5 Robot grip mechanism: control loop design considerations

5.1 Introduction

Given in this chapter is the structural diagram in Fig.1:

A = 15, B = 15, C = 85

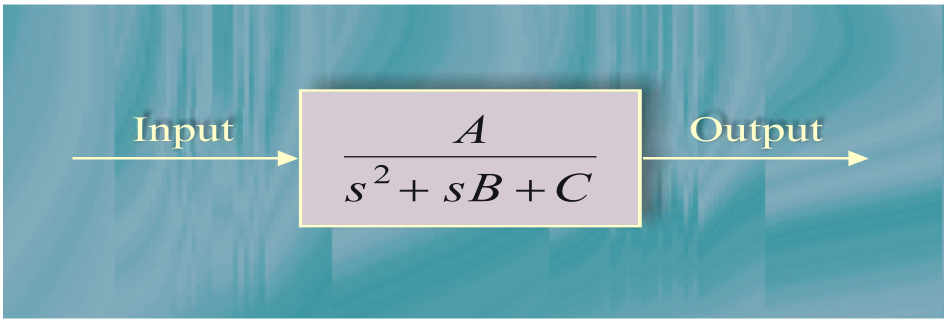


Figure 1

The closed-loop system shall have the following quality indicators for the transition process:

Peak time – . . . . 0.475 s
Percentage overshoot – 2.838%
Settling time –. . . . . 0.533 s
Output value – . . . . 1.

Showing the results of simulating the open loop system and the closed loop control system has been done by employing CODAS (Matlab). What if the Settling time, TS is reduced to 0.4 seconds while the other parameters remain the same? What could you do about this? The problems this may cause and possible solutions have been described. What other factors have been considered in designing the control system?

5.2 Open loop system

If we consider a standard second-order system [1]:

$$(1) \qquad \frac{Y(s)}{X(s)} = \frac{k}{T^2 s^2 + 2\xi T s + 1},$$

where:

$$k = A / C = 15 / 85 = 0.1765;$$
$$T = \sqrt{1/C} = 0.1085,$$
$$\xi = B / 2CT = 0.8132$$

$0 < \xi < 1$ This is therefore an under damped system [1]. Figure 2 shows the step response of the open loop system:

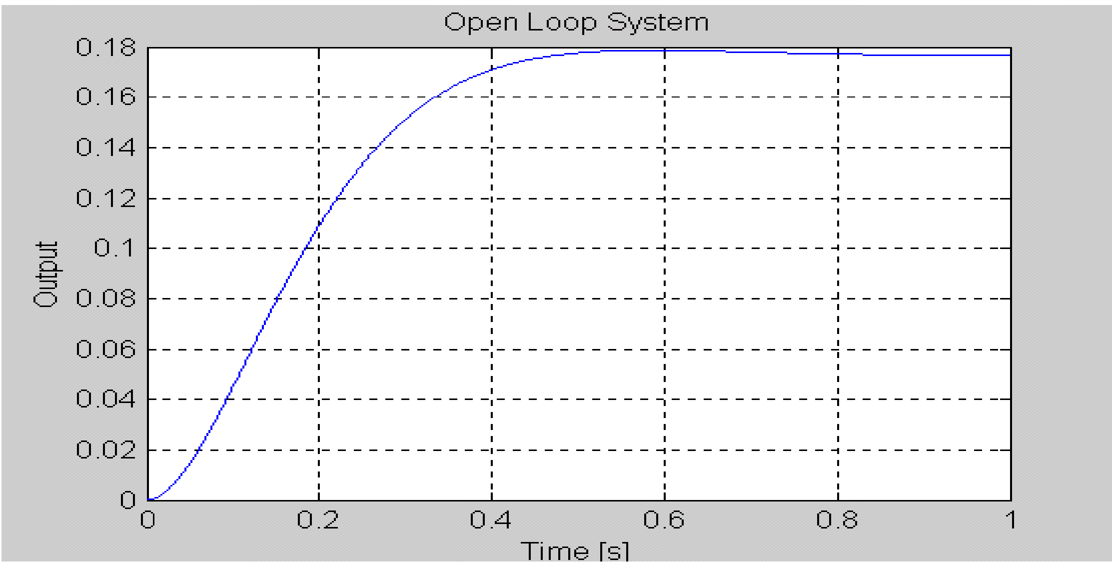


Figure 2

5.3 Closed loop control system

If we close the system using a single feedback, as shown in Figure 3:

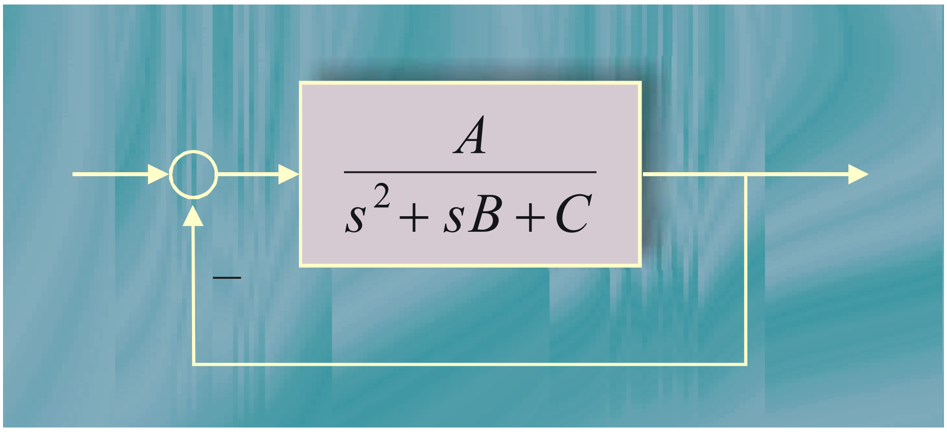


Figure 3

The transfer function is [2]:

$$W(s) = \frac{G(s)}{1+G(s)} = \frac{A}{s^2 + Bs + C + A} = \frac{15}{s^2 + 15s + 100}.$$

In steady state the gain coefficient of the system is k = 15 / 100 = 0.15. In order to have a steady state Output value of 1 we will need to provide additional signal amplification, as in Figure 4.

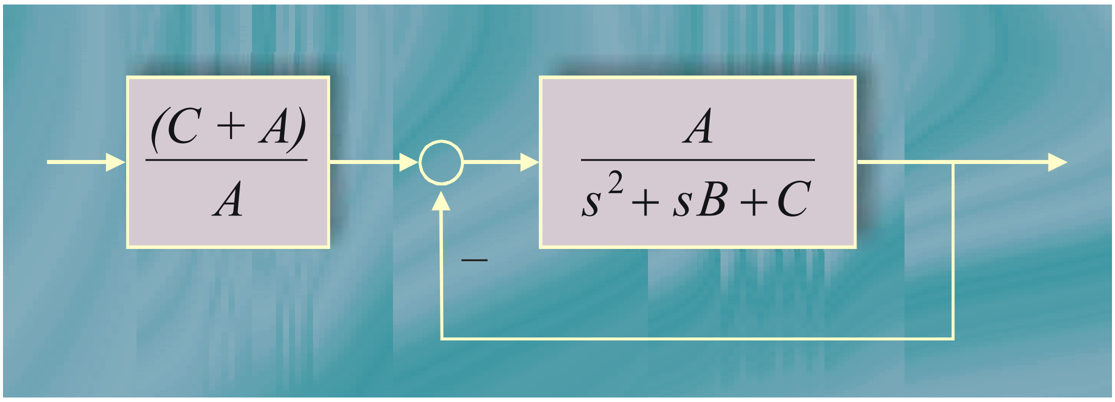


Figure 4

Figure 5 shows the step response of the closed loop system [3]:

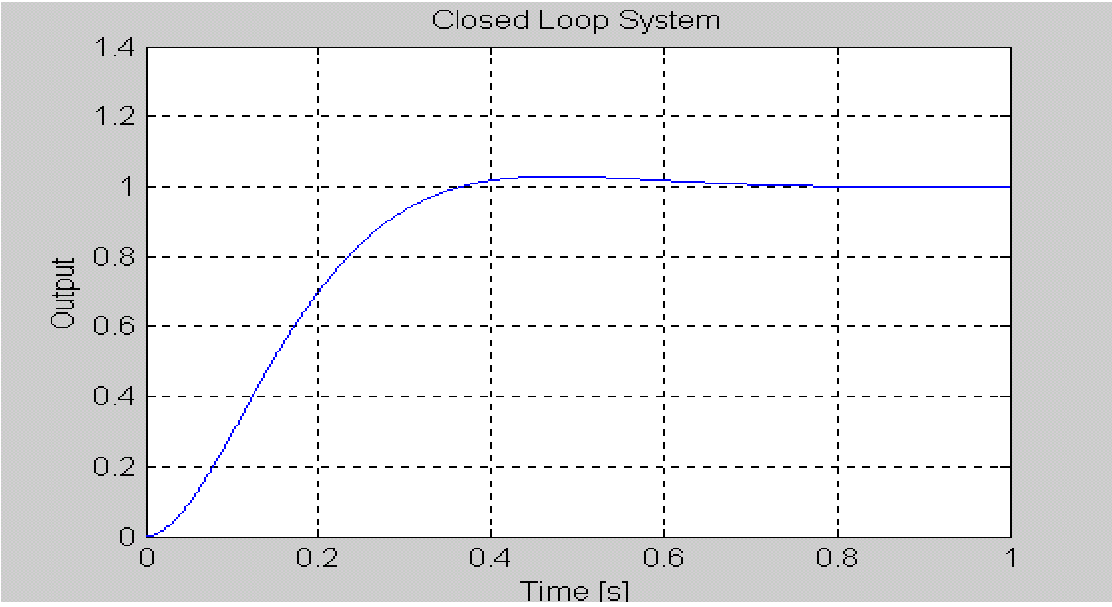
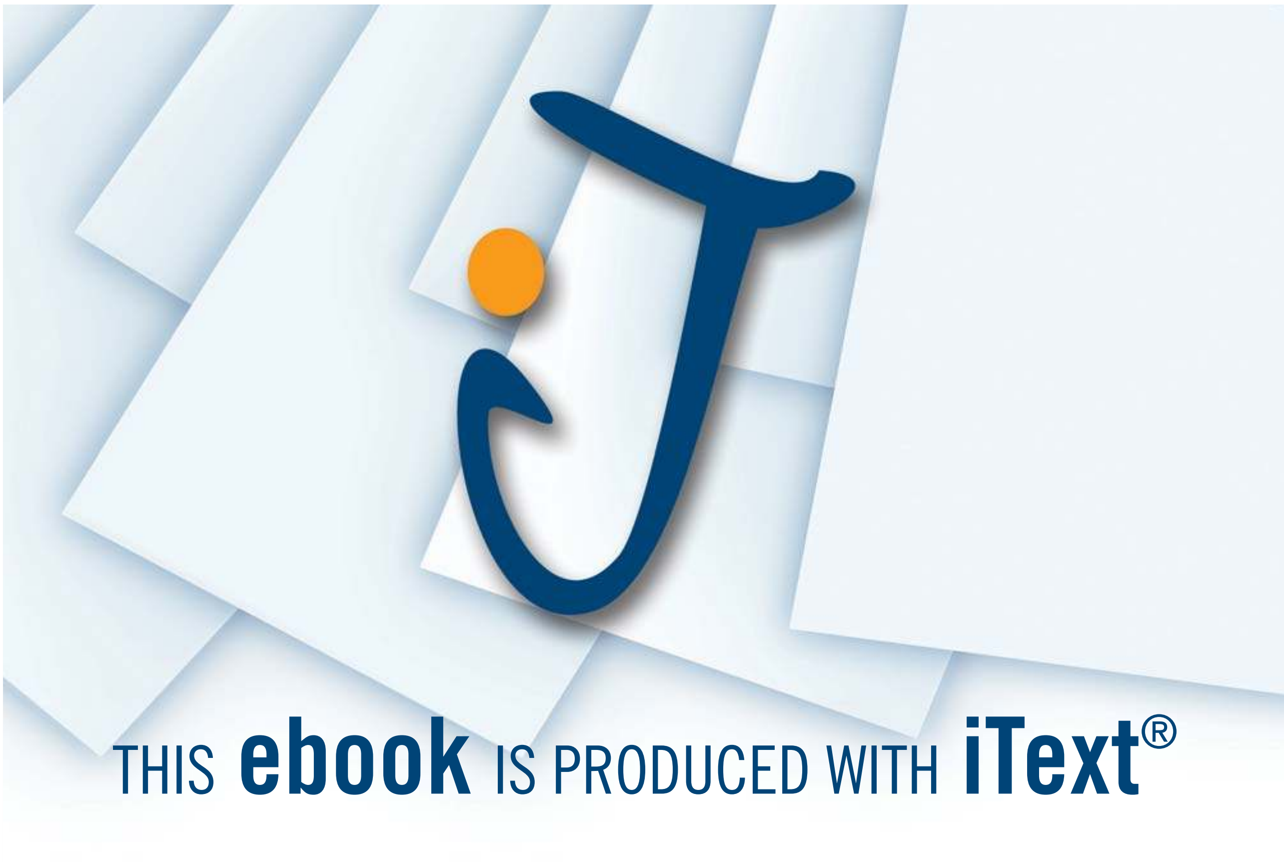


