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THE BRAZILIAN MICROELECTRONICS INDUSTRY AND ITS RELATIONSHIP WITH THE COMMUNICATIONS INDUSTRY*

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SUMMARY

This document presents an overview of the current situation of microelectronics in Brazil, its relationship with the communication industry and the Brazilian possibilities in a microelectronics programme of regional co-operation.

Equipment design has been strongly affected by the increasing trend of integrated circuits (IC) technology to integrate more and more functions on a single chip. As a result, equipment design is progressively merging with chip design. The Brazilian industry has faced great difficulties in trying to implement the complete semiconductor cycle. These difficulties are discussed and some solutions suggested.

However the world-wide trend of using ICs for big production series of equipment and semicustomized ICs being economically feasible for smaller series opens a new perspective enabling the industries from developing countries to design and produce microelectronic components for their needs. It is possible to develop a high technology activity and a complete production cycle, enabling the local microelectronic industry to become internationally competitive in many market segments. It is noted that the development of these devices will require high-technological capabilities in design methodologies and in computer-aided design tools, and that a regional co-operation programme will enable developing countries to develop in the productive area.

Regional co-operation can also be a manner of increasing the number and the results of the Research Centres' developments, as well as local developments through an R&D programme organized on a regional level, avoiding redundant efforts. It is also stressed that exchanges between researchers and technicians will speed up the work of these centres.

It is concluded that countries which have similar technological levels can implement an effective co-operative programme in human resources development, and that this would be the quickest and most economical way to enhance their skills in this high-technology field, leading to a socio-economic development less dependent on developed countries.

SYNTHESIS AND CONCLUSIONS

In 1983, the Brazilian electronic equipment production reached 3.7 billion dollars, which originated a demand of 190 million dollars in the semiconductor sector.

In order to supply this internal demand, 17 semiconductor manufacturers have produced 130 million dollars, of which 28 million is for exports. This required the importation of 26 million dollars of inputs. Additionally, imported finished semiconductors amounted to 90 million dollars.

Recently, equipment design has been strongly affected by the increasing trend of IC technology to integrate more and more functions in a single chip. As a result, equipment design is progressively merging with chip design.

As the Brazilian electronic industry has not mastered the highly complex know-how in the semiconductor sector (from design to marketing), its trend has been to become more dependent, mainly due to the increasing use of custom-made ICs in modern systems.

In 1983, the ten largest world-wide semiconductor manufacturers have reached sales of 9.5 billion dollars, i.e. 55% of the world market. Four of them have sold more than 1 billion dollars. Texas and Motorola alone have produced more than 3 billion dollars. This is 16 times bigger than the Brazilian market.

The Brazilian industry has faced great difficulties in trying to implement the complete semiconductor production cycle. Among these difficulties are the following:

- the lack of industrial scale; for mass production equipment
- the large diversity in semiconductors types and quantities, partly due to the different origins of equipment designs locally manufactured;
- the lack of up-to-date technology;
- Limited skilled human resources;

The semiconductor industry is capital intensive and even a small industrial unit requires high investment. Marketing practices of the big multinational manufacturers-consisting in producing in huge volumes for the world market and introducing a constant flow of new products at very low prices-make it difficult for a local manufacturer of standard products to achieve the industrial scale required for the feasibility of a local complete production cycle.

Today, the microelectronic field presents one of the quickest technological evolutions. High investments may become obsolete in a short period, without being paid off. In many cases, companies not able to follow this evolution have been absorbed by others, , in order to avoid more dramatic solutions.

Although Brazil has several nuclei of specialists in R & D centers and in industry, they are in a limited number and work with insufficient financial resources. So, it has been impossible for the country to cope with the high technology internationally available and therefore production does not reach the world market competitively.

However the world-wide trend of using ICs for big production series of equipment and semicustomized ICs being economically feasible for smaller series, opens a new perspective enabling the industries of developing countries to design and produce microelectronic components for their needs. So, we can develop a high-technology activity and a complete productive cycle, enabling our local microelectronic industry to become internationally competitive in many market segments.

But the development of these devices will require high-technological capabilities in design methodologies and in computer-aided design tools.

A regional cooperation program will enable developing countries to develop, in the productive area:

- new methodologies and productive processes;
- inputs development and manufacturing ;
- purchase, improvement, design and production of machinery and tools;
- training of skilled human resources.

The regional cooperation can also be a manner of increasing the number and the results of the Research Centers developments, as well as local developments through an R & D program organized on a regional level, avoiding redundant efforts. It should also be stressed that the exchange among researchers and technicians will speed up the work at these centers.

Countries which have similar technological level can implement an effective cooperative program in human resources development. This will certainly be the quickest and most economical way to enhance their skills in this high-technology field, leading to a socio-economic development less dependent on developed countries.

A regional cooperation program should also establish the joint operation of inputs and finished semiconductors industries, in order to reduce the production costs.

THE IMPACT OF MICROELECTRONICS IN COMMUNICATION

Until perhaps 15 years ago the vacuum-tube was the dominant active component of the electronic circuits that are fundamental to the operation of telecommunication systems. The vacuum-tube was too large, required too much power and was too unreliable to meet the needs of those systems for large numbers of signal-processing devices clustered in complex circuits and to operate with extreme reliability. The alternative came in the form of the transistor, which provided electronic gain in a semiconductor and was small and reliable. It led to the silicon integrated circuit, a revolution in electronics and a vast improvement in telecommunication.

Microelectronics in the form of integrated circuits is an important factor in telecommunication largely because of the combined effects of low cost high reliability and wide applicability. As increasing numbers of circuits elements are fabricated on a silicon chip, the costs of a basic circuit function decreases markedly. A circuit function of outstanding importance in communication systems (and also in computing systems) is the digital logic "gate". It controls the flow of information, providing an output signal only when the input signals are in prescribed states. From this basic element large digital signal-processing systems can be built. Hence the costs of logic gate have a considerable influence on the costs of communication equipment: on terminals, which provide the interface between people or machines and communication channels: on switching machines, which establish communication paths, and on the equipment that processes signals so that they can be transmitted over wires and cables, by radio and by light waves.

Digital technology has progressed rapidly from the logic gate consisting transistors to the integrated logic gate and now to thousands of logic gates within a single integrated circuit. During this evolution the cost has gone from about $10 for the vacuum - tube gate to about one cent per gate in an integrated circuit incorporating many gates. The cost will soon reach one cent. Equipment involving complicated signal-processing, such as the telephone with a memory, has become economically feasible as the cost of such a crucial circuit declined more than a thousandfold.

Low cost, however, is not enough. Reliability is therefore as important as cost.

The vacuum-tube logic gate was distinctly unreliable. A logic gate consisting of discrete transistors proved to be about 1.000 times more reliable than the equivalent vacuum-tube gate. A modern integrated-circuit gate is at least 100 times more reliable than the gate consisting of discrete transistors. In the progression from vacuum-tubes to integrated circuits then, the reliability of the logic gate has improved by a factor of 100.000.

The switching machines that control the routing of telephone calls provide an example of what this enhanced reliability means to a communication system. Such a machine handles up to 100.000 telephone lines simultaneously. It scans the incoming lines and detects when a customer is calling for service (having lifted his telephone off the hook). Then it collects the dialing information, connects the caller with the person he is calling, records the information needed for billing and disconnects when the caller hangs up.

The "brain" of the machine is an electronic processor consisting mostly of a central control and data-storing components. The processor also handles numerous other chores, including the diagnosis of faults and failed circuits. Since the processor is crucial to the operation of as many as 100 000 telephones, it must have a high degree of reliability. The objective set for it is that it has no more than two hours of "down" time in 40 years. (Most of that time is expected to be the result of inadvertent mistakes by operating and maintenance workers rather than of the failure of electronic components).

Such a rate cannot be achieved easily. Large-scale integrated circuits almost achieve it, however, and they have the additional advantage of low cost. The cost makes it possible to provide redundancy that further reduces the possibility of outage and also protects against failure in other elements, such as wiring and the power supply. Redundancy keeps the system functioning, and the low failure rate of the gates makes redundancy work and keeps the cost of maintenance at a reasonable level.

The size of equipment is almost always important in telecommunication, particularly with satellites and spacecraft. Even on the ground electronic equipment that is small is easier to handle and ship and takes up less space in buildings. All these benefits lead to lower costs. The memory portion of a processor for a large electronic switching system provides an example of what developments in microelectronics have done to size.

With the technology of the early 1960s the memory for a local electronic switching system required a line-up of equipment racks 104 feet wide. Data storage was on sheets of magnetic material. By the 1970s the same amount of memory could be loaded into small, tightly packages toroidal ferrite "cores" in a line-up of equipment racks about eight feet wide. Then came integrated circuits and semiconductor memories that could provide firstly 1000 bits and then 4000 bits of storage on a single silicon chip. In a circuit consisting of 4000 -bit chips the memory for the same switching systems was packaged in a single rack 2.2 feet wide. Now integrated circuits with 256000 bits per chip are available, making it possible to put the memory in about a quarter of rack.

Microelectronics has also had a significant impact on analogue circuits, although the results are not as dramatic as they have been with digital logic and memory. Consider the perhaps most basic circuit to telecommunication: the voice--frequency electrical filter. Such filters are particularly important in systems that multiplex a number of voice channels onto a single wire; the filter confines each voice channel to a certain frequency band and thereby prevents the channels from interfering with one another.

For almost 50 years the filters were made from large inductors and capacitors. Over the period from 1920 to 1970 designers succeeded in making the inductors and capacitors progressively smaller, but the filter was still bulky and expensive. By 1969 progress in stabilizing resistance and capacitance elements against the effects of time and temperature and in making amplifiers inexpensive with integrated circuits led to an equivalent filter that was somewhat smaller and cheaper. The use of integrated amplifiers (built on a single silicon chip) enabled the designer to build the equivalent of the large inductors and capacitors with small capacitors to be highly stable against time and temperature.

By 1973 this technology had advanced to the point where the equivalent of the old voice-band filter made of large inductors and capacitors could be fabricated on a small ceramic substrate. By 1975 the size of the substrate had been reduced enough to make the filter appear externally to be one small component, quite like a standard integrated-circuit package. It is expected that soon the tantalum film will be placed directly on the surface of the silicon amplifier chip. The entire filter will be microscopic. This is not the limit, however, of the capability of microcircuits in filtering analogue signals. Time-shared digital integrated circuits and charge-coupled devices (CCDs) are both promising in extending the improvement of electronic filters, and they may be even smaller than the thin-film filter.

Size is particularly important in communication terminals. The small size and other desirable features of microcircuits open new vistas in terminal equipment. Such a terminal can be amazingly "smart" while being small and compact. It is not unusual for a terminal of this kind to contain a microprocessor. The microprocessor in a communication terminal costs tens of dollars and yet can do computations that a decade ago would have required a large computer costing hundreds of thousands of dollars.

Size and weight are closely related. They are both extremely important in space communication. It is hard to see how the space program could have been accomplished without the smallness, lightness and reliability provided by solid-state circuits.

Modern communication equipment requires a good deal of built-in intelligence. Many examples can be cited, including telephones at prodigious rates, electronic switching machines with built-in diagnostic capability, private branch.

Intelligence does not require a specific level of power. A circuit performing an intelligent function can often operate at a power level just sufficient to drive circuit nodes to voltages a few times greater than the voltage of any inadvertent noise on the circuit.

It is often possible to reduce power levels still further by choosing a technology that does not require much power in its active circuit elements. One such technology is represented by complementary metal-oxide-semicondutor (CMOS) circuits. Micro-processors employing about 200000 transistors has been designed in this technology on chips that are less than a quarter-inch on a side. They are specially designed as the control elements for communication equipment. The chip can execute more than 500 different instructions, operates at speeds of up to twelve megahertz (twelve million cycles per second) and yet consumes less than .1 watt of power. A system that provides such a large amount of intelligence with such lower power consumption enables communication equipment to be operated in places that have either no commercial power or an unreliable one. It allows complex remote equipment connected to long wires or cables to be supplied with power over the same small conductors that carry the signals.

Progress in microelectronics has been much slower in the areas of communication that call for high power. Solid--state devices can be employed in radio-frequency circuits of modest power, but usually they must be in the form of discrete transistors.

The pressure to expand the capability of microelectronics to serve communication circuits of higher power is considerable: circuits able to withstand hundreds of volts would be needed to hold off surges of lightening on exposed cable systems and to transmit even the modernate amount of power required to actuate the bell on a telephone.

Many communication needs can best be met with digit al technology. Signals transmitted as digits are not degraded as long as the digits are correctly received. A large amount of noise or "cross talk" which would be objectionable in an analogue signal of the type that usually carries the human voice may have no degrading effect whatever on digital signals. As long as the noise or cross talk is somewhat weaker than the digital signal the presence of each binary digit can be detected and the digit can be regenerated fully. The signal is therefore stripped of noise and cross talk. This is a powerful advantage when the signal is being transmitted through a noisy medium.

A digital communication system is likely to operate at a high pulse rate and to employ a large number of digital logic gates. Such circuits are small and well matched to modern micro-electronics technology.

The binary numbers are transmitted as digital signals, which are periodically regenerated along the route to remove noise, cross talk and distortion. At the receiving end the binary numbers are converted back to signal samples from which the voice sound can be reconstituted.

The advantages of digital communication have been known for some time. The extent of its application has been controlled mostly by the relative economics of digital and analogue circuitry. The development of integrated circuits has greatly changed the economics, tipping the scale in favor of digital operation in many domains.

A disadvantage of digital signals is that they require more bandwidth for transmission than analogue signals. Therefore analogue techniques remain attractive in well-shielded mediums of limited bandwidth, such as coaxial cables, and in radio propagation where the bandwidth is limited by the available spectrum.

Another concept that has been enhanced by microelectronics is stored-program control. First in the form of powerful processors associated with large equipment such as switching machines and more recently in the form of micro--processors embedded in all types of equipment, microelectronics has brought to communication a rapidly expanding array of programmable devices. The service and operational features of many large systems can now be altered by rewriting or adding to the program stored in the memory.

Until recently a communication system had to be either rewired or replaced to change the type of service offered. With stored-program control the old hardware can be programmed. to perform new functions, which relate just as much to more efficient use of the people who operate and maintain the system as to service features seen by the user. The systems are almost always digital, employing a great deal of logic and memory. Microelectronics has vastly expanded the horizons of stored--program control by offering logic and memory circuits that are inexpensive and highly reliable.

The trends in microelectronics affecting equipment design are by now well established. The current position is that integrated circuits have virtually taken over from discrete transistors, and that digital processes are rapidly supplanting the analogue techniques which have been predominant up to now. The aim is to move from systems on printed boards to systems on single VLSI (Very Large Scale Integration) chips. The use of VLSI technology, increased levels of integration and makes it possible tc use new architectures and algorithms. VLSI is considered to be one of the key technologies which will have a growing impact on many product lines.

New systems like Digital Exchanges, have been developed around VLSI technology and could only be realized cost-effectively by using custom designed VLSI circuits and standard microprocessors. Where production volumes are sufficient to warrant the design costs, standard integrated circuits are being replaced by applicating specific custom designs which make optimum use of VLSI technology, using gallium arsenide, silicon (bipolar and MOS), and high voltage.

As full custom design is expensive, in many areas semi-custom design using predefined gate arrays or standard cells is taking over. Advances in this area will make semi-custom designs equal in performance to present full-custom designs.

Although Brazil has an industry of communications capable of supplying the internal necessities, the microelectronic impact has only reached Brazilian industry in the last three years, when the telecommunications sector began to introduce in the National Telecommunications System Electronic Exchanges with Stored Program Control (SPC) in substitution to the Electromechanical Exchanges totally made in the country, which represent 55% of the telecommunication equipment market.

The transition to electronic systems brought a significant change in the relative cost of the Electronic Exchange production. While in the Electromechanical Exchanges, the material costs was about 30% of the total costs, in the Electronic Exchange, using integrated circuits SSI, the cost is about 50% and using CIs LSI, 80%. Besides that, the increase of the complexity of the integraded circuits provokes a , percent increase in the cost of the components in the total cost of fabrication.

The following shows the costs structure in the production of Electronic Exchange.

	Electromechanical	Electronic SSI	Electronic LSI
Fixed costs	50%	35%	15%
Work	20%	15%	5%
Material	30%	50%	80%

The small size and the large integration level of microelectronics components has reduced drastically the necessit ies of space and people for the assembling of equipment.

According to information given by a huge Brazilian industry of Electronic Exchanges, the manpower necessary for the production of 200,000 lines of Electromechanical Exchanges is 2.200 employees, while for the production of equivalent exchanges in the electronic version is only 340 men, that is, 57% less. The reductions would be about 55% in the production area, 82% in the installation area and 55% in the administrative area.

With the turn up of new equipment for transmission, network management and supervision for Electromechanical Exchange developed in Brazil and using VLSI integrated circuits has contributed to increase this impact in the industrial area as well as services.

In the sector of radio and TV receivers the increase of the integration level of the semiconductors affected mainly the Brazilian industries from the moment that they became completely independent of the foreign technology supplier through the use of the IC custom made.

Recently, ITT has introduced on the market 8 digital microelectronics components which are able to reduce 350 parts of a TV set. Having in mind that the radio and TV markets are almost 50% of the total Brazilian electronic equipment's market it is easy to appraise the consequences that digital TV may cause to the future of this section of the Brazilian industry, if national microelectronics industry is not available.

MICROELECTRONICS FOR COMMUNICATION - STATE-OF-THE-ART

Analog integrated circuits have benefited from advances in semiconductor processes and circuit design. Low noise, high gain processing combined with increasingly sophisticated design skill have resulted in cost-effective chips with the high dynamic range necessary for telephone transmission networks, radio receivers, and pulse code modulation repeaters (where some 40 to 90 dB of wideband gain is needed).

