Solutions to Sec 3.2 Pre-lab Questions

The mark of each question is 1

1. A-3 Based on the steady-state error result of a step response from Equation ,what *type* of system is the SRV02 when performing speed control (Type 0, 1, or 2) and why?

Answer 3.2.1

Outcome	Solution
A-3	This is a *Type 0* system because the steady-state error is a constant given a step reference.

□□□

2. A-2 The nominal SRV02 model parameters, K and τ, found in SRV02 Modeling Laboratory (Section 1) should be about 1.53 (rad/s-V) and 0.0254 sec, respectively. Calculate the PI control gains needed to satisfy the time-domain response requirements.

Answer 3.2.2

Outcome A-2

Solution

Using the nominal SRV02 model parameters

$$K = 1.53 \text{ rad/(V.s)} \tag{Ans.3.2.1}$$

and

$$\tau = 0.0254 \text{ s} \tag{Ans.3.2.2}$$

along with the damping ratio given in Equation 3.1.20 with Equation 3.1.25 generates the proportional control gain

$$k_p = 1.34 \text{ V/(rad/s)} \tag{Ans.3.2.3}$$

The integral control gain is obtained by substituting the model parameters given above with the minimum natural frequency specification given in 3.1.21 into Equation 3.1.26

$$k_i = 124.9 \text{ V/rad} \tag{Ans.3.2.4}$$

Thus, if these gains are used, the speed response of the load gear on an SRV02 with a disc load will satisfy the specifications listed in Section 3.1.1.1.

□□□

3. A-2 Find the frequency response magnitude, $|P_i(\omega)|$, of the transfer function $P_i(s)$ given in Equation 3.1.27.

Answer 3.2.3

Outcome A-2

Solution

The frequency response of $P_i(s)$ is found by substituting $s = j\,\omega$ in 3.1.27.

$$P_i\,(j\,\omega) = \frac{K}{(\tau\,j\,\omega + 1)\,j\,\omega} \tag{Ans.3.2.5}$$

Taking the magnitude of this expression gives the frequency response gain

$$|P_i(\omega)| = \frac{K}{\omega\,\sqrt{\tau^2\,\omega^2 + 1}} \tag{Ans.3.2.6}$$

□□□

4. A-2 Calculate the DC gain of $P_i(s)$ given in Equation 3.1.27. **Hint:** The DC gain is the gain when the frequency is zero, i.e. $\omega = 0\,rad/s$. However, because of its integrator, $P_i(s)$ has a singularity at zero frequency. Therefore, the DC gain is not technically defined for this system. Instead, approximate the DC gain by using $\omega = 1\,rad/s$. Make sure the DC gain estimate is evaluated numerically in dB using the nominal model parameters, $K = 1.53$ and $\tau = 0.0254$, (or use what you found for K and τ in Section 1).

Answer 3.2.4

Outcome	**Solution**
A-2	Substituting $\omega = 1$ rad/s gives the approximate DC gain of

$$|P_i(1)| = \frac{K}{\sqrt{\tau^2+1}} \qquad \text{(Ans.3.2.7)}$$

Substituting the nominal SRV02 model parameters in the above expression results in the DC gain estimate of

$$|P_i(1)| = 1.53 \qquad \text{(Ans.3.2.8)}$$

or

$$|P_i(1)|_{dB} = 3.70 \text{ dB} \qquad \text{(Ans.3.2.9)}$$

□□□

5. A-1, A-2 The gain crossover frequency, ω_g, is the frequency at which the gain of the system is 1 or 0 dB. Express the crossover frequency symbolically in terms of the SRV02 model parameters K and τ. Then, evaluate the expression using the nominal SRV02 model parameters $K = 1.53$ and $\tau = 0.0254$, (or use what you found for K and τ in Section 1).

Answer 3.2.5

Outcome	**Solution**
A-1	The crossover frequency is found by setting $|P_i(\omega_g)| = 1$ in equation Ans.3.2.6 and solving for ω_g
A-2	

$$\omega_g = \frac{\sqrt{2}\sqrt{\frac{-1+\sqrt{1+4\,\tau^2\,K^2}}{\tau^2}}}{2} \qquad \text{(Ans.3.2.10)}$$

When evaluated with the nominal SRV02 parameters, the frequency where the gain is 0 dB is

$$\omega_g = 1.524 \text{ rad/s} \qquad \text{(Ans.3.2.11)}$$

□□□