OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Distr.
LIMITED

UNIDO/IS.583
12 December 1985

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

15081

SILICON FOUNDRY AND DESIGN CENTRES IN THE ARAB REGION: ISSUES AND APPROACHES*

Prepared by the ESCWA and UNIDO secretariats

54

* This document has been reproduced without formal editing.

V.85-37322

Contents

Summary

The paper is divided into three chapters, each of them presenting a separate issue. The first chapter is an inventory of microelectronics facilities and capabilities in the ESCWA region, also including an assessment of design capabilities and manufacturing facilities available. The second is a methodological outline presenting critical aspects of customized integrated circuits (ICs) design and production. The third chapter presents an approach to strengthening technological capabilities for design and manufacture of semiconductors in the countries of the region. It includes recommendations which can be useful for building up in the region indigenous capabilities in this technological field.

INTRODUCTION

1. The desire on the part of the Arab countries to strengthen their capabilities in microelectronics technology and applications and to engage in regional co-operative activities in this respect has been growing steadily in the past few years. An ECWA/UNIDO expert group meeting on "The Development of Microelectronics and Informatics in the Arab States", held at Kuwait in March 1984, recognized the need to enhance the diffusion of the technology and applications in the region and passed several recommendations for the development of local capabilities in this regard. In particular the meeting recommended to "study the feasibility of a regional silicon foundry and design centres" for the manufacture of integrated circuits (ICs). As a response to this recommendation and in preparation of the requested feasibility study, an assessment of available microelectronics capabilities and facilities in the region was undertaken, based on direct visit to most of the known facilities and institutions in the region concerned with microelectronics. Special joint ECWA/UNIDO/DIELI missions were carried out for this purpose in late 1984 and early 1985 covering Iraq, Egypt, Tunisia, Algeria and Syria.*/ Earlier missions investigating the status of microelectronics and informatics technologies and applications undertaken in late 1983 covered Egypt, Iraq, Jordan, Kuwait, Morocco, Saudi Arabia, Syria, Tunisia and the United Arab Emirates.*/ The institutions visited included government ministries. national computer centres, development institutions, universities, R&D centres and various industrial ventures. The coverage was extensive, but it could not be considered a complete survey of the situation; it can be considered only as an expert impression.

---

*/ Members of above-mentioned missions were as follows:
(a) UNIDO consultants:
Mr. Turski visited Baghdad, Kuwait, Amman, Damascus and Cairo;
Mr. Soni visited Baghdad, Riyadh, Dhahran, Abu Dhabi, Tunis, Casablanca and Rabbat;
Mr. Gilbert visited Baghdad, Cairo, Tunis, Algeria and Damascus.
(b) Consultants of the "Direction des Industries Electroniques et de l'Informatique", DIELI, of France:
Mr. Hinc visited: Baghdad, Kuwait, Amman, Damascus, Cairo, Riyadh, Dhahran, Abu Dhabi, Tunis, Casablanca and Rabbat;
Mr. Micolet visited: Baghdad, Cairo, Tunis, Algiers and Damascus.
(c) Mr. Sharif of ESCWA participated in all missions.

CHAPTER I.

STATUS OF MICROELECTRONICS FACILITIES AND CAPABILITIES IN THE REGION

I. A summary of facilities and capabilities in the region

2. It can be stated that the manufacturing base in the Arab states is presently very limited and would have to be considerably augmented to sustain self-reliance in microelectronics.

3. The market in the region as a whole for electronic products is substantial enough for an economically viable electronic industry, to be developed and growing at a significant rate. The sectors that can be singled out as potentially large market are: consumer electronics, including personal computers, communications and microprocessor-based controls, particularly for the oil industry. The combined market of electronic products in the region is estimated at about US$ 2 billion per year.

4. However, this large and fastly growing market can hardly sustain a viable integrated circuit manufacturing industry without substantial efforts in standardization, co-ordination and real enhancement of design capabilities. The design effort is minimal, concentrated in universities and R&D centres, mostly for educational purposes. Design or research efforts related to integrated circuits do not appear to exist on any significant scale in the region. A few specific applications were developed locally, some reaching the stage of operational prototype but none was industrialized. It is to be noted, however, that the design capability in the region is potentially large but dispersed in various universities and R&D centres where some research projects are undertaken for educational purposes with no links to industry or production.

5. There are limited facilities for manufacturing integrated circuits based on turn-key projects imported from abroad, already obsolete in technology and operating under 25 per cent of their capacity. The design of their products was imported with the equipment with no serious effort into the design of new products or the research of new techniques. These facilities have developed some capabilities in operating IC manufacturing technology but very little in mastering the technology or the design. Thus they were unable to produce components requested by systems industries in the region.

6. Given the gross national product of the region and its continuously increasing requirements for microelectronic products, there is a definite need to evolve national and regional strategies for the development and manufacture of electronic products and components, that can be translated into tangible action within the foreseeable future.

1. <u>Design Capabilities</u>

7. The present design capability is practically nil in the region. The current production mix was not designed locally but was purchased under license from foreign vendors, a tradition that still prevails and which did not and can not lead to the development of design capability. No known industrial facility has established a serious research or design section.

8. On the other hand, design and R&D efforts are being undertaken in various form in R&D centres and universities, mostly for educational purposes, with very weak links with local industry. Several specific applications were developed at the laboratory scale with a few reaching the stage of an operational model. None, however, is known to have reached the industrialization stage.

9. The case of the Arabic telex developed in the late seventies at KISR in Kuwait is to be pointed out, as well as several models developed by CERS in Syria that are still waiting to be industrialized.

10. Design capability is widely dispersed in the region; many potentially successful designers were misplaced or were "promoted" up the administrative ladder where they have lost their ability as designers.

11. In terms of hardware and equipment, many R&D centres and universities are rather well equipped with computers and instrumentation. However, a few have acquired needed software packages for I.C. designs or have developed their own software for design of specific applications. Most designs are still done manually, except maybe for lengthy mathematical calculations. One has to note the exception of few, rather simple, printod circuit boards designed and implemented in some R&D centres in countries such as Iraq, Egypt and Algeria.

2. Microelectronic manufacturing facilities

12. Two countries in the region (Iraq and Algeria) have ventured to establish semi-conductor manufacturing facilities for ICs and discrete components, that became operational in the early seventies. A private "packaging" facility is operating in Morocco as a subsidiary of Thomson of France.

13. These facilities are limited in their product mix and in no way respond to regional needs for microelectronic components. They are suffering from the limited market open to them due to their limited product mix and technology, high cost of production, obsolete techniques, weak linkage with systems industries etc. It is to be noted, on the other hand, that the Moroccan venture is totally dependent on the mother company, Thomson of France, importing from it unfinished integrated circuits and exporting to it the finished product, benefiting from the cheap labour advantage that Morocco offers compared to Europe.

3. Electronic systems industries

14. Most countries of the region have assembly lines for consumer electronics and limited professional electronic products. All of these ventures operate under one form or another of foreign partnership and/or assistance. Design is usually imported along with essential active components; in some cases all components and subsystems are imported while in a few countries, such as Iraq, Syria and Algeria, there is an effort to increase steadily the local input in the form of passive components, mechanical and plastic parts, relays, power supplies etc.

15. The consumer electronics market in the region is huge, e.g. two million TV sets per year are assembled in the region, but that does not necessarily form a tangible market for integrated circuit and component industries, since many of these assembly lines are tied to imported components from foreign partners, and there is a big diversity of designs, modes and needed components. A minimum of co-ordination and standardization, and a decision to increase locally manufactured inputs are needed before a solid components market is established. Moreover, a serious regional policy and co-ordination efforts are needed to develop a self-sustained components industry in the region.

4. National policy, development and investment institutions

16. No country in the region has adopted as yet a clear strategy related to microelectronic technology and applications, and obviously no regional policy is available. A few countries in the region, however, have started the process of formulating a national strategy. A "National Committee on Electronics through the Year 2000" and a "National Electronic Commission" were established in Egypt and Tunisia respectively, while co-ordinating bodies were set up in Algeria and Iraq for the development of microelectronics technology. Most countries of the region have established national electronic R&D centres that became operational in the late seventies and early eighties and are being enhanced steadily ever since.

17. On the other hand many regional development and investment agencies have become interested in microelectronics technology and applications. These agencies can play the role of catalysts and regional co-ordinators in promoting a sound microelectronics industry in the region. Here it should be mentioned that the Arab Fund for Economic and Social Development financed a study related to electronic equipment in education and is looking into the possibility of a feasibility study on a regional silicon foundry. The case of BTEI (Banque Tunisio-Emirate pour l'Investissement) is also to be noted, for the Bank is considering several investment projects in the field of microelectronics in co-ordination with the Tunisian Government, including the possibility of buying a "window" in the Californian "Silicon Valley" in order to gain experience and insight into the fast-moving technology.

5. Universities and educational systems

18. The Arab region is a region of youth where the number of university students is doubling almost every two years. Governments in the region are spending generously on the educational systems, and dozens of universities have been initiated in the past decade or so. It can be stated that many of these universities have been following rather closely the advances made in the field of electronics in industrialized countries, in courses and curriculae. Many of them have direct links with western universities and many are still relying on lecturers recruited from industrialized countries. Moreover, many of these universities are well-equipped with laboratories, computer facilities and the like and some have lavish financing for their research projects as in Saudi Arabia.

19. Several of these universities have specialization in electronics with sub-specialization in microelectronics at the graduate level, while most of them have introduced computer science as a specialization at the graduate level and some even at the undergraduate level. There is at least one case, ENIT in Tunisia, offering a technical course for maintenance of microprocessors and microcomputers.

20. Courses are being updated regularly according to various standards in advanced countries. Various research projects are undertaken in aspects related to microelectronics and computer science, including the design and development of specific applications, mostly for educational purposes.

21. The university system and, to a lesser extent, the technical education system, provide a strong base to develop needed expertise and design capabilities. However, the educational system should be linked more closely to local industrial problems and to local social needs. Graduates should be trained to cope with the problems of local industries. They should have an open mind to recognize local social needs and should have the initiative to identify solutions to such needs and to develop applications that can respond to some of the problems faced.