Figure 5



The desired movement of the system (the parameters of the assignment) can be achieved adopting various synthesis techniques – root locus, frequency domain compensator design techniques and other methods but such techniques are essentially abstract by nature and too far from the physics of processes taking place in real systems [3].

For mechanical, hydraulic, pneumatic or electrical and mechanical actuator systems that the present assignment could be referred to it would be best to employ the method of inverse problems of control system dynamics [4].

The algorithm synthesized employing the above method allows us to directly implement the parameters of the desired movement into the control formula – the reference model will be defined using the following second-order differential equation [5]:

$$\tau^2 \ddot{y}^* + 2\xi\tau\dot{y}^* + y^* = y^0 .$$

The accuracy of reproduction of the reference movement shall be determined by the value of the k coefficient in the control signal formation formula [5]:

$$x(t) = \frac{k}{\tau^2}\int(y^0 - y)dt - 2k\frac{\xi}{\tau}y - k\dot{y}. \tag{2}$$

The system (1) can be presented in the Koshi form [6]:

$$\begin{aligned} \frac{dy_1}{dt} &= y2; \\ \frac{dy_2}{dt} &= -By_2 - Cy_1 + Ax. \end{aligned} \tag{3}$$

The simulation model using Simulink is shown in Figure 6

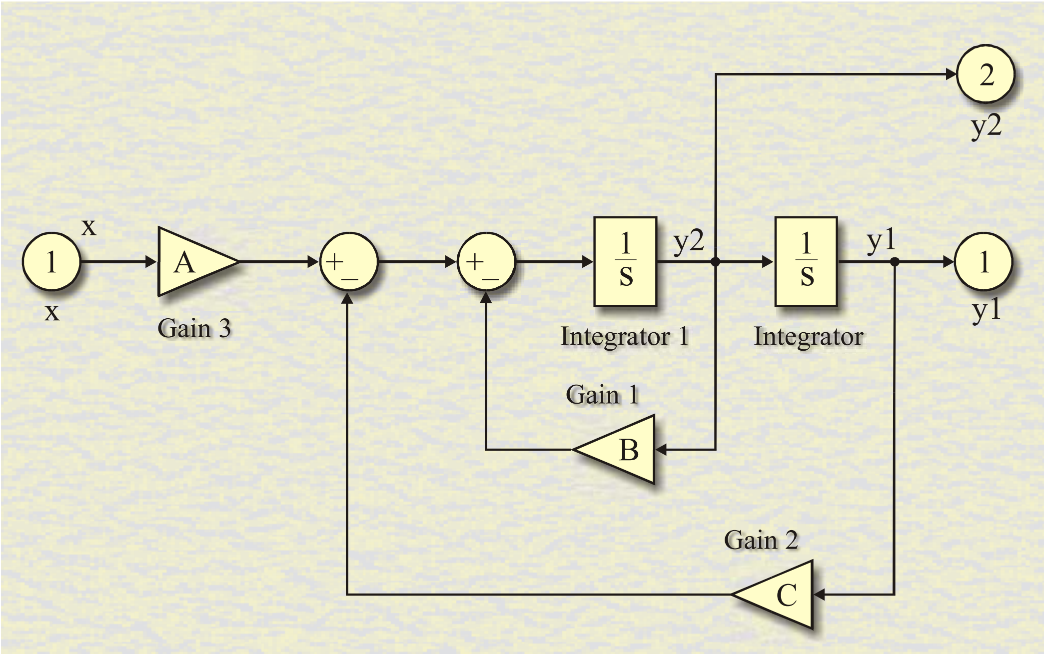


Figure 6

The object simulation model as controlled by (3) above is shown in Figure 7.

