and Control Problems of Joining Structures in Orbit



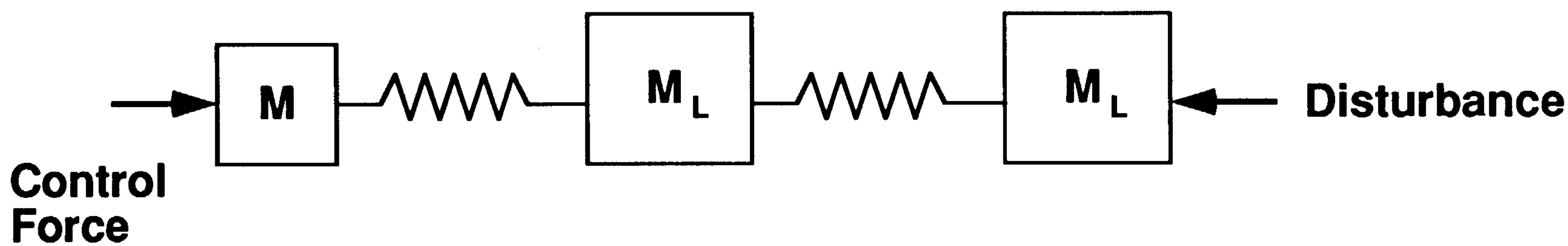
- structural vibrations
- multiple-point joining
- compliant contact

BASIC PROBLEMS

1. How will a payload controlled by active positioning devices interact dynamically with its environment?
2. How can closed-loop control be designed to achieve desired interactive dynamics?

Spring-and-Mass Models

1)



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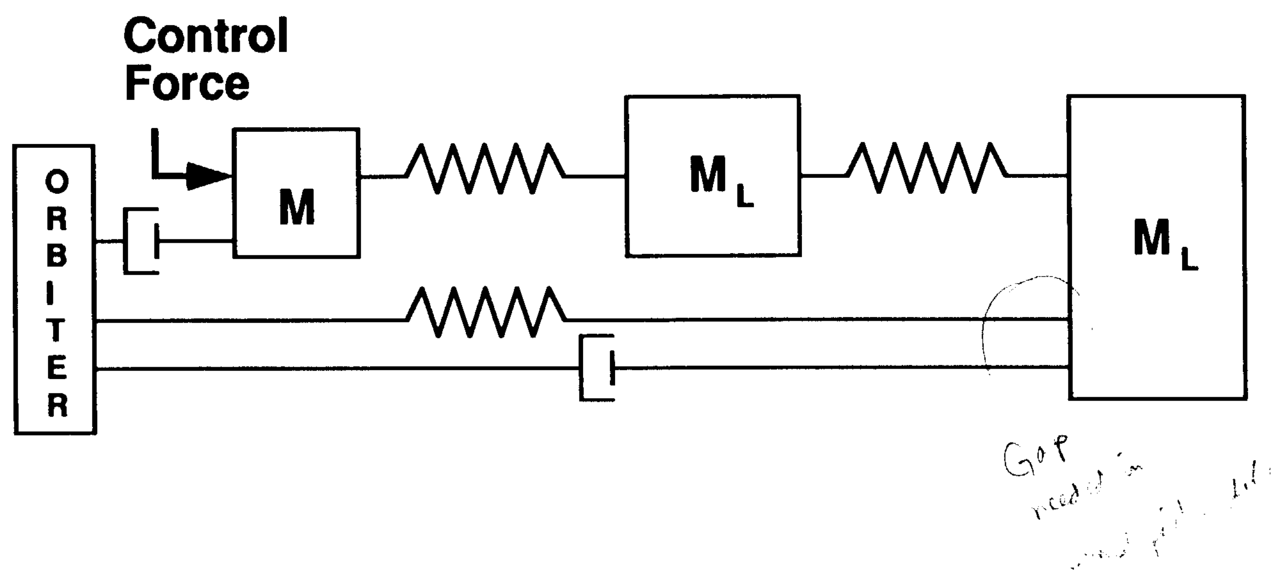
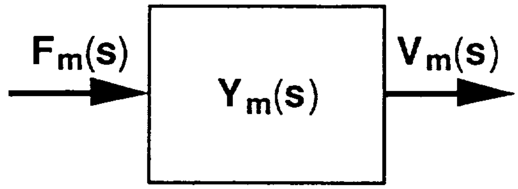
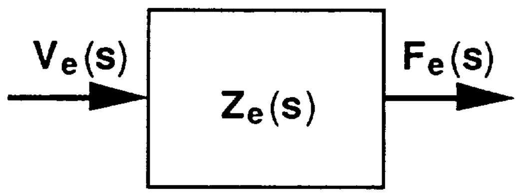