22. The educational system must be the pool from which good designers can come up. A good designer is a rare commodity that has to come from a pool of a large engineering community, and a successful application has to come by trial and error over many failing development efforts.

II. A survey of national institutions visited*/

Algeria

23. The assessment of the Algerian situation cannot be complete because the mission could visit only two local institutions: the Entreprise Nationale des Systems Informatiques (ENSI) and the Commissariat aux Energies Nouvelles (CEN). It can be stated that Algeria is among the more developed countries in the region. It has well established assembly lines for various electronic products such as TV sets, radios, communication equipment etc.; it has an IC manufacturing facility at Sidi Bel Abbas and it has various research institutions. In terms of design capability, the situation is not much different from other countries. No serious product design is undertaken anywhere, while potential design capability is latent in well developed universities and R&D laboratories.

1) Entreprise Nationale des Systèmes Informatiques (ENSI)

24. ENSI has several units, including one for informatics services and one for industrial development. The industrial development section was working on the "production" of certain computer peripherals: terminals, screens (with bilingual display), modems, multiplexers, bilingual printers etc. (mostly under license from foreign vendors).

25. ENSI was also carrying out several hardware and software R&D efforts, such as the production of a bilingual microcomputer, with technical support from foreign institutions or as a joint venture with a foreign partner.

---

*/ UNIDO consultant W. Turski participated in the 1983 mission to Iraq, Jordan, Kuwait, Syria and Egypt. UNIDO consultant G. Soni participated in the 1983 mission to Iraq, Saudi Arabia, Abu Dhabi, Tunisia and Morocco; UNIDO consultants O. Manck and S. Gilbert participated in the 1984 and 1985 missions to Iraq, Egypt, Tunisia, Algeria and Syria. DIELI consultant F. Hinc participated in the 1983 mission and DIELI consultant R. Micolet in the 1984 and 1985 missions. H. Sharif of ECWA participated in all missions.

2) Commissariat aux Energies Nouvelles (CEN)

26. The Commissariat was entrusted, among other tasks, to supervise R&D activities related to advanced technologies, including microelectronics, and acts as an advisory body to the Government on issues related to these technologies. CEN was also supervising an R&D unit at the microelectronic manufacturing facilities at Sidi Bel Abbas, some 400 km from Algiers.

27. The Sidi Bel Abbas facility was set up in 1973. It produces some analogue bipolar ICs with masks designed and manufactured abroad. It was also producing discrete transistors at the rate of half a million per year. The facility was described as a strategic option that has not reached the economic stage.

28. In co-operation with CEN, a few innovation projects were being considered for Sidi Bel Abbas, including the production of photo-voltaic cells, silicon crystals, design and implementation of specific applications etc. In this respect CEN was considering the possibility of developing the facilities into a silicon foundry or at least into a "gate array" facility catering to various countries in the region.

29. CEN has educational tasks as well. It administers graduate programmes in various physical sciences, including microelectronics, in co-ordination with the National Electronic Institute, which is an academic and technical education school, and with the universities.

3) Centre de Recherche Electronique (CEN)

30. The latter is part of the CEN structure concerned with electronics. The research undertaken there includes very sophisticated IC design techniques using gate arrays. The main problem pointed out was the identification of useful applications, a task that the researchers at the centre had not addressed, due to very weak links with industry and production. Other problems facing the centre were the chronic ones facing similar institutions in the region:

- Need for up-to-date information;
- Weak access to sources of technology;
- Difficulties in procurement of components.

Egypt

31. Egypt is potentially rich in its human resources but the industrial infrastructure needs much more efforts and development. The universities graduate every year hundreds of software and electronic engineers, well prepared in theoretical courses up-dated to standards in advanced countries, but inadequately prepared to face problems of local industries and with little or no experience in design. Various research projects undertaken at universities and R and D centres are mostly for educational purposes with no links to industry or to socio-economic realities of the country. The electronic industry in Egypt consists mainly of assembly lines importing design, parts and components from foreign vendors with no serious effort to increase local inputs. Two industrial research centres are to be pointed out: EIRDC trying to gain the confidence of the electronic industry and to build capability in microelectronic technology, and IEDDC trying to build Egyptian capabilities in various aspects of industrial and engineering design.

32. The Government of Egypt started giving more attention to the development of microelectronics capabilities in the country. A National Committee to prepare for "Electronics and informatics in Egypt through the year 2000" was established within the "National Academy for Scientific Research and Technology". The report of the committee should be ready by the end of 1985.

1) Electronics Industries Research and Development Centre (EIRDC)

33. The organization trains about 250 people in several technical areas in electronics, the most sophisticated of which is hybrid assembly. In addition to teaching circuit design and evaluation techniques, EIRDC has a full hybrid assembly capability. At present, an indigenous design is the major product, a universal power-factor controller specifically designed for regional uses.

34. EIRDC has experienced similar problems, as in other countries, in converting original designs into successfully manufactured products. The transfer of the technology from the feasibility stage to manufacturing scale is the weak link in introducing new designs into the marketplace.

35. The laboratory has identified several possible demonstration projects designed for within Egypt, such as power control for electrical distribution network, control of navigation in the Suez Canal etc.

36. Egypt requires 10 per cent of all contracts be supplied via an Egyptian company. This state policy, while implemented with the intent to foster a growing and expanding electronics sector, has not in fact accomplished that end. The contracting company typically provides 'pre-designed' components with the engineering solutions already completed, allowing for only assembly level technology development at the local level.

2) Benha Company for Electronic Industries

37. The Benha Company is a major manufacturer of electronic assemblies within Egypt. The facility is very extensive and employs 300 engineers, 200 technicians, and other specialists within an overall manpower of 3,000. It was interesting to note that although component manufacture in Egypt essentially ended in the 1960s, for reasons of economy and innovations in technology, the Benha facility continues to manufacture other elements required in assembly: cases, connectors, and other mechanical parts are locally produced while electrical components are imported.

38. The company showed interest in performing joint-venture type activities with foreign companies providing established research and manufacturing technology support.

3) National Research Council - Electronic Research Centre

39. The Electronics Research Centre is engaged in design and limited prototype manufacture of microstrip components used in communications systems. While the staff has considerable expertise in design of linear Bipolar and CMOS circuits, the manufacturing capability is not sufficiently developed to assimilate such products. Strong efforts are being put into programming microprocessors (8080 and 8085 family in particular) and in assisting assembly operations of application-specific devices such as inverters and industrial controllers. In this respect the Research Centre works in parallel with Ain Shams University. Additionally, the Research

Centre holds seminars to develop capabilities in identifying applications for differing technologies; there exists a great need for education in the newer technologies among the general engineering profession.

4) Engineering and Industrial Design Development Centre (EIDDC)

40. EIDDC is geared to provide consultation service and support including limited computer-aided design assistance. The facility contains sophisticated computer systems and capabilities such as a Hewlett Packard 9845 CAD/CAM system, with software compatible with similar systems in Iraq. Additionally, a new UNIX based ATT system will be on-line, configured for mechanical analysis via programmes such as STRUDLE (structural analysis) and finite element analysis routines. The Centre employs 65 engineers supported by 40 draftsmen, mostly engaged in manual mechanical design development. The Centre has very little capability in electronic design and rarely is called upon for such services.

41. In February 1985 the Centre hosted a seminar on CAD/CAM for mechanical and engineering industries which drew an audience of 100 persons from local industry.

42. Regional co-operation on mechanical design had been attempted, for example in conjunction with Iraq, but the effort had been hampered by poor communications due to the distance and unreliable circuits. Currently there seems to be no driving force for cross-country co-operation at the design level.

5) Ain Shams University

43. The University has approximately 40,000 students enrolled as undergraduates. The programme in electrical engineering graduates 400 students per year with emphasis on power and communications technologies. The current direction is to reduce the number of B.S. candidates in favour of an increase in the number of trained technicians. This shift in emphasis is intended to create a more favourable infrastructure within the industry for the future. Advanced research projects, while continuing in graduate

education, are not directly supported by funds from government sources. One such graduate effort was the laboratory where MOS and PMOS devices were being developed for education in processing techniques.

6) Cairo University - Faculty of Engineering

44. The faculty curriculae were highly up-to-date according to western standards for the B.Sc. programmes and the M.Sc. programmes that include specialization in electronics and computer science. The faculty has good relations with Western universities but poor contact with local industries. Research projects undertaken and various applications developed were purely for educational purposes, and not to reach the industrialization stage.

Iraq

45. Iraq is among the more developed countries in the region in the field of electronics, in terms of facilities and capabilities. It has a state-owned IC production facility which has been operational since 1983 and a systems industry producing TV sets, radio cassettes, telephone sets, PABX, personal computers etc. It has an electronic and computer research centre established in 1982, and well equiped universities. Iraq has set up in 1984 a special committee to consider plans of action relating to the development of microelectronics technology in the country, particularly upgrading the IC manufacturing facility, Al-Mansour.

1) Al-Mansour Facility, Baghdad

46. It is a semiconductor manufacturing facility for bipolar production technology that has been planned to take advantage of several factors:

- The facility support functions, such as deionized water purification and air liquification, have been established as separate economic operations and provide services not only for the semiconductor production but also serve as a source of supply for such high quality materials in the country, to share the cost of the installation with other consumers of these materials.

- The buildings have been designed to allow additional expansion within the complex for higher and more difficult technical operational levels (PMOS, NMOS, CMOS) without having to redesign distribution systems for most facilities.

- The facility is quite remarkable in overcoming the rather severe environmental constraints: airborne particulate contamination during summer dust storms, waterborne contamination of silt from the Tigres River, great extremes of temperature experienced during Baghdad summers etc.

47. The Al-Mansour facility functions at the level of discrete devices and linear bipolar devices, it has been hampered by the inability to design ICs within the facility. The original patterns for mask making are not only still "laid out" or drafted by hand but are also transferred to the final optical lithography bench by painstakingly cutting the pattern by hand into Rubylith. With the addition of a suitable pattern generator to transfer designs electronically to the mask and by eliminating the hand operations steps, Al-Mansour could be upgraded considerably. New products can then be designed and produced to better accommodate the systems industry now using only the discrete components produced by the unit.

