Microprocessors in Signal Processing, Measurement and Control

edited by

SPYROS G. TZAFESTAS

Microprocessors in Signal Processing, Measurement and Control

edited by

SPYROS G. TZAFESTAS
Electrical Engineering Department, University of Patras, Patras, Greece

D. REIDEL PUBLISHING COMPANY
A MEMBER OF THE KLUWER ACADEMIC PUBLISHERS GROUP
DORDRECHT / BOSTON / LANCASTER

Library of Congress Cataloging in Publication Data

CIP

Main entry under title:

Microprocessors in signal processing, measurement and control.

(International series on microprocessor-based systems engineering)
Includes index.
1. Microprocessors. 2. Signal processing—Digital techniques.
3. Digital control systems. I. Tzafestas, S. G., 1939– . II. Series.
TK7895.M5M53 1983 001.64 83–11067
ISBN 90–277–1497–5

Published by D. Reidel Publishing Company
P.O. Box 17, 3300 AA Dordrecht, Holland

Sold and distributed in the U.S.A. and Canada
by Kluwer Academic Publishers,
190 Old Derby Street, Hingham, MA 02043, U.S.A.

In all other countries, sold and distributed
by Kluwer Academic Publishers Group,
P.O. Box 322, 3300 AH Dordrecht, Holland

Printed in The Netherlands

PREFACE

In recent years the LSI technology has witnessed a revolutionary development, and allowed substantial reductions in the size and cost of digital logic circuitry. Computer system building blocks have progressed from the level of discrete components to the level of complex ICs involving many logic circuits on a single "chip". The invention and wide applications of microprocessors have changed the philosophy of the signal processing, measurement and control engineering fields. The microprocessor-based digital signal processing systems and controllers have replaced the conventional ones based on standard analog and digital computing equipment. The first microprocessors and "on-chip" computers have appeared towards the end of 71 beginning 72. Their evolution since then and the number of applications, in which they have been utilized, have both been extremely spectacular. New system concepts and hardware/software tools are steadily under development to support the microprocessor in its multiple and complex tasks.

The goal of this book is to provide a cohesive and well-balanced set of contributions dealing with important aspects and applications of microprocessors to signal processing, measurement and system control. The majority of contributions include sufficient review material and present rather complete treatments of the respective topics. Although an exhaustive presentation of all existing microprocessor-based applications in the signal processing, measurement and control field is not possible in a single volume, the reader can find here the major aspects, tools and techniques employed in most applications. An outline of the material contained in the book, along with a general introduction to microprocessors and their applications is given in chapter 1.

This book is certainly not intended to cover introductory aspects of microprocessors and the application fields dealt with The reader is assumed to have acquired some background know-

S. G. Tzafestas (ed.), Microprocessors in Signal Processing, Measurement and Control, v–vi.

ledge prior to reading the book. Of course each chapter is self-contained, and hence the reader can restrict his study to the chapters of his special interest without any particular difficulty. Since the book involves a blend of the experience of a large number of experts working in different environments, a multiplicity of approaches and angles of attack are offered which are of great value to those seeking for alternative designs and solutions.

I would like to thank my colleagues for their acceptance to offer some of their valuable experience for the book. Without their contribution this book would not have been possible.

Despite the variations in the organization and flavour of the particular chapters, I am convinced that students, scientists and engineers will find this volume a useful guide to current microprocessor-based modelling, signal processing, measurement, control system design, and automation techniques.

Patras 1983 Spyros G. Tzafestas

CONTRIBUTORS

M. BERTINO, System and Software Engineering, Soft Power, Torino, Italy.

F. M. CADY, Department of Electrical Engineering and Computer Science, Montana State University, Bozeman, USA.

C. S. CHEN, Electrical Engineering Department, The University of Akron, Akron, Ohio, USA.

P. CIVERA, Department of Electronics, Politecnico di Torino, Torino, Italy.

D. DELCORSO, Department of Electronics, Politecnico di Torino, Torino, Italy.

F. GREGORETTI, Department of Electronics, Politecnico di Torino, Italy.

R. GRONDIN, Systems Engineering and Electronics, Research Institute of Hydro-Quebec (IREQ), Varennes, Quebec, Canada.

F. HARASHIMA, Institute of Industrial Science, University of Tokyo, Tokyo, Japan.

R. M. HODGSON, University of Canterbury, Christchurch, New Zealand.

A. HOLMBERG, Systems Theory Laboratory, Helsinki University of Technology, Espoo, Finland.

R. D. JACKSON, Engineering Department, Cambridge University, Cambridge, England.

A. ST. JACQUES, Systems Engineering and Electronics, Research Institute of Hydro-Quebec (IREQ), Varennes, Quebec, Canada.

