Roadmap to Indian PWB industry

Introduction

Electronics business is arguably the largest business in the world at $ 1224 billion in 1999. They include all types of products starting from simple toasters to high-end workstations. It is estimated that the electronics product industry has grown at the rate of 5.8% for the past five years, and expected to grow at 6.5% for the coming five years.

Price erosion in electronics business is very high as compared to any other product: The annual price erosion is at 8-10% for technologically developing products and 3-5% for mature products. However, in the market it is not uncommon to see the overall prices coming down by as much as 25% every year. **Nevertheless electronics business has remained interesting due to the fact amazing technological advances in components and materials in particular.** For example, many electronics materials are sold in dollars per gram instead dollars per pound charged for commodity materials

Globalisation:

Globalization is a term, which has been in the mainstream vocabulary in the last few years. It basically refers to the changes in the **"political willingness and cultural environment"** in various countries to persuade economic enrichment as the goal for survival, necessitated by the economic disparities. Countries like India, having a track record of running protected economy for years have **no choice** other than to slowly yielding to such economic pressures. India commenced efforts towards globalising its economy in early 90s. Assumption, which needs to be made, however, is that the decisions made are irreversible, and the Indian economy will **fully open out** in the coming say **five years** or so. Industries should take advantage of this **"lead period"** available for them, which will allow them to make adjustments for future open competition. **Any roadmap or strategy should keep this at the background for making any realistic projections.**

Indian has chosen information technology as a **moscot** to face globalization and to mould the future economic development of the country. The gamut of information technology is quite large. It has all components of making information accessible to every one in all walks of life. The **"soft"** component of information of technology can be at best about 25%; while the rest is vested in **information hardware**. India cannot afford to remain insensitive to Information hardware that connects to information networks, because

a. It is a fundamental and essential input to the competitiveness and productivity of all other sectors of economy, including consumer, automotive, agriculture, aerospace, defense, and space, which are increasingly reliant on electronics components for their manufacturing and operational activities.
b. Electronics hardware is the second largest employer based on the value of the manufactured product.
c. By very nature, electronics cannot grow and make impact in bits and pieces.

Pragmatism dictates a strong need to choose a **"focus"** that would allow the development of a well-defined plan and at the same time positively influence the entire electronics industry.

Past performance: Due to lack of **"economic power"** India [other Asia-pacific countries] has not been able to enter the **silicon manufacturing**. Half hearted attempts in 1970s, and 80.s were failures in terms of establishing a competitive silicon technology in the country. Today silicon technology costs 100 billion dollars to establish and is beyond all economically backward countries. It was scaring to the country when the silicon giants were discussing concepts such as **"System on Chip"**; leaving no chance whatsoever for the entry of smaller players to the electronics market

The technology swings fast. The System on Chip concept, while still in the laboratory is getting rejected in favor of **System on a Package**. In fact countries like Japan have spent enormous amount of money to decide whether it is **System on Chip or System on Package** which is going to stand the test of time. Fortunately, **System on Package is emerging as a winner**, which should be a great sigh of relief for smaller players like us. Relief because, it provides **a new window of opportunity** for all those who would like to continue in the race of electronics manufacturing, without bothering too much on what is happening to the silicon chips itself.

The Indian Electronics Industry, to manufacture cost-competitive electronics products, must have sufficiently strong supply chain that one geographical region cannot force a technology bottleneck. To become a player in global electronics manufacturing scenario, it must have advanced, cost effective technology in all of its components and assembled with cost effective manufacturing process. It is to our good luck that the focus has shifted from "silicon power" to "electronics system manufacturing", which includes, design, packaging, and assembly.

While design is the essence of all electronics systems, both packaging and assembly links silicon to the system.

Design:

Design is the key element for system reliasiation. The design is done at several levels. The design of "chip", the design of package, and the design of system. Chip design [VLSI design] is an upcoming activity in India mainly as subcontract work for waferfabs. The excellence is manpower, and faster communication links have made it possible.