2) <u>The National Research Council, Electronics and Computer Research Centre (ECRC)</u>

48. ECRC was established in 1982 and is currently developing region-specific applications - using discrete purchased components - such as electric motor power-factor controllers, robotic controls for industrial manufacture etc. It has the potential to evaluate specific design applications by building feasibility circuits. Application-specific designs are currently being evaluated by breadboarding the circuits with discrete ICs purchased from foreign vendors. Availability of the more sophisticated components and devices is poor, the small quantities required for feasibility studies do not provide a sufficient profit incentive to ensure adequate supply. This institution would be a major source of semicustom designs for regional applications should a regional "silicon foundry" come into existance.

49. As is common at other electrical technical institutions, efforts are hampered by a lack of trained personnel, particularly experienced engineers at senior levels. The desire was expressed to have increased professional contact with electronic specialists in other universities and institutions.

3) <u>University of Baghdad, Electrical Engineering Department</u>

50. This department is well equipped, currently teaching general engineering skills which are necessary to form a background level of expertise. It is not, however, producing chip-level design expertise, rather teaching applications of existing chip designs and designs involving discrete devices.

51. A four-year undergraduate programme is offered in electrical engineering, with electronics subspecialization for the last two years, as well as a two-year M.Sc. programme in electronics and control. Curriculae and courses in electronics and controls are advanced, being updated regularly as recommended by IEEE.

52. Many research projects were undertaken in microelectronics applications and related topics; staff produced an abundance of publications and papers for international and professional journals and meetings, but no industrialization effort was undertaken. Good working relations were kept with the National Council for the Scientific Research "NCSR", whose staff supervised graduate students' research.

4) University of Baghdad, Computer Center

53. In the Computer Science Department aspects of the "routing" theory were studied which are applied to shorten lead lengths on a silicon chip to increase the signal speed, an important aspect of IC design.

5) Baghdad Technology University

54. The university has four departments concerned with microelectronics and informatics: electrical engineering, systems and controls, a newly established Computer Science as well as an Electrical Engineering Department at the school of Technical Education. All these departments offer four years B.Sc. programmes and two years M.Sc. programmes. Each of these departments has well established laboratories in different aspects of electronics, microelectronics, controls and computer. A new "microcomputer" laboratory for teaching purposes was being established. The university's relations with industries were described as good, for example an M.Sc. thesis was on the design of a microprocessor- based control for the electronics company.

55. The Electronics and Electrical Engineering Department has 1,600 students, among them 50 graduates, half of which are in electronics-related specialization or subspecialization. The Department is well equipped in laboratories, but short in qualified personnel. It faced difficulty in procuring needed components for the research projects. A special research

laboratory is devoted to develop micro-processor-based applications, usually selected among targets related to "national development planning": optimizing solar energy collection, data collection controllers etc. Some applications were developed into laboratory operational prototypes.

55. The Systems and Controls Department offers BSc and MSc programmes in: (1) control and instrumentations, and (2) computer hardware and related fields. Curriculae were up-dated to IEEE recommendations. Good working relations were developed with "NCSR" whose staff supervised MSc research. Several micro-processor-based applications were developed, e.g. traffic light controller, solar rays tracking collectors etc. No proto-types were developed beyond laboratory models, and no effort was undertaken to design or manufacture sensors or transducers.

6) National Company for Electronic Industries - Baghdad (IEI)

57. IEI was established in 1973 and belongs to the "mixed sector", where private shares amount to up to 49 per cent and public shares to 51 per cent, based on profit making and realizing the highest rate of growth in production and in investment (15 to 18 per cent per year). In 1983 TV sets production amounted to 50,000 units. The production of black and white TV sets was slowly being terminated, converted to black and white video monitors and computer screens. Other products at the factory were: radios, radio-cassettes, calculators, telephone sets and cassette tapes. Many parts and sub-systems of these assemblies were produced by the company, such as mechanical and plastic parts, coils, transformers, loud speakers, printed boards etc.

58. The strategic decision in the company was to manufacture locally larger portion of parts and sub-systems and to acquire freedom in modifying and improving designs assembled under licence from foreign companies; in particular many modifications were being introduced to fit better local conditions, such as extreme temperature, very dry dusty and windy atmosphere etc.

59. Basic designs of products were usually bought under different types of foreign contracts, for example technical co-operation, patent licence etc., usually more than one foreign company was contracted to the same product to keep a degree of freedom; usually these contracts ran for five years.

60. In these contracts IEI reserved the right to design the outside appearance of the product and to integrate parts manufactured locally, even if they were originating from other designs.

61. An outstanding product of IEI was the cassette-tape "Al-Kythara", of which the production in 1983 amounted to 5 million units; it was planned to increase production to 15 million units by the end of 1985, by introducing higher automation and robotics.

62. An important line in the factory is the production of printed boards, including the preparation of the photographic film, double sided boards with metallized contact holes etc.

63. In 1985 the company started two new lines for assembly of personal computers, namely home computers in co-operation with Olivetti and business computers in co-operation with NEC. The software is being developed in co-operation with NCC and with Iraqi universities.

64. IEI is also considering assembly of private PABX telephone exchanges and of process-controllers for different industries.

65. IEI has undertaken very little design work; thus with a 1,600 strong labour force only 25 were engineers and yet it had difficulties recruiting "suitable" new graduates with proper profile, who like their work, enjoy it and are ready to take it as a career. It was felt that university education was preparing students for higher education, rather than to respond to the needs of local industry; the relation between the two sides was not as intimate as it ought to be.

7) Ministry of Industry and Minerals - Data Processing Centre

66. The Data Processing Centre serves as a central computational facility that connects all public sector industries. As a central facility it can more easily access the kinds of support necessary for specific projects. The centre employs twenty programmers to provide services in using the various systems. The purchase of all computer systems in Iraq is co-ordinated through the government and equipment of a few vendors predominates. This makes for

good compatability between systems and facilitates for the exchange of data throughout the country. A new Hewlett Packard Model 9000 system has been purchased with software support capability suitable for two and three dimensional design. Such programmes could be applied to customization layouts for mask making at the Al-Mansour facility. The prime users at this time for such software programmes are mechanical engineering designers.

Jordan

67. In Jordan no electronic industry exists in any form. However, human capabilities in electronics can be found at the research institute, "The Royal Scientific Society" (RSS), and at the universities.

1) The Electronic Service and Training Centre (RSS)

68. The Centre was developed into a separate entity within RSS in the early eighties, when the importance of electronics was realized. The Centre has multiple tasks, as explained below, and acts as an advisory body to the Government on issues related to microelectronics.

- The Centre is well-equipped and well-staffed, offering technical assistance, maintenance services and training to other RSS sections and to institutions outside RSS, including industries;

- It is a certified centre for quality testing of marketed materials and consumer goods; it also provides calibration and standardization facilities;

- It provides consultancy, research and development and training services for industry, including development of specific applications;

- It offers customer-tailored training courses for operation and maintenance of electronic equipment;

- The Centre has undertaken serious efforts in design and development of microprocessor-based applications, such as a microprocessor-controller for traffic signal light to be developed into a universal micro-processor-controller, programmable in EPROM, to optimize the operation of a traffic light using data fed automatically by remote sensors;

- The Centre has developed and manufactured a variety of electronic equipment, such as a maintenance-free controller for windmill generators supplying power to electric pumps in remote areas, amplifiers, laboratory testers etc.;

- The Centre has the facility to manufacture, on a limited scale, printed circuits using automatic soldering.

69. It was difficult for the Centre to gain the confidence of industries with which it still has weak links. Efforts are exerted to enhance these links by offering fruitful services such as the ones described above.

2) <u>The University of Jordan</u>

70. The Faculty of Engineering at the University has a Department of Electrical and Electronic Engineering, but not a Computer Science Department. Advanced courses in electronics are offered, covering various aspects of electronics, microelectronics, communication and computer sciences. However, no "electronic" specialization is offered at the undergraduate level, though such a specialization was considered for the near future. Fellowships were offered to staff for specialization in VLSI techniques. The staff was also interested in residence fellowships at advanced universities and research centres to update their knowledge and enhance their experience in various aspects of this fast-moving technology.

71. Courses offered at the school of engineering are versatile, with emphasis on laboratory courses and workshop training, as a minimal substitute for the lack of industrial tradition in Jordan. It was stated that the conditions in Jordan, as in many developing countries, require engineers to play the role of designers, technicians, operators, trouble shooters etc. and thus the universities must prepare their graduates to all these tasks.

72. The university suffered from very weak linkage with industry. The only experience they have in this respect was a limited consultancy with the telephone authorities. The university, like RRS, was also suffering from low salary which encouraged "brain drain" towards the Gulf states, depriving Jordan of well-qualified personnel.

Kuwait

73. Like Jordan, Kuwait has no electronic industry. Technical capabilities can be found at the Kuwait Institute for Scientific Research (KISR) and, to a lesser extent, at the University.

1) University of Kuwait, Faculty of Engineering

74. The Faculty has an electronics department but not a computer science department. The courses in electronics and computer science are advanced and based on IEEE and ACM recommendation. The Faculty does not offer a specialization in electronics or computer science and has no graduate programme and no research activities. The Computer Centre at the Faculty has acquired respectable software development capabilities, though a large percentage of the personnel are expatriate. Computing capability is very large, doubling almost every three years, though it was usually underused at about 35 per cent capacity only. The Faculty has little contact with industry and production.

2) The Electronics Department, Kuwait Institute for Scientific Research (KISR)

75. KISR has good laboratory facilities in electronics but is unable, as yet, to develop its qualified personnel into a "self-sustained critical mass". Due to competition with the private sector very few Kuwaiti experts can be recruited, and there are difficulties recruiting expatriates.

- KISR has adequate computing facilities the maintenance of which is contracted to the vendor company. There is a serious effort to acquire more capability to develop original software for specific applications.

