What is Future Scope of PCB Fabrication & Manufacturing in Industries

[1]Manish Ranjan, [2]Sumit Kumar Singh
[1]Student, [2]Student
G L Bajaj Group of Institutions, Mathura

***Abstract* - Printed circuit board (PCB) is base of any electronics/electrical equipment. A PCB provides the connectivity to the electronic component such as resistor, capacitor, coils, pots, diodes, FET, transistor, ICs, transformer etc. to form a complete electronic circuit. In the present scenario, the existence of electronics equipment's cannot be imagined without a PCB. The PCBs are not only providing the connectivity among the electronic components but also reduces the size and increases the efficiency of the electronic equipment. Broadly the PCBs may be divided in two categories i.e. single layer PCBs and multi-layer PCBs. One can easily find the contribution of electronic industries in each and every field of our daily life i.e. entertainment, communication, education, R&D, Public Services, Defence, Transport, Agriculture, health care services etc. With the growing demand of electronic equipment's/appliances in every sphere of human beings the electronic industry is growing up with a very fast rate. Similarly, the demand of micro servicing industries such as assembling/mounting of electronic component on PCBs to meet the requirement of the small/medium/large scale electronic industries is also increasing. This Paper Discuss what is the future scope of PCB board fabrication and manufacturing in industries. Our Conclusion show that the PCB manufacturing and fabrication is very fast growth in future.**

***keywords* - PCB board, fabrication, manufacturing, PCB design industry segment, future scope, growth rate,**

1. Introduction

The world market for printed circuit boards (PCBs) reached an estimated $60.2 billion in value in 2014, growing just 0.7 percent in real terms, according to IPC's World PCB Production Report for the Year 2014. Production growth in China, Thailand and Vietnam compensated for declining PCB production in most other regions..[1] The global printed circuit board (PCB) market was valued at USD 63.1 billion 2017 and is expected to reach USD 76.9 billion by 2024, at a CAGR of 3.1%. Factors driving the growth of the market are; rising adoption of automation in various end-user industries, growing demand for wireless devices, increasing miniaturization of devices, surging need for more efficient interconnect solutions, and increasing demand for flexible circuits. Owing to the implementation of processors and sensors in smart gadgets, the size of the PCB has reduced to 74% approximately.[2]

2. Characteristics

2.1 Through-hole technology

The first PCBs used through-hole technology, mounting electronic components by leads inserted through holes on one side of the board and soldered onto copper traces on the other side. Boards may be single-sided, with an unplated component side, or more compact double-sided boards, with components soldered on both sides. Horizontal installation of through-hole parts with two axial leads (such as resistors, capacitors, and diodes) is done by bending the leads 90 degrees in the same direction, inserting the part in the board (often bending leads located on the back of the board in opposite directions to improve the part's mechanical strength), soldering the leads, and trimming off the ends. Leads may be soldered either manually or by a wave soldering machine.[3]

Through-hole manufacture adds to board cost by requiring many holes to be drilled accurately, and it limits the available routing area for signal traces on layers immediately below the top layer on multi-layer boards, since the holes must pass through all layers to the opposite side. Once surface-mounting came into use, small-sized SMD components were used where possible, with through-hole mounting only of components unsuitably large for surface-mounting due to power requirements or mechanical limitations, or subject to mechanical stress which might damage the PCB.

2.2 Surface-mount technology

Surface-mount technology (SMT) is a method in which the electrical components are mounted directly onto the surface of a printed circuit board (PCB). An electrical component mounted in this manner is referred to as a surface-mount device (SMD). In industry, this approach has largely replaced the through-hole technology construction method of fitting components, in large part because SMT allows for increased manufacturing automation. Both technologies can be used on the same board, with the through-hole technology often used for components not suitable for surface mounting such as large transformers and heat-sinked power semiconductors. [4]

An SMT component is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all. It may have short pins or leads of various styles, flat contacts, a matrix of solder balls (BGAs), or terminations on the body of the component.

 

fig.1(a) Through-hole devices mounted on the circuit board. fig.1(b) Surface-mount Components.

