DIGITAL COMPUTER APPLICATIONS TO PROCESS CONTROL

Edited by
R. ISERMANN and H. KALTENECKER

IFAC

DIGITAL COMPUTER APPLICATIONS TO PROCESS CONTROL

Proceedings of the 6th IFAC/IFIP Conference
Düsseldorf, F. R. Germany
14-17 October 1980

Edited by

R. Isermann
and
H. Kaltenecker

VDI/VDE-Gesellschaft Mess- und Regelungstechnik, Düsseldorf, F.R. Germany

Published for the
INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL
by
PERGAMON PRESS
OXFORD · NEW YORK · TORONTO · SYDNEY · PARIS · FRANKFURT

U.K.	Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, England
U.S.A.	Pergamon Press Inc., Maxwell House, Fairview Park, Elmsford, New York 10523, U.S.A.
CANADA	Pergamon Press Canada Ltd., Suite 104, 150 Consumers Rd., Willowdale, Ontario M2J 1P9, Canada
AUSTRALIA	Pergamon Press (Aust.) Pty. Ltd., P.O. Box 544, Potts Point, N.S.W. 2011, Australia
FRANCE	Pergamon Press SARL, 24 rue des Ecoles, 75240 Paris, Cedex 05, France
FEDERAL REPUBLIC OF GERMANY	Pergamon Press GmbH, 6242 Kronberg-Taunus, Hammerweg 6, Federal Republic of Germany

First edition 1981

British Library Cataloguing in Publication Data

IFAC/IFIP Conference, *6th, Dusseldorf, 1980*
Digital computer applications to process control.
1. Process control - Data processing - Congresses
I. Title II. Isermann, R.
III. Kaltenecker, H.
IV. International Federation of Automatic Control
V. International Federation for Information Processing
670.42'7 TS156.8 80-41343

ISBN 0-08-026749-1

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Printed in Great Britain by A. Wheaton & Co. Ltd., Exeter

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PREFACE

In the series of IFAC/IFIP Conferences on "Digital Computer Applications to Process Control" held in Stockholm (1964), Menton (1967), Helsinki (1971), Zürich (1974) and the Hague (1977) these papers form a basis for the sixth Conference. The aim of this Conference is, as for the previous ones, to present, discuss and summarize recent advances in the application of digital computers to the control of technical processes. A special emphasis is based on the practical realization of and experiences with modern control principles. These control principles include as well direct feedback and feedforward control as monitoring and optimization of technical processes.

In comparison with the former Conferences it can be observed: There are more applications with microcomputer control, distributed control and adaptive control. Software reliability, productivity and maintenance become more important. According to the necessity of energy and raw material saving the interest in closed-loop optimization increases. Furtheron, the performance of direct control and of monitoring process failures has been improved by digital techniques.

The papers of this Conference are divided into the following groups:

code	type	number of contributions
S	Survey papers	5
CS	Case study papers	7
T	Tutorial papers	3
A	Application oriented papers	22
G	General aspect papers	33

Five *survey papers* give a summary of trends, developments and state-of-the-art of digital computer applications, design methods, hardware and software aspects. Seven *case study papers* show the application of process computer and microcomputer control for various industrial processes in detail. Three *tutorial papers* give an introduction into selected subjects.

55 papers form the basis for the following *technical sessions*:

code	session title	number of contributions
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It is a pleasure to thank

- the members of the International Program Committee for their contributions in the selection of papers and for their proposals
- the members of the National Organizing Committee for their support in the organization

- the ladies and gentlemen of the VDI/VDE-Gesellschaft Mess- und Regelungstechnik for their efforts in preparing the Conference
- the publisher Pergamon Press for preparing this book.

The papers printed in this volume have been written and prepared for camera-ready production by scientists from 24 countries of the world. May they be a good basis for the Conference and further development of digital computer control.

May 198o

Rolf Isermann
Horst Kaltenecker

Editors

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STATUS OF HARDWARE AND SOFTWARE FOR MICROCOMPUTERS

G. Färber

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Abstract. A report on the status of microcomputer Technology must consider two categories of microprocessor systems. The Hardware and Software for these categories are developed in different ways.

