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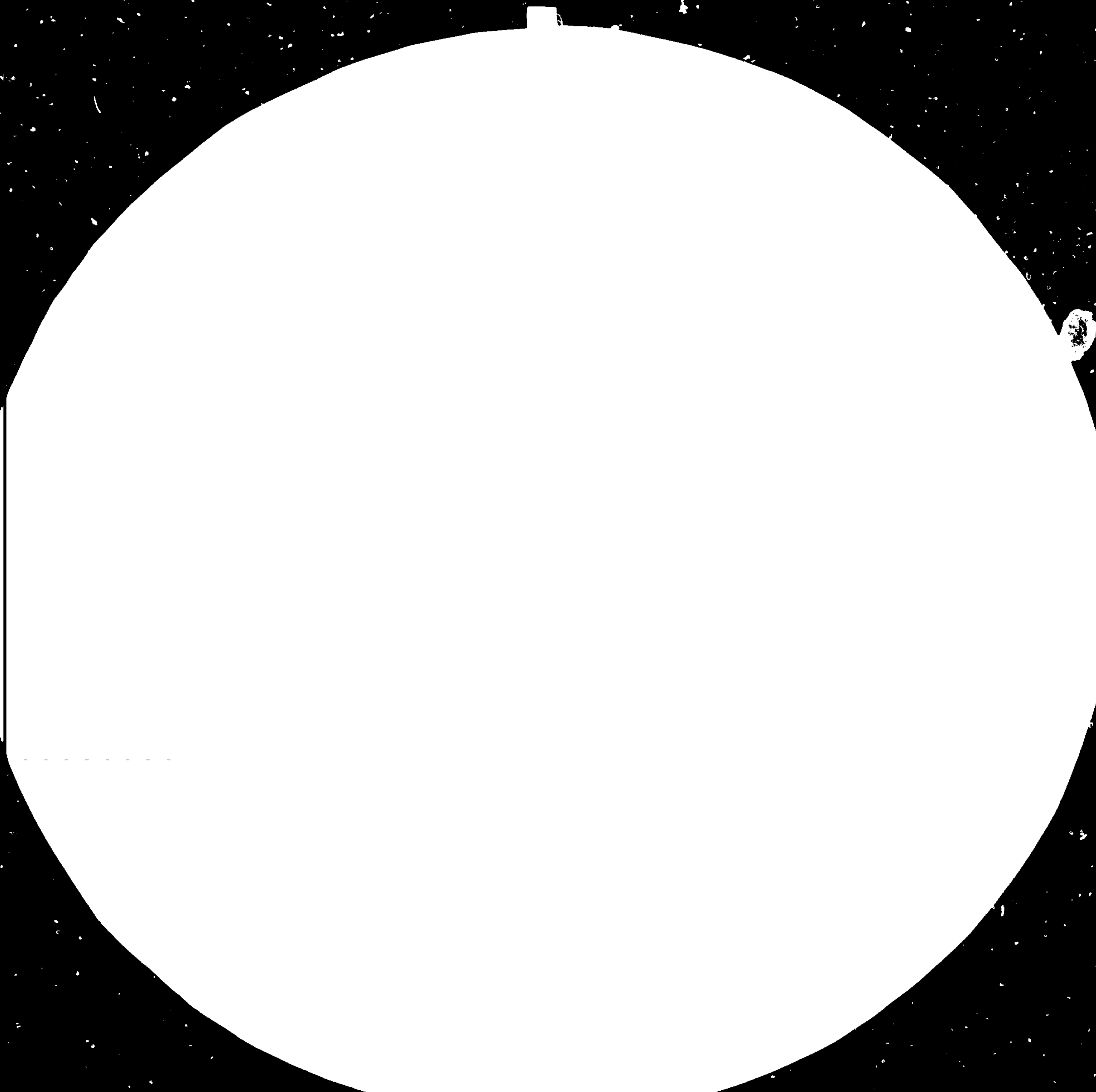

