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Minicomputers in Instrumentation and Control

The Course Proceedings edited by
Y Paker   G Cain   P Morse

The Proceedings

Minicomputers in Instrumentation and Control

A Three Day Special Course at the Polytechnic of Central London

30 May to 1 June 1973

Edited by the Organisers
Dr. Y. Paker
Dr. G. Cain
Dr. P. Morse

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Minicomputers in Instrumentation and Control Paker, Cain, Morse

EDITORS' NOTE

The special course "Minicomputers in Instrumentation and Control - 73", held at the Polytechnic of Central London (30 May - 1 June 1973), was an updated repeat of the similar course held in the previous year.

The high number of delegates attending and their varied backgrounds demonstrate the continuing interest in this field, motivated, no doubt, by the current growth in the minicomputer industry. In fact, the response to the full range of our minicomputer courses indicates that there exists a wide information gap between the high technology of minicomputers and their users, spread in surprisingly varied fields.

The worldwide acceptance of the Proceedings of the 1972 course has encouraged us to publish this edition, containing the revised material. The papers presented assume no prior knowledge of minicomputers. The Proceedings commences with an overview of instrumentation and control objectives and the relevance of minicomputers. Desired minicomputer operating requirements from the standpoint of instrumentation compatibility are then outlined, prior to moving into a description of minicomputer structure and organisation. Interfacing considerations and software are covered in some depth. Minicomputer trends are then examined. The last three papers give some typical applications derived from industrial, scientific/laboratory and biomedical fields. The Proceedings also includes a bibliography and a glossary of minicomputer terms. Finally, there is a list of the companies that participated in MINIFEST 73, an exhibition of minicomputers held in conjunction with this course.

As Course Organisers, we would like to sincerely thank the lecturers, chairmen and delegates for providing the lively and stimulating discussions. The efforts of our support team in the course organisation and implementation, too, are gratefully acknowledged. Finally, as Editors, we must express our gratitude to Miss Penny Green and Mrs. Anna Hartley for the meticulous typing which such an effort requires.

Y. Paker

G. Cain

P. Morse

The Polytechnic of Central London

September 1973

COURSE PROGRAMME

Wednesday 30th May, 1973

10:30	Registration Begins
12:00	Sherry Reception and Lunch

Afternoon Session

Chairman: Dr. P. Morse, PCL

14:00	Opening Remarks and Welcome by the Chairman
14:15	Introduction to Minicomputers - Dr. Y. Paker, PCL
15:00	The Minicomputer as a System Element - Dr. G. Cain, PCL
15:45	Discussion
16:00	Tea
16:30	Instrumentation Compatibility Constraints - Dr. A. Freedman Plessey Radar
17:45	End of First Day's Lectures

Thursday 31st May 1973

Morning Session

Chairman: I. Barron, Computer Technology

09:30	Minicomputer Structure - Dr. D. Turtle, ERA
10:45	Coffee
11:15	Interfacing - H.R. Shaylor, University of Birmingham
12:30	Lunch

Afternoon Session

Chairman: Dr. L. Michalski, Polytechnic of Lodz, Poland

14:00	Software - D.N. Shorter, British Steel Corporation
15:15	Tea
15:45	Minicomputer Trends - K. Trickett, Digico
17:00	End of Second Day's Lectures
20:00	Course Dinner

Friday 1st June 1973

Morning Session

Chairman: Dr. P.J. Coen, Logica

09:30	Industrial Instrumentation - P. Brown, CEGB
10:30	Coffee
11:00	Scientific Instrumentation - Dr. A. Carrick, Instem
12:00	Biomedical Instrumentation - Dr. J.P. Blackburn, Westminster Hospital
13:00	End of Academic Sessions; Lunch

Afternoon Session

14:30	Manufacturers' Presentations
16:30	End of Course

COURSE DELEGATES

ALLISON, P.B.
GEC Measurements Limited

ANDREW, J.
Hawker Siddeley Aviation Limited

ANTHONY, C.W.
Shell (U.K.) Limited

BAILEY, R.
Racal (Slough) Limited

BARTLETT, P.S.
BICC Supertension Cables Div.