In many cases analog implementation is the best or the only feasible solution, and analog skills will make steady progress yielding increased bandwidths, higher frequencies, and inproved reliability. Bipolar technology has traditionally been used for analog circuits, but MOS technology is beginning to take over at the low frequency end where modest noise figures and gains are acceptable. Gallium arsenide is extending the frequency range of microwave amplification.

The ingenuity of the MOS circuit designer allows full integration of filters and amplifiers (usually switched capacitor filters) and the inclusion of analog and digital functions on one chip. The result is a higher degree of integration on each chip and partitioning in a way that is appropriate to the system and not forced on the designer by the limitations of the technology.

Many big communication equipment and components manufacturers are at the forefront of so-called mixed technologies, integrating bipolar and CMOS circuits as well as high voltage MOS and CMOS. these mixed technologies offer advanced solutions for interface chips.

However, in spite of analog advances the trend to digital systems is inexorable. In exchange for increased complexity, the digital approach offers increased reproducibility (less need for functional testing), better controllability (performance can be set by the software), and extra features (storage of information). It also allows new approaches (architectures) that are not feasible in analog designs. For example, radio receivers with digital synthesizers offer drift-free tuning and can use spread spectrum techniques to improve transmission security. To give an idea of the technology and integration level reached by the components used in telecommunication industry, Tables 1, 2 and 3 shows the VLSI ICs designed and used by ITT in new system 12 exchange.

TABLE 1 - Analog and analog/digital VLSI designs

Device	Production volume	Power available	Technology (Table 3)	Design method
Subscriber line circuit interface	high	low	G,H	FC
Subset transmission network	high	very low	E	FC
2 MBit s^{-1} PCM repeater (copper/optical)	medium	medium	E	FC
560 Mbit s^{-1} PCM repeater	low	high	F	FC
Subscriber line circuit	high	low	A,I	FC

TABLE 2 - Digital VLSI designs

Device	Production volumes	Power available	Technology (Table3)	Design method
1. Digital switching matrix (switchport)	high	low	A	FC
2. Digital subscriber loop (ISDN)	low	low	B	FC
3. Digital television	high	medium	C,D	FC
4. Speech recognition processor	high	medium	B	FC
5. Digital speech codec	high	low	B	FC
6. FDM-PCM transmultiplexer	medium	medium	B	FC
7. PCM channel bank data port	low	medium	B	SSC
8. PCM multiplexer (times 4 up to 34 Mbit s^{-1})	low	medium	E	SGA
9. Digital trunk	medium	medium	A,B	FC
10. Military radio (14 designs)	low	low	B	SGA
11. Video switch matrix	low	medium	J	FC

FC - full custom
SSC - semi-custom standard cell
SGA -- semi-custom gate array

TABLE 3 - Semiconductor technologies

A	NMOS, low power, medium speed (4 MHz)
B	CMOS, very low power, medium speed (4 MHz)
C	Bipolar, high speed, low cost
D	NMOS, low power, high speed (17 MHz)
E	Bipolar, low noise, medium speed
F	Gallium arsenide (or bipolar wideband analog)
G	Integrated high voltage MOS/low voltage CMOS
H	Combined bipolar and CMOS, medium voltage
I	CMOS, combined analog and digital (double polysilicon)
J	CMOS, high speed

Source: Comunicaciones Eléctricas ITT Nº 4/1984

THE BRAZILIAN TELECOMMUNICATION INDUSTRY-GROWING NEEDS ON MICROELECTRONICS

In 1983, the total telecommunications equipment and parts sold in Brazil amounted to 690 million dollars of which 540 million dollars were allocated to Public Telecommunication Service and 150 million dollars to the Private Service.

In 1977, this value amounted to 860 million dollars of which 760 million resulting from Telebrás System. This market has been gradually falling since 1976 when Telebrás started to reduce its investments due to government policy.

In comparison, the American Telecommunications equipment market is 14 times greater than that of Brazil (9600 versus 690 million dollars). Particularly, switching systems are 10 times greater (2900 versus 280 million dollars) and multiplex equipment 8 times greater (440 versus 54 million dollars).

The Brazilian needs are at present supplied almost entirely by our telecommunications industry. Table 4 shows a summary of the number of manufacturers, the effective production capacity in the last 7 years per type of equipment.

To supply the needs of the manufacturers the telecommunication industry imported in 1975 a total of 250 million dollars. These importations were composed mostly of disassembled equipment and parts with regard to components.

TABLE 4 - **TELECOMMUNICATION INDUSTRY PRODUCTION**

TYPE OF EQUIPMENT	NUMBER OF MANUFACTURERS	INSTALLED CAPACITY (1983)	NATIONAL OUTPUT						
			1977	1978	1979	1980	1981	1982	1983
PUBLIC EXCHANGES	4	1.000.000 equivalent lines	795.400	613.800	695.000	505.100	511.971	571.953	579.769
SWITCHBOARDS (PAX, PABX, ETC)	5	286.000 terminals	127.600	135.300	156.300	197.800	171.395	203.480	135.362
FDM MULTIPLEX	3	56.000 channels	49.980	45.270	26.410	26.400	59.800	25.500	39.526
PCM MULTIPLEX	4	120.000 channels	30.500	29.580	27.200	29.300	40.190	56.310	54.134
TELEGRAPHIC MULTIPLEX	1	18.400 channels	3.024	1.500	3.720	4.312	4.600	13.800	15.640
TELEX EXCHANGES	1	20 exchanges	-	-	-	9	-	-	2
SHF MULTICHANNEL RADIO	4	1.200 transceivers	388	402	729	353	426	454	445
VHF/UHF MULTICHANNEL RADIO	5	2.000 transceivers	622	749	541	590	951	1.344	1.132
VHF/UHF MONOCANAL RADIO	3	4.500 transceivers	884	1.470	1.368	2.373	2.338	2.962	2.140
SHF/VHF/UHF SSB RADIO FM FIXED, MOBILE AND PORTABLE	22	48.000 transceivers	17.000*	19.870	20.750	21.920	20.956	18.355	18.237
SUBSCRIBER CARRIER MONO + MULTI	3	35.200 units	5.500	9.400	14.300	22.976	10.930	23.559	9.290
TELEX	2	19.200 units	5.200	5.540	7.760	11.720	9.926	10.437	7.120
SUBSCRIBER TELEPHONE SETS	5	2.535.000 sets	866.570	725.420	881.260	1.388.940	1.740.200	1.551.090	922.327
PUBLIC TELEPHONES (COIN)	2	30.000 sets	9.990	10.860	10.160	14.620	15.475	18.322	24.789
KEY SISTEMS	6	230.000 sets	112.000	115.460	175.200	157.400	131.800	129.690	108.282
TELEPHONE CABLES AND WIRES	17	32.800 tons	14.000	12.000	11.000	10.000	9.000*	9.000*	(*) 9.000
VOICE AMPLIFIER/LOOP EXTENDER	4	278.000 units	9.370	18.040	22.220	43.050	37.200	30.540	2.450

During that year the Brazilian government started an import encouragement policy to replace imports by local products due to exchange difficulties occurring because of the oil crisis. As a consequence, the importations started to fall until it reached 45 million dollars in 1984. Then the importations comprized 65% of components, 28% of mechanical and electronic parts.

The evolution of medium cost of the importation necessary to the local telecommunication equipment manufacture decreased markedly. In 1976,181 dollars of inputs per line of switching systems manufactured were imported; this value dropped to 12 dollars in 1984. In 1978, 236 dollars of inputs per channel of PCM equipment were imported. In 1984, this value fell to 9 dollars. Those residual values refer mainly to semiconductors and some components not yet manufactured in Brazil due to their complexity of lack of industrial scale.

Although the Brazilian industry has manufactured for the last seven years about 700000 lines of switching system per year they have been of electromechanical type, with less demand of semiconductors with exception of lower power diodes.

The introduction of electronic system, although being made gradually in the National communications system, will change drastically this situation in the next years, mainly when the manufacturers (who are executing the production nationalization plans accorded with the government) reach the level of nationalization of the microelectronic components.

The transition from mechanical to electronic switching system can be seen in the Table below:

TABLE 5 - BRAZILIAN SWITCHING MARKET - in 1000 lines

	1982	1983	1984	1985	1986
Exchange	380	248	221	185	197
Electromechanical	99	38	273	305	297
T O T A L	497	279	494	490	494

SOURCE: GEICOM/1984

The most important electronic exchange industry is ERICSSON, which manufactures AXE since 1981, and has already delivered until now about 300.000 lines.

ELECTRONIC SWITCHING SYSTEM

In 1975 the guidelines set forth by the Ministry of Communication established the introduction of Store Program Control Spacial Switching, SPC-S, in the Telecommunication National System, and charged TELEBRÁS with the development of a Brazilian model of exchanges with temporal technology-SPC-T, called TROPICO, for mid and long term use.

The same guidelines intend to have only one technology for the SPC-S exchanges, to be produced in the country with nationally controlled capital manufactures.

For many reasons, particularly because of the difficulties to ratify the result of the international bidding, accomplished to choose the SPC-S technology (at the end, 3 were chosen: NEC, ITT and ERICSSON), and because of TELEBRÁS limited resources for investments, only in 1979 the first contract for SPC-S was signed (50 thousand AXE-ERICSSON lines).

By this time, taking into account the development of temporal technology abroad, it was inadvisable to proceed with the introduction of spacial switching which would soon be surpassed.

In this regard, and taking into consideration the limited installation of SPC-S, in November 1981, some of the guidelines regarding the SPC exchanges were changed.

These changes established that:

- From that time on, only temporal technology would be admitted for SPC exchanges.
- The introduction of temporal exchanges with technology transferred from abroad are limited to the large metropolitan areas and a specific market is reserved to each supplier (NEC, SIEMENS and ERICSSON).
- As soon as the TROPICO exchanges, developed by TELEBRÁS, are available, the market shall be fully co tive, although at least 50% of the purchasing to be accomplished by the National Telecommunication System would follow the Brazilian model.
- To permit a total transparency of the new systems, to have similar facilities for all users and to avoid the formation of dependent markets, the exchanges shall meet the same characteristics of language, protocols and interfaces.

The first stored program control spacial switchings (SPT) used were of semi-electronic type because from the point--of-view of the components used in their circuits the following characteristics appear in their basic blocs:

- the conversation chain is composed of electro-electronic devices;
- the control equipment applies TTL ICs and memories of RAM and PROM types.

The control equipment is operated by stored program, because the logical linkage (enchainment) of its elementary function (which will allow the establishment of calls), is obtained through a series of instructions (program) stored in electronic memories, electrically changeable. Thus any change or modification to be introduced in the exchange is executed by modification in the instruction lists, without altering the wiring or the equipment.

The conversation chain is of the spacial type, because this switch between the caller subscriber and the called subscriber is established through a physical circuit individual and specific for each call. Therefore, simultaneous calls are established by separated physical ways, or spacially separated circuits.

At present, ERICSSON is manufacturing the AXE-SPT exchange of temporal type that is:

- the convertion chain is composed by integrated circuits, which transmit the conversation under the form of Pulse Code Modulation (PCM);
- the control equipment is the same used previously.

The nationalization of the production reached by these exchanges is such that in 1984 the importation level of inputs was 55 dollars per line. In 1982 this value was 140 dollars.

To manufacture the exchange ERICSSON buys the Standard I.C. from local and foreign suppliers. As for the custom made I.C. they import from their factory in Sweden

GEICOM (Inter ministerial Executive Group for Components and Materials) having analysed the components in the submission to choose the technology to be used in Brazil for the local manufacturing of Electronic Exchanges with stored program control (SPT) arrived to the following results for the standard exchange of 10.000 lined (AXE/ERICSSON):

- 88,76% of the hardware value were components of which 24% are semiconductors distributed as follows:

TABLE 6 DISTRIBUTION OF SEMICONDUCTORS

	TYPE	QUANTITY
IC	LINEAR	4289
	TTL	70460
23,64%	MOS (MSI-LSI)	3
	BIPOLAR MEMORY LSI	4163
	MEMORY MOS LSI	5040
	CUSTOM	66392
	T O T A L	150347
TR	SMALL SIGNAL	46368
	SWITCHING	15052
o,67%	POWER	1249
	FET	538
	T O T A L	63207
	SMALL SIGNAL	109283
	SMALL RETIFIER	3662
DIODES	POWER RETIFIER	2190
	ZENNER	1378
0,36%	SCR	7
	T O T A L	116520

SOURCE: GEICOM

The other manufacturers of electronic exchanges are NEC with the NEAX and EQUITEL (SIEMENS) with the EWSD. They have not yet started to produce; in this first phase they are importing the parts and making the final assembling.

For the manufacturing of a NEAD exchange of 30.000 lines 88 different types of integrated circuits are needed, of which 44 are custom made by NEC, 27 are from MOTOROLA, 5 are from TEXAS and AMD and the others from INTEL and SHARP. 2 types have a demand around 36000 units, 1 type has 24000 ', 1 type has 10000 and 17 types a demand around 2000 to 6000 units.

OTHER EQUIPMENT

The telecommunication equipment that use great quantities of semiconductors are multiplex equipment FDM and PCM. In the last 4 years the market has around 80000 channels one side per year. In 1984 29200 FDM channels and 48000 PCM channels were manufactured.

In Brazil the trends to digitalize the network are to use more and more the PCM, mainly the MCP 30 developed in CPqD - Centro de Pesquisa e Desenvolvimento (Research Center of TELEBRÁS) Which granted the right to manufacture the equipment to all multiplex manufacturers.

In 1984 23000 channels (one side) of MCP 30 were manufactured and their semiconductors needs were:

- 305000 diodes of 17 different types with the demand concentrated in 3 types of diodes Zenner (185000 units) and 1 type of signal diode (190000 units).

- 315000 transistors of 11 different types with the demand concentrated in four types.

- 205000 TTL I. C.s with 50% of the demand concentrated in 4 types.

- 120000 Linear IC with more than 50% of the demand concentrated in 2 types.

Other equipment which tend to increase the need of semiconductors are the terminals, as telephone sets, which become electronic and increase their functions, justifying the elaboration of custom made IC due to economic scale (3 million ICs with 2 types).

In a general way the local demand of semiconductors of telecommunication industry was supplied by local industry of semiconductors and by the importations as seen in Table 7 which represent a potential market for the Brazilian microelectronic industry.

I.C. MAIN TELECOMMUNICATIONS INDUSTRIES IMPORTS

TABLE - 7

	U. S.$ 1000	
	1982	1983
ERICSSON	1.176	666
NEC	1.083	321
EQUITEL	505	450
MULTITEL	-	222
SUL AMÉRICA PHILIPS	110	235
ABC TELETTRA	14	59
SITELTRA	15	3
ELEBRA INFORM.	641	564
OLIVETTI	342	625

SOURCE: CACEX/1984

THE BRAZILIAN DEMAND FOR SEMICONDUCTORS

The Brazilian Industry produced, in 1984, 3,8 billion dollars of electronic equipment generating a demand for 192 million dollars of semiconductors.

To evaluate the semiconductor market in quantity and value having as a base the local production of electronic equipment is a complex task, because increased integration scale reduces the number of I.C. used in the equipment. For example, in 1980, a microcomputer of 64 k bytes of RAM memory had the memory composed of 64 x 8 = 512 I.C.s of memories of 1 k bytes. In 1983, with the introduction of memories of 64 k bytes only 8 I.C. were necessary with a total cost inferior to the 512 I.C.s used in 1980.

Also the semiconductor cost is falling with time, for example, the INTEL 8086 microprocessors cost in January 1981 38 dollars; in January 1984 its cost dropped to 15 dollars. In the same way INTEL 2764 memory cost in January 1982 26,6 dollars. In January 1983 its price fell to 13,5 dollars.

The cost of transistors diodes, thyristors, etc., has been maintained stable for the last few years. Tables 8 and 9 show the demand for the last 4 years.

BRAZILIAN DEMAND FOR SEMICONDUCTORS (IN VALUE)

TABLE 8 IN MILLION DOLLARS

	Signal Transistors	Power Transistors	Signal Diodes	Power Diodes	Opto Electronics	Thyristors	Linear IC	Digital IC	TOTAL
1980	28,8	40,5	12,1	19,8	2,1	8,0	33,3	31,3	175,6
1981	24,2	33,9	10,6	16,5	2,2	5,8	26,2	34,0	153,4
1982	26,0	36,7	12,7	18,4	1,9	9,9	30,4	40,9	176,9
1983	26,1	37,1	13,5	19,0	3,2	5,7	30,8	44,2	179,6
1984	27,4	37,3	13,8	19,2	3,7	6,7	32,7	51,4	192,2

SOURCE: GEICOM/1984

BRAZILIAN DEMAND FOR SEMICONDUCTORS (IN PIECES)

TABLE 9 IN MILLION OF PIECES

	Signal Transistors	Power Transistors	Signal Diodes	Power Diodes	Opto Electronics	Thyristors	Linear IC	Digital IC
1980	230,2	63,2	253,8	83,3	12,1	3,1	32,8	30,5
1981	183,9	47,2	244,1	90,8	17,7	2,5	36,8	30,0
1982	190,1	51,1	242,9	89,4	24,4	3,5	37,3	33,4
1983	201,4	51,7	259,9	92,0	33,7	2,7	39,7	36,4
1984	211,3	52,1	265,1	93,2	40,2	3,3	41,7	42,5

SOURCE: GEICOM/1984

Regarding the distribution by industrial sub-sectors the Brazilian demand of semiconductors is made as follows:

- CONSUMER and AUTOMOTIVE 73%
- DATA PROCEEDING 11%
- TELECOMMUNICATION 11%
- INDUSTRIAL ELECTRONICS 3%
- OTHER SECTORS 2%

In 1983 the total demand reached 179,6 million dollars, of which 75 million dollars for the I. C. market distributed as follows:

LINEAR I. C.	- 39 pieces	(30,8 million dollars)
	- Coloured TV	10,5 million pieces
	- B & W TV	2,8 million pieces
	- Radio	6,6 million pieces
	- Autoradio	9,5 million pieces
	- Communications	3,9 million pieces
DIGITAL I.C.	- 44,2 pieces	(36,5 million dollars)
	- CUSTOM MADE	10,5 million pieces
	- SSI/MSI	22 million pieces
	- LSI	4 million pieces

SOURCE: ABINEE/1984

The Linear I.C. present a large number of pulverization types. There are about75 different types, several of them having the same functions but different electrical characteristics. It is a market of custom-made type.

