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Three Reasons Why You Should Design Your Next Product With Laser Drilled Micro-Vias

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Abstract
If in designing your next product you are interested in cost reduction, reliability improvement, and increased electrical performance, then you should be considering using laser-drilled vias. Not only high end product design gains advantages, but commercial products should consider using laser-drilled vias. Discussions about cost, reliability and performance are presented.

Introduction
Laser drilled microvias have been in use since 1980. Patents in the 80's include IBM, Tektronix, Larry Burgess and others. Other methods of creating small blind vias exist such as photo defined, plasma etched, chemically etched, drilled and screen-printed. However, of these, the laser-drilled microvia presents the most advantages in most circuit board production situations. Each supplier of HDI (High Density Interconnect) boards has experience with particular processes and materials.

The Basics
Microvias (holes of diameter equal to or less than 0.15mm (6 mil.) must usually be used in conjunction with other elements of HDI such as a change in materials, lines and spaces less than 0.128 mm (5mil.).

Unless your final product is as thin as your microvia diameter, the use of microvias in most products will be used in the form of blind or buried microvias in conjunction with other layers, which have been processed conventionally as a multilayer printed circuit board. (See diagram below.)

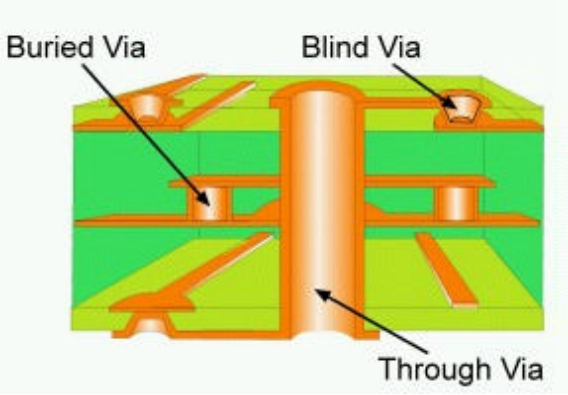

Figure 1 - Buried and Blind Via

The blind via pictured above makes an electrical connection between a surface layer and the layer under it. This allows a connection to be formed on the first innerlayer thus removing a conductor from the surface.

The buried via pictured in Figure 1 makes a connection between any two innerlayers. This via is not visible on the final product so is called buried.

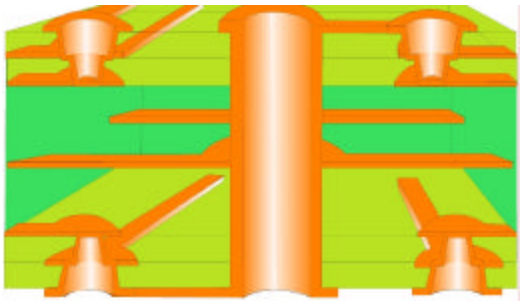

Figure 2 - Three Layer Depth Vias

The vias is Figure 2, in the corners, connect circuits from the surface layer to two internal layers or extend two layers into the board to connect the surface layer to the second innerlayer.

Why/When to Use Microvias
When a goal of the design is to accomplish any of the following, and large BGA (>1500 ball) components are to be mounted on the board, then you should consider microvias.
Microvias have the ability to:

1. Increase component density.
2. Reduce board size.
3. Improve signal quality.
4. Reduce board cost.
5. Improve reliability.
6. Decrease design time.
7. Accomplish the design when there is no other way.

One of the requirements to the use of HDI and microvia is the fact that a great deal of planning must

be done to properly use microvias without incurring negative results. That is to have increased cost, poor yield, no board size reduction and a decrease in performance. This planning is mechanical and electrical evaluation, pre-route studies and coordination with your supplier. Stack-up, via size, materials of construction all need to be firmly planned before starting the actual design.

Detailed simulation of the circuit interconnect must be performed to assure that bus lengths will work, and that the inductance and line characteristics will transmit the signal in a quality manner.

Mechanical evaluations of the materials being used, and thermal considerations must be well simulated and be in an acceptable range.

Cost of Product Designed with Microvias

Just calling up your supplier and asking "How much additional will it cost me to add microvias?" will yield an answer: "A whole bunch!" This is a common approach, and one which has held back the utilization of microvias.

