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# MICROPROCESSORS - STATUS, APPLICATIONS AND SETTING UP A MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE*

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** Government of India, Department of Electronics.

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TABLE OF CONTENTS

| S.No. | Chapter | Page No. |
|---|---|---|
| | Glossary | iv |
| | List of Abbreviations | vii |
| 1. | Microprocessors Status, ASICs, and System Design Issues | 1 |
| | - Background | 1 |
| | - RISC Processors | 6 |
| | - Fuzzy Controllers | 8 |
| | - Fuzzy Tools | 9 |
| | - Selecting a Microcontroller | 9 |
| | - Application Specific Integrated Circuits | 10 |
| | - Field Programmable Gate Arrays | 13 |
| | - Some Recent Advances | 13 |
| | - System Design Issues | 14 |
| | - Electronic Bread-boarding | 14 |
| | - Concurrent Design | 15 |
| 2. | Microprocessor Applications | 18 |
| | - Sugar Industry | 18 |
| | - MAPCON | 19 |
| | - MIPMOS | 20 |
| | - MICRO-TEIMAC | 22 |
| | - Paper and Pulp Industry | 27 |
| | - Textiles | 29 |
| | - Machine Vision Quality Inspection System for Textile Industries | 31 |
| | - Mini-Steel Plant | 31 |
| | - Railways | 33 |
| | - Office Automation | 34 |
| | - Non-Impact Printer Applications | 34 |
| | - Automatic Computer Vision System for Blood Analysis | 36 |
| | - Computer-Aided Testing Station for VCRs | 36 |
| | - Expert Systems for Process Control Industries | 37 |
| 3. | Setting up a Microprocessor Application Development Centre in Developing Countries | 39 |
| | - Background | 39 |
| | - Microprocessor Application Development Centre for Process Control Applications | 42 |
| | - Organisational Structure | 42 |
| | - Staffing | 46 |
| | - Training | 47 |
| | - Capital Equipment and Software | 49 |
| | - Financial Details | 51 |
| | - Financing Mechanism | 52 |

| S.No. | Chapter | Page No. |
|---|---|---|
| | - Microprocessor Application Development Centre for Embedded Systems Application | 53 |
| | - Organisational Structure | 53 |
| | - Staffing | 55 |
| | - Training | 55 |
| | - Capital Equipment and Software | 55 |
| | - Financial Details | 56 |
| | - General Issues for Configuring the Microprocessor Application Development Centre | 56 |
| | References | 80 |

## List of Tables

| | | Page No. |
|---|---|---|
| Table-1: | The World's Top 20 Electronics Companies | 59 |
| Table-2: | Share of Top 10 Semiconductor Companies in the World | 60 |
| Table-3: | High-end Microprocessors available with Motorola | 61 |
| Table-4: | Products Utilising Fuzzy Logic | 62 |
| Table-5: | Comparison of Different ASIC Methodologies | 63 |
| Table-6: | Estimated Comparison of Various System Design Approaches | 64 |
| Table-7: | ASIC Application Markets | 65 |
| Table-8: | Factors Influencing the Introduction of Microelectronics in Industrial Sectors | 66 |

## List of Figures

| | | |
|---|---|---|
| Figure-1: | Product-wise World Market Share of ICs | 71 |
| Figure-2: | Steps in Selecting a Microcontroller | 72 |
| Figure-3: | Indicative Cost Comparison of the Three Implementations viz., Standard Parts, Gate Arrays, and Full-custom | 73 |
| Figure-4: | Concurrent Design Methodology | 74 |
| Figure-5: | Textile Quality Inspection System | 75 |
| Figure-6: | Microcomputer System for UHPF | 76 |
| Figure-7: | Expert System Features and Expert System Structure for Process Control Application | 77 |
| Figure-8: | The Organisational Structure of MADC | 78 |
| Figure-9: | Staffing Profile for the MADC | 79 |

# GLOSSARY

1. Application Specific Integrated Circuits: Application Specific Integrated Circuits (ASICs) are essentially ICs designed to suit a particular application. ASIC design can be a mix of gate array, standard cell, as well as full-custom approaches. ASICs lead to higher reliability and reduction in volume and cost of the end-product as compared to a non-optimal design based on standard parts.

2. Code Compatibility: The compatibility of source code is one of the major issues involving system upgradation through switching from one family of microprocessors to another, e.g., CISC to RISC.

3. Complex Instruction Set Computing: Initially the approach was to have as complete and complex a set of instructions as possible for computers to improve their utility for general purpose applications. This resulted in the Complex Instruction Set Computing (CISC) architecture. Recently, it has been recognised that this may be an overkill for a range of applications - see Reduced Instruction Set Computing.

4. Concurrent Design: Increasing design complexity and tighter time to market deadlines have led to the concurrent design philosophy as against the conventional sequential approach. A variety of disciplines covering hardware, software, testing, manufacturing, marketing, etc. are made to interact concurrently to conceptualize, develop, manufacture and market a product.

5. Co-Processor: These are building blocks which fit with a microprocessor for building a complete system. The co-processor may perform mathematical functions in parallel while the main processor continues with time consuming operations.

6. Embedded Processor: From the application viewpoint, microprocessors may be classified into general purpose processors and embedded processors. Embedded processors are intended to be used within a hardware system without the user being aware of its existence. Embedded processors have features which reduce the number of components external to the processor and aim at as few pins as possible in the package.

7. Expert System: An expert system is essentially an intelligent programme that uses knowledge and inference procedure to solve problems that are complex enough to require significant human expertise. The objective, therefore, is to simulate the decision making process of an expert.

8. Field Programmble Gate Arrays: The increasing need for rapid prototyping has witnessed the emergence of Field Programmable Gate Arrays (FGPAs). These combine the logic integration advantage of full-custom circuits with the design, production and time to market benefits of user programmable devices.

9. Fuzzy Controller: A semiconductor device based on Fuzzy Logic.

10. Fuzzy Logic: The conventional digital logic is binary and is based on 'Yes-No' decisions. Real life control situations often require decision making based on incomplete knowledge. Fuzzy Logic enables a computer to handle shades of grey as compared to black and white. Fuzzy logic is, thus, a superset of conventional logic.

11. Fuzzy Tools: Computer-aided design tools for developing and modelling systems around Fuzzy controllers.

12. Molecular Electronics: This is an active area of research where the search is on for organic substitutes to replace the inorganic, silicon based devices. Molecular electronics devices could form the basic building blocks of the optical computer.

13. Optical Computing: The inherent physics and technology dictated limitations of silicon based circuits have led to the search for optical equivalents of the traditional electron/hole based technology. Optical computing uses aggregates of photons as the basic information element as compared to bunches of electrons/holes.

14. Radhard: Radiation Hardened (RADHARD) devices are based on special process technology to enable them to withstand the radiation encountered in space as well as the strong electromagnetic pulses resulting from a nuclear explosion.

15. Reduced Instruction Set Computing: In addition to the original Complex Instruction Set Computing (CISC) architecture, the Reduced Instruction Set Computing (RISC) architecture is finding widespread applications. RISC processors employ significantly less number of instructions as compared to the CISC processors and thus have enhanced throughput at the same technology level.

16. Scalable Processor Architecture: The Scalable Processor Architecture (SPARC) is a type of RISC architecture developed by SUN Micro Systems, USA. The advantage of SPARC is its scalability with upgradation in technology.

17. Transputers: This is an acronym of transistor computer. This is a device specially designed so that arrays of them can work in parallel enabling realisation of parallel processing architecture. Transputers require specialised parallel processing languages, such as Occam, for maximum efficiency.

18. Virtual Reality Technology: Virtual reality enables one to enter entire new worlds and actively explore new environment, e.g., an architect designing a nursery school could shrink himself to the size of a three year old and see the school from the perspective of a small child.

## List of Abbreviations

| | | |
|---|---|---|
| 1. | ASIC: | Application Specific Integrated Circuit. |
| 2. | BIPS: | Billion Instructions per second. |
| 3. | CISC: | Complex Instruction Set Computing. |
| 4. | CMRR: | Common Mode Rejection Ratio. |
| 5. | CPU: | Central Processing Unit. |
| 6. | CSIC: | Customer Specified Integrated Circuit. |
| 7. | DRAM: | Dynamic Random Access Memory. |
| 8. | DSP: | Digital Signal Processing. |
| 9. | EIU: | Economic Intelligence Unit. |
| 10. | FPGA: | Field Programmable Gate Array. |
| 11. | LIFE: | Laboratory for International Fuzzy Engineering. |
| 12. | LSI/VLSI: | Large Scale Integration/Very Large Scale Integration. |
| 13. | MAPCON: | Microcprocessor based Automatic pH Control System. |
| 14. | MICRO-TEIMAC: | Integrated Microprocessor based Automatic Centralised Industrial Temperature Indicating, Monitoring, and Controlling System. |
| 15. | MIPMOS: | Microprocessor based Pan Monitoring System. |
| 16. | MIPS: | Million Instructions per second. |
| 17. | MITI: | Ministry for International Trade and Industry. |
| 18. | NIC: | Newly Industrialising Countries. |
| 19. | OECD: | Organisation for Economic Cooperation and Development. |
| 20. | PCB: | Printed Circuit Board. |

21. PLA: Programmable Logic Array.

22. PLD: Programmable Logic Device.

23. RISC: Reduced Instruction Set Computing.

24. SPARC: Scalable Processor ARChitecture.

25. SSI/MSI: Small Scale Integration/Medium Scale Integration.

26. ULSI/WSI: Ultra Large Scale Integration/Wafer Scale Integration.

27. WDR: World Development Report.

# CHAPTER I

## MICROPROCESSORS STATUS, ASICs, AND SYSTEM DESIGN ISSUES

### BACKGROUND

1. The world-wide electronics industry turnover in 1990 was estimated at around US $ 750 billion. This is expected to cross the US $ 1 trillion mark by 1995-96. USA, Japan and Europe continue to be the leading electronics manufacturing countries. USA and Japan figure prominently in the world's top 20 electronics companies with 8 companies each. IBM Corporation had sales of US $ 62.71 billion followed by Matsushita Electric Industrial Co., Japan, with a turnover of US $ 31.32 billion. IBM is also the leading company in the world in the area of personal computers and mainframe computers with market shares of 15% and 58%, respectively. The picture in the area of telecommunications is evenly spread with Alcatel NV of the Netherlands being the leading company. The production figures for the top 20 companies in electronics is given at Table 1. In the area of semiconductors, Japan has the leadership role with the top 3 positions amongst the top 10 companies having a market share of 45% of the total semiconductor market of about US $ 50 billion. The list of the top 10 companies with their market shares is given at Table-2.

2. A recent publication, the International Electronics Industry, published by the Economist Intelligence Unit (EIU) in London, UK, has made the following predictions for the electronics industry during the 1990s.

- Computers will increasingly become a replacement market;
- Software, telecommunications, and opto-electronics will be the pace-setters;
- The market for the microchip will grow four to five times in the next decade, and miniaturization will revolutionize more products;
- Mass production of HDTV will begin;
- Government spending on defence R&D will decline, forcing the US government and private industry to rethink R&D strategies;
- The industry will become more international and more competitive, although cooperative strategic alliances will become more popular.

3. Microelectronics which refers primarily to integrated circuits ranging from small scale integration (SSI) to large and very large scale integration (LSI/VLSI), ultra-large scale integration (ULSI) and the recent wafer scale integration (WSI), is recognized as a vital ingredient of electronics equipment and systems. Microelectronics is an enabling technology and has been likened to the crude oil of the 21st century. The increasing levels of integration have enabled entire sub-systems and systems to be fabricated on chips of a few sq mm size. Microelectronics is, thus, making possible the revolution in management and movement of information. Information and knowledge based technologies are expected to be the driving engines of the national economies in future.

4. The microelectronics revolution started with the invention of the transistor by Shockley, Bardeen and Brattain at BELL Laboratories, USA.

Since then the growth in this area has been phenomenal. The year 1955 witnessed integration of several active devices on a semiconducting substrate at Texas Instruments, USA, by Jack Kilby resulting in the invention of the integrated circuit. The subsequent years have witnessed the doubling of the integration level every 16 months whereas the expenditure on the chip lay-out and design has doubled only every 32 months.

5. The technology driver in microelectronics has been the DRAM. With the availability of 16K DRAM in 1977, the memory density has been increasing by a factor of 4 every three years. While a 16K DRAM chip can hold information equivalent to a single newspaper column, the 4 Mbit DRAM which is currently beginning to be produced in volume, has the capacity to store an entire book. Halfway through 1990, Hitachi surprised the industry by announcing the first 64 Mbit DRAM. This chip packed 140 million electronic components on a chip of 10 mm x 20 mm. Although several technology issues remain to be resolved, the 64 Mbit DRAM volume production is expected by 1995-96 in line with the three year cycle for introduction of a new memory device with four times the capacity of the previous generation.

6. Besides the memory products, namely, the different variants of ROMs and RAMs such as DRAM, SRAM, PROM, EPROM, EEPROM, etc., the other main semiconductor product category is that of microprocessors. The microprocessors currently constitute about 17% of the semiconductor market. The evolution of the microprocessor over the years as a percentage of the semiconductor market is shown in Figure 1. The term microprocessor was first coined in 1972. The beginning, however, was made in 1971 with the introduction of Intel 4004. This was a "Micro Programmable Computer on a Chip" consisting of an integrated CPU complete with a 4 bit parallel adder, 16 4 bit registers, an accumulator and a push down stack on a chip. The 4 bit Intel 4004 contained only 2300 transistors. Successive generations of microprocessors, which increased the word length, the complexity of the instruction set and the speed of operation, were introduced in 1972, 1974 and 1981 with the arrival of the 8 bit, the 16 bit and the 32 bit microprocessors. This period has witnessed order of magnitude increase in the number of devices per chip, the clock frequency and the overall throughput. In fact, the pace of development has outstripped the advancement in computers.

7. The microprocessor is primarily a central arithmetic and logic unit of a computer put on a silicon chip. The early microprocessors performed only a few basic functions. During the early years, microprocessors were used almost exclusively as micro-controllers on a dedicated basis in the area of process control. Over the years, the evolution of superior system architecture, availability of higher level languages and the increase in power and flexibility has significantly enhanced the scope of microprocessor usage. The original Von Neumann architecture is no longer expected to be the only possible solution. Initially, the approach was to have as complete and complex a set of instructions for the microprocessors to improve their utility as general purpose microprocessors leading to the Complex Instruction Set Computer (CISC) architecture. In recent years, it has been felt that the complex instruction set may indeed be an over-kill since certain instructions were used only for a small fraction of the time. This led to the search in the direction of arriving at an optimal set of instructions which resulted in the Reduced Instruction Set Computer (RISC) based microprocessors. The RISC processor has significantly less instructions as compared to the CISC

processor and enhances the throughput of the microprocessor at the same semiconductor technology level.

8. Along with evolution of microprocessors, development has also taken place on building blocks which fit with the microprocessor to build a complete system. A variety of co-processors have been developed which allow the computing power of a system to be increased manifolds, e.g., the co-processor may perform mathematical functions in parallel while the main processor continues with time consuming operations. Co-processors can typically perform input-output graphics control and communications control.

9. In the beginning, microprocessors were programmed in machine code or assembly language. The modern processors are complex and the natural requirement is for programming in user-friendly or higher languages. This automatically leads to the requirement of language translators especially compilers which are under continuous development. The number of bits which can be processed by a microprocessor in a single instruction determines the value of the largest number which can be processed without chaining instructions together. Since chaining instructions naturally takes longer to execute than a single instruction, the number of bits acquires importance when arithmetical operations are required to be carried out on large numbers. Current microprocessors have a word length of 32 bits. The co-processors operate on much larger word-lengths.

10. The increase in the level of integration of ICs has enabled integration of a variety of functions and facilities provided by the co-processor as well as peripheral function devices such as interrupt controller on to the microprocessor chip. This has led to the computer on a chip. Such devices are ideally suited for embedded system applications and make ideal controllers for washing machines, toys, etc., where the user does not have to add any other IC.

11. From the application viewpoint, microprocessors are generally classified into general purpose processors and embedded processors. The general purpose processors have a wide range of facilities such as direct memory access and the ability to interface with a range of memories of different speed. They may form a subset of more powerful processors whose usage has been in digital systems and personal computers. Such processors are very fast and powerful but their usage in industrial applications is not generally desirable. The PCB design for these processors is relatively more complex and expensive and most industrial applications do not require the speed or power of these high performance processors.

12. The next logical step from the general purpose microprocessor was towards application specific microprocessors. The major microprocessor in this category is the digital signal processor. The DSPs are required for executing high speed arithmetic operations required in digital signal processing. Usage of the general purpose microprocessor for carrying out such highly complex and specific algorithms would be sub-optimal. Typical applications of the DSPs include digital filters, adaptive filters, correlation and convolution, Fourier transformation, speech and image processing, wave-form synthesis, etc. The embedded processors - as the name implies - are intended to be used within a hardware system without the user being aware of its existence. Typically, they have their programmes stored in ROM and may possess only limited memory. Some applications include smart sensors and management systems for car engines as well as a wide range of

domestic and industrial applications. The processors optimized for embedded applications have features which reduce the number of components external to the processor and aim at as few pins as possible in the package. The most commonly known embedded processor is the microcontroller. Some of the 32 bit processors catering to the embedded applications include the 80376 which has evolved from the highly successful 0386 processor as well as the 80960. Processors of this type are intended for situations requiring high speed. These include robot control, vision systems applied in real time, telecommunication network control, etc.

13. Besides using the co-processor for increasing system speed, two other techniques have also been developed to realise this objective. In the multi-processors approach, more than one processor operates in a system possibly on common data. Each processor runs its own programme and some mechanism is provided to enable messages to be passed between the processors. Another direction has been the development of the transistor computer - transputer. The transputer is a device designed so that arrays of them can work in parallel. For maximum efficiency, these must be programmed with specialised languages to handle parallel processing. Typically, Occam is the preferred language although 'C' and Pascal can also be used for certain processors.

14. The major microprocessor vendors are currently Intel and Motorola, both of USA. In fact, Intel is the only major company in the area of semiconductors which is not vertically integrated in terms of equipment and systems. Beginning with the introduction of Intel 4004 in 1971, Intel has brought out more complex and powerful microprocessors at regular intervals. The increase in the transistor count on these microprocessors is given below:

| Microprocessor | No. of Transistors |
| --- | --- |
| 4004 | 2300 |
| 8080 | 6000 |
| 8086/88 | 29000 |
| 80286 | 130000 |
| 80386 | 275000 |
| 80486 | 1200000 |

15. The original IBM PC introduced in 1981 was based on the Intel 8088 microprocessor. The introduction of 80286 was soon followed by the PC-AT based on this microprocessor offering 4 times the performance of the IBM PC. The introduction of the 80386 in 1985 heralded a new 32 bit architecture which would serve as the microprocessor platform for the next decade. The new architecture has prompted software developers to start creating 32 bit applications taking advantage of the unique functionality of the 80386 CPU. While the Intel microprocessors are upward compatible, i.e., software written on 8088 and 286 would also run on 80386, the reverse is not generally true and some of the current software written for 80386 is not compatible with 80286 or 8088.

16. With the architecture of the 80386 as the basis, the 80486 brought a new level of integration incorporating the Intel 387 maths co-processor and cache memory on the same chip. Bringing these functions on to a single chip significantly accelerated the system performance. Against this backdrop,

Intel has now launched a major project, namely, Micro 2000 for developing a microprocessor for the turn of the century. The preliminary specifications of this microprocessor are given below:

| | |
|---|---|
| Transistors | : 100 million |
| Die Size | : One sq.inch |
| Clock Rate | : 250 MHz |
| Processing rate | : 2 BIPs ( 2 billion instructions per sec) |
| Upward Compatibility | : From the 386 CPU |

17. The Micro-2000 would require line widths of 0.2 micron. The transistor size will have to be reduced by a factor of 25. From the current levels of approximately 200 defects per million die, the defect density will have to be reduced to close to zero to realise reasonable production yields. The development of these microprocessors will lead to high integration solutions by providing a compact low cost CPU for everyday applications coupled with high performance solutions which would provide the highest level of CPU performance for demanding CPU applications. In the first category, an application in the year 2000 could be an affordable computer of the size of an appointment book with a built-in microphone for recording important business meetings. The CPU's voice recognition will instantaneously transcribe the meeting. It would be too small to have a keyboard but would have a built-in screen and stylus and also an antenna for access to remote computers using radio waves. In the high performance direction, the tasks that are currently reserved for super-computers would be handled routinely by the PCs of the year 2000 covering applications such as weather prediction, financial modelling, biomedical engineering, etc. This would also enable affordable solutions for esoteric applications such as virtual reality technology using 4D graphics which is currently possible only with multi-million dollar computer systems. Virtual reality enables one to enter entire new worlds and actively explore new environment, e.g., an architect designing a nursery school could shrink himself to the size of a three-year old and see the school from the perspective of a small child. On the way to the Micro-2000, Intel has already introduced the 80486 SX during 1991 which would eventually make the 80386 obsolete and has plans to follow-up with 80586 in 1992 with 2 million transistors and at least twice the 80486 performance. The mission of 80586 is to compete with the RISC chips. In parallel, the 80686 is currently under development with likely introduction in 1993-94 with the mission to include sound and video processing features for multi-media.

18. Keeping pace with Intel, Motorola has been coming out with successive microprocessors in its MC 68000 series culminating with the current MC 68040. This chip delivers 20 MIPs at 25 MHz and has 1.2 million transistors based on Motorola's 0.8 micron HCMOS technology. The 68040 is fully compatible with the 68000 series including the 68000, 68020, and 68030 microprocessors. The 68040 provides an average of 3.5 Mflops and a peak of 8 Mflops making it suitable for graphics applications, computer simulations and financial analysis. A comparison - according to Motorola - between the 68040, the scalable processor architecture (SPARC) chip introduced by Sun Microsystems and the 80486 of Intel is given below:

| | 68040 | SPARC | 80486 |
|---|---|---|---|
| MIPS @ 25 MHz | 20 MIPS | 18 MIPS | 15 MIPS |
| MFLOPS @ 25 MHz | 3.5 MFLOPS | 2.6 MFLOPS | 1.0 MFLOPS |
| Price | $ 795 | $ 1735 | $ 950 |
| Dollars/MIPS | $ 39.75 | $ 96.39 | $ 63.30 |
| Chips required for system | 1 | >5 | 1 |

19. Some of the high-end microprocessors available with Motorola with their clock speeds and approximate unit price are given in Table 3. Also, more than 50 Customer Specified Integrated Circuit (CSIC) microcontrollers are available with Motorola to cater to the high volume need for 8 bit microcontrollers based on the M68HC05.