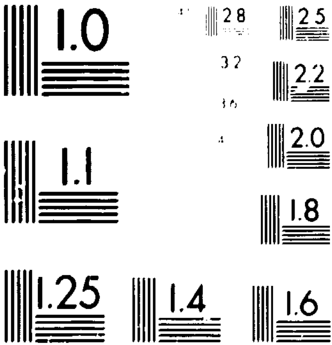

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS

STANDARD REFERENCE MATERIAL 1010a

ANSI and ISO TEST CHART No. 2

13387

Distr.
LIMITED

UNIDO/IS.444
22 February 1984

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

A SILICON FOUNDRY TO SERVICE DEVELOPING COUNTRIES' NEEDS: A PRELIMINARY APPROACH

Prepared by the UNIDO secretariat*

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V.84-82125

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1. Trends in Microelectronics and the Needs of Developing Countries

The semiconductor industry operates at the forefront of current technology. Microelectronics is continuously advancing and perhaps the most obvious trend in it is the rapid increase in complexity of integrated circuits.

The first experimental integrated circuit produced in the 1950s contained only a few components per chip. By 1964, commercially available chips had around ten components; by 1970, that number was close to 1000; by 1976, it had risen to 30,000 and today it is close to 1,000,000. In fact, this growth has been stated in the form of a law: Moore's Law, first expressed in 1974. Based upon the short history of the industry, Moore's Law predicted that the number of components per chip would aproximately double each year. And so it has. Along with the rapidly increasing complexity has come an equally rapid decrease in the cost per function for chips produced in large volumes.

These two trends have combined to make the integrated circuit suitable for a wider and wider range of applications. In the days of small and medium scale integration with fewer than about 1000 devices per chip, IC's were used mainly for fabricating the fundamental building blocks of digital computing systems such as logic gates, flip flops and so on. These types of circuits were usable in a tremendous variety of applications and were demanded in huge volumes. Thus the cost was low. However, as the complexity of chips has increased they have, in general, become more and more specialized and fewer of each are required. Thus with increasing complexity the use of IC's has become more widespread while at the same time the use of a particular type of IC has become more and more limited. 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.

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.

One is the micro-processor - a complex circuit with a very wide range of applications. The fundamental reason why the micro-processor has been so successful is that its actual function is not defined until after it has been completely manufactured. The function is defined by the software and the software can be tailored to satisfy a wide range of needs.

It is well accepted now that micro-processor technology has immense potentialities for development-catalyzing 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 literary and community-level publication - especially in areas where the written medium employs scripts widely different from the Latin alphabet.

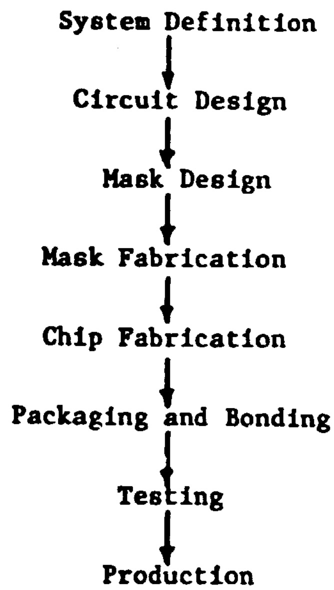
2. Silicon Foundry Approach for Developing Countries

One major characteristic of the integrated circuit industry up until recently has been its vertical integration, at least to the stage of circuit production. There are many steps in the process of going from idea to integrated circuit. The initial steps of system definition, logic design, circuit design and mask design are manpower intensive and "thought intensive" and depend upon having a set of design skills which are almost independent of how the device will actually be made. These steps also establish the eventual function of the device. On the other hand, the later steps: mask fabrication, chip fabrication, bonding and packaging require technical skills and sophisticated equipment and facilities.

