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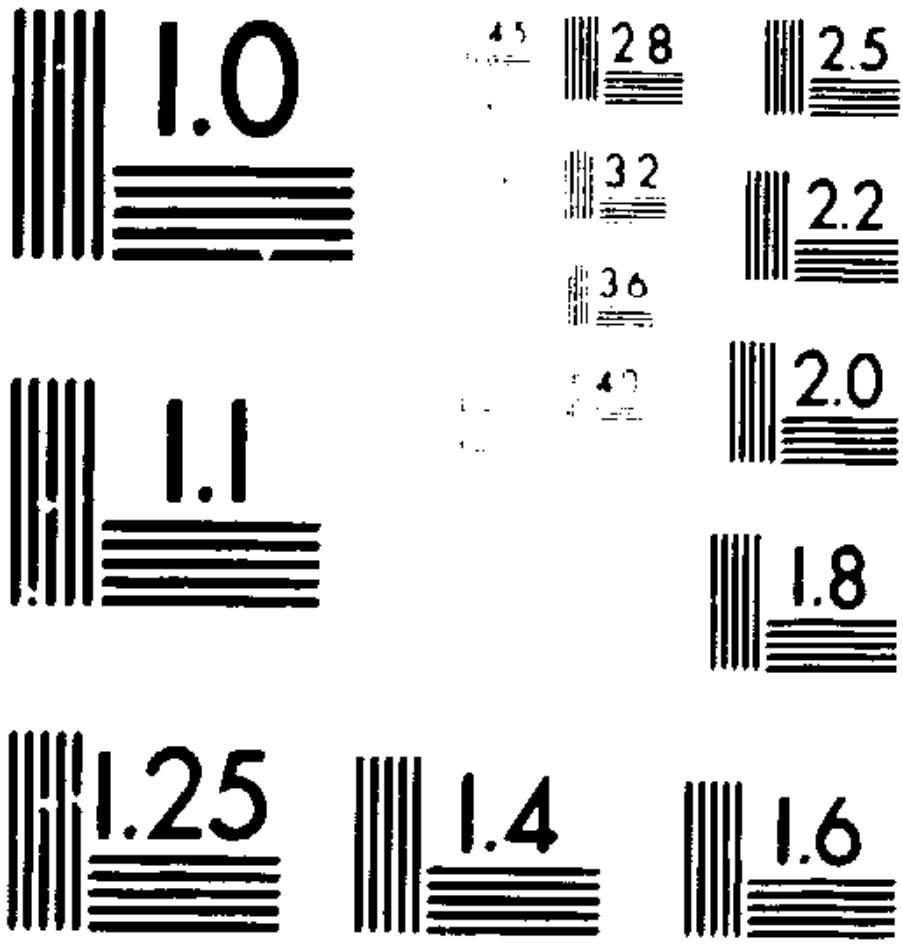

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UNITED NATIONS
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STATE-OF-THE-ART SERIES ON MICROELECTRONICS

No. 2: INDIA*

Prepared for the Technology Programme

by

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EXPLANATORY NOTES

References to dollars ($) are to United States dollars. References to rupees (Rs) are to Indian rupees. In October 1984 the value of the rupee in relation to the dollar was $1 = Rs. 11.70.

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In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used in this study:

Abbreviations

CAD	Computer Aided Design
CADS	Computer Aided Design System
CCD	Charged-Coupled Device
CMOS	Complementary Metal-Oxide Semiconductor
CPS	Central Processing System
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSDN	Circuit Switched Data Network
HMC	Hybrid Microcircuits
IC	Integrated Circuits
LSI	Large Scale Integration
MSI	Medium Scale Integration
NMOS	N-Channel Metal-Oxide Semiconductor
PSDN	Packet Switched Data Networks
PSTN	Public Switched Telephone Network
R and D	Research and Development
SCS	Single Crystal Semiconductor
SSI	Small Scale Integration
VLSI	Very Large Scale Integration
VDU	Visual Display Unit

Organizations

AMI	American Microsystems Inc.
BARC	Bhabha Atomic Research Centre
BEL	Bharat Electronics Limited
BHEL	Bharat Heavy Electricals Limited
CEERI	Central Electronics Engineering Research Institute
CMC	Computer Maintenance Corporation
CMTI	Central Machine Tool Institute
CSIO	Central Scientific Instruments Organization
DCM	Delhi Cloth Mills
ECIL	Electronics Corporation of India Limited
ER and DC	Electronics Research and Development Centre
IBM	International Business Machines
IEEE	Institute of Electrical and Electronics Engineers
IETE	Institution of Electronics and Telecommunication Engineers
IIS	Indian Institute of Science
IIT	Indian Institute of Technology
IL	Instrumentation Limited
ITI	Indian Telephone Industries
NAL	National Aeronautics Laboratory
NCL	National Chemical Laboratory
NCSDCT	National Centre for Software Development and Computing Techniques
NIC	National Informatics Centre
NPL	National Physical Laboratory
OEM	Original Equipment Manufacturers
ORG	Operations Research Group
RCA	Radio Corporation of America
SAIL	Steel Authority of India Limited
SCL	Semiconductor Complex Limited
TIFR	Tata Institute of Fundamental Research
TRC	Telecommunication Research Centre

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S U M M A R Y

The study reviews the state of the art and anticipated future developments of the Indian microelectronics industry as well as research undertaken; applications of microelectronics products nationally developed and existing as well as possible co-operation at regional and international levels in this field.

In the main subsectors of microelectronics industry developed in the country, such as consumer products, industrial products and components, it is reasonable to expect India to become self-reliant in the next few years for most of the needs. The rate of growth in the output of electronics products is high and averaged more than 20 per cent over the past three years. Some of them have developed a number of software packages. A number of software packages have also been acquired from abroad. However, gaps in the software packages still exist and need to be promoted before a comprehensive competence in CAD for LSIs can be claimed. These limitations are, however, not a major deterrent to LSI design.

National R and D in the field is carried out in national research institutes, in the R and D departments of two public corporations (BEL and SCL), in the research laboratories of dedicated departments (e.g. Atomic Energy, Space, Communication, etc.), and in five of the Indian Institutes of Technology. Several industrial and research institutions have set up design capability up to LSI level.

Manpower and training are one of the major bottlenecks in the development of composite technology for ICs. It results mainly from the fact that many trained engineers are more lucratively employed abroad. It is partly balanced by the intensive training in microelectronics technology and use of computers, undertaken by several institutions.

The competence and infrastructure spans the entire gamut of microelectronics viz. IC design and fabrication, applications, software development, system engineering, raw material, manpower, etc. It could share its strengths with other developing countries in the region. It also has a number of gaps in technology and would seek support from other countries which are in a position to bridge the gaps. Countries can also co-operate on a joint programme complementing strengths of each other to achieve a common objective. Broad areas where India can co-operate with other countries have been outlined in the study.

The Government has recognized microelectronics as one of the thrust areas, with the Electronics Commission playing a leading role. During the last few years, the Government has adopted several measures towards promotion of electronics industry. It has adopted a liberal policy towards import of raw materials and equipment not available in the country and has considerably reduced the tariff on such imports. The approach towards know-how collaboration with foreign companies has also been less stringent. A number of fiscal incentives like higher rate of depreciation on plant and machinery than most other industries, duty drawback, etc. have also been provided. The emphasis now is on economically viable scales of production rather than fragmentation of capabilities as in the past. In the coming years, it is expected that there will be a radical transformation in the complexion of the industry in the country with microelectronics playing a key role.

1. INTRODUCTION

The development of point contact transistors in 1947-48 laid the foundation of microelectronics. The point contact transistors were soon replaced by the junction transistors. These miniature solid state devices built on a tiny semiconductor chip could replace bulky and voluminous vacuum tubes in an electronic circuit and thus reduce the size and weight of the circuit. They also provided further advantages of lower power consumption, improved ruggedness, higher reliability and lower cost.

Miniaturisation and the above advantages received further boost with the development of integrated circuits using bipolar technology in 1959 when whole circuits/sub-circuits consisting of several diodes, transistors and passive components on a single chip could be produced. The Metal-Oxide Semiconductor (MOS) technology for ICs was developed in 1963. In the years that followed, the microelectronics industry experienced an explosive growth which still continues unabated. The level of integration in the ICs has been doubling every year, and today half a million components on a single chip is a practical reality. Among the products that have made phenomenal contributions to the industry are microprocessors, semiconductor memories, single chip microcomputers and other standard/custom circuits for data processing, communications and consumer electronics.

In view of the all embracing importance of microelectronics, no nation can develop a strong industrial base without establishing

a sound capability in microelectronics. India recognises the key importance of microelectronics in its development strategy. Although the existing market volumes are not large owing to many socio-economic factors and despite the resource constraints, the country has been making serious efforts in establishing competence over a wide range of microelectronics.

Microelectronics in India started appearing around the year 1970. Since then it has made a remarkable impact in various fields. Innumerable applications have been successfully developed and systems have been used in industrial, scientific and other applications.

The importance of the need for making the hardware readily available to the designers is also not undermined. In fact, keeping this in view, the Government of India has encouraged more than 125 manufacturing units in the small scale and the organised sectors to develop microprocessor based systems, peripherals, general purpose single board computer cards etc. Though at present, there is a large influx of devices, circuits and systems from abroad, it is reasonable to expect India to become self-reliant in a few years to come for most of the needs. Production base for integrated circuits of lower integration level already exists. Necessary facility for the manufacture of large scale integrated circuits is being created which in fact is going to be more than the required to meet the present local demand. The designers have started to look at the indigenous circuit boards and systems for their use.

Government of India regards science & technology as the basis of economic progress. It has recognised microelectronics as one of the thrust areas. During the last few years, the Government has adopted several measures towards promotion of electronics industry. It has adopted a liberal policy towards import of raw material and equipment not available in the country and has considerably reduced the tariff on such imports. The approach towards know-how collaboration with foreign companies has also been less stringent. A number of fiscal incentives like higher rate of depreciation on plant and machinery than most other industries, duty drawback etc. have also been provided. The emphasis now is on economically viable scales of production rather than fragmentation of capacities as in the past.

In the coming years, it is expected that there will be a radical transformation in the complexion of the industry in the country with microelectronics playing a key role.

