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Digital Computer Control Systems

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Macmillan New Electronics
Introductions to Advanced Topics

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**To Ann, Bernadette and Trese,
and to the memory of my Father.**

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Series Editor's Foreword

The rapid development of electronics and its engineering applications ensures that new topics are always competing for a place in university and polytechnic courses. But it is often difficult for lecturers to find suitable books for recommendation to students, particularly when a topic is covered by a short lecture module, or as an "option".

Macmillan New Electronics offers introductions to advanced topics. The level is generally that of second and subsequent years of undergraduate courses in electronic and electrical engineering, computer science and physics. Some of the authors will paint with a broad brush; others will concentrate on a narrower topic, and cover it in greater detail. But in all cases the titles in the Series will provide a sound basis for further reading in the specialist literature, and an up-to-date appreciation of practical applications and likely trends.

The level, scope and approach of the Series should also appeal to practising engineers and scientists encountering an area of electronics for the first time, or needing a rapid and authoritative update.

Paul A. Lynn

Preface

Digital control methods are replacing most conventional analogue systems. It is therefore important that the control engineers of the present and future are familiar with the features and facilities available, and are aware of the limitations of such systems. The aim of the book is to present an up-to-date introduction to these systems, and to instruct and assist readers so that they are able to connect digital computers to real systems for control and/or analysis purposes. The main aspects such as discretisation and system design methodologies which need to be considered for solving a particular application are discussed so that the reader is able to successfully perform a complete system design for his/her problem.

The material assumes that readers have completed a first course in control systems where the classical continuous domain methods have been covered, as well as some of the concepts of the state-space approach. Hence knowledge of such areas as the Laplace transform, frequency (Bode, Nyquist, Nichol, etc.), and time domain analysis methods, root locus, compensator design, etc., is assumed. These methods are extended to the discrete z -domain so that computer control can be implemented. Both input/output (classical control) and state-space (modern control) methods are presented with application to illustrative examples. At the end of some of the chapters, numerical problems are included with sample solutions provided in an appendix.

It is not the intention to concentrate on one particular application area but to present an overall systems design approach, so that the generic control methods can be applied to a variety of different areas. Hence the book should be of interest to third year undergraduate or master's students in all branches of engineering and applied mathematics as well as practising engineers and scientists.

The book chapters are set out as follows. The first chapter gives a historical perspective on computer control, and considers aspects such as interfacing (A/D and D/A converters), sampling rates, quantisation effects, hold devices and the problems caused by aliasing. In chapter 2 the z -transform and its properties are introduced, and how it is used in studying digital processes and systems. Discrete approximations can simplify the analysis

greatly and are therefore considered in some detail. Since the z -transform analysis can only define the time responses at the discrete sampling instants, the modified z -transform is also presented so that inter-sampling time values can be described. In addition, the usefulness of multi-rate sampling is discussed so that computer resources can be optimised and appropriate sample rates used to maximise the effectiveness.

Chapter 3 considers the study of systems in the z -domain. The stability methods of Routh, Jury and Raible for sampled-data systems are presented and how time domain, frequency domain and root locus analysis are performed. Most of the methods are extensions of the well known continuous domain techniques. Controller design is the main objective of chapter 4, where several different designs for a rigid-body satellite example are presented. The methods illustrated include continuous and digital domain analysis (in the w' -plane); root locus design in the z -domain; state feedback control; digital PID implementation; deadbeat response design; and optimal controllers. All the designs are performed on the same example so that the different controllers can be compared objectively. A brief introduction to sampled-data control systems under noisy conditions is also presented.

Chapter 5 considers the overall hardware and software considerations in real-time computer systems and how such systems can be designed. The important features such as hardware requirements and software aspects that control engineers need to be aware of when constructing a suitable system are presented. Guidance on the co-ordination of the overall system design is also given. In chapter 6 some of the latest developments, namely artificial intelligence, and parallel processing, are discussed. These are likely to have an enormous impact on control applications where the computers will use concepts such as fuzzy logic and other knowledge-based expert systems with appropriate inference engines to think and deduce solutions in a similar fashion as humans do. Such computers will need to possess vast processing power that can only realistically be achieved using parallel processing techniques. Here the computational task can be distributed over a network of processors that can work on sub-tasks and can communicate between each other so that the overall solution can be determined. The majority of computer users at present are experienced only in the traditional sequential "flow diagram" programming approach. The effective programming of parallel computers requires the users to be retrained so that problems such as deadlock, problem partitioning, communication synchronization, computer architecture optimisation and program termination can be solved. These issues are discussed with particular emphasis to transputer systems programmed in occam.

Much of the work described in this book has arisen from lecture courses given by the author to students in the Department of Control Engineering, University of Sheffield as well as to students at Sheffield City Polytechnic and University of Southampton. Constructive comments received from un-

dergraduate and postgraduate students over the years have improved the material greatly. Also many colleagues have assisted and commented on earlier drafts of some of the chapters. This feedback is gratefully acknowledged and appreciated. In particular the author is grateful to Ian Durkacz, Panos Kourmoulis and Gurmej Virk for their help in preparing sections of the manuscript and diagrams. Dennis Loveday and Joe Cheung proof-read the whole script and made very useful suggestions. In addition the comments made by the series editor Paul Lynn on an earlier draft of the book were invaluable and have been gratefully received to improve the presentation of the manuscript. Finally the author wishes to pay tribute to his wife Ann Marie for her encouragement and understanding over the years. Without her moral and physical assistance this book would never have been accomplished.

Gurvinder Singh Virk
January 1991