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Sandoz AG, Switzerland

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Central Electricity Generating Board

FACCINI, G.
SNAM Progetti, Italy

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National Physical Laboratory

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HERNANDEZ, Señor
Industrias Agricolas, Spain

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HORNBY, N.
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E.G.D., The Netherlands

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PUGH, J.
Lockheed Hydraulic Brake Company Limited

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Newcastle Polytechnic

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Junta de Energia Nuclear, Spain

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SENDALL, D.M.
CERN, Switzerland

SEVERY, R.
Dowty Rosol Limited

SODER, A.
Sandoz Limited

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IBM Zurich Research Laboratory, Switzerland

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STC Limited

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WADE, M.J.
Civil Aviation Authority

WARD, P.G.
British Steel Corporation

WEAVER, J.J.
Shell Research Laboratory

WOOD, R.A.
DOE Transport and Road Research Laboratory

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Westminster Hospital

BROWN, P.
Central Electricity Generating Board

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Polytechnic of Central London

CARRICK, Dr. A.
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INTRODUCTION TO MINICOMPUTERS

Dr. Y. Paker

Polytechnic of Central London

Dr. Yakup Paker completed his undergraduate work at Istanbul Technical University and then continued his studies at Columbia University, New York, receiving an M.Sc. degree in 1961 and a Ph.D. in 1965. He taught at the Middle East Technical University, Ankara, from 1965 to 1970. After industrial (Electronic Associates Inc., New Jersey) and teaching (Federal City College, Washington D.C.) experience in the United States he joined PCL as a Senior Lecturer in 1971. He is currently developing interactive computing and research into minicomputer instrumentation and parallel digital simulators.

INTRODUCTION TO MINICOMPUTERS

MINICOMPUTERS IN PERSPECTIVE

Since the beginning of the sixties one has become accustomed to phenomenal growth in general-purpose digital computers as each year has brought in more powerful and larger systems with their price far exceeding the six-figure mark. These general-purpose data processing machines have required special environmental conditions, large operational and support teams and special maintenance. During the same period, a rather curious development has taken place in the small computer field where machines have been getting smaller in size with improved performance at steadily declining costs, approaching the three-figure range. Today such machines, although identical in basic concept, are named "minicomputers" to differentiate them from their big brothers. The "mini" which can be bought from £2,000 to £30,000 can be plugged into a 13A point, placed on a table in the corner of a laboratory and is accessible to anyone with zeal to learn a relatively simple programming language and typing. The steady trend in lower cost, smaller size, higher reliability machines backed up by sophisticated peripherals and software, is opening up new application areas undreamt of before. We are now observing an exciting period in this field, as new components and technologies are rapidly finding their way into minicomputer construction and almost every month a new development is announced.

Minicomputers first appeared about the beginning of the sixties. Their progress followed closely the development of digital circuit technology. First transistors, then integrated circuits and now MSI (Medium Scale Integration) and LSI (Large Scale Integration) circuits are being used in their construction. To illustrate the rate of expansion, in 1969 about 8,000 machines were installed. In 1975 this figure is expected to reach 40,000 installations [1]. In the UK the number of installations per year is expected to increase to 3,200 in 1975 from 1,200 in 1970 [2]. Although worldwide the number of installations per year is expected to increase by a factor of five between 1969 and 1975, the total value of installations will increase by a factor of three from 40 million pounds to 120 million pounds during the same period. This clearly indicates the fall in the mainframe prices. Another interesting factor is the ratio of central processor cost to the total system cost which was 1/2 in 1969 and is expected to become 1/4 in 1975. This is also partly due to the sophisticated peripherals designed for the minicomputer market that are becoming available. As the applications become more complex, the peripherals will make up a large chunk of the total system. The total value of the minicomputers installed will rise from about 100 million pounds in 1969 to 1,000 - 2,000 million pounds in 1975. The UK's portion is about 10% of these figures. In 1968, 45% of all computers delivered cost less than £20,000; by 1970 this proportion had risen to 60% and it is expected to be 80% by 1975. At present more than 80% of computers installed in Europe cost less than £50,000.