RISC PROCESSORS

20. RISC processors are finding large usage in embedded control applications such as laser printers, robotics and industrial process control. These chips are commercially available in a wide range of architectural choices spanning a throughput range of 5 to over 65 MIPS. In fact, embedded control applications consume a larger number of RISC processors than the workstations and servers. Some of the popular RISC processors are - the RX 000 family from MIPS computer systems, a range of SPARC processors from SUN micro systems, the Clipper from Intergraph and the M88000 from Motorola. While these processors are typically employed in general purpose computing, they are finding applications in embedded control as well. The manufacturers are developing versions of the general purpose processors to cater to embedded applications. While most RISC processors are 32 bit machines, they have both upward and downward compatibility. Future improvements in microelectronics technology is expected to push the RISC processors well past the 100 MIPS mark in the next few years. Different manufacturers such as Cyprus, Fujitsu, Advanced Products, LSI Logic, Texas Instruments, etc. offer different solutions catering to the user requirements as perceived by them. In most of these approaches, the pin-count is reduced significantly along with a reduction in the unit price. For example, Cyprus came out with the CY7C611 by reducing the address bus and bringing the package down to a low cost 160 lead plastic package. The cost was about one-third the price of the standard SPARC chip, namely, the CY7C601.

21. The 32 bit RISC and RISC-like processor arena also includes the transputer family from INMOS. There are also the Forth processor from Silicon Composers, a RADHARD CPU from United Technologies and the Acorn Processors from VTI, USA, etc. Harris is also developing a 32 bit version of the Forth processor. The transputer family has primarily been confined to Europe. The T 400 or T 800 processors are quite competitive with many of the moderately priced RISC processors. INMOS is developing higher performance versions slated to exceed 150 MIPS and 20 MFLOPS. VTI is also working with Sanyo to develop a version of the Acorn chip optimized for embedded control with multiple on-chip resources. Weitek have updated their RISC processor family to cater to the page printer market with the introduction of the XL-8220 hyperscript processor.

22. CISC and RISC processors are both contenders for embedded control applications. The key parameters to be evaluated include integration level and price/performance ratio - not only for the CPU but for the cache memories and additional peripheral devices. Other considerations include compatibility with existing code and interrupt handling which is particularly important for real time embedded applications. RISC processors suffer in comparison to CISC processors due to non-availability of comprehensive software and hardware support. However, the situation is improving rapidly and high quality compilers, debuggers, cross development tools and real time operating systems are being offered by various vendors.

23. While most high-end RISC and CISC processors were designed for workstation applications, their basic architecture is quite suitable for embedded applications. As brought out above, most embedded RISC and CISC processors are basically repackaged workstation processors optimized for low cost. This is achieved primarily by eliminating silicon area and power hungry functions, e.g., memory management and floating point units which are usually not required for real time applications. Some of the processors being offered include a family of parts based on the MIPS R3000 CPU, the 32 CG16 and 32GX32 from National Semiconductors, plastic packaged MMU less versions of the 68000 series by Motorola, 68000 core combined with specific ASICs by Motorola, 960 CA from Intel, etc. An innovative approach has been adopted by LSI Logic by offering the core version of the MIPS and SPARC devices as cells in their standard cell library to enable designers to design their own controllers.

24. A key issue in system upgrade for a CISC or RISC processor is code compatibility. Switching to another processor family, e.g., from CISC to RISC requires re-compilation of source code which is problematic. For applications involving de-novo design or a major systems overhaul, price/performance ratio can be critical and the RISC processors may prove more advantageous. The hardwired architecture of the RISC processors with very little micro-code enables these processors to approach the speed of one instruction per clock cycle. The drawback of the RISC devices is that individual instructions accomplish less. Consequently, the RISC programmes tend to be 25 to 100% larger than equivalent CISC programmes. From the performance viewpoint, the increase in code size is usually more than compensated by the reduction in average clocks per instruction. For cost sensitive applications, the requirement of high performance memories may inhibit usage of RISC processors. It is to be noted that RISC devices do not outperform CISC devices across the entire spectrum of applications. The RISC processors depend solely on efficient pipeline scheduling and high cache hit-rates. For applications with poor data locality or those requiring frequent interrupts, branches, etc., the speed of the RISC processors is reduced significantly with little performance advantage over CISC.

25. At the recent IEEE International Solid-state Circuits Conference in February, 1991, a chip capable of 100 MIPS and digital signal processing with 64 bit RISC architecture was announced by National Semiconductor. The chip is primarily meant for embedded applications. The chip has 50 MHz core, incorporates two independent integer units, a floating point unit and instruction and data caches along with DSP functions. While the inherent RISC capability is one instruction per clock, the chip offers super-scaler performance which means that its pipelined pair of integer execution units can execute two instructions per clock cycle, thus, leading to the 100 MIPS speed with a 50 MHz core.

26. The chip can also operate at 25 MHz to ease interface design and reduce system cost. Dynamic bus sizing allows interface with 8, 16 and 32 bit input-output peripherals. Samples are likely to become available during the third quarter of 1991 with production after one year. Applications include high-end printers, print servers, copiers and colour fax.

27. An experimental 100 MHz CMOS microprocessor was also announced by Portland Technology Group of Intel Corporation. This is based on the 50 MHz 80486 and is essentially meant to push the performance limits of the process technology. Intel considers this experimental chip as a test bed for new design ideas which could find their way into future products.

FUZZY CONTROLLERS

28. The conventional digital logic is based on "Yes-No" decisions. Real life control situations are often required to be met with incomplete knowledge similar to human reasoning. Neural Networks and Fuzzy Logic are expected to make computers and controllers behave like human beings in decision-making. While fuzzy logic enables machine handling with shades of grey as compared to black and white, neural networks enable control of chaotic systems. According to Prof. Zadeh, who conceived Fuzzy Logic in 1965, fuzzy logic is a superset of conventional logic. Fuzzy logic has found maximum usage in Japan. MITI has launched a US $ 70 million programme for commercialising fuzzy logic by creating the Lab for International Fuzzy Engineering (LIFE) with objectives of building a robot, develop fuzzy applications for expert systems, decision support, and reasoning; and build a fuzzy computer on a chip. Omron Corporation has announced a line of fuzzy logic processors and anticipates a turnover of US $ 765 million in 1994. Engineers using fuzzy logic must learn entirely new concepts and terms. Some of the new terminology include membership functions or degree of belief curves, defuzzification. Some of the applications of fuzzy logic controllers include control of air-conditioners by Mitsubishi, sub-way system control by Hitachi, transmission shifting and automatic brake control by Nissan. The fuzzy controller in air-conditioners cools the room five times faster than the existing controller. Some other recent applications of fuzzy controllers cover a system for plasma etching metal surfaces to prepare moulds for injection moulding which produced the mould in 35 minutes instead of the previous 51 minutes. This system monitors the temperature of oil in which the work-piece is immersed, the voltage between the cathode and the work-piece and the current flowing between the two with a view to eliminate the carbon build-up on the work-piece. The system then adjusts the gap in light of expert information included in the memory of the fuzzy controller.

29. Some of the available fuzzy controllers are : Togai InfraLogic, Inc. (Irvine Calif.) - The FC 110 a digital fuzzy processor chip is used on other products, including a VME card with four microprocessors and an IBM AT Bus version. Another application is a 10 sq.inch board with a fuzzy processor that emulates the hardware interface of eight popular microprocessors; Micro Devices Div. of Chip Supply Corp., (Orlando, Fla) - A fuzzy set comparator chip, the MD1210 combines a fuzzy logic front-end with two tandem neural networks on the back. They store and identify nine patterns for fuzzy data comparison applications, such as in robotic control; Omron Corp., (Schaumburg, Ill.) - The FZ 5000, a fuzzy controller introduced recently in Japan, uses a hybrid of fuzzy and digital logic. Priced from $ 12000 to $ 25000, it processes fuzzy inference and defuzzification at a speed of 15

micro-seconds per rule, using a fuzzy processor on a high-speed analog bus. The CPU unit sets rules and membership functions and samples fuzzy data on a general-purpose digital bus that is compatible with VMEbus. Table-4 gives some of the products utilising Fuzzy logic.

FUZZY TOOLS

30. A number of tools have become available for developing and modelling fuzzy controller systems. CubiCalc from Hyper Logic Corpn., USA, is a graphical development tool for fuzzy systems. Togai Infralogic has created the TIL shell which is a computer-aided software engineering tool for building fuzzy expert systems with 'C' language software. The software runs on either an IBM PC-AT or Mackintosh and is priced at US $ 4600. Hardware accelerator boards using the FC110 fuzzy processors are available on IBM PC-AT compatibles and VME systems. These boards allow fuzzy logic functions to be used with embedded controls in large systems. The fuzzy VME accelerator board is priced at US $ 4500 and the FC110 processor alone sells for US $ 80 when purchased in quantities of 1000. While the current applications of fuzzy logic have been in traditional control arena, fuzzy logic is a very powerful tool for fields such as expert systems, decision-making and information processing. The programme used by Tokyo's Yamaichi Security Co. uses fuzzy decision-making to manage a US $ 350 million stock market portfolio. The Sony PCT500 hand-held computer uses a fuzzy recognition system to interpret over 3000 handwritten Japanese characters as input. The system which sells for US $ 1400 eliminates the need for a large and cumbersome keyboard. To summarise, fuzzy logic is cost-effective methodology for automated control. Products designed with fuzzy logic are simpler, more user-friendly and easier to construct and test and offer smoother control than the traditional systems. The primary barrier to the use of fuzzy logic system is more psychological than commercial. Once a big player like IBM or DEC proves that it works, fuzzy logic is expected to make major in-roads into the US market.

SELECTING A MICROCONTROLLER

31. Unlike microprocessors, which are designed for a broad range of applications, microcontrollers are generally designed for a specific application in mind. For the designer of an embedded system, the choice of a microcontroller is a basic and vital decision. The microcontroller tends to include all the peripheral features needed to implement a computer portion of an embedded application. Because the application constraints are known in advance, the designer is usually able to select the lowest cost microcontroller unlike microprocessors which usually wind-up in general-purpose computers whose final use is not known to the designer. Fig. 2 gives the steps involved in the selection of a microcontroller.

32. Most often, it is not necessary to seek an absolute match between requirements and features during the initial search. Minor changes in the requirements or the addition of a peripheral chip could create the most cost-effective solution from a second-best pairing. Microcontroller selection is a difficult task involving a large number of decisions. There can be no universal check-list. As a matter of fact, design experience is a vital ingredient along with a well-defined set of system requirements for appropriate selection of a microcontroller. The article by Dave Bursky in the August, 1990 issue of Electronic Design provides a description of some of the currently available microcontrollers.

33. Choosing the tools for software development is atleast as critical as the choice of the microcontroller itself. It may indeed be more important since software can account for 50-75% of the total cost of a microcontroller based project. Developing software for applications whether it is a toy or a game or a scientific instrument is a complicated process dependent on several inter-related variables. The tools help the programmer in writing the code, debugging and verification. The choice of tools depends on the microcontroller chosen, the programming language, the budget, the project schedule, reliability requirements, experience of the programmer, support offered by the software vendor, etc.

34. Most of the tools are language specific and would vary for assembly language, C, Pascal, Fortran, Ada or Forth. Assembly language is generally best-suited for smaller and relatively simpler applications in appliances like microwave oven, in consumer electronics for video camcorders and instruments like battery testers, etc. High level languages on the other hand are favoured in larger, more complex applications such as automotive electronics, instrumentation and industrial automation. These languages relieve the programmer from attending to the low-level details of assembly language but require higher memory and are generally slower in execution. C has emerged in recent years as the language of choice for embedded control. It combines the compactness and speed of assembly language with the portability, control flow constructs, data structures and modular programming support of high level languages. In fact, it is even called a high level assembly language.

35. For any application, the entire cost of the development tools should be considered including the platform, the total development system covering high level language compiler, assembler, linker, debugger monitor software, debugger hardware, cables as also training. The development tools can range from a few hundred dollars for an evaluation module type system to thousands of dollars for an in-circuit emulation system with associated peripherals.

36. Another factor that needs consideration is whether the software tool is invasive or non-invasive. The invasive tools are generally cheaper but affect the performance of the microcontroller by their sheer presence. Many large companies sometimes use such tools for preliminary design evaluation and prototyping but go in for non-invasive tools for large volume production. The non-invasive tools are carefully constructed to replicate all microcontroller functions including timing without any difference. Computer-Aided Software Engineering (CASE) tools which impose a disciplined approach to programme writing are increasing in popularity as adjuncts to assemblers and compilers. It would be desirable to use these tools due to their utility in documenting, application modelling, etc.

## APPLICATION SPECIFIC INTEGRATED CIRCUITS (ASICs)

37. The IC industry is currently witnessing the spectacular emergence of Application Specific Integrated Circuits as the fastest growing (25%) segment of the semiconductor industry which is slated to grow at a CAGR of around 15% into the 1990s. It is interesting to observe that out of the new start-ups in USA over the last 10 years, about a third have been ASIC companies. The worldwide thrust is, therefore, clearly on value-added design rather than low cost manufacturing of commodity products popularly known as "jelly-beans". In fact, the industry's changing perceptions have already led to major re-structuring of several US suppliers. Some

acquisitions of relevance are: Fairchild Semiconductor Division by National, Monolithic Memory Inc. by Advanced Microelectronics Devices. Texas Instruments and Intel are also collaborating on the development of cell libraries around successful standard products. VLSI Technology Inc., USA, has tied up with Hitachi. NEC - the world leader in the semiconductor industry - is planning to increase the ASIC fraction of its production from 38% to 50%. Another trend is the creation of decentralised design centres by major semiconductor houses all over the world to cater to the diverse systems requirements.

38. ASICs have a special relevance for developing countries since their electronics industries are characterised by the requirements of a large number of different circuits in small quantities. ASICs permit an equipment designer to create an IC to suit his specific needs. This leads to higher reliability, reduction in volume and less cost of the end-product as compared to designing a product non-optimally with standard IC parts. Availability of powerful workstations and a diversity of technology independent CAD tools offer the equipment designer a wide choice of different implementation methodologies and foundries.

39. ASICs are usually classified into Programmable Logic Devices or Arrays (PLD/PLAs), Semi-custom ICs and Full-custom ICs. Other user programmable devices such as ROMs and microprocessors are not normally considered as application specific elements since customisation does not occur until the parts have been delivered to the end-user. Semi-custom ICs are either based on gate arrays or standard cells whereas the Full-custom IC implementation can either be totally ab-initio design of all circuit elements or rely on a hybrid approach based on some standard cells. The most popular methodologies at present are based on gate array and standard cells.

40. Traditionally, IC design has used an approach where every device and circuit element on the chip is "hand crafted" for that particular chip. The full-custom approach is suitable only when it is vital to have the minimum possible chip size or when implementing a function that is not available as an IC or cannot be configured optimally with semi-custom or standard ICs. Minimising the chip size reduces the fabrication cost and increases the yield which improves exponentially with reduction in the chip size. The major disadvantage of the full-custom approach is the time taken to complete the design for a highly complex chip, which could run into several hundred man-years of very expensive design effort. Currently, the full-custom design approach is adopted only in cases where the total number of devices per chip does not exceed a few hundred or when the circuit structure is highly repetitive or when the very large potential requirements, e.g. for commodity products, justify the expenditure on design.

41. Semi-custom ICs make use of gate arrays and standard cells. The gate arrays consist of a regular array of transistors and a fixed number of bonding pads each incorporating an I/O buffer. Gate arrays of complexities ranging from a few thousand gates to 400,000 gates are currently available. Customization requires the designer to generate an interconnect pattern and the corresponding fabrication steps are those of metallisation and bonding. The gate array vendor or a software vendor provides the CAD tools which enable a circuit designer to customise the gate array. Designing with gate arrays is quite straightforward and is generally favoured by systems engineers for prototyping. The design time is short and the fabrication time and costs are also less as compared to the standard cell approach since only the

metallisation steps are required to fabricate the circuit. However, the area utilisation is inefficient. This handicap has largely been overcome recently by the sea-of-gates approach.

42. The standard cell approach is based on a comprehensive library of well-characterised building blocks viz. standard cells. The equipment designer uses these cells to implement a circuit. The cells can be analog or digital and can have arbitrary size. The design time is longer than that for gate arrays. The fabrication time and costs are also higher since the full process requiring typically twelve or more masks is needed to fabricate the chip. The advantage is a more efficient utilisation of the silicon area and realisability of a broad range of circuits as compared to the gate array approach. A comparison of the different methodologies is given in Table-5.

43. The ASIC approach is adopted to perform a function that cannot be done using standard parts, or to improve the performance of existing circuits based on standard parts. A sizeable portion of the ASIC market is based on the latter. A typical example is replacing glue logic with ASICs. Usually, 7 to 8 PCBs using SSI/MSI level standard parts are replaced by a single PCB using LSI/VLSI level ASICs. A techno-economic comparison of the three implementations viz., standard parts, gate arrays and standard cells is shown in Table-6. The indicative cost comparison is given in Fig. 3.

44. While designing new equipment, the designer has to evaluate the standard parts based implementation vis-a-vis the ASIC approach. Clearly, in cases where only 10 or 20 pieces are required, an ASIC implementation may prove to be too expensive. ASICs are usually cost-effective in the range of 1000 to 100,000 pieces. Each equipment manufacturer has to examine his development schedule, the total cost per gate and the risks involved. Development schedule is the time between specifying a circuit and having fully tested prototypes. This is the most important economic variable since early introduction of even a non-optimally designed product can set standards and capture a large portion of the market. It is estimated that a 10 month delay in reaching the market place can make a product unprofitable. Total cost refers to the device cost consisting of design and fabrication costs and the systems cost including design PCB assembly, maintenance, power needs, testing, etc., and the interest cost. It is necessary to reiterate that cost-benefit analysis has to be done for the product which is sold in the market and not only for ASICs. ASICs are able to compete well with SSI/MSI due to their higher level of integration. The ASIC implementation is able to score over even standard parts of LSI/VLSI complexity since the low integration level peripheral devices can now be integrated into ASICs. It appears that gates per pin is a key determinant of total IC related cost. ASICs raise the number of gates per pin from less than 10 for SSI/MSI implementation to a range of 40-200. The key issue in ASICs is design productivity, especially for complex circuits.

45. From the current level of US $ 9.2 billion, the ASIC business is expected to grow to US $ 18.2 billion by 1995. Main user of ASICs is the computer and peripheral industry. The second place belongs to the telecommunication area. Most designers of electronic equipment are committing their future designs heavily towards ASICs which is fast moving from the initial replacement of discrete or SSI/MSI level circuits to major sub-systems and systems on a chip. Microprocessors, microcontrollers and ASICs would provide a key ingredient for most of the system designs of the future. The ASIC methodology also incorporates mega cells which could be

lower-end microprocessors. The current and future ASIC applications are given in Table-7.

FIELD PROGRAMMABLE GATE ARRAYS (FPGAs)

46. With the pressure for rapid prototyping, the industry has witnessed the emergence of Field Programmable Gate Arrays (FPGA). Some of the major players in this area are : Xilinx and Altera of San Jose, USA, and Actel of Sunnyvale, USA. In fact, FPGAs are encroaching into the domain traditionally held by programmable logic devices (PLDs) and gate arrays.

47. The FPGAs combine the logic integration advantage of custom VLSI circuits with the design, production, and time to market benefits of the user programmable device. FPGA densities currently range from about 1000 to 9000 equivalent gates. FPGAs have certain inherent advantages as compared to programmable logic devices (PLDs) in terms of the difference in architecture; the FPGA architecture is additive whereas that of PLDs is subtractive. Additionally, FPGAs consume less power and provide more I/O resources. System clock rates for FPGA based systems have increased significantly since their introduction in 1985. Current speeds are around 60 MHz and are expected to reach 100 MHz in the near future.

48. FPGAs provide certain advantages as compared to the gate arrays in terms of no NRE charges, off-the-shelf delivery, no inventory risks, no requirement to generate test vectors, less time spent on simulation. FPGAs with about 1200 gate complexity cost around US $ 10 per piece. FPGAs at the higher gate level can cost around US $ 30 to $ 40. In terms of turn-around time, FPGAs can enable a turn-around of as low as two weeks. The software support for FPGAs which is available on PCs and workstations can cost from US $ 3000 to 10000 for PCs. Simulators can cost an additional US $ 2000 to 6000. FPGAs are available in a variety of plastic and ceramic packages as well as surface-mount technology and are also finding wide-spread use in even military applications.

SOME RECENT ADVANCES

49. The conventional silicon based technology is projected to run into technological and physics based limitations. The search has, therefore, been on for alternatives to this technology. One of the major contenders is based on realising optical equivalent of the traditional electron/hole based technology. AT&T Bell Laboratories have recently demonstrated the world's first digital optical processor. This is an experimental machine which carries out information processing with light rather than electricity. This could eventually lead to the optical computer which is expected to be a 1000 times faster than today's best silicon based machines. Bell Laboratories also project a 10000 fold increase in the intelligence of microelectronics chips perhaps with inter-connections as complex as the human brain.

50. Besides looking for optical equivalent of silicon based circuitry, research is also continuing to make transistors the size of a single molecule by the turn of the century. It is widely anticipated that this would come through the use of an organic molecule and not an inorganic one based on silicon. A novel property of organic materials being studied in this context is their ability to change colour after excitation by a laser beam. In fact, molecular transistors could form the basic building block of the optical computer. Scientists at Cavendish Laboratory, UK, have already made a

transistor based on organic semiconductors. The electro-optic effects found in the molecular devices could find widespread application in optical fibre communication and optical computing and in interfacing between conventional electronics based computers and optical transmission equipment.

51. A new integrated circuit called "Fuzzy Neuron Chip", merging the fuzzy theory, which deals with ambiguity, and neuro technology, which copies the works of brain cells, has been successfully developed by a professor of the Kyushu Institute of Technology and the Fuzzy System Research Institute of Fukuoka Prefecture. The new chip can read one symbol in one-millionth of a second and is fast to recognize other patterns.

52. Artificial reproduction of the high-level processing of information by the brain is a major goal of computer technology. The combination of the fuzzy theory and neuro technology copying brain neurons has drawn keen interest worldwide. This is said to be the first time that the two fields of research have been merged into one tiny semiconductor element. The newly developed chip is 7.5 square millimeters in size. In one second, the chip reportedly can read 1000 pages of A-4 size paper, by far faster than conventional devices.

SYSTEM DESIGN ISSUES

Electronic Bread-Boarding

53. Breadboard/prototype testing is the oldest and most prevalent way of finding and fixing design problems. Engineers who have spent much time at the test bench will appreciate that some types of design problems are particularly tedious to isolate on a breadboard. Some problems may not be found during breadboard testing but will show up when the first production run is made. Electronic breadboarding allows the engineer to begin testing his design before building a breadboard/prototype or while waiting for it to be built. With it, the engineer can readily isolate and correct these troublesome and intermittent design problems more easily than on an actual breadboard.