In 1984 the I.C. market reached 84 million dollars, 32 .7 million regarding Linear I.C, the largest demand coming from the consumer sets with 27 million dollars, followed by telecommunications with 3.5 million dollars.

The demand for I.C. digitals reached 51. 4 million dollars thus distributed by different industrial subsectors.

- Data processing with 26. 8 million dollars of which 17 million dollars are demanded by IBM/BURROUGS.
- Telecommunications with 12.? million dollars.
- The remainer 12 .4 million dollars are "custom made" for calculator watches, video games, etc.

As for the technology used the demand of digital I.C.s are thus distributed:

BIPOLARS	14.6%		
MOS	65.4% of which	LOGICS	35 .7%
		MEMORIES	23 .2%
		MICROPROCESSORS	6 5%

In a global way, in 1984, 80% of I.C. demand were of Standard Devices, and 20% Custom, thus distributed:

. FULL CUSTOM	60%
. GATE ARRAYS	36%
. STANDARD CELLS	4%

THE SUPPLY OF THE BRAZILIAN DEMAND FOR SEMICONDUCTORS

From the macro-economic point of view, in 1983, the internal demand for 179·6 million dollars in semiconductors, 117·1 were locally produced: 30·2 million dollars were imported and 27 7 million dollars were exported.

To manufacture the equivalent to 117 1 million dollars the semiconductors industry had to import microelectronic materials in the amount of 25·3 million dollars.

Tables 10 and 11 show the supply of the Brazilian market of semiconductors in 1983.

SUPPLY OF THE BRAZILIAN MARKET OF SEMICONDUCTORS

IN MILLION DOLLARS

TABLE 10	1979	1980	1981	1982	1983
DEMAND	145,3	175,6	153,4	176,9	179,6
LOCAL PRODUCTION	95,4	116,5	95,4	113,0	117,1
IMPORTATION	78.2	104,7	100,8	92,2	90,2
EXPORTATION	28,3	47,0	37,1	28,3	27,7
IMPORTATION OF MATERIAL FOR MANUFACTURE SEMICONDUCTORS	37,3	52,0	28,1	26,3	25,3

SOURCE: GEICOM/1984

SUPPLY OF THE BRAZILIAN MARKET OF SEMICONDUCTORS

1983 IN MILLION DOLLARS

TABLE 11	DIODES	TRANSISTORS	INTEGRATED CIRCUITS	THYRISTORS	OPTO ELECTRONICS
DEMAND	32,5	63,2	75	5,7	3,2
LOCAL PRODUCTION	24	52,1	37	3,4	0,6
IMPORTATION	11,4	11,3	62,2	2,6	2,6
EXPORTATION	2,9	0,2	24,2	0,3	0,08

SOURCE: GEICOM/1984

However, the main part of the demand, mainly with regard to integrated circuit VLSI and LSI circuit as well as custom-made I. C. is met by imports.

The value of the importation of those items can be seen in Table 12.

VALUE OF IMPORTATION OF CUSTOM-MADE ICs

TABLE 12 IN MILLION DOLLARS

SEMICONDUCTORS IMPORTATION	1982	1983
DIODES	12,0	11,4
TRANSISTORS	14.0	11,3
THYRISTORS	8,1	2,5
LIGHT EMITTED DIODES	1,4	2,6
INTEGRAGED CIRCUITS	56,6	62,2
OTHER SEMICONDUCTORS	92,3	90,2
T O T A L	92,3	90.2

SOURCE; CACEX/1984

The distribution of those importations by industrial subsector can be seen in Table 13.

DISTRIBUTION OF IMPORTATIONS BY INDUSTRIAL SUBSECTORS

TABLE 13

INDUSTRIAL SUBSECTOR	DIODES	TRANSISTORS	INTEGRATED CIRCUITS
CONSUMER	76	80	41
TELECOMMUNICATION	7	9	11
DATA PROCEEDINGS	2	4	31
OTHERS	15	7	17

SOURCE: GEICOM/1984

CHARACTERISTICS OF THE MICROELECTRONICS INDUSTRY

It is not feasible for any company or government to implement an antieconomical industry for a long period of time. An industry of microelectronics has specific characteristics as to its own product, fabrication and market.

The main factors to be considered on production and product procedures are:

SCALE ECONOMY

The typical plant for microelectronic devices (up to date technology) has a high minimum cost, which tends to grow year after year with the necessary evolution towards a better integration.

Up to now, this cost is about 20 to 30 million dollars, likely to increase specially in case of a plant with a great automatization level aiming at the production of high density memories. Indeed, this high minimum cost is related to the indivisibility of certain equipment, which leads consequently to a scale economy.

Another important factor to be stressed is the manufacturing process learning curve associated with the rate production/ /time to produce a component . High costs for small volumes of production result from those factors.

The learning curve allows a gradual increase of manufacturing efficiency, which can affect the economic process.

The memory manufacture is, for that reason, extremely important to the manufacturers, because it has a uniform structure, each cell being similar to the other allowing a great integration in testing and, also the development of new manufacture procedures due to the handling of a product which will have a high production volume for long time. This learning procedure is then transferred to other products.

The need to reach an adequate level of productivity makes it difficult to use several procedures at the same production line, and even a great number of different products with a single process on line. Therefore it is most important to have a relatively large and homogeneous market for those products using the same manufacture procedure to make a plant feasible.

FINANCIAL STRUCTURE

The semiconductor industry is capital intensive and even a small industrial unit requires high investment. Marketing practices of the big multinational manufacturers - consisting in producing in huge volumes for the world market and in introducing a constant flow of new products at very low prices - make it difficult for a local manufacturer of standard products to achieve the industrial scale required for the feasibility of a local complete production cycle.

In 1979, in USA, for each 2.5 dollars sold the manufacturers were investing one dollar in future growth.

MICROELECTRONIC PRODUCTS

Microelectronic products can be standard type -

-products relatively standardized and available in the market, as for example the memory chips; full custom taylor-made components for specific use as for example a component for a watch or a toy; finally the semicustom where the component is left semi-finished after an initial manufacture to be finished later according to the customer's specification.

From the customer's point of view, for a small individual consumption, the cheaper solution would be the use of standard components in the project. With a greater volume, it would be worth using a microprocessor, because there is a sufficient scale to justify the cost of software development.

Today, with a volume in the range of about 5000 to 100000 units, the suitable solution is the semicustom; on the other hand, for greater volumes which can justify the cost of specific development, the best solution is full custom.

When discussing the competition in microelectronic industry, we tend to reason, as if the products of this industry were homogeneous. In fact, this is not the case. The most typical standard products of the industry are the memories. One of the most common aspects is the constant fall of the bit price, associated with a growing market value. For example, the DRAM memory market ('Dynamic Random Access Memory') of 4 billion dollars in 1984 is estimated to reach more than 7 billion dollars in 1987, showing a real half price per bite.

Every three years practically a new generation with better price/performance is introduced in the market. The Japanese manufacturers have chosen this market segment, of great volume and value, to introduce their products, making them highly competitive. In this context all the technological factors previously indicated, as the scale economy, productivity and financial structures, become dangerous.

There is a great variety of types of standard products. Memories are one of them. Only in 1980, there were 59 models of microprocessors and microcomputers and 259 models of support circuits and peripherals. Forty nine companies manufactured them and 28000 equipment industries bought them in bulk directly from these manufacturers. The diversity of products, associated with quick technological evolution created opportunities which constantly allow for the undertaking of new enterprises.

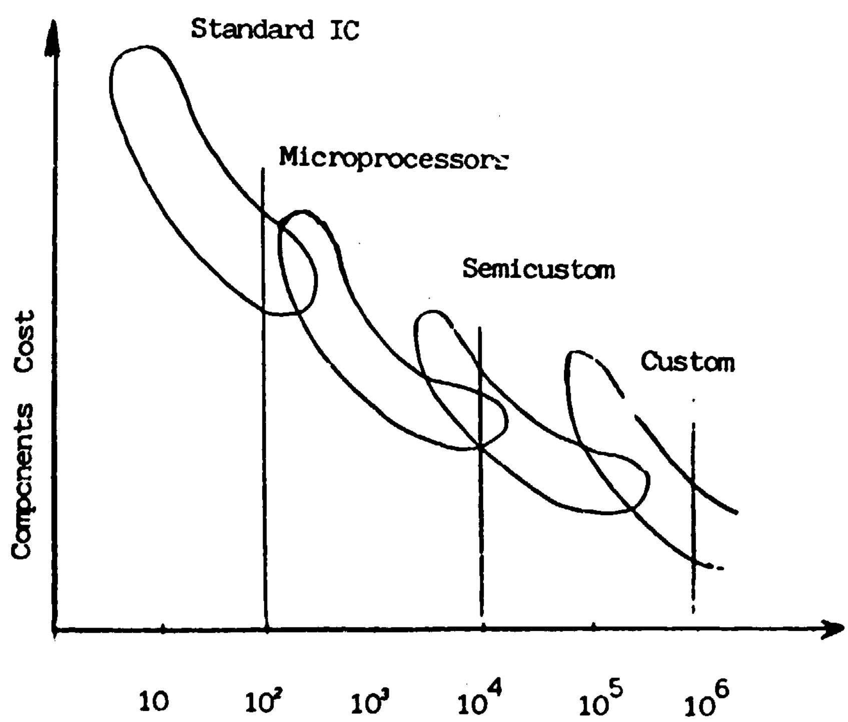


Figure I -ANNUAL CONSUMPTION OF COMPONENTS

CUSTOM I. C.

Standard integrated circuits can perform many of the tasks required in a system, but in many cases the best performance-to-cost ratio (e.g. highest throughout with low power and low unit cost) is achieved with a custom design circuit. Indeed, in certain cases the need to achieve maximum performance makes it essential to use custom circuits.

Conventional assemblies of standard integrated circuits on printed-circuit boards, such as microprocessors, memories, wired logic, interface or buses, result in considerable bulk in systems that are not always optimized for the end requirements since many of the integrated functions remain unused.

The use of a microprocessor, for example, involves the unfolding of a program, which in turn necessitates a multitude of operations, each requiring hundreds of nanosecond and hence very thirsty in terms of logic gates. A properly adapted custom circuit can sometimes do the job in a few tens of nanoseconds while at the same time replacing several standard circuits. In the case of a custom circuit, the whole secret of an industrial system may reside in an integrated-circuit chip.

Any attempt to copy it would require a lot of ingenuity and, above all, extensive resources. Other advantages of the custom circuit are low power consumption and greater reliability.

Custom integrated circuits manufactured by conventional techniques are justified only if they are mass-produced.

Although the semiconductor world is suffering from a shortage of integrated-circuit design specialists due to the explosive demand created in this field, custom circuit will grow to become more than 50% of all integrated circuit sales by 1986.

Economic development and production of these components is only possible with a high technological capability. Many I.C. design centers recognized this early on and have built up a competitive position in design methodologies, computer-aided design tools, process.

SEMI-CUSTOM IC FOR LIMITED PRODUCTION RUNS

- Through its leads to extremely small chip areas and hence to maximum mass production costs, the traditional method of designing custom integrated circuits usually leaves much to be desired as regards lead times. Moreover, it requires hundreds or thousands of hours of design work and mobilized the services of highly qualified design staff at a time when such men are scarce. Many design centers will in most cases propose solutions permitting automated design. This approach involves the so-called "preprocesses circuits" which are of two kinds: precharacterized (standard cell) and prediffused circuits (gate array).

Gate arrays are a type of preprocessed (prediffused) integrated circuit chip that carries very large number of components (from 2000 to 10000 gates) in a repetitive pattern, all interconnected by metallization. The designer obtains the circuit diagram he wants by merely drawing in the connections between components on the chip plan. The diagram is then transferred to the chip by etching the one or more metallization layers. This method is very similar to the method of manufacturing printed circuits and results in a less efficient exploitation of the chip area than the method employing optimized basing functions. On the other hand, development time is reduced to the time it takes to design one or two masks only (as against that needed on an average for an integrated circuit). and the cost of the initial prototypes may be as little as one-tenth that of a traditional custom circuit since all that the customization of prediffused circuits requires of the manufacturer is the etching of one or two metallizations to match the interconnections required by the user.

The cost of production will depend directly from the silicon area and from the number of layers that will be used.

This method offers other advantages as well. The etching can be done quickly at the Design Center itself; and since the stages in the customization process are few in number, the chances of getting the circuit right at the first try are extremely high. Lastly, a modification to the circuit can be done quickly and cheaply.

It is also recognized that VLSI design capability must be made available at design centers close to the system development centers, to ensure that products can take advantage of these techniques. This need and the knowledge that specialized products may have low production volumes have led to an emphasis on semi-custom design for the smaller design centers.

Where large numbers of a circuit will be manufactured, product cost and chip size must be minimized. The best results are obtained by full custom design tailored to the semiconductor technology. For modest volumes and performance, semi-custom techniques cut development cost by reducing the design time. Figure II below illustrates the tradeoff between custom and semicustom design.

The crossover between the optimum areas for custom and semi-custom depends largely on the design skills, maturity of the computer aided design tools, and processing technology.

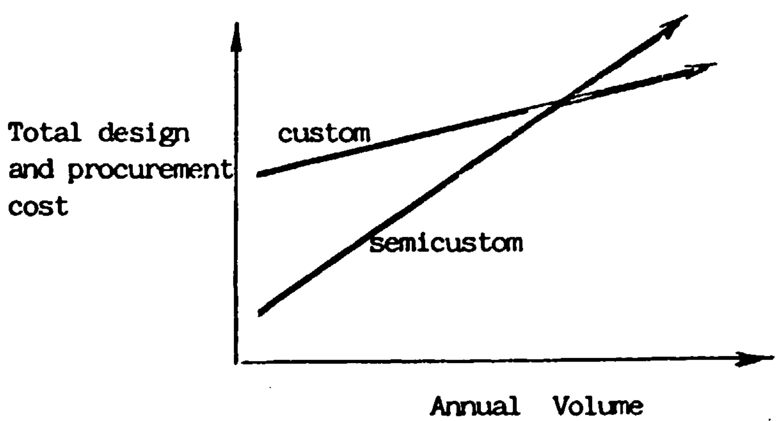


Figure II. Tradeoff between Custom and Semicustom Design.

Another advantage of semicustoms is of the time of development and the training level necessary for the designers in both cases, much less than the ones made to order. These advantages associated with the typical series of the manufactured products of countries recently industrialized, makes this a very interesting option.

The precharacterized circuits (standard cells) involve mainly 80 basic functions, all the integration data concerned are stored in a computer library. The designer with the client's specifications constructs his circuit diagrams solely on the basis of these basic functions, then designs the interconnections between the corresponding library--available mask elements. Design time is significantly reduced as a result by comparison with a conventional custom-designed circuit, since in this case whole functions - some of them complex - instead of transistors are assembled one by one.

When the masks are made, they are sent to a silicon foundry, i. e. manufacturers of specialized components receive masks from clients and produce the respective components for small volumes and in reduced time.

Finally, in "silicon compiler" not existent in an efficient way, but fundamental for the very large integration (VLSI), the electronic requirements of the project would be automatically and efficiently expressed in masks, reducing greatly the cost of individual project of each component.

THE VERY LARGE SCALE INTEGRATION (VLSI)

The very large scale integration (VLSI) practically puts the equipment inside the component.

Therefore, it is necessary that equipment producer and component producer co-operate to some extent. The same knowledge is necessary in a simpler way for the semi-customs. By all means the semi-customs bring several advantages to the developing countries:

- they require less investments;
- they train designers for microelectronic devices but for a simpler technology;
- they allow that specific needs of their products and markets be attended in an efficient way;
- they are a natural way for the very large integration of component projects;
- they create for the component supplier an accurate system philosophy which will predominate in the future.

These advantages would be profited only if it was settled:

- a local need for project for the consumer goods and manufacturing equipment;
- an increasing number of capable technicians;
- at least one local microelectronic manufacturer to attend step by step the semi-custom market, with the necessary economy and quickness.

It can be concluded that the diversivity of micro-electronic products is substantial and that it is being explored specifically to make production viable to local industry. The custom ICs indicate an interesting partial future alternative.

TECHNOLOGICAL UP-TO-DATENESS

Every three years a new memory is introduced with four times more capacity than the previous one and with a better price-performance.

This tendency we can find already in other products of the industry.

This evolution is a direct consequence of the growing miniaturization obtained by the technological changes in manufacturing processes and also an evolution of the quality and the yield.

Each time that new elements are put into a component it becomes more difficult to design the component and obtain efficient methods to test them. Today big resources are applied to solve these problems.

Because of the increase of competitors in the sector and the need to keep up-to-date many companies adopt the following series of action:

- great investments in research and development in 1984; the six American big producers spent 8.5% from their sales in this activity;
- association of microelectronic companies in financially strong groups, thus allowing big investments in R & D;
- purchase of shares or effective control as a method of reaching technology up-to-dateness. This method is being used by American and European companies.

THE BRAZILIAN SEMICONDUCTOR INDUSTRY

There are 21 enterprises with industrial operation of semiconductor devices in Brazil.