2. SCOPE OF THE PRESENT STUDY

This report examines the state of the art of microelectronics in the country. The term microelectronics is used to mean integrated circuits - device fabrication as well as applications and covers all levels of complexity viz. small scale integration (SSI), medium scale integration (MSI) & large/very large scale integration (LSI/VLSI).

It will be useful to review the status of microelectronics in the context of the overall electronics environment existing in the country. Towards this end, Section 3 presents a bird's eye view of this industry in the country. The next four sections viz. 4 to 7 are devoted to the technology of manufacture of integrated circuits and cover the existing production status, R&D base, the technology capabilities, availability of raw materials as well as equipment. An overall assessment of the present status and the future possibilities has been made. The coverage is restricted to integrated circuits only and does not include discrete semiconductor devices, like small signal transistors and diodes and high power devices like thyristors, rectifiers etc.

The existing infrastructure for microelectronics development with particular reference to manufacture of hardware and peripherals has been reviewed in Section 8. The proliferation of microelectronics

usage has been so varied that it would be difficult to cover each and every area. However, an attempt has been made in Section 9 to present some of the important applications developed and put into actual use. Several foreign suppliers of computer equipment and technology are indicated in Section 10. An attempt is made to review briefly the R&D activities with regards to microprocessor based instrumentation and process control, computer hardware and software in Section 11. Manpower training has assumed considerable importance in India and some of the important programmes of various organisations have been described in Section 12.

The research and development capabilities covered in this report relate only to the civilian sector. The report is expected to give a comprehensive picture of the microelectronics activities in the country. While efforts have been made to keep the language simple, it is assumed that the reader has the basic concepts of microelectronics technology and applications.

3. PROFILE OF ELECTRONICS INDUSTRY IN INDIA

3.1. Historical Development:

Until about 1970, Electronics in India remained confined to mostly entertainment sector with radio and TV commanding the lion's share. The industry was generally using discrete devices. As a result, the IC production was totally absent. The discrete device production in the country started in 1962 when Bharat Electronics Limited, a public sector company set up manufacturing operation for Germanium diodes and transistors. Production of Silicon discrete devices started in 1966, initially as an assembly operation based on imported chips followed by chips fabrication in 1970.

During the 70s, there has been a significant development of activities in microelectronics. The industry witnessed considerable diversification extending to professional and industrial sectors in addition to expanding its coverage in the consumer sector. A wide range of integrated circuits began to be used. However, bulk of the end products continued to use discrete semiconductor devices or SSI level ICs. Although production of ICs started in 1971, the demand remained low. Due to considerations of economic viability, many types of ICs could not be produced in the country and had to be imported.

The last few years have witnessed the introduction of systems with higher complexity level ICs. The emphasis on industrial electronics has increased. A large number of new systems for communication, data processing, space research, broadcast etc., were produced. However, the production of ICs has not grown significantly both in terms of quantity as well as level of integration. As a result, import of these devices progressively increased. Further, due to the various limitations associated with import, the growth of microelectronics in the country has been a constrained one. A major development during this period has been the implementation of a long pending decision to set up a dedicated facility for LSIs- Semiconductor Complex Limited, a Government of India company at Chandigarh, Punjab. The company has started trial runs and is expected to be in production shortly. When in full production, the company is expected to lead a national effort in the manufacture, design and development of LSIs.

3.2. Industry Perspective :

The production of electronics during 1982 was worth Rs.12,050 million averaging a compound growth rate of 20.5% over the last 3 years. While the data for 1983 is not yet available, it is expected that the growth during the last year will be at least equal to the average growth rate in the preceding years. Sectorwise production of electronics during the last 3 years is given in Table I.

Table I: Production of Electronic Equipment & Components

(Rs. Million)

Sl. No.	Sector	Calendar Year Production 1980	1981	1982
1.	Consumer Electronics	2140	2460	3370
2.	Communication & Broadcasting Equipment.	1845	1540	2550
3.	Aerospace & Defence Equipment	680	690	1085
4.	Computer,Control & Instrumentation.	1600	1885	2420
	Equipment Total	6265	6575	9425
5.	Electronic Components	1630	1730	2140
6.	Production in Export Zone.	165	255	485
	Total	7895	8305	12050

3.2.1 Consumer Electronics

In the consumer electronics sector, 88% of the production in 1982 is accounted for by radio receivers, television receivers and audio tape recorders. Till recently TV transmission was only in black & white. Colour TV transmission was introduced only in 1982. Production of colour TV sets in 1982 was 70,000 numbers worth Rs.400 million. These sets were all based on imported kits. Manufacture of colour TV sets based on indigenous components has been taken up now. Production of black & white TV sets was 0.57 million numbers in 1982. The radio receiver industry stood at 7.09 million units.

The other main items in the consumer sector manufactured in the country are electronic watches and clocks, amplifiers, PA systems, record players, musical instruments, head phones, electronic projectors, audiovisual equipment, video/TV games, TV booster amplifiers, telephone diallers and flash guns.

3.2.2. Components:

A large variety of components used in the electronics industry are produced in the country. These include electron tubes, TV picture tubes, semiconductor devices, resistors, capacitors, potentiometers, connectors, loudspeakers, TV tuners, tape deck mechanisms, deflection components, printed circuit boards, permanent magnets, ferrites etc.,

The country produced Rs.2140 million worth of components in 1982 with the break-up as in Table II.

Table II: Production of Components in 1982.

(in Rs. Million)

Sl. No.	Item	Production
1.	Electron Tubes.	230
2.	Semiconductor Devices.	360
3.	Passive Components	960
4.	Electromechanical & other Components.	590
	Total	Rs.2,140 million.

Details of production of semiconductor devices are given in Table III.

Table III: Production of Semiconductor Devices in 1982.

(in Rs. Million)

Sl. No.	Item	Production
1.	Small signal devices:Diodes and Transistors.	232
2.	Power semiconductor devices	77
3.	Integrated circuits.	26
4.	Rectifiers.	10
5.	Opto-electronics/display devices	1
6.	Other semiconductor devices (Solar cells,microwave devices etc.)	11
	Total	Rs.357 million

There are, at present, about a dozen manufacturers engaged in production of semiconductor devices including discrete small signal, power devices and ICs. In the case of small signal devices and some power devices, most of the country's requirements are met by indigenous production. In respect of ICs, however, the indigenous production at this stage is inadequate and hence they have to be imported. However, this situation is expected to improve considerably in the near future.

3.2.3. Computers, Control and Instrumentation

The computer, control and instrumentation sector has achieved a production level of Rs.2420 million in 1982. A significant feature of this growth has been a 68.4 per cent increase in the indigenous production of computer systems and microprocessor based systems. In terms of value, the production of computers (including microprocessor based systems) has reached Rs. 520 million in 1982.

A break up of the production of different categories of equipment is given in the Table IV.

Table IV : Production of Computers, Microprocessor Based Systems

(in Rs. Million)

Sl. No.	Item	Production 1982.
1.	Data Processing Systems (Large/Mini/Micros) Peripherals.	370
2.	Microprocessor based Systems (Data Acquisition, Business and Others).	144
3.	Electronic Teaching Aids.	6
	Total	520

The production of process control equipment, power electronics and special application instruments has grown at the rate of 20 percent. The production of these items has reached Rs. 1830 million in 1982 as can be seen from Table V.

Table V : Production of Process Control, Power Electronics and other instruments

(in Rs. Million)

S.No.	Item	Production. 1982
1.	Electronic measuring Instruments.	279
2.	Medical electronics equipment.	129
3.	Analytical instruments	20
4.	Special applications.	80
	Sub-total.	510
5.	Process control equipment.	538
6.	Power electronics	624
7.	Industrial electronics, automation and control.	78
8.	Miscellaneous.	60
	Total	1830

3.2.4. Communication & Broadcasting:

The production of items in the communication and broadcasting sector has shown a substantial improvement in the year 1982 having reached Rs.2550 million. The details are given in Table VI.

Table VI: Production of Communication and Broadcasting Equipment

(in Rs. Million)

Sl. No.	Item	Production 1982
1.	Broadcasting Equipment (Radio/Professional).	96
2.	Communication equipment (Line/Power line/Radio etc).	2459
	Total	2550

4. PRODUCTION OF ICs

So far Bharat Electronics Limited, Bangalore, a Government of India undertaking has been the only production organisation doing complete processing of ICs starting from chip manufacture. Some companies in the private sector, however, have been doing assembly operation based on imported chips. This year, Semiconductor Complex Limited, Chandigarh, the newly set up Government company is expected to start production of Large Scale Integrated Circuits (LSIs).

4.1. Bharat Electronics Limited (BEL), Bangalore :

The manufacture of integrated circuits started in the country in 1971 when BEL fabricated the TTL 7420 IC with the know-how developed by TIFR. At about the same time, BEL entered into a contract with RCA for know-how for ICs using bipolar and CMOS technologies. Since then it has produced over 50 types of bipolar ICs and 16 types of CMOS ICs many of them with indigenous efforts. Among the bipolars produced by BEL, 20 types are of digital TTL version and the remaining are of the linear type for applications in TV, AM/FM radio, multiplexing applications and voltage regulation.

The production of CMOS ICs started in 1977. The initial production was in 16 pin dual in-line packages, but subsequently a more reliable frit seal package was adopted which could meet the high reliability defence requirements. The CMOS ICs of BEL include eight chips in CD 4000 series which is a functional analogue of TTL 7000 series.

The ICs produced by BEL so far have SSI/MSI level of complexity. In addition, it has fabricated a prototype watch chip which has LSI capability. In the next few years, it proposes to manufacture microprocessors and memory chips using RCA's technology in addition to several new circuits of MSI level under design in-house currently.

The total investment by BEL on production facility including design, mask making, wafer fabrication, assembly and testing is Rs.70 million. Currently its production is at 1 to 2 million level. At this level it has considerable surplus capacity.

4.2. Semiconductor Complex Limited (SCL),Chandigarh

Semiconductor Complex Limited set up by Government of India would shortly start production of Large Scale Integrated Circuits. It has entered into a technical collaboration agreement with American Microsystems Inc. (AMI), Santa Clara, USA, for the transfer of 5 micron CMOS & NMOS silicon gate technology. The agreement also includes,at SCL's option within 4 years, transfer of more advanced 3 microns CMOS & NMOS silicon gate technology. SCL also proposes to enter into bipolar area at a later date.