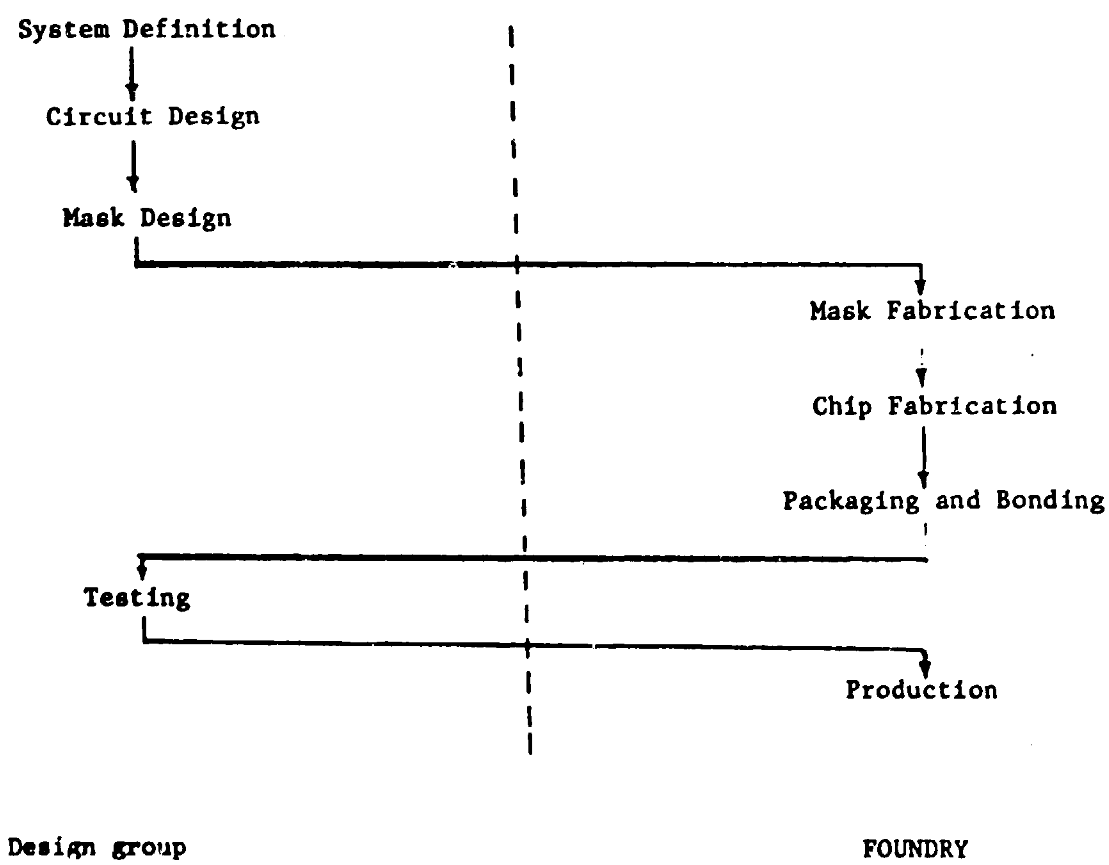
However, these steps are in some sense mechanical, in that once the fabrication process has been properly established no changes are required in order to produce a completely different integrated circuit. Nonetheless, because of the enormous capital cost and operating cost of such fabrication facilities only a very few large companies could afford the risk of establishing a fabrication line.

Figure I

TRADITIONAL MICROCIRCUIT DESIGN STEPS



SILICON FOUNDRY APPROACH TO CUSTOM INTEGRATED CIRCUIT DESIGN



The silicon foundry approach to integrated circuit design is aimed at completely restructuring the semiconductor industry in such a way that anyone with an idea can get that idea cast in silicon at a reasonable cost. To achieve this end the "thought stages" associated with design are separated from the "mechanical stages" associated with fabrication (see figure I).

The resulting structure is similar to that found in the hobby photography industry. Someone exposes a piece of film according to a known set of rules. Someone else processes it into the final picture. The film processor doesn't need to know what the pictures are, how they were produced, or what they will be used for. He only needs to know the type of film used. The photographer, on the other hand, doesn't require knowledge of the film processing techniques. He only needs a set of rules given by the film manufacturer about how to expose the film in order to produce safisfactory results. It is also the photographer who tests the results and makes the final judgement of the success of the picture taking exercise.