Package design is appreciated only as interconnectivity on the board. It is treated as passive act required only for real estate optimization for cost reduction gains. In the changed scenario of excessive miniaturization of electronics products, the board substrate material, like silicon, can take dynamic part in the circuit functionality. In a sense, the "package" design is an extension of "chip" design capabilities deserving more attention. **The capabilities exist; but need execution.**

Packaging:

Packaging is the art and science of combining components into useful electronic products and systems. While the heart of the product is its components, it is for the most part, the **packaging strategy** that determines the size, weight, ease of use, durability, performance, and cost of the product. These variables are the key attributes to market success.

Board level packaging technology has taken a quantum jump. The board material itself is an active element with a new variety of construction methods making it possible to realize complex functions on reduced real estate. The approach is generally termed as "**high density interconnection with micro-vias**". No future miniaturization is possible unless India adopts this new strategic approach for board building.

Assembly:

Assembly includes the materials, processes, equipment, tools, and activities required to assemble and join many transistors, integrated circuits, displays, resistors, capacitors, other passive components on a substrate, usually a printed wiring board. India has so far adopted limited number of assembly strategies - wave soldering and slow switching over to reflow soldering of discrete SMDs. The next generation of electronics products be it consumer, automotive, agriculture, aerospace, defense, or space, will require paradigm shifts in packaging and assembly strategies and methods to link ever growing complexity on silicon. Therefore, the future lie in adopting **new strategies** such as flip-chip assembly, chip on board assembly and direct chip attach and also MCM reliasiations.

Significant part of the whole scenario is that, unlike silicon technology, the key paradigm shifts and the trade-off technologies fall within the capabilities of financial and technical muscle in the country. What are needed is a "focus" and a strategic plan to achieve the objective.

Nature of electronics products

Electronic is applied in every segment of life; and every segment of application has maintained its own growth pattern as indicated Table 1 below:

Table 1

1998/99 99/2000

Percentage of products

- **Computer and Business Equipment38.70 39.20**
- **Communications25.60 26.80**
- **Consumer12.30 11.60**
- **Industrial and Medical10.10 10.10**
- **Military8.507.70**
- **Automotive4.804.60**

For the coming 5 years the forecast is while there may not be very significant variations in the share of each segment of application, computers and communications will continue to lead, followed by a small spurt in the Automotive electronics which has shown declining trends.

Miniaturization trends are the key for the success of electronics. The Silicon packaging has reached a new peak at 0.13-micron technology ruling the future miniature packages. The board packaging as well as assembly methodologies have kept pace through evolving new approaches such as high density interconnection, micro-vias, multi chip modules, chip on

board, direct chip attachment, and flip chip attachment. All this is focused towards product miniaturization with greater reliability, and reduced cost.

Product miniaturization is the nett effect of improvements in design abilities, board manufacturing, and board assembly, keeping in pace with silicon technology. Any mismatch will result in failure. Miniaturization is the basic drive. Smaller and lighter products with more functions and lower costs are the future of almost all electronics products. The **Table 2** lists different electronics products of today/tomorrow categorized under various system heads, along with their production volumes in 1998 to the closest round figure:

Table 2

Computers and Business Equipment	
Representative Product	Millions of Units
Calculators	178
Desktop PCs	75
Printers	82
Notebooks	21
Photocopiers	11
PDAs	3
Workstations	2
Servers	8
Communication Industry	
Representative Product Millions o Units	
Cellular/PCS Handsets	112
Line cards	62
LAN Cards	51
Pagers	40
Modems	67
Fax Machines	33

Automotive Electronics	
Representative Products	Millions of Units
Entertainment	61
Engine control	47
Airbags	48
ABS	18
Electronic Dashboard	13
Navigation/GPS	3
Electronic Mirrors	5

Military Electronics	
Representative Products	Millions of Units
Mobile Communication	0.65
Fire control System	0.37
Missiles	0.3
Avionics Radar	0.06
Satellite link	0.05

India as a favorable place for electronics business:

It is difficult to exactly position any country with respect to its competitiveness and contributions to world electronics market. However, one **index**, which is sometimes used to ***quantify*** the investors choice of a particular country is the amount foreign investment, which the country attracts. This is because it would reflect the confidence in factors such as the political environment, infrastructure availability, and competitive labor. However, this is not always true. Countries like China, which have attracted maximum foreign investments are drawing flak due to the fact that picture projected to ***outside world*** is not complete true. Therefore, Institutions like International Institute of Management Development [IMD] and World Economic Forum [WEF] have made realistic models of economic competitiveness of various countries using hard and soft inputs. They have created an index allotting 100 points to USA as the most favored country and ranking them first. **India with 19.64 points** is ranked **41 amongst the 46 countries** which are included in the survey, with Singapore with 84.25 points at second place, and Hong Kong with 69 points at third place China with 43.9 points at 24th place and small countries like Indonesia, Thailand, Brazil closely placed to India. Lower ranking of India is a positive factor to drive the change.