- KISR has acquired important capability in the development of microprocessor-based applications in the past few years. It has succeeded in producing several prototypes, some with the help of outside technical assistance and some developed by KISR personnel alone.

(a) First attempts were made in co-operation Technology International, USA. As a result operational prototypes for an Arabic telex and derivatives such as a smart Arabic typewriter etc. were developed. The designs were implemented into successfully tested prototypes, but efforts in industrialization failed due to the lack of operational transfer mechanisms.

(b) The experience gained in design and implementation was very important and tested again in the development of new successful prototypes such as a controller for multiple data acquisition systems used in scientific and engineering experiments, micro-processor-controlled display of flight information in Arabic and English at Kuwait airport and others.

- KISR was instrumental in developing qualified human capabilities in design of specific applications. The important strategy here was to gain qualified expertise by assigning KISR personnel for several months to work in more advanced countries in actually designing and implementing specific applications. An accelerated know-how acquisition was obtained in this way.

- KISR is offering consultancy, testing, calibration and maintenance services to different industries and ministries in Kuwait. it acts as a consultative body to the Government of Kuwait on issues related to science and technology including microelectronics.

Morocco

76. In Morocco there exist several small assembly plants for consumer electronics, a few workshops producing passive components and a modern factory for printed circuit boards. Next to that there is a plan for an assembly line of microcomputers for schools and another one for a bilingual terminal. But the most important electronic industry in Morocco is Thomson-CSF with its Moroccan subsidiary SFRM.

77. In terms of research and design capability the university hosts several successful design projects of microprocessor-based applications, including one for Arabic speech processing. The Scientific Research Centre has already started its microelectronic laboratory with several ongoing research projects. The Moroccan Government has expressed its interest in promoting microelectronics in the country through its support to various institutions mentioned above and through the development agency "Organisation du Development Industriel" (ODI) which was considering a few industrial projects related to microelectronics.

1) IMEG

78. IMEG is a private software firm. Supported by the Moroccan Government, it is undertaking a project on assembling microcomputers for schools in co-operation with a European partner. Two lines of microcomputers were planned:

(a) for schools with 82 kilobytes RAM, and floppy disk drive, costing around MD 2,000; and

(b) for business with 512 kilobytes RAM, and hard disk drive, costing about MD 40,000.

79. The production per year was expected to be 100 micros for the high level and 300 for education. The project would be procuring all components from abroad with possible manufacturing of certain components later.

2) <u>Companie Générale de Construction de Téléphone (CGCT)</u>

80. The Company is a joint venture, with 50 per cent state owned assets and 50 per cent partnership with CGCT of France. It has two functions at the service of PTT Morocco:

- Installation of telephone network (i.e. exchanges and lines);
- Assembly of electro-mechanical telephone exchanges.

81. In 1982 the company started installing electronic exchanges purchased at Meta Conta of France. Then the Moroccan PTT switched to Ericson and CIT-Alcatel electronic systems. The Company faces the possibility of stopping all assembly operations and releasing an already well-trained workforce of more than 150 people including 10 engineers.

82. In 1982 CGCT started assembling private intercom under license from PICART-LEBAS of France and is negotiating assembly of private telephone sets for PTT customers.

3) <u>Société de Fabrication Radioélectrique Morocaine (SFRM)</u>

83. SFRM is a joint venture, 49 per cent of the shares held by Thomson CSF of France and 51 per cent owned by Moroccan public and private shareholders. SFRM has two factories. The Bouskoura factory, with a workforce of 500 persons, is limited to assembly of systems and subsystems. The Ein Sba'a factory is specialized in packaging of semiconductor components and has a work force of 1,000 persons.

84. Thomson has another affiliate in Morocco, SADA, spe[illegible]ed in assembly of colour and black and white TV sets for the local market, w[illegible] capacity of 100 sets per day. Philips has an affiliate in Morocco assembling 30 TV sets per day.

85. SFRM represents a special type of "joint venture" where all technical know-how is supplied by Thomson France. No design, engineering or modification of any kind is undertaken in Morocco, the justification being the

"prohibitive design cost". Morocco is supplying the premises and the cheap labour force. Nowhere the name SFRM appears on the product, whether it is a system, a sub-system or a component, except for products sold on the local market.

86. There are many European companies, such as IBM of France, contracting the assembly of their subsystems to SFRM, the European company supplying all design, components, parts and even machines, SFRM supplying only the labour force.

(i) The Bouskoura factory

87. The Bouskoura factory has several sections:

(a) Assembly of electromagnetic telephone exchanges for PTT Morocco. The section was closed (150 employees) because the client switched to electronic exchanges.

(b) Subcontracting assembly to European companies, including electronic subsystems, wiring, cabling etc.

(c) Assembly of systems for Thomson-France including Transceivers, professional communication electronics, navigation aids etc.

(d) Assembly of subsystems for Thomson-France including ferromagnetic core memories, hybrid circuits, active filters, miniroping wiring for computers, demagnetizing nodes for colour TV etc.

(ii) The Ein Sba'a factory

88. The Ein Sba'a factory is specialized in packaging semiconductor components including analogue ICs, transistors, diodes, rectifiers, thyristors etc.

The production capacity of the factory in 1982 was:

77,000,000 semi-conductors

1[illegible],000,000 relays

[illegible]00,000,000 hybrid circuits

20,000,000 cables for computers

All products were "exported back" to Thomson France.

89. The main comparative advantages of the Ein Sba'a factory can be summarized as follows:

(1) final cost in Morocco is much less than can be achieved in Europe and only slightly higher than in the Far East;

(2) proximity to Europe: direct and always available and cheap communication links with designer and customer in Europe, the "common" language, since French is commonly spoken in Morocco, easy access by air or sea etc.;

(3) cheap, direct and always available transportation of products, even by land via Gibraltar, to Europe;

(4) the manpower is capable of acquiring important qualifications: trained in short time, disciplined and docile, capable of sustaining European demand in endurance and productivity, though not as much as in the Far East where traditional obedience is overwhelming.

90. The assessment of the management is that the factory is keeping high standards, even when compared to European factories, in cleanliness, order, organization, efficiency etc.

91. As for the assembly of electronic systems, the assessment is against it when contrasted with the Far East.

92. In systems assembly, the quantity is the single major factor in cost, and the Far East has the lead in the market worldwide. On the other hand the Far East has established a tradition of expertise in all levels and types needed for different electronic systems, including the presence of design facilities and components manufacturing within the proximity, which is lacking in Morocco. While in the Far East there is a real electronic industrial base, in Morocco almost everything is to be imported.

4) <u>Printed circuit boards</u>

93. An advanced laboratory for manufacturing at industrial scale, high quality double faced printed circuits, using thick film technology and metallized holes contacts was mentioned. The laboratory was well equipped up to European standards manufacturing high-quality product. The laboratory was operating under license from a French company that went bankrupt, leaving the Moroccan venture on its own.

Saudi Arabia

94. There exists no serious electronic industry in Saudi Arabia, except maybe a few assembly plants for consumer electronic items, subsidiary to internationally known brands, and except for two embryonic computer projects, Al-Farabi and Al-Raed. However, Saudi Arabia is in the process of acquiring respectable potential in design capability, through the development of electronics and computer sciences faculties and departments in various universities and research centres, well equipped with computing powers and laboratories. It is worth pointing out here the University of Petroleum and Mineral, UPM, in Dhahran and its research centre, UPMRI, and King Saud University in Riyadh with its faculties of electrical and electronics engineering and computer science. ARABSAT, a regional communication organization, is also based in Riyadh, Saudi Arabia. It has supervised the design and launching of two communication satellites and is now supervising their operation, thus gaining serious capability in this field.

1) The University of Petroleum and Minerals (UPM)

95. UPM is one of the oldest technical universities in Saudi Arabia. It has three departments related to microelectronic technology: computer science, systems engineering and electrical engineering, with a total student population of about 500, including some 80 graduate students. The university has facilities for computer aided instruction, and a well furnished laboratory of computer graphics, based on a VAX 11/780. The laboratory could be developed into a design unit for ICs, by superimposing on it suitable software of design that can be purchased from various vendors in Source Code. Based on it, it would be relatively simple to implement the concept of silicon foundry using design rules of the manufacturing facilities.

2) The King Saud University

96. The Faculty of Engineering at the university has two colleges related to microelectronics. The College of Electrical and Electronics Engineering and the Computer Science and Engineering College. These colleges had in 1984-85 a total of about 800 students and had newly established graduate programmes leading to MSc degree. They are well equipped with computing power and laboratories.

97. Several research projects were undertaken at the university, including the design of an Arabic terminal with graphic capability, the design of a microcomputer with special features for the efficient treatment of the Arabic language and various designs of specific applications.

3) Saudi computer industries

98. Two computer industry projects exist in Saudi Arabia: Al-Farabi and Al-Raed.

99. Al-Farabi would apparently be the first purely "Arabic microcomputer from the early design stage to delivery, including the development of "original" Arabic programming language, operating system and compiler. The machine was expected in the market in late 1984 or early 1985.

100. Al-Raed is a bilingual business microcomputer developed and produced in California, USA, by a Saudi-owned company. An assembly line was expected to begin production in late 1985 or early 1986 in Saudi Arabia itself.

Syria

101. In Syria the electronic industry is still at the early stage of development, while the technological capabilities were more at CERS, the scientific research centre with successfully developed prototype models and an ambitious plan to establish a pilot plant for IC manufacturing.

1) General Organization of Engineering Industries

102. The organization supervises all engineering industries including an electronic one, "Syronics". In 1968-1970 an attempt was made at local manufacturing of electronic components and later to manufacture hybrid circuits. The result was uneconomical and the business failed. Since then there has been no real effort to establish a components industry at the manufacturing level. The feeling was that the required design infrastructure is not strong enough to create a local components industry at this time. New efforts at industrialization have taken the direction of assembly, typically PBX public telecommunications exchanges with a French joint-venture partner providing the design.