Essential ingredients in the separation of design from fabrication are a clear set of design rules which, when followed, result in a satisfactory chip and an appropriate data format for communicating the design from the designer to the fabricator. Experiments, mainly at Universities in the United States e.g. Minnesota, Carnegie Mellon, Cornell, and other countries have demonstrated the feasibility of the foundry approach to custom IC design and fabrication.

Standard data formats have evolved which allow the designer and foundry to communicate and sets of simplified design rules have been produced which are manageable even for inexperienced designers.

By the summer of 1982, over 30 companies in the United States offered silicon foundry services for nMos, CMOS, pMOS or bipolar circuits. Limited prototype and production runs were offered with turnaround time being from 4 to 12 weeks. Also in Europe, e.g. in laboratories in Leuven in Belgium and Edinburgh in Scotland, this approach was adopted. The list of silicon foundries can be found in June/August 1983 issue of VLSI DESIGN magazine.

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. 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 VLSI or even LSI chips. However, several developing countries, for example Argentina, Brazil, India, Mexico, currently have the know-how to undertake the design of chips one part of silicon foundry activity.

There are many reasons for nurturing and promoting this design activity in the developing countries. Firstly, the motivation for producing specific designs could naturally arise only in the developing countries, since the chips for application of the type listed earlier are primarily needed only in these countries, and not in developed countries. 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 micro-electronics technology for development-catalyzing 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. The enormous impetus all these activities would provide to minimize the movement of highly-qualified science and technology professionals from the developing countries to the developed countries (i.e. reversing the brain-drain) is yet another benefit that should be highlighted.

Given that the design of LSI/VLSI chips could be undertaken by the developing countries to meet special application 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 pull their resources together then the fabrication facility could be established as a joint enterprise.

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. Firstly, at least at the initial stages, the foundry would also have to serve as a base for providing know-now. 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. Secondly, existing commercial foundries are unlikely to be able to devote the capacity needed for meeting the developing countries' needs. Lastly, restrictions imposed by western countries on access to high technology resources in their countries from time to time make existing foundries in these countries not of long-term value to developing countries to meet their needs.

There exists, then, a clear case for establishing a silicon foundry for joint use by developing countries to meet their fabrication needs. For the reasons outlined earlier, the foundry must be a base not merely for fabrication, but for also providing training in, and transferring design know-how. So the establishment should have the capacity in all the design and fabrication stages as sketched earlier. But the design and training could also be established independently in national design focal points of many different countries. Only fabrication should have one location.

What is the technology that such a foundry should cater for? Clearly, it must meet two criteria. It must be a technology that is operationally well understood and can be readily established. It should be able to process wafers of the requisite complexity to meet the kinds of application needs earlier discussed. Both these considerations would suggest MOS technology capable of handling a 2-micron geometry. LSIs and the initial end of VLSIs could be handled by such a foundry immediately. This should serve the needs of the developing countries for the decade of the 1980s. While servicing the needs during this decade using this installed technology, the foundry could equip itself to meet demands involving the next level of sophistication in the 1990s.

This suggestion is reinforced by the following feature of the present world pattern. Out of the total IC market worldwide bipolar and MOS have an almost equal share. However, it must be noted that in terms of LSI/VLSI, MOS continues to be dominant accounting for over 70 per cent of the LSI market today.

3. Investment Estimates

3.1 Investment for fabrication

Facility investment trends for an IC wafer fabrication production module rises sharply with shrinking feature size. A typical module investment for a self-contained operation designed for a single process technology of 2-micron capability and handling 1500 wafer starts per day, will be approximately $ 60 million today, and even after reducing several parameters, would not be less than $ 30 million.

3.2 Operational costs

There is a fixed minimum cost which is associated with manufacturing of the set of masks required for fabrication and for a production run of one batch of wafers. This cost is in the area of $ 30,000. A single batch of wafers typically produces several thousand identical circuits and thus the cost per circuit is low. However, circuit design always includes at least one prototype run to demonstrate successful operation of the circuit. The cost of a minimum wafer run is the same no matter whether the circuit is a prototype or a proven design. Furthermore, several prototype runs are often required before the design is completely debugged. Thus development costs are still very high. The real difficulty with prototyping is that using the normal procedures you still get several thousand chips from a minimum run when only a few are really required for testing purposes.