Admittance model of the manipulator.

$$\int_{t_0}^{T} F_m^T(t)\, V_m(t)\, dt \geq 0$$

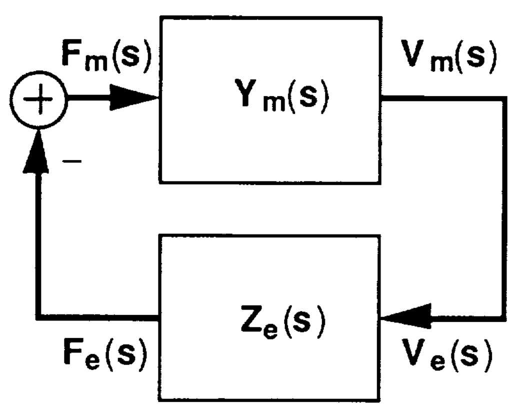
Condition for manipulator passivity



Impedance model of the environment.

$$\int_{t_0}^{T} F_e^T(t)\, V_e(t)\, dt \geq 0$$

Condition for environmental passivity



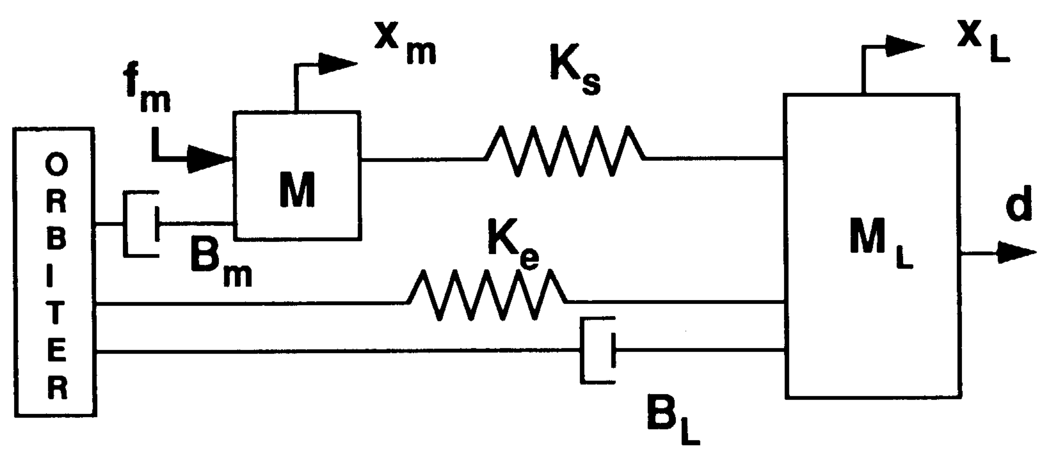
Model of manipulator coupled to environment.