Most of them only execute the assembly and test stages. Only four of them execute the complete productive process, that is, diffusion, assembly and test. SID MICROELETRÔNICA, for transistors and integrated circuits, SEMIKRON and AEGIS for signal and power diodes, and HELIODINÂMICA produces solar cells starting from the crystal growing of monocrystalline silicon.

These enterprises are generally multinational ones, performing only the final stages of production for economical reasons due to production scale.

In the semiconductor industry the manufacturer's costs of several microelectronic devices, exclusive of losses in the manufacturing process are thus proportionally distributed as follows:

MANUFACTURING STAGES

DEVICE	DIFFUSION	PACKAGING	TEST
Transistors	17	75	8
IC SSI	21	62	18
IC MSI	32	39	29
IC LSI	40	22	38

The packaging and test correspond to the higher portion of cost and do not depend so much on the production scale. Also, they need smaller investment and lesser technology capability.

SID MICROELETRÔNICA

From the industrial point of view, the only Latin American operation of semiconductors in "State of the Art" is made by Microeletrônica located in Belo Horizonte. This enterprise is a result of the purchase by SID in early 1983, of the joint-venture FORD (Philco) and RCA, which started its assembly in November 1980 and its diffusion activities in 1982, dedicated to the domestic market and exportation.

In 1983, before interrupting its operations the joint-venture assembled about 40 million transistors (TO 92, TO 126, TO 220, TO 3), 5.5 million Linear I. C. and diffused 8000 3" wafers of which about 50% were Linear I. C. and 50% planar transistors.

Their industrial installations of fotoengraver, diffusion, as well as other processing areas have strict humidity and temperature control as well as a treatment station for water de-ionization and environmental particles control (0.5 micron) specially in laminar flux stations that reaches class 100 with the possibility of reaching class 10 with appropriate proceedings, having thus environmental conditions compatible with LSI. Its production capacity is 60 million units/year for TO 92, about 10 million units/year for TO 126, TO 220, TO 3, and 17 million of Linear I. C. (8L, 14L, 16L, 24L, WINGTAB) with a manufacturing level from the diffusion process to the final test.

It also has the capacity to diffuse 80000 of 3" wafers per year of linear integrated circuits considering two production shifts per day.

Their capabilities concerning available equipment are the following:

- Environmental conditions compatible with LSI
- State-of-the-Art (Linear)
- Possibility of adjustment for 4" and 5"
- Charge and discharge through cassettes to avoid hand touch/faults
- Microprocessor control
- Etching and cleaning stations
- Laminar flux chapels (all charge and discharge stations)
- Layout
  . flexible
  . expandable
  . VLSI philosophy
- Critical operations: photo, pre-diffusion, cleaning, deposition, etc)
  . in-line
  . class 100
  . absolute filtering

Another manufacturer worthy of mention is HELIODINÂMICA, which produces silicon solar cells starting with the crystal growing of monocrystalline silicon (Czochralski process).

With a nominal capacity of production of 300 slices and/or cells per year, they intend to create a crystal growing unit by Float Zone process for use exclusively in microelectronics.

They also plan to substitute diffusion processes for ions implantation.

SEMIKRON and AEGIS are vertical companies executing productive processes of rectifiers, diodes and thyristors starting from the diffusion of the silicon slice.

The institutions and industries which manufacture and project semiconductors can be seen in Tables 14, 15 and the global production in Table 16.

SEMICONDUCTOR MANUFACTURERS IN OPERATION IN BRAZIL

TABLE 14

EMPRESAS	DIODES		TRANSISTORS			thyristors	optoelectronics	digial I.C.	Linear I.C.
	up to 20 A	power	signal	medium power	power				
AEGIS	•	•				•			
FAIRCHILD	•		•	•					
HITACHI	•	•				•			
IBRAPE	•		•	•				•	•
ICOTRON	•	•	•	•		•	•		•
NEC			•	•					•
M. C.							•		
SID (EX PHILCO)			•	•	•	•			•
PHILIPS NE.									•
POLITRONIC							•		
ROHM	•	•					•		
SANYO			•						
SEMIKRON	•	•				•			
STEVENSON			•						
TEXAS			•		•	•	•	•	•
THOMSON-CSF			•						
WESTINGHOUSE	•	•				•			
NATIONAL	•		•						
HELIODINÂMICA							•		

COMPANIES AND INSTITUTIONS OPERATING IN THE SEMICONDUCTOR COMPONENTS AREA IN BRAZIL (JUNE 1984) (UNIVERSITIES NOT INCLUDED)

Table 15

COMPANY OR INSTITUTION	NOTES	START OF OPERATIONS (DATE)	HOME BASE	MAIN PRODUCTS	AVAILABLE MANUFCTURING PROCESS	STATUS
AEGIS	FOUNDED IN 1982	1983	BRAZIL	POWER DEVICES Di Tir	 D,P,M,T D,P,M,T	 IN OPERATION BEING ESTABLISHED
DOCAS MICROELETRÔNICA	FOUNDED IN 1984	-	BRAZIL	IC	D P,M,T	BEING ESTABLISHED PLANNED
FAIRCHILD		1974	ABROAD	Di, TR	M,T	IN OPERATION
HELIODINÂMICA	FOUNDED IN 1980	1983	BRAZIL	SILICON PHOTO-VOLTAIC CELLS SILICON WAFERS	D,P,M,T P	IN OPERATION IN OPERATION
IBRAPE (PHILIPS)		1961	ABROAD	Di,TR,IC	M,T	IN OPERATION
ICOTRON (SIEMENS)		1973	ABROAD	Di,TR,Tir,LED,IC	M,T	IN OPERATION
ITAU COMPONENTES - ITAUCOM -	FOUNDED IN 1983	1983	BRAZIL	IC	D M,T P	IN OPERATION BEING ESTABLISHED PLANNED

cont'd

Table 15 cont'd

COMPANY OR INSTITUTION	NOTES	START OF OPERATIONS (DATE)	HOME BASE	MAIN PRODUCTS	AVAILABLE MANUFACTURING PROCESS	STATUS
MC - MICROCIRCUITS		1980	BRAZIL	TR, LED	M,T	IN OPERATION
NEC DO BRASIL		1979	ABROAD	TR, IC	M,T	IN OPERATION
PHILIPS ELETRÔNICA DO NORDESTE	OPERATING ONLY FOR EXPORT	1975	ABROAD	IC	M,T	IN OPERATION
POLITRONIC		1978	BRAZIL	LED	M,T	IN OPERATION
ROHM		1980	ABROAD	Di, LED	M,T	IN OPERATION
ROBERT BOSCH DO BRASIL	CAPTIVE	1982	ABROAD	Di	M,T	IN OPERATION
SANYO DO BRASIL		1971	ABROAD	TR	M,T	IN OPERATION

cont'd

Table 15 cont'd

COMPANY OR INSTITUTION	NOTES	START OF OPERATIONS (DATE)	HOME BASE	MAIN PRODUCTS	AVAILABLE MANUFACTURING PROCESS	STATUS
SEMIKRON		1967	ABROAD	Di Tir	P,M,T M,T	IN OPERATION IN OPERATION
SID-MICROELETRÔNICA	IN 1984 BOUGHT PHILCO SEMICONDUCTORS PLANT WHOSE OPERATION HAVE STARTED IN 1982	1984	BRAZIL	Di,TR,Tir,IC	P,M,T D	IN OPERATION BEING ESTABLISHED
STEVENSON	CAPTIVE	1982	ABROAD	TR	M,T	IN OPERATION
TEXAS INST. DO BRASIL		1973	ABROAD	Di,TR,Tir,LED,IC	M,T	IN OPERATION
THOMSON CSF		1972	ABROAD	TR	M,T	IN OPERATION
WESTINGHOUSE DO BRASIL		1978	ABROAD	Di, Tir	M,T	IN OPERATION

cont'd

Table 15 cont'd

COMPANY OR INSTITUTION	NOTES	START OF OPERATIONS (DATE)	HOME BASE	MAIN PRODUCTS	AVAILABLE MANUFACTURING PROCESS	STATUS
RASEARCH AND DEVELOPMENT CENTER OF TELEBRÁS (CPqD)	TELEBRÁS IS THE GOVERNMENT OWNED HOLDING COMPANY FOR THE BRAZILIAN TELECOMMUNICATION OPERATING COMPANIES	1983	BRAZIL	IC SEMICONDUCTOR LASERS	D D,P,M,T	IN OPERATION IN OPERATION
MICROELECTRONIC INSTITUTE, INFORMATICS TECHNOLOGICAL CENTER	LINKED TO THE SPECIAL SECRETARIAT OF INFORMATICS	1983	BRAZIL	IC	D M,T P	BEING ESTABLISHED IN OPERATION PLANNED

KEY TO SYMBOLS:

Di = DIODES
TR = TRANSISTORS
Tir = TIRISTORS
LED = LIGHT EMITTING DIODES
IC = INTEGRATED CIRCUITS

D = DESIGN
P = PROCESSING
M = MOUNTING
T = TESTING

BRAZILIAN SEMICONDUCTORS INDUSTRY

ASSEMBLY CAPACITY AND EFFECTIVE PRODUCTION*

TABLE 16 MILLIONS OF PIECES PER YEAR

COMPONENTS	ASSEMBLY CAPACITY 2 SHIFTS	PRODUCTION		
		TOTAL	FOR LOCAL CONSUMPTION	FOR EXPORT
DIODES UP TO 20 A	650	450	150	300
TRANSISTORS UP TO 1 A	220	140	105	35
MEDIUM POWER TRANSISTORS	55	17	15	2
POWER TRANSISTORS	18	2	2	-
LIGHT EMITTING DIODES	48	25	13	12
INTEGRATED CIRCUITS **	63	42	25	17

* Evaluation of ABINEE components group July 1984

** Does not include Philips Northeast operation (only for export)

SOURCE: GEICOM/1984

The Brazilian exportation of semiconductors in 1983 reached 29 million dollars, 24 million dollars for integrated circuits.

The highest exportation rates were reached by PHILIPS DO NORDESTE (42%), TEXAS (30%), BURROUGHS (13,5%), ending activities in this field in early 1984) and SEMIKRON (6,7%).

In 1983, the Brazilian Industry of Semiconductors had to buy inputs in the local market and make importations to produce 117 million dollars.

Table 17 shows the main inputs imported in 1982 and 1983.

MATERIAL IMPORTED FOR MICROELECTRONIC INDUSTRY

TABLE 17 US$ MILLION

DESCRIPTION	1 9 8 2	1 9 8 3
"WAFERS"	3,4	3,6
"CHIPS"	8,6	12,0
"LEAD FRAME"	3,4	4,1
METALLIC COVERS	0,2	0,2
METALLIC BASIS	0,9	0,5
CERAMIC CASE FOR I. C.	0,06	0,1
COMPONENTS FOR SEMICONDUCTORS	7,0	4,2
OTHER PARTS	2,7	0,6
T O T A L	26,3	25,3

SOURCE: CACEX

SUPPLY OF MATERIALS FOR THE BRAZILIAN SEMICONDUCTOR INDUSTRY

The input and equipment performance of semiconductor component manufacture are important factors in microelectronics. Besides the strategic significance of technological availability of input and equipment manufacture the economic importance of inputs for finished products, should be pointed out because their manufacture know-how is less sophisticated than the component manufacture. It should also be taken into consideration the multiplier factor resulting from the creation of an input supplier industry.

The percentage of these inputs on device global costs (industrial plus commercial costs) are the following:

- Lead frame (5-9%)
- Epoxi mass for packing (2-4,5%)
- Gold wire (1-1,5%)
- Moulding tools (1%)
- Chemical products (0,5%)
- Chips (9-23%) and Semiconductor slices (3-4%)
- Metallized ceramic capsule (7%)
- Nonoxided copper cover (2%)
- Passing metal-glass (15-30%)
- Quartz diffusion tubes (2%)
- Diode terminals (7-10%)

The most important inputs used in the semiconductors manufacture are:

BASIC INPUTS

- MONOCRYSTALLINE SILICON	- In sliced form (Cz and Fz types)
- DOPANTS	- Arsenic, phosphorus, electronic grade Boron
- METALLIZATION MATERIALS	- Aluminium, gold, nickel-chrom, tantalum nitrate, high grade purity nickel
- OTHER MATERIALS FOR SEMICONDUCTORS	- Germanium, arsenic, phosphones
- SUBSTRATES FOR DEVICE HYBRIDS	- Aluminia, sapphire
- INKS AND PASTE FOR THICK FILMS.	

PROCESSING MATERIALS

- HIGH GRADE PURITY SPECIAL CASES	- Silane, trichlorosilane, Silicon tetrachloride, amonia, Diborona, phosphina, arsina, Hydrogen, Argon, etc.
- HIGH GRADE PURITY ORGANIC SOLVENTS	- Freon, trichloroethylene, isopropyl alcohol
- HIGH GRADE PURITY ACIDS	- Sulphuric, arsenic, phosphoric, acetic acids
- PHOTORESISTS	- Positive, negative, developer removers, etc.
- PHOTOMASKS	- Emulsion, chrome, iron oxide, developers, etc.

AUXILIARY MATERIALS

- ABRASIVES	- For pruning and polishing of silicon slices - 0,5 to 15,0m Aluminium oxide, silicon carbide
- TEFLON TUBES	- Polypropylene, etc.
- HIGH GRADE PURITY GRAPHITE	- Epitaxial reactor suceptors, resistors and crucibles
- HIGH GRADE PURITY SPECIAL CERAMIC	- For diffusion furnaces
- FURNACES	- For conventional gases, corrosive gases, for water and so on

PACKING MATERIALS

- THIN WIRE FOR MICROWELDING	- Gold, aluminium, silicon--sluminium
- LEAD FRAMES	- For integrated circuits, transistor, diodes, etc.
- METALLIC ALLOY	- To manufacture Lead Frames KOVAR, OLIN 194, ALLOY 42, Cooper-Zirconium
- PACKING RESINS	- Silicones, epoxies, etc.
- CONDUCTOR EPOXIES	
- METALLIC CASES	- For Hybrid Integrated Circuit, Power Transistor, etc.

The inputs liable to short and mid-term industrialization, persuant to the Brazilian government agencies, due either to their economic fcasibility or to existing developments and pilot scale-developed technologies, are the following:

1. Electronic degree silicon
2. Silicon slices
3. Photomasks
4. Frame and capsules and its alloys Lead
5. High purity metal - thin wire and for evaporation (Aveal)
6. Chemical products - acid and high purity solvent
7. Epoxies resins and silicones

ELECTRONIC DEGREE SILICON

The electronic degree silicon is a basic input of the silicon semiconductors components industry.

The availability of domestic high-quality raw materials, such as quartz (natural silicon oxide); metallurgic degree silicon produced and exported by Brazilian companies; the existing domestic capability of universities to assist new undertakings; the attractive condition of the electronic degree silicon market (10 ton/year of internal consumption growing 20% a year and 3000 ton/year of internal consumption with an expressive increase) - all these factors, however, due to the high investments involved, do not attract the interest of private business.

The expected increase of demand due to the expressive application of silicon in solar cells, both internal and external, is already met by the Brazilian solar cells manufacturer from monocrystalline crystal growth. This monocrystalline crystal, however, is not pure enough to permit its use in the transistors and ICs slices.

The result of silicon process in semiconductors industry is so economically important that it can be evaluated regarding silicon prices according to the industrial process level.

DIFFERENT FORMS OF SILICON	RELATIVE MEDIUM PRICE
. Metallurgic grade	1
. Polycrystalline	65
. Monocrystalline:	
- czochralski	270
- "float zone"	420
. Slices (wafers):	
- cut	880
- polished	2050

The monocrystal production phases are:

a. Electronic degree silicon production
b. Trichlorosilane production
c. Polycrystalline silicon production
d. Czochralski growth of monocrystal or transformation by "Float zone" method
e. Monocrystal cutting and manufacturing
f. Polishing of slices (wafers) of monocrystalline silicon.

Phase a is usually carried out in Brazil by the metallurgic industry, obtaining up to 6000 ton/year with a 98-98,5 purity ratio. For silane production, the purity of metallurgic grade silicon, should be improved by selected raw materials.

One of the Brazilian producing companies, LIASA Ligas de Alumínio S/A, Pirapora (Minas Gerais), achieved a 99,3 purity ration.

Phases b and c are not accomplished in industrial scale in Brazil. However, four companies intend to operate with silicones in Brazil. They are: Wacker-Chimie, Rhodia, Bayer and Dow Corning. The availability of silanes is essential for this industry. Wacker Quimica do Brasil (Wacker--Chimie) started its own production at Camaçari (Bahia) for the supply of raw material to the other companies (Rhodia, Bayer and Dow Corning).

There is a short distance between trichlorosilane and the manufacture of electronic degree polycrystalline.

Considering the strategic importance for semiconductor industry and production of monocrystalline crystal, the Brazilian Government encouraged local production at technological pilot laboratories, by using trichlorosilane furnished by Wacker.

Three undertakings are in progress in Brazil, at Instituto Militar de Engenharia - Rio de Janeiro, Grupo de Materiais e Metalurgia da FEC (UNICAMP), and Divisão de Metalurgia do IPT (Instituto de Pesquisas Tecnológicas - São Paulo). The latter, on a pilot-production scale, using float zone process, has the purpose to meet the Brazilian needs for a long period of time. Last, Fundação Centro Tecnológico de Minas Gerais, handles the silicon monocrystal growth process.

It should be pointed out that since 1983, HELIODINÂMICA has been producing crystal and slices of silicon monocrystal (Czochralski process) for the production of solar cells.

Concerning c, e and f phases, most processes are açcomplished in Brazil, except the "Float Zone" process. The EPUSP microelectronic laboratory has produced, since 1974, silicon slices with several resistivities and orientations, types p and n, with diameter up to 75mm.