There have been several recent innovations which have changed this situation dramatically. The first is what is called a multiproject chip. Each chip on the wafer contains a number of independent prototype designs, usually between five and ten. During the bonding and packaging steps only one circuit on each chip is actually connected to the pins on the package. All other circuits are dormant. However, enough samples of each circuit can be produced from a single wafer run to ensure adequate testing. The cost of the prototype production can therefore be shared by a number of different designers. Even with multiproject chips many more samples are produced than are actually required. The obvious next step is to produce a set of masks which have many different chip designs on them. Each chip design can still be a multiproject chip. This results in what is called a multiproject wafer. Typically, thirty or forty independent prototype circuits can be produced from one fabrication run with the cost being shared.

One example of the success of this approach is the Australian Multiproject Chip Programme (AUSMPC) coordinated by the CSIRO in Adelaide. Prototype designs have been accepted from universities in Australia and New Zealand. from government research organizations as well as from small industries both in Australia and the United States. Fabrication is carried out at foundries in the United States and Australia. A turnaround time of three months has been achieved and the cost to the designer is around $ 375 per square mm of chip area.

In Canada, a MPC experiment was started in 1980, as a cooperative venture between Queen's University and Northern Telecom Electronics Limited. Because of the success of the effort Northern Telecom offered to provide a foundry service for all Canadian universities and institutes.

Up to the present time, coordination of design submission and distribution of fabricated chips has been handled by Queen's and 12 universities have participated. The success has been so great that an independent. non-profit corporation is presently being established at Queen's to provide the coordinating service. One unique aspect of the programme in Canada is that Northern Telecom offers the fabrication service free of charge to educational institutions in order to encourage improvement in the training of engineering students in the area of integrated circuit design.

4. Training

The most essential ingredient is skilled manpower with background in the areas of system design and circuit design. The detailed knowledge required for the mask design can be acquired relatively rapidly. Graduate students in electrical engineering at Queen's enter the programme with some system and circuit design experience but with essentially no background in the details of integrated circuit design. During a single 12 week course they not only learn the techniques of design but also produce a prototype design for fabrication. Typically, these designs contain between 1000 and 2000 components and are produced with the aid of a small computer and some very simple computer aided design tools.

One of the initial tasks a designer of custom circuits faces is that of designing the subcircuits, such as gates and registers, which will be combined and used many times to produce the final design. A number of commercial companies have sprung up recently which supply a library of tested standard cells for a variety of different fabrication processes. The designer then has only to select, place and interconnect these standard cells in order to produce a prototype custom design. Design time and therefore development cost are reduced and the design skills required are limited mainly to system design since most of the circuit design is incorporated in the library of standard cells.

5. Conclusions

The Expert Meeting Preparatory to the International Forum on Technological Advances and Development, held in Moscow, 29 November - 3 December 1982, recommended that the UNIDO secretariat should examine the possibility of setting up a task force of experts to examine further the concept of establishing silicon foundries as an instrument for acquiring the capability to manufacture chips for specialized needs.[1/]

The International Forum on Technological Advances and Development, held at Tbilisi, USSR, in April 1983, also considered this issue and recommended that a centre on microprocessor applications should be established to serve national and regional needs. It also suggested that UNIDO should initiate steps to explore the possibility of such a centre, taking into account the needs of the developing countries.[2/]

1/ Report of the Meeting on Technological Advances and Development (ID/WG.384/16).

2/ Report of the International Forum on Technological Advances and Development (ID/WG.389/6).

The ideas on a silicon foundry presented here are of an introductory nature. They show that the establishment of a silicon foundry as a joint developing countries' enterprise seems to be feasible. It would match many articulated needs of the countries and produce chips having application in the specific environment of those countries.

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.

However, to transfer these preliminary ideas into an applicable project, a more detailed techno-economic report has to be prepared by UNIDO in co-operation with interested countries.

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