

# EXECUTIVE SUMMARY

## 0.1 WORLD SEMICONDUCTOR INDUSTRY

### 0.1.1 Development and Growth

Semiconductor industry worldwide has reached US \$ 41.5 billion (1989) in just about four decades. The first decade was that of the transistor, the second of power devices, the third of integrated circuit and the fourth of VLSI. New ideas, new processes, new machineries, new products continue to evolve thus keeping this industry more active and dynamic than any other industry.

The changing product mix of the world Semiconductor industry can be demonstrated by the data of the main producers (USA, Japan, EEC) :-

(In Percentage)

	1975	1980	1985	1990*
Low Power Devices	40	20	13	9
Power Devices	7	9	10	11
Analog IC's	15	18	17	16
Digital IC's	38	53	60	64
	100	100	100	100

(\*Estimated)

The shares of the output among the important producing areas are shown below (% in value) :-

(In Percentage)

	1975	1980	1985	1990
Europe	26	23	22	21
USA	47	45	41	36
Japan	25	29	32	37
Rest of World (ROW)*	2	3	5	6

Rest of World\* does not include the East Block (data unavailable) but is predominated by Pacific Rim Countries (mainly Korea, Taiwan, Hongkong, Singapore, Malaysia) whose aggregate output has risen to \$ 3 billion. The production in these areas began with assembly of devices for re-export to USA but these countries used the opportunity to absorb the technology, train up manpower, expand and integrate to enter the world semiconductor arena in a significant way.

### 0.1.2 Structure and Size

The world semiconductor industry is now dominated by giant multi-national and multi-product conglomerates, who are not only in semiconductors but in other electronic, telecommunication, electrical or engineering products as well. Among the top ten companies, nine are such giant conglomerates. The semiconductor output of top 10 conglomerates is nearly four times that of the top ten independents.

Semiconductor industry is also highly concentrated. The top ten companies (including IBM) accounted for 65% of the output in 1986 and the next ten companies accounted for 20%. This means that rest of the companies (other than those in East Block) only produced an aggregate of 15% of world semiconductor production.

Japanese producers especially aim at large corporate size not only to reduce costs but also to fund R&D so important to this field. Among the top 20 leading companies, 10 are Japanese, 6 are American, 3 are European. From among other nations, only one (Samsung of South Korea) appears among the first 20 in size and is also a multiproduct company.

Some of the more innovative but smaller companies thrive by specialising. This is much more true in USA than elsewhere. Throughout the four decades of semiconductors, there have been notable "start-ups" finding niche markets at the edge of technology. Fairchild, Intel, LSI Logic, VLSI Technology are only a few of the names.

In sum, semiconductor companies do start small but have to grow very rapidly in scale to survive in free markets. Further, they have to innovate and advance all the time for which risk investments in R&D have to be made to survive. This can only be done if they operate on a large enough scale or are part of a larger corporation.

### **0.1.3 Technology Trends**

Basic technological direction in electronics as a whole and in semiconductors particularly is the compressing of more and more performance into even smaller size with lesser energy consumption. This simple objective has led to greater ease of use, penetration into new applications, lower cost, wider markets. The technology has moved in four basic paths:

- Ever smaller circuit geometries - now below one micron.
- Increasing digital route to circuit design.
- Incorporation of intelligence by way of softwarization.
- Integration of maximum possible functions on one small chip of silicon using a single process.

This trend is accompanied by development of new manufacturing techniques and processes. Major advancements are in the area of computerised graphics for designing, electron-beam “writing” of IC patterns, use of plasma enhanced processes, ion-implantation of doping material, multilevel or 3-D processing, and so on.

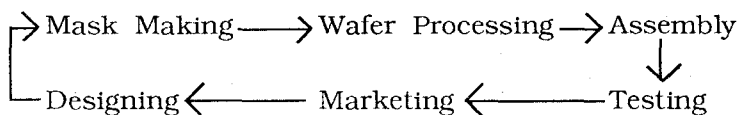
To implement the improved processes calls for new and more advanced equipments developed jointly by specialist equipment makers and over the years, these machines have become increasingly automated and the processes have been linked to form a continuous line so that human handling of the parts and materials is greatly reduced. The latest in this direction the “cluster” concept where processes are sequenced around a central vacuum chamber.