3. PCB Manufacturing Process

3.1 PCB Constituents

Printed circuit boards, PCBs, can be made from a variety of substances. The most widely utilized in a sort of optical fibre-based board referred to as FR4. This provides an inexpensive degree of stability under temperature variation and is doesn't breakdown badly, while not being excessively expensive. Other cheaper materials are available for the PCBs in low cost commercial products. For high performance frequency designs where the dielectric constant of the substrate is vital, and low levels of loss are needed, then PTFE based computer circuit boards can be used, although they are far more difficult to work with.[5]

In order to make a PCB with tracks for the components, copper clad board is first obtained. This consists of the substrate material, typically FR4, with copper cladding normally on both sides. This copper cladding consists of a thin layer of copper sheet bonded to the board. This bonding is normally very good for FR4, but the very nature of PTFE makes this more difficult, and this adds difficulty to the processing of PTFE PCBs.

3.2 main types of PCB board

There are three main types of PCB in current manufactures are

- **Single-Sided Circuit Boards:** These boards when made with a FR4 base have rigid laminate of woven glass epoxy material, which is then covered on one side with a copper coating that is applied in varying thicknesses depending on the application.

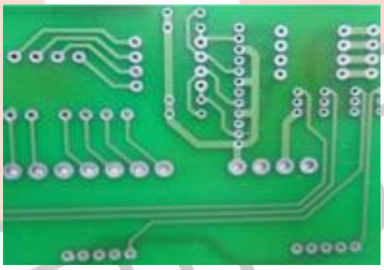

Fig.2 Single layer PCB Board

- **Double-Sided Circuit Boards:** Double-sided boards have the same woven glass epoxy base as single-sided boards — however, in the case of a double-sided board, there is copper coating on both sides of the board, also to varying thicknesses depending on the application.

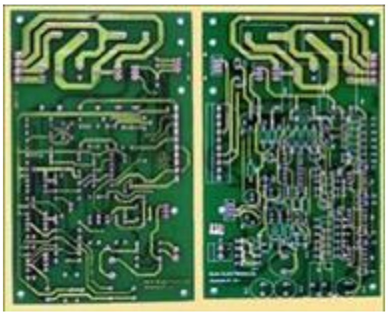

Fig.3 Double sided PCB Board

- **Multi-Layer Boards:** These use the same base material as single and double-sided boards, but are made with copper foil instead of copper coating — the copper foil is used to make "layers," alternating between base material and copper foil until the number of desired layers is reached.

Fig.4 Multi-layer PCB board

3.3 Part of PCB

There are four main part of PCB

- **Substrate:** The first, and most important, is the substrate, usually made of fiberglass. Fiberglass is used because it provides a core strength to the PCB and helps resist breakage. Think of the substrate as the PCB's "skeleton".
- **Copper Layer:** Depending on the board type, this layer can either be copper foil or a full-on copper coating. Regardless of which approach is used, the point of the copper is still the same — to carry electrical signals to and from the PCB, much like your nervous system carries signals between your brain and your muscles.
- **Solder Mask:** The third piece of the PCB is the solder mask, which is a layer of polymer that helps protect the copper so that it doesn't short-circuit from coming into contact with the environment. In this way, the solder mask acts as the PCB's "skin".
- **Silkscreen:** The final part of the circuit board is the silkscreen. The silkscreen is usually on the component side of the board used to show part numbers, logos, symbols switch settings, component reference and test points. The silkscreen can also be known as legend or nomenclature.

Fig.5 Main part of PCB

3.4 Basic Manufacturing Process

With the bare PCB boards chosen and available the next step is to create the required tracks on the board and remove the unwanted copper. The manufacture of the PCBs is normally achieved using a chemical etching process. The most common form of etch used with PCBs is ferric chloride.

In order to gain the correct pattern of tracks, a photographic process is used. Typically, the copper on the bare printed circuit boards is covered with a thin layer of photo-resist. It is then exposed to light through a photographic film or photo-mask detailing the tracks required. In this way the image of the tracks is passed onto the photo-resist. With this complete, the photo-resist is placed in a developer so that only those areas of the board where tracks are needed are covered in the resist.