2) Syronics: Syrian Electronics Industry

103. Syronics is mainly an assembly operation of TV; black and white and coloured of all sizes up to 26 inches. It assembles also telephone sets and small private telephone exchanges of up to 120 lines, mostly for the local market. It manufactures some parts for its assembly lines, for example black and white television screens, power supplies, plastic TV boxes, some printed circuits etc. The percentage of manufactured parts is increasing steadily. It was about 10 per cent in 1979, achieving 35 per cent in 1983.

104. Syronics adopted special "technology acquisition contracts", the main features of which can be summarized as follows:

- Supplier is to provide components for an agreed number of products to be assembled over a period of two years, after which Syronics has the option to produce the same product for another period of ten years with the supplier providing components, at request, at the prevailing market prices.

- Syronics is to manufacture parts for the assembly line. The percentage of manufactured parts increased over the years as explained above. It is entitled to introduce all innovations brought about by supplier company during the validity of the contract.

3) <u>University of Damascus - School of Mechanical and Electrical Engineering</u>

105. The school offers a five year B.Sc. programme in electrical engineering, that includes three years of specialized studies, with electronics as one of available options. Curriculae were ambitious and regularly modernized, based on IEEE recommended text books, including many advanced courses on microelectronics and computer technology. It is well equipped, well staffed and enjoys strong government support.

106. 75 electronics engineers graduate per year providing a reasonable pool of "qualified personnel" in anticipation of changes expected to be brought to Syria by microelectronics and computer technologies and applications.

107. The school established good contact with the "Scientific Research Centre" (CERS) but very little contact with industry.

108. There were many theoretical research programmes for development of microelectronics applications, mostly for educational purposes, with little efforts at developing workable prototypes.

4) <u>The "Centre d'Etudes et de Recherches Scientifiques" (CERS)</u>

109. CERS is a well developed R and D centre that has activities in various scientific fields, including some activities in "Arabic Speech Recognition" using computers and some I.C. designs related to the speech recognition research. There is other electronic research related to the military.

110. The Centre has acquired a relatively high capability in design, actually implementing several laboratory models, for some of the specific applications developed. CERS is contemplating to set up a laboratory-scale pilot plant "Silicon foundry" to implement developed designs.

Tunisia

111. Tunisia seems, among the countries of the region, most interested in promoting microelectronic technology and industry. The Tunisian Government has established in 1984 a National Electronic Commission consisting of representatives of various public and private institutions concerned with microelectronics in the country, to assess the potentialities and propose a course of action, based on the assessment that Tunisia has a well-developed educational system that can sustain a good technical capability in design and manufacture. The Commission proposed the establishment of two microelectronic facilities:

(1) A design unit for the development of specific applications to the operational prototype stage;

(2) A microelectronic unit for design and manufacture of components, including ICs.

112. A project proposal was submitted to UNIDO in early 1985 to assist technically and financially in the establishment of these two units, with the understanding that the Tunisian Government is willing to share substantially in requested resources.

1) Ecole Nationale Supérieure de l'Enseignement Technique (ENSET)

113. The school is a national education centre graduating engineers and technical instructors. It has a 4 years BSc programme in Engineering and a six-years (third cycle and DEA) programme for technical instructors. The specialization in Electronics is available in the six-years programme only.

114. ENSET offers advanced courses in controls, sequential command situations etc., with special courses on microprocessors and microinformatics in the DEA programme. Many microprocessor-based applications were developed at the laboratory scale, such as process controllers, multiple data acquisition systems etc. In these applications the researcher developed the algorithms and designed the interface modules, including all needed software and hardware. No industrialization was attempted. In most of these applications,

the microprocessor used was the Intel 8085, although there were difficulties procuring it in needed quantities and procuring other needed parts of ongoing research projects.

115. The school has moderately equipped control laboratories, including one microprocessor and one microcomputer laboratories where a design of a microcomputer model was developed and implemented for educational purposes. It has some computer-aided instruction, CAI, equipment and limited CAD equipment is used in Engineering design even by offices outside the school.

116. ENSET has very limited contact with industry because "industrialists were not of the daring type and preferred proven technologies bought outside". A few industries were starting to call on the school for technical assistance, e.g. Airport flight control authorities were asking for the development and implementation of a software application "to optimize the use of available runways and avoid plane collisions, using data of incoming flights processed on available microcomputer" etc.

2) Ecole Nationale d'Ingénieur de Tunis (ENIT)

117. The "Tunis School of Engineering" is 15 years old, with a students body of more than 1,500. It has three programmes after secondary education:

(1) High technician (TS) education, a two-years programme or first cycle;

(2) A BSc engineering, a four-years programme or second cycle;

(3) An MSc equivalent programme (six years or third cycle).

118. ENIT offers an electrical option at the BSc level with electronic subspecialization; it offers electronics and control specialization at the third cycle and a biomedical electronic technology at the first cycle level. A three-years programme on computer technology for operation and maintenance of computer hardware and software was introduced lately with the assistance from IBI to enhance the national computerization programme. Hardware and software aspects were taught to all engineering students to acquaint them with capabilities and limitations of the computer.

119. A wide research programme in informatics and microelectronics is carried out at ENIT. In informatics, research covered artificial intelligence, recognition and processing of sound and visual signals, pattern recognition etc.

120. In microelectronics, the research covered computer-aided design of chips and systems, development of bilingual terminals and wordprocessors that included Arabization within the hardware itself etc.

121. The microprocessor Intel 8085 was used to develop some industrial controls, e.g. management of electric dispatching network, processors for the phosphate industry etc.

122. Due to limitation in available human capability, most applications were developed to the laboratory scale only with no production of operational prototypes.

3) Banque Tunisio-Emirate pour l'Investissement (BTEI)

123. The Bank has elaborated, with the Tunisian Government, the idea of establishing an "electronic infrastructure zone" for electronic industries, systems and components, for export to benefit from the well-established educational system and R&D centres in Tunisia.

The Bank was considering several projects including production of:

(a) Passive components: transformers, relays, motors etc., i.e. basically windings;

(b) Transmission equipment for PTT Tunis and other North African Countries, based on the newly established digital time sharing modulation (most probably with CIT-AL CATEL);

(c) IC components as a joint venture looking for a partner to supply the high technology and part of the market.

124. The IC project consideration was based on three factors: availability of qualified manpower in Tunis, a high-tech partner and a thorough study of the potential market.

125. The bank was investigating mostly the market for power transistors, MOS techniques, and other linear ICs. US$ 50 million were provided for the venture expected to start with the packaging stage. The bank was also considering to buy a "window" in the Californian "Silicon Valley", i.e. to buy a small company in the field of microelectronics to gain experience, access to technology and insight into the high-tech market.

4) El-Athir Electronic Company

126. The company is basically an assembly complex, set up about 20 years ago as a joint venture with Thomson-CSF of France. It caters to the Tunisian market and takes assembly subcontracting for export as well.

127. The company production is usually based on designs imported from anywhere in the world according to profit-making criteria, with most components imported as well. The company has no strategy to increase local inputs, due to cost/benefit considerations, but is willing to buy local components or "regional" components, when available at competitive cost and quality. They were manufacturing simple passive, non-mechanical components, such as relays, plastic covers etc.

Production:	90,000	TV sets/year (30,000 colour) of various sizes
	100,000	portable radios
	10,000	Radio-cassette recorders and cassette recorders for cars
	70,000	TV antennas

5) Centre National de l'Informatique (CNI)

128. The prime purpose of the Centre National de l'Informatique is to provide a central computational facility for government functions. The facility is well equipped with the most modern Honeywell Bull system (1 MIPS) and communicates over a 50 Kilobaud data communications network with remote

terminals. A working example is the 120 termi customs network linked to the central computer data bases which provide instantaneous information to the remote customs inspectors. Software applications currently operational were developed within Tunisia by Tunisian personnel. Each year the Centre trains 20 to 30 students to the MSc level in programming. The future direction of the Centre's activities will focus on software engineering with emphasis on developing workstation concept - all with little or no reliance on foreign programming assistance.

129. There is interest in supporting private efforts (for profit) with computational skills as well as with programming capability. While no CAD is being performed on the mainframe system, there is strong interest in establishing a design/computational centre to link university workers more closely with manufacturing.

III. Assessment of design capabilities in the region

130. Based on the above brief review of institutions visited the following assessment of microelectronic design capabilities available in the region could be made.

1) In most countries of the region high priorities are given to the development of microelectronic capabilities: education, research and the like. The region as a whole has begun to realize the impact microelectronics will have on all respects of economy and life and there are serious efforts to enhance the participation of the region in the development of this technology.

2) Regionally, there exists a cadre of foreign educated and trained indigenous engineers, researchers and managers capable of and dedicated to advancing the technology. Well established university programmes exist in most countries ensuring a continuing supply of engineers, programmers and technicians. However, this pool of human resources must be trained to the necessity of the new fast moving technology, and must be continuously exposed to innovations brought about in advanced countries.

3. The current products mix was not designed within the region. It was purchased expertise which did not lead to the development of design capability locally. Tools supplied may be used well, but the process of creating tools remains with foreign vendors. There is an attitude of a certain lack of respect for locally developed products. More effort should be put by present facilities to improve quality control and reliability of products to gain some confidence of the local market.

4. There is no in-place procedure to maintain an up-to-date technical community by continuous training and contact with state-of-the-art institutions and industry. Current process expertise is approximately 10 years out of date and is falling behind rapidly. In this high technology environment it is not unusual for the technical staff to require about 15 to 20 per cent of their time to be devoted to up-date their know-how and talent.

5. The most striking weakness is the almost total absence of linkages between universities and R and D centres on the one hand and industry and socio-economic needs on the other. Industries rely totally on imported "well-established technologies and design", while academics, by and large, live in a theoretical isolated environment. Moreover, the lack of industrial traditions and of a wide industrial infrastructure deprive new university graduates from badly needed practical experience. While most universities prepare their students for further education and teaching courses are up-dated to meet standards of advanced countries, no serious preparation is provided to face problems of local industries and societies.