The factory environments and all the inputs to the line are therefore superpure. All chemicals, materials, special water, parts, even the very air have to be totally free of particles, fumes, inclusions to the extent of “parts per billion” (PPB). Machine movements and human traffic is minimised and a rigid discipline has to be followed.

In conclusion, the world semiconductor industry is becoming increasingly capital intensive without which the front line quality and precision cannot be obtained. This applies not only to the initial investment but the continuous additions and renovations that need to be made thereafter and the enormous R&D that supports the leaders in the game.

#### **0.1.4 Role of Manpower**

Various parts of the activity-cycle have different levels of capital intensity. There are parts of the process which require ample skilled manpower. The sub-parts of an integrated semiconductor unit can be described as below :-



The steps of Mask-making and Wafer Processing are indeed very capital intensive and manpower is generally minimised in these steps. Assembly and Testing require individual device handling; marketing, applications and designing require qualified engineering skills. These steps can give an opportunity for manpower surplus nations like India.

Manpower intensiveness also varies according to products undertaken :—

- High power devices being manpower intensive
- Small-signal devices being less manpower intensive
- Bipolar and Analog MSI are more capital than manpower intensive
- LSI and VLSI require enormous capital and low manpower

While more sophisticated products need less manpower, the quality of manpower and the skills they must possess are far higher. Trends are that more and more sophistication is built into the machines thus requiring greater carefulness and training for the manpower.

## **0.2 INDIAN SITUATION**

### **0.2.1 Requirement and its Fulfilment**

Equipment designs the world over have rapidly moved towards greater reliance on IC's than on discretes. Valuewise in India as of 1988 the ratio of discrete to IC usage was nearly 45:55—a situation which applied ten years earlier in advanced countries. This is partly because of following reasons :

Indian production inclines heavily to consumer apparatus which is less IC intensive.

- Computer and telecom (which are heavy users of ICs) have yet to become dominant in the Indian usage.
- India adapts designs from abroad which are passed on several years after they have matured in advanced countries.
- Training and competence of local designers in use of ICs has only recently accelerated.

The emphasis is to highlight that discrete semiconductor devices will continue to form an important requirement for Indian electronics industry. In value terms (though not in market share) their demand will continue to rise for years to come. However, IC usage is fast catching up as local design capabilities and new areas of application get established.

Local production of semiconductors however grew only at about 13-15% per annum (mostly in Discrete Devices where ample unutilized capacity still exists). If this trend is allowed to continue, the imbalance between demand and supply would be as below :-

(Million Rs.)

			1984	1986	1988	1991	1993	1995
Small Signal	-	R'qmt.	337	505	693	900	1003	1125
		Supply	215	374	380	545	620	720
Power Devices	-	R'qmt.	266	505	882	1675	2325	3205
		Supply	110	151	307	585	860	1280
Integrated Circuits	-	R'qmt.	325	827	1925	5250	9000	14500
	-	Supply	38	80	159	515	1040	2040
Difference (Imported) (FOB \$ Million)			26.2	51.4	102.6	185.7	294.7	444.8

Despite ample capacity set up over two decades, supply of even discrete devices is falling farther behind the requirement. On the one hand capacity is only 60-65% utilized while on the other circuit assemblers complain about inadequate local supplies. One can therefore say that the basic discrete semiconductor industry has not been healthily developed. Recent attention and interest of policy makers has been diverted to the more sophisticated area of microelectronics while the basic device industry struggles against a number of constraints.

## **0.2.2 Major Indian Players**

India has so far invested around Rs. 1200-1400 million gross block in semiconductor producing units over two decades. This does not take into account the investment of Rs. 500 million or so in Semiconductor Complex Ltd. which unfortunately was damaged by a fire in early 1989. Nor does it include investments in associated ancillary industries or in earlier units which did not survive.