The next stage in the process is to place the printed circuit boards into the ferric chloride to etch the areas where no track or copper is required. Knowing the concentration of the ferric chloride and the thickness of the copper on the board, it is placed into the etch froth e required amount of time. If the printed circuit boards are placed in the etch for too long, then some definition is lost as the ferric chloride will tend to undercut the photo-resist.

Although most PCB boards are manufacturing using photographic processing, other methods are also available. One is to use a specialised highly accurate milling machine. The machine is then controlled to mill away the copper in those areas where the copper is not required. The control is obviously automated and driven from files generated by the PCB design software. This form of PCB manufacture is not suitable for large quantity but it is an ideal option in many instances where very small quantities of a PCB prototype quantities are needed.

Another method that is sometimes used for a PCB prototype is to print etch resistant inks onto the PCB using a silk-screening process.

4. Top global PCB Manufacturers

FLEX Ltd

Flex Ltd is one of the third largest global electronics manufacturing service company. This company offers a wide range of electronic design services including PCB design, microelectronics, robotics, and more.

Eltek Ltd.
Eltek Ltd. is a leading manufacturer of advanced PCBs for sophisticated electronic products. Eltek's products are used in some of the world's most advanced electronics including defence, aerospace, and medical applications. Eltek is registered and fully licensed through the Dept. of State, meeting all required guidelines as an exporter of defence articles and services.

SCHMID Group.
SCHMID Group has been the recognized technology leader in the PCG industry for over 50 years. The company is known for its excellence in the areas of metallization, surface and resist technology. This company follows standardized technologies and customized solutions to implement market demands and customer's requirements appropriately.

Corintech Ltd.
Corintech Ltd provides high quality and competitive PCB assembly services. The company remains on the cutting edge of technology by continually advancing in new hardware. Corintech delivers quality products using all assembly processes.

SMTC Corporation
SMTC Corporation is a mid-size provider of end-to-end electronics manufacturing services (EMS) including PCB production, systems integration, comprehensive testing services, enclosure fabrication, product design, and supply chain management services. SMTC has facilities in the United States, Mexico, and China.

Celestica Inc.
Celestica Inc**.** offers a range of engineering solutions for the communications, enterprise and cloud, industrial, aerospace and defence, renewable energy, health tech, and semiconductor industries. Revenue in 2016 was $6 billion.