The minicomputer applications cover a wide range such as instrumentation of intensive care units, nuclear reactor control, spectroscopy, data handling, business applications, front ending, telecommunications and so on. The number of machines to be installed in 1975 will roughly be distributed as follows [1]:

1/3 in industry
1/9 in telecommunications
2/9 in business
1/9 in laboratory
2/9 in other applications.

The industrial and telecommunications requirement of mass produced reliable machines has created a large OEM (Original Equipment Manufacturer) market (about 50% of the total) in which minicomputers that are manufactured under mass production techniques are supplied in quantity to OEM firms which build them into their own equipment such as numerical control machinery. This is very significant for instrumentation since a minicomputer can now be tailored to suit a specific application and becomes a *component* of a larger instrumentation and control system, usually at a fraction of the total cost.

WHAT IS A MINICOMPUTER?

This is a difficult task, since it involves drawing boundaries between maxis, midis and micros, all too hazy concepts. Nevertheless, let us try to explain what a minicomputer consists of as the term is used currently.

Types of Computers

Computers are machines which perform certain mathematical and logic operations on data presented (input) to it and produce an output. We can group such machines into two categories: analog and digital. In an analog computer physical variables, such as voltage, are used to represent the information that is being processed and computation is carried out continuously. We do not have to pursue this any longer since a minicomputer is not an analog device, although it is normally tied to such signals in the process control field.

A digital computer stores and processes information which is in digital form, i.e. numbers and characters. Thus the input consists of a string of digits and characters, coded into digits at the first opportunity, as is the output. A desk calculator, then, is a digital computer, satisfying the above definition. It is, however, a special-purpose machine since it can perform a number of operations, such as addition, which are wired permanently into the construction of the calculator. Let us emphasise here that a "mini" is not a calculator.

Stored Program Digital Computer

When we talk of a general-purpose digital computer we imply a "stored program" machine. This is what makes these machines so flexible; the penalty is, however, the necessity of programming. A block diagram of a general-purpose digital computer is shown in Figure 1. This oversimplified figure shows three distinct units: memory, central processor and input-output. Memory contains a number of locations (cells) where information can be stored (write) and accessed (read). This information consists of raw data that we are processing or the instructions that make the machine function. For example, if we would like to add A and B, the numbers A and B are contained in the memory and so is the instruction "Add A to B". Memory is only a storage device and the actual "execution" of an instruction takes place in the central processor. This is the unit which controls the actual flow of computation which means accessing instructions from memory and carrying out the steps prescribed by them. These steps usually involve reading numbers from the memory, processing them (such as applying arithmetic operations) and storing them back in the memory. The functioning of the digital computer thus requires execution of instructions stored in the memory in a "sequential" manner, i.e. one after the other. The whole process of determining the instructions for a specific job is called "programming", as will be discussed subsequently.

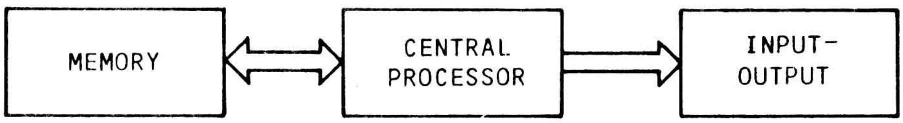

FIGURE 1

Minicomputer Definition

A minicomputer is a stored program, general-purpose digital computer which differs from large scale machines in terms of price, performance and field of applications.

CURRENT MINICOMPUTER PROFILE

The diminutive title "mini" should not mislead as to the actual computational power of such machines. In Table I we list various features of minicomputers and quantify them in relation to what might be called a "small", "average" and "large" configuration. The numbers given here refer to machines currently available and thus they are in a constant flux. It is seen that a wide range of choice exists in the size of configuration available.