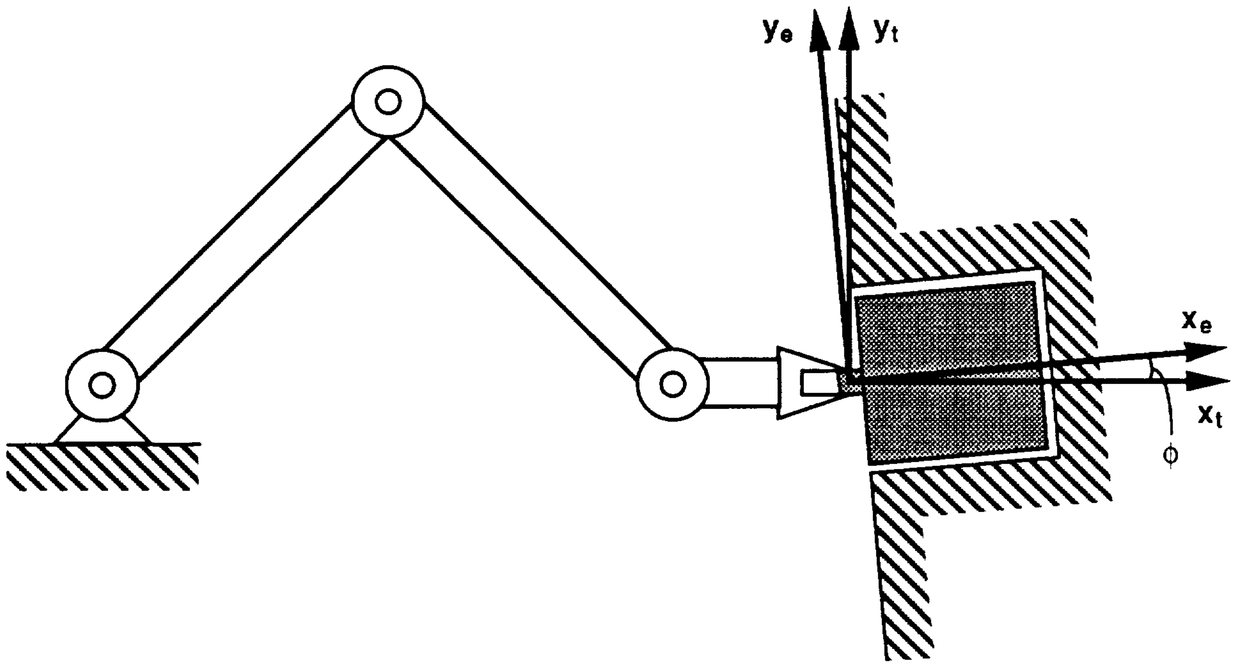
A Simple Example

$$\begin{bmatrix} x_m \\ x_m \\ x_L \\ x_L \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -K_s/M & -B_m/M & K_s/M & 0 \\ 0 & 0 & 0 & 1 \\ -K_s/M_L & 0 & dK/M_L & -B_L/M_L \end{bmatrix} \begin{bmatrix} x_m \\ x_m \\ x_L \\ x_L \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ -1/M & 0 \\ 0 & 0 \\ 0 & -1/M \end{bmatrix} \begin{bmatrix} f_m \\ d \end{bmatrix}$$

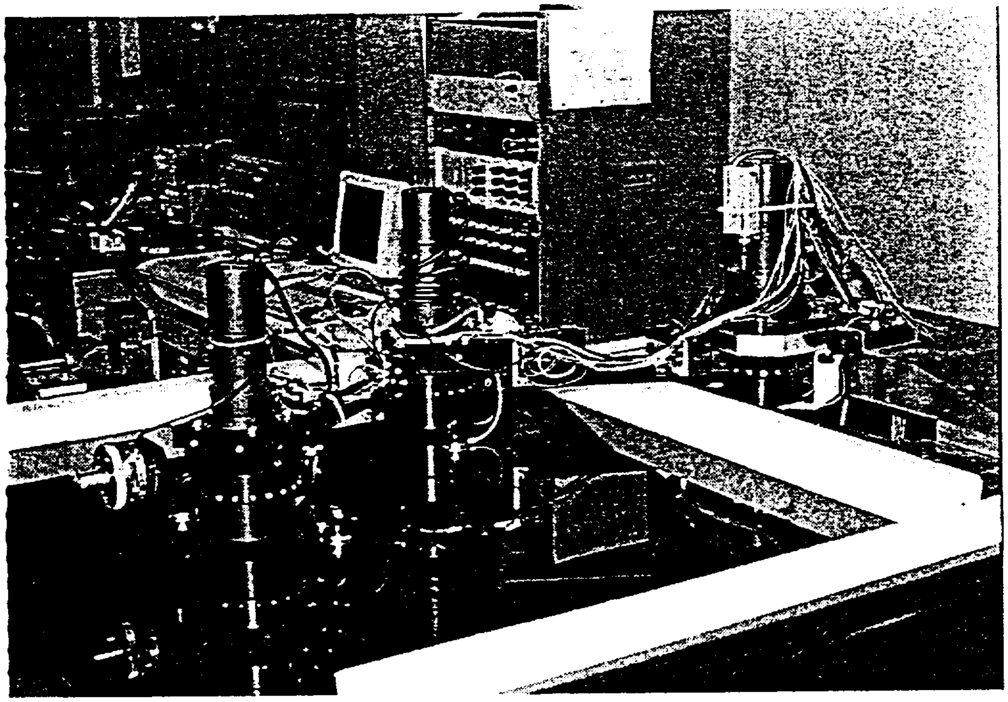
Feedback controls:

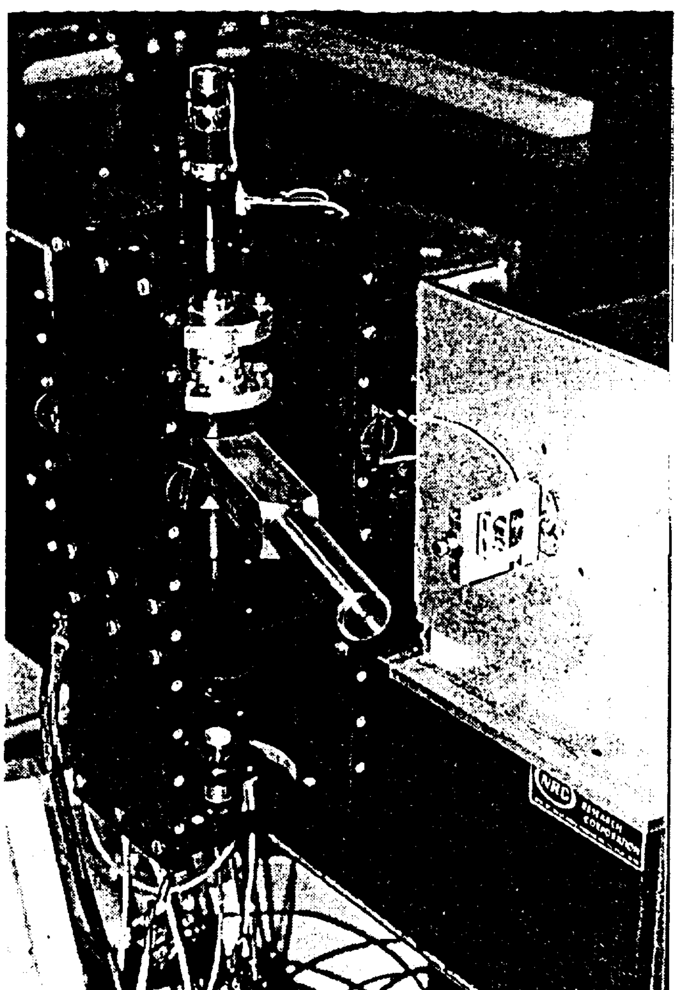
1. simple PD control
2. Torque loop
3. Impedance shaping

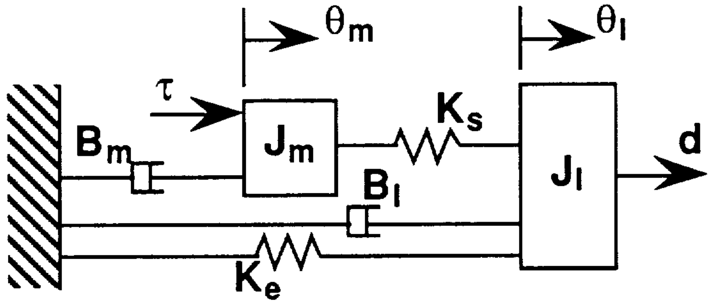




Removal/insertion of a misaligned module.