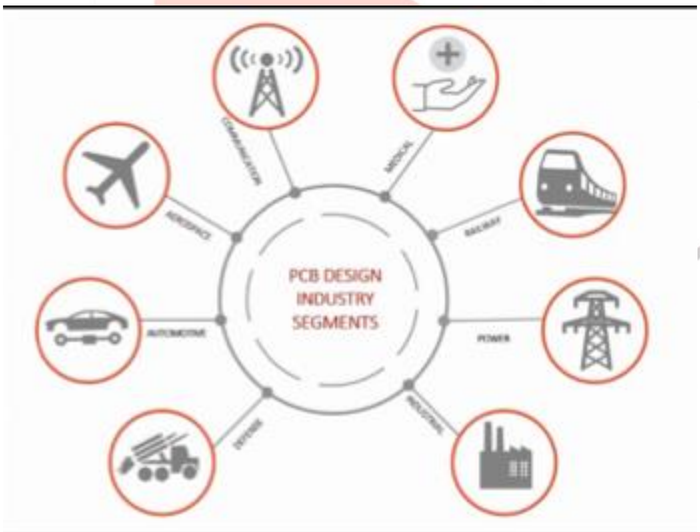

Fig.6 PCB Design industry Segment

5. Latest Trends in PCB Design
Despite its critical nature in high-speed circuitry, PCB layout is often one of the last steps in the design process. This article aims to help designers be aware of the various considerations they need to address when designing board layouts for high-speed circuitry. Better the designing, better the PCB manufacturing! PCB layout is an important step in the designing of any electronic device. It determines the success or failure of a piece of equipment. With the constant evolution of technology, complexity and expectations of PCB designs have reached new heights. Thus, PCB design rules and production processes have also evolved to achieve new layouts and capabilitie. [6]
PCB design software has helped with this progression by providing tools that help electronics engineers to design better PCBs from the ground up. A PCB is essential for everyday appliances and industrial machines alike. PCB technology will need to adapt to the fast-paced world to allow the devices to keep up with the growing demand for speed.
Printed circuit boards (PCBs) play an integral role in modern-day life. PCB board manufacturing products can be found in almost every room you enter. You can find circuit boards in your television, cell phone, calculator, and even home appliances like washing machines and dishwashers. Updates and advancements in PCB technology have made it important for application in the military, aerospace industry, and healthcare. Printed circuit board manufacturers would agree that these boards are the most commonly used today.

5.1. Micro PCB boards
Many of today's commonly used technologies only seem to be getting smaller. Televisions need to be as flat as possible, and many people want their laptops to be thin so they are easy to store. Even smartphones, which have actually grown in

screen size over the past few years, need PCB board technology which will pack in as many components as possible, given the amount our phones do these days. In these cases, PCB manufacturing companies haven't any other choice but to miniaturize their circuit boards and components.[6]
Many of today's PC boards have components that are tiny in comparison to components of the past. Despite their size, these micro components are actually much more powerful than more traditionally sized components. Sometimes the dimensions and power of those mini-components leave computer circuit board manufacturers struggling to figure out optimal practices for fabrication. However, many manufacturers have found ways around these initial issues and have PCB miniaturization down**.**

5.2 Large PCB boards

Before technology became as sophisticated and complex because it is today, large PCB components ruled the market. PCB board manufacturing was solely dedicated to the assembly of traditionally sized components. Today, manufacturers find it best to go in the opposite direction of miniaturization for a PCB board that packs a punch. Macro PCB boards are common today and are utilized in automotive and aerospace production, also as within the construction of solar panelling and lighting.
Large PCB board configurations are thicker than standard board units and are identifiable by their wide traces. Larger PCBs are high-powered and are built to endure extended periods of high voltage. The goal in developing these PCB boards is to form them strong and long-lasting. [6]

6. What Next for PCB's

Since their invention at the turn of the century and their patenting by Paul Eisler in 1943, printed circuit boards have evolved and advanced far beyond their original functionalities. PCBs today are tiny, multi-layered, complex systems that hardly resemble their earliest ancestors. They're also produced at a much higher and more efficient rate than ever before thanks to sophisticated design software and manufacturing processes. Even 10 years ago, micro-vias, HDI and FPGAs were only seen in the most expensive designs, yet are now readily available to designers worldwide. As technology and consumer demand grows and develops, however, so must PCBs. As the basis of all electronic devices, PCBs feel intense pressure for development and growth. With consumers pushing for slimmer and faster devices, and with industries seeking improved functionality, the PCB must continue developing into the future. [7]

6.1 New Technology Changes the PCB industries

6.1.1 High-Density Interconnect and Miniaturization

Manufacturing as a whole is in the eye of a whirlwind of innovation right now, much of it performed in service of miniaturization. Our computers have gotten smaller, but so has everything else.
Across the consumer spectrum, folks seem to be gravitating slowly toward smaller footprints. Miniaturization means we can build smaller and more efficient homes and the means to climate-control them, cheaper and more efficient automobiles and much, much more.
Since PCBs are a critical foundational component in consumer-level goods — what doesn't have a computer in it these days? — PCBs must also relentlessly pursue miniaturization.
In the PCB market, specifically, this means high-density interconnect technology. Additional refinements in HDI technology will further reduce PCB size — down to .4 mm in the near future — and touch a dizzying number of neighbouring industries and goods in the process.