This ranking has put India at the back seat. What has changed since this raking in the year 1998? Virtually nothing…. except a policy decision by the Government of India that Information Technology will receive extra support. Information technology has two components, both of which should be given equal priorities for balanced growth. The two components are "Information Software and Information Hardware. The importance of software is a direct consequence of developed resident hardware. Even in the software sector, India has not performed well, with its contribution rated at maximum 1% of the world software market. Excessive emphasis on software alone will result in handicapped growth, ultimately leading

Keeping the background information provided as above, the following facts were considered in arriving at the Technology roadmap:

A developing country like ours has several barriers which impede the effectiveness of any implementation, including:

a. Current Critical state of Industries
b. Cultural resistance to change
c. Inflexible legacy systems
d. Factory culture
e. Weak fundamental process knowledge
f. Large dependence on imports
g. Escape from accountability

These impediments can be overcome by:

a. Current Critical state of Industries Pragmatic Government Support

b. Cultural resistance to change Education

a. Inflexible legacy systems Liberal Globalization
b. Factory culture Training
c. Weak fundamental process knowledge Develop in house

   Education material

d. Large dependence on imports Encouraging Applied research in academic circles
e. Escape from accountability Incentives to successful projects

While it is true that all the above listed impediments will be operational in some magnitude, immaterial of taking above mentioned actions, a positive thinking in the right direction will see the country through in the coming 21st Century.

Information Hardware - International Scenario

Consistent impact of silicon complexity has made every component of board technology grow almost to the levels of saturation. However, the market at any given point of time is quite diligent in adopting only those forces, which will be advantageous for quick economic benefits. Significant among those adopted by the industries is lower line width/gaps,

smaller via sizes, lower dielectric separation, newer dielectric material, and methods of construction, The **Table 3** summarizes the accepted trends in the world market

Table 3

	Year			
Paramater	**1998**	**2000**	**2002**	**2006**
Line width[mm]	0.10	0.075	0.050	0.030
Gap[mm]	0.125	0.10	0.065	0.040
Via size[Dia]	0.15	0.10	0.070	0.050
Dielectric separation	0.20	0.10	0.050	0.025
Tg of Substrate[C]	140	160	170	210
Via creation	Photo/Laser	Photo/Laser	Laser	Laser/Plasma
Passives	Discrete	Discrete	Burried	Integrated
Operating Temp[C]	55	55	70	100
Junction Temp[C]	125	125	100	170
Max Pin count	400	675	880	1500
Chip Pad count	450	810	1200	1600
IC thickness[mm]	2.0	1.00	1.00	0.50
Frequency]MHz]	50	66	150	200
Attachment	Wire	Bond/ WB/FC	FC	FC/DCA
Soldering				

[* Extracted from Roadmap of National Semiconductors]

It should be observed that the expected trends are far beyond the figures provided. The market acceptability of the above listed figures have emerged from consolidation of existing core competence levels and successful internalization of new technological, process, materials and equipment areas.

Information Hardware - Indian Scenario

In planar board making technology, India is at a threshold of saturating at 0.15-mm technology. In board assembly, India has to make significant jumps - with Surface Mounting just picking up pace. Board assembly and board manufacture - which should be improved first..? It is like chicken-and-egg situation. Planar board technology will not change unless assembly technology is geared-up and vice-versa. **Table 4** shows the current status of India in planar board making and assembly technologies:

Table 4

Paramater	**1998-2000**
Line width[mm]	0.15 **N0 FUTURE PLANNING**
Gap[mm]	0.18
Substrate	FR-4 [Rigid]
Via size[Dia]	0.30 mm
Dielectric separation	0.30 mm
Tg of Substrate[C]	130 C
Method of Via creation	Only Drilling
Passives Predominantly	**Discrete/Through Hole**/SMD
Operating Temp[C]	45
Junction Temp[C]	100
Max Pin count	256
Chip Pad count	260
Frequency[MHz]	20
Attachment Soldering -	wave/reflow/hand

This technological change-over will not happen overnight. In fact **"quantum jump"** in technology is just not possible. Progress is natural, built on experience. Any future action should fit into natural progression rather than wishful quantum changes.

