

# Small cavities, big impact: Optimizing microvia reliability in high-density circuit boards

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Figure 1. With the right knowledge and strategy, microvia reliability can be substantially improved, resulting in more efficient and dependable designs. Source: Gorodenkoff/Adobe

High density interconnections (HDI) are pivotal in modern electronics manufacturing and enable the development of devices that are both smaller and more complex. At the forefront of HDI technology are microvias, small but critical components that allow for the layer-to-layer electrical connections in multilayer circuit boards. Despite their benefits, microvias introduce substantial reliability challenges due to material behavior under heat, complex assembly processes and their intricate configurations.

While many rules of thumb have guided the industry over time, innovation and deeper understanding of microvia reliability is now changing the way they are used and implemented into designs. Exploring challenges with microvias and insights into the latest strategies for enhancing their reliability through advanced material selection, design optimization and innovative testing methodologies results in better designs and more knowledgeable engineers.

## What are microvias?

Microvias are high density interconnections typically created using laser drilling machines, designed to form vertical electrical connections between different layers of a multilayer PCBs. Unlike traditional vias that may connect multiple layers across the full stack of the board, microvias are traditionally used to allow a connection between two layers.

Microvias typically have a diameter of 150 microns or less. This is significantly smaller than traditional vias, which can be 0.6 mm or larger. This smaller size allows for a higher density of vias in a given area, which is critical for supporting the compact layouts required in modern electronic devices. The depth of microvias is also tailored to

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connect specifically targeted layers, reducing the amount of board space used vertically. This aspect is particularly beneficial in applications where space is at a premium, and efficiency and performance are critical.

### Importance of miniaturization

Microvias play a crucial role in the miniaturization of electronic devices. By allowing electrical connections to be made with minimal space usage, they enable designers to pack more functionality into smaller footprints. This capability is essential in industries such as mobile computing and telecommunications, where device size and functionality have a direct impact on consumer appeal and usability. Microvias reduce the need for larger drill holes and allow for a more efficient routing of interconnects, thereby facilitating the design of thinner, lighter and more sophisticated electronic devices without compromising performance.

### Enhanced electrical performance

Microvias significantly enhance the electrical performance of PCBs. By shortening the path that signals must travel between layers, they reduce signal reflections and decrease the likelihood of interference, which is crucial for maintaining signal integrity in high-speed and high-frequency circuits.

Additionally, the use of microvias can help in reducing noise and improving the thermal characteristics of the PCB. This improvement in electrical performance is particularly important in applications such as high-speed computing and telecommunications, where maintaining signal integrity is vital for device functionality and reliability.

### The requirement for reliability

When it comes to HDI, the reliability of microvia stacking and staggering forms a critical area of concern. Microvias are pivotal in HDI designs but their reliability can be threatened by numerous factors such as material expansion, reflow temperature and microvia pitch. Understanding these factors is critical to preventing potential microvia failure.

### Preventing microvia failures: Understanding material expansion and design considerations

Microvias are a key enabler behind advanced electronics, but only if they don't cause failures. Failures can occur due to the material's expansion within the microvia, causing separation from the target pad at the bottom. The thickness of the dielectric largely influences this. The industry has established guidelines to prevent such failures, including:

- Limiting the stacking of microvias to two
- Avoiding the stacking of microvias over buried epoxy filled mechanical vias
- Maintaining a specific aspect ratio for microvias

These guidelines have helped in many cases but fail to consider the material's Z expansion or the reflow temperature, both of which can significantly affect microvia reliability.

Material selection and the comprehension of their expansion rates are fundamental for ensuring microvia reliability and performance. The interconnection between the expansion rate of the material, the temperature gradient during reflow and the design of the microvias can substantially influence the overall performance of the PCB.

Material expansion — particularly the resin expansion within the laminate — is the primary cause of microvia failures. In this scenario, the resin undergoes significant expansion during the assembly reflow temperature, potentially leading to microvia failures. Managing the resin content and predicting the material's expansion rate are vital considerations during design. Laminate suppliers provide the expansion rate on the laminate's data sheet. It is also worth mentioning that the expansion rate escalates once the glass transition temperature is reached.

### Pitch and material selection for improving reliability

It is crucial to remember that microvias are essentially butt joints and are inherently weak due to their limited mechanical engagement. They are especially prone to shear stress which can result in failure under shear loads. The sudden change in material continuity at the butt joint, combined with material expansion during reflow, can trigger a shear event across the microvia's bottom. Enlarging the surface area at the microvia's bottom can enhance its survival chances by better distributing the load.