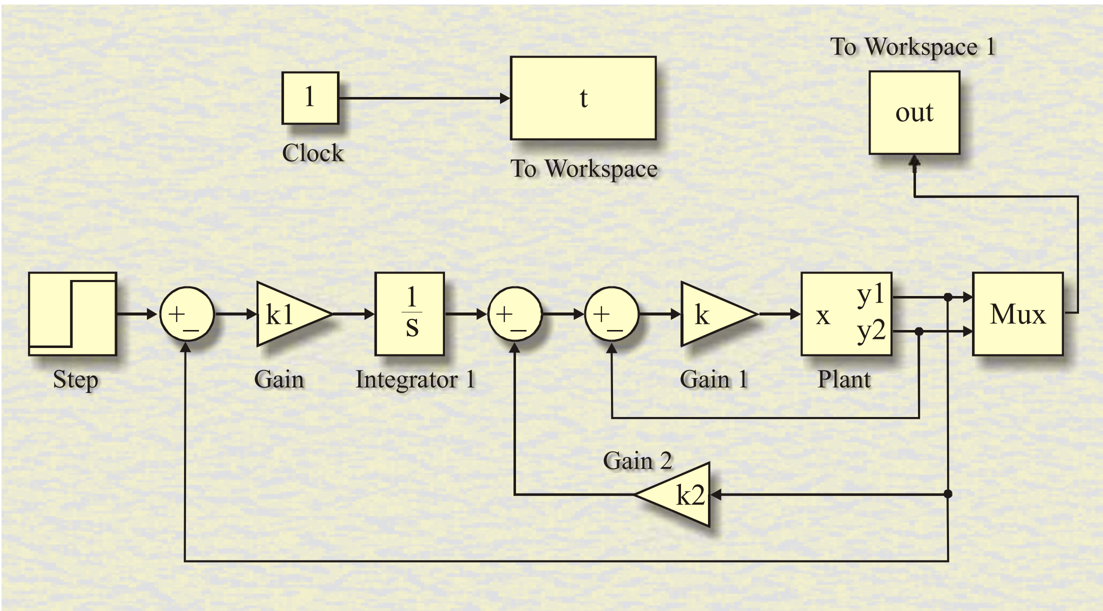


Figure 7

Where:

$$k_1 = \frac{1}{\tau^2}; k_2 = 2\frac{\xi}{\tau}.$$

If we maintain percentage overshoot values constant, ξ respectively and change the settling time to 0.4 s we will get the results shown in Figure 8 for coefficient k values of k = 0.5, 1, 2, 10, 20.

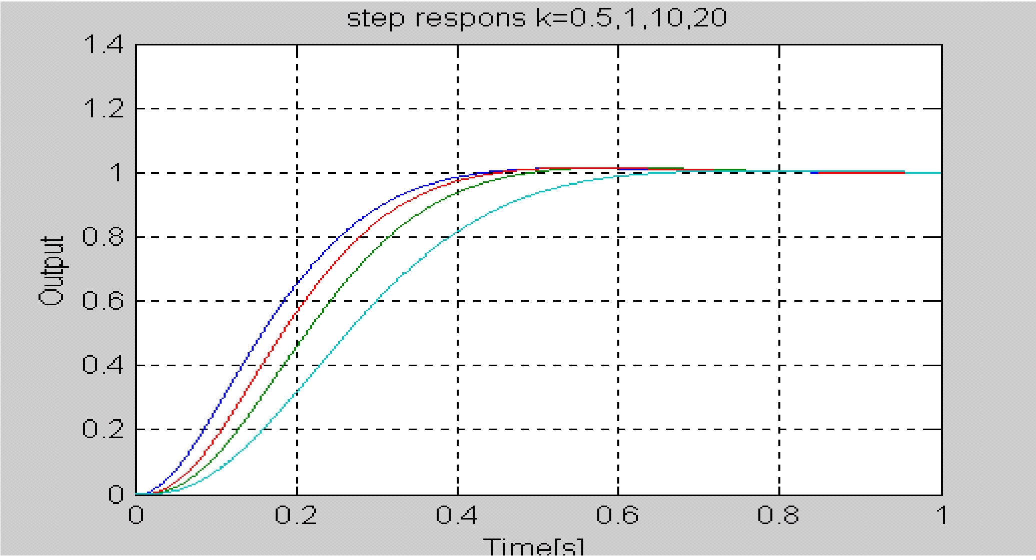


Figure 8

It can be seen from Figure 8 that when coefficient k = 20 the reference movement defined by equation (2) is coincident with system Output y.