The company would undertake manufacture of a broad range of standard LSIs including watch chips, calculator chips, telecom chips, memories, microprocessors and speech synthesisers. The range of products would also include custom LSIs, modules and sub-assemblies based on LSIs, gate arrays and standard cells.

In some cases, while the company may start with the standard products available , the specific requirements of the Indian electronic industry may require redesign of these products at a later date.

The initial investment for plant and machinery at SCL is Rs.350 million. The capacity of the plant is 9 million devices per year, which can be raised to 20 million level by addition of balancing equipment. The production in the initial few years is, however, expected to be around 5 million units per year.

4.3. Economics of IC Production

Integrated circuit technology is highly capital intensive in nature requiring large injection of investment periodically. For an optimum growth of the industry it is essential that the industry is economically viable which calls for large production volumes.

The production level of ICs in the country has remained low during the entire decade of 70s. The annual output of BEL during this period has been less than 0.5 million units. It started increasing gradually from 1980. This year, the production is expected to reach 2 million units valued at Rs.30 million.

This production level is less in order of magnitude than the international levels, existing in average plants. Among the reasons

for low levels of production of ICs in the country so far are :

1. Most of the high volume electronic systems made in the country are based on discrete devices. However, a progressive shift towards ICS is now discernible.

2. Various ranges of electronic systems require a large variety of types ,only a fraction of which is covered by indigenous production and the rest has to be imported. The users have a tendency to import the indigenously available integrated circuits also along with the others as a complete package.

3. Due to the low levels of production, the cost of production of ICs which is highly scale dependent is significantly higher than the international prices which in turn constrains the demand.

4. Most of the critical raw material is imported. Besides procedural difficulties in procurement, the import tariffs raise the cost of raw material making the production cost higher . It is,however,to be pointed out that during the last few years, the Government has adopted a more liberal policy in respect of imports of raw materials.

5. Resource limitations at the levels of the average individual as well as the nation as a whole.

5. TECHNOLOGY INFRASTRUCTURE

5.1. The R & D Base

While BEL has already a vertically integrated facility covering design, mask making, wafer fabrication, assembly and testing upto the level of MSIs, SCL is building up a comprehensive production and R & D base up to the level of LSI/VLSIs. The BEL facility can be upgraded to LSI level by marginal additional investment. It has been carrying on R & D activities in addition to drawing on the know-how provided by RCA. The R&D wing of SCL will undertake LSI/VLSI design and projects aimed at establishing and upgrading the capability of the company for meeting the various needs of the country.

In addition, there are several other organisations in the industrial and R & D sectors having strengths of varying levels in some or all the segments of the technology. These organisations include Central Electronics Engineering Research Institute, Pilani, Tata Institute of Fundamental Research, Bombay and Indian Telephone Industries, Bangalore. In the academic sector, Indian Institutes of Technology (IITs) at Delhi, Kanpur, Kharagpur, Madras and Bombay have got fairly extensive facilities. Barring a few gaps, the infrastructure in these organisations taken together is capable of developing ICs upto the LSI level of complexity.

5.1.1. Central Electronics Engineering Research Institute (CEERI), Pillani

CEERI is a national laboratory set up by the Government of India for advanced R&D in electronics. The development work on ICs started in 1967. Initially, the work was limited to the study of certain components required for IC technology. Some simple circuits like TTL gates were successfully fabricated. In 1976, the institute initiated a programme on "Advanced Technology for Semiconductor Devices" with joint support of Government of India and UNDP. It has since set up a complete line of equipment including computer aided design, mask making, wafer processing, ion implanter, encapsulation and testing. The total investment on capital equipment is about Rs.50 million. Its basic interest lies in NMOS process and has already developed some circuits of LSI complexity.

5.1.2. Tata Institute of Fundamental Research (TIFR), Bombay

TIFR has built up an active group and a strong infrastructure in IC design and fabrication. The first IC made in the country by BEL, the bipolar TTL 7420 was developed at TIFR in 1971. It has a composite facility to handle up to 4 micron geometries. It has, on its own efforts, fabricated an ion implantation system which can accelerate ions upto 150 kev. It has also developed, in-house, a computer aided design system which is similar to the commercially available system Applicon. Using this system, one can lay out and process LSI designs. The institution has processed software packages from abroad and has implemented the same to aid LSI design. Some

of these packages have been installed at other institutions also.

TIFR is currently working on CMOS metal gate and silicon gate technologies. It has in hand R&D projects on dielectric isolation technology, CCDs for imaging and design automation.

5.1.3. Indian Telephone Industries (ITI), Bangalore

ITI a public sector company is a leading manufacturer of telephones and communication equipment. With the rapid breakthroughs in technology taking place in this sector, ITI has decided to undertake R&D in LSIs with a view to keep its communication systems design at the state of the art level.

It has a strong group working in the design of LSI sub-systems using CAD. The company is now setting up a pilot line for the fabrication of custom LSI circuits. The integrated facility costing about Rs.40 million consists of CAD with interactive graphics, mask fabrication system, photolithography, diffusion, ion implantation, assembly and testing systems. Its programme envisages development of process technologies adaptable for custom-design of sub-systems in transmission, telephone and switching equipment. To begin with, it will establish a CMOS silicon gate 5 micron process. The company is already engaged in the development of expertise in semi-custom LSI design using standard cells.

5.1.4. Indian Institute of Technology(IITs)

There are five IITs located at different geographical regions viz., Delhi, Bombay, Madras, Kharagpur and Kanpur. These are premier institutions of engineering and technology with high academic standards matching well with leading academic institutions in developed countries. All these institutes have basic device processing facilities and are carrying out research studies as well as teaching at graduate and post-graduate levels.

IIT Delhi has developed a degree of competence in MOS analog signal processing components around NMOS technology and some key MOS LSI processes such as oxides including characterisation. The institute has recently nucleated active programs in LSI design area including digital system software, layout, MOS circuit design , standard cell design etc. It has also a strong group working in the area of microlithography. IIT Kanpur, Kharagpur and Madras are engaged in device modelling and unit processes. IIT Kharagpur has a programme in Group III-V materials and devices. IIT Madras over the last few years is laying emphasis on CAD with the assistance of Tata Institute of Fundamental Research,Bombay. Many circuits based on the CMOS silicon gate technology have been designed by students of the institute. IIT Bombay has expertise in microwave semiconductor devices. It plans to work on device technology also.

5.2. Technology Capabilities

The main segments of technology where a high level of competence is required are (i) Design of ICs and mask making, (ii) Wafer fabrication. Each of these areas has several fundamentally different approaches which are further subject to rapid changes. The technology of IC production also involves packaging, testing and evaluation. While significant breakthroughs in respect of equipment are taking place in these areas, as well, these mostly relate to increasing the throughput and reliability through automation. Equipment of various sophistication levels is available depending on the scale of operation.

In the following, the capabilities of technology existing in the country are examined.

5.2.1. Design of ICs

Design of circuits at high levels of integration like LSIs requires the use of Computer Aided Design System. Automated design of engineering systems can speed up design innovations by saving a number of man years of routine work and increase the efficiency and precision. The performance of a circuit under development can be predicted and the design optimised by computer simulation and analysis before the prototype is built.

Several industrial and research institutions have set up design capability up to LSI level. The organisations working in this area include ITI, Bangalore, BEL, Bangalore, CEERI, Pilani, and TIFR, Bombay, SCL, Chandigarh, IIT Delhi, IIT Madras & IISc, Bangalore. Some of them have developed a large amount of software packages. A number of software packages have also been acquired from abroad. However, gaps in the software packages still exist and need to be promoted before a comprehensive competence in CAD for LSIs can be claimed. These limitations are, however, not a major deterrent to LSI design.

Several MSI circuits have been laid with the use of CAD. Some of the circuits that have been laid are :

TTL circuits (20 types), balanced modulator, audio amplifier, tape recorder circuit, CMOS clock circuits, 3 pin regulator, telephone dialler, telephone amplifier and coder/decoder. While a number of these designs have gone into production, trial fabrication of some of them has been done at silicon foundries abroad.

Designs based on standard cells and gate arrays have also been undertaken. Design of LSIs, standard as well as custom/ semicustom, will be a major activity in the R&D programme of SCL. The company would also undertake software development.

TIFR has developed a CAD system with interactive facility which is equivalent to the commercially available system Applicon. The institute is now engaged in the development of design automation system for VLSIs with complexities up to 10,000 gates. The project

envisages development of design tools for geometric, logic and circuit design which can be integrated to realise VLSIs.

Although several institutions in the country possess CAD facility, the competence for IC design is limited to a few individuals in each of these organisations. There is a need to significantly increase the manpower base in this area.

The Government of India has launched a Computer Aided Design Programme with the support of UNDP. The outlay consists of Rs.34 million contributed by Government of India and $ 1.54 million by UNDP. The programme which is fairly general covering other areas as well involves R&D for CAD applications in mechanical engineering, heavy engineering, real time control systems, chemical engineering, metallurgical engineering in addition to electronics and integrated circuit design. The project which started in 1983 is of four years duration. It is being implemented at several centres and will provide training/ education facilities for CAD and establish CAD software exchange system through software library.

The chip fabrication technologies have become fairly standardised all over the world although unit processes/technologies are undergoing breakthroughs periodically. In view of the enormous possibilities of use of IC chips in new applications on the one hand, and large investments required in chip production on the other hand, the concept of decentralised design centres and centralised chip production facilities (silicon foundries) is gaining momentum

the world over. The country plans to set up a chain of design centres. Fabrication of chips on the designs from these centres will be done in silicon foundries abroad till a provision is made in the country. It is expected that SCL and BEL would start functioning as silicon foundries in the near future.

The design area is considerably labour intensive requiring highly competent personnel. The competence in design is cumulative in nature. With its low wage rates and high competence level, India is favourably placed in this area. The country can provide design services to both the developed as well as the developing countries.

5.2.2. Mask Making

Manual mask making facilities exist in many organisations in the country. The current capability in the country in mask fabrication is based on pattern generator and photorepeater which have been in regular use at BEL,Bangalore for several years now and lately, at CEERI,Pilani. Both the organisations have CAD facilities as well which generate the mask drawings on magtapes. These magtapes serve as the input to the pattern generator which generates the pattern on a high resolution glass plate for making working masks.