SILICON SLICES

Nowadays, the Brazilian market shows a rapid growth of about 300 000 units of silicon slices for diffusion, at an approximate value of 1 million dollars.

In this activity, the raw material whose international quotation of US$ 70/kg (medium value) changes into a final product value of US$ 2 000 /kg.

In spite of being imported, a local manufacturer called HELIODINÂMICA uses them to produce solar cells, and is beginning to perform silicon slice polishing.

LME-USP has the slice production know-how.

An investment of up to 2 million dollars, for an initial production of 300 000 slices/year with 75-100mm diameter is expected.

PHOTOMASKS

For the manufacture of semiconductor components, (transistors and I. C.s), a set of photomasks for photolithographical process is necessary.

Except for some special conditions where circuits to be manufactured are projected straight in silicon slices, all others use 3 basic types of photomasks:

- emulsion photomasks
- chrome photomasks
- iron oxide photomasks

Emulsion photomask is the usual one. Chrome and iron oxide photomasks are used in case of great production of a same component.

Currently, in Brazil, the emulsion photomasks are used for the diffusion process.

A small quantity of photomasks is used in Brazil. Under an economic viewpoint, it is inexpressive. However, it is important, strategically speaking, considering the diffusion phase and the possibility to develop semiconduct or projects on-site or when the supply of masks or slices is interrupted.

Photomasks are strongly linked to the micro-electronic sector known as computer aided design (CAD).

With the aid of this tool, it is conceived the integrated circuit, and as a result, emerge a band containing the "lay-out" of the circuit with its several layers.

Starting from this instruction, an automatic table of drawing (plotter) or a pattern generator will produce a final ar', in Rubilith or a reduced photographic plate (20 times less), referring to the circuit.

If the path chosen were the plotter, a second reduction (now 10 times smaller) would be necessary to achieve the adequate point. These photomasks obtained from this reduction are named "standard photomask of circuit" and they are reproduced to obtain photomasks which will be used in photogravure process.

The USP microelectronic laboratory has a complete photomask manufacture line to be used with silicon slices up to 38mm (1.5 inches). This 1.5 inches standard can only be used in research and development.

Considering the size of the Brazilian semiconductor industry, one single factory of photomasks could supply all the Brazilian industrial needs.

SEI and GEICOM agree that it is very important for the country to implement a modern system for the photomask manufacture, both in R & D and industry, considering strategic aspects of this fundamental input. For that reason, they have proposed to install a photomasks production system at a R & D institute to meet the internal needs up to the LSI circuits level.

Considering the private criteria and the speed of the industrial project, on a second phase we could install other systems at the semiconductor device industries.

Regarding the scale pilot project, IPT in São Paulo proposed to install a scale pilot of generation and photomask production to supply national needs up to the large scale integrated circuits (LSI) level.

Investment on this system are estimated to be 1.5 million dollars, by late 1987, CTI will be producing chrome masks.

HIGH GRADE PURITY METAL - THIN WIRES AND WIRES FOR EVAPORATION

A small quantity of aluminium and very pure gold for metallization in transistors and I. C.s processing is used in Brazil. The purification of these materials and transformation in thin wires are being studied by the material group of electronic grade material of FEC/UNICAMP.

Gold and aluminium ultra-thin wires are used in some quantity in Brazil, which makes it possible to implement industrial activities in the country. In 1982, the assembly and manufacture industries used three million meters of golden wire (diameter 25, 50 and 65 micra) and three hundred thousand meters aluminium wire (25 micra). 80 micra of golden wires are manufactured by a Brazilian industry with the purpose of entering that market.

Should industrial scale be reached by means of regional cooperation through industrial completion, the implementation of a manufacture system (500 000 dollars investment) for that input would be feasible, since refining and shaping of microwires are already performed in Brazil.

LEAD FRAMES AND CAPSULES

The high value of these inputs concerning the final product cost, relatively low investments, as well as the global market makes production highly economic for micro-electronic industry.

Therefore, the Brazilian market pulverization has been responsible for a limited production in Brazil.

As an example, companies from the Federal Republic of Germany, United States, Holland and France installed in Brazil, packed the same type of transistor with lead frame of several shapes and metallic alloys. To make viable the Brazilian production, it is important to stimulate the local production of metallic alloys (KOVAR, ORIN-194, LIGA 42 and so on) and reduce the different shapes to a minimum.

Concerning lead frames for integrated circuits, it is important to standardize the different packings all over the country, to reach industrial scale.

The Brazilian market for this input is evaluated as follows:

- To-92 (for transistor) demand is about 180 million units per year;
- To-116 (IC of 14 and 16 leads) - 35 million units per year;
- To-3 (Power transistors) - 30 million units per year;
- To-126 (Power transistors) - 20 million units per year.

SOURCE
GEICOM

The Brazilian manufacturers of this input are: Koop & Odenwald, Vecambrás, IBRAPE (PHILIPS) and S Eletro-acústica.

Experts have estimated that 250000 dollars would be necessary for the development of metal alloys and plates.

CHEMISTRY PRODUCTS

Notwithstanding the domestic technical chemistry production and the R & D capacity for improving those products, the electronic grade chemistry industry has not been developed yet, however, acetone and trichloroethylene are already produced in Brazil.

Initially, it would be necessary to refine at an electronic level the organic acids and solvents most used in the local industry and, at a later phase, to produce photo-resistants, dopants, gases and other products.

RESINS (EPOXIES AND SILICONES)

These inputs have a great economic and strategic significance with a highly sophisticated technology. Although Brazilian chemistry industries manufacturing epoxies and silicones have not reached an electronic grade quality.

THE BRAZILIAN R & D IN MICROELECTRONICS

The semiconductor components technology is, in fact, a gathering of several technologies. In order to obtain an I. C. knowledge on solid state physics, computing, chemistry, chemistry engineering, science of materials, etc., would be necessary.

In short, it could be said that the technological processes are directly related to the manufacturing of integrated circuit, as shown in Table 18.

The gathering of all those technologies in Brazil is still incipient. Local companies do not use all the main technologies described above; they use the ones related to the final phases of manufacturing for the reasons described in the chapter referring to industries, except SID MICRO-ELETRÔNICA, SEMIKRON, AEGIS, and HELIODINÂMICA. Others, such as ITAU COMPONENTES, although having not started industrial operations, are already executing I. C.s LSI projects.

Table 19, shows the conditions of the industrial companies.

University activities are the following:
Since 1968, some efforts have been accomplished to prepare personnel and set up basic technical development in microelectronics. The Brazilian government made an estimated investment until 1982, of about 20 million dollars in the several laboratories, LME and LED being the most important ones in the microelectronic sector. Those laboratories have

Therefore, we could expect to have some locally developed technology in Brazil for the production of I. C. (MSI and LSI types). However, manufacture technologies would be required mainly in the masks processing, WAFER processing, quality control, automatic design for I. C.s LSI and VLSI types. That would be even more necessary as the period for the mastering of the mentioned technologies become shorter. The response to that would be the introduction of financial resources and the quick development of highly qualified human resources (which seems to be lacking in Brazil). The income of LSI/VLSI technology or even of MSI could be obtained through agreement with foreign technicians, licencing from companies with a well-known technical capacity and training of domestic personnel abroad or through an international cooperation program.

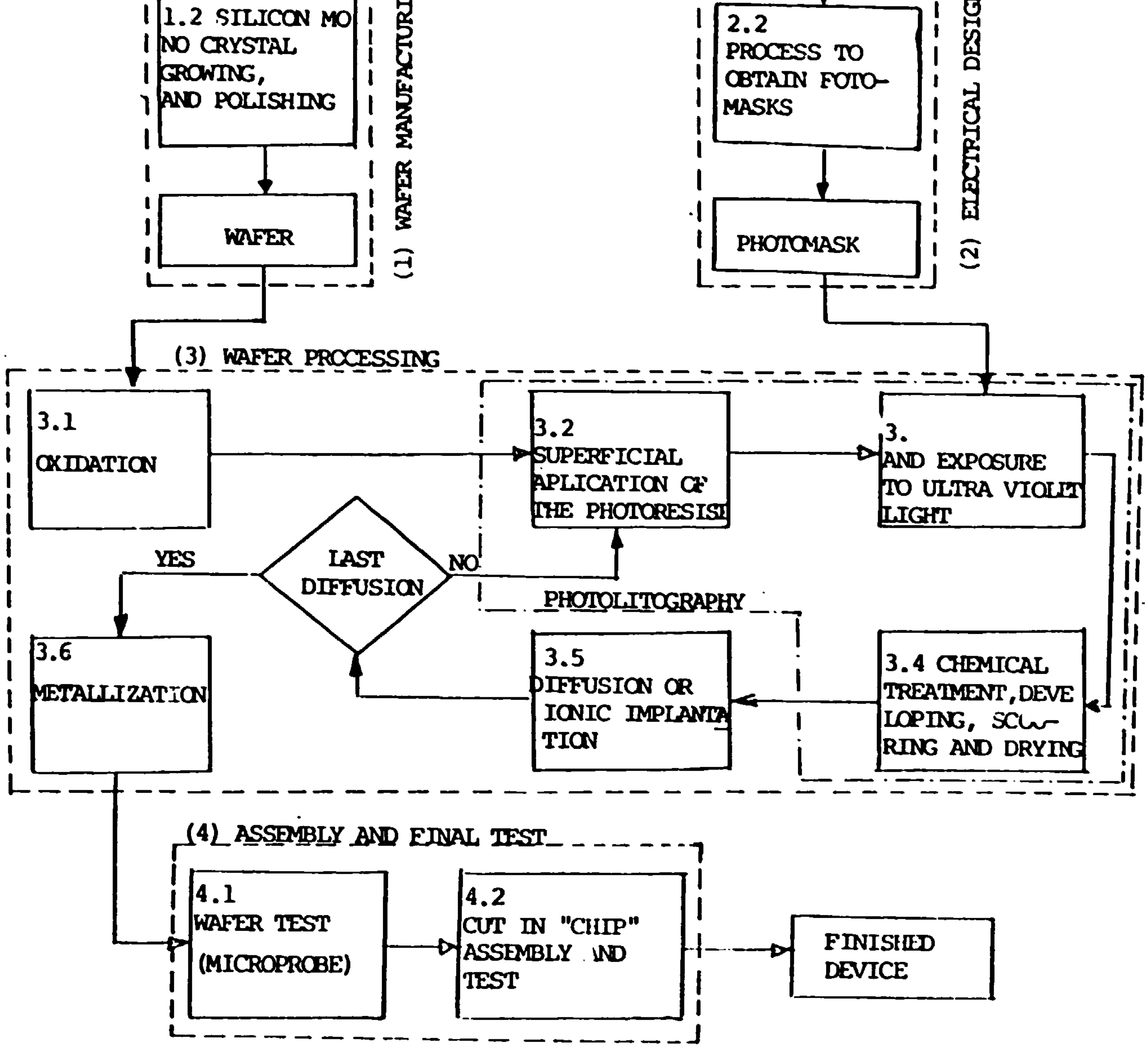
TELEBRÁS RESEARCH AND DEVELOPMENT CENTER (CPqD)

The creation of CPqD

TELEBRÁS was founded in 1972. Since then, it has been developing a significant Research and Development effort with the purpose of establishing the conditions for generating telecommunication technology.

Four types of agents were designated to carry out the R & D works, in addition to other supporting elements chosen pursuant to their own basic activities:

- University Groups, through development agreements, used as an industrial segment of each project due to become an industrialized product;
- TELEBRÁS. Operating companies, through technical cooperation agreements, with the participation as members of Programs and Projects during the specification phase and mainly for field trials and result evaluation;



At present, 30 projects are being carried through, the most important of which are the following:

- Digital Switching
- Digital Transmission
- Optical Communications
- Data Communications
- Communications via Satellite
- Parts and Materials
- Network Studies and Development
- Product Technology

The main CPqD projects relying basically on microelectronics are:

- Digital Switching

An Electronic Switching program, destined to develop telephone exchanges by means of computer-stored programs, CPA, for several traffic capacities.

TROPIC C

Line Concentrator

TABLE 19 Characteristics of Components

MANUFACTURER	TECHNOLOGY IMPLEMENTED IN THE STAGES OF MANUFACTURING											
	1		2		3						4	
	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2
AEGIS					X	X	X				X	X
FAIRCHILD												X
HITACHI											X	X
IBRAPE											X	X
ICOTRON											X	X
NEC												X
MC												X
SID			X		X	X	X	X		X	X	X
PHILIPS NORDESTE											X	X
POLITRONIC												X
ROHM												X
SANYO												X
SEMIKRON					X	X	X	X	X	X	X	X
STEVENSON												X
TEXAS											X	X
THOMSON												X
WESTINGHOUSE											X	X
NATIONAL												X
ITAUCOM			X									
HELIODINÂMICA	X	X										
CPqD	X		X	X	X	X	X	X		X	X	X

TECHNOLOGIES IN DEVELOPMENT AT THE BRAZILIAN UNIVERSITY

R & D CENTER'S

TABLE 20

BRASILIAN UNIVERSITY R & D CENTER'S	TECHNOLOGIES (BASICS) IN DEVELOPMENT — MANUFACTURING PROCESSES (SEE TABLE 18)												MOS	BIPOLAR	BIPOLAR I2L	THIN FILMS	THICK FILMS	QUANTIC-OPTIC	RESEARCH IN RAW MATERIAL	EPITAXIAL GROWING	YON INPLATATION	ELECTRIC MEASURES
	1		2		3						4											
	1,1	1,2	2,1	2,2	3,1	3,2	3,3	3,4	3,5	3,6	4,1	4,2										
IME/USP		*	.	.	*	*	*	*	*	*	*	*	*	*	.	*				*	*	+
LED/UNICAMP	*		*	*	*	*	*	*	+	.	.		*	*	.				+	+	+	+
MEC/UNICAMP	+	.																	.			
FÍSICA/UNICAMP	+															+		+	+			+
IME			+	+												+	+			+		+
CETEC			+	+													+					+
COPPE/UFRJ																						+

* DEVELOPED TECHNOLOGY

\+ TECHNOLOGY IN DEVELOPMENT

. TECHNOLOGY IN IMPLEMENTATION PHASE

ELECTRONIC AND DEVICE LABORATORIES

The Electronic and Device Laboratory (LED) of the UNICAMP Engineering Faculty (Campinas University) was created with the purpose of establishing technology necessary for developing microcircuits destined to national telecommunication equipment system, particularly MCP-30 SYSTEM being developed by TELEBRÁS.

This objective was extended not only to support the development of specific microcircuits, but also to provide basic technology necessary to the project and manufacture of microcircuit equipment and, specially, the formation of skilled personnel. That was how, in its short existance, LED substructure facilities were built, a substantial part of its own equipment was projected and built, project facilities were implemented and microcircuit manufacture activities started.

For that purpose, LED made arrangements to act within an organized and coherent project system, including manufacture and device process evaluation.

The following developments and measure equipment, are noteworthy: ion implanter, diffusion furnace, photorepeater, photoplotter, measure system on process and dispositive characterization, measure system on chemical composition of material surfaces, measure systems of hall effect, sputtering system, cleanness system by ionic plasma, growth system of monocrystal by horizontal zonal fusion process, purification system of silicon tetrachloride.

This intended to establish a basic national capacity to create and improve new equipment, as well as to develop old ones.

Concerning the integrated circuit LSI project, LED developed and maintained on duty the first computer-linked project system, which permits to do a mask, automatically or semi-automatically in any technology.

This system, associated to the photoplotter and to the photorepeater will permit to obtain a chip of up to 6 x $9mm^2$.

Furthermore, the project and making of two 8-bite decoder for MCP-30 system, one with MOS technology and the other with 1^2 L, was carried out Compared with TELEBRÁS research center, LED's PAC-1 (CAD) system is being used for masking project and thick film circuits.

Up to the present, the PAC-1 (CAD) system has been extended to microwave area and GAS devices in high frequencies to provide support in activities related to these devices inside the LED. In 1985, the next step will implement deposition process induced by laser connected with photolithographical and jet diffusion processes.

It is important to point out that, through its human resources activities, LED graduated masters and doctors on a full-time basis. The researchers responsible for 14 eletronics subject-matters on graduation level. Two of them are specifically destined to microeletronics and also to post-graduation on that subject.

LED's operational substructure makes it possible to maintain a type of documentation that enables a global transference of technological information to other institutions. Besides this documentation, that includes technical designs, circuits operation handbooks, instructions of execution processes and so on, LED has created an internal publication named CODEX, that is distributed to researchers.

This documentation system, unique in the laboratories specialized in microeletronic in Brazil, permits a close study of the statistics control process, fundamental for industrial production.

LABORATORY MGE ELETRONIC GRADE MATERIAL

The project called ELETRONIC GRADE MATERIALS of the Engineering/UNICAMP (Campinas University) is the result of incentives and investments made by TELEBRÁS, aiming at creating a substructure on basic inputs and "RAW MATERIAL" for the manufacture of eletronic devices in Brazil.

The Research, Development and Human Resources Formation project on MGE Technology was then created. Starting in 1976, the first phase, of the project had the financial support of TELEBRÁS through its research and development center. Its 3 year-period had the following purposes:

- Obtaining and purification of eletronic grade silicon from the mettalurgic silicon;
- ultra-purification of several materials used by eletronic industry;
- conformation of capilary metalical wires used in microeletronic;
- project and construction of necessary equipment using materials and components;
- human resources formation program in MGE area, inexistent in Brazil aimed at disclosing the know-how developed till then.

Regarding the previously established purpose we may thus conclude that the initial objectives have been achieved. The following points have been developed:

- equipment and processes of silicon deposition on eletronic level from thriclorasilone obtained from domestic raw material;
- furnace of zonal fusion with resisting and inductive heating for purification of materials with fusion point up to 1500 ºC;
- capillary wire equipment designs to make copper wire of up to 50 micra;
- and gold and aluminium wire within a short time.