During the planning phase previously mentioned, board cost must be reduced by any or all of the following approaches:

1. Some consideration must be given to significantly reduce the board size so as to provide a cost advantage to pay for the additional materials and processing necessary to accomplish the microvia interconnect. For example, the size reduction will allow additional boards to be processed on a panel, and then the microvias will save you money!
2. Or if the reduction in layers is significant, this may pay for the microvias.
3. Or, if this is the only way to accomplish the interconnect, then additional cost must be incurred.
4. If controlled impedance is difficult in the design, blind microvias with their significant reduction in capacitance will help ease the controlled impedance design issues.

Your board supplier will have a great deal of influence on the materials to be used, as well as the design of the via pads, hole diameter of the microvia and cost of the microvias. All of these will depend on the method of producing microvias, (laser, photo, plasma or other type of via forming) the experience of the supplier with microvias and the utilization and speed of his facility for producing microvias. You should find a supplier which will support your design path for several generations, and one who can support your simulation with at least material characteristics and electrical characteristics. Costs will vary greatly depending on the panel sizes the supplier is processing microvias on, the process used and his experience with production of this type of product.

You May Have to Find a New Supplier!

Not all suppliers have the capability to supply microvias, nor may they have the ability to support your type of design because of volume requirements, electrical requirements, or cost factors. Utilization of microvia equipment, speed of producing vias, and process materials and cost all vary by 100%, at the present time, from supplier to supplier.

In the case of laser formed vias, the type of equipment will dictate the speed which a laser can form microvia holes. If the laser forms only 30 holes per second, and you have 160,000 holes per panel, this will take over 8 hours to form the microvias. However, if the laser performs at 500 holes per second, only a little over five minutes will be required. You will pay for the operator and equipment during the via forming time.

Another cost factor overlooked by the designer, when choosing a supplier, is utilization of the equipment. If utilization is low, then you will be paying more for the vias. Utilization of 10% may cost you 10 times as much for the vias as utilization of 90% will cost. This provides a new question to ask when choosing your microvia supplier. However, a high utilization conflicts with the question of how a supplier will support your production demand. More lasers, more shifts, or a change in the material or process used for producing the vias.

Industry examples of cost based utilization of microvias are: Camcorders, cell phones, pagers, printers, and notebook computers being produced by such companies as Matsushita, JVC, Samsung and IBM. Indeed cost driven markets!

Conclusion on Cost!

Careful evaluation of electrical need, materials, supplier and process are necessary to design a cost effective microvia board. Meeting the design cycle time also carries a cost, which if not met, may overshadow all other costs. However, not doing this evaluation may require that an additional 4 layers are added to the product late in the design cycle just to make the interconnect with drilled through vias possible. In many cases this explains 20 to 30 layer boards in production today. These boards usually have a poor yield of 10 to 50%. Again impacting the cost!

When all is lost and the use of microvia is necessary to connect 1mm or smaller pitch devices, or to meet electrical requirement, microvias to the rescue!

Electrical Performance of Microvias

The electrical performance of microvias is far superior when compared to though hole vias. The inductance and capacitance of through holes and microvias needs to be simulated, depending on the stack-up of the board, but some typical values follow.

Table 3 - Typical Inductance/Capacitance of Vias

Component	L (nH)	C (nF)
Through Hole Via	1	1
Blind via	.01	.0001

The question is, do you care in your design about capacitance and inductance in these values? Only complete simulation will answer this question. Remember that each via on a bus must be counted.

When you think about bus length, through vias add to the bus length as well as providing a discontinuity to the impedance of the traces as indicated by the inductance and capacitance values in table 3. As edge rates decrease and frequency increases, the vias have a greater and greater effect on signal quality.

Capacitors, which are connected using through vias may have significant inductance added to the electrical path of that capacitor, which negates the quality and performance of that capacitor. A 0603 capacitor will have about 531 pdf of inductance due to its construction. If hooked to the circuit with two through vias this will add another 2000 pF of inductance and change the performance of this capacitor. Low inductance capacitors are more seriously affected because their package inductance can be as low as 70 pF and when burdened with two through vias for a total additional inductance of 2000 pF, results in elimination of the worth of the low inductance capacitor! This is an often overlooked use for microvias!

Another use for microvias, which is often overlooked, is for grounding connections for shielding applications. Vias are often used to attach ground shielding on the surface to ground planes on internal layers. Large quantities of microvias may be added to the design to efficiently provide an infinite number of return paths to avoid current loops at high frequencies. Little or no additional cost is involved, assuming that microvias are already in use on the design. Via spacing for this application can be simulated and microvia spacing determined.