With these systems, one can make chrome/emulsion masks of size 6" x 6" with a resolution of 1 micron and a maximum die size

of 6 mm x 6 mm. The existing facilities will be adequate for the next few years. However, when the transition to 3 micron technology takes place, there will be a need to augment mask fabrication capability based on electron beam technology.

5.2.3. Wafer Fabrication

Wafer fabrication equipment in a conventional facility include diffusion furnaces, chemical vapor deposition systems, contact photolithography equipment, wet etching and vacuum evaporation systems. The feature size provided by this kind of facility is 10 to 7.5 microns. The advanced facilities which provide feature size down to 2 microns include in addition to the above, ion implantation system, projection photolithography equipment, dry etching, vacuum sputtering and electron beam metalisation. Some of the more advanced equipment are X-ray lithography system, electron beam lithography system, electron beam writing on wafers. These equipment provide still finer feature size. At this stage they are mostly used at the R&D level. Internationally, the size of wafers used has increased from 2 inch diameter in 1971 to 4 inch in 1981 and is rising further to 5 inch and 6 inch.

The country has competence to process wafers up to 7.5 micron and comprehensive facilities exist at several organisations in industry, R&D and academic sector. The equipment at these organisations has been in general, suited to the processing of wafers of maximum

diameter of 2" only. This capability can be raised to 3" diameter without significant additional investment. Some of the R&D organisations have a few advanced equipmont like ion implantation system, dry etching,vacuum sputtering and electron beam metallisation which are in regular use.

The wafer fabrication facility at SCL is fairly contemporary and would process wafers of 4" diameter although most of the equipment is capable of handling 5" diameter wafers. The facility would provide feature size of 5 microns to begin with and is expected to progress to 3 microns by 1985-86.

Whereas the fabrication facilities in the world have a considerable degree of automation in handling of wafers, manual handling has been , so far, adopted in India. Manual handling causes reliability and yield problems. The newly set up company SCL would introduce automation at all critical steps.

5.3. Hybrid Microcircuits (HMCs)

Hybrid microcircuits are complete functional modules with various active & passive devices interconnected by a thick film array on an insulating substrate. The active devices can range from discrete devices to complex LSIs and can be in chip form or packaged form.

HMCs offer most of the advantages of IC technology as well as printed circuit boards. The basic processes of fabrication are

screen printing, drying, and firing thick film pattern on a single or multilayer substrate, attaching active and passive components and packaging. They find applications where monolithic ICs cannot be fabricated on account of uneconomic volumes or on some technical considerations. Much of the attraction of HMCs lies in the low capital cost and flexibility of the thick film processes. New and modified circuit designs can be quickly and easily made. These advantages are ideally suited to India where demand volumes are low. HMCs have established key importance in communications and space research. They have also entered the automotive market, medical electronics, instrumentation and industrial controls.

About a dozen organisations in the country have facilities for fabricating HMCs primarily for in-house use. The more notable among them are BEL & ITI in the production sector and CEERI in the R&D sector who besides meeting their internal needs have also fabricated HMCs for other users.

BEL & ITI have been regularly producing HMCs for the last few years. While BEL has produced hybrids for several application areas e.g., audio frequency amplifiers, radio frequency amplifiers, resistor networks and filters, ITI has mostly concentrated on communication circuits. Another public sector company, Electronics Corporation of India Ltd., Hyderabad presently has a modest facility suitable for simple circuits. However, it has already taken action to augment the facility with advanced equipment.

CEERI has developed capability of fabricating circuits of high complexity. Some of the HMCs developed by it include TV tuner,

click suppressor circuit for use in telephone, specific circuits for telemetry and voltage controlled oscillator.

The equipment at all the facilities in the country can process only single layer HMCs. There is at present no capability to fabricate multilayer circuits which becomes necessary at high integration levels. Further, most of the equipment is geared for low-level production with manual/semiautomatic operations. The typical features of HMC fabricating capability in the country are: line width 300 microns minimum, and spacing between two lines 500 microns minimum.

The current status in the world is multilayer capability with much finer line width (typically 100 microns) and resolution (typically 125 microns). However, the existing set up in the country meets most of the present requirements.

There is at present no academic organisation providing courses in HMCs. Indian Institute of Science is shortly acquiring an elementary facility in this area. It plans to include HMCs in its curriculae in this academic year.
It would also provide training to enterpreneurs and engineers from industry.

5.4. Manpower Situation

Highly specialised and motivated manpower is an essential prerequisite for healthy growth of the IC industry. In this sense, the country has in the past not been favourably placed despite creation of facilities at a number of places. The bright engineers after acquiring the basic training have a tendency to go abroad on more lucrative assignments. There has also been lack of incentive among students to undertake IC technology as a major discipline. As a result, the lack of adequate manpower of appropriate calibre has been a major bottleneck in the development of composite technology for ICs.

The above situation has been mainly due to limited opportunities in the past as the production of ICs was at a low level and was restricted to SSI/MSI range of complexity. Nevertheless, there are certain pockets where competent people with high level of expertise in certain segments of technology exist. The country is now embarking on a major programme of LSI production and development with the establishment of SCL. Plans are now being drawn to develop advance technologies indigenously to meet the needs of the country.

The existing academic base comprising of the five IITs, IISc and some universities and engineering colleges possess enough infrast-ructure to meet the challenges of the future. In-house training at R&D and production organisations can also be provided. There is need to coordinate activities and bring about linkages between various institutions. Appropriate incentives will also need to be provided to promote and retain the competence in this area.

6. MATERIALS & EQUIPMENT

6.1. Materials

Integrated Circuit industry uses a large number of raw materials in varying quantities. They can be broadly divided into the following categories :

(i) Single crystal semiconductors,

(ii) Chemicals,

(iii) Gases,

(iv) Dopants,

(v) Photolithography materials,

(vi) Ultrapure Metals,

(vii) Quartzware & Teflonware,

(viii) Packaging & Assembly materials.

Easy availability of all the essential raw material is a prerequisite for a successful IC development programme. The country at present depends on imports for most of its requirements of critical raw materials. Although some infrastructure for the production and R&D of these materials exists in the country, it needs to be considerably strengthened. In the following, the status in respect of the materials is reviewed.

6.1.1.Single Crystal Semiconductor

At present silicon is the most important semiconductor material used in IC fabrication. Gallium Arsenide is another important base material for IC fabrication.

Single crystal silicon semiconductor is being produced at two government run organisations viz., BEL, Bangalore, and Bharat Heavy Electricals Limited (BHEL) Bangalore for several years. ECIL, another public sector company has also been, in the past, producing this material but has suspended production a few years ago. However, the production in BEL & BHEL is mainly for in-house consumption. The production at BEL meets only a small part of its requirements with the rest being imported. BHEL uses the material in the manufacture of power devices like rectifiers and thysistors.

Recently three companies in the private sector have come up for merchant supply of silicon, single crystal and wafers, for the microelectronics industries. Some sample quantities have been supplied to users. They can produce wafers up to 4" diameter. Commercial production is expected to start soon. It is likely that the Government of India also sets up a facility to undertake production and R&D of all types of silicon materials for IC production as well as for photovoltaics.

While the country is still importing most of its requirements of single crystal silicon, it is expected that the country would be self-reliant and produce surplus as well in the near future.

There is at present no production of gallium arsenide, in the country.

6.1.2. Chemicals

The country has a good infrastructure for the production of chemicals, including electronic grade. However,at this stage, due

to low requirements of the electronic grade chemicals, many of them are not being made in the country.

Chemicals like methyl alcohol, trichloroethylene, acetone, isopropyl alcohol, ethyl alcohol, xylene, toluene, ectasolve acetate, transene, hydro-chloric acid, sulphuric acid, nitric acid, hydroflouric acid, hydrogen perooxide , ammonium hydroxide etc., of Analar/Electronic grade are being made. Several companies in the private sector are supplying these chemicals. At this stage, due to low off-take by the semiconductor industry, the prices of these chemicals are generally higher than the international prices by a factor of 1.5 to 3.

6.1.3. Gases

The IC processing requires very high purity gases. The main gases which are required in large quantities are nitrogen, oxygen, hydrogen, and argon. These gases are available in the country. However, at this stage, the purity level is not consistent and the prices are high compared to the international prices. These gases are supplied in cylinders unlike in other countries where some of them are generally supplied in liquid form which is more economical.

6.1.4. Dopants

The liquid phase dopants like Boron Tribromide and Phosphorous Oxychloride are being made by Special Materials Plant, a Government company based at Hyderabad. These have shown satisfactory results. However, owing to the present low quantity requirements, the prices

are high. The IC manufacturers prefer to import these dopants. The gaseous phase dopants like Phosphine, Arsine and Diborane are being imported, mainly from USA.

6.1.5. Photolithographic Materials

Photolithographic materials include photoresist, photoresist thinner, developer, ultra high resolution photographic plates, and some other proprietory materials. These are all being imported at present. Some efforts at R&D level have been made to produce photoresist materials.

6.1.6. Ultra Pure Metals

The most important metals used in IC industry are alluminium, gold, tungsten, tantalum, indium etc., Special Materials Plant & Mishra Dhatu Nigam at Hyderabad are manufacturing these materials.

6.1.7. Quartzware & Teflonware

The quartzware like furnace tubes, transport tubes ,rods, etc., are at present being imported. Likewise teflonware for storage and jigs for processing are being imported. Some companies in the country are making efforts to produce them at the specifications required for semiconductor industry.

6.1.8. Packaging & Assembly Materials

The important materials in this category are bonding wire, lead-frames, moulding compound, glass to metal seals & conducting

pastes. These are at present mostly being imported. Some attempts have been made by Indian manufacturers for producing gold wires and limited success has been achieved. Electronics Corporation of India Limited is making glass to metal seals required in metal can packages. BEL is making some of its requirements of lead frames and conducting pastes.

6.2. EQUIPMENT

The manufacture and R&D of integrated circuits requires large number of processing and testing stages with sophisticated equipment at each stage. Rapid break-throughs are taking place in manufacturing technology of equipment leading to evolution of new integrated circuits with enhanced capabilities. As a result, the obsolescence rate in the equipment area is very high and most of the equipment becomes unsuitable in 4 to 5 years. The production of equipment in IC industry is, therefore, highly expensive and enormous design and development as well as R&D efforts are required. Some of the major manufacturers in the world are putting in enormous efforts in research, development and design and have become leaders in the production of certain ranges of equipment.