TABLE 1

CHARACTERISTICS	SMALLEST CONFIGURATION	LARGEST CONFIGURATION	AVERAGE CONFIGURATION
Price	£2,000	£30,000	£10,000
		HARDWARE	
Memory			
Word length (bits)	8 - 12	24	16
Size (words)	1-4K	32-64K	8K
Speed (microseconds)	2	.3	1
Parity check	No	Standard	Optional
Memory protect	No	Standard	Optional
Direct addressing	128 word	The whole memory	256-1024 words
Indexing	None	16 separate index registers	1-4 index registers
Processor			
General-purpose registers	1	16	2-4
Hardware multiply/divide	No	Standard	Optional-Standard
Floating point hardware	No	Standard	Optional
Number of instructions	20	250	60
Input-Output			
Interrupt level	1	64	16
Direct memory access	No	Standard	Optional
Real-time clock	No	Standard	Optional
		SOFTWARE	
	Assembler Diagnostic Pr.	Assembler Debug Editor FORTRAN-ALGOL Conversational Pr. (BASIC) Diagnostic Pr. If a disc is included: File Handling Disc Operating System Real-Time Operating System	Assembler Debug Editor Operating System Conversational Language Diagnostic Pr.
		CONFIGURATION	
	4K Processor TTY and Interface	32K Processor TTYs and Interface High speed paper tape read/punch And a subset of: Card read/punch Printer/plotter Magnetic tape/disc Analog-to-digital converter and multiplexer Digital-to-analog converter Digital Interface Data set adaptor Graphics Etc.	8K Processor TTY and Interface High speed paper tape read Analog-to-digital converter Digital-to-analog converter

THE MINICOMPUTER AS THE CENTRE OF INSTRUMENTATION AND CONTROL

Figure 2 shows a macro diagram where a minicomputer is interacting with a variety of systems. This "external world" consists of three main links: man-machine, computer-computer, and computer-real world. The man-machine interaction is normally achieved by a teletype. Larger configurations may include a card reader/punch which also provides a medium to carry programs or data to a larger central computer. Recently, cathode ray tube-based display and graphic systems that have been introduced are enhancing this man-machine interchange.

Minicomputers can also communicate with a larger supervisory computer, through hard-wire or telephone links, which can handle a number of such systems. This provides backup for the minicomputer or a front-end processor for the larger machine [3].

The "real world" shown in Figure 2 refers to an instrumentation and/or control system where variables of analog (continuous) or of discrete nature are dynamically changing in "real time", i.e. with respect to the time reference. The role of the minicomputer is the monitoring of relevant quantities such as temperature and/or introduction of control signals so as to force the system to behave in a predetermined fashion. The control action is normally taken by programmed computations based on measurement of pertinent variables. In such a control loop, first analog quantities are standardised by means of transducers and signal conditioners which convert these quantities to electrical voltage levels (±10 volt). These voltages then are measured by means of a selection circuit (multiplexer) and a device (an analog-to-digital converter) which converts the voltage values to digital form [4]. In the reverse direction, the minicomputer provides digital information to a device (digital-to-analog converter) which in turn provides output voltages proportional to the input number provided. This voltage is fed to the desired output point by a demultiplexer and it is maintained, until it is updated by the minicomputer. This voltage level then is used in a variety of ways, such as setting a valve position.

A different type of signal that needs handling is of a digital and logic nature. The minicomputer as a digital machine with logic instructions is naturally suited to handle such signals. Unlike the analog structure, in this case no conversion is necessary. Transducers, however, are needed to convert the signal levels or logic states to electrical signals that are compatible with the minicomputer. For example, if the on-off state of a relay is to be monitored, corresponding high or low voltage levels need to be generated and applied to the minicomputer as digital inputs. The on-off state of a relay corresponds to one bit of information (a zero or one in the machine). Normally a minicomputer is capable of handling 8 to 24 bits of input or output information during each memory cycle (about one microsecond). Thus the minicomputer is an extremely fast and versatile machine which will monitor relay or valve states, make logical decisions and effect necessary controls. Finally, it can also control indicator lamps and mimic diagrams to communicate to an operator the state of the system.

The applications that are mentioned above require continuous supervision by the minicomputer. This is normally done by periodic scanning of the monitored variables, carrying out necessary computations and introducing control levels. However, there may be alarm conditions in the system that require immediate response. For this purpose, interrupt lines exist which cause the suspension of the program which is being processed and the initiation of an interrupt program which services the alarm condition. At the completion of this program, the suspended program is resumed.