6. It is essential that appropriate linkages are created between university workers and the developing industries. One must realize that the designers trained within the university system are the consumers of microelectronic technology. It is these engineers that will choose the particular microelectronic device used to accomplish an application. It is unreasonable to expect local engineers trained to use foreign products exclusively throughout their education, and taught that these devices are superior, to adapt locally produced devices into their application designs.

R and D and university designers should contribute their knowledge to industry and help shape the capability of the industrially designed devices. This co-operation is symbiotic in that the designers benefit in receiving hardware knowledge and the hardware personnel benefit in appreciating the needs of the designers.

It is very important to realize that education in this field is not and cannot be stagnant. In other engineering fields one would not hesitate to reject techniques of construction, architecture, or transportation 30 years out of date. In the semiconductor field five years is equivalent to 30 years in more traditional engineering fields. Design engineers must constantly improve their skills by working on successful applications, as completion of successful projects is a learning experience necessary to gain and retain competence.

7. Many enterprises in both the public and private sectors can be expected to have a good grasp of fundamental knowledge required to have thought of the application in the first place, but not have the technical base to complete the entire application design. It was a common complaint that efforts progressed to a certain point and then were forced to stop because the necessary connections to the next logical step did not exist. It is desirable to create an entrepreneurial atmosphere within the technical community, a spirit directly responsible for the tremendous expansion in microelectronics capabilities in developed countries. The physical requirements for a successful design group are present at several facilities in the region: computer systems, educated professionals, buildings and the like - but they do not have the entrepreneurial atmosphere to creatively define and manufacture new microelectronic products.

IV. <u>Assessment of available manufacturing facilities</u>

131. In developing countries, such as in the Arab States, a legitimate objective is to set up microelectronics manufacturing facilities, so as to develop a degree of regional self-sufficiency in the technology and applications, even though such a venture may not be economically viable at the regional level or competitive at the international level. It is apparent that

such an objective was behind setting up the facilities at Al-Mansour in Baghdad and at Sidi Bel-Abbas in Algeria. Assessing these facilities in the light of such an objective the following could be stated:

1. The facilities visited represent a tangible step in the effort to gain a degree of self-sufficiency in microelectronic manufacturing. The operational experience attained was comparable to similar facilities elsewhere. It was stated, for instance, that the Al-Mansour unit was attaining 92 per cent of product yield.

2. Technical capability gained in human expertise was noticeable. The trained personnel working at the facilities were qualified to operate in any sophisticated microelectronic production facility with on-the-job training for new technologies or innovations. It can be stated that the experience gained in these facilities represents a net gain in terms of "technology transfer".

3. The experience gained was restricted, not only within the same country (Iraq and Algeria), but even within the country to a very limited group of people, i.e. those directly involved in the production. Such facilities may represent a much bigger asset and a higher degree of gain in self-sufficiency if they are open to a wider group of people.

4. These manufacturing facilities are suitable for addition of MOS processing IF suitable volumes of product, or other strategic considerations, warrant the sizable capital investment required; the facilities are immediately suitable for an increase in the level of technology in the fabrication/design of Bipolar Linear ICs, as stated below. This improvement would raise the operational level allowing semicustom gate array technology to be processed at the plants.

5. No design capability was developed. The facilities were manufacturing designs imported from vendors' companies, with minor adjustment, if any. The real gain in technology transfer is obtained only when local personnel become capable of successful designs and of implementing new products. Design capability in microelectronic technology is very important to develop because of the fast changing nature of the technology and products.

6. There were no serious efforts at modifying and/or updating the imported technology, whether it be in equipment or processes. A much higher degree in self-sufficiency can be gained if local personnel can, by trial and error, succeed in modifying imported technology - to improve efficiency, reduce production cost, adopt modifications that suit better local conditions or adapt innovations appearing elsewhere in the world. Such effort can be exerted only if a separate department for industrial research is set up within the establishment facilities.

7. In considering the establishment of any microelectronic production facility in a developing country, and hence in the Arab States, the economic viability of the project and the international competitiveness of the product may not be of paramount interest, except in special circumstances, such as in the Republic of Korea. More stress is usually given to the objective of attaining a degree of self-sufficency in the technology. But then such an objective should be taken seriously in the establishment of the facility as well as in its operation. It is expected that national personnel will be given the opportunity to participate in the design and installation of the facility; that the product mix be selected and/or modified to better respond to local needs. Moreover, it is expected to encourage national experts to exert serious efforts, after the establishment of the facility, to design new products and to upgrade the facility to cope with local conditions and as much as possible, with innovations in the technology world-wide.

CHAPTER II.

DESIGN AND FABRICATION OF CUSTOMIZED INTEGRATED CIRCUITS

132. One of the most characteristic trends in microelectronics is the rapidly increasing complexity of integrated circuits (ICs). While by 1970 the number of components on a single chip was close to 1,000, it is nowadays in an order of one million. With the rising complexity, chips become more and more specialized and fewer of each kind are required. Thus, with increasing complexity, the use of a particular type of IC is more and more limited.

133. Design time has increased with complexity as has the cost of documentation of the design. Therefore, the price paid for developing and producing a complex, specialized chip tends to be increasing.

134. There have, however, been several technological innovations which have allowed the industry, and thus the user of integrated circuits, to break out of the cycle of greater complexity - smaller range of applications - higher costs.

135. One trend which has become very apparent and is growing in importance is the demand for customized chips. The market for uncommitted logic arrays, gate arrays, standard cell and full customized chips is continually expanding. The European market for these devices is estimated to be growing at around 50 per cent a year which is about twice the rate for ICs total. However, the market is still small and these chips only account for approximately 5 per cent of all ICs sold. As designers of electronic equipment become more knowledgeable the benefits offered by customized chips are more apparent. Also the advances which have been made in CAD and automated layout have made the task of the designer much easier when specifying customized chips.

Steps in customized IC production

136. To produce an integrated circuit many steps must be performed, going from an idea to the implementation of the integrated circuit. The three initial steps, i.e. system definition, logical design as well as circuit and mask design, are skilled manpower intensive and depend mostly on the availability of highly qualified designers equipped with appropriate design tools. Those three steps may be visualized as transformation of a design idea into formal description following a certain set of rules. The formal description (after verification) contains enough detailed information, sufficient to produce the chips automatically. The following steps, mask fabrication, chip fabrication as well as bonding and packaging, require specific technological skills with sophisticated equipment and facilities. However, these steps are in some sense mechanical and once the fabrication process has been properly established, no changes are required in order to

produce a completely different integrated circuit. It should be stressed that the production facilities involved in the last three steps are extremely capital intensive, while the three initial steps are rather skilled manpower intensive.

137. The idea of separation of the design process (the three initial steps) from the production process (the three last steps) is a logical conclusion from the above. Moreover, it is possible to create several geographically distributed design groups or centres working for one production facility. This is the rationale of the silicon foundry approach.

Silicon foundry approach

138. According to figures put out by the Integrated Circuit Engineering Corporation the total worldwide market for non-standard Integrated Circuits in 1984 was worth approximately US$ 1.6 billion. It is anticipated that by 1990 this figure will have increased to US$ 7.7 billion giving an annual compound growth rate of 31 per cent. One of the more spectacular growth areas is likely to be MOS gate arrays which will increase from US 153 million in 1983 to just over US$ 1 billion in 1989 which represents 38 per cent annual compound growth rate. Standard cell designs which in 1983 only represented US$ 43 million in revenue are likely to climb to US$ 1,2 billion by 1989 which represents an annual compound growth rate of 72 per cent.

139. New reports estimate that by 1988 more than 50 per cent of all IC usage will consist of some form of full custom and semicustom ICs. It is also estimated that 86 per cent of full custom and semicustom circuits designed by 1988 will use gate arrays and standard cells.

140. It is well accepted now that micro-processor technology has immense potentialities for development-catalysing applications for developing countries in areas such as agriculture, healthcare, education, rural industrialization etc. The best possibilities for exploiting this technology lie in designing and fabricating processor chips for well-defined applications in these areas, e.g. soil-testing, blood-sugar analysis, other suitable pathology tests, analysis of fat content of milk in dairy industry and so on. Similarly, there would seem to be a considerable scope for applying

microelectronics to the advancement of literacy and community-level publication - especially in areas where the written medium employs scripts widely different from the Latin alphabet.

141. The silicon foundry approach, i.e. to distinguish a design stage and a fabrication stage, could be extremely useful from the developing countries' point of view, if they decide to put together their financial resources aimed at chip production. As it was said, microelectronic chip fabrication is a very capital-intensive operation. Very few developing countries would be in a position to establish and operate a chip fabrication facility to make VLISI or even LSI chips. However, several developing countries, for example Argentina, Brasil, India and Mexico, currently have the know-how to undertake the design of chips, one part of the silicon foundry activity.

142. As was said earlier, the basic advantage of the silicon foundry is the separation of the design process from the production process. The problem was discussed in detail in study UNIDO/IS.444, A Silicon Foundry to Service Developing Countries' Needs: A Preliminary approach. An additional advantage in the silicon foundry appproach, especially in the case of developing countries, is the possibility to establish one IC production unit where designs from many design centres, which are geographically spread in the country or in the region, may be performed.

Process of customized IC production

143. The development of semiconductor technology as well as the increasing complexity of integrated circuits have prompted several approaches to the design problem. The object of a design process, a semiconductor chip is fabricated through a photolithographic process. A substance which hardens when exposed to ultra-violet light is spread on the silicon surface. Light from an ultra-violet source is directed on the surface through a mask containing shapes of circuit elements. The spacing between shapes is one of the main features of IC integration. Currently the two-micron size is acceptable as a modern standard. It should be added that in research projects of the most advanced producers sub-micron technology is being tested.

144. The tendency to decrease minimum feature size results from the fact that a two-fold reduction of the feature increases (theoretically) four-fold the density of the elements. Another factor influencing the number of functions (and the complexity) of the single chip is its size. However, the increase of the single IC's size is limited by the probability of defects resulting from the technological process of chip fabrication. If the improvement of the production technology will continue, the size of chips will grow.