54. Electronic breadboarding overcomes some of the limitations and problems with breadboard debugging. Electronic breadboarding does not replace prototype verification, but it considerably shortens the time required and allows design debugging to proceed while the prototypes are built. It is best described as a computer model of the design and a lab bench full of test equipment to verify it. Usage is very similar to actual benchtop breadboarding. Interactively, the design engineer makes cuts and jumpers, changes parts to a faster or slower technology, adds gates, overrides signals, etc. Many electronic breadboarding systems have a logic analyser style display/interface. ICs are probed and clipped by typing their names instead of trying to physically find them on a board. The engineer can isolate sections of a design and concentrate on one section at a time, just as he would on the testbench.

55. In addition to avoiding the physical problems of benchtop breadboarding mentioned above, electronic breadboarding also helps by constantly looking for certain types of troublesome design problems, such as bus conflicts and timing violations. It is the 'right' tool for finding bus conflicts because it can determine and display which ICs are enabled on the bus, regardless of complexity. It also checks for any violations of all the manufacturer's

timing specifications for all parts all the time - something an engineer could never do manually.

56. For microprocessor-based designs, a register-level display synchronised with the logic analyser display gives visibility into code execution and interaction with the hardware. To aid the code debugging, the registers may be altered and code executed for one instruction at a time. Code-patching capabilities make it easy to try simpler code corrections. These capabilities make the engineer's task of performing hardware/software integration much easier.

57. Some of the features that one needs to look for in electronic breadboarding are;

- Interactiveness - how much can you do without leaving the electronic breadboarding environment?: change parts, alter circuit wiring, patch code, create new test patterns;

- What design problems will it find automatically with minimum effort on your part?

- Intuitive interface for ease of use and quick learning;

- Convenience and thoroughness of on-line help;

- RAM, ROM, PAL, PLD, and microprocessor support;

- Easy and powerful test pattern entry/editing: waveform editing, accepts data from test equipment, high-level language;

- Intelligent interface from schematic to minimise time and effort;

- Capacity and speed;

- Completeness of component library for your needs;

- On-line tutorial for quick learning.

## Concurrent Design

58. Increasing design complexity, intense competition, and tighter time-to-market deadlines will soon render the traditional "over-the-wall" operation of a design team obsolete. No longer can the engineering group complete its portion of the design before turning it over to the test group, and the test group finish its segment before the design reaches the manufacturing group, and so on. This serial approach has problems because the designers in the cycle's later stages do not have any input into the design until its almost finished. In other words, each group hands off not only its portion of the design, but also a host of problems. Dataquest estimates that in a traditional serial design environment, the cost of making a change increases by an order of magnitude for each phase of the design cycle. For example, in a large manufacturing operation, a change that costs \$ 1000 during design would cost \$ 10000 during testing. To offset these headaches, the design teams of the 1990s and beyond will turn to a multidisciplinary, concurrent approach. In other words, all types of disciplines from every phase of product development will work together up

front (concurrently) to define the product specifications (Fig. 4). These disciplines include hardware design, software development, test, manufacturing, packaging, documentation, marketing, and even the customers themselves. The team will work together to make the right trade-offs right from the beginning, when mistakes are less costly and easy to fix. This new team will require a change in the design environment, and adjustments in team management and the way engineers interact with each other.

59. In a serial design process, each engineering discipline has its own vocabulary, priorities, and purpose for doing a design. Proper management is critical to bring these disciplines together into a concurrent environment. Management must help the engineers obtain a commonality between vocabulary, priorities, and purposes in an effort to create a design. It must have a vision, and define what the group is going to accomplish as a team.

60. The emergence of concurrent design will force emergence of new disciplines into the design cycle and will consequently bring a change in related disciplines. The key discipline that will become vital is to understand the customer's requirements and have participation of all groups involved in the process in designing the product specifications. Another major area that will appear is workflow management. Future concurrent design teams may find that the amount of concurrence in the design process is limited by the team's tasks and their functions. For example, if an engineer is working on digital logic simulation, the layout work cannot be completed in parallel.

61. Most design tools needed for this new environment now exist. Current tools can be used for concurrent engineering, even though they may not work together and are not optimized for concurrent processes, because management can use internal processes as a bridge. What is needed is improvements in frameworks, data bases, data management, control systems, and measurement systems. In future concurrent-engineering environments, frameworks will be like operating systems, something designers expect to have so that processes start working. Frameworks help the environment by providing constant access to common data, and by bringing a consistency of invocation. It is predicted that frameworks will be a standard part of operating systems within the next three to four years.

62. Concurrent design involves a change in the philosophy of the design approach. This can put some strain and cause disruptions in an organisation attempting to implement this methodology. However, the benefits to be gained in terms of time and consequently cost are expected to more than compensate for the initial period of adjustment. The Institute for Defence Analysis report R-338 gives seven recommendations for using concurrent design:

(i) Top-down implementation: The initiative for change must come from the very top;

(ii) Executive-level commitment: Top management's commitment to concurrent engineering should be in the form of learning, understanding, and leadership;

(iii) Pilot projects to accelerate methodology and technology deployment: There is a need to select and conduct demonstration programs;

(iv) Build onto existing programs: Take advantage of the progress made by various existing programs and efforts that relate to concurrent engineering;

(v) Education and training: Education is essential, and must start at the top level of management;

(vi) Method and technology development: A number of methods and technologies have evolved that support the application of concurrent engineering;

(vii) Identify and reduce barriers and inhibitors: While applying concurrent engineering methods, many barriers and inhibitors stand in the way.

## CHAPTER II

## MICROPROCESSOR APPLICATIONS

1. The preceding chapter has brought out the enormous range of microprocessors covering CISC as well as RISC architectures, the variety of microcontrollers used for embedded applications, the newly emerging discipline of Fuzzy logic, Fuzzy controllers; the integral and increasing role of ASICs especially FPGAs in system design using microprocessors and microcontrollers as well as some ideas relating to system design including the recent trend towards the concurrent system design methodology. Microprocessors primarily find their usage in computer systems covering PC, PC-XT, PC-AT, workstations, minicomputers, super minicomputers, super computers, parallel processors; office automation applications including xerox machines, fax machines, laser printers; industrial electronics equipment, entertainment electronics, etc. Microprocessors and microcontrollers are truly the "jelly-beans" of electronic applications.

2. An application area of special relevance to the developing countries is that of industrial process control and corresponding productivity improvement Some of these areas involving process control cover the sugar industry, paper and pulp industry, fertilizer, leather, cement, steel plants, food processing, dairy applications, tea industry, tyre manufacture, plywood industry, etc. Table-8 gives a representative list of some areas of applications and comments on the pros and cons of adopting microelectronics based solutions.

3. Some of these applications are described in the ensuing paragraphs. The application of microprocessors in the sugar industry is covered in some detail to serve as a case study of how the applications need to be developed, demonstrated, promoted and sold to the potential equipment manufacturer as well as the end-user in a developing country.

### SUGAR INDUSTRY

4. Sugar industry is one of the largest and significant industries in many agriculture based developing countries. It is labour-intensive and concentrated in the rural areas of developing countries. There is good scope for introduction of microprocessor based instrumentation and appropriate automation in the sugar industry covering the following stages of sugar production: controlled growth of cane involving controlled drip irrigation, micronutrient control through soil analysis, etc.; cane handling & crushing operations up to the stage of milling; boiling house operations from juice weighing through various stages of processing such as juice heating, purification, evaporation, panboiling, centrifuging, drying, grading, final weighing and bagging of plantation white sugar; boiler house operations involving various controls for improving boiler efficiency for saving bagasse. Microprocessor based control systems can improve performance of the various unit processes by making it possible to calculate, specify, control the performance of variables which are usually neither measured nor controlled. In the sugar industry, microprocessor based instrumentation and control systems can find use in the following areas: improvement in the average efficiency of existing factors including improved management and accounting systems, improvement in cost processing stages leading to increase in productivity and quality, designing and manufacturing parts of new plants based on modern techniques.

5. The Central Electronics Engineering Research Institute (CEERI), Pilani, India has been working on a major programme for introduction of microprocessor based instruments and control sytems in the sugar industry. Some of the instruments developed by CEERI in this context are described below.

Microprocessor Based Automatic pH Control System (MAPCON) for Sugar Industry

6. This was one of the first systems identified for development by the Sugar Industry. Based on exhaustive studies on the effect of pH on the chemical composition and resultant removal of different non-sugars, carried out in some commercial sugar factories and as a result of several technical discussions, CEERI started work on an automatic pH control system for controlling lime and $SO_2$ feed to control pH values in three stages.

7. CEERI developed a system based on contemporary international technology, e.g. Microprocessor based Automatic pH Control System (MAPCON) for sugar industry. The system has been developed with the necessary software as well as hardware and has the following facilities:

- Preliming control and indication of pH of prelimed juice;
- Shock liming control and indication of pH of shocked limed juice;
- $SO_2$ control and indication of final pH after sulphitation ($7 \pm 0.15$) pH.

8. Although the system has been provided with three pH control loops, any one of the loops can be made operative independent of the other two. The system can be made easily applicable with minor modifications to any kind of the sulphiter designs existing in any sugar factory having different crushing capacities. This is a fairly advanced and complex closed loop control system using three PID control loops for the juice clarification stage which leads to many quantifiable advantages such as:

- Minimum rise in CaO content;
- Rise in apparent purity leading indirectly to increased recovery;
- Less scaling of evaporator tubes;
- Improved clarification efficiency;
- Higher settling rate;
- Resultant reduction in the cleaning operations due to better removal of scaling compounds.

This system was field tested in a commercial sugar factory in Uttar Pradesh for two consecutive seasons and received good performance reports.

9. After user acceptance of the system, the Department of Electronics, Government of India and CEERI jointly identified the following parties for commercialisation of the technology:

- Satwik Electric Controls Pvt. Ltd., Nashik, Maharashtra;

- Scientific Instruments Co. Ltd., Allahabad. UP;

- Simbhaoli Sugar Mills, Simbhaoli, UP;

- Electronics Corporation of Tamil Nadu, Madras, Tamil Nadu.

10. These licensee firms have established regular production of the system. About 80 units of this system are already in operation in various factories and more are being installed. The users have responded very enthusiastically and the performance acceptability has been encouraging. Many more production organisations have also shown interest in transfer of this know-how.

11. Vasantdada Sugar Institute (VSI), Pune, has undertaken a systematic study of the operational experience of the MAPCON system with a view to further quantify the practical advantages obtained by this system. In particular, VSI has carried out a study of the fouling problem of the glass electrodes and a monograph on pH measurement has been brought out for users of the MAPCON system so that the electrodes can be used with greater care and longer life.

12. Some of the observations on the MAPCON system based on the user's reports are:

a) Higher rise in apparent purity from mixed juice to clear juice, compared to manual control (0.7 to 0.9 compared to 0.5 to 0.7 with manual control obtained in the same factories);

b) Reduction in rise in the CaO content from the mixed juice to clear juice (150 to 250 mg/litre reduction observed in practically all factories);

c) Reduction in consumption of sulphur (0.06 to 0.08% compared to 0.08 to 0.09% with manual control);

d) Faster settling rates due to proper removal of non-sugars (about 20% increase);

e) Improvement in clarity in juice colour (about 20%).

Microprocessor Based Pan Monitoring System (MIPMOS) for Sugar Industry

13. The sugar crystallisation process in sugar industry is one of the critical process steps in the formation of crystals in vacuum pans. Most of the systems in India are manually operated and estimation of supersaturation level is a subjective judgement depending on the skill of the pan man. Panometers, developed earlier by CEERI, have been installed in a number of sugar factories for measuring on-line a.c. resistivity of the massecuites, removing the subjectivity in judgement. CEERI has designed, developed and field tested the Microprocessor Based Pan Monitoring System (MIPMOS) for the Pan Boiling Stage of the sugar industry. The unit measures 4-parameters in the pan on-line. Sensors for on-line measurement cover a.c. resistivity, viscosity, temperature and level and are mounted inside the pan. The information obtained from the sensors in the form of 4-20 mA current loop signals is subsequently converted into digital signals for further digital signal processing through an 8-bit microprocessor along with an arithmetic processing unit and other peripheral devices. The unit computes pan

parameters such as brix, purity, degree of super saturation and vacuum and displays all the eight parameters (four acquired and four measured) on a centralised console. The prevalent parameters are also displayed on the pan floor, which aid the pan man in monitoring the sugar boiling strikes. The system also has built-in PID-control algorithms and gives standard 4-20 mA current loop signal for controlling any commercially available motorised control valve for regu'ating the feed to the pan. The system also displays any 4 (selectable) parameters for bar-graph display and pan status, such as pan start, seeding, hardening, initial, middle and final boiling and pan drop. For grain making, the slurry can be fed on the basis of purity of the starting media and pan can be boiled by regulating feed valve (intake molasses feed) on the basis of standardized chart involving both a.c. resistivity and viscosity measurements. The pan can finally be dropped depending upon the final dropping purity, brix and level of massecuites.

14. The system has the following salient features: 16 channel data acquisition system (4 channel/pan) 12 bit resolution; 32-bit wide fixed and floating point mathematical functions, display of measured and computed parameters (8 parameters) (of one pan); bar-graph display of any 4 process parameters (of one pan), pan status display, on-site testing facility under simulated conditions, flexibility in card placement on PBIB bus, 8 channel D/A card with 4-20 mA current output for valve; on board PID controller and regression polynomials, programmable look-up table for highly nonlinear data, on-site display of parameters (any four) at pan floor, and programmable A/D conversion time, engineering scale conversion, etc.

<u>Advantages</u>

15. The advantages of the system are:

- Dural variable measurement which avoids formation of false grain;
- Instant display of brix and purity;
- Reduction in total boiling time (by 15-20%);
- Reduction in movement water consumption (by 25%);
- Saving in exhaust/vapour (by 20%);
- Higher productivity by way of indirect increase in throughput per pan; and
- Consistent boiling and dropping purity of massecuites.

<u>Expected Economic Fallouts</u>

16. One unit saving in final molasses purity (approx.) leads to a saving of four lakh/pan/crushing season (150 days); indirect increased throughput of 15% leading to an increased capacity of 1000 tonnes/crushing season for a 60 tonnes pan, reduction in movement water, saving in exhaust/vapour results in direct saving of energy, approximate payback period of 2 crushing seasons.

Economic Data

| | |
|---|---|
| Minimum Economic Units | 24 Units/year (single shift) |
| Fixed Capital | 6,60,000.00 |
| Working Capital (Mfg cost for 90 days) | 50,00,000.00 |
| Cost of Production per unit | 4,83,333.00 |

Summary:

| | |
|---|---|
| 1. Selling price per unit | 5,78,000.00 |
| 2. Total Revenue | 1,38,72,000.00 |
| 3. Total cost of Production | 1,16,00,000.00 |
| 4. Annual Return | 22,72,000.00 |
| 5. Return on Investment | 40% |

All figures are in Indian rupees (Rs). Current conversion rate is 1 US $ = Rs.26.00

Integrated Microprocessor based Automatic Centralised Industrial Temperature Indicating, Monitoring and Controlling System for Energy Economisation and Process Optimisation for Sugar and Allied Industries (MICRO-TEIMAC)

17. In a sugar industrial unit producing 100 tonnes of mixed juice per hour, the cost of heating the mixture by 1°C works out to be about Rs.50,000 per season. By accurately monitoring and controlling the temperature using the MICRO-TEIMAC system, developed by CEERI, it is possible to save lakhs of rupees (10 lakhs = 1 million) per season and also the process performance can be improved. The system can be used in other allied industries also.

18. The MICRO-TEIMAC system consists of the following five sub-systems:

(i) Precision 4.5 digital industrial grade temperature indicator: It is a digital thermometer using thermocouple as sensor. Reference junction is combined with it if it is used as stand-alone indicator otherwise it is combined with the scanner unit. A novel and patented digital linearizer is incorporated after the analog to digital conversion. Main features and specifications are:

| | |
|---|---|
| Display | 4.5 digit |
| Temperature range | 0-125° C for type-K. |
| Resolution | 0.1°C |
| Accuracy | 1.0°C |
| CMRR | > 120 dB |
| NMRR at 50Hz with 1K ohm higher resistance at lower end | > 60 dB |

| | |
|---|---|
| Protection of solid state circuits from high accidental voltage up to | 1 KV |

Other important features are: very reliable and accurate; hybrid circuit ADC and IIA; the drift with time and temperature is negligible; field-tried over several seasons in sugar factory; mechanically robust and independent unit; and interfaced to 16-bit micro-computer.

(ii) Multichannel scanner unit: Microvolt signals of all thermocouples are scanned using zero thermal offset reed relays. It has a provision for scanning 24 channels which can easily be extended to 100 channels. Displays of real- time clock as well as channel number are the added advantages. The unit does not require any internal adjustment. Other important features are: Scanning frequency, 1 channel/s (presently) but user programmable also, specially designed for scanning microvolt signals, control signals available for each channel to transfer or latch data, protection from high accidental voltage from input upto 1.5 KV, reed relays have insulation resistance greater than 10 exp 12 ohms, and clock and channel are easily accessible for HEX keyboard of the micro-computer.

(iii) Monitoring panel: Continuous display of each process parameter of all the 24 channels is provided. The display is sequentially updated after every 24s. Red, yellow and green signals are also generated corresponding to the temperature data lying above maximum limit, within the band and below the minimum limit, respectively.

(iv) Microcomputer: The major features and specifications are as follows:

| | | |
|---|---|---|
| CPU | : | 8086, 16 bit microprocessor operating in max. mode |
| Clock | : | 5 MHz |
| RAM | : | 32 KB expandable to 128 KB |
| EPROM (user's) | : | 16 KB expandable to 64 KB |
| Parallel I/O | : | 48 lines |
| Serial I/O | : | Two RS 232 C ports |
| Timers/Counters | : | Three |
| Interrupt lines | : | Eight |
| Keyboard and display | : | 28 keys and 8 seven segment displays |
| Other features | : | 4 additional chip select lines<br>Battery backup for RAMs<br>Multibus interface |

| | | |
|---|---|---|
| Power supply | : | 5V, 5A. |

(v) Sixteen channel micro-controller: This provides 4-20 mA control signals for control of sixteen process steps. This signal can be used either for manual control or automatic control and for records. The output signal of controller can be used for control of control status and deviation indicator, stepper motors or electro-pneumatic valves. Major features and specifications are:

| | | |
|---|---|---|
| Number of channels | : | 16 |
| Scanning time | : | 1 channel/s |
| Data bus | : | 8 bit |
| Compatibility with microprocessor | : | Yes |
| Output | : | 4-20 mA current with max. load of 1K ohm |

Other significant features are: Bar graph facility for each channel, deviation indication, modular design of control boards, remote control facility for each channel, and two power supplies - one 5V, 10 A and another 30V, 2.5A.

1. Control status and deviation indicator (CSDI): Where manually controlled valves are still used (in sugar industry 90% of the valves are manually operated) control status and deviation indicators are a boon, useful to the operators of control valves for controlling the process. Major features and specifications are: Driven by 4-20 mA controller, consists of 20 LEDs out of which one glows at a time, situated at the site of the manual valve, and rugged.

2. Automatic stepper motor controls (ASMC): With this arrangement, one can control the temperature of the desuperheated steam or air supplies to sulphur burners or any other point where low torque valve is required.

3. Automatic electro-pneumatic controller (AEPC): Using the electro-pneumatic valve, its positioner and IP converter and applying 4-20 mA current control signal to the IP converter, one can control the temperature of the juice heater or any other process point where high torque valve is required.

All the subsystems are interfaced to 8086-based micro-computer. Each subsystem is also an independent instrument/equipment. In addition to the above units, the system needs one 5V, 20A; two 5V, 10A; and one 30V, 2.5A power supplies, 24 thermocouples and telephone cables for transmitting control signal. A unique feature of MICRO-TEIMAC system is the sixteen channel controller. It provides 4-20 mA controller current output which drives control status and deviation indicator for manual control operations, stepper motor control for low torque valve control and IP transducer for valves requiring high torque operations. Another important feature is ± 1°C system accuracy over the ambient temperature in a sugar factory. The temperature indicator, multichannel scanner, monitoring panel, 8086 based microcomputer and sixteen channel controller form the basic configuration of the system. Depending upon the requirements, the number of control status and deviation indicators (CSDI) and actuators for automatic control, i.e. stepper motors and/or electro-pneumatic valves can be chosen.

## Economic Fallouts

19. With the growing awareness for making best use of the available energy sources, instruments/systems for energy conservation and efficient use are becoming increasingly popular. MICRO-TEIMAC developed at CEERI with financial support from the Department of Electronics, though meant specifically for the sugar industry, is equally well suited to other process industries such as cement, food, textile, petrochemical, etc. It is a low cost system and is appropriate for Indian conditions. The cost is very much reduced by direct transmission of microvolt signals in the field instead of using a transmitter for each channel. In a sugar factory, the juice is heated at several stages and hence the financial benefit which can be drawn by employing accurate and reliable instrumentation is manifold. After the field trials of the MICRO-TEIMAC system, it is found that more than 2% (i.e. 0.5 TBH) of energy saving is achieved.

## Economic Data (Illustrative)

| | |
|---|---|
| Minimum Economic Units | 10 Units/Year<br>Single Shift |
| Fixed Capital | 8,00,000.00 |
| Working Capital<br>(Mfg.cost for 90 days) | 15,50,000.00 |
| | ------------ |
| | 23,50,000.00 |
| Cost of production per unit | 4,28,000.00 |

Summary

| | |
|---|---|
| 1. Selling price per unit | 5,10,000.00 |
| 2. Total revenue | 51,00,000.00 |
| 3. Total cost of production | 42,80,000.00 |
| 4. Annual return | 8,20,000.00 |
| 5. Return on investment | 35% |

All figures are in Indian rupees.

20. The three equipments described above, namely, MAPCON, MIPMOS and MICRO-TEIMAC have all been licensed for production. These equipments are much cheaper compared to the imported equivalents. In future, CEERI plans to develop improved versions of these equipments using the latest microprocessors and incorporating the feedback received from the users.

21. The Indian sugar industry produces direct consumption plantation white sugar but consumes on an average 30% more energy than the minimum requirement. The mills of the industry work on an average only for 21.5 hours a day instead of 23.5 hours a day. Thus, the figures for energy consumption as well as productivity of the industry are far from the desired results. Therefore, the scope of improvement in the sugar industry lies in two fields, i.e. energy saving and productivity improvement.

