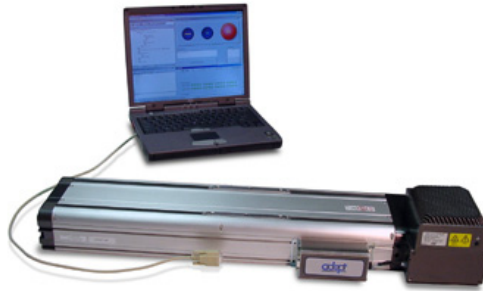


Midterm Project for

EE392m - Control Engineering in Industry, Spring 2005

Problem description

The problem is to design a basic control system for the robotics linear motion module shown in the picture below. The module is used in semiconductor manufacturing applications.



The job consists of the following tasks

Task 1. Formulate and implement detailed simulation model for analysis, V&V

1. Use the model description in the next section of this document. Take into account
 - Structural flexibility, as described by this model
 - Parameter variation (payload may vary from zero to maximal)
 2. Include the following pertinent detail in the model
 - Saturation of actuators and sensors
 - Velocity estimation from position measurement
 - Digital sampling (2 msec)
 - Sensor noise - quantization noise
 3. *Bonus:*
 - Simulate vibration generated during the motion, 0.5N excitation force amplitude
- The model can be implemented in Matlab, Simulink, or other suitable environment. Simulink is recommended.

Task 2. Design of main controller functions

1. Formulate a simplified rigid body second-order dynamics model as a basis for the design.
2. Design servo feedback. Use the simplified continuous time model. The bandwidth should not exceed the sampling rate. Make the controller design robust to unmodeled dynamics (ensure necessary gain and phase margins): take into account payload uncertainty, and presence of flexible dynamics.
3. Design setpoint profile generator. Use simplified model, the designed feedback loop model, and controller design specs.
4. *Bonus:* Design feedforward controller improving the tracking of the setpoint profile .
5. Implement the designed functions (servo feedback, setpoint profile generator, feedforward) as software modules suitable for system integration

Task 3. Integration tuning and validation of the controller

The controller shall include the following three main parts

1. Integrate detailed simulation (Task 1) and controller modules (Task 2). Allow implementation of the required motion scenarios of point-to-point motion control
2. Validate and tune servo system feedback controller.
3. Validate and tune setpoint profile generator and feedforward.
4. Demonstrate controller performance and generate plots for the report.

Deliverables

Present results in a design report. The report should have the following sections

1. Problem description
2. Controller architecture and main modules
3. Controller design: explain controller design and justify parameter choice.
4. Detailed simulation model description
5. Results of controller validation using simulation with the detailed model.
6. Appendix: controller code

Model description

The system dynamics includes control/actuation, sensing, motor inductance, structural flexibility. The linear model equations are as follows

$$m\ddot{y} + \beta\dot{y} + b(\dot{y} - \dot{x}) + c(y - x) = F$$

$$M\ddot{x} + b(\dot{x} - \dot{y}) + c(x - y) = 0$$

$$F = fI, \quad T_I\dot{I} + I = gu$$

Add more pertinent detail as defined in Task 1 description: Use the following data when defining the model

System specifications for modeling	
Maximal Stroke	500 m
Payload	0-40 kg
Thrust	200 N
Repeatability	± 0.02mm
Maximum Speed	1.2 m /sec
Maximum Acceleration, no payload	16 m/sec ²
Module moving weight, no payload (motor inertia)	6 kg
Mechanical time constant: no payload, moving weight	0.1 sec
Electrical motor time constant	1 msec
Oscillations with full payload when stopped at full speed	10 Hz, $\zeta=0.3$
Sampling interval in the digital servo	2 ms

Design of the control system

Sensor data/input ports

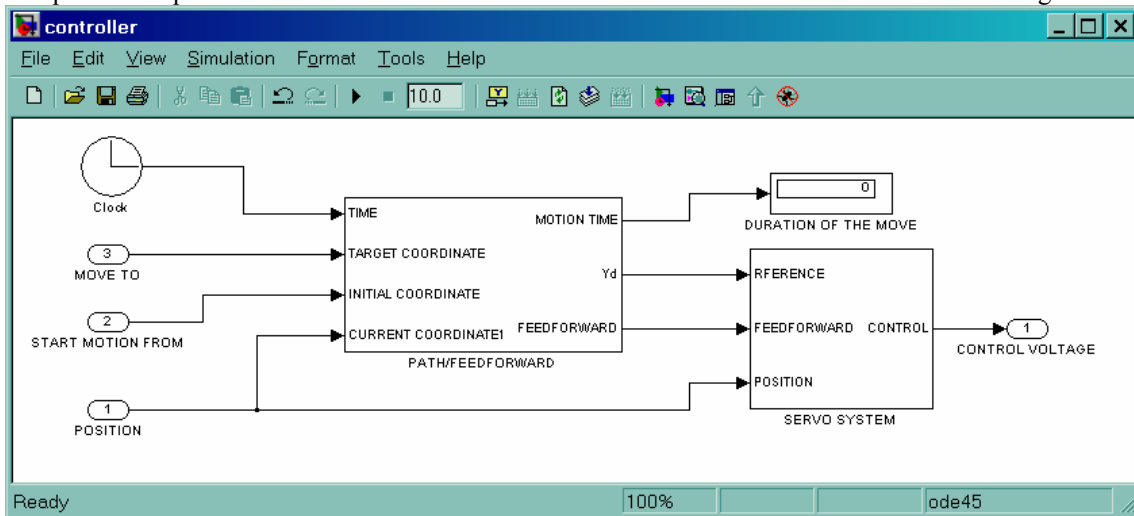
- the only measured variable is the motor position
- this is a digital measurement
- this measurement is subject to quantization noise with amplitude $\pm 0.02\text{mm}$

Actuators/output ports

- there is one actuator in the system, the electric motor
- the controller outputs control voltage $\pm 10\text{V}$ through DAC

Controller high-level architecture:

- The controller will consist from two main modules: **PATH/FEEDFORWARD** and **SERVO SYSTEM**. The input and output data for the controller modules as well as their interconnection is shown in Figure below.



- The simulation should be able to take the following settings and parameters: initial and final coordinates, load mass (unknown to the controller)
- The **PATH PLANNING/FEEDFORWARD** module will plan the motion path and compute feedforward. It will continuously provide the reference input to the **SERVO SYSTEM**
- The **SERVO SYSTEM** module will implement the feedback (servo) controller and output control voltage. It will use the actual and reference positions as inputs

Control system design constraints, specifications and suggestions

- The control performance is defined through a total move time = initial move time + transient time
- This is for the worst case in the payload range
- Suggested controller design approach: PID + smooth path planning
- Might need to use some low-pass filtering to avoid exciting the flexible modes, perhaps notch filtering
- Perform loop analysis: loop gain, disturbance rejection, sensitivity, etc.
- Sampling
- Use simple design model for controller design
- Use detailed analysis model for simulation, V&V, and uncertainty characterization in design

Test scenario

Test and validate the performance of the designed controller in the following simulation runs

- 0mm to 400mm, half payload
- 400mm to 200mm, no payload
- 200 mm to 0mm, half payload
- 200 mm to 400 mm, full payload

Administrivia for the EE392m Midterm

1. The report is due next Wednesday, May 4
2. Working in small groups is encouraged: 3 groups of 3 people each
3. Split the 3 tasks among the three people.
4. The lead (Task 3) gets bonus points

Modeling for the Midterm

Sdfgh