H. H. LE, Systems Engineering and Electronics, Research Institute of Hydro-Quebec (IREQ), Varennes, Quebec, Canada.

C. T. NGUYEN, Systems Engineering and Electronics Research, Institute of Hydro-Quebec (IREQ), Varennes, Quebec, Canada.

I. OKUMURA, Technical Research Institute, Japanese National Railways, Tokyo, Japan.

J. ORAVA, Systems Theory Laboratory, Helsinki University of Technology, Espoo, Finland.

J. B. PLANT, Graduate Studies and Research, Royal Military College of Canada, Kingston, Ontario, Canada.

E. J. PRENDERGAST, Engineering Department, Cambridge University, Cambridge, England.

N. K. SINHA, Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada.

S. SONE, Engineering Research Institute, Faculty of Engineering, University of Tokyo, Tokyo, Japan.

A. SOWIŃSKI, Industrial Institute of Electronics, Warsaw, Poland.

D. TABAK, Department of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel.

G. A. TENDULKAR, Department of Control and Automation Systems, Siemens AG, Erlangen, FRG.

H. TOFFER, Physics and Engineering Analysis, Operations Division, UNC Nuclear Industries, Richland, Washington, USA.

S. K. TSO, Electrical Engineering Department, University of Hong Kong, Hong Kong.

S. G. TZAFESTAS, Control Systems Laboratory, Electrical Engineering Department, University of Patras, Patras, Greece.

P. URONEN, Department of Process Engineering, University of Oulu, Linnanmaa, Oulu, Finland.

CONTENTS

PART II SIGNAL PROCESSING

Chapter 4
DESIGN AND IMPLEMENTATION OF THE DIGITAL FILTER VIA THE SIGNAL PROCESSOR
C. S. Chen

Chapter 5
MICROCOMPUTER-BASED WAVEFORM ANALYZERS AND THEIR APPLICATIONS
R. D. Jackson and E.J. Prendergast

Chapter 6
MICROCOMPUTER-BASED INTERACTIVE IMAGE PROCESSING
F. M. Cady and R. M. Hodgson

PART IV CONTROLLERS

PART V APPLICATION TO CONTROL AND AUTOMATION

Microprocessors in Signal Processing, Measurement and Control

Part I GENERAL ASPECTS

CHAPTER 1

MICROPROCESSORS AND THEIR APPLICATIONS—OUTLINE OF THE BOOK

S. G. Tzafestas
Control Systems Laboratory
University of Patras
Patras, Greece

1. INTRODUCTION

Microprocessors have already been recognized to be important tools for the electronic and system designer [1-9]. Microprocessor-based computing systems have shown a great influence on signal processing and control, similar to that of large-scale digital computers in the decade of sixties. Their success is mainly due to the cost reduction and design flexibility increase they offer. After the introduction of the PDP-5 (1963) and PDP-8 (1965) minicomputers a steady reduction rate in the cost of signal-processing and computer-control has occured, (about 30 per cent per year) owing primarily to the improvements of semiconductor *IC* technology. The transition from *PDP-8* (which is programmable mainly in machine and assembly language) to *VAX-11* (a high-level language machine) needed 15 years, whereas analogous progress in microprocessors was made in less than half that time. The microcomputer offers a unique compactness and modularity in instrumentation, signal processing, and control, which makes now possible many new applications, that previously needed much more expensive dedicated computers. Actually, the application of microprocessors is limited more by the imagination of their users than by their technology. As more and more system designers are familiarized with the capabilities of microprocessors the number of new microprocessor-based applications increases very rapidly. It is remarkable that in only a few years we had a transition from the laboratory utilization of the microprocessor to a mass production and utilization of microprocessor based systems. Of course, in the early stages of the microprocessor revolution, the new technology has been used merely to replace TTL implemented systems, but presently an increasing number of products are surfaced which would be impractical without the microprocessors.

S. G. Tzafestas (ed.), Microprocessors in Signal Processing, Measurement and Control, 3–12.

2. MICROPROCESSOR CAPABILITIES

Microprocessors are the result of the semiconductor industry effort to accomodate an ever-increasing number of transistors in a single integrated circuit, and can implement a given function with a smaller number of chips than older devices. They have replaced hardwired logic with programmed logic that can be placed into ROMs offering even more capability per chip. Any basic microprocessor module can be enriched with a great logic power by simply adding of few more IC's. The most important characteristics of today's microprocessor usage is not so much in replacing hardwired logic or the low-end minicomputers, as it is in a substantial shift in the philosophy of electronic design and in using them in the new applications where use of big computers is not economically justified. The major microprocessor disadvantage is its low speed. Compared to minis, the micros have smaller istruction repertory, fewer features, and weaker software support.

Compared to the hardwired logic, the microprocessor offers greater flexibility, since wired connections and SSI/MSI devices are being replaced by bits in memories. Thus, modifications, improvements, and product expansions, instead of requiring new hardware designs and/or replacing logic gates and interconnections, simply require reprogramming and substituting bits in memory. It is noted that, although microprocessors have in general low speed, quite fast real-time programs can be written especially for slow industrial applications (such as temperature sensing in a heating plant, reading synchro signals, etc). When higher speed requirements exist, for which the conventional single chip μP is not fast enough, one can use multi-chip microprocessors with bit sliced architectures, most of which are intended for microprogrammed applications.

Microcomputers can replace minis for controlling industrial processes, reducing the cost by a factor greater than two. Originally the microcomputers were scale-down versions of existing minicomputers. This allowed the utilization of the mini control software with nearly no change. Today many microcomputer systems are being designed from the beginning with unique properties.

The major advantages of microprocessor-based systems over their random logic counterparts are the following:

(i) Lower manufacturing cost (60 to 20 percent of the TTL equivalents).

(ii) Lower time and cost of original design and development.

(iii) Faster production of new systems in closer corres-