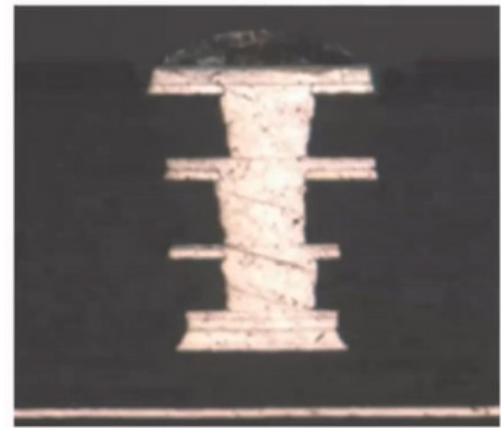


Figure 2. A micro-view of a microvia. Source: Summit Interconnect

### Proper pitch

The pitch or distance between microvias is a key consideration for microvia strength and reliability. Since these joints are inherently weak, common sense might suggest that farther spacing is better. In practice, however, keeping microvia groupings tighter seems to enhance strength. For instance, a .4mm pitch, compared to a 1mm pitch, shows a higher number of reflows before failure due to the closer spacing of the microvias. This proximity allows them to effectively resist expansion through a process known as mechanical crosstalk. Acting like rivets, the microvias hold down the area, thereby enhancing reliability.

### Proper material

In the past, the industry has successfully stacked microvias with .4mm and .5mm pitches without significant problems. Yet, when the pitch increased to 1mm, failures began to occur. This posed a significant issue in the space industry where component costs are extremely high, and any failure can lead to substantial financial loss.

To address these challenges, the first step involves selecting a material with a lower expansion rate. This can be accomplished by using a single-ply prepreg instead of a two-ply construction, which reduces the expansion. Also, choosing a material with a lower CTE Z expansion can postpone the expansion onset and thus reduce the force exerted on the microvias during reflow.

### Simulation to save time

Simulating microvia performance before construction and testing provides a reliable starting point for material selection and predicts the assembled PCB's reliability. Simulating different pitch sizes, material selections and prepreg combinations can predict microvia performance without a physical board to save substantial time and resources during the design process. The simulation should factor in the material's expansion rate, reflow temperature and microvia design.

### Effective strategies for design and testing

Designing microvias to withstand reflow forces involves a strategic approach. One effective method is staggering the microvias, which enhances their structural strength. The success of this method depends on the pitch of the microvias. For devices with tight pitches, both stacked and staggered microvias are viable options. For wider pitches, staggering is advisable to ensure reliability.



Figure 3. Depending on the design, microvias can either be stacked or staggered for optimal results. Source: Summit Interconnect

### Optimizing pitch size

As previously mentioned, microvia reliability is significantly influenced by the pitch: the distance between the centers of two neighboring holes. As the pitch decreases, microvia reliability generally improves, but this improvement plateaus at around 0.65mm. Beyond this, pitch reductions do not notably enhance reliability; thus, a balance between pitch size and reliability is essential in design.

### *Know when to stack and when to stagger*

Stacking microvias also warrants consideration. Stacked microvias, especially mixed two or three stacks, risk failure due to top-down heat expansion. This risk can be minimized by limiting the ground layers to the second layer, which reduces stress. Stacking microvias exposes them to greater stresses than staggering them, which is why staggered options are often preferred. Outside of a tight-pitched design, microvias should be staggered.

### *Testing and D coupons: “You will only know what you reflow!”*

Testing microvias is another critical factor. The D coupon or test coupon should reflect the pitch used on the board to accurately assess the microvias. Including both stacked and staggered via structures on D coupons allows for comprehensive microvia testing and comparison.

With the right knowledge and strategy, microvia reliability can be substantially improved to result in more efficient and dependable HDI designs. Considering material expansion, reflow temperature and microvia pitch in conjunction with industry guidelines is the best bet to avoiding potential design issues. It is important to note that these guidelines are not fixed and should be tailored based on the specific design and material employed.

### **Summit Interconnect: Pioneering microvia reliability**

Summit Interconnect has long stood at the forefront of the PCB manufacturing industry, distinguishing itself through relentless innovation and an unwavering commitment to quality. As the electronics sector continues to evolve — driven by advances in technology and increasing demands for performance and miniaturization — Summit has consistently led the way in pioneering new solutions to meet these challenges including in the field of microvia reliability.

With decades of collective experience and a dedicated team of industry experts, Summit Interconnect offers unmatched expertise in the design and manufacturing of high-density interconnect PCBs. Their approach integrates state-of-the-art technology with robust design and testing methodologies to ensure each PCB meets the highest standards of reliability and performance. Summit not only follows industry trends; they create them.

Summit continues to push the boundaries of PCB technology and invites new partners to join them in shaping the future of electronics. Whether you're facing challenges with microvia reliability, needing to integrate more complex circuitry into compact formats, or looking to improve the performance of your electronic products, Summit Interconnect is an ideal partner to collaborate with.

[Contact Summit Interconnect](#) today to discuss how they can support your next project and drive the future of electronic design together.

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Summit Interconnect is one of the leading providers of complex, rigid, and flexible printed circuit boards in North America, offering solutions ranging from advanced prototyping to high mix, low-to-mid volume production. Summit serves customers across the aerospace, defense, and other highly demanding commercial sectors and has facilities in California, Illinois, and Toronto, Canada. Summit is a recognized industry leader in quick-turn manufacturing and has expertise with a wide range of materials like high-speed digital, RF/microwave, and mixed constructions.