The first category of microcomputers has been created by the requirements for dedicated, mass-produced applications. The technological advance here is to integrate more and more functions (memory, digital I/O, analog-digital-converter, communications adapter) on to one Silicon-chip. Specialized microcomputer-versions adapted to the requirements of high-volume-applications are already available. Software support includes machine-oriented and high-level languages; to aid the non-computer-experts, problem-oriented languages (e.g. block-diagram languages for control applications) are on the way. Small real time operating systems are available, sometimes in form of on-chip-Firmware. The fact that usually multiple microcomputers of this category are tied together in one system, requires standardized communication protocols as well as very efficient diagnostic tools.

The second category of microcomputers is characterized by the fact that they start to invade the classical domain of mini- or even midi-computers. The technology is used here to produce devices with higher speed and better architecture: It is defined by the requirements of the software technology where e.g. it is essential to execute intermediate code as efficiently as possible - the first symptoms for a substitution of today's machine languages by intermediate languages may be observed: The required control constructs, data types, memory assignment etc. will be supported by hardware. Since systems as well as applications software demands more code- and data-memory, large address spaces and suitable addressing modes are very important. Since multitasking is essential for process control applications, operating systems primitives are already provided by hardware. To enhance the computer systems performance further and to allow the construction of redundant systems, the architecture of today's microcomputers also provides aids for multiprocessor-operations.

Sixteen-bit-single-chip-microprocessors with the performance of upper-class-minicomputers are already available. Even more powerful systems may be designed with bit-slice-processors since microprogramming is a very efficient way to implement special architectural features. However, microprogrammable single-chip-microprocessors (with internal or external - writeable - control store), which will be available in the near future, will replace the bit-slice-approach.

High-level languages are mandatory for these high-performance microprocessors. PASCAL, with some extensions (allowing concurrency), or PASCAL-derivatives seem to have become a defacto-standard. A trend may be observed to use the same high level language for applications and systems programming - an important step away from machine-oriented languages.

Finally the new operating systems provide - supported by hardware - means for multitasking as well as for multiprocessing. Since in process control applications microcomputers will interact in computer networks, network control functions like message switching, network monitoring and downloading will be added to the software catalogue in the near future.

INTRODUCTION

This report on the status of microcomputer technology tries to reflect its impact on control engineering applications. The use of principal technological possibilities to achieve higher performance, more advanced systems architecture or just lower cost will be discussed: In fact, the structure of process automation system will be changed significantly by these new devices.

Fig. 1 demonstrates computer development over the last two decades: From the general-purpose-computer, the mainframes and the minicomputers (used also for process control) have been derived; a further refinement is characterized by the terms "microcomputers" and "midicomputers". Now the microprocessors start to invade all performance-classes:

- Motorola /1/ microcomputer families include one-chip-microcomputers like M6805 at the low end and high performance midilike systems, like M68000.
- The National Semiconducter /2/ family span the range from 1-Dollar-microcontrollers (COP 411) to very powerful 32-bit-computers (NS 16032).
- In /3/ an overview of Intel's future plans is given, using the terms "microcontroller/micromini/micromaxi/micromainframe".

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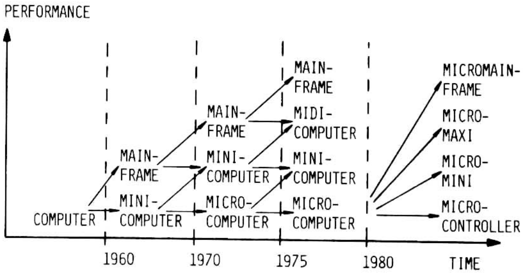


Fig. 1. Development of Computer and Microcomputer Performance

At least two classes of microcomputers have to be considered independently if the impact on control engineering is discussed; the next two chapters are defined by these categories. It is of interest that the basic hardware for both categories may even be identical: The difference in software concepts and flexibility defines the class of applications and demonstrates the growing influence of software.

SMALL MICROCOMPUTER SYSTEMS (SMCS)

SMCS - Hardware

The term "Small Microcomputer System" applies to small to medium sized systems - "small" being an attribute of the systems' flexibility more than its physical size or memory extensibility.