Regular post-graduation courses have been offered to professionals on MGE area.

THE SÃO PAULO UNIVERSITY MICROELETRONIC LABORATORY

In 1968, the São Paulo University (USP) inaugurated a microeletronic laboratory. Pioneered in Brazil, it received at the beginning, financial support from BNDE, FAPESP and CNPq.

In 1970, the USPs L.M.E. was working on the most important microeletronic basic technologies such as: Bipolar, MOS and hybrid. Its basic objectives were personnel formation research, development and support to industry in local development microeletronic. TRANSIT was the first Brazilian manufacturer of a complete semiconductors cycle. The available know-how was used at LME. It has not been industrialized until now.

Two million dollars a year have been spent by LME since 1978. The post graduation area was given priority, graduating about 5 masters per year. In the same year, LME had conditions to project mid and high scale integration I.C.s ROM memory of 2 thousand bits of information was developed.

Since its creation, governmental resources (about US$ 20 million dollars) have been allocated to LED. A 5 million dollar building (current evaluation) has been built. Nowadays, LME can collaborate efficiently with Brazilian microeletronic growth; it also has a team of theoretical and pratical technicians able to project and construct several components essential to domestic eletronic industry.

USP's LSI -INTEGRABLE SUBSYSTEM LABORATORY

Financed by FINEP and by FAPESP (scientific financing agencies) jointly with USP (São Paulo University), the laboratory's main objective is the formation and development of personnel in integrable subsystems areas equipment for microeletronics, and information storage devices.

Its main microeletronic-related activities are:

- Microeletronic project

  Purposes:

  - Technical development of project in microeletronic;
  - Model and process framework in component s area;

- Human Resources formation in the area.
- Equipment for Microeletronic.

Purposes:

- Research and Development in ionic and electronic optic
- Applications in electronlythographic equipment.
- Human Resources formation in the area.

UFRJ's ELETRONIC COMPUTING CENTER

In 1981 a Team of UFRJ's (Rio de Janeiro Federal University) Eletronic Computing Center designed the first integrated circuit in Brazil. Their goal was to set up in a chip all the access logic to NEC's local network using LSI (Large Scale Integration) Technology. Two engineers had to work full-time for 8 months on the design and creation of the I.C. At the same time, a team of software researchers and three analysts worked to supply the necessary tools for the project, with a graphic terminal and a complex software.

As it was impossible to perform the manufacturing phase of diffusion in Brazil, it was made in USA. At present, that team is in charge of feeding a digital system project Laboratory in LSI, basically to develop a new CAD station consisting of tools (micro,video,plotter,printer and microcomputer) and logical units (graphic issuer, regular structure generator, verifier of rules of project and of logical mistakes).

CTEX - ARMY TECHNOLOGICAL CENTER

The CTEX project and material technology program to develop microelectronic circuit for military application, is destined to train human resources to overcome the difficulties in I.C. projects, CMOS/LSI, custom and semicustom, in order to supply the design of equipment for military use in acoordance with its specification.

After analysing the techniques developed in other laboratories, particularly CPqD of TELEBRÁS, CTEX decided to execute the following programs.

- In the Project Area:
  - To obtain knowledge in semicustom project using "gate array";
  - Development of one project station of "gate array" software circuits;
  - Development of software tools for "semicustom" gate array/LSICMOS project;
  - Project of specific "semicustom" chips for military equipment.
- In the Processing Area:
  - Gate array metallization
  - MOS process study, in the phases of oxidation ionic implantation and deposition by CVD.

CTI-INFORMATIC TECHNOLOGICAL CENTER

In December 1982, the Brazilian Government created the Informatic Technological Center CTI/SEI (Informatic Special Secretariat) with the purpose of developing IC design together with other companies. The design on silicon know-how should then be transferred to the industrial company.

CTI started microelectronic operations with packing, testing and design phases. Foreign research institutions will be in charge of diffusion until the implementation of its own diffusion line.

This pilot line is due to perform the custom slices diffusion, to develop new methods and to obtain a better insight of the microelectronic industrial process.

CTI has started the implementation of a photomask production system and is expected to be in condition to perform all the production phases of integrated circuits within two years.

CTI's basic duties are the following: the introduction of informatic technologies in productive process; incentive and coordination of scientific research between university centers and industry; promotion of technological development to obtain prototypes capable to meet industrial needs; follow up the nationalization programs in industry.

For that purpose, CTI is discussing with Brazilian microelectronic companies the establishment of a R & D program.

CTI is an important technological branch of SEI's structure. Besides the microelectronic projects automation, computation and maintenance activities will be developed.

In 1983, the CTI's budget was 2,4 billion cruzeiros, Thirty percent were allocated to civil constructions; thirty percent to the purchase of equipment and forty percent to personnel. The most important project being designed is the creation of a logical and physical interconnection network for microcircuit users, with the purpose of maintaining a compatibility between projects and the available manufacture resources.

For that, a data bank containing the compatibility rules of manufacturers to improve the project has been created. Through the network, the capacity of projects in the research centers and companies will be spread all over the country. The researchers will then be in condition to develop a semiconductor component for CTI to produce on a pilot line custom I.C.s for specific applications for testing.

Recently, CTI has purchased all the assembly, packing and testing equipment from Burroughs Electronica, first installed in São Paulo, then transferred to Campinas, where final assembly and test of the custom I.C.s of some industries, are being performed.

• Digital Transmission

Its main purpose consists of establishing the gradual digitalization of Telecommunication Systems. The following projects should be pointed out:

. MCP-30

Telephone multiplex using PCM voice and data signals digital processing. This is a basic equipment for digital telecommunication systems. Upon conclusion, it was transferred to the industries, and many thousand channels (one side) are operating on a regular basis at the TELEBRÁS companies.

. MCP-120, MCP-480, MCP-1920

Higher hierarchy equipment using MCP-30 as a basic unit. The first two ones have already been transferred to industry.

. MDT-101-B

Time-division multiplexing equipment developed to be used in telex and data communication services. Many thousand channels are operating at the National Telex Network.

. RADI-834

Digital concentrator for text switching including Telex, Teletex and Data Communications up to 2.400 bps speed. 25 subscribers can be concentrated in up to 64 trunks.

. Optical Communications

The CPqD Optical Communications Program comprises laser, optical fiber, repeater and terminal equipment programs (ELO-34).

. The LASER Program

This Program is aimed at developing semiconductor laser diodes manufacture technology applicable to optical communications, specially to ELO-34 project. The Laser Program has been developed since 1973, at first at the Campinas University laboratories during its research application phase. The results obtained were excellent, which led to the implementation of a laser production pilot line at CPqD associated with the R & D laboratories for that purpose.

The telecommunication optical fiber manufacture technology can be compared to that now being used for field trials abroad (3dB/km, gradual ratio). It has been fully developed and is now being manufactured by the Brazilian industry.

. ELO-34 Program

Advanced technology with optical line equipment equivalent to 480 telephone channels being used in the system, which operates with 34 Mbits/s used specially at telephone exchanges trunking. The optical equipment used is that of the LASER and OPTICAL FIBER programs.

Third hierarchy MCP-480 Digital multiples is also used.

. Data Communications

Two projects are being developed for the installation of data communication digital networks:

REXPAC - Main purposes:

- development of a packet switching exchange
- technical support to a network being implemented in Brazil, destined to teleinformatic studies.

. COMPAC

Development of the equipment forming a packet switching data communication network: switching exchange, concentrator and supervision and control center. A hundred engineers and system analysts are involved in this vast program.

The National Packet Switching Network - RENPAC - is EMBRATEL's data communication switched public network. Its initial phase is being implemented with imported equipment. From 1985, COMPAC Program equipment will be used.

. Communications via Satellite

The following Programs should be noted:

. ERTV

TV receiving station via satellite used for TV distribution all over the Brazilian territory.

. ETP

Station destined to meet the needs of public telephony via satellite using parabolic antenna with 10 meters and 6 meters diameter, developed locally.

. Parts and Materials

CPqD has been developing a Parts and Materials Program with the purpose of:

- carrying out parts and materials research for use in telecommunications;
- carrying out dedicated parts project and development;
- making a contribution to develop the scientific-technologic-industrial infrastructure of Brazilian parts and their inputs.

The following projects are part of the program:

- thick-film hybrid integrated circuits;
- thin-film integrated circuit projects;
- computer-assisted integrated circuit projects;
- electronic grade materials.

In order to increase the level of technology of those projects, CPqD started, in 1980, the Semiconductor Area within the Parts and Materials Department, in charge of the installation of dedicated I. C.s project capacity within the Center.

The main purpose of the project consists of:

- designing the dedicated or semidedicated integrated circuits necessary for the National Telecommunication System;
- setting up a Project allocated capacity;
- adapting and/or developing all the necessary CAD support;
- having the manufacture performed by Brazilian companies preferably;
- creating the capacity to evaluate, improve and test prototypes;
- ensuring the projected I. C.s supply;
- reaching and maintaining international operat-tion levels concerning Projects and CAD.

Therefore, the selection and basic training of programmers was started in 1981, and their training at AMI, USA, started soon thereafter.

From 1982, laboratory assembly was performed by means of the installation of APPLICON AGS 860 system of VAX 11/780 SYSTEM and the basic structure of CAD and Tests.

The installation of CAD and Tests Laboratories was concluded in 1984 and the works for manual project internal capacity, cellular and gate array were started from NMOS and CMOS digital integrated circuit technology.

The allocation of semidedicated I. C.s project capacity, the internal capacity of analogic and bipolar circuit project and the conclusion of CAD and Test Laboratories are expected to take place in 1985.

The integrated circuits designed for the several technologies used are:

CMOS

- Logic interface for multiplex equipment MDT-101-B (technique: standard cells)
- Synchronous unit for a 2400 bps multiplex equipment (technique: full custom)
- Synchronizer/Desynchronizer for digital multiplex MCP equipment family (technique: full custom)
- Link control for application in CPAs Tropic family (technique: standard cells)
- Pulse generator for Brazilian keyboard telephone set (technique: full custom)

NMOS

- Terminals interface for Tropic family (technique: full custom)
- MCF tone digital detector, for CPAs (technique: full custom)

B - Circuits: being developed

CMOS

- Voice link controller and format-maker for Tropic family
- Direct implementation of 4 dedicated I.Cs for MCP-60 equipment (technique: 3 full--custom, 1 standard cell)

CPqDs Integrated Circuit Projects Laboratory is one of the best equipped and modern laboratories in Brazil.

The basic resources available for the execution of the semiconductor project necessary for the equipment development are the following:

CAD Laboratory

Hardware:

VAX 11/780 - VMS System

- 4 Mbytes memory
- 750 Mbytes hard disk
- Tape
- 2 Graphic terminals
- 24 terminals

Applicon - AGS 860 System

- PDP 11/34, 256 kbytes
- Digitalizer and 2 plotters
- 2 full graphic stations:
  500 x 500 screen and keyboard

JUNCTIONS TABLE

digitalizer

- tape

Software: (MASCOTE System developed by CPqD)

For the Electronic Project

- Unique user communication language (DIALOGO) (via text or graphic)
- Operating simulator (CARLOS)
- Logic simulators (LOCIGO, MASCOTIM, HILO)
- Electric simulators (SPICE, SUICIDA)
- Graphic post-processor (PLOTE)

For Layout and correction

- Graphic editors (CHUTE, LUDICO, APPLICON)
- Automatic Cellular Layout (PINCEL)
- Circuit Extractor (TIRADENTES)
- Rule checker and tape format-maker (CHECK & PG)

Trial Laboratory

Facilities implemented:

- Manual microtester
- Wafers automatic tester
- General use tools

Under implementation:

- Trial automatic system and I.Cs characterization at wafer

CPqD has developed these activities jointly with SGS ATES, the LOUVAIN University (Belgium) and MOSAID (Canada); furthermore, it has been supported by the University of the State of São Paulo, by the University of Campinas and by the University of California at Berkeley.

Specific software books have been prepared with AMI/USA.

Technology Trends

- Reduced evolution charges
- Predominant trend towards CMOS technology
- More sophisticated and indispensable CAD tools
- Project individual stations based on super-microcomputers
- Stronger significance of electric packing
- Increased use of project structured or semi-dedicated methods
- 1990: 50 percent of I. C. s market based on DEDICATED circuits.

HUMAN RESOURCES

The training of human resources on all levels on semiconductors, microeletronics and input is deemed an essential point. Not only the number of research centers and researchers but also the annual rate of researchers graduation is considered extremely low. Natural losses occuring in the existing centers cannot be offset.

On the other hand, human resources are limited because the maximum high-level experts training capacity does not meet the market requirements. Therefore, the supply of market needs would inevitably empty the training centers, where these high-qualified experts are working.

SEIs (Informatic Special Secretariat), Microelectronic Special Committee determined, as shown below Brazilian human resources working in microelectronics.

YEAR 1983	University Degree (BS)	DOCTORS (MS and PhD)
INDUSTRIES	85	9
LME/USP	50	7
LST/USP	14	2
LED/UNICAMP	30	4
MGE/UNICAMP	15	6
LPD/UNICAMP	38	13
IME	8	2
UFRJ	5	3
CPqD/TELEBRÁS	18	5
T O T A L --------------	283	42

There are also some small groups at CETUC-Rio de Janeiro (4), INPE (2) and COPPE-UFRJ (2), as well as in Rio Grande do Sul, Minas Gerais and Pernambuco Federal Universities.

This is not sufficient, considering the needs and production plans for 1985. Nowadays, Bell Laboratories in the United States employs 8000 specialists on microelectronics.

Those 283 experts are skilled in the packing and testing phases only.

In fact, only a few researchers are spilled in the diffusion and circuit design phases.

On industrial level, diffusion and circuit design spill is virtually inexistent nowadays, except for a small group of SID MICROELETRÔNICA.

To evaluate the human resources requirements for the few next years, SEI's Microelectronics Special Committee conceived that an industry, or a completed cycle of industries on semiconductors, installed in Brazil, would have, at a 5 year-period, an annual production equivalent to about 100 million dollars. Comparing those industries with similar companies in USA, having the same income, and studying their needs for device projects, correlate areas, chips manufacture, as well as other support activities, (industrial engineering, maintenance quality control, etc) it has been conceded that the USA companies need about 50 university-degree experts at the processing area and 200 for projects.

Five R & D Centers are expected to be in operation. One of them will concentrate its efforts on processing, the others on projects. As a result, 35 specialists will be required in processing and 100 in projects.

At the university, 240 experts would be required for all the centers. Commission evaluated, therefore, the Brazilian needs for the next 10 years would be of 1250 researchers, if we take into account a dispersion of 50 percent of that work force.

On the other hand, the committee concluded that the training of human resources should include:

- Technicians
- Undergraduate (BS)
- Graduate (MS and PhD)

The training of technicians and undergraduated degree experts would have two purposes: to prepare professionals working at productive sectors; to select vocations for future researchers, whose training would start from Master and Doctor programs.

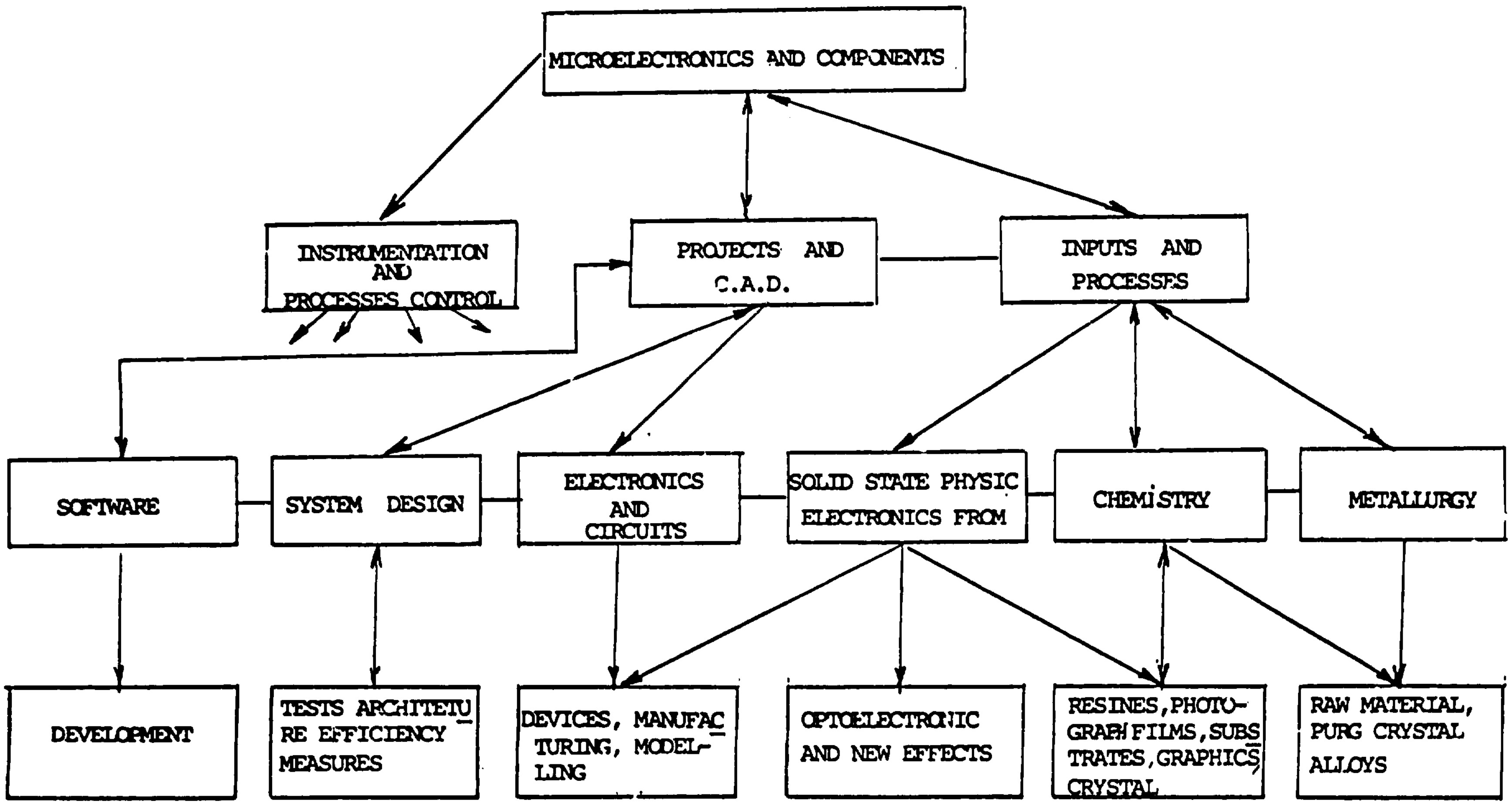
Masters should preferably be involved in material engineering, microelectronics and physics for computing activities.

