7.0: Prelude to Design of Sampled-Data Systems

The sampled-data control systems include clock-driven elements and reflect the current trends in the design of feedback control systems. In the contemporary control systems technology, data acquisition card (DAQ) is commonly used to sense, sample, and process variables of interest. The controller is digitally implemented as a software routine on a programmable logic controller (PLC), microcontroller, or digital signal processor (DSP).

The sampled-data control systems employ software-based controllers that work with discretized time. The discrete-time system models are represented by difference equations, with input and output variables represented by number sequences. The analog-to-digital (ADC) and digital-to-analog (DAC) converters are modeled as sampler and hold devices (Figure 7.1).

A continuous-time system model can be converted to a discrete system model by assuming a piece-wise constant input generated by a zero-order hold (ZOH). In the MATLAB, the continuous-to-discrete conversion is handled by the ‘c2d’ function in the Control Systems Toolbox. The function allows a variety of input methods.

The z-transform for discrete-time systems serves as the equivalent of Laplace transform for continuous-time systems. Discrete system models are represented by pulse transfer functions that are valid at sampling instances. The added phase angle due to sampling adversely affects the dynamic stability of the closed-loop system. The discrete system stability is indicated by the roots of the characteristic polynomial being restricted to inside of unit circle.

Analog controllers designed for transfer function models of continuous-time systems can be approximated for their application toward sampled-data systems. Assuming a high enough sampling rate (five to ten times the system bandwidth), the digital controller obtained by emulation gives comparable performance to the analog controller it mimics.

Root locus technique can be similarly used for controller design in the case of discrete systems. The design is performed on the z-plane, keeping in view the stability boundary, i.e., the unit circle. The performance criteria defined in
terms of settling time, damping ratio, etc., can be reflected on the z-plane, as conveniently done by using the ‘grid’ command in MATLAB.

In this chapter, we will discuss models of sampled-data system, their properties, stability characterization, and the analysis and controller design for such systems.