Reliability of Microvias

Over the last 15 years, most major corporations are concerned enough with the reliability of microvias, have tested the concept themselves. In no cases, except for poor quality, have microvias proven to be anything but reliable. In fact data indicates that small <2.95mm (0.010") through holes will fail long before microvias of a diameter of 75um (0.003) fail. This is judged by liquid-to-liquid thermal shock. Microvias produced by most processes pass at least 100 thermal cycles, and laser drilled processes typically produce vias which will withstand at least 1000 thermal cycles.

The above thermal cycles consist of a five minute soak at -55 °C and a four second transition to 125 °C.

Material delamination was evident in these tests, but no effect on the via quality was noticed.

Through hole failure is typically seen with this similar thermal cycle at 10 to 50 cycles, depending on the copper plating, drilling quality, and height to diameter ratio of the drilled hole.

In summary, reliability should be discussed with each supplier and data obtained from them on their testing of their process before choosing a microvia supplier. However, in general if a quality-plated microvia is produced using good material, there is no great concern for long-term reliability.

How to Get Started Using Microvias

A good idea would be to educate yourself on microvias and HDI (High Density Interconnect) prior to starting on this new project. Much can be learned from suppliers, seminars and if you can get a preliminary copy of the new IPC standards IPC/WECC-2226 and IPC/JPCA-2315. These will provide additional information about design using HDI. To determine if your next project needs microvias:

1. You must gather together the people in your organization who do thermal and electrical simulation, with the circuit designer and the circuit board designer. All of the requirements and component types to be used must be identified. Physical simulation as well as electrical simulation based on the stack-up for the board, must be done using both through hole technology and microvias. Trial routs as well as proposed stack-up should also be done at this time.
2. During the initial evaluation phase, if the product can be designed without microvias, then go for it. If microvias are needed then proceed as below.
3. Concurrently the proposed supplier for this product must be included in the above evaluation

in order to correctly include the proper materials for the stack-up and the dielectric constant for each of these materials. Also, the supplier will be able to add his capability to produce line widths, via diameters and impedance control capability to the assumptions made during simulation. A wise supplier will be able to accomplish some of the simulation or at least add the correct assumptions about the board product to the simulation.

4. Expect that some simulations will not work! Combinations of materials, vias, and electrical properties of the proposed stack-up may not combine efficiently to produce your next product. At this point either the chosen supplier will have to vary his capability, or a new supplier will have to be chosen and the simulations will have to be run again using the new suppliers input about his capability.
5. Be flexible and determine that which can be determined at this time. Changes will still happen, but should not be of a catastrophic nature.
6. If your project includes microvias, re-look at the project and see not only where you need microvias, but evaluate all of the opportunities in the design to use them instead of mechanically drilled holes. One hundred mechanically drilled vias will cost almost as much as 10,000 microvias with an efficiently run process.
7. Remember to identify and include all of the characteristics of the design. Materials, stack-up, line widths, via type and size, as well as copper thickness requirements. Record and document all of these as a project record, and during the design keep these in mind.
8. Then look at the project and see if you can simplify it! Reduce the number of via diameters if you can. Be sure to separate out your vias per diameter, layer, depth and whether blind or buried and provide separate drill files for each.

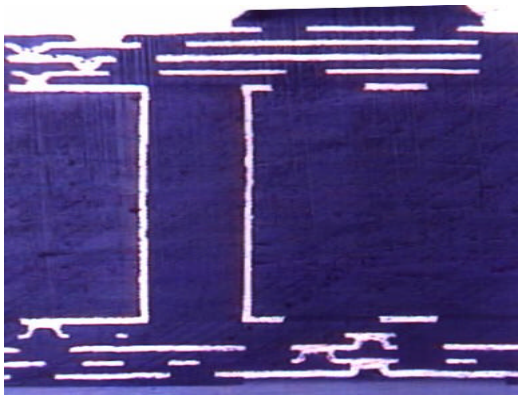

Figure 3 - Example of A Complex Microvia Board No One Combination Fits all requirements

The above exercise seems like a lot of work. It is the first time. But each pass through this process will become easier and it will be more and more evident why no one has been able to provide a single solution to HDI requirements. There are too many requirements and too many combinations of these requirements to have one solution provide all designs with the perfect combination of cost, performance and reliability.

Conclusion

The requirement to evaluate rather than design by habit, will provide your company with efficient designs, which are cost effective and keep you from designing boards with higher and higher layer count as the preferred option.