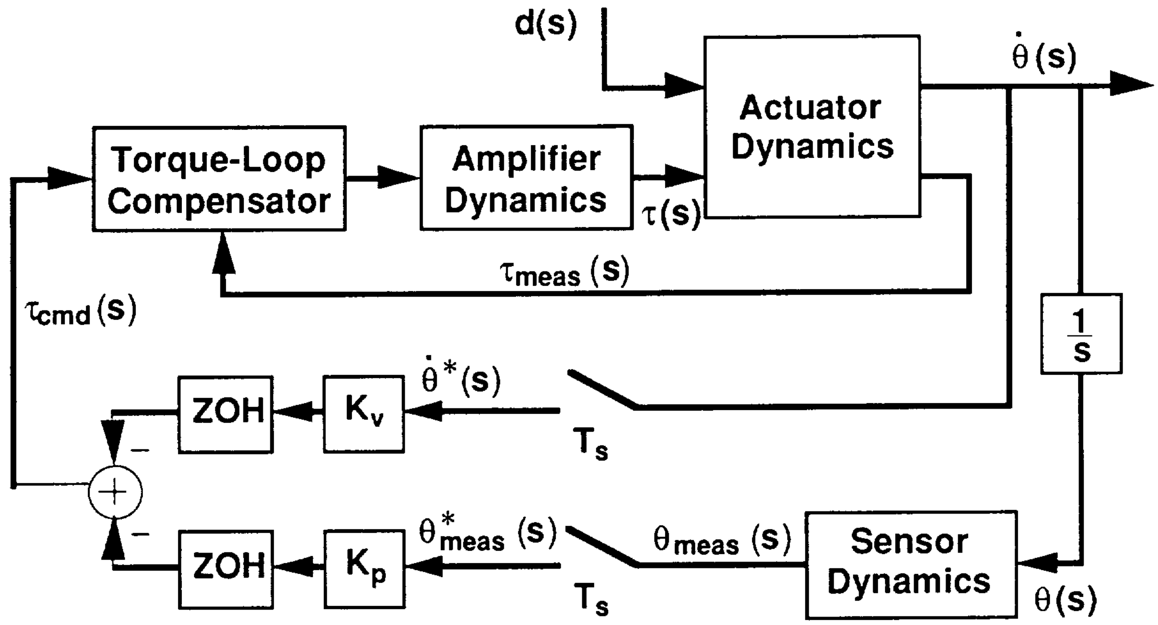




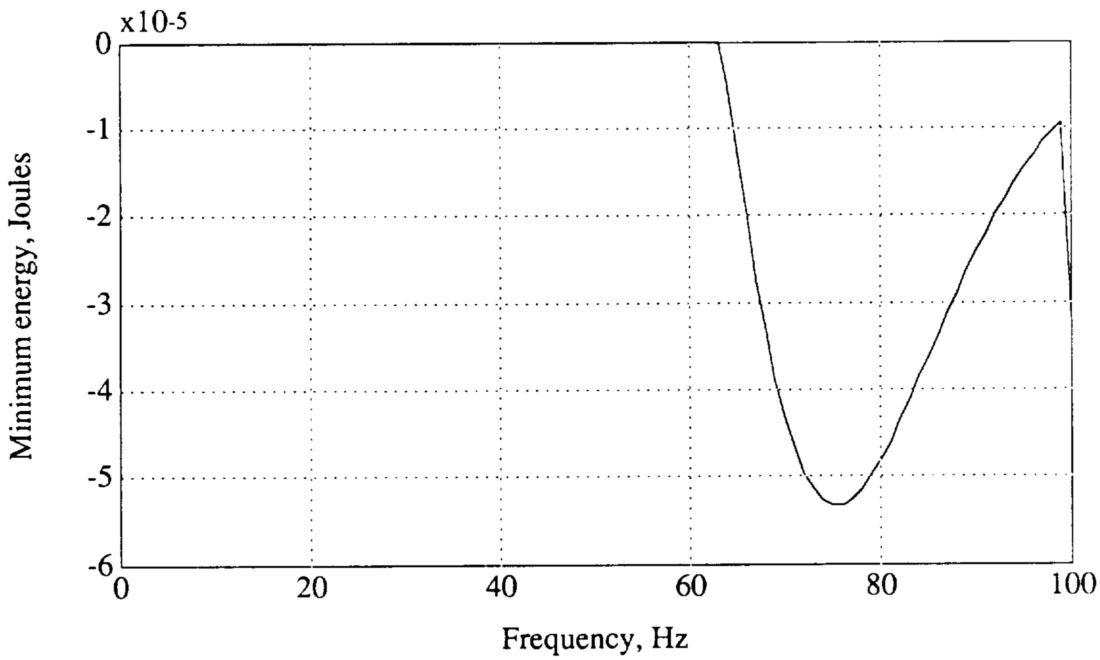
Model of a "typical" actuator.