6.1.2 Advanced Materials and Greener Manufacturing

PCBs are a product like any other. Well — not quite like any other, but they're still susceptible to some very real influence from political, climatic and social pressures. To put it more simply, PCB manufacturing processes need to keep up with the rest of civilization's mad dash toward cleaner and more sustainable production.
In fact, PCB manufacturers are and always have been in the hot seat when it comes to the crossroads of legislation and industry standards. As an example, the introduction — or, rather, the required rollout of — lead-free solder required more energy-intensive manufacturing processes. The industry has since been forced to find a new equilibrium.
In other ways, PCBs have been ahead of the curve. Traditionally, PCBs are created using fiberglass as a substrate, which is viewed by most as a relatively environmentally friendly material. Additional advancements might see fiberglass give way to materials better-suited for a high rate of data transfer — such as resin-coated copper and liquid crystal polymer.
This tick-tock of social need versus what's convenient for production and business will likely become a new norm as manufacturing efforts of all types continue to reconcile their footprint with a changing planet.

6.1.3 Wearables and Ubiquitous Computing

We've already touched briefly on the technological fundamentals of PCB technology and how they allow for greater complexity on thinner boards, but let's put that concept into practice. PCBs lose thickness and gain functionality each year because they can, certainly, but also because we have lots of practical applications for ever-smaller boards.
Consumer electronics as a whole have been a significant driver of PCB manufacturing and use over the last few decades. Now that wearables have entered that field and begun to come of age as a credible consumer-level product type, PCBs will be there right alongside.

Wearable technologies require printed circuit boards just as smartphones do, but they take things one step further. They emphasize efficiency of design to a degree not remotely possible with yesterday's technologies.

6.2 PCB's future Scope

One of the upcoming trends is using PCBs as active system components. Currently, PCBs are used as connecting components in electronics, relaying messages between active components so the complete device can work. Engineers are currently working on active PCBs, which will reduce the number of components in the PCBs while maintaining functionality.

Augmented reality (AR) and virtual reality (VR) could change the face of electronics design, as these are making rapid inroads in the consumer electronics world. Their potential application in PCB design is to address issues such as fitting electronic packages into unconventional shapes. This will ensure circuit connections work properly and reduce the time-consuming process of place-and-route.

The idea of training using AR with simulation software is also under exploration. In the near future, augmented PCBs could be used to reduce cost and wastage of materials used in current training methods. It could replicate magnetic and electric fields generated by a product as an alternative way to ensure that the product meets regulations. "Much like the integration of 3D into PCB design, AR is a solution to many problems of advanced technology," says Ben Jordan, senior manager product and persona marketing, Altium.

As consumer demands change, so must technology. High-density interconnect (HDI) boards are one of the fastest growing technologies. These have higher density circuitry than traditional circuit boards. This provides designers the option to place more components on both sides of the PCB. [7]

Multiple via processes allow designers to place components that are smaller even closer together. Decreased component size allows more input/output in smaller geometries. This results in faster transmission of signals and significant reduction in signal loss.

There's also plenty of room to grow in the manufacturing process itself as increased PCB complexity introduces new challenges for manufacturing companies. That's why most predictions for the printed circuit boards future focus strongly on the following areas.

6.2.1 PCB board Cameras

A PCB board camera is mounted directly onto a circuit board. It consists of a lens, aperture and image sensor. It is designed to take both digital pictures and videos, and can be mounted on any PCB, irrespective of size.

Board cameras have developed quickly to take high-resolution images and videos with ease. In the future, board cameras are expected to develop to create powerful solutions for both industry and consumer electronics. Small board cameras have found important applications in the medical industry for non-invasive and minimally-invasive procedures. Pill-sized cameras allow doctors to take comprehensive videos and images from inside the digestive tract without invasive surgery. These small cameras can also be used to monitor homes and businesses for intruders.

6.2.2 3D Printed Electronics

3D printing technology is probably one of the most exciting technological innovations in recent years. From 3D-printed organs to firearms and ammo, 3D printing has accomplished some incredible things in a variety of industries. The PCB industry is no different.

3D printing has proved integral to one of the big PCB innovations in recent years: the 3D PE. 3D-printed electronics, or 3D PEs, are positioned to revolutionize the way electrical systems are designed in the future. These systems create 3D circuits by printing a substrate item layer by layer then adding a liquid ink on top of it that contains electronic functionalities. Surface-mount technologies can then be added to create the final system. The result is a circuit that can take any shape imaginable.