22. There are two topics of urgent interest to the Indian sugar industry in order to improve its energy saving. One lies in the field of boiler control and the other in the use of energy in the industry. On-line efficiency monitoring and control of bagasse-fired boilers of the sugar industry is the first step towards improving energy generation efficiency. Similarly, the energy audit in the boiling house of the sugar industry is the second complementary step towards reducing energy consumption. The power generation efficiency for the Indian sugar industry can also be increased by using a high pressure boiler, say operating at 1200 psi and producing about 15 MW of power for a 100 TCH factory. The combustion efficiency of the bagasse-fired boilers can be increased by use of fluidised-bed combustion techniques. This technique is not available at present on the international market, but CEERI has done some initial laboratory work for successful fluidised-bed combustion of bagasse of size limited to 1 inch average length on a 25 cm x 25 cm bed using bloated clay aggregate as bed material. A patent has also been applied for improving the steam generation efficiency in the boilers using the fluidised-bed combustion of bagasse. However, these are only lab-scale experiments. These are required to be upscaled on a pilot-plant for a bed surface area of at least 100 cm x 100 cm. Automatic control of continuous evaporators and application of continuous vacuum pans in the sugar industry will smoothen the process steam demand of the boiling house as the evaporators consume about 40% of the total process steam demand and the batch vacuum pans cause process steam demand to change and fluctuate.

23. The sugarcanes being fed to the milling station at present is controlled by measurement of volume per unit time which is not the correct way of feeding into the mills as the density of sugarcane loaded on the cane carriers varies due to voids created by physical placement of the cane. For increasing the productivity, the mills have to be fed on the basis of weight of the cane per unit time instead of the volume in order to provide uniform load on the mills so that the mills are not choked thereby causing stoppages. In this way the mill is able to run for a relatively longer time and hence the productivity of the mill will increase. Automatic brix control of the last mill juice is another field where control is required in order to produce juice of uniform brix from the last mill. This control also helps to produce bagasse of uniform low moisture from the mill. Due to these controls, operations in the boiling house as well as boiler house become relatively smooth.

24. The fluidised-bed burning of bagasse requires some basic work and it will be an R&D project of significance. Further, application of continuous vacuum pans for crystallisation of massecuite has not picked up in India due to its high capital and maintenance cost. The automatic control of evaporators would help to reduce the process heat requirement of the sugar industry as more than 30% of process heat is required for evaporation of water from the sugarcane juice. The generation of steam at high pressure can be done with the technology available in India but India is at present not manufacturing high pressure condensing-cum-back pressure type steam turbines in the output range of 15-20 MW, so the technology has to be imported.

25. The following projects are expected to be of significant economic benefit to the Indian sugar industry:

On-line efficiency monitoring and control of bagasse-fired boilers;
Energy audit in sugar industry;
Automatic cane feed control on weight basis;

Automatic brix control of the last mill juice.

PAPER & PULP INDUSTRY

26. The importance of paper and paper products to modern economy is self-evident. Electronic systems usage has been a part of paper manufacture all over the world. This has helped in maintaining the quality of the product besides improving productivity and minimising steam energy usage. Over the years, these electronic systems have been linked to computers to control all parameters of paper production from the raw material to the finished stage.

27. The basic parameters which are required to be monitored/controlled towards keeping the paper quality under control are the following:

Basis weight of paper supplied;
Moisture content of the final paper;
Thickness or caliper of the paper;
Brightness and opacity of the paper;
Ash content in the paper;
Head box consistency monitoring;
Stock consistency control;
Quality of the pulp through controlling the digester working.

Additional factors which are equally important include the bursting and tensile strength of paper.

28. Microprocessor based integrated electronic systems would not only enable the production of quality paper but also help the management to economise production and avoid wastage of raw materials and energy. Measurement and feedback control of basis weight typically reduces reel average deviations from the target value by 70%. This reduction in variations by itself constitutes an improvement in the quality of the product. The potential savings in the area of raw materials and energy are through the reduced use of fibre and improved energy efficiency. The basis weight can now be fixed to a lower average value through feedback control, keeping the specification (with respect to basis weight) above the minimum value. This shift in the basis weight average means less fibre usage during production. Maintaining lower basis weight average also means reduction in energy usage. Quality improvements come from reduced product variations resulting from accurate measurement and control. Quality improvements are the results of direct measurement and control of basis weight, moisture, consistency, etc.

29. Moisture uniformity is probably the most powerful variable in paper manufacturing because of its far reaching effects on product characteristics and subsequent processing. Reduced moisture variations may result in less energy usage per ton of paper produced. Lower variations in moisture means maximum value. Moisture shifts of 1 to 2.5% have been documented resulting in energy efficiency improvements up to 10%. By monitoring the moisture profile at the reel (Dry end), it is possible to reduce the moisture variations and shift the average moisture to a point that the peak moisture is just under the higher tolerable limit. An increase in 'End Moisture' permits an equivalent reduction in fibre content while maintaining the required basis weight. The result of increasing the 'End Moisture' permits an increase in machine speed without increasing the dry steam quantity. It has been observed that 1% increase in 'End Moisture' permits 3 to 15% increase in speed depending upon the particular paper machine, and the paper

produced. Since the increase of speed permits an increase in production, it could be concluded that increasing the 'End Moisture' increases the machine speed.

30. Microcomputer based nucleonic control system for basis weight and moisture measurement installed in paper machine between the calender and the reel enables production control. However, it is essential to initiate action first on raw materials control, processing of raw materials at the bleaching, refining, and at the stock preparation zone and then come to the paper machine. This would enable a homogenous flow of pulp from the pulp mill and the quality of paper gets improved. Subsequent paper machine instrumentation would help to stabilise production and improve productivity by cutting down time and the wastage. The Indian pulp mills particularly handle non- conventional raw materials which are agricultural in character like bagasse, rice and wheat stock, and waste paper. This is likely to be the case in many developing countries. In this context, it is essential to first develop and use microprocessor based instrumentation that would help utilising optimally the non-conventional materials in the existing digesters, bleach plant, etc. Microprocessor based electronic systems usage in the digester zone essentially improves the pulp yield, reduces steam consumption per tonne of pulp and the uniformity of the steam demand on the boiler house.

31. CEERI, Madras Center has developed a few microprocessor based systems including appropriate sensors for the measurement of basis weight, moisture, caliper etc. Some of the systems envisaged for future development are: chipper house/digester instrumentation, stock and bleach plant instrumentation, on-machine instrumentation, moisture profile controller, basis weight profile controller, head box slice profile controller, and the direct digital millwide control system.

32. It is estimated that modernisation of the pulp and paper mill could be done by spending about Rs.25.00 lakhs, on an average. The total investment towards modernisation, say for 100 mills could then be Rs.25.00 crores (1 cr = 10 million). Assuming the savings, for an installed capacity of 20 lakh tonnes/year, say, on steam - 5%, on production (fibre) - 5%, on moisture - 2%, on ash - 3%, i.e. a total of 15% and working at an efficiency of 65%, the savings could be approximately 1.95 lakh tonnes/year. At a cost of Rs.13,000/ton, this means an annual savings of approximately Rs.250 crores. The return on investment could be in about 6 to 9 months duration.

33. There is a good scope for usage of such systems in China and South East Asian countries in view of the similar set-up of the paper industry functioning there. The production of paper and paper boards (including newsprint) in People's Republic of China (PRC) is expected to cross 11 million tonnes by 1990. Five years ago, the production was around 5 million tonnes. The per capita consumption has more than doubled in 5 years and is at present around 11 kgs as against 2.0 kgs in India. Out of over 5000 units, nearly 1900 units are well organised. These comprise mostly of small and some medium and large mills. The share of forest based large mills is only 40%. PRC has taken rapid strides in the past five years to develop a large agro-based production of paper and boards based on straw, bagasse, grass and other annually renewable raw materials which account for nearly 4 million tonnes per year. The heterogenous nature of the paper industry is very similar to that in India.

TEXTILES

34. We will describe a typical usage of microprocessor based system in the textile industry for yarn testing. Microprocessor based yarn testing instruments allow rapid evaluation and extensive analysis of yarn irregularities. The effect of different raw materials or altered spinning machine settings can be studied with rapid and definite recognition of yarn faults. This facilitates search for hidden causes of faults and makes immediate improvements possible. In this way, the use of testing instruments help the industry in effective quality control and improved supervision of various stages of yarn manufacturing. It also makes it possible to forecast the yarn behaviour in subsequent processing and finished fabric. Increasing demand for very high quality finished fabrics has boosted the growth and development of highly sophisticated quality control systems for yarns in textile mills. The appearance of fabric is deteriorated by the irregularity in the cross-section of the yarn. In high quality yarns, it is necessary that all the yarn faults are detected before the fabric is woven.

35. The sensor assembly of the yarn tester consists of two identical high frequency oscillators. One of these uses the sensor plates as tank capacitor. The capacitance is changed by introduction of yarn between the capacitance plates, which causes dielectric variation. The variation in capacitance is proportional to the weight per unit length of yarn. The microprocessor based system measures and analyses the frequency difference caused by this variation. The system uses a drive unit to run the material at constant speed through the gap of the sensor plates. Different speeds are used for different types of material under test. The gap between the sensor plates varies with the type of material e.g., yarn, sliver, roving etc. An instrument developed by Physics Research Laboratory (PRL), Ahmedabad, at present is capable of testing yarn for evenness and counting thick places, thin places and neps.

36. The currently available conventional equipment for measuring yarn quality cost around US $ 20,000. The high cost of this equipment has deterred many of the textile mills from using it. The low-cost microprocessor based system including yarn evenness testing and yarn fault classification developed by PRL is described below:

Sensor type

- Dual oscillator capacitance sensor.

Sensor gap

- Four air gaps: 0.4, 0.6, 0.8 and 1.0 mm.

Processor Unit

- Z-80 microprocessor operating at 2 MHz;
- 32 k bytes program memory;
- 8 k bytes data memory;
- Six 8-bit parallel I/O ports used for:
    - Display;
    - Keyboard;
    - Printer;

- Cassette;
- Three 16-bit counters used for:
  - Display and keyboard interrupt;
  - Data acquisition;
  - Cassette storage (optional).

Display

- 6 digits of red LEd display.

Printer

- 18 column numeric printer EPSON-720/620 model;
- Removable from processor unit.

Power

- 230 volts, 50 Hz AC single phase.

Dimensions (in mm)

- 312 x 195 x 88 - processor unit;
- 115 x 58 x 55 - sensor.

37. The features of the evenness tester for the low-cost and PC based models are given below:

Improved high stability solid state sensor;
Real time display of yarn cross section histogram;
Adjustable threshold for thick place, thin place and neps measurement;
1 msec. sampling makes it suitable for yarn fault classification;
Continuous thread cross section display of 850 meters of yarn at 100 m./min. measurement;
Spectrogram using FFT;
Hardcopy of the data, histogram, spectrogram, etc;
Minimum interfacing hardware;
Easy interfacing to any IBM PC;
Built-in diagnostic and stability checks;
Automatic recording of the data on the disk.

38. The results obtained with the above tester have good correlation with the results obtained from the internationally accepted USTER tester. Besides yarns, this system is capable of testing rovings and slivers. The know-how of the instrument has already been transferred to a manufacturer.

39. In the Indian context, due to insufficient awareness and familiarity - this could be relevant to many other developing countries as well - there was wide apprehension in the industry that electronics was too sophisticated to operate and maintain. The Ahmedabad Textile Industry Research Association (ATIRA), the Bombay Textile Research Association (BTRA) along with the Appropriate Automation Promotion Programme of the Department of Electronics are playing a major role to promote and proliferate the usage of microprocessor based instrumentation and automation in the textile industry. The textile industry in India ranks next to agriculture in importance to the economy. The industry accounts for 26.73 million installed spindles, 60,000 open end rotors and 1,85,000 looms spread over 1051 units. In addition there

are 3.9 million handlooms and 1.2 million powerlooms in the scattered decentralised sector. About 13,000 million meters of cloth are produced but unfortunately Indian export in 1989-90 was of the order of only 2% of the total world trade ($ 160 billion) which is growing at 10% per annum. Twenty countries of the world, e.g., UK, Japan, the Republic of Korea, China, Taiwan, etc., control the major portion of the exports/imports in textiles and clothing. An investment of around Rs.500 crores in the first phase and Rs.350 crores in the second phase would need to be made on microprocessor based instrumentation and automation for the 1000 textile mills in India who have set a target of Rs.50,000 crores for the turn of the century.

Machine Vision Quality Inspection System for Textile Industry

40. In textile manufacture, a workstation is typically used for quality inspection. Recently, a system has been proposed for developing a machine vision quality inspection system. The system is based on computer vision techniques and is implemented in a parallel multi-processing environment. The system aims at improving the quality of the inspection as well as the speed.

41. The methodology used in this system is based on the pre-processing and segmentation of the image captured by the camera. The treated image defects are located, classified, and recorded. The system consists of 3 main hardware components. The scanning unit contains a high resolution monochrome CCD camera which is interfaced to the host through a frame grabber card based on a T-800 transputer. This card is embedded in a PC-AT which contains a hard disk of 20 MB. Fig. 5 gives the block diagram of the system.

42. An important characteristic of the system is the modularity and the hardware independence. This system has been implemented under the operating system MS-DOS 3.2 and in OCCAM-II programming language. Exactly the same system can be used under any host environment which supports TDS D700D (TDS stands for Transputer Development System) in which is included the OCCAM-II language. UNIX and VMS also support transputer application environment. The system can be utilised even on a multiuser workstation. The speed of the system increases almost linearly with the number of transputers. The addition of more transputers does not need software changes for adaptation. One parameter is provided for declaration of the used processors. Future extension would be construction of a stand-alone fully automated system.

MINI-STEEL PLANT

43. A mini-steel plant vis-a-vis a large steel plant has certain distinguishing characteristics:

(i) Production of steel in a mini plant is at least two orders of magnitude less than that in a large steel plant;

(ii) The input feed to the mini plant is basically iron and steel scrap; recently sponge iron is also being used as the feed;

(iii) Electric Arch Furnaces are used in the mini plant;

(iv) Continuous casting is the principal technology.

44. A microprocessor based system has been suggested for monitoring and control of the Electric Arch Furnaces (EAF) in the mini-steel plant. The

functions performed by the system include data acquisition, monitoring, display, and operator guidance. The range of functions required to be performed lead to a multi micro-computer architecture consisting of the main computer and a number of auxilliary computers. Recently, an Ultra High Power Furnace (UHPF) has been installed and commissioned in a mini-plant near Bombay. The metallurgical processes in the UHPF are so fast that computer control is mandatory. The system has been designed to perform the following functions for the UHPF - scrap preheating, optimization of loading, oxy-fuel burner control, energy calculation, tap changing, alloying, oxygen lancing, prediction of liquid metal temperature, monitoring, data logging, data bank. The system configuration is shown in Fig. 6.
Hardware details are given below:

Main Process Control Computer (PROCON)

Processor;

- PC-AT.

Memory

- 1 MB of ROM + EPROM + RAM;
- 20 MB Winchescer disk drive.

Analog I/O

- 128 SE/64 DD analog inputs;
- 8 analog outputs, 12/16 bit resolution.

Digital I/O

- 256 opto-isolated digital I/O lines;
- 16 opto-isolated serial ports.

KBD+Display

- Full ASCII Keyboard with numeric and function keys;
- Colour CRT display.

Software

- RMX-86 Operating System (OS) with
  ASM-86, PL/M and Pascal Support.

Data Bank Computer

Processor

- PC/XT.

Memory

- 512 KB of ROM + EPROM + RAM;
- 20 MB Winchester Drisk Drive.

KBD + Display

- Full ASCII Keyboard with numerical and function keys;
- Monochrome CRT display.

I/O

- 16 Opto-isolated serial ports;
- 44 parallel I/O lines.

Software

- CPM-86 or PC-DOS OS with ASM 86, PL/M and Pascal Support.

45. Use of a micro-controller system is expected to yield the following benefits:

Reduction in power consumption - 4%;
Increase in productivity - 5%;
Increase in electrode life - 10%;
Increase in refractory lining life - 3%;
Improvement in ferro alloy balance - 3%.

RAILWAYS

46. Most developing countries have a railway system of various degrees of complexity and coverage. Advanced railway systems have extensively been using microprocessor and computer based systems covering a range of disciplines such as track construction, relaying, maintenance, monitoring, interlocking, communication, mobile power, power monitoring system, etc. These have been used not only to improve the quality of servicing and economising of maintenance inputs but also to improve the speed.

47. Some of the potential systems based on microprocessor are indicated below:

(i) Microprocessor based track recording system;

(ii) Vehicle monitoring system including the RIDE quality meter, vibration-cum-speedometer, measuring wheel analyser.

48. Microprocessors may also be employed usefully in operations involving the construction of railway tracks. Some of the equipment that can be developed in this context are - weld geometry monitor, curve realignment calculator. Some other areas of interest are:

- Training movement simulation for electronic inter-logging;

- Microprocessor based random block programming for testing the fatigue failure of specimen actuator in fatigue testing lab.

49. One of the difficulties that may be faced by a developing country in indigenously developing microprocessor based systems for railway applications could be the non-availability of reliable transducers. In fact, the

microprocessor based digital electronic part of the system may cost much less than the transducer and the associated amplifiers. While in the initial stages it may be worthwhile to import whatever parts of the system are not available locally with a view to demonstrate the feasibility of these systems, it would be desirable in due course to develop an indigenous base for manufacture of transducers.

## OFFICE AUTOMATION

50. A variety of low to medium complexity products are required in the broad area of office/laboratory automation. These may relate to local area network, statistical multiplexer, printer servers, etc. Two examples are described below to illustrate the possibility of using a microprocessor.

51. A Local Area Network (LAN) for IBM PCs or compatibles has been developed by the Indian Telephone Industries (ITI), Bangalore, which is suited for small businesses and offices with up to 16 users. This consists of an adaptor networking software and accessories. This is a distribution LAN and does not require a dedicated file server and can be operated on the IBM PC with 256 KB base memory. The adaptor is compatible with Novell Network. Another product developed by ITI is the Netnode which is a disk-less workstation providing a low-cost solution in networking environment. This operates from a centralised server and is ideally suited for office applications like word processing, spread-sheet, accounting and inventory. The technical specifications are given below:

Hardware features:

| | |
|---|---|
| CPU | - INTEL 8088/NEC V20; |
| Speed | - 10 MHz max.; |
| Memory | - 256 KB base memory expandable to 640 KB; |
| Display | - Monochrome/color; |
| Keyboard | - Standard XT/AT Keyboard; |
| LAN Interface | - 2.5 Mbit/sec Arcnet compatible; |
| Port | - A serial (RS 232C) compatible. |

Software features:

Operates under MS-DOS 3.0 and above.

52. Some other applications which are under development are X.25 add-on card for IBM PC compatibles based on Intel 80188 CPU, Asynchronous communication server for LAN, computer communication, a laser based data link for short haul data communication which can be used to connect two LAN networks, etc.

## NON-IMPACT PRINTER APPLICATIONS

53. Since 1983, the non-impact printer market has experienced dramatic changes - laser printers with limited capabilities were priced at $ 6000 to $ 10000. Today, fully featured laser printers can be purchased for less than $ 1000. The demands upon the printer control processor have been even more profound - from simple text print-and-space control emulating daisy wheels to compound document generation with sophisticated fonts, graphics and languages that approach emulation of low resolution type setters. Until

1989, virtually all of the printers were based upon the 68xxx processor family. Accordingly, real application performance gains had not kept pace with the general PC industry. As one analyst reported "...the (Post Script) laser printer has replaced the water cooler as the department's social gathering place...". Today, the 68xxx designs are being replaced by higher performance RISC and CISC processors and, in many cases, augmented with ASICs, floating point units and other co-processing capabilities.

54. The convergence of certain industry technology and market forces drive the need for (affordable) speed and promise moving targets for the designer:

Memory returning to reasonable levels of pricing and availability. Page description languages, graphics, fonts and higher resolutions are memory intensive.

Good pricing and availability of a broad range of high performance CISC and RISC processors. Several suppliers offer processors and peripheral ICs that are optimized for embedded applications such as printers.

Expanded development of key languages and fonts - The code for the popular languages (such as Post Script) and industry standard fonts that had been closely controlled are becoming available to multiple developers.

Sophisticated applications have outpaced the performance capabilities of printers, and the availability of these applications to the average user has highlighted the problem.

PCL (HP's printer command language) and PDL (Adobe Post Script for example) are evolving and appear to be converging. For many user environments, they represent coexisting standards.

Networking of PC's and printers is vital to system acceptance. Sharing equates to multi-user and multi-application environments for printer controllers.

The specialised demands on laser printer control processors traditionally exceed those of the host PC driving them.

55. Some pointers in the non-impact printer area are:

Applications will continue to drive the need for higher performance.

Applications determine the page make-up, which directly influences performance. Predicting the applications performance is impossible.

A standard (no "s") performance measurement system is required to allow a meaningful constant in the price/performance equation.

PCL (Level 5) processing demands are approaching those of PDL.

System performance is determined by more than processors.

## AUTOMATIC COMPUTER VISION SYSTEM FOR BLOOD ANALYSIS

56. In the field of haematology, one needs to identify and measure three kinds of blood cells - red cells, white cells and blood petals. Recently, a laboratory tool has been developed for processing the black/white blood images taken by a CCD camera through a microscope. All different categories of cells are recognized, counted and classified. The white cells are further treated for their classification into different classes according to the morphological characteristics of their nuclei. The final classification is brought out in a special format for the physician.

57. The localisation of the cells is achieved during the pre-processing stage using a thresholding tool. For the identification and classification, a special algorithm and procedure has been developed. The histogram indicating the variants of the volume of each cell are calculated and printed. These histograms help the doctors to define the blood type of the person and identify possible abnormalities.

58. The system has been developed on a microvax 2/VMS 4.5 machine. The CPU time needed to process an image was about 4 minutes with a success of 98%. The processing time and the results have been found acceptable by the physicians. The algorithm has been designed in a modular way so that it could be easily transferred to other systems. It is, therefore, possible to use special hardware to reduce the processing time dramatically and a fully automatic and reliable system can be developed.

## COMPUTER-AIDED TESTING STATION FOR VCRs

59. Microprocessor based test systems are used in conventional testing of video cassette recorders (VCRs) for mass production. The microprocessors in these systems usually act as sequence controllers for the testing requirements, and the programs are normally written in low-level assembly languages. Programming and debugging in low-level languages are tedious and time-consuming processes. In a rapidly changing market place where new products and designs are continually evolving, test systems must be able to be reconfigured rapidly to cope with new changes. Test results are normally recorded by hand, and this can lead to errors and problems for data analysis and report generation. In addition to the problems described above, there is the requirement of a dummy VCR to generate test signals for testing of the servo board in conventional test systems. The mechanical deck of the dummy VCR, under long hours of operation and mechanical stress, has wear and tear problems, thereby incurring high operating costs.

