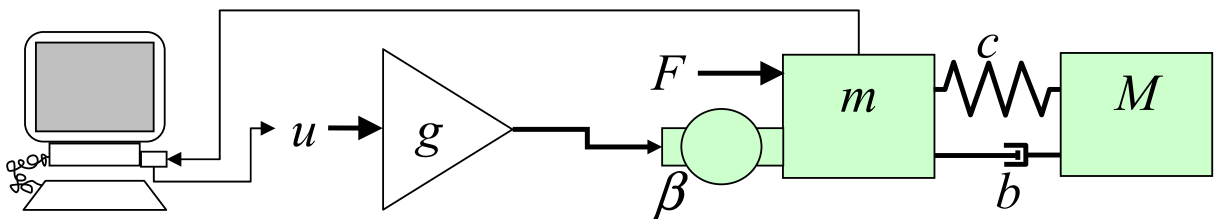
Midterm Project for

EE392m - Control Engineering in Industry, Spring 2005

Modeling Notes

The system schematics is shown in the picture below



It is described by the following equations:

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

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

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

where the variables are as follows

y – is the coordinate of the mechanism parts before the flexible transmission belt. The coordinate y is directly related to the motor coordinate, which is measured by a digital position sensor.

x – is the coordinate of the payload after the flexible transmission belt

u – is the control voltage output by the D/A converter of the control computer

m – is the inertia (equivalent mass) of the mechanism parts, including the motor rotor, before the flexible transmission belt

M – is the payload mass, the mass of the mechanism parts after the flexible transmission belt can be assumed small and neglected

β – is the equivalent back e.m.f. (electromagnetic force) coefficient associated with the motor

c – is the lumped stiffness of the flexible transmission belt

b – is the lumped damping in the flexible transmission belt

F – is the force developed by the motor

I – is the motor current

f – is the coefficient (factor) relating motor current to motor force

g – is the coefficient (factor) relating control voltage of the power amplifier to the motor current

T_I – is the electrical time constant of the motor armature

The parameters can be determined form the modeling specifications in the table as follows:

- The payload mass M is the given percentage (0%, 50%, or 100%) of the maximal payload in the Table (row 2)
- The mechanism mass m is given in the Table (row 7)
- The transmission belt stiffness c can be determined from the oscillation frequency of the masses M and m connected by a spring c. The frequency is given in the table (row 10)
- The damping b can be determined from the masses M and m connected by a spring c and the damping ratio ζ in the table (row 10). A simple on-line explanation of mass-spring-damper system is at http://users.ece.gatech.edu/~bonnie/book1/applets/suspension/background.htm
- The product of the coefficients fg can be determined from the mass m and maximum acceleration given in the Table (row 6). Assume the maximum control voltage of 10 V. The coefficients f and g cannot be separately determined from the table data and only their product is of importance for the analysis. The simulation could assume $f = 1$.

- The equivalent back e.m.f. coefficient β can be determined as the time constant of the velocity step response in the equation $m\ddot{y} + \beta\dot{y} = F$, where F is a control input. The time constant is given in the table (row 8)
- The electrical time constant of the motor armature T_I is given in the table (row 9)
- The position sensor resolution can be derived from the repeatability given in the table

	System specifications for modeling	
1	Maximal Stroke	500 m
2	Payload	0-40 kg
3	Thrust	200 N
4	Repeatability	± 0.02mm
5	Maximum Speed	1.2 m /sec
6	Maximum Acceleration, no payload	16 m/sec²
7	Module moving weight, no payload (motor inertia)	6 kg
8	Mechanical time constant: no payload, moving weight	0.1 sec
9	Electrical motor time constant	1 msec
10	Oscillations with full payload when stopped at full speed	10 Hz, ζ=0.3
11	Sampling interval in the digital servo	2 ms