Indian electronics always provides small but niche market for products in strategic sectors in industry, defense, and space and to a small extent in consumer goods. Therefore, board technology has to first address to our own small but demanding needs on the strength of which international competition can be faced. Every element of electronics product development should be addressed without leaving any loose ends to be tied.

Technology Roadmap to Indian Packaging Industry

Critical review of what is existing:

It is generally presumed by default that advances in Silicon technology is almost solely responsible for the kind of products described above. While silicon is still the heart of any electronics system, it cannot exist with out matching enabling technologies identified as

- board manufacturing
- board assembly
- high pin count board assembly
- area array board assembly
- flip-chip board assembly
- chip scale board assembly

  - Integration of passive components

- electrical, thermal and EMI management

These are the technology areas, which give access to the outside world and make the manufacture of electronics system possible. The enabling technologies listed as above when effectively combined to produce a product will result in the emergence of **System on a Package Concept**. The implementation of the SOP concept is open to all who have not been able to get in to silicon fabrication, but still interested in electronics product design and manufacture. India is a typical example, which fits into this situation.

As mentioned earlier, quantum jump in technology areas is only wishful thinking, not realizable. By and large, the current Indian packaging industry is nothing more than printed wiring board manufacturing, and surface mount assembly picking up only recently. The abilities in both these areas are just average, far below international standards.

Let us first take the example of board manufacture. There are about 30 recognized industries in the country manufacturing printed wiring boards. Technologies wise all of them are almost at par; except some of the larger industries have more sophisticated equipment and also produce relatively more in terms of quantity. All of them depend on imported materials. They have in them processing capability of only FR-4 rigid substrate. The export market of some of them who are having it, is only for designs which are getting phased out, and therefore short lived. They are already under pressure to upgrade their technology levels to meet the export requirement. All of them are worried about their future. Other technological abilities are summarized in Table 3/4 above.

Looking at the assembly, the scene is no better. Surface mounting has just begun not by choice but by force. Designers in India are not yet familiar with designing with new packages. Assembly of larger pin count and area array packages is still not possible. Flip-chip technology, which is the essence of mounting modern packages, is unknown.

The paradigm shift in product packaging dictates new role for interconnecting substrates and assembly. In their new role, interconnecting substrates will also be performing circuit functions such as impedance control, or utilizing integral inductive/resistive/capacitative layers. These will place new requirements like edge definition control, and dielectric

thickness control. The interconnecting and mounting structures will require greater precision in placement definition of the conductors, and in the dielectric properties of the material. Moreover, the substrate will require addition of materials necessary for attachment of components such as solder bumps, palladium coated lands, and conducting adhesives.

Solution

The industry needs to take care of the above requirements can be summarized as follows::

Import new HDI technology at the APPROPRIATE TIME…as has been the case always…? That may not be possible for the following reasons:

1. New technologies will be prohibitively expensive . Indian industries do not have such finical capabilities
2. Buying machines, as was in the past by it self will not provide technological solutions required.
3. More significantly there are a wide variety of technological options making the choice-decision very difficult.

Answer can be only in developing indigenous technology. Is this possible? The answer can be yes if the industry is interested in:

1. Sustaining in the competitive market
2. Offer the HDI boards for in-house and exports
3. Would like to have common R & D base
4. Nominal investments for mutual gain is fine
5. Like to produce DS boards with micro-vias
6. Like to graduate from DS to MLB
7. Develop more Export potential

    1. Educate staff to deliver optimized output

Based on the above assumptions the projection for Indian Packaging Industry can be summarized as below:

Paramater	Existing	Desirable	Future
Line width[mm]	0.15	0.10	0.05
Gap[mm]	0.18	0.12	0.80
Substrate	FR-4	New substrates	
Via size[Dia]	0.30	0.10	0.05
Dielectric separation	0.30	0.10	0.05
Tg of Substrate[C]	130	160	180
Via creation	Drilling	Photo	Laser/Plasma/Photo