Permissions in the form of Registrations or Letters of Intent, or Foreign Collaborations or Industrial Licenses were granted to more than 60 entrepreneurs during the last two decades. Permissions have been granted for projects for many products - diodes, zeners, transistors, LED, IC, LSI, and so on. Low power, medium power as well as high power devices and Bipolar as well as MOS products were approved.

As of this report, about 20 units are on record as being in production. Market survey by Consultants informs that in the area of power device assembly, there may be about 4-5 further unregistered but active units. Units in operation have product capability to cover all the popular devices in discretely and to make a good beginning in Bipolar ICs. The area of MOS/LSI is hardly touched with the demise of SCL in the fire.

One group of players comprise six organised sector units engaged in products ranging from small signal to medium power devices and just touching upon the IC field. Investments range from about

Rs. 350 million down to about Rs. 50 million per unit. All these together have been able to fulfill just over half the market requirements for discretely in face of severe import competition. BEL (Bangalore) holds the largest local share and even so BEL size is about a tenth of the scale of the lowest of the top 20 units worldwide.

A second group covers the range from medium power discretely to high current/high voltage devices. Eight organised sector units and four to six small sector units have entered this field. Investments range from about Rs. 70 million down to less than Rs. 5 million in the small-scale units. Here too the growing market is less than half fulfilled and the output may be considered very scattered among the organised units with small market niches going to small sector units.

The integrated circuits area is barely touched at all and the burgeoning IC requirements by value are met to about 10% only, 90% of ICs in 1988 were imported. The important players are BEL (Bangalore) and SPEL (Madras); the latter are assembling from dice procured from abroad. At a smaller level, the other small-signal device makers are also assembling and selling few of the common ICs. The products locally supplied are generally the run of items. Products needed in more sophisticated designs are not taken up. Examples are : high performance transistors, Schottky diodes, MOS-power devices, high power and frequency transistors, GTO Thyristors, Smart-power IC, and many others.

Even the devices locally available are not all diffused in-house but about 30%-35% are imported in chip form for local assembly. Local industry operates under many severe constraints which are treated together under Conclusions and Recommendations.

### **0.2.3 Technology Inputs and Absorption**

The most competent of the Indian facilities is at BEL (Bangalore) started 25 years ago. The unit has benefited from a continuous input of integrated technology through a series of elaborate



collaboration agreements and extensions first with Philips (Holland) and later with RCA (USA). These agreements (incorporating lump-sum as well as royalty) have provided free and regular access to information and training on a continuing basis. A similar situation applies at BHEL Semiconductor Division (Bangalore) where similar access to Siemens technology has been possible in High Power Devices.

Over the years, these two units have passed through the stages of "knowhow transfer", "local implantation and establishment", and "utilization of integrated technology". These units (in the products taken up) have arrived at the level of "self-reliance" as they are able to do engineering, on their own, for further capacity, equipment and tooling for their need. At BEL a horizontal expansion to associated products and horizontal transfer to associated units in Sikkim and Goa is taking place. However, "generation and innovation" of new technologies is some years away even in these top units.

A second group of units (SEM, CDIL, Hirect, Ruttonsha) obtained technologies through agreements covering lump-sums and minority participation. These units have passed through the early phases of "knowhow transfer" and "local implantation" has been accomplished. To a limited extent for the most popular products "integration" of upstream processes has taken place. Similar is the case with other "one time" technology transfers without any financial participation (HCL, MELTRON, NGEF, ECIL).

Some units (GSL, SPEL, Small Units) in the more liberal era of the eighties have been operating without formal collaboration payments. Technology base has been provided by technical people from older units or those returning from abroad. Some augmentation has taken place through assistance from suppliers of machinery, diffused dice, etc. Such units would be unable to go much beyond the stage of "utilization" of those limited techniques without proper injection of up-to-date technology.