Here the technological and architectural advances developed for mass-produced applications are very important: Microprocessors as required for automotive or consumer product applications are very well suited to control engineering:

- Very high reliability is required to keep the maintenance problem manageable.
- Environmental influences have to be minimal (electrical, mechanical noise, thermal and atmospheric environment).
- The architecture must be directed to realtime applications, e.g. in a car or a tape recorder very critical response constraints must be met.
- Analog and digital peripherals as well as a fair amount of memory must be on chip in order to keep costs low.

Therefore these units may serve as pioneers for other control engineering applications - the low cost of high volume produced components should help them penetrate new fields.

The increasing functional density on Silicon is used here to add more functions to the same chip (Fig. 2) /4/:

- More memory (up to 4 K bytes ROM, RAM) to include more programmed functions.
- Input/Output, and controller functions.
- Analog to digital and digital to analog-converters including multiplexers and additional analog circuitry (Intel 8022, 2920 /5/).
- Communication-oriented functions to enable the integration into higher level systems.
- Simple diagnostic functions.

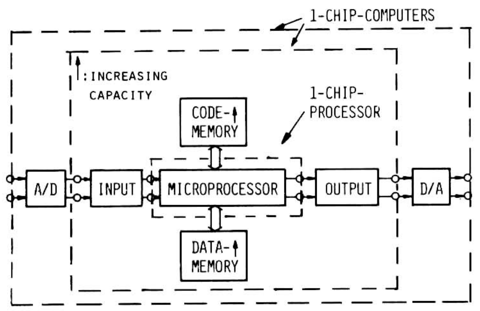


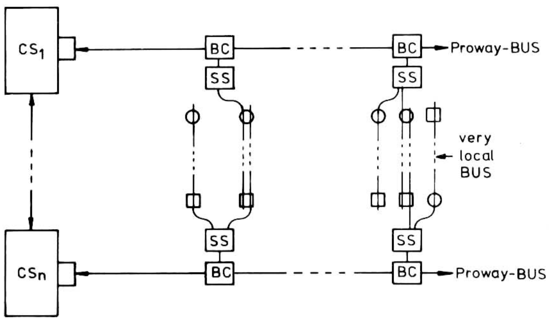
Fig. 2. Increasing functional Density in 1-chip-microcomputers

Mostly the CPU-architecture remains unchanged; beside some medium comfortable architectures (e.g. Motorola 6801, TI 9940) very basic and irregular instructions sets make programming a difficult task (Intel 8048, National COP-family).

In control engineering the use of such components results in high volume / low flexibility applications: Since most program memories in single chip microcomputers are ROM-based, the resulting components behave inflexibly like hardware and must be ordered in larger quantities. Typical applications are:

- The use of dedicated microcomputers to make sensors "intelligent". Sometimes the intelligence is used just to compensate non-linearities or poor reproducibilities of cheap sensors; sometimes more complex functions like calibration or the calculation of values from indirectly measured physical units are provided. The same microcomputer may also be used to connect the sensor to a "very local bus"; Sensors may be tied directly to that bus system. As Fig. 3 shows, a redundant connection to 2 busses may also be realized. /4/.

- The same idea is of interest for "intelligent actuators"; a dedicated microprocessor may control a semiconducter switch (e.g. the Intel 8022 provides a zero-crossing indicator for phase-locked triggering). For stepper motor control, preprogrammed microprocessors are already available /6/. Supervisory functions as well feedback control may be dedicated. These units can also be tied to a local bus (Fig. 3).



CS: Computer System

SS: Substation

BC: Bus-Coupler

O: Intelligent Sensor

: Intelligent Actuator

Fig. 3. Intelligent Sensors and Actuators connected to very local Bus-Systems.

Some companies already offer programmed 1-chip-processors to perform a special bus protocol:

- Mostek uses the 3870 to realize the SCU-1 /7/.

- Intel offers the iSBC 941, an "industrial digital processor" (IDP) based on the 8041-processor /12/.

- Intersil developed the REMDACS-System (Remote Data Acquisition and Control) on the basis of the 8048 (They hope to use their own CMOS-version in the future) /8/.

- The system house, PCS, developed an "intelligent cable" with small analog and digital adapter-modules /9/.

As the above applications show, a standard on the "very local-bus"-level has also become important.

