PREFACE

This is a text on continuous-time systems. In our use, a system is defined as an object with inputs and outputs. An input is some excitation that results in a system response or output. System theory is the study of the relations between the system inputs (or stimuli) and the corresponding system outputs (or responses). Two major categories of system theory are analysis and synthesis. Analysis is the determination and study of the system input–output relation; synthesis is the determination of systems with a desired input–output relation. For analysis, signals are used as inputs to probe the system, and in synthesis the desired output is expressed as a desired operation on a class of input signals. Thus signals are an important topic in system theory. However, this is not a text on signal theory. In signal theory, the object being studied is a signal and systems are chosen to transform the signal into some desired waveform. In system theory, on the other hand, the object being studied is a system, and signals are chosen to be used either as probes of the system or as the medium used to express system input–output relation. Thus the discussion of signals in this text will be in terms of their application in system theory.

System theory lies at the base of science because system theory is the theory of models, and a basic concern of science is the formation and study of models. In science, one performs experiments and observes some of the quantities involved. A model involving these quantities is then constructed such that the relation between the quantities in the model is the same as that observed. The model is then used to predict the results of other experiments. The model is considered valid as long as experimental results agree with the predictions obtained using the model. If they do not agree, the model is modified so that they do agree. The model is continually improved by comparing a large variety of experimental results with predictions obtained using the model and modifying the model so that they agree. One does not say that the refined model represents reality; rather, one only claims that experiments proceed in accordance with the model. In this sense, science is not directly concerned with "reality." The question of reality is addressed in philosophy, not science. However, there are areas of science and philosophy which do influence each other. Some of these are briefly mentioned in our discussion of system models.

As an illustration, the electron is a model of an object that has not been observed directly. In an attempt to predict certain experiments, the electron was first modeled as a negatively charged body with a given mass which moves about the nucleus of an atom in certain orbits. This model of the electron helped to predict the results of many experiments in which the atom is probed with certain inputs such as charged particles and the output is the observed scattered particles. This model also helped predict the results of experiments in which the atom is probed with electromagnetic fields and the output is the observed spectra of the radiation from the atom. However, to predict the results of other experiments, this model of the electron had to be modified. The model of the electron has been modified by giving it spin, a wavelength, and other properties. Does the electron really exist? Science does not address that question. Science just states that experiments proceed as if the electron exists.

The modern development of engineering and science requires a deeper understanding of the basic concepts of system theory. Consequently, rather than an applications-oriented presentation, basic concepts and their system interpretation are emphasized in this text. The chapter problems are to help the reader gain a better understanding of the concepts presented. To study this text, the student need not know mathematics beyond basic calculus. Any additional required mathematical concepts are logically developed as needed in the text. Even so, all the mathematics used in the text is used with care. Mathematical rigor is not used; that is the province of the mathematician. However, mathematics is used with precision. For example, the impulse is not something with zero width and infinite height. The accurate development of the impulse presented also lends greater insight to its various applications discussed in the text. The careful discussion and application of mathematics results in the student having a better appreciation of the role of mathematics and a more sophisticated understanding of its application in science and engineering.

Linear systems from a functional viewpoint is logically developed in this text. Each topic discussed lays the basis and motivation for the next topic. In order that the development be consistent with a systems orientation, many new results and also new derivations of classic results from a systems viewpoint are included in this text. Thus, many topics such as the Fourier and Laplace transforms and their inverse are not just stated. Rather, I have developed new methods to motivate and derive them from system concepts that had been developed previously.

The text begins with a discussion of systems in general terms followed by a discussion and development of the various system classifications in order to motivate the approach taken in their analysis. The time-domain theory of continuous-time linear time-invariant (LTI) systems is then developed in some depth. This development leads naturally into a discussion of the system transfer function, gain, and phase shift. This lays the basis for a development of the Fourier transform and its inverse together with its system theory interpretation and implications such as the relation between the real and imaginary parts of the system transfer function.

The discussion of the Fourier transform and its inverse motivates the development of the bilateral Laplace transform and a full discussion of its system interpretation. One important class of systems which is analyzed is that of passive LTI systems. Although, as discussed in the text, there is no physical law that requires a system to be causal, it is shown that a passive LTI system must be causal. Constraints that the impedance function must satisfy are then obtained and interpreted.

A new approach to the unilateral Laplace transform is presented by which the bilateral Laplace transform can be used in the transient analysis of LTI systems. The s-plane viewpoint is then used to discuss basic filter analysis and design techniques. The discussion of the s-plane viewpoint of systems concludes with the analysis of feedback systems and their stability, interconnected systems, and block diagram reduction.

Because system theory is the theory of models and the construction of models is one of the main objectives of science, a discussion of the consistency of models and some of the paradoxes in LTI system theory that can arise due to improper modeling is given. The text concludes with an introductory discussion of the state-variable approach to system analysis and the types of problems for which this approach is advantageous. Thus the textual material lays a solid foundation for further study of system modeling, control theory, filter theory, discrete system theory, state-variable theory, and other subjects requiring a systems viewpoint.

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