Since system (1) is a linear type of system we can achieve the desired quality of the transfer process for any value of the quality indicators (settling time, overshoot, etc.) – the computer would take anything. However, this is not true when real systems have to be designed as we will then be limited by the energy capabilities of the physical processes [6].

5.4 Other control loop design considerations

Real physical systems are non-linear and unsteady by nature. Models of the (1) type are a result of a number of assumptions and linearization of non-linear models. Despite of the fact that control loops are usually synthesised based on linear models, it is necessary to check the results using computer simulation on non-linear models or physical models [7].

The control (3) works successfully even when included in some non-linear systems. When selecting the suitable reference movement (2) we have to consider the energy capabilities of drive power units, which are usually limited.

For example, when the drive power source is a DC motor, then $\tau \geq \tau m\ p$, where τm – is the electro-mechanical constant of the motor. When this condition is not met we cannot expect to meet the step response quality criterion. It is interesting to find out how will an eventual essential change in object parameters affect the step response quality [7].

For example, if we increased or reduces the values of A, B and C by 20%.

A=18, B=18, C=102,
A=12, B=12, C=68.

Simulations are performed using a gain coefficient of k = 20. The results are shown in Figure 9.

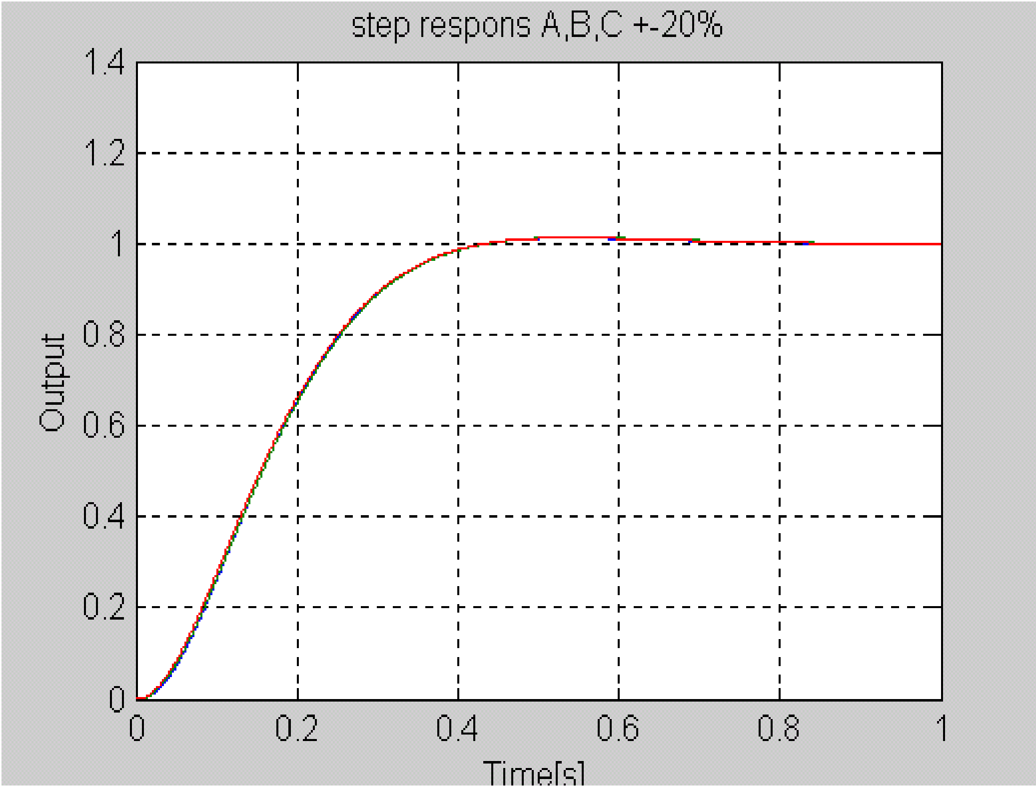


Figure 9

We can conclude from here that there are practically no differences in the step response characteristics. This means that the loop thus synthesised shows adaptive properties when it comes to varying object parameters [8].

5.5 Conlcusion

Other methods of control loop synthesis are also possible. However, the results would in one way or another be similar to the ones obtained above since all synthesis methods in one form or another are derived from the inverse problems of control system dynamics [9].

References

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