Parameter	Value	Units
Motor Inertia, J_m (reflected to output side)	0.0934	kg-m^2
Motor Viscous Damping, B_m (reflected to output side)	3.4	N-m/(rad/s)
Harmonic Drive Stiffness, K_s	1600	N-m/rad
Load Viscous Damping, B_l	0.7	N-m/(rad/s)
Representative Load Inertia, J_l	0.64	kg-m^2
Gear Ratio	100:1	N/A

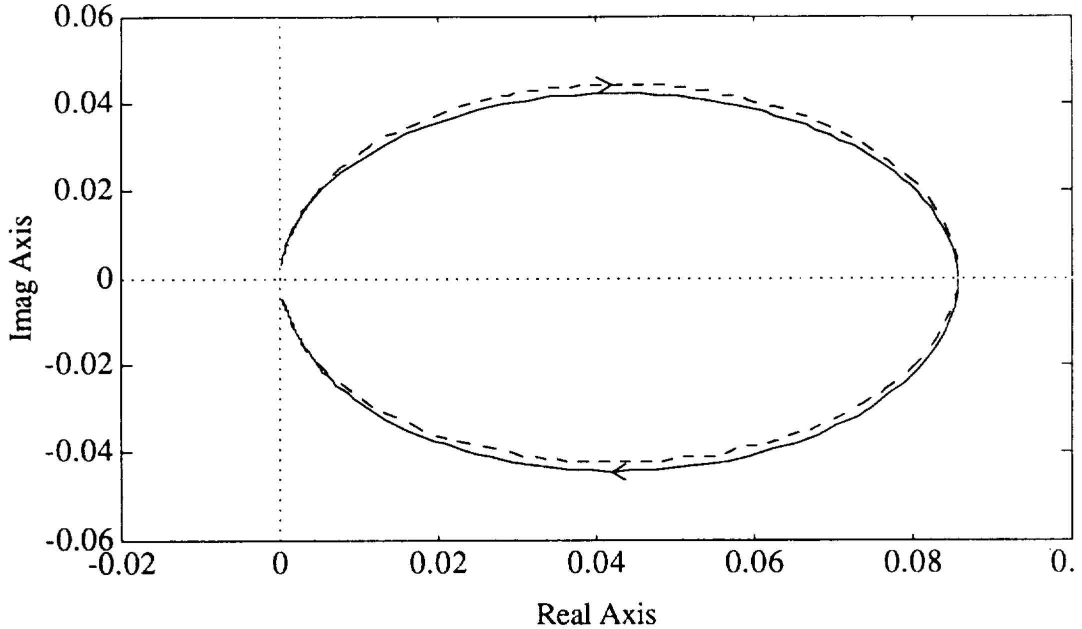
Representative Actuator Parameters



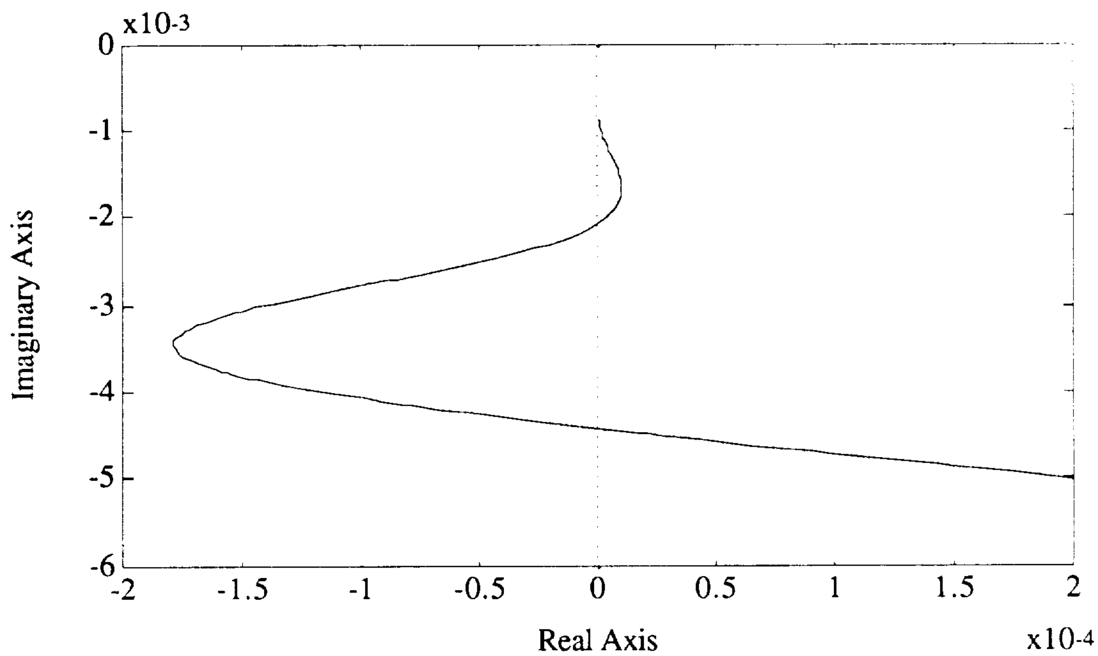
Moderate fidelity model of PD position-controlled actuator.