Post-graduation training would be intended to form researchers, professors and specialists highly qualified for microelectronics activities, and as such are conceived as an elite. Nowadays, this training capability is not very expressive in Brazil. For that reason, there is an urgent need to invite foreign professors to teach at the existing centers and at others to be created. It is also very important to trigger an aggressive post-graduation program abroad, trying not to send abroad all professors at the same time, even for a short period of time.

Another strategy would consist of sending experts to specialized centers. For that purpose bilateral agreements should be made with the universities and the existing internatio- nal agreements should be activated.

The group of disciplines necessary for the training of manpower in microelectronics can be seen in Table 21.

Table 21


MICROELECTRONICS AND COMPONENTS
INSTRUMENTATION AND PROCESSES CONTROL
PROJECTS AND C.A.D.
INPUTS AND PROCESSES
SOFTWARE
SYSTEM DESIGN
ELECTRONICS AND CIRCUITS
SOLID STATE PHYSIC ELECTRONICS FROM
CHEMISTRY
METALLURGY
DEVELOPMENT
TESTS ARCHITETU-RE EFFICIENCY MEASURES
DEVICES, MANUFAC-TURING, MODEL-LING
OPTOELECTRONIC AND NEW EFFECTS
RESINES, PHOTO-GRAPH FILMS, SUBS-TRATES, GRAPHICS CRYSTAL
RAW MATERIAL, PURG CRYSTAL ALLOYS

MICROELECTRONICS NATIONAL POLICY

On October 29, 1984 the Brazilian Government set up the informatic law, after several years of discussions in Congress.

Pursuant to that legislation Microelectronic is defined as "informatic activities" that include also research, development, production and importation/exportation of electronic components, opto-electronics, semiconductors, as well as inputs on electronics degree.

GENERAL GUIDELINES OF BRAZILIAN MICROELECTRONICS POLICY

The main purposes of Brazilian microelectronics policy are:

- to create the base for the implementation and development of the Brazilian industry of microelectronics, in order to reach technological and economic capability to reserve the national market to Brazilian industry of semiconductors and opto-electronics components.

- to set up the conditions to meet the needs of Brazilian microelectronics companies, in order to supply all the necessary components.

The implementation and the development of the Brazilian microelectronics industry should be made without charging the users, trying to ensure that:

- The semiconductor components availability at the internal market is maintained;
- The quality of products made in Brazil meets the needs of the users;
- The semiconductor components are offered at suitable prices.

The implementation and the development of microelectronics industry should be carried out with the support of Brazilian companies having a real enterprising capacity particularly in technological and financial fields. They should also have an accurate investment and development program, including their own know-how, by means of technological contracts and agreements signed with foreign companies.

The law foresees in detail several actions and tools referring to informatic and microelectronics activities.

The main tool to protect Brazilian microelectronics industry is the national market reserve of semiconductors and opto-electronics components, which can be obtained as follows:

- Importation control;
- Adjustment, analysis ans follow up of development and manufacture projects;
- Fiscal incentives and benefits allocated to research, development and production projects on microelectronics;
- Establishment and execution of a research and development plan as well as technological capability on microelectronics;
- Establishment and execution of a human resources training and specialization plan, where universities, research centers and companies can work together;
- Product approval, certificate of quality and establishment of rules and standards on microelectronics;
- Special financing conditions that promote the investments required to set up a microelectronics industrial set;
- Creation of an industrial and technological policy for electronics degree inputs for the microelectronics industry.

The application of those criteria as a policy tool, such as importation control, project approval and incentive allocations, should comply with the importance of each company/project. Those having a high technological complexity should be favored the most.

NATIONAL MANUFACTURERS OF SEMICONDUCTORS COMPONENTS

The G.A.M. (Microelectronics Advisory Group) of SEI INFORMATIC SPECIAL SECRETARIAT submitted document not yet approved by the Brazilian Government, containing regulations for fiscal and tax incentive concessions provided for by the informatic legislation that could be based on the following criteria:

- Companies involved in the preparation of integrated circuit design could be granted all the incentives necessary to the fulfillment of their activities.
- Companies involved in assembly and test manufacturing phases could be granted incentives for their fixed assets and domestic inputs requirements. Incentives for the purchase of foreign fixed assets could only be granted to those companies that accomplish their components assembly using wafers manufactured by Brazilian companies.
- Companies involved in the whole manufacture process of microelectronic industry - from design to marketing - could be granted full incentives, including those related to the commercialization of imported components.

For the effective implementation, development and consolidation of a national microelectronic industry, the operation of foreign companies in Brazil must be governed in such a way that they do not obstruct the development and the hold of the marked destined by law to Brazilian companies.

SEMICONDUCTOR USER COMPANIES

The semiconductor user companies are allowed to continue to import components, provided that no similar product manufactured in Brazil is available.

The incentive applied to component user companies pursuant to the law - twice the purchase value deduction are valid only for components produced (manufactured and/or assembled/tested) by Brazilian companies involved in all the microelectronic process phases. As to customs I.C., the incentive can be granted provided that the components are designed in Brazil.

THE BRAZILIAN POSSIBILITIES TOWARDS A MICROELETRONICS REGIONAL COOPERATION PROGRAM

INDUSTRY

- MICROELETRONIC PARTS DESIGN

The industrial trend in microelectronics has been the centralization of the productive processes and the decentralization of device designs. Therefore, the microcircuit would merge with the equipment and system project, with a view to their optimization and updating. For that purpose, Brazil and South America will need five times more specialized resources within three years, to work on the implementation of a hardware, software, documentation and communication system necessary to improve the efficiency of project groups existing in Brazil.

Regional cooperation could be most useful to the development of an integrated system design in the countries of the Region.

. This cooperation would be aimed at forming a critical mass of microelectronic semi-custom and full-custom project makers covering specifications, measuring and testing of ordered integrated circuits.

. A critical mass of CAD tools' developers for "gate-arrays" integrated circuit test and project, standard cells and full-custom digital and analogic circuits.

- Integrated circuit design systems that may be disseminated to an increasing number of users at competitive prices.
- Research programs for improving CAD tools for integrated circuits.
- Execution of production processes at the region, together with the implementation of domestic processes.
- Creation of a regional project station with a complete ICs cells library interconnected through communication means (DATA TX) to the various domestic low-cost project stations, in order to process a substantial part of the programs necessary to the project.

This goal could be attained as follows:

- Software and hardware standardization to allow for the communication and portability of programs being used.
- Project and design methods established pursuant to domestic and/or foreign procedures.
- Software professional documentation and libraries necessary to the project.
- The search for persons who have already proposed, created, prepared, characterized and criticized new structures or materials.
- Availability of courses.

- FINAL PRODUCT -

Domestic companies, as SID MICROELETRONICA, HELIODINÂMICA, AEGIS and ITAU COMPONENTES can be interested in creating a technologic cooperation program and a products and inputs industrial complement program for their production, specially concerning the following:

- production equipment (diffusion and assembly)
- production processes
- quality control (reception, production processes and tests)
- personnel training
- MASKS manufacture and supply
- CHIPS diffusion and supply
- final product supply (to complete the marketing supply line)

All other companies, in view of their easily obtained technology, new devices and inputs for production, due to the strong links with their headquarters abroad, could be interested in view of the import-restraint policy and incentive to local production, specially the development of new materials.

- INPUTS -

• ELECTRONIC GRADE SILICON

The R & D centers and the Brazilian industry are able to cooperate with industries abroad by supplying technology, training human resources and supplying inputs, as for instance:

- Metallurgic Grade Silicon
- Trichlorosilane
- Policrystalline Silicon
- Monocrystalline Silicon
- Cut and/or polished wafers (for solar cells production)

. SILICON WAFERS

Brazilian industry needs highly resistant wafers obtained from MONOCRYSTALLINE SILICON produce by float zone method for I.C. diffusion. Two million dollars are deemed necessary for producing 300000 wafers with 75 - 100mm diameter.

. PHOTOMASKS

Photomasks are scarcely used in Brasil. This small quantity is economically inexpressive if considered as an isolated input, however, it is strategically necessary for diffusion and the possibility of performing the semiconductor projects developed locally.

Taking into account the extent of Brazilian and Latin American industries, one single photomasks generation center would meet the needs of local industry at LSI ICs level. That plant could copy working photomasks and generate photomasks with the existing design final art made by the R & D laboratories. CTI is making investments in photomasks manufacture. By late 1987 it will be manufacturing chrome masks.

In view of privacy and expediting criteria of industrial designs, other systems could be installed at a later stage in semiconductor devices industries.

- HIGH GRADE PURITY METAL
- THIN WIRES AND WIRES FOR EVAPORATION

A small quantity of aluminium and very pure gold for metalization in transistors and ICs processing is used in Brazil.

Gold and aluminium ultra-thin wires are used to some extent in Brazil, which makes it possible to implement industrial activities in our country. In 1982, the assembly and manufacture industries used three million meters of golden wire (diameter 25, 50 and 75 micra) and three hundred thousand meters aluminium wire (25 micra). 80 micra golden wire are manufactured by a Brazilian industry with the purpose of entering that market.

Should industrial scale be reached by means of regional cooperation through industrial completion, the implementation of a manufacture system (500 000 dollar investment) for that input would be feasible, since refining and shaping of microwires are already performed in Brazil.

• LEAD FRAMES AND CASES

Their high aggregate value for the final product costs, relatively low investment and global market make the manufacture of lead frames and cases the most economic input for the microelectronic industry.

In order to increase industrial scale for making it possible to manufacture them at reduced costs, in addition to regional cooperation at industrial completion level, the number of several lead frames geometry should be reduced and metal alloy production should be encouraged.

Three companies are operating in Brazil for that purpose. Experts have estimated that 250 000 dollars would be necessary for development of metal alloys and plates.

Brazilian industry can supply progressive stamp tools for the manufacture of lead frames.

. CHEMISTRY PRODUCTS

Notwithstanding the domestic chemistry technical grade production and the R & D capacity for improving those products, the electronic chemistry industry has not been developed yet.

Initially, it would be necessary to refine at electronic level the organic acids and solvents most used in local industry and at a later phase to produce photoresistants, dopants, gases and other products.

. RESINS (EPOXIES AND SILICONS)

These inputs are economically significant and technologically sophisticated. Epoxies and silicons are produced by chemical industries in Brazil, although not in eletronic degree.

. METALLIZED CLAY CAPSULES

. DESOXIDE SUPER COVER AND BASES FOR SEMICONDUCTORS

. QUARTZ TUBE FOR DIFFUSION

These inputs are not manufactured in Brazil.

Other industrial programs could be implemented by means of regional cooperation:

- Industrial production technique program on microelectronics:

Aimed at exchanging and creating new industrial production techniques, joining the industry and R & D efforts for developing basic techniques for implementing new products and methods.

- Testing and quality guarantee, reliability techniques, development program:

Aimed at disclosing quality guarantee techniques for microelectronic methods and products.

- Microelectronic equipment and tools program:

Aimed at improving and developing new equipment and tools for microelectronics. Industries, R & D agencies and universities should be encouraged to participate in this program.

- Microelectronic metrology program:

Manufacturing projects and methods characterization is a basic factor for microelectronic quality and product control.

RESEARCH AND DEVELOPMENT

Better results could be attained in R & D if human and financing resources were more numerous in Brazil.

. R & D AT THE UNIVERSITY

The main hindrance is the significant limitation of qualified personnel. A great effort should be made towards forming human resources at the university. The exchange with foreign organizations would speed up and upgrade training. Research should stress knowledge rather than production. Research topics should be updated in order to enable the students to keep up with industrial needs to follow up the most advanced world developments. This training can be provided in Brazil.

. R & D INSTITUTES

International and regional cooperation is a basic factor for the good results intended in this area. Investments in the most advanced technologic research activities should not be abruptly granted with the purchase of sophisticated equipment. It should be the result of a natural evolution of research activities. Group activities should be encouraged, specially on, THIN AND THICK FILMS; QUANTIC OPTICS; EPITAXIAL GROWING, ION IMPLANTATION technology, and on RESEARCH IN RAW MATERIAL AND DEVELOPMENT OF NEW METHODS FOR ELETRICAL MEASURES.

Particular attention should be devoted to research for the industrial consolidation of technology using 1,5 - 2 m geometry for mid-term microstructures and 1 m for long term ones, as well as the creation of project capability programs and the manufacture and characterization of Power Devices.

. R & D IN INDUSTRY

Industries should perform R & D works related with all products intended to be manufactured on an industrial basis.

The R & D effort should concentrate, then, on the technology used by industry itself.

The semiconductor companies should perform R & D works specially on:

- devices design
- new design techniques
- new production techniques
- quality control and failure analysis methods
- new eletronic packaging methods
- testing and test methods criteria

Few companies in Brazil perform an R & D effort due to economic and investment return problems. A regional cooperation program with the purpose of assisting the implementation of R & D in companies would be desirable.

HUMAN RESOURCES

In 1982, Brazil had 335 microelectronic special ists of which 42 had a University degree. This number was extremely poor, if compared with the 8000 microelectronic experts of BELL LABORATORIES (USA).

Those 283 experts concentrate their knowledgement on packing and test phases. A few have some experience on circuit diffusion and conception phases. At industrial level, circuit diffusion and conception is practically unknown in Brazil, except by a small group working at SID SEMICONDUTORES.

Our requirements for the next 5 years comprise 35 method experts and 100 project experts at the R & D centers, and 240 experts for the universities.

Taking into account the needs of device projects, corresponding activities and of chips manufacture (methods) as well as other supporting activities (industrial engineering, maintenance, quality control, etc), which also require technical qualification, industry would require 50 experts on methods and 200 experts on projects .

Our present capacity to form human resources is extremely inadequate.

The lack of human resources, investments and time turn this program into a task that can be accomplished by means of regional and international cooperation only.

Visiting professors should be invited to give courses at the existing centers, and a post-graduation program abroad should be implemented.

Regional cooperation for obtaining human resources could be made at the following levels:

-technical
-under-graduation
-graduation

Technical and under graduation levels would have two basic purposes : training experts on production and selecting new researchers for master of science and doctorate programs training.

Subjects should relate to special topics as engineering materials, microeletronics, solid state physics, chemistry, metallurgy, etc. (See Table 21).

Graduation courses should form highly qualified researchers, professors and technicians to work on the various segments of microelectronics.

In view of the lack of human resources and in order to obtain higher efficiency, specialization of educational centers existing in the several countries of the region would be advisable.

THE ELECTRONIC MARKET IN BRAZIL

EQUIPMENT

The electronic market in Brazil showed a 3.4 billion dollar volume in 1983 with a 10 percent decrease as compared to 1982. The communication sector showed the highest operational ratio, in the amount of 2.3 billion dollars, i.e. 68 percent of the total volume. It was also responsible for the global electronic market decrease of 13 percent as compared to the previous year.

Of that 2.3 billion dollar revenue, 1.58 billion dollars were obtained from radiobroadcasting receivers; 690 million dollars from telecommunications; radiobroadcasting transmissions accounted for the remaining revenue. Other equipment accounted for 350 million dollars, i.e. 8.51% less than in 1982.

In 1983, the computation equipment was respnsible for a 569 million dollar revenue, decreasing 4 percent. Tools and control equipment accounted for 80 million dollars with a 13 percent grow.

The domestic market of electronic equipment is supplied almost entirely by Brazilian products. Therefore,the communication activities are fully supplied by local industry. The external supply of electronic equipment accounts for 3.5 percent of the market value. On the other hand, Brazilian industry participates in the electronic equipment external market having shown an export volume of 480 million dollars in 1980. In 1983 that volume amounted to 300 million dollars.

The requirements of this market are met by the electro-electronic industrial establishment, made up of about 3 000 companies, ten percent of which are light and mid-sized companies.

The electronic industry in Brazil has more than 380 companies. Seventy companies manufacture equipment and telecommunication parts; forty eight manufacture radio and TV sets; thirty six manufacture radiobroadcasting equipment and transmitters; forty one manufacture data processing equipment and eighty manufacture electronic parts and components. More than 120 000 employees work for those companies; 12 500 have an university degree.

To manufacture, in 1983, 3 8 billion dollars in electronic equipment (domestic market and exportation) the electronic industries have imported the amount of 720 million dollars.

The participation of electronic components in these importations is:

Telecommunications	69%
Consumer Electronic	65%
Data Processing	8%

The semiconductors importation reached in 1983 90.2 million dollars. 62.2 million regard Integrated Circuits, 11.4 to transistors and 11.5 to diodes.

The importation of inputs for domestic manufacturing of semiconductors reached 25.3 million dollars.

