

MCE/EEC 647/747: Robot Dynamics and Control
Homework 3 - Fall 2008

OUT: 09-25-08. DUE: 10-09-08

1. (15 pts.) Create a Simulink diagram implementing the feedback system in Fig. 6.6 in SHV. Use a step input block for the disturbance. **Use symbolic entries in each block and write an m-file that loads values for these entries.** Add a saturation block at plant input, using a symbol in the block for the saturation limit.

Add a PID block at the input of the saturation block, acting as a cascade compensator. Close the feedback loop (as done in Fig. 6.8, but using the full plant model instead of the simplified one and using a PID block instead of just PD). The m-file must also assign values to the symbolic PID gains used in the block. Use a step input block for $\Theta^d(s)$.

Add To Workspace blocks to save the following simulation signals: I_a , V , Θ_m , Θ_d .

The joint is driven by a Baldor MT-3353-D servomotor. Find the parameters below from the manufacturer's website:

http://www.baldor.com/support/literature_load.asp?LitNumber=BR1202-F

- Motor inertia: J_m
- Motor friction: B_m
- Motor torque constant: K_m Nm/A
- Back-emf constant: K_b V-s (check that it equals K_m)
- Motor resistance: R
- Motor inductance: L

MAKE SURE YOU ARE USING SI (MKS) UNITS!

Verify that your model is running by setting $K_I = K_D = 0$ and $K_P = 1$. Also set the feedforward compensator to $F(s) = 0$ and the saturation limit to inf . Apply a step input $\Theta^d(s) = 1/s$. Despite possibly poor performance, the response should stabilize at $\theta = 1$.

2. (25pts) Use the reduced model of Eq.(6.13) as a design model. Note that Fig.6.8 uses a re-defined input $u = (K_m/R)V$, so the numerator is 1. **Maintain the numerator as in Eq.(6.13), so that the control input is still V .**

Use zero disturbance and set $K_I = 0$. Set the saturation limit to inf . Use the reduced model $G(s)$ and choose K_P and K_D so that the closed-loop poles have a natural frequency of 12 and a damping ratio of approx. 0.75. Simulate the unit step response using the chosen gains and the full model. Plot $\theta_d(t)$, $\theta(t)$, $i_a(t)$ and $v(t)$.

3. (25pts) Set the disturbance to step in some time after the settling time above. Use $\tau_l/r = 0.005$ ($D(s) = 0.005/s$) N-m. Use the reduced model and the final value theorem to predict the steady error due to disturbance. Verify by simulation. Plot $\theta_d(t)$ and $\theta(t)$.

Activate the I-gain and tune the PID gains to preserve the response time above as much as possible, while minimizing the overshoot. Simulate to verify that $e_{ss} = 0$. Plot $\theta_d(t)$ and $\theta(t)$. What is the maximum control effort (in absolute value)?

Set the saturation value to 50 percent of the maximum control effort. Change the disturbance to a rectangular pulse which starts some time after the response has settled and lasts one settling time. Simulate again with the same PID gains and plot $\theta_d(t)$, $\theta(t)$ and $v(t)$. Also plot the voltage at the input of the saturation block. Is the windup phenomenon occurring?

4. (35pts) Now set the disturbance to zero and the saturation limit to \inf . Implement the feedforward compensator of Fig. 6.18 to track $\theta_d(t) = \sin(10 * t)$. **Note: Simulink will not allow you to use a transfer function with more zeroes than poles. To implement the $J s^2 + B s$ term, differentiate $\theta(t)$ analytically and use the appropriate blocks to inject the feedforward signal at plant input.**

Simulate and plot $\theta_d(t)$ and $\theta(t)$.

How to turn in the homework:

Any hand calculations must be explained. Please scan any handwritten sheets. Email the instructor, attaching the hand calculations, m-file(s) and Simulink files (.mdl). Please save the Simulink files as version 6.4 or earlier (Matlab version 2006a or earlier). You are encouraged to consult the instructor on issues related to the Matlab/Simulink.