Pad size	0.52	0.16	0.08
Buried via	Limited	Yes	Yes
Blind via	Nil	Yes	Extensive
Passives	Descrete/ Through	Hole/SMD	SMD Buried
Operating Temp[C]	45	55	80
Junction Temp[C]	100	120	150
Max Pin count	256	500	800
Chip Pad count	260	540	880
IC thickness[mm]	2.0	1.00	0.50
Frequency]MHz]	20	100	200
Attachment	Soldering WB/FCA/COB/DCA/CSA		

Achievement of the set parameters as above would mean developing strength in the following **core technological** needs:

a. **Micro-via technology - new substrates and processes**
b. **Embedded passives**
c. **Flip-chip interconnection, DCA and COB**
d. **Green electronics assembly - Lead free solders**.

Equally important are **"Trade-off technologies**" in support of the above in terms of equipment, processes, and materials. They include:

a. Liquid film [curtain] coating technology - process and equipment
b. Stencil technology for Fine pitch/BGA assembly prints and Buried passives printing
c. Imaging technology for fine line - 0.05 mm and less.
d. Anisotropy conducting adhesives - for interlayer solid interconnection
e. High performance organic substrates -low dielectric constant, high modulus materials
f. Fine line etching and/or additive copper builds
g. Double side treated copper foils - for resin coated copper foils
h. Electrical test equipment- fine pitch flying probe equipment
i. Improved design tools - for building HDIs.

Strictly speaking all core technologies, as well as trade-off technologies listed are required for making HDI-PCBs. However, some of them may be long term goals with lots of research content, and some others, such as trade-off technologies" could be realized in relatively shorter time..

Development proposal

Development of a technology without market force is useless. It is very necessary to first establish the market intentions and then bring synergy in the development plan to achieve the goal - obviously with in a time frame.

The Indian industry is still not used to large volume production - whatever may the technology addressed. Strangely enough, many of us survey through selecting niche areas, which require small to medium volumes only. The Industries within the country should determine whether they will stick to the same policy or would like to understand the dynamics of large volume products to reach Global markets.

Another significant decision of the hour is whether the shift to **"large volume production"** is for serving designs done outside the country or within the country. In the past three decades of electronics history of India, there is not a SINGLE product, which is designed for international market. That is the reason why Indian PWB industries have not geared-up for large volume productions. It is an accepted fact that always it is the **DESIGN** which drive the Manufacturing. The country has been making empty noises of progress in electronic business by claiming success in software sales; which again is more a service to outside agencies rather than for supporting indigenous hardware. Therefore, it is high time that the **DESIGN and MANUFACTURE** of electronics products for the **internal as well as international market** must be addressed quickly.

There has been some effort to moot the idea of contract manufacturing. Indeed contract manufacturing provides excellent market. The figure below shows the quantum of global contract manufacturing available.

Estimated Global IT Hardware

Sub-contract Manufacturing Market in [$ billion]

Year Value of

business

[$ billions]

1. **41**
2. **49**
3. **59**
4. **74**
5. **83**
6. **124**
7. **165**
8. **224**
9. **252**
10. **288**

The **DESIGN services**, which are rendered by VLSI design centers in India, is in fact comes in the purview of **contract service**. However, when one needs to extend the contract service to contract manufacturing, bottlenecks emerge. Global contracts can be won only on the basis of technology/cost competitiveness- and India does not have sound manufacturing base yet in either **board manufacturing or contract assembly**.

Identification of test vehicle

Computers and Communication provide a lot of opportunity product identification. In computers for example, two products are emerging

Professional computers

Low cost computers

While the cost of a professional computer is around $ 1800, the low cost version is generally less than $1000 in the international market.

The Tables 5 and 6 campers the cost inputs for the two types of PCs

Table 5

Table 6

It is forecast that the market for low cost PCs will grow at the rate of 22% in the next three years. It is clear that cost reductions are concentrated in the cost of the processor, hard disk drive, dram, DVD-ROM drive and modem. The rest of the inputs for PC is same for low cost as well as processional computers. **The board and assembly for low cost PC is a product, which India can plan to produce.**

G. Ananda Rao