Surprisingly, all units surveyed indicated that they would need and go for further inputs of technology to improve themselves, add newer products and further automate. With exception of BEL, few

signs of R&D either in-house or sponsored in other organizations were noticed during survey.

Summarising, successful collaborations in semiconductor need not only be the initial injection of knowhow but continuous and long-term access to further improvements, periodical training and upgradation and above all involvement and interest of the foreign collaborator to see the matter through to the stage of "integration and self reliance" if not to "further generation of own technology".

#### 0.2.4. Utilization

From the units surveyed it is clear that there is considerable under utilization of capacity despite demand running ahead of production. An aggregate capacity (on 2 shift basis) can be estimated at:

Small Signal Devices (below 1A)	...	450 - 500 M pcs.
Medium Power Devices (1-30A)	...	35 - 40 M pcs.
High Power Devices (30A-up)	...	1 - 1.5 M pcs.
IC's (mostly Bipolar)	...	25 - 30 M pcs.

This is assessed at assembly stage. In those units where wafer processing exists, the diffusion capacity would be more than the assembly capacity by a considerable amount (subject to some additions and balancing).

Aggregating the responses of the major units surveyed the estimate is that the above capacity may be utilised roughly as below:

Small Signal Devices	...	55% - 60%
Medium Power Devices	...	45% - 50%
High Power Devices	...	50% - 55%
ICs	...	35% - 40%

Estimates are bound to be approximate due to variations in product-mix, packaging, automation, shifts and so on being practised at various places.

The diffusion capacity in units where it is installed is utilized to about 30% - 35% . Diffusion capacity is usually assessed on long continuous runs and can be readily augmented by increasing wafer size from 2" to 3" (i.e. doubling of capacity without addition of equipment).

In sum, the aggregate investment in the semiconductor industry of Rs. 1200-1400 million is currently giving an output between Rs. 900-1000 million, an unacceptably poor ratio for electronic components. The ratio is even more adverse if we include cost of investments such as SCL (Mohali) and some of the earlier units which have closed down. Clearly there is scope to double this output which would make the capital: output ratio more acceptable. The speculation is that given proper handling the output could even exceed this doubling. Dramatic improvements in costs could be realised by such increase of scale.

### **0.2.5 Local Added Value**

In case of small signal devices, the respondents indicated that the foreign exchange outflow varied between 20% - 30% of their output. The best among them being the earlier units which have had time to establish indigenous subsuppliers and to integrate upstream to a certain extent.

For power devices, the import content depends upon the type of packaging. Medium current and medium voltage devices have low package costs and some of their packaging can be obtained locally. Their imports amount to 25% - 30% of their output. High current and high voltage devices require external casing and other packaging parts of high precision and quality. They also form a rather high proportion of materials cost. Import content of 30% - 35% of output is more than the norm.

Local diffusion provides perhaps 65% -70% (in numbers) of the dice used (mainly the simpler, low rating and low cost types of products). The imported dice are mainly for more advanced devices (RF, Hi Volt, Hi Current, IC's, etc.) which are spread over a large variety in small quantities each. They are higher in value and hence in value terms the imported dice is about equal the value of dice processed in India.

Though there is proven local technology and capability to provide raw silicon wafers, this capacity lies used to less than 20%. Reasons are discussed in detail in the body of the report.

Mechanical part of semiconductor devices (such as lead-frames, headers, casings, caps, heat-spreaders) could readily be taken up as sub-contracts by press-shops. However concerted effort at standardizing, tooling, and vendoring have been lacking and only some minor efforts by small scale entrepreneurs to make the simpler articles are visible.

Broadly, capability exists (though scattered) for Indian semiconductor industry to integrate its production all the way back to raw materials and thus increase local value and minimise imports. If accomplished properly one should expect corresponding benefits in cost, volume and import substitution — a stage which India desperately needs to reach.