60. For a computer-aided VCR test system (CAVCRTS) developed recently, test results are automatically logged into the storage system of the computer at each test station and are continuously transferred to the central data base system by the computer network. The data can then be retrieved from the central database sytem for processing and analysis. The device-under-test (DUT) is checked, according to its functional specifications, by controlling the inputs to the DUT and observing its response.

61. A PC-based tester has the advantage of using commercially available compilers and programming languages to develop its software. In the CAVCRTS, the C language was used to write the software for the tester because of the portability and efficiency of the programming language.

62. A prototype test station for a computer-aided VCR test system has been designed and developed. It is currently used in the production line to test the power supply and servo boards of a VCR and the results are very encouraging. An annual cost saving of US $ 223200 is achieved. This cost saving will be increased as the production volume grows. This is due to the costs of the test tapes and the mechadeck in addition, testing time is reduced by about 50%. The system is able to automate the test procedures and store the test results on hard disks. The use of high-level language, which formed the basis of the design philosophy for the CAVCRTS, has greatly benefitted the process of developing the test program.

EXPERT SYSTEMS FOR PROCESS CONTROL INDUSTRIES

63. The above applications covering various process industries such as sugar, paper and pulp, steel as well as other diverse applications in the area of office automation, health, etc., are primarily microprocessor-based or PC-based instruments, equipment and systems which result in productivity improvement, savings in energy, cost-reduction, etc. In many developing countries, the process control industry has advanced significantly. There is a large number of experienced process engineers, instrumentation experts, etc. In several cases, microprocessor/microcontroller based instruments and systems may indeed be finding wide utilisation through direct imports of these systems and/or some parallel indigenous developments. In this background, there is a need to look at the rapidly emerging area of expert systems in the process control industry.

64. As defined by Prof. Feigenbaum in 1981, an expert system is an intelligent programme that uses knowledge and inference procedure to solve problems that are difficult enough to require significant human expertise in their solutions. The objective of an expert system is, therefore, to simulate the decision-making process which an expert typically follows in order to solve a problem. The knowledge of the expert can be in terms of rules of thumb, heuristics, deep intuitive knowledge of the processes, etc. It goes without saying that the expert system at best can only be as knowledgeable as the chosen expert/experts. Expert systems are typically built by the knowledge engineer who interacts with the expert/experts to extract their knowledge and, thereafter, uses certain specialised software tools to build the expert system.

65. Industrial process industries have several potential applications for expert systems, e.g., interpretation of sensor data, diagnosis of system faults, prediction of the consequences of actions taken, cost optimisation, etc. In the case of real-time process control systems, decision-making naturally has to be done in real-time. Given the complexity of the process technologies and the data inputs, the task becomes extremely difficult. Complex real-time process control industries are, therefore, good candidates for expert systems. Fig. 7 gives the general features of the expert system along with a typical structure for process control applications.

66. Expert systems are being used extensively in the area of plant control in the cement industry, blast furnace operation control in the steel industry, distillation column control in the chemical industry, etc. A variety of software tools such as process intelligent control (PICON), process diagnostic system (PDS), G2 - a real-time expert shell implemented in common Lisp, etc. are available. Building an expert system for real-time process control requires considerable effort in obtaining a suitable shell

and, thereafter, mapping the expert knowledge on to the knowledge base. It would be worthwhile to initiate long term R&D activity in this area in the developing countries to cater to their specific needs.

# CHAPTER III
## SETTING UP A MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE (MADC) IN DEVELOPING COUNTRIES

### BACKGROUND

1. It is instructive to examine the overall global scenario covering the less developed countries, the newly industrialised economies as well the developed world to get an appreciation of the macro-economic and technology imperatives. Every year the World Development Report (WDR) offers a review of global economy and projections. The WDR for 1990 has focussed on poverty. Echoing a view already expressed by other UN agencies, the WDR 1990 admits that for many of the world's poor the 1980s was a lost decade. Weighed under huge debt burdens, many of the Latin American and Sub-Saharan African economies experienced an absolute fall in income levels. On the other hand, for the developed industrial economies, the 80s was a good decade. Some of the industrial economies especially the USA and the UK were still in some trouble but the situation was much better than that anticipated in the beginning of the 80s.

2. For the countries who were hoping to break away from the vicious circle of under-development, the 1990s are unlikely to offer better prospects if the developed countries do not take a more liberal and supportive attitude towards them. The WDR has expressed concern over the insularity of the rich countries towards the developing world. The situation is further aggravated by the on-going trends in the global economy. These include the rising protectionism in the developed economies, market unification in Western Europe leading to Europe '92 and the growing trade relationship between the erstwhile Eastern Europe and Soviet Union with the developed market economies. This would make it all that more difficult for the less developed and newly industrialised economies to find their rightful place in the global order. In this context, 1990 survey report of IMD International and the World Economic Forum of Switzerland is also of interest. This report has classified 34 countries under their survey into two groups. The first consists of the 24 developed countries which are all members of the OECD while the second group includes the 10 newly industrialised economies.

3. Recently, the IBRD Report on competitiveness of developing countries in advanced electronics has specifically drawn attention to the technology gap between the developed world and the newly industrialising countries (NICs) like Brazil, Republic of Korea, Taiwan and India. The report makes the point that this technology gap will be a barrier to the aspirations of at least some of the NICs. The report suggests a restructuring of the industrial base of low wage countries like India, China, Bangladesh and Indonesia to upgrade technology absorption and diffusion in advanced electronics. Even with this, the world market for advanced electronics is likely to be dominated by the developed countries.

4. New products and processes would determine global competitiveness in electronics. Since the new technologies would be based on advanced electronics, the relatively slow growth in the development of electronics in the NICs would adversely affect their global competitiveness. In 1970s, the competitive advantage of the developing countries in electronics primarily stemmed from the cheap unskilled and semi-skilled labour that these countries could provide. Over the years, with the advances in technology, electronics

has become more and more capital intensive and automated, thus leading to much higher output per person. Thus, the developing countries would need to look into other avenues for competitive advantages. As a matter of fact, the highly skilled scientific and engineering talent available in many of these countries like the Republic of Korea, Taiwan, India - which has more than demonstrated its abilities in the developed countries like the USA - provides the natural niche for the developing countries in global competitiveness. The thrust, therefore, would have to be in areas requiring substantial value addition in terms of scientific and engineering inputs. This naturally leads to areas such as application software, research and development, equipment design, etc.

5. From the above, it emerges that for quite sometime in the future, the developing countries are unlikely to be significant players in terms of the volume of electronics production. To illustrate, India's total production of electronic goods in 1990 was about US $ 4 billion. This is less than the semiconductor production alone of NEC, Japan, whose total production is about US $ 25 billion. Most of the developing countries are likely to follow the approach to the growth of electronics which would be a mix of self-reliance, imports and value addition. The specificity of the mix would depend on the broad macro-economic policies followed by a particular country. India has recently embarked on a major restructuring of its industrial and trade policies with a view to unshackle them from bureaucratic controls and give the industry a strong export orientation. As a matter of fact, many of the countries might witness a shift from the earlier paradigm of "growth-led export" to "export-led growth".

6. The approach followed by the Asia-Pacific countries in developing their electronics and informatics industry is interesting. Primarily, two development strategies have been followed to create an environment that nurtures and sustains high technology industries. The first strategy was pioneered by Japan and followed with some variations by the Republic of Korea while the second has been defined by Taiwan and has served as a model for other countries in the region. In the case of Japan, the Government planned, coordinated and oversaw the acquisition and internal diffusion of foreign technology into the domestic high technology industry. More important, at the same time it protected the domestic markets from foreign competition. This resulted in creating strong competition amongst domestic industries. The Government also played a key role in developing the resources necessary for firms to respond to the pressures of innovation. MITI along with engineering research associations played a vital role in this endeavour. Programmes to improve the technological capability of small and medium size enterprises reinforced the positions of Japan's larger industrial companies.

7. The Republic of Korea followed the Japanese model with the variation that the Japanese and American multinational companies were provided access to the Korean market in return for technology transfer/licences. The Government played a strong promotional role to direct a multinational corporation into joint ventures with a small number of relatively large size companies - the Chaebols. In fact, Samsung, Lucky-Goldstar, Hyundai, and Daewoo currently account for about 60% of all production and 90% of all exports. The Koreans excelled in refining and improving the acquired production technologies and have focussed on highly cost effective manufacture of a limited number of products. The weakness in this approach has been the lack of strength in the smaller companies in terms of research and development. The Government is now taking actions to correct this.

8. In the case of Taiwan, the Government's role has been more passive. Due to the small domestic market available to the multinationals, the Taiwanese Government encouraged them to set up export processing ventures in Taiwan. Taiwan took the lead in the Asian-Pacific region in this approach and was able to attract a large number of multinationals in the 1960s. Lately, however, the local employees have started leaving the parent companies to form companies of their own. The Taiwanese model is characterised, therefore, by a large number of small but extremely competitive companies. Singapore's development of its electronics and information technology is also representative of the Taiwanese experience.

9. From the above, It is apparent that the developing countries have a wide range and diversity of technological environments. The consumption of electronic goods in any developing country is a combination of direct import of finished goods and indigenous manufacture with import content varying from zero to 100% depending on the extent of local value addition. For example, in India the import intensity varies from a low of about 16% for consumer electronics to a high of about 64% for computers. The value addition usually is in terms of the labour, indigenously available raw materials and components, sub-assemblies, etc. At the lowest end of the spectrum for manufacturing industry, the only indigenous value addition is in terms of labour. However, in the case of application software, the value addition in terms of engineering manpower can be substantial.

10. Typically, manufacture in most developing countries is either at a wholly-owned subsidiary of a multinational company either in a export-processing zone or in the domestic tariff area or through a joint venture with a local company or through licence manufacture by a local company. Most developing countries have fallen into the trap of perpetual successive imports of new versions of products/technoicgies. Thus, what is generally lacking is value addition on the imported know-how in terms of design inputs coupled with lack of indigenisation of the raw materials, components, sub-assemblies - and, most important, capital equipments so as to keep pace with the technologies that are moving extremely fast internationally.

11. While most of the electronics production covering computers, consumer electronic goods including TV, VCR, radios, industrial electronics, telecommunications, etc. contributes directly to the electronics production of a developing country, another dimension is that of productivity improvement through the usage of electronics in a variety of non-electronics industrial sectors. This could be from the usage of computers in the office and factory, as well as process control instrumentation in a range of industries. Chapter II has given an illustrative description of the usage of microprocessor based systems in process control industries such as sugar, paper and pulp, textiles, steel as well as a host of diverse applications such as railways, office automation, health, entertainment electronics, etc.

12. Different configurations of a microprocessor application development centre may be found appropriate by different developing countries as best suited to their particular needs. This would, above all, depend on the budget availability - since this is a key consideration for any developing country - and the status of the related infrastructure, e.g., PCB design, development and manufacturing; display devices; equipmant packaging technology, geographical imperatives - concentration versus proliferation,

availability of telecommunication facilities, etc. However, the key objectives of such a centre would normally cover the following:

(i) To promote and proliferate the manufacture of microprocessor based systems with a view to broaden the manufacturing activity in electronics covering different sectors such as telecommunications, entertainment electronics, industrial electronics, computers, etc;

(ii) To promote and proliferate the usage of microprocessor based systems in a variety of electronics as well as non-electronics industrial sectors covering process industries such as fertiliser, sugar, tea, textiles, steel, cement, etc., as well as other sectors of economy such as energy, transport, etc.

## MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE FOR PROCESS CONTROL APPLICATIONS

### Organisational Structure

13. The MADC for process control applications (MADC for PCA) addresses itself to a sub-set of S.No. (i) and (ii) of the objectives outlined above. We would first describe the suggested organisational structure for such a centre. There is a specific reason for doing so in the case of developing countries. It is to be noted that many of the developing countries at different stages of development of their economy and technological environment usually have a strong hierarchical, administrative culture. The organisational structure of the MADC and its coupling with the Government and Government-controlled institutions, the industrial sector and the academic environment, therefore, needs to be carefully defined. A 3-tier management structure is proposed for the MADC:

(i) The Governing Council;

(ii) The Technical Advisory Committee;

(iii) The Programme Management Committee.

#### Governing Council

14. The Governing Council (GC) would have the responsibility to oversee the overall programme of the MADC, provide guidelines and serve as a forum to discuss broader macro-economic issues. The GC should be chaired preferably by the concerned Minister himself or the top-most civil servant under him. It should have as its Members, senior Government officials from the relevant departments such as industry, science & technology, finance, etc., as also representatives from the target industries such as sugar, tea, steel, cement, fertilisers, etc., at the Chief Executive Officer (CEO) level. The GC would probably be the most critical interface for the MADC with the external world since it would be the understanding and appreciation by these key decision-makers in the Government and industry of the importance of microprocessor applications, and their enthusiasm to canvass support for the usage of microprocessors in different applications which would determine the success of the Centre to a large extent. The Director of the MADC would serve as the Member-Secretary to the GC.

15. The support of the Government in terms of financing and policy cannot be over-emphasized particularly in a developing country. For example, if import of microprocessor based systems is freely available to the various process industries, the efforts of the MADC would be infructuous. A certain amount of protection in the initial stages would need to be provided for domestic market - incidentally this model has been followed very successfully by Japan. The idea is not to stop imports of microprocessor based systems for the process industry since productivity improvement in any developing country would take precedence over indigenisation of microprocessor based systems. The policy should be to bootstrap the MADC to reach the same levels - in terms of system sophistication and cost - as compared with the best available internationally. For example, the GC can ensure that where imports are essential, the MADC is associated with the import of the systems so that the scientists and engineers of the MADC are able to absorb some of the technologies and the design, manufacturing and maintenance strategies of state-of-the-art systems.

16. In a different direction, the GC can again ensure effective end-user participation in the MADC by posting representatives from the concerned target industries to work alongside with the MADC scientists and engineers in system development. In fact, this model has been highly successful in the case of the Centre for Electronic Design & Technology set up at Bangalore in India under the Indo-Swiss collaboration programme. The GC will discuss and approve the annual budget for the MADC as well as the 5-year profile and also discuss and define inter-sectoral priority amongst the end-user industries.

17. Once the annual budget is approved by the Governing Council, the Director of the MADC must have total flexibility and freedom to operate the budget. If possible, the MADC could be formed as an autonomous registered society instead of a Governmental programme/project/activity so that it enjoys the flexibility and freedom of operation of the best international labs. Incidentally, this approach has been adopted by India in the case of certain major programmes launched as missions. These include the Centre for Development of Telematics (CDOT) and the Centre for Development of Advanced Computing (CDAC) and have proved to be highly effective. Further delegation of administrative, technical and financial powers should also be done by the Director to the various Group Leaders so as to enhance the flexibility and efficiency of the Groups.

## Technical Advisory Committee (TAC)

18. The TAC would serve as a forum for discussion of the state-of-the-art in the area of microprocessor applications covering advances in the latest application issues, hardware, software, etc., and would advise the Director, MADC on the new directions in terms of applications as well as updating of the hardware and software available at the MADC. The TAC could be chaired by the Director, MADC and would have as its Members eminent technical experts drawn from the industry, R&D labs and academic institutions. It is to be emphasised that the TAC is essentially a technical committee and would concern itself with purely scientific and technical matters addressing microprocessor applications, the latest hardware and software tools available for developing systems, emerging trends in ASICs, SMDs, etc. Inputs from the TAC would enable the Director, MADC, to project ideas about new applications as well as augmentation to the GC in terms of hardware and software for consideration by the Governing Council. The Group Leader of

Group II of the MADC (delineated below) dealing with product design and development would be the Member-Secretary of the TAC.

Programme Management Committee

19. This would be an internal committee of the MADC and would concern itself with scientific, technical, administrative, and financial aspects of the day-to-day running of the MADC. In the initial phase, the Director of MADC could be the Chairman with the Group Leaders as Members and the Group Leader of Group VI dealing with Administration and Finance as Member-Secretary. In course of time, the Director, MADC, should delegate the Chairmanship to the most senior technical Group Leader.

Organisational Structure of the MADC

20. The MADC would consist of the following six groups:

I. Applications Development and Product Definition Group;
II. Product Design & Development Group;
III. Product Engineering and Transfer of Technology Group;
IV. Human Resource Development Group.
V. Consultancy Group.
VI. Administration and Finance Group.

The organisational structure of the MADC is shown in Fig.8. The Group Leaders of these groups would report to the Director, MADC.

I. Applications Development & Product Definition Group

21. The main responsibility of this Group would be to prepare a series of - Microprocessor Applications in Industry - reports covering all likely target industries where microprocessor based instruments and systems would improve the productivity of the existing process technology, lead to instruments or systems which could improve the process technology or bring about altogether new process steps, effect savings in energy, reduce the cost of manufacturing, etc. These reports would serve the dual purpose of not only analysing potential microprocessor applications but at the same time, would define the existing status of the process industries in the country. These reports would be discussed by the GC and would serve as the basis for short-listing a few carefully selected industries for development of microprocessor applications. Once the target industries are chosen by the GC, this group would have in-depth discussions with these industries as well as likely manufacturers of the microprocessor based systems to be developed in case the requirement is for large numbers. In this context, the database on the country's electronics equipment manufacturing industry would need to be made available to this group or would have to be generated in parallel by the group itself through their own efforts or a subcontract.

22. This would be the key group of the MADC with highest visibility and would be its interface - at the working level - with the external world. The staff for this group should be drawn preferably from scientists and engineers with some experience in interaction with the end-user industry. They would need to have the necessary technical expertise coupled with maturity and ability to visualise applications and would also need to have good "marketing" skills. It may be a good idea to include one or two people with management and/or business administration background. This group along with

the human resource development group will have to launch a series of half-day and one-day workshops to "sell" the efficacy of microprocessor based solutions to the end-user industry. The half-day workshop could be arranged for the CEOs/mmanaging directors/top executives and a variety of one-day workshops could be arranged for the middle management/engineers from other disciplines, e.g., mechanical engineering, chemical engineering, textile engineering, metallurgical engineering, etc. In fact, this group would need to closely interact with the human resource development group for preparation of the courses/workshops.

II. Product Design and Development Group

23. This, along with Group III, would be the hard-core technical groups of the MADC. Once an application/product definition has been done by Group I, this group would need to first sharpen these inputs into clear-cut system specifications. Once again, very tight coupling and interaction between Group I and Group II would be essential for success of the MADC. As a matter of fact, it is highly desirable and strongly recommended that the MADC adopt, whole-heartedly, the methodology of concurrent design which has been brought out in Chapter I. Concurrent design in its essence acknowledges the need for close interaction between different groups in a mode close to parallel/interactive processing in a computer against the conventional approach of sequential, over-the-wall design and product development. This group - after definition of the product specification for a particular application - would then select and implement the most cost-effective solution using the hardware and software tools available at the MADC. The staff would need to be well-versed with the design and development of microprocessor based systems and should also have a good grasp of manufacturing processes in the electronics equipment industry. The key is to design products which should not only be manufacturable but also cost-effective. The group will have to demonstrate the maturity in judgement in choosing what can be done in-house at the MADC and what is better done outside or even abroad. For example, it may happen that a particular application can be made more cost-effective if an ASIC is designed and fabricated abroad rather than partitioning the design in FPGAs or doing a sub-optimal, inferior design with a standard microprocessor.

III. Product Engineering and Transfer of Technology Group

24. As the name suggests, this group would provide the product engineering finishing touches to the products and applications developed by Group II and, thereafter, ensure effective transfer of technology to the system manufacturer in case substantial numbers are required to be manufactured. In the initial stages, this group along with Group I would need to work closely with the user industry where the system is to be used for any debugging and system improvement based on field trials. This group will have to work with Group II to ensure manufacturability of the system, prepare extensive design documentation, manufacturing drawings, documentation, etc., so as to develop a full transfer-of-technology package which can then be passed on to the manufacturing industry - which ought to result in know-how charges and/or royalty payments to the MADC - for production and supply to the end-user. The senior level staff in this group should have a strong manufacturing background and should be drawn - to the extent feasible - from the local electronic equipment manufacturing industry. One or two of the staff should have a BS (Mechanical Engineering) degree to provide this vital input to product engineering.

IV. Human Resource Development Group

25. The group is named Human Resource Development Group to emphasize that its role should be wide-ranging and there would be other elements such as creation of awareness and exposure to microprocessor applications and their benefits to a broad spectrum of individuals covering administrators, technocrats, financial personnel, scientists, non-electronic engineers, etc., besides training and upgrading the skills of MADC and non-MADC electronics professionals. The task of this group would, thus, be twofold. In the first instance, this group would provide the training and updating support to the members of the MADC from the other groups. The second would be to define, prepare and organise a series and variety of lecture courses, workshops, demonstrations, seminars, etc., for non-MADC personnel. This would include the people from the Government departments, electronic equipment manufacturing industry, the various electronic and non-electronic process industries, R&D labs, academic institutions, etc. While the members of this group would usually serve as the common faculty, wherever feasible, for the courses/workshops etc., the group would naturally draw on experts from the other groups of the MADC as well as non-MADC experts from within the country as well as abroad. This group would also plan and organise fellowships/training of MADC and non-MADC staff in selected organisations within the country as well as abroad and would also arrange short-term and long-term visits by experts from abroad to the MADC. The staff of this group would need to consist of people with considerable experience in this area with enthusiasm for this type of activity and good communication skills.

V. Consultancy Group

26. In the case of a developing country with reasonably advanced infrastructure in terms of electronics industry and an enlightened end-user process industry, a need may arise for the MADC to provide consultancy support to the electronics equipment manufacturers as well as the process industries. The support, for example, could be in terms of helping the equipment manufacturers in upgrading a particular microprocessor based product or assisting the process control industry in the usage of microprocessor based systems. Formation of this group should normally be done two to three years after the MADC has been operational. In the initial stage, members drawn from Group I to IV would indirectly be discharging part of the functions of this group.

VI. Administration and Finance Group

27. This group would be responsible for all administrative and financial matters relating to the MADC and would ensure that scientific and technical personnel of the MADC are free from the shackles of any administrative, financial responsibilities and are able to devote their energy fully to the technical and related tasks. This group should make extensive use of administrative, personnel, and financial software packages in their functioning. The Director of MADC should ensure that this group functions effectively as a support group for the other groups.

Staffing

28. There are a variety of staffing patterns available for the MADC, e.g., the AT&T Bell Labs follows the all encompassing and convenient label of Member of Technical Staff (MTS). The scales of pay and exact salary of each

MTS is negotiated at the time of appointment and is held in confidence. The advantage of this approach is that the staffing is flexible and the pay-scale/pay can be chosen to suit a particular candidate. Each developing country would naturally have its own distinct pay scales, designations, etc. Even in India the experience is that while functional flexibility can be provided through registered society approach, the pay scales have a one-to-one correspondence with Government pay scales. Each developing country would have to adopt the pay scales and designations which are best suited to it. Another point to be noted is that all the group leaders of the various groups need not be at the same level. All of them would, however, need to be designated as group leaders.