In view of the capital intensive nature, high rate of obsolescence as well as low internal demand of the semiconductor equipment, the country is at present importing most of its requirements Some of the companies in the country have made efforts to produce

equipment like diffusion furnaces, vacuum evaporators microscopes, wire-bonders, die bonders, laminar air benches, ultrasonic cleaning systems, lapping machines, transfer moulding machines and metal can sealing machines. They have achieved varying degrees of success and their machines are being used by some of the semiconductor facilities. In particular, the indigenously made vacuum evaporators, laminar air benches, ultrasonic cleaning systems and metal can sealing machines have been highly successful.

7. OUTLOOK FOR THE FUTURE

7.1. Demand Projections

The country has, over the years, established a sound technological and production infrastructure over which it can, in the near future, build up a strong capability in integrated circuits. The awareness of the potentials of ICs in various applications is growing fast. Further, some of the plans of the Government of India like opening of new TV stations, major modernisation plans in telecommunications, and industry sectors like steel, fertilizers, petrochemicals, cement etc., introduction of computers in schools and colleges, promoting use of microelectronics in railways, agriculture and health/care etc. are expected to provide considerable boost to IC demand.

Preliminary estimates indicate that the demand of ICs in the country by 1990 would be about Rs.3000 million, made up of Rs.1600 million for SSI/MSI level ICs and Rs.1400 million for LSI/VLSIs. It is expected that about two thirds of this demand would be met by indigenous production. In the case of LSI/VLSIs, optimists believe that the demand can go up to Rs.4000 million with market promotional efforts.

In order to meet the above demand, an all round upgradation of production, R&D, materials and manpower base will be required.

7.2. The Task Force on LSIs/VLSIs

Recognising the importance of microelectronics, Government of India set up in 1982, a Task Force to review the existing technological base in the country and to recommend a strategy to bridge the technological gap in order that India establishes a viable presence in this area over the next decade.

The Task Force has examined the entire gamut of technology covering process techniques, technologies of materials and equipment, computer aided design, manpower development as well as future demand estimates. While the final report has not yet been submitted, it has already identified the gap areas and recommended an investment of Rs.2300 million towards R & D, production and manpower development programmes over a period of 10 years.

8.0. EXISTING INFRASTRUCTURE FOR MICROELECTRONICS APPLICATIONS AND SYSTEMS

The Indian computer industry has a checkered history since 1970s with foreign enterprises such as the IBM, ICL and Burroughs holding the major share of the local market. The Government of India owned only public sector undertaking, namely, the Electronics Corporation of India was the source of 8.5% of the systems installed during the period 1967-72 while IBM continued to be the source of supply for three-fourths of the system during this period. Between 1973 and 1977, ECIL moved ahead and became the single large supplier in India and the market share of others dwindled drastically.

The picture has changed with the advent of microelectronics technology. By the end of the last decade i.e. 1970s, several wholly Indian owned companies not under the direct control of the Central Government, began designing, assembling and selling systems in the country and continued to grow as an important force in the Indian market. At present India has built itself during the last few years to a level that there are more than 30 firms which are solely engaged in computer and microcomputer manufacturing activity in some way. About 20 items with a varying degree of indigenous contents are now being indigenously manufactured which include microcomputers, desk top and minicomputers, word processors, peripherals such as dot matrix and line printers, magnetic tape drives, floppy and hard disc drives, CRT terminals and so on.

In the organised sector there are several units possessing industrial licences/letters of intent for the manufacture of minicomputers, data loggers, peripherals including printers, terminals, disc drives etc. A number of firms in the small sector have been approved for manufacture of a number of computer peripherals. The total production of computers and other microprocessor based systems was Rs. 520 million in 1982.

8.1. Computer Systems

As regards computer systems manufactured in India, they can be classified into 8/16/32 systems. There are more than 15 firms manufacturing 8 bit systems and another 15 firms manufacturing 16 bit systems. An analysis of the firms and their product range indicates that most of the 8 bit systems are based upon 3 main processors namely 8080 A, 8085 and Z 80 A. Most of them have one to four hard discs with 10/20/40 Mb capacity, 100/120/150/180 cps dotmatrix printers and 1/2/4 floppy disc drives. While this similarity is expected, similarity also exists in the software packages and operating systems. It is observed that most of them provide CP/M compatible operating systems with a few others developing their own. Systems are also offered with multiprogramming and multi-tasking capabilities and utilities such as sort/merge etc. Almost every manufacturer supports languages such as FORTRAN, BASIC, COBOL with PASCAL as an additional feature.

8.1.1. Electronics Corporation of India, Hyderabad

The government-owned ECIL is making a note worthy

contribution in the field of computers which have a major role to play in the general industrial development of the nation. Since 1969, ECIL manufactured computer systems ranging from 8 bit and 16 bit systems and supplied to over 200 installations in the country. ECIL is engaged in hardware design, software development, manufacturing, marketing and maintenance. The latest addition to ECIL's range of computers is the 32 bit computer 'System 332' developed and manufactured indigenously.

The system 332 has powerful instructions for byte string, single and double precision floating point, decimal arithmetic and input/output operations. Autonomous I/O processors function parallel with CPU having separate and simultaneous access to memory resulting in high throughput. It has a versatile operating system which supports commercial, scientific and Real-Time applications. Features like Multiprogramming with job priority, Input-output spooling, multi tasking, job accounting, file management system, communication software to transmit information to remote places and Automatic volume recognition are offered.

ECIL has demonstrated the system 332 for its remote graphic capability by linking through the Indian satellite APPLE to another system in a remote earth station. It is planned to deliver about 15 such computer systems during 1984. The indigenous value added is about 60% in this development. The company has about 600 engineers/scientists out of which 300 are software engineers. ECIL has developed special purpose hardware and software for a number of applications such as telephone directory enquiry information,

airlines flight data recording, criminal report generation for police, message switching and so on.

8.2. Computer Peripherals

Regarding computer peripheral equipment, a number of firms have started manufacturing since 1982 with most of them in technical collaboration from western countries. A range of alphanumeric display terminals based on microprocessors are available ranging from dumb to intelligent terminals with semigraphic facilities. Some of the firms have reported completion of development work on graphic display terminals.

Indigenous dot matrix printers with printing rates of 150 CPS, bidirectional and logic seeking features have also appeared in the market recently. The line feed speed is 33 ms and there is control for horizontal and vertical tabulations. One firm has been engaged in the manufacture of floppy disc drives with technical collaboration from BASF, the Federal Republic of Germany and yet another firm with Shugart, USA. For each of the category of peripherals such as magnetic tape drives, printers impact and non-impact type, winchester disc drives, floppy disc drives and video terminals the status of indigenous effort is given in the form of table.

8.2.1. Magnetic Tape Drives :

In India, most computer systems manufacturers offer one or more tape transports with their system. Several key-to-tape units

are available with 7 inch reel tension arm tape transports. The size of the OEM market in India is estimated at US $ 300 million and is growing but not at the same dramatic rate of growth as disc drive market. A few Indian companies have planned to indigenously manufacture tape drives.

8.2.2. Floppy Disc Drives

As mentioned earlier, the Indian microcomputer manufacturing activity is predominantly in the non-government units who have based their designs on the 8 bit, and 16 bit systems. The systems produced are general purpose systems as well as systems tailored to meet the requirements of scientific, business, inventory control, office management and other data processing applications. Indigenous capability for floppy disc drives is being established with one of the firms meeting primarily its own in-house requirements, while another firm has started supplying other users. Besides there are several others who have plans to indigenously manufacture and a few others representing reputed firms abroad till such time the total indigenous market demand is taken care of. While most of the users have based their designs on 8" floppies, future systems are being planned for 5/4" mini floppy drives by manufacturers of word processors, personal computers and so on. Considering the prevailing conditions in India it is estimated that in the year 1984 the demand for floppy disc drives of various sizes can be placed around 6000 to 8000. This figure is based on the fact that the work in R&D as well as application engineering areas are expected to have a snow-ball effect in the next few years.

8.2.3. Computer Terminals

Several Indian firms have made terminals of different kinds - dumb to intelligent with semigraphic facilities. However, there are no terminals manufactured in India with graphics capabilities which continue to be imported. VDUs are available with full ASCII keyboard, 24 lines X 80 ch/line, 5x7 dot matrix and 1/2 dot shifting in 9x15 dot character cells. Most of the Indian market for VDUs is through manufacturers of computer systems (OEMS), consoles for R&D applications, industrial process control applications. The current prices of terminals in India may vary from Rs.15000 to Rs.35000 on OEM quantities depending on the options required such as number of pages, video features, peripheral interfaces, user memory etc. In single quantities one may have to invest around Rs.20,000 and above depending on the features required. It is expected that with the recent duty reductions announced by Government of India, the prices are expected to fall with an increase in demand. As far as teleprinter terminals are concerned the Hindustan Teleprinter Limited, Madras a public sector company is manufacturing machines which can cater to most of the Indian market.

Table VII : Status of Indigenous Development of Computer Peripherals

1.	Printers	: Line, band and dot matrix printers with foreign know-how;
2.	Floppy disc drive	: 8" floppy disc drives available indigenously Future plans to manufacture 5'14" drives.
3.	Magnetic tape drives	: Indigenous manufacture planned.
4.	Video Terminals	: Dumb to intelligent terminals with semigraphics available
5.	Teleprinters	: Indigenously manufactured.

9.0. MAIN FIELDS OF APPLICATIONS OF MICROELECTRONICS IN INDIA

With the proliferation of microelectronics and their decreasing cost, it can be reasonably expected that almost every organisation in the world will go in for applying this technology in future. The role of microelectronics has been one of the major elements in the fabric of the developed countries. The use to which these latest tools can be put is only limited by the imagination of the designer, in their quest to provide either better or new solutions to problems in information processing, communication, instrumentation and other countless industrial applications. It is little wonder India too is attempting to exploit the full potential of this technology to reap the full benefit. The question is no longer 'should we' but 'how do we' and in what manner so that it fits well within the framework of activities in the country. However, India has to consider the availability of resources such as manpower, capital equipment to effectively enter the field of microelectronic applications and gain control of the directions of the technology.

