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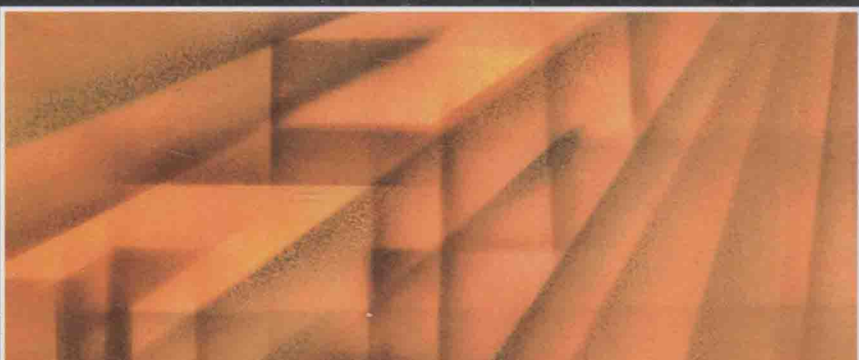
Series Editor: Leon O. Chua

FRACTIONAL ORDER SYSTEMS

Modeling and Control Applications

Riccardo Caponetto • Giovanni Dongola
Luigi Fortuna • Ivo Petráš



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Preface

This book is devoted to fractional order systems, their applications to modelling and control. It is based on derivatives and integrals of arbitrary (real) order, fractional differential equations and methods of their solution, approximations and implementation techniques.

The advantages of fractional calculus have been described and pointed out in the last few decades by many authors. It has been shown that the fractional order models of real systems are regularly more adequate than usually used integer order models.

Applications of these fractional order models are in many fields, as for example, rheology, mechanics, chemistry, physics, bioengineering, robotics and many others.

At the same time, fractional integrals and derivatives are also applied to the theory of control of dynamical systems, when the controlled system and/or the controller is described by fractional differential equations.

The main goal of the book is to present applications and implementations of fractional order systems. It provides only a brief theoretical introduction to fractional order system dedicating almost all the space to the modelling issue, fractional chaotic system control and fractional order controller theory and realization.

The book is suitable for advanced undergraduates and graduate students.

It is organized as follows:

Chapter one is a brief introduction to the fractional order systems. Some historical notes, definitions and fundamentals are described.

Chapter two is dedicated to Fractional Order PID Controller defining their stability regions when first order with time delay plant have to be controlled in closed loop.

Chapter three is on fractional order chaotic systems. In this chapter, a survey of well-known chaotic systems is presented. Mathematical models of nonlinear dynamical systems contain the fractional derivatives. Total order of the system is less than three, however, the chaotical phenomena, as for example, in strange attractors can be observed in such systems.

In chapter four the operator s^m, where m is a real number, is approximated via the binomial expansion of the backward difference and then a hardware implementation of differintegral operator is proposed using Field Programmable Gate Array (FPGA). This building block represents the basic element to implement fractional order control systems.

Chapter five is devoted to microprocessor implementation of the fractional order controllers. Fundamentals on discrete approximations of a fractional operator as well as control algorithm for implementation of the controllers are described. Also presented are three examples of the discrete fractional order controllers implemented on PIC, PC with PCL card, and PLC, respectively. A real measurement and obtained results are shown for each particular case. Some concluding remarks close this chapter.

Chapter six is dedicated to the implementation of the fractional order PID controller by using the analog counter part of FPGA that is Field Programmable Analog Array (FPAA).

Chapter seven presents a possible implementation of an Integrated Circuit by using the switched capacitor technology. The aim of the chapter is to start a research activity that can provide an integrated circuit implementing differintegral operators.

Chapter eight concludes this book showing an useful modelling application of fractional order system on Ionic Polymeric Metal Composite (IMPC) membranes. Going beyond the IMPC, the proposed modelling approach shows that it is possible to obtain low order fractional order models instead of bigger order integer one.

More than 140 references are listed and cited in the book, even if it cannot be a complete bibliography for this area of interest. Readers can find many other references related to this topic.

Riccardo Caponetto
Giovanni Dongola
Luigi Fortuna
Ivo Petráš

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