29. A suggested profile for the MADC is given in Fig. 9. The designations used, namely, Jr. Systems Analyst (JSA), Sr. Systems Analyst (SSA), Principal Systems Analyst (PSA) are drawn from the Indian experience. Typically, JSA is a person with a BS or equivalent degree with 0-2 years of experience. SSA would have 4-6 years of experience after BS and a PSA would have around 8-12 years experience after BS. The staffing pattern for the different groups has been suggested keeping in mind the large number and diversity of process industries that could exist in a developing country. Thus, Group I and Group II would need to be heavily staffed. In fact, as the MADC grows in experience, intra-group transfer of the staff is strongly recommended to provide individuals with broader experience and understanding of the totality of the requirements and also assist in facilitating concurrent design methodology.

30. As described earlier, the MADC should strongly encourage short-term/long-term positioning of individuals from the electronic equipment manufacturing industry as well as process industry to the MADC to work with the personnel of the MADC. As a matter of fact, the Governing Council should use its good offices to assign, if possible, individuals from the potential equipment manufacturing industry to work with Group II and the end-user process industry to work closely with Group I. In the other direction, the MADC should also depute its staff to the manufacturing industry and the user industry for a first-hand appreciation.

31. A suggested pattern of growth for the MADC would be appointment of the Director, Group Leaders I, II, III, IV and VI along with 50% of the remaining staff in the first year itself. Thereafter, additional staff could be added in phases (30%, 20%) to reach full strength by the third year. Director, MADC, must have the flexibility to appoint meritorious candidates at any time. A flexible recruitment approach based on newspaper advertisements, campus interviews, special interview for a single candidate, etc., would be necessary to get the right mix of staff. Flexible complementing should be adopted for career development so that promotions are based on performance and merit and are not denied due to non-availability of posts.

## Training

32. The requirement of different types of training has been described in the work description of Group IV dealing with human resource development. As

indicated, the training would be for MADC personnel as well as non-MADC people. The different types of courses and workshops that would need to be developed are given below:

(i) Basic Course on Microprocessor: This could be a 2 week course coupled with lab work, aimed primarily at the entry-level officers of the MADC so as to teach them the basics of microprocessors in case it has not been covered adequately in their BS curriculum;

(ii) Advanced Microprocessor Courses: The core course in this category would be a 2 week course dealing with advanced microprocessors' architecture, comparison, usage and systems design. The prerequisite will be course (i) or equivalent knowledge. This course could also be offered to non-MADC personnel. Variants of this course would need to be run to cater to recent advances in microprocessor based design. For example, under this heading one could visualise specific courses such as "system design with transputer", "RISC versus CISC in system design" etc;

(iii) Basic Course on Application Specific Integrated Circuits (ASICs): This course would bring about the complementary role of microprocessors and ASICs. The basic course of 2 week duration would cover the different methodologies for ASIC design and touch on the cost benefit advantages;

(iv) Advanced Courses on ASICs: The advanced courses would focus on specialised topics such as field programmable gate arrays, gate arrays, sea-of-gates, standard cell based design, full-custom design, etc. These should also be of 2 week duration;

(v) Half-day Workshop for Microprocessor Awareness: This would be targetted primarily towards the Chief Executive Officers, Managing Directors, Top Executives of the process control industry so as to expose them to the advantages of having microprocessor based systems in process industry and the resulting benefits in terms of productivity, energy saving, cost reduction, etc. These workshops could be tailored specifically to the target process industry, e.g., sugar, steel, cement, etc. and must give specific case studies;

(vi) One-day Workshop for the Industry: This would target the middle management/sr. engineers of the user industry and would primarily be addressing non-electronics engineers such as mechanical engineers, metallurgical engineers, civil engineers, chemical engineers, etc. This workshop would naturally go into more details of specific microprocessor applications. A variant of this workshop should also be arranged for the technicians and operators in the process industry who, in the ultimate sense, would be the end-users of the products developed by the MADC. The emphasis here would be more on operating instructions, precautions, practices, maintenance, etc;

(vii) Allied Courses: These courses would address a variety of topics covering project management and control, life cycle costing, PCB design, sensors, etc. MADC personnel would need to be exposed to a broad range of disciplines to enhance their effectiveness. For most of these, MADC personnel could be deputed to attend such courses in the country or abroad and/or lectures arranged by local or foreign experts.

33. As brought out earlier, the training would also encompass fellowships for MADC and non-MADC personnel for training abroad as well as organising seminars, workshops, and lecture courses involving eminent experts from the developing countries and the developed world.

34. Some suggested topics for such national/international workshops/seminars/conferences are:

(i) Microprocessors for productivity improvement: This could focus on the cost benefit aspects, economic benefits from the usage of microprocessor in the process industry;

(ii) Microprocessor applications in process industry - X : This should be a series of seminars on specific industry so that X = sugar, paper and pulp, steel, cement, textiles, leather, tea, fertilisers, chemical, etc. These should focus on current microprocessor based instrumentation and systems as well as case studies from other developing countries and the developed world;

(iii) Expert systems in process industry: In several developing countries, usage of microprocessors in process industries may be at an advanced stage based on local as well as imported systems. These countries may be feeling the need for more sophisticated control systems. This could focus on the development of expert systems and their applications with case studies;

(iv) Fuzzy controllers: This is an area which is gaining large momentum in Japan and is soon likely to make inroads in the USA, Europe, and UK. The course could cover the basics of fuzzy logic, available controllers, software and applications.

35. The above is a representative list and many more topics could be chosen as the activities of the MADC evolve. In this context, it would be highly desirable to decide on one or two topics such as "advances in microprocessor design" which could become regular annual events so as to give a sense of continuity. The content and focus in these events could change from year to year. For example, in the area of LSI/VLSI design, international conferences on VLSI design are being organised regularly since 1987 in India. The regularity has proved very effective in boosting the interest and awareness in this area. The attendance at the conferences has increased and the technical content and the scope has grown in quality over the years. Such events should consist of one day for tutorials and two days for papers, case studies, panel discussions, etc.

Capital Equipment and Software

36. The MADC facilities would need to adequately address microcontroller based systems, microprocessor based systems, advanced microprocessor based systems, and PC based systems. As brought out in Chapter I, some of the lower-end applications are best carried out with microcontrollers whereas more sophisticated applications would require microprocessor/PC based systems. It is suggested that the MADC should not be limited to a particular family of microprocessors and should provide the necessary infrastructure to

enable designs based on contemporary CISC and RISC processors available from Intel, Motorola, MIPS, etc. as well as transputer based systems.

37. ASICs have established themselves as important building blocks for system design. Most contemporary systems include both microprocessors and ASICs. As brought out in Chapter I, different methodologies are available for ASICs. One could go for PLDs, EPLDs, PLAs, gate arrays, FPGAs, standard cells, hybrid approach, etc. The MADC must have the capability for ASIC design.

38. The hardware and software required for the MADC is described below:

(i) Universal emulator: Emulators supporting multi-processors, microcontrollers and microprocessors up to 32 bit would be required for a broad range of systems development. In addition to the emulator, a variety of personality modules would also be needed. Two numbers of emulators are proposed so that redundancy is built-in.

(ii) Micro-system trouble shooter: This would be required for trouble-shooting of bus based systems. Again several personality modules would also be required.

(iii) Logic analyser: This should support at least 100 channels and have operating speeds up to 200 MHz.

(iv) Workstations (SUN/APOLLO etc.).

(v) PC-ATs (for microprocessor based design as well as office automation).

(vi) Hardware support for manpower training & general administration:

- Slide projector;
- Overhead projector;
- Xerox machines (light duty, heavy duty);
- FAX machine;
- Desk top publishing;
- VCR, colour TV, projection screen;
- Electronic typewriters.

(vii) General test instrumentation: This would cover oscilloscopes, digital multimeters, function generators, soldering strip, repairing kits, etc.

(viii) Photo-plotter.

(ix) Development support software for EPROM, PLD, PGA and PAL.

(x) Specialised development system support for specific RISC, DSP chips, etc.

(xi) Software tools for real-time applications.

(xii) Languages for embedded control.

(xiii) Object-oriented development tools.

(xiv) AI and expert system tools.

(xv) CAD tools for simulation of analog/digital/microprocessor hardware, e.g., Visula.

(xvi) Field Programmable Gate Array (FPGA) system, e.g. Xilinx, Actel etc.

(xvii) Medium level ASIC development system for gate array/standard cell design, e.g., Cadence, VTI, Mentor Graphics, LSI Logic, etc.

(xviii) Fuzzy logic controller based development system software and associated tools.

(xix) Utilities software library.

39. The above is an illustrative list of the hardware and software support that would be required at the MADC. The total cost is estimated at US $ 1.2 million.

Financial Details

40. The MADC would require expenditure to be incurred for the initial setting up towards the capital equipment including computer hardware peripherals, other instruments as well as software tools. The sustaining expenditure would be required to cover salaries of the staff, travel expenditure, allocation towards fellowships, visiting scientists, maintenance of capital equipment and software, periodic updates of hardware and software, contingencies, etc. The initial and sustaining expenditure over a period of 5 years for the MADC would be as follows:

| | US $ Million |
|---|---|
| A. Initial Expenditure | |
| - Capital Equipment (including hardware, peripherals, instruments, software) | 1.20 |
| Sub-Total (A) = 1.20 | |
| B. Sustaining Expenditure for 5 years | |
| - Maintenance of capital equipment and upgrades | 0.80 |
| - Consumables and sub-contracts for services (for eg. PCB fabrication, ASIC proto-typing, etc.) | 0.50 |
| - Salaries | 0.80 |
| - Travel<br>- Local - 0.15<br>- Foreign - 0.15 | 0.30 |

| | |
|---|---|
| - Fellowships and study tours for MADC personnel | 0.30 |
| - Visiting experts from developed countries | 0.30 |
| - Contingencies | 0.30 |
| Sub-Total (B) = 3.30 | |
| Total (A) + (B) | 4.50 |

41. Adequate provision has been made under the capital equipment head to cover a variety of computer hardware peripherals, laboratory instruments, software tools, etc. Provision has also been made to cater to the hardware and software requirements for ASIC design including FPGA and a few other methodologies, system design using fuzzy controllers as also the usage of AI/expert system tools. The numbers, specifications and other details could vary from centre to centre. The subcontracts for services such as PCB fabrication, ASIC prototyping etc. would be essential ingredients for microprocessor based systems development. Liberal provision has been made for travel - both local and foreign. It is to be noted that an important ingredient of the functioning of the MADC would be frequent travel by the MADC personnel to the electronics equipment manufacturing industry and the end-user process control industries in the country and abroad as well as for attending conferences and seminars abroad. Complementing this would be parallel visits to the MADC by personnel from the equipment industry and the process control industries. It is the general experience that providing budget provision for these complementary counterpart visits is a key facilitator for such visits. Correspondingly, provision has also been made in the salaries budget to enable short-term/long-term postings at the MADC of scientists and engineers from academic institutions, R&D laboratories, electronic equipment industry as well as the process industries. Fellowships, study tours and visits of experts from developed world would go a long way in boot-strapping the technical capability of the MADC personnel in the shortest possible time to international levels.

Financing Mechanism

42. In most developing countries, it would be extremely unlikely that a programme such as the MADC could be launched by the private sector or private sector consortium. Most often such programmes are initiated and supported by the Government. Thus, primary source of funds for the MADC would be the Government through the appropriate funding mechanisms. It is strongly recommended that the MADC be provided part financial support through the United Nations Development Programme (UNDP). A suggested input from the UNDP for this programme could be US $ 2.25 million covering: capital equipment - 1.10, maintenance and upgrades - 0.40, fellowships and study tours - 0.30, consumables - 0.30, contingencies - 0.15. It is to be noted that the counterpart Government funding would be the balance of US $ 2.25 million plus the investments in kind covering building, electricity, water and other related overheads which would be of the order of US $ 1.0 million over a 5 year period.

MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE FOR EMBEDDED SYSTEMS APPLICATION

Organisational Structure

43. The first MADC profile had addressed itself to application of microprocessor based systems in the process industry covering applications such as sugar, tea, paper and pulp, cement, steel, fertilizer, textile, etc. Some of these applications would require manufacture of the microprocessor based products in large number by the manufacturing industry whereas other applications may require products in very small quantities. There is another category of applications of microprocessors in areas such as energy, transportation, telecommunications, office automation, health, etc. It would require development of microprocessor based products requiring large volume manufacture by the electronics industry. In many of the lower-end applications such as toys, games, etc., the word embedded system has come in vogue. The implication is that the user is unaware of the existence of the microcontroller or microprocessor in the product since whatever software is required for that particular application has usually been built into the product. This centre would thus also be addressing itself to a sub-set of the objectives at S.No.(i) and (ii) of para 12.

44. Broadly speaking, most of the details for MADC for process control applications would apply "mutatis-mutandis" to this centre. The organisational structure would remain identical since the basic rationale behind creating this structure remains the same. Thus, this centre would also have a 3-tier structure consisting of the Governing Council (GC), Technical Advisory Committee (TAC) and the Programme Management Committee (PMC). The philosophy and imperatives of the GC would remain similar. However, the GC would need to have a much broader representation from the various electronics equipment manufacturers. Since this centre would be addressing a different category of end-users, it would also be desirable to include representatives from the ultimate consumers of these products which could cover consumer associations, hospital personnel, etc. The composition of the technical advisory committee and the programme management committee would remain the same.

45. The MADC should have the same organisational structure as that for the MADC for process control applications (MADC for PCA) and would, therefore, consist of the following six groups (Fig. 8):

(I) Applications Development and Product Definition Group;

(II) Product Design and Development Group;

(III) Product Engineering and Transfer of Technology Group;

(IV) Human Resource Development Group;

(V) Consultancy Group;

(VI) Administration and Finance Group.

(I) Applications Development & Product Definition Group: In this case, the responsibility of the group would be to prepare a series of microprocessor application reports covering the likely products that could be designed using microprocessors, microcontrollers, PCs, etc. These reports would also need to address the end-usage of electronics products in different segments such as consumer electronics, computers, control and instrumentation, telecommunications, defence electronics, etc., along with obtaining a first-hand appreciation of the electronics equipment manufacturing industry in the country. Based on the reports prepared by this group, the GC would identify target products for development. The group would, thereafter, have further discussions with the potential manufacturing industries as well as the ultimate end-users of these products to more clearly define the application/product. Other considerations for this group would be similar to that of the MADC for PCA.

This would again be the key group of the MADC with maximum interaction with the external world. The staff for this group should be drawn from scientists and engineers with some experience in electronics manufacturing industry. The staff would not only need the technical expertise but maturity and ability to conceive new product applications and would also need good marketing skills. It would be useful to have one or two people with management and/or business administration background. This group along with the Human Resource Development Group would need to develop a series of half-day and one-day workshops for the potential equipment manufacturing industry as well as the end-users in diverse sectors of economy such as telecommunications, computers, railways, health, agriculture, etc. In many cases, it would be useful to arrange these workshops for specific professional associations involved with these sectors.

II. <u>Product Design & Development Group</u>: As described in the case of the MADC for PCA, this group along with Group III would be the hard-core technical Groups of the MADC. The role and philosophy of operation of this group would thus be identical.

III. <u>Product Engineering & Transfer of Technology Group</u>: Being essentially a technical group in nature, the considerations would remain similar as for the MADC for PCA. In this case, the target ultimate end-users would be consumer groups for entertainment electronics items, railways, telecommunications, health, etc., while the transfer of technology would naturally be to the electronics manufacturing industries.

IV. <u>Human Resource Development Group</u>: The philosophy, functioning and scope of activities of this group would by and large be the same as the group for the MADC for PCA, with the natural difference that the non-MADC target audience would now include a different set of ultimate end-user groups and industries.

V. <u>Consultancy Group</u> : Considerations for this group would be similar to those for the group for MADC for PCA.

VI. <u>Administration & Finance Group</u>: Considerations for this group would be similar to those for the group for MADC for PCA.

Staffing

46. The rationale and considerations regarding staffing of the MADC would be similar to those for the MADC for PCA. The same staffing profile as given in Fig. 9 should be adopted for this MADC.

Training

47. As described in the previous case, the training courses for this centre would also consist of the following:

(i) Basic course on microprocessor;

(ii) Advanced microprocessor courses;

(iii) Basic course on application specific integrated circuits;

(iv) Advanced courses on ASICs;

(v) Half-day workshop for microprocessor awareness;

(vi) One-day workshop for industry;

(vii) Allied courses.

The difference would arise in the target audience for the half-day and one-day workshops at S.No.(v) and (vi).

48. The MADC - as in the previous case - would also need to organise fellowships for MADC and non-MADC personnel for training abroad as well as organising seminars, workshops, and lecture courses involving experts from developing countries and the developed world. Some suggested topics for such national and international events could be:

(i) Fuzzy controllers;

(ii) Microprocessors in Industry-X : These could be a series of seminars on specific target industries so that X = computers, telecommunications, consumer electronics, energy, railways, health, etc.

As pointed out in the previous case, it would be desirable to have three days for these national/international events with the first day devoted to tutorials followed by two days of workshops/seminars.

Capital Equipment and Software

49. Since the basic objective of the MADC - as in the previous case - is to design, develop and prototype microprocessor/microcontroller/PC/ASIC based products, the requirement for hardware and software as well as associated instrumentation, peripherals, etc., would remain the same. It is suggested that certain additional tools, e.g., standard protocol analyser for telecommunications products, etc. could be appropriately included based on the target industries identified for product development by the Governing Council. The budget provision of $ 1.2 million for the hardware and software for this centre along with the provision for upgrades of hardware and software

should easily permit acquisition of industry specific software tools and related hardware, etc.

## Financial Details

50. As in the case of MADC for PCA, this centre would also have the financial requirements for initial expenditure and sustaining expenditure over a period of 5 years as follows:

| | US $ Million |
|---|---|
| **A. Initial Expenditure** | |
| - Capital equipment (including hardware, peripherals, instruments, software) | 1.20 |
| Sub-Total (A) = 1.20 | |
| **B. Sustaining Expenditure for 5 years** | |
| - Maintenance of capital equipment and upgrades | 0.80 |
| - Consumables and subcontracts for services (e.g. PCB fabrication, ASIC proto-typing, etc.) | 0.50 |
| - Salaries | 0.80 |
| - Travel<br>- Local - 0.15<br>- Foreign - 0.15 | 0.30 |
| - Fellowships and study tours for MADC personnel | 0.30 |
| - Visiting experts from developed countries | 0.30 |
| - Contingencies | 0.30 |
| Sub-Total (B) = 3.30 | |
| Total (A) + (B) | 4.50 |

## GENERAL ISSUES FOR CONFIGURING THE MADC

51. As discussed earlier, each developing country could modulate the framework described above for the MADC by increasing/decreasing the capital equipment, software tools, staffing to suit its needs. For example, a downward scaling in terms of capital equipment could be affected by dropping the medium level ASIC design system or even the FPGA system, restricting oneself to a PC-AT environment only, and decreasing the staffing element by say 25%. Enhancement on the other hand, would primarily be through having more of the PCs, workstations, and staff so as to be able to carry out a larger number of system development projects in parallel.

52. The infrastructure in most developing countries would include academic institutions having BS/MS/Ph.D level programmes, R&D labs - mostly state-owned - covering various facets of electronics, and the electronics manufacturing industry addressing different product areas. It would be highly desirable to use the MADC as a nodal, resource centre. Depending on the availability of funds and the preparedness of the various academic institutions, R&D labs and industries in acquiring microprocessor technology, the nodal MADC could be coupled with a series of area specific, focussed MADCs or through joint development projects executed at the nodal MADC along with staff from these organisations. The academic institutions and R&D labs could look at relatively long range application scenarios whereas the industry would cater to the microprocessor system needs of that particular industry, e.g., telecommunications, control and instrumentation, computers, etc. For most developing countries it may not be possible, at least in the initial stages, to merely replicate the MADC proposed above at different locations.

53. In this context, the approach followed by the Department of Electronics (DOE), Government of India, in different sectors of electronics could be of interest. For example, in the area of fibre optics, DOE is implementing a programme involving three academic institutions and two production agencies. The role of DOE is primarily that of programme planning, funding, coordinating and monitoring. The technical work in specific areas is carried out by the academic institutions and production agencies. In the areas of microprocessor and appropriate automation, the role of DOE has been enhanced to include inhouse technical activities while maintaining the concept of additional centres/activities at academic institutions, R&D laboratories and industry in a network manner. In the area of LSI/VLSI design, DOE is implementing a three-level framework. The Level I Centre of the DOE for VLSI Design & Prototyping would serve as the nodal resource centre to coordinate and support the activities of the Level II centres at major academic institutions, R&D laboratories and industry, as well as the CAD awareness activity at the Level III centres at the engineering colleges.

54. As indicated in the beginning, the World Development Report 1990 has symbolically chosen poverty as the major theme for their report. The difference between the least developed countries on the one hand, and the smaller group of countries close to getting into the developed countries category, are enormous. These differences include the GDP, geographical areas, population, climatic conditions, range and depth of industrialisation, consumption of electronic goods, etc. The MADC profiles described earlier with minor variations may suit the needs of a particular developing country or a group of countries. Some other possible scenarios for the MADCs could be as follows:

(i) Fairly developed countries, say in the top 5 to 10 newly industrialised economies with substantial electronic consumption:

In this case - depending on geographical, political and social considerations - one could envisage a single enhanced MADC with a total outlay of about US $ 6 million. This would be suitable for a country with small geographical area, good transport, etc. The enhancement could be primarily towards additional personnel, workstations, PC-ATs, more copies of software tools, etc.

A variation of this approach could be the MADC with an outlay of US$ 4.5 million coupled with 3 or 4 smaller MADCs with total outlays ranging from US $ 1 million to US $ 2 million each. The smaller, satellite MADCs should be at major industries (electronics as well as non-electronics), R&D laboratories as well as universities depending on the state of preparedness/willingness and geographical imperatives. The total outlay for such an approach would be around US$ 10 to 12 million.

(ii) Less Developed Countries:

In such cases, the approach suggested in (i) above would, in all probability, be unaffordable and even if resources could be found, is likely to be an overkill since the general level of infrastructure as well as the industrial and technological development would not match the output from such a centre. It would be desirable, therefore, to implement a compressed version of the MADC with total outlay of US $ 2 to 3 million. Most of the reduction would be in the area of hardware and software. For example, one could dispense with expert systems, artificial intelligence, gate array/standard cell ASICs, etc. with corresponding reductions in maintenance updates and consumables. The manpower may be reduced only marginally, say 25%.