## **0.2.6 Research and Development**

Out of the 20 or so active units, only 9 appear on DSIR registration list. Some are registered as overall corporations (BEL, BHEL, NGEF, ECIL) and some are specifically semiconductor units (CDIL, Greaves, Hirect, Keltron, Meltron).

Most of the units surveyed clarified that their efforts are inclined towards improvements in quality, yield and cost rather than innovation. Substitution with local materials is also attempted. In most cases all this work by R&D is done directly on the production line. It is perhaps only at BEL that separate R&D exists.

Certain national institutions are substantially endowed with research facilities for semiconductors. Device - oriented work goes on at CEERI and SSPL while NPL and ACE have been doing materials-oriented work. A separate Microelectronic pilot facility exists at ITI, Bangalore (a non-producer of semiconductors) which is designing and piloting LSI for telecom requirements. It is only the latter unit where movement from R&D to production seems a clear route.

Academic organisations in the main teaching institutions, universities undertake studies in unit processes and product parameters with assistance from DSIR and DOE funds.

Recently, the National Microelectronics Council (under DOE) has been seeding advanced work in the area of VLSI. A clear plan to establish Design Centres of different competence has been taken - Level III at engineering colleges (PC based); Level II at prime Institutes and National Laboratories (with super-micros); Level I with micro computers and powerful software at selected ERTL under DOE. In addition ITI, BEL and SCL have their own Level I facilities.

While accepting that these facilities represent considerable outlay, it needs to be pointed out that once again these are scattered over many different organisations and that forward linkage to the product arena is weak.

## **0.3 RECOMMENDATIONS**

### **0.3.1 Strategic Approach**

- (a) Semiconductors form the heart of electronics and electronics now is the nerve system of commerce, industry, Government and defence. The Indian semiconductor industry calls for strategic change from the past. Change need to be initiated through restructuring of present capacity, development of effective integration, improvement of linkages with ancillaries, attacking all sources of cost escalation thus creating a strong base for the VLSI age which is fast sweeping over even developing countries.

- (b) An urgent element of the strategy is to bring existing investments in the discrete device segment into a profitable position, capable of pushing back the tide of imports on a competitive basis at reasonable level of protection. As volumes increase after substitution of imports, further cost reduction can be attempted for exports to selected markets.
- (c) Though the attention of planners seems to be turned towards ICs (especially LSI/VLSI etc.) it must be appreciated that the discrete device area - where the country already has huge investments and capability - is also one of continuing volumetric growth. Technologically, power devices would also continue in discrete form for a long time to come. Special efforts should be made to build upon the existing strengths to make India a major international player in this niche product area.
- (d) The recommendations call for cooperative and constructive action from the existing units, the financial institutions, and the Government. A concerted campaign and program to implement a new strategy is highly recommended.

### **0:3.2 Restructuring for Scale**

- (a) Scale can be enhanced by the existing units agreeing to specialise in certain product ranges in certain units - if necessary exchanging products among themselves at fair inter-factory prices. These can be broken up into rational groups - diodes, zeners, audio transistors, HF transistors, power transistors, etc. In each case, there should be at least two or at most three sources operating on a competitive basis at respectable scale per product line.
- (b) Where units are too small to be viable (for example numerous assemblers of power devices), slave operation or merger with a larger unit can be a neat solution so as to minimise overheads and reduce costs of engineering, marketing and management.

- (c) Having thus concentrated capabilities and specialization, the restructured units with higher volumes would compete against imports with limited protection. As stated in a later subsection, policy action may be taken by the Government to reduce taxes on the inputs to this industry so as to enhance its ability to compete with imports and later even to export. Such a step would have spiralling effect on scale and productivity.

### **0.3.3 Restructuring for Integration**

- (a) With product specialization and restructured scale, integration into wafer processing becomes viable, enhances added value, lowers costs and reduces reliance on imported dice.
- (b) Where backward integration in certain product ranges cannot be done within the same unit, pooled arrangements to share diffused dice (in competition with landed prices of imported dice) should be possible.
- (c) BEL has high capability to diffuse HF small signal transistors while some of the others are importing the HF dice due to non-viability. BEL can quadruple its HF diffusion and offer the dice (in landed competition with imports) to others who are importing today.
- (d) This kind of restructuring will enable better use of existing diffusion facilities which are lying dormant. It will enable overhead reduction, add local contribution, provide better grasp over technology.