145. Beyond the size and the density another factor may increase the complexity of the produced chip - the number of mask levels utilized in the manufacturing process. Previously, to produce one chip, the photolithographic process was repeated four times with different masks. In the modern technology in many cases the number of masks exceeds ten and, as a result, the structures of the chip are three-dimensional rather than two-dimensional as those in former processes. The number of masks opens another possibility for increasing complexity and it is expected that in future it will be increasing further.

146. From the complexity of the chip outlined above, it follows that a computer-assisted design process for the chips is the only effective way to overcome the extreme design complexity of the problem.

147. The design methodology which evolved could be roughly divided into two approaches:

(a) Totally customized design approach being unconstrained by any built-in limitations;

(b) Gate array approach in which the designer acts on predefined pattern of transistors.

148. In the fully customized approach the designer has unrestricted possibilities to optimize the design to match as close as possible the application requirements. In this case the design process usually includes the preparation of each individual shape on a CRT terminal with a light pen. Design software makes it possible to group the design circle elements in order to perform the required logical function. The software also makes it possible

to replicate and rotate shapes. The design software includes also a checking and analysing mechanism to increase the efficiency of the design process. As a result of this approach chips of high performance and high density are obtainable. However, the process is time consuming and involves high design costs.

149. The second approach - gate array - is utilized in most existing design systems. For this approach an identical predifined pattern of transistors grouped in the cells covers the whole chip. All circuit designs in which prefabricated transistors may be arranged into are stored in the file of the design system. Technologically, the creation of these circuits is reduced to metallization patterns which interconnect the prefabricated transistors in each cell. It should be added that in this case the customization process is reduced to creation of final interconnections, whereas all masks to create transistors are identical for all chips and utilized in the prefabrication process.

150. Functionally, the design process in the gate array approach consists of selection of the right patterns from the file, specific to obtain the needed logic function. Design circuits are usually placed in the cells, normally in a way which allows several circuits implementing one higher-level function to be placed in the neighbouring cells. Then the cells are properly interconnected. Applying gate array methodology, the designer restricts his activity to predefined distribution of cells containing standard transistors and to predesigned variation of circuits in the file. Therefore the circuits designed according to the approach have relatively lower density and lower performance. Not necessarily all transistors in cells must be included into circuits and some of them remain useless. For most complicated designs all cells contained in one chip may not be sufficient to perform the needed function whereas the function can be easily implemented on the same size of the chip using the custom approach. On the other hand, the design process, in comparison with the custom process, is relatively simple and not so much time and cost consuming. Also, as the designer deals with prefabricated transistors, he does not design any shapes himself.

Design of ICs

151. The design process of an integrated circuit requires a significant amount of expert knowledge with a variety of forms which are also technology specific or even circuit-type specific. A designer must have access to and understanding of the expert knowledge contained in a design environment usually in the form of software. The form of expert knowledge is usually a well integrated collection of design aids. Those aids enable to investigate the element of circuit design and include specification, simulation, expert system design aids and also a stored pattern of successful previous designs. All those aids enable to define models of circuits and predict their behaviour.

152. Design environments provide usually menu-driven graphic interfaces for editing and displaying structures of circuits as well as a language for specifying a design in functional aspects. Besides that, it contains a simulator which could simulate specific circuits and their hierarchical structures. Using colour graphic displays design refinements could be introduced. The design can be also supported by an expert system data base containing a library of prototype components.

153. The design process can be viewed as the transformation of an initial specification into a final one which represents in details the structure of the circuit to be produced. The initial specification, usually not fully precise and in many instances incomplete, reflects mainly the functionality. The final specification is rather structure-oriented and may represent the geometry of the fabrication mask. It could also include specifications of the circuit performance. In the case of a more complicated circuit all their details could not be grasped at once. Then the transformation of an initial specification into a final one is a many step process in which gradual refinement is performed. This specification must be tested and evaluated against the assumed functionality and constraints.

154. The circuit design systems should provide the designer with tools to assist him through the process of design specification and verification.

155. Those systems usually utilize the specific complex software as well as hardware parts, e.g. specific graphic displays.

156. The nature of the design function is special in a solution and matches an individual design application. However, it can be applied in whole or part to many other applications.

157. It is apparent then that sharing successful designs among several designers and maximizing their interaction would accelerate their learning and efficiency. Designers are the major "creative" elements within the microelectronics field and require a certain level of interaction among their colleagues to create a "critical mass".

158. Accordingly, by dispersing design centres throughout the region a closer contact can be maintained between the designers and the users of applications.

159. However, while it is feasible to locate design installations remotely from the fabrication facility it is also imperative that good regional communications be maintained between design facilities and the fabrication facilities and among designers in various relations.

Reasons for customized ICs production in developing countries

160. There are many reasons for nurturing and promoting the design activity in the developing countries.

161. Firstly, the motivation for producing specific designs could naturally arise only in the developing countries, since the chips specific for developing countries' applications, e.g. for arabization, are primarily needed only in these countries, and not in developed countries.

162. Secondly, the possibility of designing customized chips for such applications as these would itself act as an incentive to the rapid absorption and deployment of the microelectronics technology for development-catalysing applications. Such a design base, if grown and nurtured, could act as a focus for creative activity in high-quality science and technology. This design activity could generate interest and activity in related fields, e.g. graphics, CAD, software engineering and so on. In special circumstances, this could even trigger off interest and activity in hardware design and construction to assist the design activity of microelectronics chips.

163. Thirdly, the enormous impetus all these activities would provide to minimize the movement of highly qualified science and technology professionals from developing countries to the developed countries (i.e. reversing the brain-drain) is yet another benefit that should be highlighted.

164. Given that the design of LSI/VLSI chips could be undertaken by the developing countries to meet special applications demands, the next stage, converting these designs into actual hardware, i.e. fabrication, may be beyond the means of most developing countries. But if they pool their resources together, then the fabrication facility could be established as a joint enterprise.

165. There exists a good case for establishing a silicon foundry to meet the customized needs of developing countries. Commercial foundries in the western countries would not be able to serve this need for a variety of reasons:

166. Firstly, at least at the initial stages, the foundry would also have to serve as a base for providing know-how. The design teams currently operating in developing countries are likely to be at varying levels of expertise. Also new design teams would have to be grown to meet the emerging needs of developing countries. Existing commercial foundries obviously would not be in a position to meet these training demands. Even if they are willing to, the costs are likely to be prohibitively high.

167. Secondly, existing commercial foundries are unlikely to be able to devote the capacity needed for meeting the developing countries' needs.

168. Thirdly, restrictions imposed by countries on access to high technology resources from time to time make existing foundries in these countries not of long-term value to developing countries to meet their needs.

169. Therefore there is a clear case for the adoption of the silicon foundry approach in developing countries, especially on a regional level. In this case the design of integrated circuits (the three initial steps indicated

earlier) could be established independently on a national level in national design focal points of many different countries, whereas fabrication (the three last steps indicated earlier) should preferably have only one location inside (or intially even outside) the region.

170. The idea of separation of production facilities located in one selected place from the design, which could be distributed and performed in many different countries, decreases the entry cost for each country. Besides that, national focal point design groups could prepare the designs of chips specifically needed in their countries. The skills acquired by members of these groups could influence the countries' technological development.

Step-by-step approach

171. There is no need to create a silicon foundry in a one-step effort. It is possible to assess the level of technology in a quantitative manner by dividing along the skill levels necessary to implement a particular semiconductor operation. This is not to say that this represents a quality distinction, but rather that differing skills are required to perform at each operational level.

172. Such a division of operations would resemble the following functional operations:

(a) Assembly of complete electronic products from vendor-supplied electronic subassemblies and component parts;

(b) Design and production of printed circuit boards and subassemblies;

(c) Production of simple passive component parts, i.e. resistors, capacitors etc.;

(d) Design and production of solid state discrete active components;

(e) Design and production of simple linear ICs and gate array customization;

(f) Design and production of semicustom ICs;

(g) Design and production of custom ICs.

173. As one proceeds down the list, the operational level of technology necessary to successfully perform the next level is cumulative.

174. The cost of production facilities could vary over a vast range and depends on several factors, e.g. the technology selected, the amount of production, the existing infrastructure etc. It could be estimated that for small laboratory/pilot production facilicies the cost will be of an order of 10 to 20 million dollars. In addition, the operational cost of several millions a year should be taken into consideration.

175. The adoption of the multichip approach, i.e. fabrication of several different circuit designs in one production cycle which are being produced on the single chip and separated later, after the production process is completed, could help to optimize the operational cost of the foundry.

176. It should be added that several technological approaches may be adopted to achieve the goal and they could vary from one to the other foundry. In this context upgrading existing facilities would be an important option.

CHAPTER III.

APPROACH TO STRENGTHENING TECHNOLOGICAL CAPABILITIES IN DESIGN AND FABRICATION OF SEMICONDUCTORS

177. A review of the current situation in the Arab region, in particular through the expert missions carried out in the past three years reveals certain strengths as well as weaknesses. The strengths are essentially derived from the following facts. There is a high degree of awareness of the importance of microelectronic technology and its potential and impact on industrial and economic development as well as on the educational and cultural fields. There are no reservations on using the technology but on the other hand there is the desire to participate f[illegible] in technical progress in microelectronics. A considerable amou[illegible] of computer and other

microelectronics equipment exists within the region as also well-established university programmes in some countries. In the region as a whole there is available a cadre of foreign educated and trained engineers and managers capable of and dedicated to advancing the technology. Microelectronics applications in the region are already on the increase but the potential market is even greater.

178. At the same time certain weaknesses exist. The equipment and services purchased were not designed for the region nor have they led to the development of local design capability. There is no means or mechanism for maintaining the technical community up-to-date by continuous training and through contact with the state-of-the-art institutions and industry. Communication with the cutting edge of the technology is a vital necessity to retain and keep the technical skills of the individual engineer at the current level of technology. As a result, the design activity in the region is marginal. There is a lack of interaction of engineers and R and D personnel with industry and users both within and between countries in the region. The potential demand for microelectronics products is also yet to be articulated into effective demand. The manufacturing facilities, apart from a few notable exceptions, are essentially assembly operations of complete electronic products from imported sub-assemblies and component parts.