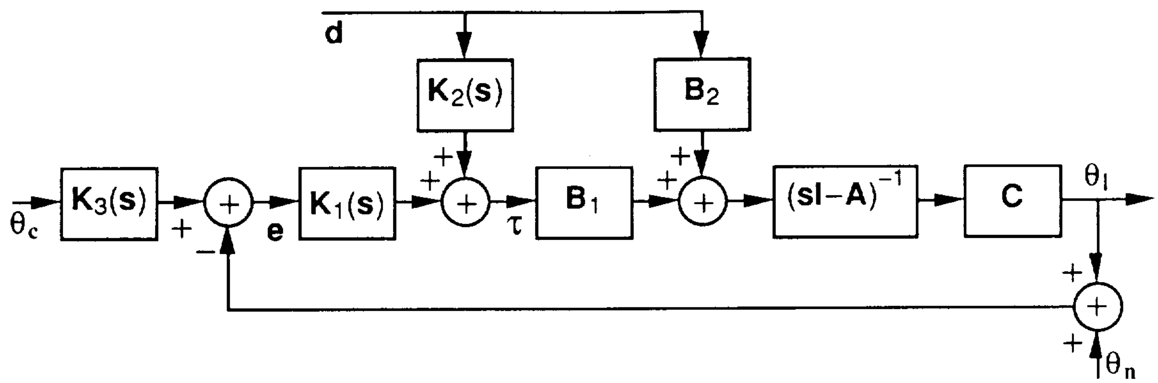
Minimum total energy delivered to the system over 1 second for a 1 N-m amplitude sinusoid disturbance torque (100 Hz bandwidth torque loop, 100 Hz bandwidth sensor dynamics, 1000 Hz bandwidth amplifier dynamics, 200 Hz sample rate, Kp=116, Kv=12.5)



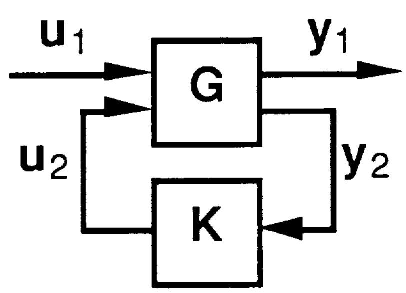
Nyquist diagram of the admittance response for the PD position-controlled actuator (sampling and ZOH modeled by time delay of half the sampling period).



