Chapter 4
Linear Control System Design

Abstract In this chapter a review of the design of multivariable feedback controllers for linear systems will be considered. This review treats mainly deterministic control objects with deterministic disturbances. After giving an overview of the type of linear systems to be treated, this chapter will handle the basic control system design method known as pole or eigenvalue placement. First systems where measurements of all the states are available will be treated. For cases when such complete state measurements are not available the concept of deterministic observers to estimate the states which are not measured directly will be introduced. It will also be shown that it is often possible to design reduced order observers where only the unmeasured states are estimated.

4.1 Control System Design

Before going into the specific task of designing linear control systems it is necessary to set the ground rules for the treatment. This can be done by presenting an overall picture of the components and configuration of the system which is to be considered.

A control system is a dynamic system which is designed to operate in a prescribed manner without external interference, in spite of unavoidable effects (disturbances) which impede its proper operation. The main purpose of this book is to present methods to analyze and synthesize such systems. A second purpose is to present methods to model disturbances and design control systems for minimum disturbance sensitivity. This requires a tabulation of the main elements of such systems and a presentation of their general configuration.

The main components of a control system are

1. The plant or control object.
2. The actuators or drivers for the plant.
3. The sensors which measure the current operating point of the plant.
4. The controller which drives the plant in accordance with the overall control objective given the sensor measurements.
A block diagram of a typical control system is presented on Fig. 4.1. Note, that the actuators and sensors are usually considered to be external to the control object itself. However it is often necessary that the dynamics of these components are taken into account in the design of the overall feedback control system.

The plants or control objects which may be controlled in this way can be of many different types: mechanical, electrical, fluid dynamic, economic, biological, etc. or combinations of such plants. The only limitation to the nature of the plant (as far as this book is concerned) is that it be described in terms of a coupled set of differential or difference equations. Actuators are devices which are coupled to the control inputs of the plant to supply the energy necessary to effectuate the control commands of the controller. Sensors are devices for measuring the outputs and/or states of the plant. This general description can be used on many types of systems. The controller is in general a dynamic system which on the basis of the measurements provided by the sensors gives an input to the actuators which drive the control object in such a way as to accomplish the desired control objective.

The main feature of control system theory is feedback. This means use of the sensor measurements to derive a signal or signals which are used to drive the actuators of the control object to accomplish a given control task. Such a feedback (loop) is shown on Fig. 4.1 and it is in general external to the control object itself. This mechanism is used to increase the speed or bandwidth of the control object, to increase control accuracy at one or many operating points or to achieve some other desirable control effect.

Another important feature of feedback control systems is an external input which is inserted into the controller in order to provide information as to what the desired control point or trajectory is. This input is shown on the bottom of Fig. 4.1 and is commonly called the reference or command input. Often this input takes the form of a desired value for one or more of the outputs or states of the control object. It may be either constant or variable.