(iii) Least Developed Countries:

In such cases, it is quite likely that policy and decision makers may have many other more pressing priorities such as food, clothing, housing, etc., in terms of funding. The industrial infrastructure is quite likely to be primitive as compared with the developed world. However, it is precisely such countries where the impact of electronics usage in say, agriculture, food processing, primary health, etc., can be dramatic. It may be advisable to set up a small MADC around US $ 1 to 2 million in such cases. The budget could be shared equally between the capital equipment, maintenance and upgrades on the one hand and the salaries, training, etc., on the other.

55. In fact, for each developing country interested in setting up an MADC, a detailed project report would need to be evolved which would require - as prerequisites - an in-depth study of the local electronics and non-electronics industry; the Government policies, programmes and plans covering science & technology, industry, and trade; the different financing mechanisms available, etc. The project could be financed by the United Nations Development Programme, and UNIDO can play a key role in providing support in the formulation of the detailed project proposals for setting up and operating these centres in the developing countries.

## Table-1
## The World's Top 20 Electronics Companies

| Company | Country | Electronics sales, in millions of US dollars | Electronics as percent of total sales |
|---|---|---|---|
| IBM Corpn. | US | 62710 | 100 |
| Matsushita Electric Industrial Co. | Japan | 31319 | 72 |
| NEC Corpn. | Japan | 24957 | 100 |
| Toshiba Corpn. | Japan | 22674 | 71 |
| Hitachi Corpn. | Japan | 22055 | 43 |
| Phillips NV | N'lands | 21594 | 80 |
| Siemens AG | W.Germany | 19825 | 61 |
| Fujitsu Ltd. | Japan | 18477 | 100 |
| Sony Corpn. | Japan | 16904 | 81 |
| General Motors Corp. | US | 16880 | 14 |
| AT&T Co. | US | 16612 | 46 |
| CGE | France | 13307 | 59 |
| Digital Equipment Corpn. | US | 12943 | 100 |
| General Electric Co. | US | 12369 | 29 |
| Mitsubishi Electric Corpn. | Japan | 11862 | 55 |
| Xerox Corpn. | US | 11602 | 100 |
| Thomson-CSF | France | 11175 | 93 |
| Unisys Corpn. | US | 10097 | 100 |
| Motorola Inc. | US | 9620 | 100 |
| Canon Inc. | Japan | 9593 | 98 |

Source: Elsevier Advanced Technology, Oxford, England.

a) The electronics-only sales have been converted at the 1987 average exchange rate.

b) Equipment sales only; if financial and insurance services are included, the percentage is 66 percent.

Table-2

Share of Top 10 Semiconductor Companies in the World

| Rank | Company and country | Market Share |
|---|---|---|
| 1 | NEC Corpn., Japan | 8.8% |
| 2 | Toshiba Corpn., Japan | 8.6% |
| 3 | Hitachi Ltd., Japan | 6.9% |
| 4 | Motorola Inc., US | 5.8% |
| 5 | Fujitsu Ltd., Japan | 5.2% |
| 6 | Texas Instruments Inc., US | 4.9% |
| 7 | Mitsubishi Electric Corpn., Japan | 4.5% |
| 8 | Intel Corpn., US | 4.2% |
| 9 | Matsushita Electric Industrial Co., Japan | 3.3% |
| 10 | Phillips NV, the Netherlands | 3.0% |
| | Others | 44.8% |

Source: IEEE Spectrum, Jan, 1991.

Table-3
High-end Microprocessors Available with Motorola

| Device | Clock Speed (MHz) | Unit price each for 1000 piece quantity | Surface-mount packaging type |
|---|---|---|---|
| 68020 | 16,20,25,33 | \$47 @ 16 MHz | CQFP |
| 68000 | 8,10,12,16 | \$5.50 @ 8 MHz | PLCC |
| 68HC000 | 8,10,12,16 | \$7.10 @ 8 MHz | PLCC, PQFP |
| 68HCC001 | 8,10,12,16 | \$7.10 @ 8 MHz | PLCC, PQFP |
| 68302 | 16 | \$39.60 @ 16 MHz | CQFP |
| 68881 math coprocessor | 16,20 | \$38 @ 16 MHz | PLCC |
| 68882 math coprocessor | 16,20,25,33 | \$44 @ 16 MHz | PLCC |

Source: Motorola.

## Table-4
## Products Utilising Fuzzy Logic

| Product | Company | Role of Fuzzy Logic |
|---|---|---|
| Elevator control | Fujitec/ Toshiba | Evaluates passenger traffic to reduce waiting time and enhance car announcement accuracy. |
| Golf diagnostic system | Maruman Golf | Selects best golf club for an individual's physique and swing. |
| Video camcorder | Sanyo Fisher/ Canon | Determines best focus & lighting when several objects are in picture. |
| Washing machine | Matsushita | Senses quality & quantity of dirt, load size, and fabric type, and adjusts wash cycle. |
| Vacuum cleaner | Matsushita | Senses floor condition & dust quantity and adjusts vacuum cleaner motor power. |
| Hot water heater | Matsushita | Adjusts heating element to correspond to temperature and amount of water being used. |
| Air conditioner | Mitsubishi | Determines optimum constant operating level to prevent power-consuming on-off cycling. |
| Television | Sony | Adjusts screen brightness, color, and contrast. |
| Handheld computer | Sony | Interprets handwritten input for data entry. |
| Auto transmission | Subaru | Senses driving style & engine load to select best gear ratio. |
| Stock trading program | Yamaichi Securities | Manages stock portfolios. |

Source: IEEE Spectrum, November, 1990

Table-5
Comparison of Different ASIC Methodologies

| | Gate Arrays | Standard Cells | Full-Custom |
|---|---|---|---|
| 1.Chip density | 16-20000 gates | Hundred to many thousand gates | Hundreds to many thousand gates. |
| 2.Percent of wafer pre-processed | 80.90 | 0 | 0 |
| 3.Development cost | $ 10,000 to $ 40,000 | $ 40,000 to $ 1,00,000 | $ 1,00,000 to $ 5,00,000 |
| 4.Ability to make design | Easy, fast and in-expensive | Easy, but some-what more ex-pensive and slower than gate arrays. | Harder,slower and more expensive |
| 5.Unit cost of chip | High | Medium | Low |

Source: Sherlekar, Short-term Course on Designing with Semi-customs ICs, August, 1986, IIT, Bombay.

Table-6
Estimated Comparison of Various System Design Approaches

| | TTL Parts | Gate Arrays | Cell based |
|---|---|---|---|
| System complexity | 20,000 gates | 20,000 gates | 20,000 gates |
| Average gates/IC | 12 | 1500 | 3000 |
| Number of ICs | 1,667 | 13 | 7 |
| Average Pins/IC | 18 | 68 | 80 |
| Total IC pins | 30,006 | 884 | 560 |
| Number of boards | 33 | 1 | 1 |
| PCB cost | $ 165,000 | $ 10,000 | $ 5,000 |
| IC development cost | 0 | $ 260,000 | $ 245,000 |
| Excess development cost | 0 | $ 95,000 | $ 80,000 |
| Ave. cost/IC | $ 0.50 | $ 10.00 | $ 15.00 |
| Other cost/IC | $ 2.83 | $ 20.00 | $ 30.00 |
| Manuf. cost/unit | $ 5,551 | $ 390 | $ 315 |
| Total cost (10.00 units) | $ 55.5M | $ 3.9 M | $ 3.2 M |
| Cost saving | 0% | 93% | 94% |

Source: Dataquest, February, 1986.

Table-7
ASIC Application Markets
(Figs. in $ millions)

| Field | 1990 | 1995 |
| --- | --- | --- |
| 1. Computer | 3,734 | 8,416 |
| 2. Telecom | 2,020 | 4,402 |
| 3. Consumer | 1,740 | 2,354 |
| 4. Industrial | 1,010 | 1,982 |
| 5. Military | 693 | 1,044 |
| Total | 9,197 | 18,198 |

Source: ASIC Technology and News, June, 1991.

Table-8

Factors Influencing the Introduction of Microelectronics in Industrial Sectors

| Sector | Factors favouring the adoption of microelectronics | Factors retarding the introduction of microelectronics |
| --- | --- | --- |
| 1.Chemicals | Improvement in process and quality control-accuracy, reproducibility, safety. | Capital-intensive industry with plants of long life. |
| | New options for automated and/or continuous operation including on-line optimization | Tradition of incremental process innovation. |
| | | Tradition of low-techno-process controls (except petrochemicals). |
| | Some saving of labour. | Low labour intensity. Shortages of maintenance workers and especially instrument and electronic technicians. |
| | Savings in energy and raw materials through better controls (especially on high throughput processes, as in petrochemicals). | Inadequate development of sensors and actuators for some processes and vulnerability of microelectronics to hostile environments. |
| | Improved production management by better information and monitoring systems. | For special chemicals like pharmaceuticals. |
| | Automation in packaging and improved stock-keeping and distribution. | Research intensive industry with little emphasis on production efficiency and much emphasis on product innovation. |
| | Reduced need for work in hostile environments. | High profit margins even with low production technology. |
| | Improved pollution controls. | |

| Sector | Factors favouring the adoption of micro-electronics | Factors retarding the introduction of micro-electronics |
|---|---|---|
| 2. Paper and allied products | Possibility of fully automated production. | Highly manual labour intensive industry subject to trade cycles and low profit margins (in India). |
| | Improved control of processes and quality. | Low labour usage even with low technology. |
| | Savings in energy and in materials, especially in additives. | Lack of suitable sensors and actuators. |
| | Improved materials handling and distribution systems, better waste recycling facilities. | No tradition of innovation. |
| | Possibility of wider range of products through finer control of composition. | |
| 3. Food and drink | Shift towards continous automated production. | Slow rate of plant renewal in relatively capital-intensive and low-profit industry. |
| | Improvements in mechanical handling of fragile products. | High cost of materials and devices. |
| | Improved process and quality control. | Intense competition and pressure from legislation. |
| | Improved control over additives in response to public acceptance. | Labour cost relatively small portion of total costs. |
| | Automation of packaging and distribution. | Highly specialised process and quality variables for which no adequate sensors and actuators exist. |
| | Improved stockholding. | |
| | Some labour saving. | No tradition of process innovation. |

| Sector | Factors favouring the adoption of micro-electronics | Factors retarding the introduction of micro-electronics |
|---|---|---|
| | Saving in energy and materials. | |
| | Shift to process improvement as alternative to product innovation to remain competitive. | Large-volume operations, (for instance, biscuit, bread manufacture), already highly mechanised (not electronically). |
| 4.Plastics and rubber | Improvements in process control, offering savings in energy and materials. | Much of the industry composed of very small plants with very short production runs. |
| | Improved monitoring and control of production process e.g., improved scheduling. | Prices determined mainly by costs of raw materials. |
| | Automated and integrated operations, continuous or semi-continous, with self-feeding and optimization. | Profit margins depressed by intense competition. |
| | Handling machines for feeding moulding presses. | |
| | Improved safety. | |
| | Some labour saving. | |
| 5.Motor vehicles & accessories | Automated warehousing improving stock control. | Industrial relations problems. |
| | Improvement over wide range of production controls, e.g. automated assembly, spot welding robots, automated machining, press transfer machinery. | Shortages of labour with required skills<br><br>Large investment in existing production facilities. |
| | Considerable labour saving, skilled and unskilled. | |
| | Some saving of materials. | |

| Sector | Factors favouring the adoption of micro-electronics | Factors retarding the introduction of micro-electronics |
|---|---|---|
| | Opportunities for Computer-aided design. | |
| | Improved flow of production. | |
| | Possibility of working to finer tolerances leading to improved product quality. | |
| | Improved products incorporating microelectronics. | |
| 6.Metals | Process control and monitoring remote from hostile environment. | Fragmented capital intensive industry with a few large and many small firms. |
| | Improved quality and reproducibility of products. | Small firms have low level of technical awareness in management, strong traditional orientation, and shortage of capital. Industrial relations problems. |
| | Savings in energy and materials, labour saving in some cases. | |
| | Improved safety. | Technical limitations of microelectronics in hostile environments. |
| | Improved working environment. | |
| 7.Textiles | Automated manufacture and continuous operations. Control of manufacture, including stockholding and distribution. | Industrial relations problems. |
| | Material handling. | Strong commitment to existing (often outdated) plant; high capital cost of new plant. |
| | Weaving, printing and dyeing can be made very flexible by computer control. | |
| | Improved speeds and quality control. | |

| Sector | Factors favouring the adoption of micro-electronics | Factors retarding the introduction of micro-electronics |
|---|---|---|
| | Extensive savings on labour. | |
| | Tradition of programmable operations. | |
| 8.Electronics | Improved production control. | Severe competition and considerable import penetration, especially in some components. |
| | Automated machining, assembly and wiring. | |
| | Extensive labour saving (at least in some sectors, notably telecommunications). | Certain areas fragmented and not highly automated. |
| | Extensive know-how available. | Shortage of skills in certain areas. |
| | Product innovation and manufacturing innovation go hand in hand as many mechanical linkages are replaced by electronic logic. | |
| | Semiconductor industry requires adequate environmental and process control which are only possible by use of microelectronics. | |

<u>Source</u>: Proceedings of the National Symposium on Current Practices and Future Trends in Industrial Electronic Systems, CEERI, Pilani, India, September 1989.

## PRODUCT-WISE WORLD MARKET SHARE OF ICs

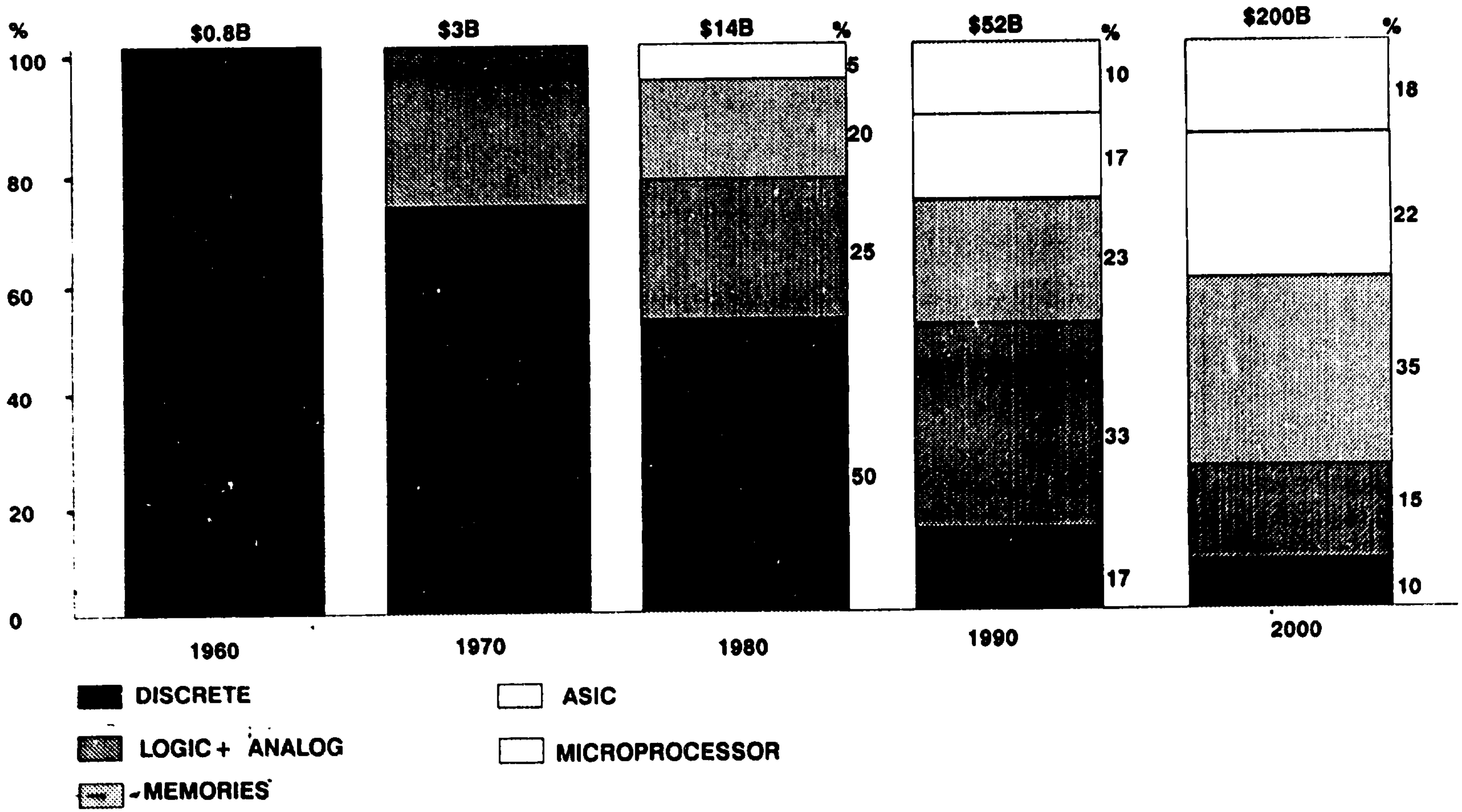



Fig.1

# STEPS IN SELECTING A MICROCONTROLLER

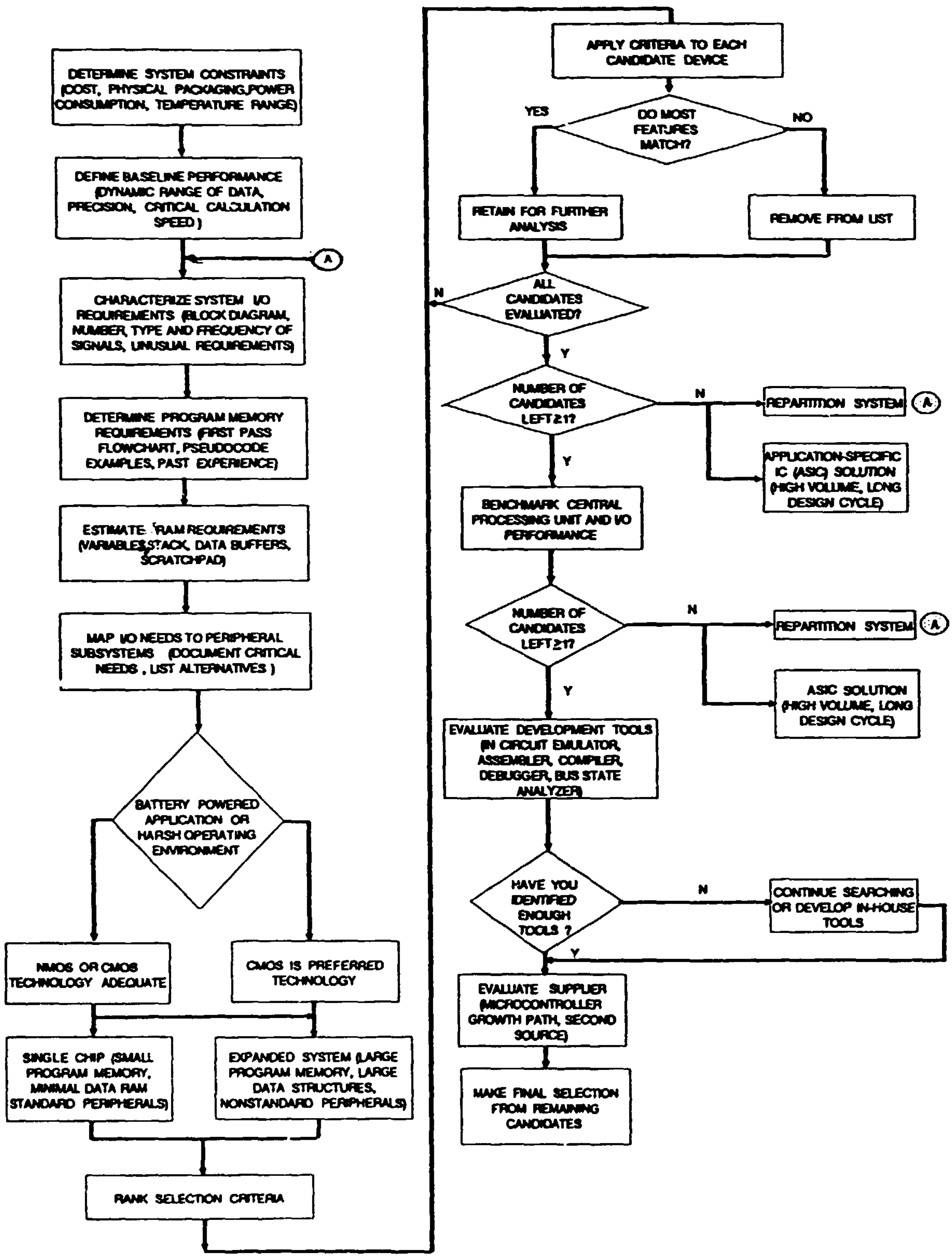
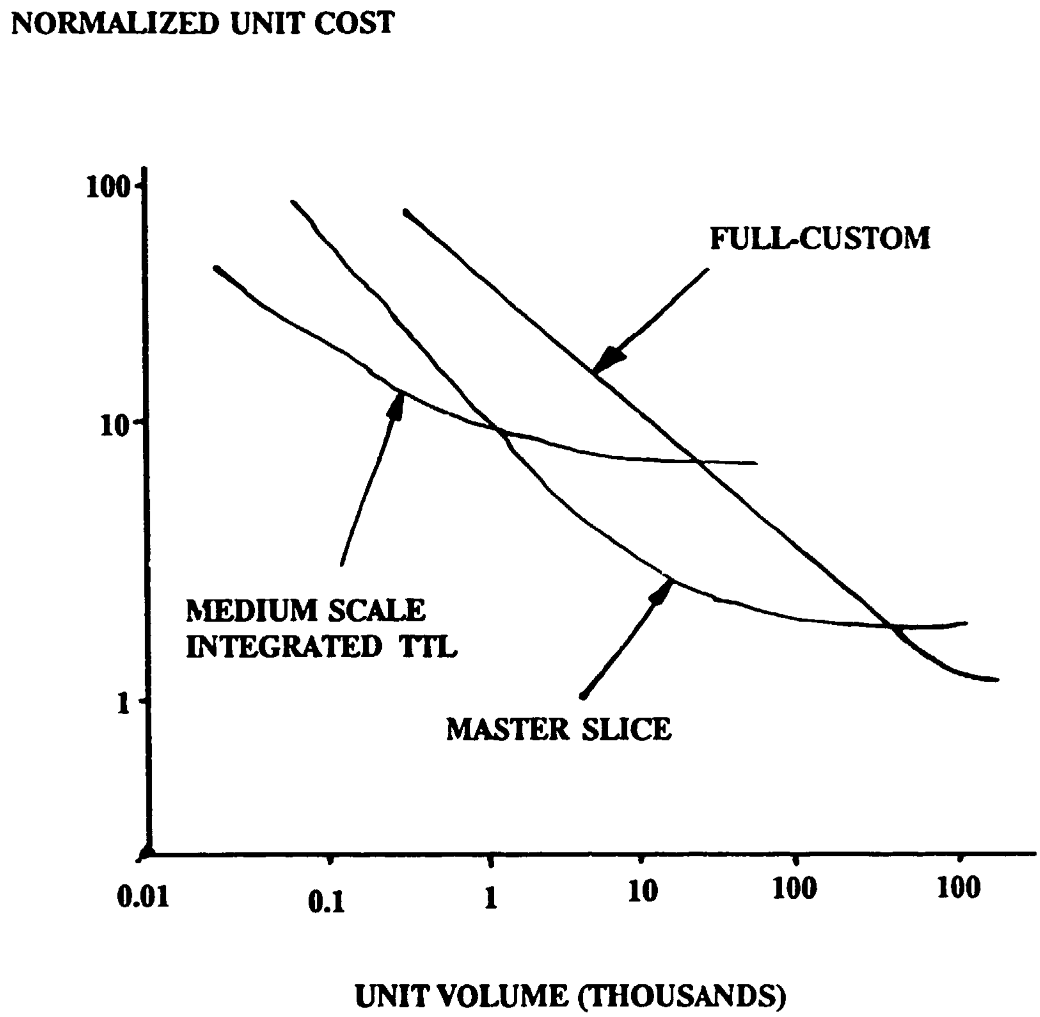



**FIG.2**

**<u>SOURCE:</u> IEEE SPECTRUM, NOV, 1990, pp. 107.**

# INDICATIVE COST COMPARISON OF THE THREE IMPLEMENTATIONS VIZ., STANDARD PARTS, GATE ARRAYS, AND FULL-CUSTOM




SOURCE: SHERLEKAR, SHORT-TERM COURSE ON DESIGNING WITH SEMI-CUSTOM ICs, AUGUST, 1986, IIT BOMBAY.