It has been realised that India will do well in the design of microprocessor-based systems, especially in the development of software. The hardware realisation of mini/micro processor systems is within the country's competence. Microelectronics applications in India is undergoing almost a metamorphosis as compared to the situation a couple of years ago. Microelectronics has been applied to a very successful degree in industries, transportation, energy sector, communications, data processing, scientific and other

instrumentation. It has also entered the fields of health care and agriculture, the emphasis here at present being to utilise the equipment supplied from other countries. In this Section, a brief account of the applications in various fields is given with the development efforts covered elsewhere in this report.

9.1. Industrial applications

There are certain priority sectors of economy in India such as steel, cement, power, textiles, chemicals and fertilisers which obviously deserve more immediate attention. Microelectronic applications too have got their fair share in this direction. The above mentioned industries have planned for rapid modernisation of their programmes because of strategic importance. The emphasis is to increase the productivity and improve the quality of production, to meet the domestic consumption demands and in some cases even to face the international market situation.

9.1.1. Iron & Steel

India executed one of the iron ore projects in a record time of about 2-3 years in the late 1970s. Microelectronics application in this project has been to a great extent responsible for the success of this project. The major electronic systems were obtained from other countries and Indian equipment meeting the requirements was integrated into the overall system. The entire project was completed with the direct involvement of local engineers in the

system engineering. The major purchase for the expansion/ modernisation programmes in Bokaro, Rourkela and others has also been based on indigenous supplies. Optimisation, cold rolling mills operation, blast furnace control, material handling are some of the critical areas where sophisticated microelectronic equipment has been used. Some of the new projects have been designed to use complex distributed digital control systems for which a major portion of the systems are being acquired from indigenous suppliers as well as from outside the country.

In certain cases, the electronic hardware is obtained along with the plant and machinery acquired from outside sources as part of the cooperative agreements. However, the high degree of competence that is being achieved has enabled India to successfully integrate indigenously developed microelectronic equipment.

9.1.2. Cement

The Indian Cement industry has realised the need to go in for modern electronic methods of control. The process being complex, microelectronics has come to the rescue and many of the Indian cement plants have adopted electronic controls. Programmable Controllers, material handling, quality control instruments, analytical instruments for X-ray analysis are some of the specific applications of microelectronics in the Indian cement industry.

A large percentage of the microelectronic equipment requirements

of this industry is being met within the country. Computer based tele-supervisory systems, use of industrial drives and controls are some of the areas in which a beginning is made.

9.1.3. Chemicals and Fertilisers

This is one industrial sector where considerable effort was made in the last few years to use electronic equipment and computer for total plant control, though, this was not met with great success. But the engineering capability has been built up to a great extent and there are certain consultancy organisations in India who have bagged turnkey contracts outside the country. Expertise has been built over the few years and the present trends are to go in for distributed process control with advanced microelectronic technology.

9.1.4. Oil Exploration

Microelectronics has been largely applied in this sector. A big project called TITAN which employs modern complex controls for telemetry and telecontrols has been launched in collaboration with one of the firms outside India. However, a well established public sector company has acquired the technical expertise and knowhow to execute the project. This venture has also boosted up the level of competence and expertise to take up all subsequent projects in this important field of application. An off-shoot of this exercise has been the capability of the Indian firm to extend the application of microelectronic controls and supervisory systems for other industrial sectors such as steel, cement etc.

Facilities are being augmented to clear large back log of data processing which was carried out by transporting the data abroad.

9.1.5. Power

Thermal power generation has been one of the main efforts and is considered very vital for India's industrial growth. In India today, there are several manufacturers of process control equipment which use advanced microelectronics technology. Almost all the firms have technical tie-up with leading manufacturers in the world. Process control equipment, analytical instruments such as gas analysers, data acquisition, monitoring and control, are some of the areas where advanced techniques such as distributed microprocessor control systems are adopted. Microprocessor based programmable controllers, event sequence recorders, temperature scanners, alarm annunciation systems have already been introduced in many power generating plants. There are also a few hydro-electric generating plants in India which apply microcomputers for their controls. Power systems control and load management is another area which has applied computers and microcomputers and large projects are currently in progress.

9.2. Transportation

Considering the size of the country, a high degree of importance is being attached to the transportation sector. Several programmes are being expedited and the microelectronics has found the desired role of application. The existing computing system of Air India has been upgraded keeping in view the compatibility of

hardware and software. It is also envisaged to expand the system to meet the demand by 1990. A computerised reservation system is also being installed very soon by the Indian Airlines which is the major internal transporter of air traffic. A system is also being designed for the Air India/Indian Airlines message switching reservation system.

Computerised Passenger reservation system for the northern region of Indian Railways has been taken up as a first step in this area. A national network has been planned for railways and the hardware and software requirements are being taken care of accordingly.

9.3. Communications

In India, 1980s is going to be a decade of large scale induction of electronics particularly digital switching, the thrust now being towards digitalisation of the network of communication. In the field of data communication service, efforts are made to keep pace with the modern technology and provision of services available elsewhere in the country, a few dedicated circuits being provided to start with. The introduction of Public Switched Telephone Network (PSTN) is on the anvil. The Circuit Switched Data Network (CSDN) is in an experimental stage using telex network and serious consideration is being given to the introduction of Packet Switched Data Networks (PSDN).

Microelectronics is going to play a major role in the pursuit to bring new technologies and services. Microprocessors and

microcomputers are planned to be used extensively in modems, data conversion equipment, multiplexers, protocol controllers, packet assembler, disassembler, packet switching etc. New tele-informatic services like teletex and videotex, tele-conferencing are some of the high speed data communication applications of microelectronics identified for the future in India.

9.3.1. Mass Communication

Computers have been used for mass communication through India's INSAT 1 Satellite programme. It is planned to bring Television coverage to about 70% of the population of the country and the satellite has been very recently dedicated to the nations efforts in this direction. It is also expected that educational, agricultural, health care and other programmes will get a boost through this programme.

9.4. Health Care

The Indian industry is currently making available a wide variety of medical electronic equipment for patient monitoring, diagnosis and therapy. The current trend is towards development of microprocessor based equipment for which there is an increasing demand in Indian hospitals. A notable feature in the field of medical electronics was the development and introduction of indigenous X-ray CT brain scanner. This highly sophisticated and expensive machine, currently imported has significant demand in the country and is used by neurologists for diagnosis of brain diseases,

disorders and head injuries. Some highly specialised hospitals/ nursing homes are being set up which require large quantities of sophisticated medical electronic equipment employing microcomputers and computers. Imports in medicah electronics area are comparatively high for sophisticated and life saving equipment.

9.5. Instruments and Instrumentation

The indigenous effort in this area is mainly in the form of utilising the microelectronic equipment imported from outside the country. Standard test and measuring instruments such as programmable digital instruments with IEEE - 488 bus compatible outputs, logic analysers, oscilloscopes with multi function capability, etc. are useu for a variety of scientific and industrial applications. However, a sizable portion of imported middle level technology instruments is being replaced by indigenous production. New products employing microprocessors, such as signal generators, digital LCR bridges, signature analysers and logic analysers have been introduced in the market. Instruments such as gas chromatographs, programmable instruments for biology and chemical studies, spectrophotometers using microprocessor based systems, computer based instruments for crystallographic studies, instruments for Nuclear Magnetic Resonance based studies are some of the other innumerable instruments which are widely used in India for scientific applications.

9.6. Data Processing Applications

Socio-economic planning, banking, hotel management, inventory

control, accounting and marketing, word processing are some of the application areas of microelectronics in India. Several systems using indigenous as well as imported computers have been developed and implemented and only a few examples are cited below .

9.6.1. State-level Planning and Information System

The Government of Madhya Pradesh in India has taken a pioneering step in the socio-economic planning in the State by installing a computer network using indigenous machines. A comprehensive information system for the 7,700 villages in the State will be put on the computer. This will contain demographic information, basic agricultural statistics, socio-economic data and so on which will be used for state and district plans. Personnel information, evaluation of offecers, Provident Fund Accounting are some of the uses planned for the future.

9.6.2. The INSAT 1 programme launched recently in India is expected to help in meterological data collection and also flood forecasting. About 100 flood warning stations in the country have been set up which receive half hourly pictures through the Satellite as compared to the 2 pictures per day. This advance information will be utilised to serve and save the country from many catastrophic situations.

9.6.3. Hotel Management

Hotel Management is another application in practice in one of the big hotels in India. The hardware has been imported and the

software has been developed within the country. Front office system such as reservation, guest history, guest accounting, house keeping, auditing, has been taken care of to start with. Eventually it is proposed to use the computer in all aspects of hotel operations and management. In India there are several companies who offer hotel management software packages.

10.0. MAIN SOURCES OF TECHNOLOGY AND EQUIPMENT

India has been relying on import of capital equipment required for the development of microelectronics. However, the manufacture of microelectronic system and development of hardware and software is being progressively and increasingly indigenised. System engineering has also assumed considerable importance and in many large industrial projects efforts are made to maximise the use of indigenously developed products. This has led to the development of indigenous industry to a great extent and there are specific instances of indigenous hardware and systems being used in turnkey contracts abroad.

It is however to be appreciated that till such time indigenous hardware and systems are freely available imports cannot be avoided. Technology inputs have been desirable in certain specific areas which also helps the growth of indigenous technology and systems. Further, as many of the industries have planned for immediate modernisation, it becomes essential to rely on imports for technology as well as equipment.

Large computer systems are not being manufactured in India and hence are imported from countries such as the United States, the United Kingdom of Great Britain and Northern Ireland, France, and Union of Soviet Socialist Republics (USSR). The same is applicable to process control computers which of course form part of control equipment and have been imported from the United States, the United Kingdom of Great Britain and Northern Ireland, France and the Federal Republic of Germany.

The computer peripheral industry is showing steady improvement. The terminal industry is fairly well established and imports have reduced. For floppy disc drives 2 or 3 manufacturers have been allowed to import technology and have started supplying indigenously manufactured systems to local users. However, hard disc drives continue to be imported though a private firm has been licensed to collaborate with another USA firm for manufacture of Winchester drives. Countries such as USA, UK, USSR, Bulgaria and Hungary have been supplying computer terminals.

Digital control technology and equipment for process control applications, data acquisition systems, telemetry and telecontrol are imported at the moment. However, there are a few leading firms in both the public and private sector who are able to assimilate the technology and have gone into production. These firms will very soon cover more or less the entire Indian market. Some of the countries which have supplied technology and equipment in this field are USA, UK, Japan, France and the Federal Republic of Germany.