Implicitly the discussion has been restricted to 8-bit-microcomputers: Many of 4-bit-units are available too, but the semiconducter companies usually restrict the minimum number of identical components to more than 10.000 - 100.000. Very few control engineering applications fit that requirement.

The processing power of 1-chip-microcomputers is not restricted to very small tasks (e.g. controlling one sensor or actuator). In /10/ a 8049-System is described which controls complex multivalent heating systems (Fig. 4):

- Multiple heat sources like heatpumps, solar collectors, storage systems or conventional oil and gas furnaces are controlled - once per second the system optimizes the configuration.

- A weekly schedule (no heat at night or on weekends) is stored in the system.

- An adaptive control algorithm avoiding manual misadjustment is implemented.

- Diagnostic procedures to detect faults in the microprocessor as well as in all other parts of the heating system are included.

The program requires only 2 K bytes of ROM and controls a fairly complex technical process using 16 analog inputs and some digital I/O. This example shows an important consequence: Even complex control engineering concepts (like adaptive control) invade the field of consumer-type products: The control engineers skill becomes increasingly important even for very small applications.

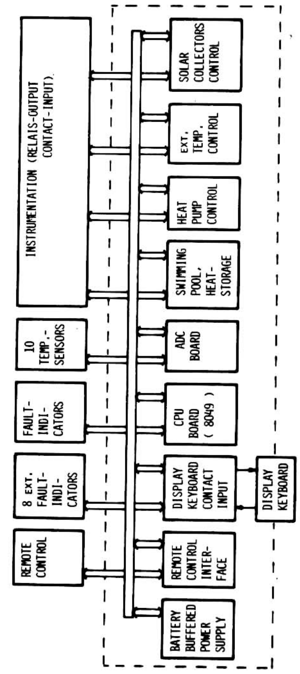


Fig. 4. Modular multivalent heating control system based on 8049-singlechip-microprocessor.

Also medium volume - medium flexibility-applications are realized by systems of the small microcomputer class. Eight- or 16-bit processors of various performance are used to build systems with limited programmability:

- Today the classical 8-bit-processors (Intel 8085, Zilog Z80, Motorola 6800, 6502) are mainly charged with these tasks.

- The new 16-bit or 16-bit-like processors such as Motorola 6809, Intel 8086 and 8088 or TI 9900/9980 and the non-segmented version of Zilog's Z8000 are starting to replace the older units.

- For timecritical applications (e.g. control) bit-slice-processors (AmD 2900-series) are adequate.

Some classes of applications will be supported in the future by specialized processor architectures. The area of programmable controllers (PC) requires processors as well suited for bit-oriented as for word-oriented operations. The Intel 8051 e.g. has an instruction set capable of direct manipulations of Boolean expressions /3/. The SBA of General Instruments (Sequential Boolean Analyser) is also designed for this field.

The new distributed process control systems pioneered by Honeywell's TDC 2000 are based totally on microprocessor technology. In fact, the 16-bit microprocessor CP 1600 (General Instruments) was originally developed for that application. Half a dozen similar systems are now on the market: They show how the flexibility of microprocessors must be limited in order

- to ease programming of special installation and

- to avoid dangerous software faults.

Fig. 5 gives an example of the structure of one system (Siemens Teleperms M /11/). The hardware could be used for totally different purposes too - but the major costs arise from software development.

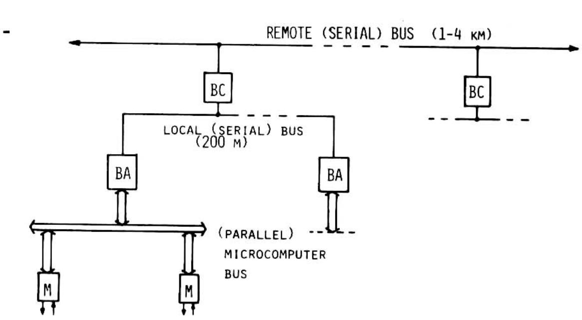


Fig. 5. Hierarchy of bus systems for distributed processcontrol systems.

A special processor category still has to be mentioned: The new one-chip signal processors /12/. They provide a very fast execution of instruction