ELECTRONIC COMPONENTS

In the developed countries, the professional electronic field is responsible for a great part of the demand of services. Other electronic activities receive the technological benefits generated for that professional sector. However, in Brazil this demand is generated by the radio and TV receivers. For competitive reasons in the internal and in the export market, the use of current foreign design discourages the development efforts in view of the economic scale.

This communication subsector is responsible for a 70 percent internal demand of semiconductors; 85 percent of electrolitic capacitors; 90 percent of film resistors; 90 percent of charcoal potentiometers; 98 percent of ceramic capacitors, etc.

Therefore, as the demand concentrates on a sole segment, the electronic component field in Brazil is highly vulnerable to any purchase reduction by the entertainment industry.

THE ELECTRONIC COMPONENTS INDUSTRY

At present, more than 80 industrial plants manufacture components and parts for the electronic industry in Brazil. Most of them are medium and small sized companies; 74 percent of them are national capital-controlled; 26 percent are foreign capital-controlled. They have about 30000 employees. The 80 most important companies had a revenue of 920 million dollars in 1983. They have about 21500 employees, 2 percent with a university degree and 8 percent with high school degree.

The industrial establishment of components has 17 semiconductor, 6 resistor, 16 capacitor, 5 professional printed circuit, 28 linear and coaxial connector, 17 telephone wires and cables, 27 key , 14 relay, 12 fuses, 5 ferrite nuclei manufactures.

THE WORLD MARKET OF ELECTRONIC PRODUCTS

The Western world market of electronic equipment reached in 1984 a volume of 285 billion dollars. The United States headed this volume, selling approximately 168 billion dollars, followed by Western Europe (11 countries) with 60 billion dollars and Japan with 40.5 billion dollars. Brazil participated in this market with internal sellings amounting to 3.4 billion dollars and external sellings amounting to 0.3 billion dollars.

To meet this demand of equipment, electronic and electromechanical components had to be supplied, in the amount of 45 billion dollars. The United States were responsible for 11.4 billion dollars. The Brazilian demand surpassed the amount of 1 billion dollars.

In 1983, this demand of electronic components reached the amount of 39 billion dollars: 17.9 billion dollars were for semiconductor components. The United States had 56.5 percent of that market; Japan had 27.5 percent, and Western Europe countries had 16.2 percent.

Integrated circuits represent more than 75 percent of this demand, having reached 16.5 billion dollars in 1984, when the semiconductor market reached a volume of 21 billion dollars.

According to "A Report on Integrated Circuit Industry ICE - 1980" the great consumers of semiconductors in the world were:

- Data Processing and Communication

  44 percent of the total distributed as follows:

RAM memories	36%
PROM, EMPROM, REPROM	21%
ROM	7%
SERIAL	3%
Microcontrollers	8%
Microprocessors	12%
Logics	8%
Datacom and I/O	5%

- Consumer Products

  28% of the total distributed as follows:

Calculators	24%
Games and toys	23%
Watches	16%
Radio and TV	10%
Automotive	8%
Others	19%

- Telephony

  10% of the total distributed as follows:

Switching Exchange	43%
PABX and KS	46%
Transmission	10%

- Processes of Control and Instrumentation

  10% and Army 8% of the total.

To supply this demand, the 10 greatest semiconductor manufacturers of the Western World, according to STATUS Report 1983, have produced in 1982 7.7 billion dollars. The other manufacturers produced 9.95 million dollars, 17.7 to attend the world demand of 14.6 billion dollars. In 1973, the situation of the world market changed.

Demand surpassed the offer, resulting in delayed supply and a great increase of prices. The opposite had occured in the last few years. In mid 1984, the situation grew better and an equilibrium between offer and demand was attained at the end of 1984.

Table 22 shows the world demand of semiconductors and Table 23 gives a list of the main manufacturers of semiconductors in the world and their production in 1983. The traditional computer and telephone equipment manufacturers should also be mentioned, as IBM and WESTERN ELECTRIC, which also produce their own I.C.s

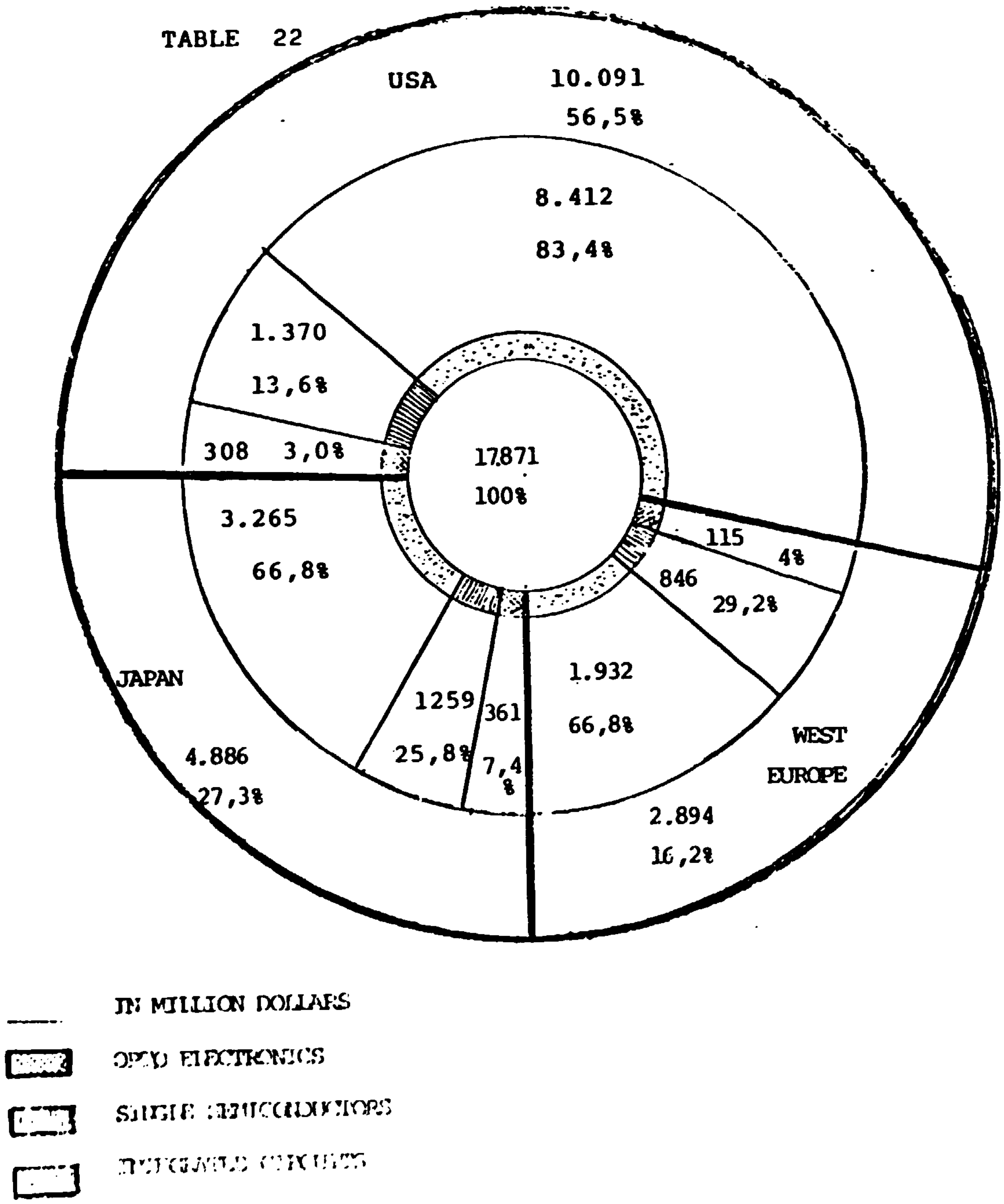
It should be noted that only IBM had a fixed market of 1.6 billion dollars in 1980, meaning that their individual production was substantially higher than the greatest independent manufacturer, TEXAS INSTRUMENT, with a production of 1 billion dollars.

SEMICONDUCTOR'S MARKET

WESTERN WORLD + JAPAN

1983

TABLE 22



THE 10 FIRST SEMICONDUCTORS MANUFACTURERS IN THE WORLD

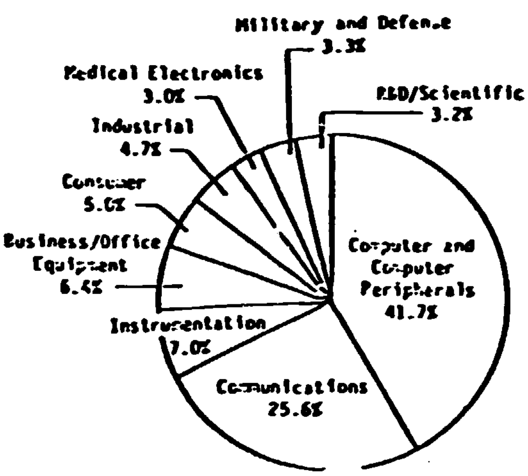
TABLE 23

POSITION	ENTERPRISES	SEMICONDUCTORS PRODUCTION IN 1983 US$ MILLION
1	MOTOROLA (USA)	1.550
2	TEXAS INSTRUMENTS (USA)	1.530
3	NEC (JAPAN)	1.340
4	HITACHI (JAPAN)	1.035
5	TOSHIBA (JAPAN)	880
6	NATIONAL SEMICONDUCTOR (USA)	850
7	INTEL (USA)	745
8	FUJITSU (JAPAN)	530
9	AMD (USA)	485
10	PHILIPS (HOLAND)	475
TOTAL OF THE 10 FIRSTS		9.440
OTHER MANUFACTURERS		7.440
TOTAL (WORLD-WIDE)		17.410

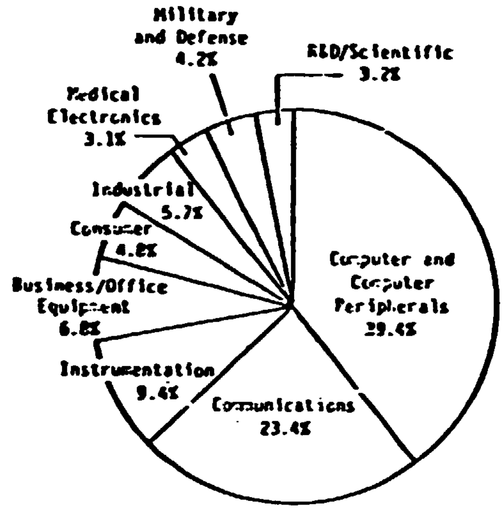
SOURCE: INTEGRATED CIRCUIT ENGINEERING CORP.

CUSTOM AND SEMICUSTOM WORLD MARKET

TABLE 24
SEMICUSTOM

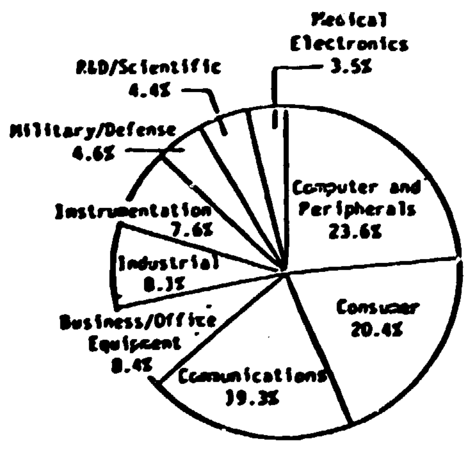


1982
$632.4 Million

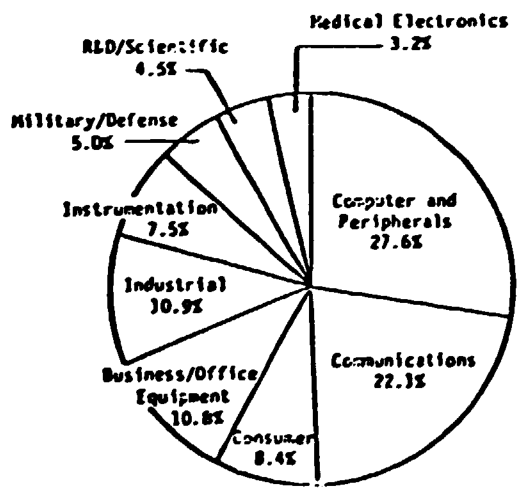


1985
$1950.2 Million

TABLE 25
CUSTOM



1982
$1748.0 Million



1985
$3158.9 Million

Source: Gnostic Inc. (1983)

STANDARD CELLS SUPPLIERS

TABLE 26

COMPANY	PROCESS	DESIGN RULES (MICRONS)	LAYERS OF METAL
ALPHATRON INC.	CMOS S. GATE	3 4	2 1
AMI	CMOS S-GATE NMOS S. GATE	3 5 4	1 OR 2 1 1
ARRAY TECHNOLOGY	CMOS S-GATE NMOS S. GATE	3 4	1 1
CIRCUIT TECHNOLOGY	CMOS S-GATE CMOS, SOS	4 5 3 4 5	1 2 1 1 1
CUSTOM MOS ARRAYS	CMOS S-GATE CMOS M-GATE	3 5	1 1
FUJITSU MICROELECTRONICS INC.	CMOS S-GATE	2.8	2
GTE MICROCIRCUITS	CMOS S-GATE	4 5	1 1
HARRIS	CMOS S-GATE	3	1
HUGHES	CMOS S. GATE	2.5	1
INTEGRATED CIRCUIT SYSTEMS	CMOS S-GATE CMOS M-GATE NMOS M-GATE	3 5 7.5 4.5 5	1 1 1 1 1
INTEL	CMOS S-GATE	2	1
IMI	CMOS S-GATE	3	2
IMP	CMOS S-GATE	3 5	2 1
MASTER LOGIC CORP.	CMOS S-GATE CMOS M-GATE	4 4	1 1
MCE SEMICONDUCTOR INC.	CMOS S-GATE CMOS M-GATE LINEAR	3.5 5 6	1 1 1
MICROCIRCUITS TECHNOLOGY INC.	CMOS S-GATE NMOS S-GATE	3 5 3	1 1 1
MICRO POWER SYSTEMS	CMOS M-GATE (LINEAR-COMPATIBLE)	4	2
NCM CORP.	CMOS S-GATE CMOS M-GATE	5 7.5	1 1
NCR CORP.	CMOS S-GATE NMOS S-GATE	3 4	1 1
NITRON	CMOS S-GATE CMOS M-GATE	5 6	1 1
PLESSEY	CMOS S-GATE NMOS	2.5 6	2 1
RCA	CMOS S-GATE CMOS, SOS	3 5 7 3 6	1 1 1 1 1
SGS-ATES	BIPOLAR	6	2
SIGNETICS	BIPOLAR	5	2
SILICON SYSTEMS INC.	CMOS S-GATE	3	2
SILICONIX	CMOS S. GATE	3 5	2 2
SYNERTEK	CMOS S-GATE	3	1
TEXAS INSTRUMENTS	CMOS S-GATE	3	1
VLSI TECHNOLOGY	CMOS S-GATE HMOS	3 3	1 1
ZYMOS	CMOS S. GATE CMOS M GATE	3 5 6	1 1 1

NEW SUPPLIERS

TABLE 27

COMPANY	MAJOR PRODUCTS
APPLIED MICRO CIRCUITS CORP. (AMCC)	BIPOLAR GATE ARRAYS
ARRAY DEVICES (SOLITRON)	CMOS GATE ARRAYS
INTEGRATED DEVICE TECHNOLOGY (IDT)	CMOS STATIC RAMS
INTERNATIONAL MICROELECTRONIC PRODUCTS (IMP)	CUSTOM MOS
LSI LOGIC	GATE ARRAYS, ROMS
MICRON TECHNOLOGY	HIGH DENSITY DRAMS
SEEQ TECHNOLOGY	EEPROMS, EPROMS, ETHERNET
SEMI PROCESSES INC.	CMOS LOGIC, GATE ARRAYS
SILICON SYSTEMS	MOS TELECOM, ROTATING MEMORY
TELMOS	CMOS GATE ARRAYS, TELECOM
UNITRODE	BIPOLAR LINEAR
UNIVERSAL	CMOS GATE ARRAYS
VLSI TECHNOLOGY	STANDARD CELL, ROMS
XICOR	EEPROMS, NOVRAMS
ZYMOS	STANDARD CELL MOS

SILICON FOUNDRIES

TABLE 28

COMPANY	PMOS		NMOS		CMOS			BIPOLAR		OTHER
	METAL GATE	SILICON GATE	METAL GATE	SILICON GATE	METAL GATE	SILICON GATE	ISO-CMOS	I^2L	LINEAR	
ACRIAN INC.			X		X					
AMI	X			X	X	X	X			
CHERRY								X	X	OPTOELECTRONIC
CITEL	X	X	X	X	X	X		X	X	
COMDIAL				X		X	X			ISO-NMOS
EXAR				X	X	X		X	X	-
FOUR-PHASE SYSTEMS	X		X	X	X	X				
GI				X		X				
GTE MICROCIRCUITS				X			X		X	
HARRIS	X	X	X			X				STL
HUGHES					X	X				
IMP				X		X				
MICREL	X	X		X	X	X			X	TTL
MICRO-CIRCUIT ENGR.					X	X				BIFET, BIMOS
MITEL						X	X			ISO-CMOS
MOSFET MICRO LABS	X	X	X	X	X	X				
NATIONAL	X		X	X	X	X		X		SCHOTTKY
NCR				X		X				
NITRON					X	X				
PLESSEY				X		X	X			ECL
POLYCORE					X			X	X	
RCA					X	X				SOS
SEMI-PROCESSES					X	X				
SILICON SYSTEMS					X	X			X	
SSS				X	X	X				
STC		X		X		X				
SUPERTEX					X	X				
SYNERTEK				X		X				
UNITED MICROELECTRONICS				X	X	X				
UNIVERSAL SEMI				X		X	X			
VLSI TECHNOLOGY				X			X			[illegible]
ZYMOS					X	X				

Notes

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