Bulk of the digital communication equipment and technology imports have been taking place from France, the United States and other countries. However, large expansion programmes for Indian manufacture have been planned and are expected to materialise within the next two years.

Table VIII indicates the main foreign sources of supply for technology and equipment in the different fields mentioned above.

Table VIII: Main Suppliers of Equipment and Technology

1.	Computer Systems	USA, UK, USSR, Netherlands
2.	Computer Peripherals (Floppy drives, Tape drives, Hard disc, drives etc.)	USA, UK, Japan, FRG Sweden, Bulgaria, Hungary
3.	Process Control Equipment (Digital equipment & Computers)	USA, UK, France, Sweden, West Germany.
4.	Data Acquisition and Control Systems	USA, Japan, France, UK
5.	Communication equipment	France, USA, Switzerland
6.	Electronic Instruments including special applications.	USA, Europe (UK, Netherlands and others)

11.0. NATIONAL R&D IN MICROELECTRONICS

India as a developing nation has to quicken its pace of development and achieve larger goals of a welfare state. Because of major Governmental shares in the management of energy, transport, communication and heavy industries such as Steel, Textiles, Chemicals and Fertilisers, Sugar, Mining, the role of chief promoter of use of microelectronics including computers as a developmental tool would also have to be that of the Government. A cultural transformation in these areas is also bound to influence others such as education, health care systems and agriculture. Microelectronics, therefore, are not only needed for economic growth in business and industry in India but also for education health and agriculture. The Government of India, therefore, is encouraging several national laboratories and other organisations to conduct design and development work to suit specific industrial, scientific and other civilian needs. The following paragraphs describe briefly the national R&D activity that is being carried out in India. It is, however, to be appreciated that a detailed coverage in this field will be outside the scope of the present report.

11.1. Microelectronics in Instrumentation

The current status of micro-electronics development in instrumentation, process control and special application areas can be summarised best in the form of Table IX given below.

TABLE IX

A representative summary of R&D activity in electronics in instrumentation in India

Sl. No.	R&D Institution	Present programme	Future programme
1.	NPL, New Delhi	Establishment, custody, and maintenance of and R&D on national standards of based and derived units of measurement at internationally accepted level of accuracy. Calibration service at Echelon-1 level. Some activity on development of scientific instruments and application of microprocessors in instrumentation.	Extension of present infrastructure and activity for development and installation of primary standards and calibration facilities.
2.	CSIO, Chandigarh	Development activity spans on instruments for data acquisition and control, process control instruments, geophysical instruments, interactive graphics, general purpose precision laboratory and industrial instruments and instruments for agro, dairy, and	Future activity relates to development of microprocessor-based instrumentation such as data-logger for engine testing, data acquisition for weather forecast, integrated process control system, interactive

Sl. No.	R&D Institution	Present Programme	Future Programme
		Tea Industry.	graphics, microprocessor based test and measuring instruments with IEEE 488 interface bus, and microprocessor-based special instruments for agro, dairy, and tea industry.
3.	CEERI, Pilani	Development of instrumentation for sugar industry.	Development of microprocessor-based instrumentation for process control. (sugar and mining).
4.	NAL, Bangalore	Development of load cells, strain guages, signal conditioners and processors, and datalogging systems. R&D on vibration and noise transducers and instruments including field studies for vibration and noise measurement. High speed measurement system for applications in aeronautics, fluid mechanics, and structural engineering.	Further development of strain guages and load cells, infra-red sensors, real-time data acquisition systems, and airborne instrumentation.

Sl. No.	R&D Institution	Present Programme	Future Programme
		PCM telemetry system for meteorological applications.	
5.	NGRI, Hyderabad	R&D in geo-physical instrumentation. Development of resistivity meter, magneto-meters, EM instruments, instrumentation for airborne as well as marine surveys.	Design and development of micro-processor-based geophysical instruments.
6.	CECRI, Karaikudi	R&D in electro-chemical instrumentation. Developments include potentiostat, potential controller, function/scan generators, hydrogen permeation monitors, interrupted current sources, coulostat, polorography instruments, and corrosion monitoring instruments.	R&D on electro-chemical sensors. Development of microprocessor-based polorographics, multi-purpose electro-chemical instruments.

Sl. No.	R&D Institution	Present Programme	Future Programme
7.	ER&DC, Trivandrum	Development of a 'Unified, Structured, Microprocessor-based system for industrial control (USIC)'. Technology development for microprocessor-based system for industrial control such as annunciation systems, SER, data-loggers, load management systems programmable controllers, and process computers.	Extension of 'USIC' to include building-blocks for test and measuring instrumentation. Development and promotion of fully modular instrumentation with respect to hardware, software and packaging. R&D on advanced, microprocessor systems for industrial control such as interactive colour graphics speech annunciation, distributed data acquisition system, PC networks, distributed control systems, and 32-bit process computers.

Table X : Analysis of gaps in technology in electronics in instrumentation

Sl. No.	Area	Indian Status
1.	Test and measuring instruments	Only simple and medium complexity general purpose test and measuring instruments available. No substantial work on mudularisation, bus-compatibility and application of microprocessor techniques. Development activity distributed in several laboratories with considerable duplication. Development of several custom-design instruments underway for specific laboratory and field applications.
Process Control Instrumentation		
2.	Closed-loop Control	Manufacturing capability established for advanced electronic analog control systems through foreign collaborations. Some developments realised on microprocessor-based single-loop multiple-loop controllers.
3.	Open-loop Control	Only two manufacturers of programmable controllers. Further developments including application promotions underway.
4.	Man-machine systems	Developmental capability on temperature scanners, dataloggers, sequential Events Recorders just established. Capabilities on minicomputer-based data acquisition systems is being established through know-how acquisition and foreign collaborations with leading world manufacturers.

Sl. No.	Area	Indian Status
5.	Telemetry and Tele-control systems	Capability acquired by ECIL through foreign collaboration.
6.	Process computers	Availability of third generation 16-bit process computer from ECIL, and recently from other manufacturers. However, minicomputers for stringent control applications continue to be imported.
7.	Analytical instrumentation	Developmental activity confined to BARC, TIFR, NCL, RRL, Jorhat, CSIO and CEERI. Indigenization and technology upgradation underway at IL and Keltron for on-line analytical instrumentation required in power plants and process industries.

The R&D on test and measuring instrumentation spans across a large number of research laboratories, academic institutions and R&D units of private and public sector organisations. Analysis of the instruments developed or under development at different laboratories shows that the activities confine to only simple and medium complexity instruments. Except for the captive R&D units of the manufacturing organisations the technology transfer has not been very effective. However, research laboratories in the dedicated departments such as Atomic Energy, Space, Defence, Railways and Communication have developed high complexity instrumentation predominantly for their own use. One also sees development of several special instruments for specific applications such as sugar, textiles, jute, agriculture, Geo-scientific, meteriology, oceanography. With the impact of microprocessors, R&D activity has shifted to application of embedding microcomputers in instrumentation. Here, there is further need for an organised approach as most of the efforts can be classified as competence building and custom design.

11.2. Microelectronics in Process Control

The development of process control instrumentation is confined only to a few laboratories such as Central Scientific Instruments Organisation, Chandigarh, Central Electronics Engineering Research Institute, Pilani, Electronics Research and Development Centre, Trivandrum, and public sector units such Instrumentation Limited, Kota, Electronics Corporation of India Limited, Hyderabad, KELTRON Trivandrum and UPTRON, Lucknow. As is expected, the present emphasis

on R&D is the development of microprocessor based systems for measurement and control. Some successful development in this field are temperature scanners, sequential event recorders, data loggers, programmable controllers, close-loop controllers etc. In this field some interesting and notable developments are presently forthcoming from Keltron, Uptron, ECIL and DCM. The Table below indicates the R&D status in this area.

The developments on analytical instruments are confined to CSIO, CEERI, TIFR, NCL and BARC. Some indigenisation efforts are underway at IL and Keltron for their imported knowhows for on-line water and gas analysing group. Table X indicates the R&D status in this area.

11.3. Computers and Software

The computer technology has derived its impetus from industrial and business automation and therefore, has been a preserve to developed economies like the United States, the United Kingdom, France and Japan. In India the situation has been interesting. India has better access to product information from developed countries and has manpower which can be highly skilful. However, there is greater need for general industrial infrastructure though India has embarked on production of 32 bit main frames. The efforts have been mostly to reverse engineer processor architecture which are the initial steps in production. However, the system engineering approach adopted in space technology development has undoubtedly contributed to communications technology and its fall out include weather forecast and mass education.

The current level of awareness in all areas related to computer technology can be rated fairly high, though one must admit most efforts are in geographically scattered institutions with little coordination. Given below is the list of institutions and activities revealing the potential in India.

R&D Capabilities

- Architecture oriented including special purpose processor designs.
  TIFR, IITs, IISc, ISRO, NAL etc.
- Computer communication, electronic switching etc.
  TIFR, TRC, IIT-Delhi, ECIL, CMC, NIC.
- Computer aided design (system based)
  ITI, Bangalore, IIT, Delhi, CMTI, Bangalore,
  TRC, Delhi, DCM, NIC.
- Computer aided design (technology based)
  TIFR, CEERI, IIT, Delhi
- System Software development,
  IITs, NCSDCT, ECIL, ORG, HCL, DCM, NIC.
- Real-time system design capability
  TIFR, IITs, ECIL, CMC, SAIL, Air India.

Industrial Capability

- Manufacturing
  ECIL (32 bit main frame down to 8 bit micro computer),
  ORG, DCM, MMC, HCL, etc.

- Major Systems Engineering Capability

  ECIL, CMC, TIFR, TATA R&D, DOE.

- Peripherals

  At best up to slow character peripherals including printers and floppy disc drives.

- Software Capabilities

  Generally high in application software but limited in system software at contemporary level due to architectural limitations of the machines under production.

12. MANPOWER TRAINING

With the advent of microelectronics the need for manpower training has assumed great importance. Such training needs are found to be concomitant and to meet these, several programmes are launched countrywide in which government agencies, industries, research organisations and educational institutions, and other professional bodies are actively involved. An integrated approach has been formulated in the area of microprocessors to be adequately self-reliant in the technology development in future. Several programmes pertaining to education, information, research and application engineering are initiated and a brief account of the same are given in the following paragraphs.