179. Irrespective of current weaknesses, the long-term goals should be clear. There is a need for every country and the region as a whole, to master the basic technology of microelectronics over a period of time so that the technology can be put to the best advantage of the region and the widening technology gap is at least contained. The market for applications for the Western Asian region is increasing and could be expected to increase even more in the future. Hence it is but reasonable that the countries of the region should have adequate technological capability to satisfy the needs of the market. Moreover, special applications, particularly suited to developing countries, could be developed if a basic technological capability exists. Such applications are unlikely to be developed by firms in the developed countries and it is for regional institutions and firms to develop such applications, for example those related to arabization. It should not also be forgotten that the international market for custom and semicustom chips is

increasing rapidly and hence this is an activity in which the region can hope to have a market share. Microelectronics should be considered as a strategic option in the region's quest for self-reliance.

180. There is therefore a clear and urgent need for establishing within the Arab region, through regional co-operation, a sound design and fabrication capability, which will enable the region to realize the potential of microelectronics technology. The establishment of a regional design and fabrication centre together with a network of national centres will provide a concrete expression, and a critical mass, of the concerted effort that is necessary to meet the aforesaid need. Such a mechanism could be a "centre of excellence" or a network of such centres and be a major stimulant for the growth of microelectronics activity in the region. A centre of this type could even function as an international design and fabrication centre.

181. It may be argued that the technology is too sophisticated and beyond the reach of the region. The reply to such an argument is that a step-by-step approach could be adopted with the institutional facilities that exist already in some countries in the region together with trained manpower, so as to enable the mastery of technology over a period of time. It may also be argued that heavy investment will be needed for a silicon foundry. For example a pilot plant may cost some US$ 20 million and a full-scale manufacturing facility some US$ 80 million. But the Arab countries do make large investments in various industrial sectors. Such an investment should be regarded as a developmental investment with long-term socio-economic benefits which will have a major impact on the technological capability in the region and also stimulate local applications. Moreover, different alternatives could be employed before a fully dedicated silicon foundry is established. For example, initially the institutions in the region could link themselves to a silicon foundry outside the region. Pilot plant facilities could be created in the region. One or more existing semi-conductor fabrication facilities in the region could be equipped to function as silicon foundries in their respective technical range. Thus, the establishment of a separate silicon foundry could be envisaged as a medium-term operation.

182. The silicon foundry has to be seen not so much as a stand-alone hardware institution but linked integrally with several design centres. It will thus be at the heart of capability building in microelectronics in the region.

183. A long-term approach to developing technological capabilities in the region should therefore be adopted with distinct but interrelated phases and involving strengthening national institutions and promoting regional co-operation among them at each step. The long-term approach must adopt a global viewpoint which connects the entire process of industrialization of microelectronics industry. Identification of applications, design, manufacturing, distribution and maintenance should all be considered in both national and regional perspectives.

184. The first phase could include the following steps, several of which should be taken concurrently:

1) Establishment of design groups in national institutions

Suitable national institutions should be identified for starting of design groups. Such an activity will be the responsibility of the respective countries. It will involve the training of personnel in design methodologies, identification of application areas, interaction with users and the equipment needed for design. The level and degree of sophistication of the design activtity will have to be decided in each case according to the requirements of the country. Assistance in the establishment of design groups could be provided externally, for example by UNIDO/ECWA or through regional co-operation.

2) Strengthening of national institutions

Together with the promotion of the design activity the general infrastructure needed for the design activities to bear fruit would also require to be promoted. This may involve activities, such as the promotion of establishment of new industries at the national level or as joint ventures between countries, surveys of markets on mutually agreed application areas, promotion of standardization etc. Here again, the primary responsibility is that of the national institutions while external assistance, for example from UNIDO/ECWA or through regional co-operation may be requested.

3) Networking of national institutions

A regional network of interested national institutions may be established. It could start with networking of the design groups, since desi , is seen as a fundamental activity, and could be extended to other activities and institutions according to needs and the interest expressed. It may be mentioned that UNIDO has promoted a similar network (REMLAC) in Latin America and the Caribbean region which has been able to draw up a programme of joint activities.

4) Training programme for upgrading design capabilities

Such training programmes will have to be tailored to different levels of design sophistication. In the first phase the approach may be to have training programmes up to the level of sophistication of semi-custom design based on the gate array approach, as explained in the previous chapter. A separate note on possible training programmes and the rough costs thereof is under preparation.

5) Market surveys for regional applications

The potential demand for applications has to be articulated. This should be a major activity in the first phase so as to provide a meaningful basis for design activity and fabrication facilities. Potential applications will nave to be identified in selected areas on the basis of which the design groups could start their activity. Initially, some of the areas of regional interest may be consumer electronics, telecommunications and petroleum refining and petrochemicals industry. The surveys will have to adopt a combination of methods including visits to firms and institutions, interviews etc. Such surveys will determine in a large measure the nature of activities undertaken in the second phase. In addition to such selected sectors, the design groups should also seek to identify and develop applications specific to the development needs of the region and its requirements, such as Arabisation.

6) Access to fabrication facilities

Pending the establishment of a separate silicon foundry alternative modes of access could be attempted concurrently. As a first step links could be established with a silicon foundry outside the region. Secondly, the existing fabrication facilities in the region could be upgraded and access could be provided to them. Thirdly, the establishment of a pilot plant for semi-conductor could be promoted - which could also serve as training functions. These three steps need not be mutually exclusive, since each of the fabrication facilities could cater to a specific type of semi-conductor technology and a specific level of sophistication.

185. The second phase would be the establishment of a separate regional silicon foundry cum design centre. This will result in a regional combination of a dedicated silicon foundry, a regional design centre together with satellite national design centres.

186. Projects could be formulated for one or more activities in the two phases mentioned above and submitted for funding to regional funding organizations. However, such projects should be framed within an agreed overall perspective and conceptually as well as practically interrelated so as to provide synergy to the regional effort.

CONCLUDING REMARKS

187. The meeting may wish to adopt an agreed overall approach to develop capabilities in the region in the field of semi-conductor design and fabrication. A time-bound programme may be worked out involving national and regional institutions and spelling out the actions required. To start with at least the following actions seem to be essential:

1) the adoption of a time-bound long-term approach;
2) the initiation of a regional network;
3) a regional programme of action to upgrade capabilities in design and to strengthen national institutions; and
4) a detailed regional survey cum feasibility study for a regional foundry cum design centre including the various intermediate steps that may be necessary. Such an activity should incorporate as an essential element the survey of application areas which may be undertaken as one of the first activities.

188. UNIDO and ECWA will continue to help the national and regional efforts in this respect.

Annex

Designing and Manufacturing Microelectronics Circuits - Major Stages

I. DESIGN

1) Conception of a new circuit

- Specifying the functional characteristics of the device;
- Selecting the processing steps required to manufacture it.

2) Preliminary design

- Estimating the size and approximate location of every circuit element;
- Computer simulation of operational characteristics.

3) Final layout

- Determining the precise positions of the various circuit elements, by means of CAD.

II. MASK MAKING

1) Generation of optical reticle
(= generating from the computer memory a complete pattern for each layer of the circuit by scanning a computer-controlled light spot across a photographic plate in the appropriate pattern)

1) Pattern generation by electron-beam lithography
(= allows to write the pattern directly on the mask from the information stored on the computer memory; eliminates 2 photographic reduction steps)

2) Master masks made by step-and-repeat method

3) Working-copy masks made for photolithography

III. WAFER FABRICATION

Inputs: Photomasks, process chemicals and prepared silicon wafers (can be produced in-house or bought from sub-contractors, see stage III.1).

(1) Producing the prepared silicon wafers)

- Reduction of raw silicon from its oxide, the main constituent of common sand;
- Purification of raw silicon up to a purity level of 99.999 999 per cent;
- Melting (1420^{o} C) and adding desired impurities, known as dopants, to produce a specific type of conductivity, characterized by either positive (p type) charge carriers or negative (n type) ones;
- Growing of a large single crystal;
- Cutting into wafers with a thin high-speed diamond saw;
- Smoothing the wafers by grinding and polishing them in an absolutely clean environment.

2) Fabrication of the integrated circuits

(i) Etching a pattern into an oxide

Chemical etching techniques
("Wet etching")
(= films of aluminium or polycristalline silicon are selectively removed by chemical treatment; yields large quantities of corrosive acids)

Plasma etching
("Dry etching)
(= the use of hot gas to lay down or remove material from the wafer)

(ii) Lithography

(= the key to microelectronic production technology, repeatedly required for the processing of any device, at least once for each layer in the finished structure)

Photolithography

- visual alignment techniques
- projection alignment techniques (the image of the mask is projected onto the wafer through an optical system)

Electron-Beam and X-ray Lithography
(= allows to write the image of the mask directly on the wafer)

(iii) Selective introduction of dopants

Diffusion
(Silicon is heated to a temperature of ca. 1000° C, so that impurity atoms begin to move slowly through the crystal)

Ion implantation
(Dopant atoms are ionized, i.e. stripped of one or more of their electrons, and are accelerated to a high energy by passing them through a potential difference of tens of thousands of volts. Advantages: can be done at room temperature; doping level can be very accurately controlled)

(iv) Depositing and patterning thin films

(forming the uppermost layers of integrated circuits; is of critical importance for the overall yield and performance of the circuits)

Chemical-vapour deposition
(wafers are heated at around 1200° C in a dilute atmosphere of silane, and a uniform film of polycrystalline silicon slowly forms on the surface)

Low-temperature deposition
(advantage: high temperatures can cause warping and damage to the fine features that have already been inscribed upon the wafer)

(v) Electrical test

(each die on the wafer is probed to determine whether it functions correctly; usually computer-aided)

IV. ASSEMBLY

1. Sectioning of the wafers into individual chips;

2. Bonding the good circuits into packages;

3. Connecting them to the electrodes leading out of the package by extremely fine wires, the so-called wiring;

4. Sealing of the packages;

5. Final Testing (the packaged circuit goes through an exhaustive series of electrical tests; except for simple devices, final testing today is in most cases automated).