### **0.3.4 Scale of Ancillaries**

- (a) Because of the present scattered capacity, there is lack of standardization and demand on sub-suppliers is sporadic and varied leading to small runs and lack of competitiveness against imported inputs. Parallel to restructuring of the manufacturing base, effort is also required to optimise the volumes on the sub-suppliers and build them up to viable levels.

- (b) Quality of inputs from local suppliers has always been a source of concern for device manufacturers. Whilst individual manufacturers are able to equip themselves for checking mechanical parts etc., they are unable to individually afford and adequately utilize the very expensive and esoteric equipments for testing purity of chemicals, gases air purity etc. A centralized test facilities for such tests can be funded by the Government - possibly under the aegis of C - MET and all other such laboratories.
- (c) More importantly, the basic silicon wafer-producing capacity existing in the country can be more fully booked. This is a very important strategic step of national importance leading to full integration of semiconductors within the country.

### **0.3.5 Injection of Technology**

- (a) Those units which were able to arrange continuing support and involvement from the collaborator on a non-terminating basis have grown best of all and provided quality products, and could partially face the onslaught of imports. The units which had short-term injection of technology (or tried to rely on borrowed technology) have reached a ceiling of achievement and are hardput to compete effectively.
- (b) Further technology inputs are needed by several units. Terms of collaboration should be such as will retain the long term interest and involvement of the collaborator and enable free access by the Indian party to the collaborators expertise.

### **0.3.6 Advance to Integrated Circuits**

- (a) Having provided a strengthened and integrated structure of the discrete device segment, the same units should build on that strength to tackle the challenges of Integrated Circuits. There should be no need to induct new and additional units for what is really the next phase in the semiconductor product cycle namely ICs.



- (b) Fractionating capacity, overlapping the product ranges, creating non-standardization, integrating at the inappropriate time and so on need to be avoided. Once again ability to compete with imports must be the criteria. This should now be possible for Bipolar ICs which is a fast-rising current requirement which must be entrusted to existing signal device manufacturers.
- (c) In the area of C-MOS LSI/VLSI/ASICs (which is the field of the future), a stepwise approach is necessary since investments are very high. A beginning is being made by establishing Applications and Design Centres which can develop and establish a proper standardised market-base. These designs can be "silicon foundered" outside the country and brought back here for assembly, testing and marketing for a start. This concept of "Fabless Manufacture" has already been successfully employed by a small speciality IC makers in the US.
- (d) The "silicon foundry" having a major investment of Rs. 50-100 crores (depending on capacity) calls for careful evaluation as to the structure of the investment and its viability. Best option would be a "pooled" unit owned between existing semiconductor units who wish to advance to ICs.

### **0.3.7 Policy Recommendations**

- (a) Restructuring, pooling and modernising recommended in this report calls for constructive and promotional approach by Government and financial institutions to ease and accelerate the path towards nationally beneficial objectives. Speed of response is crucial in international trade. Procedure should be streamlined to facilitate replacements etc. when defects are reported. Industry associations can investigate such difficulties in detail and work out solutions.
- (b) Attention is also needed to genuinely rationalise the duty structure. To encourage integration and local added value, there should be a minimum of 15% duty differentials between

the steps of finished device - processed dice - raw silicon wafer - mechanical parts - basic materials and consumables.

- (c) Semiconductor plants are investment intensive. Operation on 3 shifts is essential to compete internationally. Units are finding difficulty in getting permissions to use women operators beyond the first shift.
- (d) The imports can surely be reduced and progress even made towards exports if there is mutual understanding of the problems involved and cooperative working between industries, financial institutions and Government.