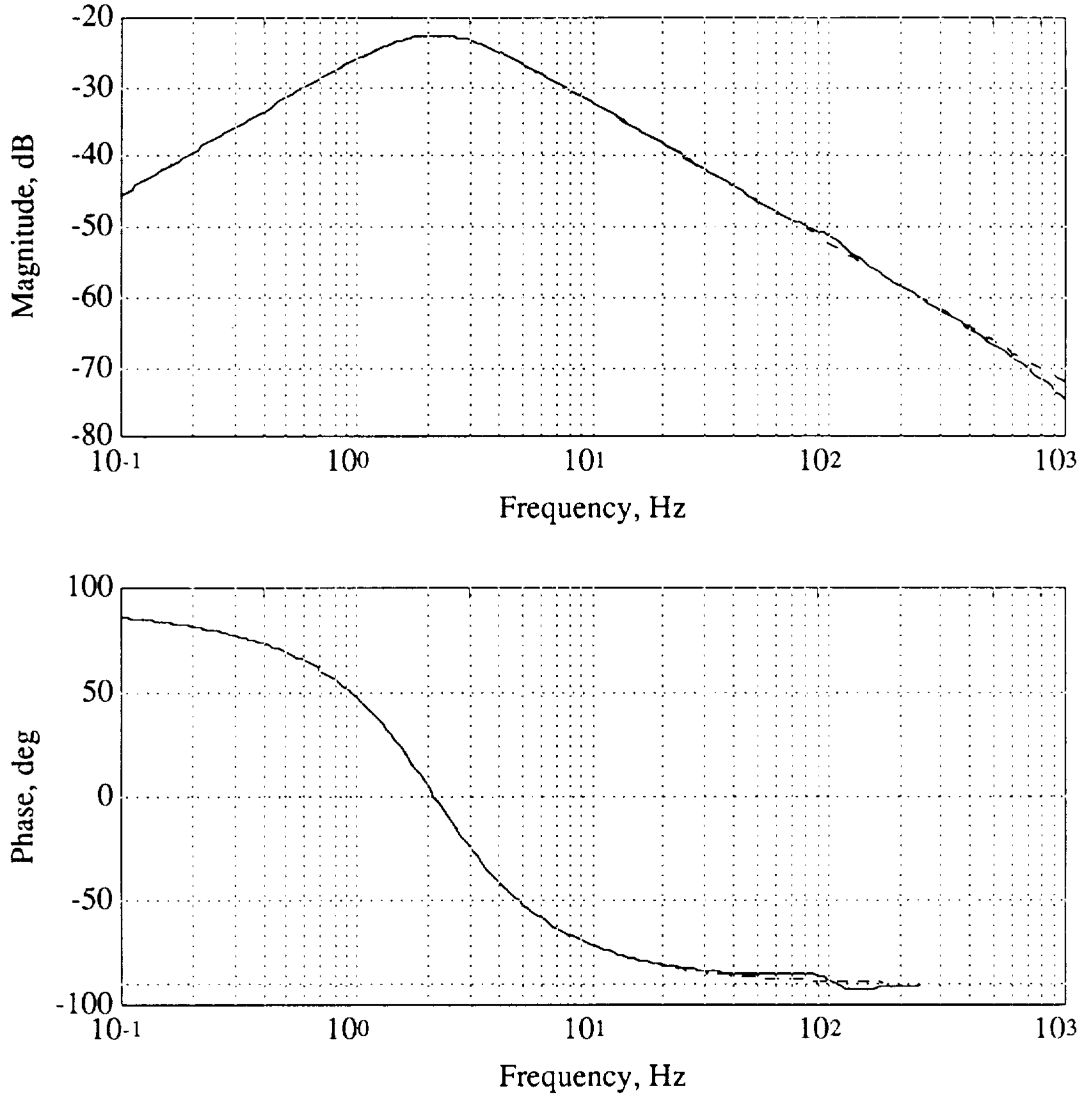
Nyquist diagram of the admittance response above 50 Hz for the PD position-controlled actuator (sampling and ZOH modeled by time delay of half the sampling period).



Generalized Actuator Control Block Diagram.



Standard H_∞ minimization problem.



Achieved (solid line) and target (dashed line) admittance responses for example H_∞ design using $K_1(s)$.

Fuzzy logic - Ren Su working

Conclusions

1. Absolute passivity is not practical as a design goal for the active devices which bring the structural payloads into contact.

2. A method has been developed for estimating the environment stiffness above which the operation of attachment may become unstable.

3. Preliminary results have been obtained in a procedure for feedback control design to achieve desired contact compliance.