12.1. Education

A comprehensive national programme on microprocessor education to be introduced in the graduate and under-graduate curriculum has been drawn up and is being implemented in phases. This programme was initiated by the Government of India with support from educational institutions and industries. During the first phase, teachers from engineering colleges were given training through an intensive 'hands-on' course. To nucleate the microprocessor laboratory and teaching activities for the engineering colleges in India, a functional microprocessor laboratory comprising an 8 bit training kit, digital electronics training kit, interface cards etc., was offered to the teachers. All the hardware systems and software was indigenously designed and developed. Besides, a

set of text books and other instructional material were also given to enable the teachers to initiate the activity in the respective colleges. A comprehensive syllabus covering the fundamentals and principles of applications was circulated.

As a second phase of this approach, the Government of India has launched nationwide microprocessor training laboratories at the IITs, IISc and a few other recognized universities. Under this programme, it is expected that about 3000 teachers would be trained by the year 1985 in the field of microelectronics.

Government of India had set up a panel of experts in early 1980, to study and recommend programmes for manpower development in the field of computers. As a follow up of this panel's recommendations, degree and diploma courses are being implemented as several institutions. To bridge the gap at the console/data entry operations level, certificate level courses are being initiated. Computer apprentice programmes for students and industry personnel are also planned for the future. The need for computer education at schools is now widely recognised. The government of India is launching a pilot project under which computer education would be introduced at secondary and higher secondary levels in about 50,000 schools in groups of 500. The computer education will be a full subject as a regular part of students' curricul m and the programme would consist of lectures and practical sessions for hands-on training.

12.2. Research & Development

The Government of India has realised the need for establishing facilities in Research and Development organisations to carry out work in the field of microelectronics covering devices and circuits fabrication, system development and application software development. Several R&D organisations have been encouraged to set up microelectronics laboratories to carry out work in quite contemporary technology with some of the latest equipment being made available. Every organisation is advised to identify one or more particular application areas such as industry, science, data processing and so on. These organisations continuously update their knowledge and equipment requirements to meet the needs of the industry in terms of training and development of hardware as well as software.

12.3. Industries

The industrial applications of microprocessors are becoming increasingly important. There is a general lack of awareness in the industry regarding the microelectronics technology and its applications. There is a growing demand for a continuous supply of trained manpower with several Indian industries which have plans to modernise their programmes. Specific problems of the industry are required to be attempted and develop hardware and software. The Appropriate Automation Promotion Programme of the Department of Electronics, Government of India supported by the UNDP/UNIDO is an excellant example to meet these objectives. Under this

programme, the engineers and scientists from industries and other organisations are trained in the field of microelectronics and applications. As a follow up of such training programmes, user defined development projects are initiated jointly with the industry. The programme is expected to bring about a cultural transformation in the Indian industry and acts as a catalyst in doing so. Specific instances of energy, transportation such as railways, commercial industries such as textiles, chemicals and fertilizers can be cited in this connection. While this programme is covering automation including microelectronics applications, yet another programme on microprocessor application engineering is being launched very soon. This programme envisages creation of dedicated groups to develop hardware and software for various applications; to serve as consultancy groups; help in systems engineering in industries for microelectronics and to also train the personnel in various application areas identified.

The Computer Maintenance Corporation conducts professional programmes in various aspects of software technology through another UNDP assisted project called INTERACT. At present, the programme comprises 17 different types of courses on computers and computer languages, data communication networks, real time systems and DBMS. As an extension of this training activity, a one year apprentice course in programming and applications has been started. Open to graduates, it is intended to produce highly skilled programmers in business data processing and systems analysis.

The Centre for Electronics Design Technology at the Indian Institute of Science, Bangalore is another important programme in India which offers specialised training to small industry sponsored personnel. The centre offers a one year diploma course in all aspects of electronics design during which the participants are trained in theory and practice of microelectronics system design and fabrication. The emphasis in this programme is to bridge the gap between the competence required for the production environment and the academic training. This programme has been very successful and one more centre has been started in the northern India at Srinagar. Currently, there are plans to help Thailand in the setting up a similar centre at one of the universities.

18.4. Professional Bodies

The Institution of Electronics & Telecommunication Engineers, IETE (India) chapter, Computer Society of India and others are making excellent afforts in manpower training. The IETE in particular, over the last decade or more has been organising several programmes which suit the employed personnel who cannot devote full time for studies in an academic environment as students. Certificate courses, courses equivalent to diploma/degrees are organised in all parts of the country. Currently the importance of microelectronics technology is being given thrust and the activities are planned at the national level with the help of academic institutions, R&D, government and other agencies. Special lectures, short-term training programmes, conferences

are also organised to bring all the professionals together and exchange ideas and information. A monthly journal serves as an excellent medium for information dissemination.

The IEEE, USA has an India chapter which at present is concentrating on workshops, seminars and conferences in several areas including microelectronics. This offers a change to all professionals to keep their knowledge up to date with an opportunity to interact with professionals abroad.

The Computer Society of India in the last few years has been the forum to bring almost all microelectronic professionals, including academicians, designers, manufacturers, government officials, together through an Annual convention. Such conventions are held in major cities in India every year and is attracting high quality work. Remarkable progress can be seen during every convention and during the exhibition, the industry displays the indigenous capability in design and manufacture of microelectronic systems. The CSI organises short term training programmes at various levels in the microelectronics and computer field. A news-letter brought out periodically serves as a means of exchange of information.

While the above programmes are specific in nature, several educational institutions, R & D organisations are engaged in manpower training activities. It is thus a massive attack on preparing persons for new technologies in India which has enormous technical capabilities of international standards.

13. Regional Cooperation in Microelectronics

Microelectronics is a highly capital intensive technology. Further it is charactarized by rapid rates of innovation and obsolescence. It also requires a high level of competence. It is mainly due to these factors that this technology has not grown significantly in economically backward countries in the past. Even in affluent countries, it is becoming difficult for individual companies to meet the mounting cost of development. Companies are joining hands to achieve economic viability in new developments and market opportunities. Already Japan's Cooperative VLSI programme has been a phenomenal success. For developing countries where both financial resources and competence are scarce, cooperative efforts in this area are highly desirable for best results.

India has recognised the role of microelectronics as one of the major elements in the fabric of the development of the country. Government of India has identified microelectronics and its applications as one of the thrust areas. Emphasis is being given to exploit the full potential of this technology.

The country has, over the years, developed significant capabilities in several areas of microelectronics and is poised for rapid growth in this technology in the coming years as a result of strong government support. The competence and infrastructure spans the entire gamut of microelectronics viz.IC design and fabrication,

applications, software development, system engineering, raw material, manpower etc. It could share its strengths with other developing countries in the region. It also has a number of gap areas in technology and would seek support from other countries which are in a position to bridge the gaps. Countries can also cooperate on a joint programme complementing strengths of each other to achieve a common objective. In the following broad areas where India can cooperate with other countries have been out-lined.

13.1. IC Technology

The country has already a strong infrastructure for the production and R&D in IC technology. Bharat Electronics Limited, Bangalore has been in production of ICs of SSI and MSI complexity for more than a decade. SCL, Chandigarh is a dedicated facility for the production of LSI/VLSIs. Both BEL and SCL have, at present, spare capacity in production. A number of organisations like CEERI, TIFR, ITI and IITs at Delhi, Madras, Kanpur, Kharagpur and Bombay in addition to BEL and SCL are engaged in R&D of IC technology. A chain of design centres is expected to be set up at different locations in the country during the next few years. The fabrication of chips for these centres would be done at SCL and BEL serving as foundries. The Task Force on LSI/VLSIs has recommended an ambitious programme of developing one micron technology at R&D level and two micron technology at production level by 1990.

India can cooperate with other countries in IC technology in the following ways:

(ii) Software development is one of the strong points in favour of India in view of the vast resource of highly skilled technical manpower. There is great capability for the development of application software which can be of service to other countries in the region. There is , however, need for strengthening capability for development of systems software though a few groups have developed their own. A few public and private groups are however engaged in the export of software to other countries in the world.

13.2. Systems Engineering & Third Country Exports

A few consultancy organisations have demonstrated the capability of executing turnkey contracts comprising systems from indigenous sources as well as from abroad. Specific examples of Steel, Power, Fertilizers etc. can be cited in this connection. India can take up such jobs independently and can also support some of the European countries to handle third country export contracts.

13.3. Manpower Training

Section 12 describes in great detail the manpower training efforts in India. Recently, through programmes such as the Centre for Electronics Design Technology, India is planning to help other countries such as Thailand. India, therefore can take up manpower training of personnel in industries and other disciplines for many countries in the region.

i) Providing design and fabrication facilities for custom/ semicustom chips. The design area being labour intensive, the country with its low wage structure can provide design services to both the developing and the developed countries.

There are some gaps in software packages for design of LSIs. The country will look farward to support in this regard.

ii) Jpint Development teams can be set up to develop special chip requirements of cooperating countries.

iii) Training of students from other countries in IITs and R&D organisations. Likewise, Indian students may obtain training in other countries with better facilities.

iv) Exchange of scientists & engineers between cooperating countries.

v) In view of considerable expertise and infrastructure available in the country, a centre for IC design and technology can be set up providing services to member countries in chip development, R&D and personnel training.

13.4. Application Engineering & Software Development

(i) Microelectronics has been applied to a great number of areas in India. This application engineering capability will be of benefit to other developing countries in the region.

13.5. Promotional Programmes

India has evolved, after thorough study of the situation in the country and abroad, unique programmes for promoting microelectronics in various disciplines such as education, industries, Research and Development. Specific programmes such as the Appropriate Automation Promotion Programme and Microprocessor Application Engineering Programme are launched by Government of India and have received support from the UNDP. Technical cooperation for these projects is also being established with advanced countries such as USA, the Federal Republic of Germany and Japan. The training and development efforts under these projects are expected to bring about cultural transformation in the Indian industry as well as certain other sectors such as medicine, agriculture etc. Several centres in the country have been planned for promoting microelectronics applications in India and also for training of personnel from other developing countries under the TCDC programme. A national microprocessor software library is being set up as service facility for the designers and other users in the country. Thus, these programmes are capable of nucleating major steps for international cooperation in the region.