6.2.3 High Speed Capabilities

High-speed PCBs are a unique subject for designers, mostly because the definition of a high-speed PCB is relatively loose. The generally agreed-upon definition of a high-speed PCB is one where the integrity of the signal is affected by the circuit layout. This can mean different things:

- **Digital Signal:** In digital PCB signals, the intelligence is contained in the digital pulses. Therefore, effects on signal integrity can manifest as delayed or cancelled digital signals.
- **Analog Signal:** In a high-speed analog circuit, the intelligence is in the shape of the signal. In these cases, signal integrity problems will appear as altered signal shapes.

In both cases, signal integrity can be adversely affected by several factors, both in and around the PCB. These include the dielectric of the PCB, the length of the tracks, the proximity to other signals and EMI, among other factors. Many high-speed designers know how to adjust designs to mitigate these problems, but new methods are constantly under development as well as new software tools to manage high-speed designs.

7 PCB Market Growth

Asia-Pacific occupies the first position (Largest Market Share) as it contains around 77% of the Market share in 2017. The major growth in APAC is accredited to the presence of various semiconductor manufacturers and rising adoption of smart devices. North America up in the second position (Second largest share of the Global market) in 2017, owing to the high demand for military and aerospace sectors. Thanks to strong demand for smartphones and tablets as they have been the major drivers for PCB market. Moreover, PCB's have revolutionized the electronics industry have been used in every possible electronics gadget.

According to Energies Market Research, the global Printed Circuit Board (PCB) market was valued at 63.1 billion in 2017 and is expected to reach USD 76.9 billion by 2024, at a CAGR of 3.1%.[8]

Fig.7 Global PCB Market 2017-24

8 Challenge and Development areas in PCB designing

Poor electromagnetic compatibility (EMC) is one of the main reasons for PCB re-designs. This is most likely because there are stringent regulations in sectors such as medical and aerospace that require EMC value to be under control throughout use. So, products being developed are designed with this in mind.

For instance, cell phone developers require wireless connectivity and are well-versed in minimising the risk of unwanted radiations. The most affected equipment of EMC issues are toasters, fridges and washing machines. These are joining the plethora of Internet-enabled devices connected wirelessly to the Internet of Things (IoT). Potentially high-volume boards may result in re-spinning PCBs, which can introduce further product launch delays. [9]

Built-in electrostatic discharge (ESD) protection systems are required for circuit design and component selection. One should always make sure to leave enough time for PCB layout. Since today’s boards are becoming more complex, compact and lightweight, designing requires close observation and advanced instruments.

Growing popularity of flexible PCBs complicates the process further. An inadequate layout can result in problems such as electromagnetic interference (EMI), conflicts from components on either side of the board, limited board functionality and even total board failure. If designers do not get the layout right the first time, they will need to rework it, which can cause manufacturing delays and added costs.

9 REFRENCES

[1] *"iconnect007 :: Article". www.iconnect007.com. Retrieved 2016-04-12.*

[2] *Research, Energias Market. "Global Printed Circuit Board (PCB) Market to Witness a CAGR of 3.1% during 2018-2024". GlobeNewswire News Room. Retrieved 2018-08-26.*

[3] *Electronic Packaging:Solder Mounting Technologies* in K.H. Buschow et al (ed), *Encyclopedia of Materials:Science and Technology*, Elsevier, 2001 ISBN 0-08-043152-6, pages 2708–2709.

[4] "Surface-mount technology" – news · newspapers · books · scholar · JSTOR *(October 2017)*

[5] From the webpage: https://www.electronics-notes.com/articles/constructional_techniques/printed-circuit-board-pcb/pcb-manufacturing-process.php.

[6] Star Engineering Inc. article- Latest Trends In PCB design. Dec 13th 2019.

[7] Pcbcart available [online] https://www.pcbcart.com/article/content/future-of-pcbs.html

[8] Energias Market Research- “Global pinted circuit board market report” 2017-24.

[9] Nikola Zlatanov* conference paper of “PCB Design Process and Fabrication Challenges” Conference: PCB West, At Santa Clara, CA