FIG.3

# CONCURRENT DESIGN METHODOLOGY

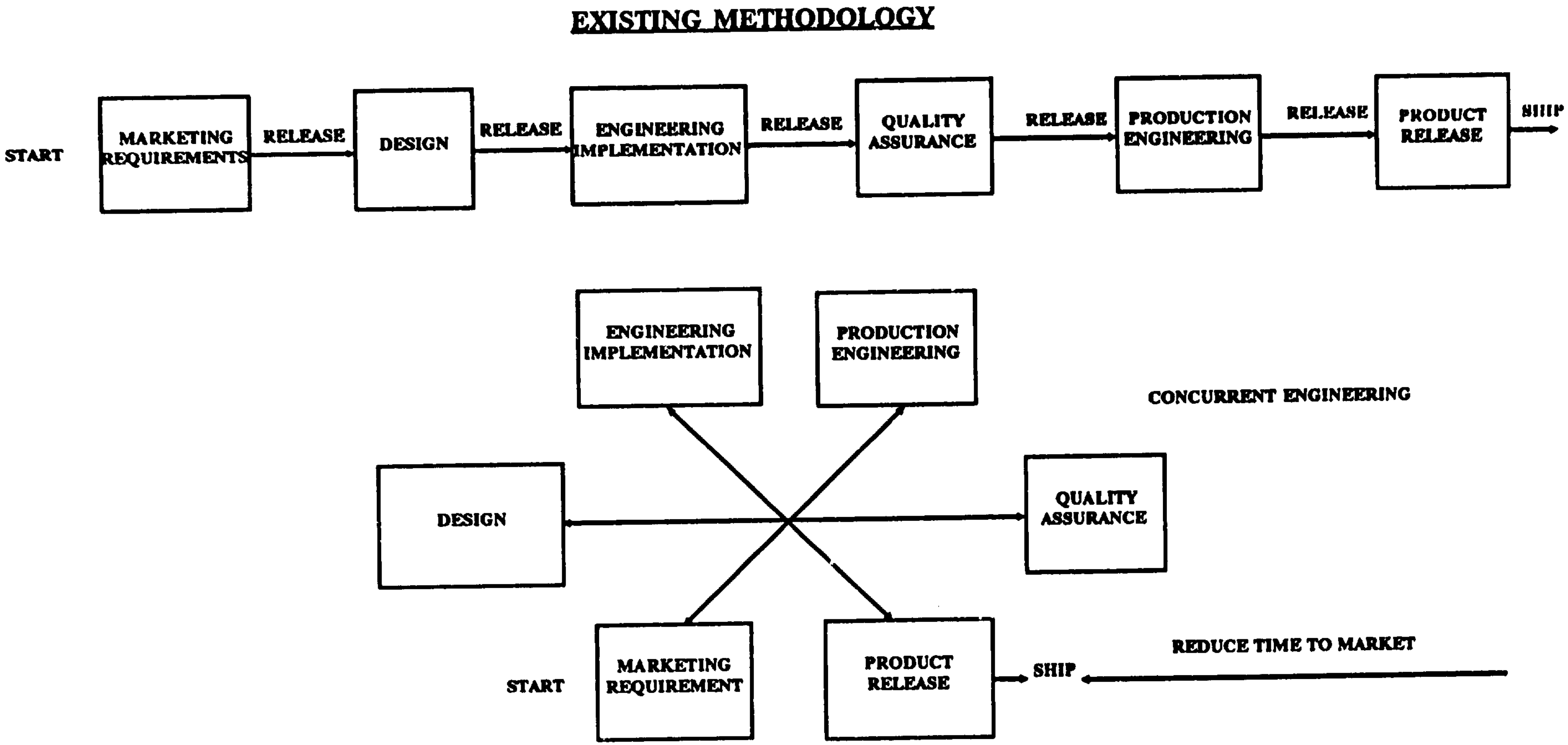



FIG.4

SOURCE: ELECTRONIC DESIGN, JANUARY, 1991.

## TEXTILE QUALITY INSPECTION SYSTEM

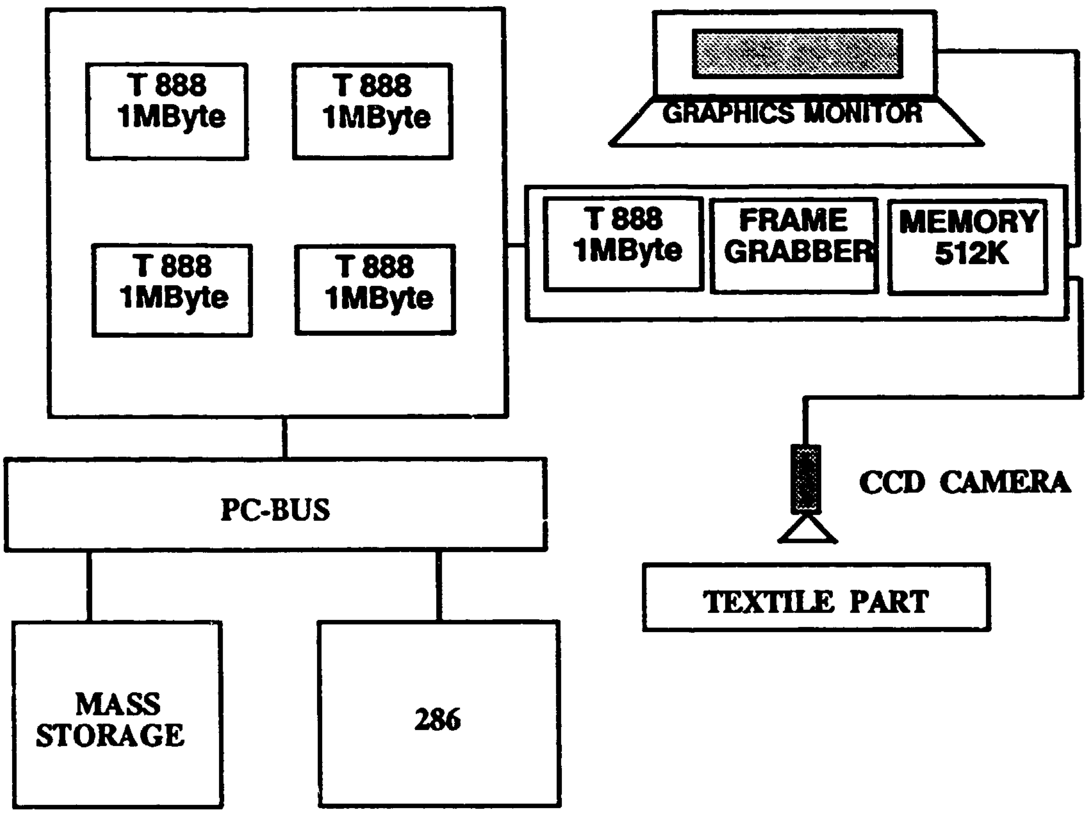
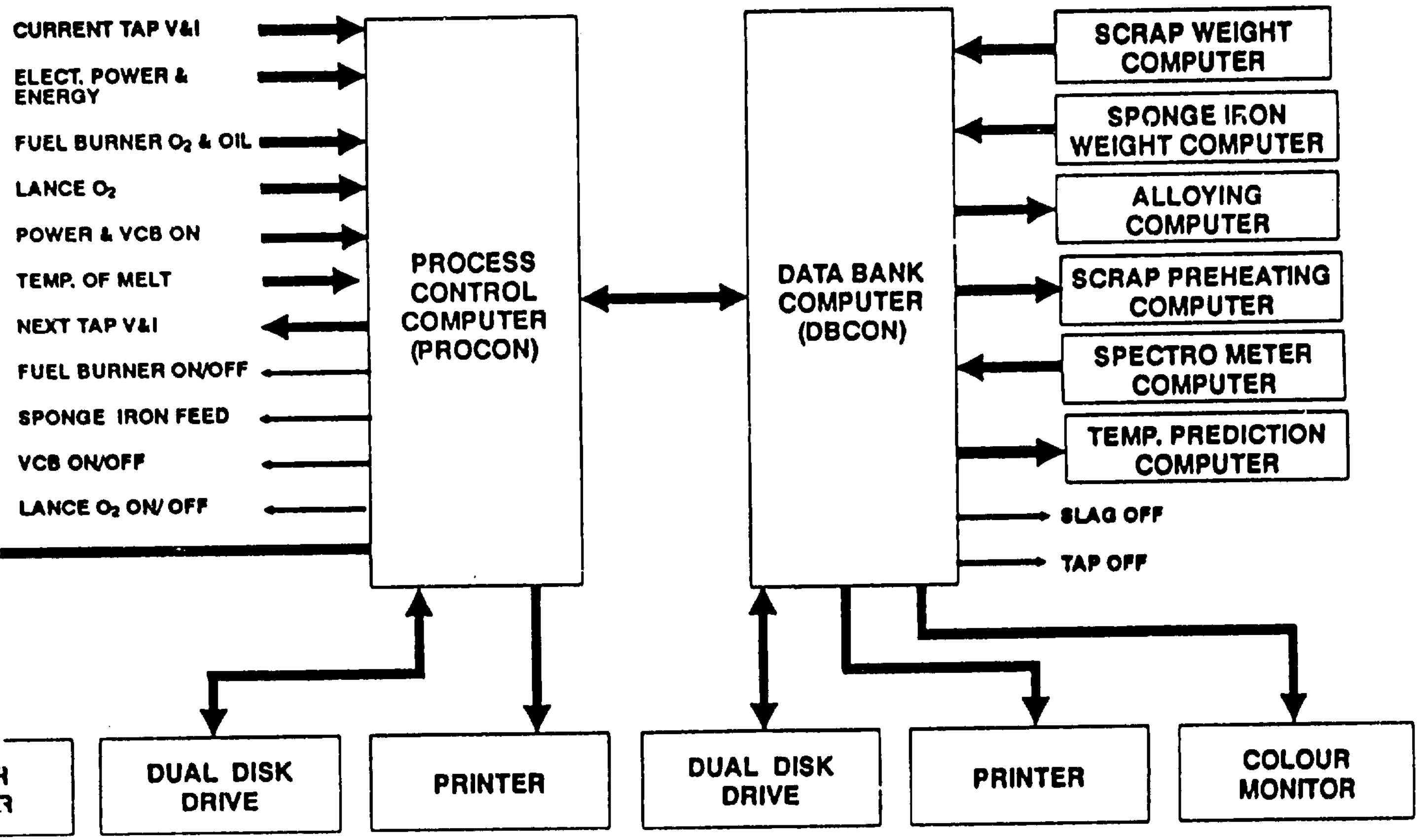



FIG.5

Source: S.Karkanis et.al, Microprocessing and Microprogramming Journal, 28 (1989), pp.247-252.

## MICROCOMPUTER SYSTEM FOR UHPF




SOURCE: Proceedings of the National Symposium on Current Practices and Future Trends in Industrial Electronic Systems, 1989.

FIG.6

UHPF = ULTRA HIGH POWER FURNACE

# EXPERT SYSTEM FEATURES AND EXPERT SYSTEM STRUCTURE FOR PROCESS CONTROL APPLICATIONS

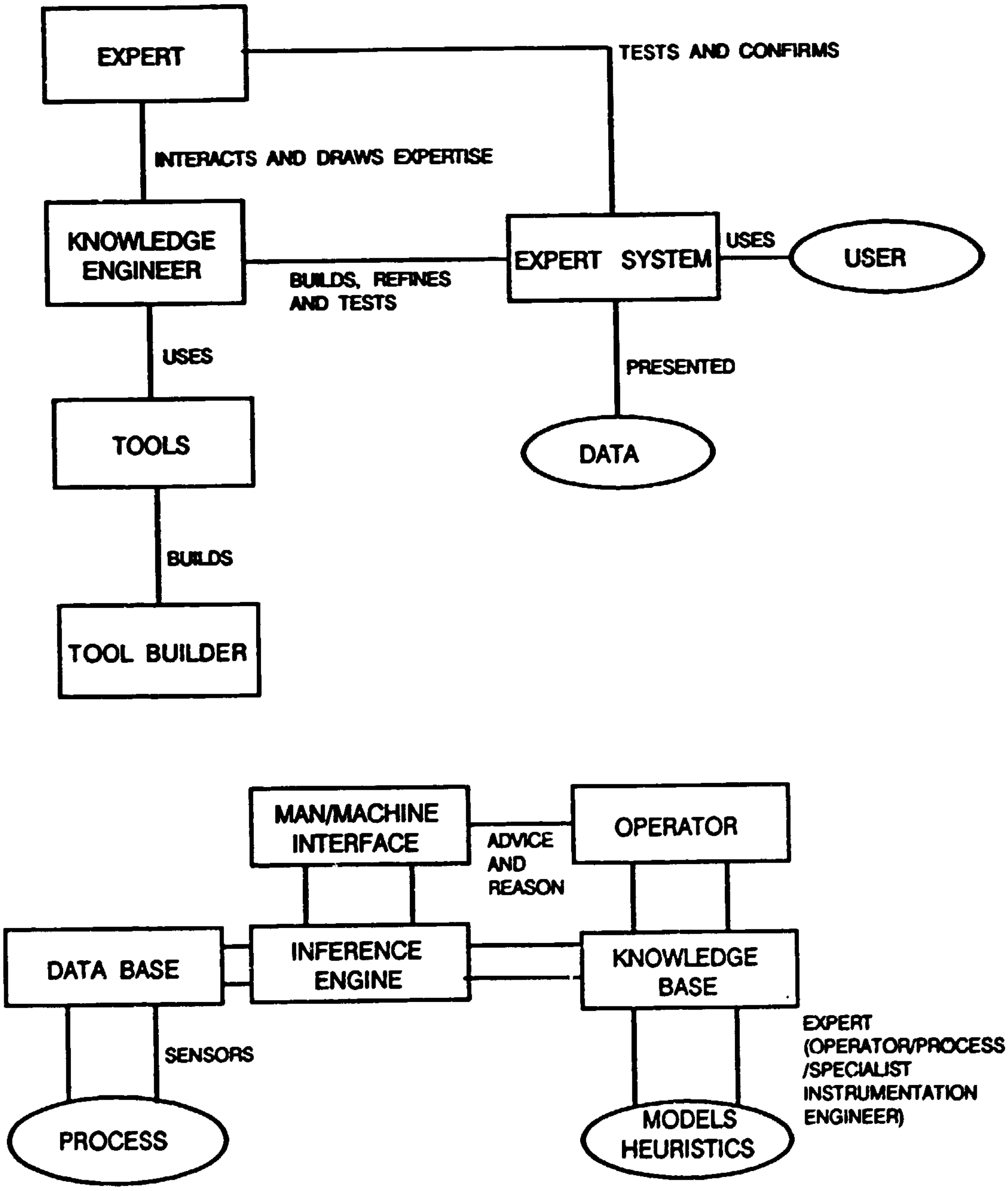



FIG.7

SOURCE: ARTICLE BY Mrs. HEMA KHURANA "EXPERT SYSTEMS FOR PROCESS CONTROL", ELECTRONICS INFORMATION & PLANNING JOURNAL, DECEMBER, 1988

# MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE (MADC)

## ORGANISATIONAL STRUCTURE

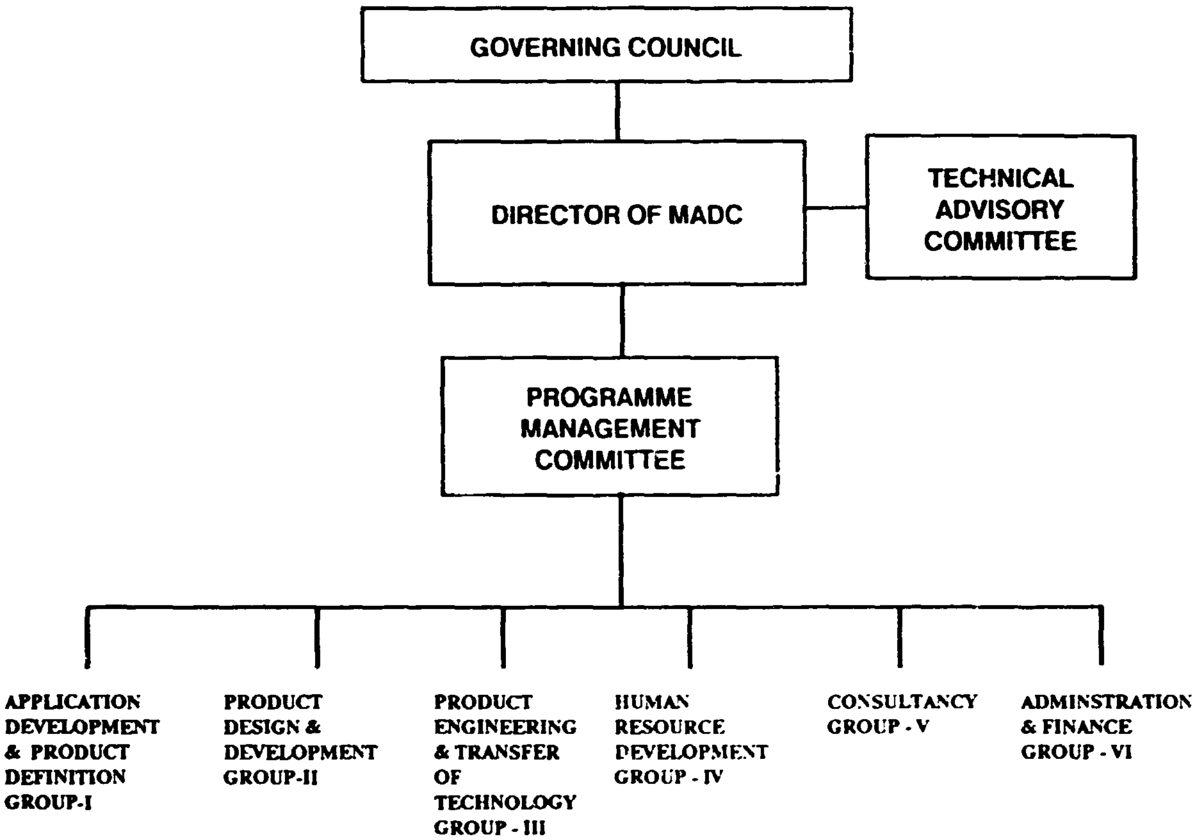
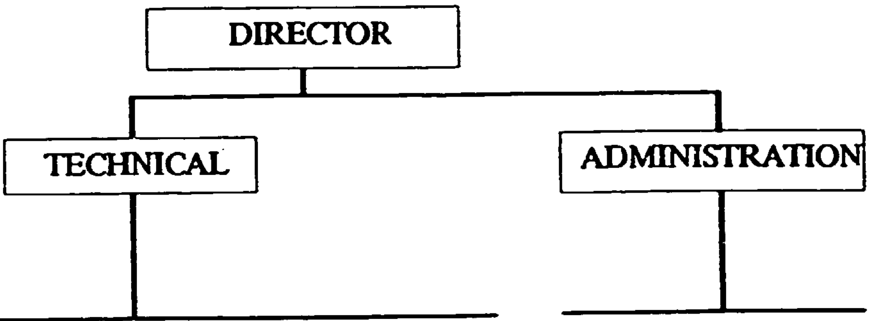



FIG. 8

# MICROPROCESSOR APPLICATION DEVELOPMENT CENTRE (MADC)

## STAFFING PROFILE




| GROUPS | I | II | III | IV | V | TOTAL |
|---|---|---|---|---|---|---|
| GP LEADER | 1 | 1 | 1 | 1 | 1 | 05 |
| PSA | 3 | 3 | 2 | 3 | 1 | 12 |
| SSA | 3 | 6 | 2 | 3 | 2 | 16 |
| JSA | 6 | 6 | 2 | - | - | 14 |
| PROGRAMMER | - | 3 | - | - | - | 03 |
| LAB ASSTT. | - | 3 | 1 | - | - | 04 |
| DRAFTSMAN | - | 2 | 1 | - | - | 03 |
| STENOGRAPHERS | 7 | 3 | 2 | 4 | 2 | 18 |

| | VI |
|---|---|
| ADMN. OFFICER | 1 |
| ADMN. ASSTT. | 1 |
| FINANCE ASSTT. | 1 |
| STENOGRAPHER | 2 |

**TOTAL :**

TECHNICAL-57
SUPPORTING-18
ADMINISTRATIVE-5

**NOTE:**

JUNIOR SYSTEM ANALYST (JSA)- BS or equivalent with 0-2 years experience.
SENIOR SYSTEM ANALYST (SSA)- BS or equivalent with 4-6 years experience.
PRINCIPAL SYSTEM ANALYST (PSA)- BS or equivalent with 8-12 years experience.

FIG.9

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14. **The Development of High Technology in the Asia-Pacific Region** - A Study undertaken by Investec (Taiwan) Ltd.

The following journals regularly carry articles relating to state-of-art of microprocessors, microcontrollers, fuzzy logic, ASICs, microprocessor applications, etc.

IEEE Spectrum.

Electronic Design.

IEEE Transanctions on Indus: :ial Applications.