Application Brief

How DLP® Technology Enables Panel-Level Advanced Packaging

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DLP® technology is more than just an industry-leading display technology for projectors. The same technology that enables brilliant, immersive projection can also serve as a programmable photomask for digital imaging systems used in the manufacturing of advanced and panel-level packaging. This application brief covers trends in advanced packaging and how DLP technology unlocks the potential of this manufacturing process. Figure 1 shows a rendering of photolithography using maskless techniques with DLP digital micromirror devices (DMD).

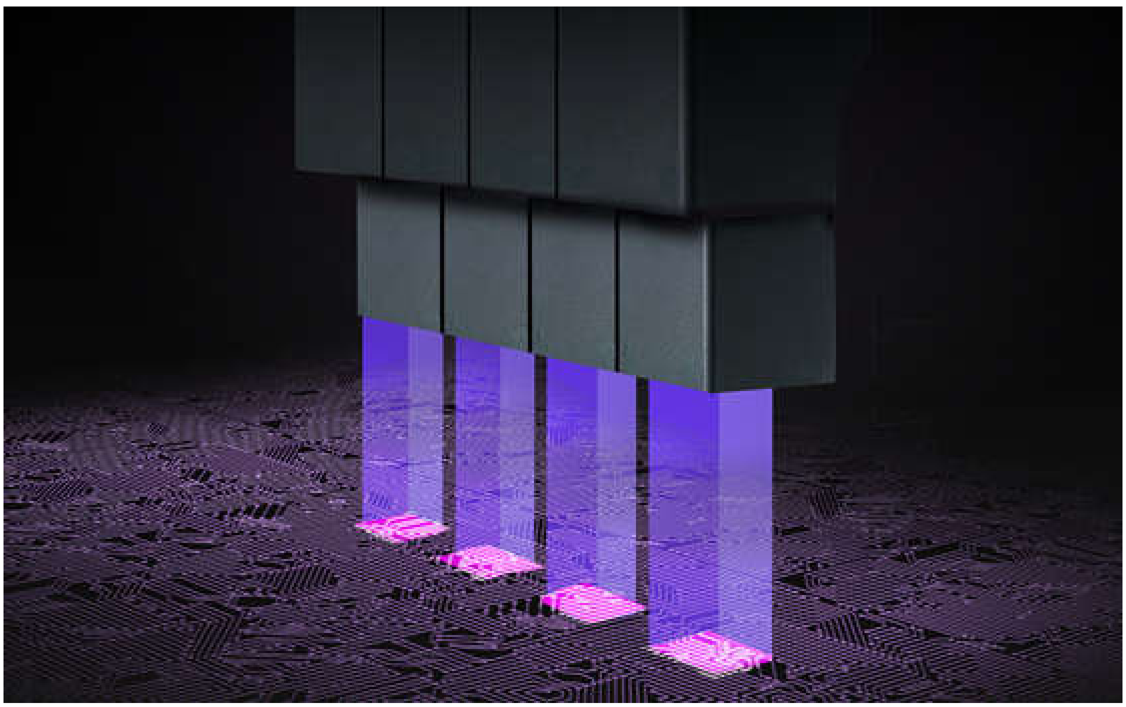

Figure 1. Maskless Photolithography using a DLP DMD

What is advanced packaging?

Advanced packaging is an emerging manufacturing method that combines and integrates multiple semiconductor components into a single package with high-density interconnects to enable improved performance, power efficiency, and functionality when compared to conventional packaging. Essentially, this refers to individual semiconductor packages that contain more than one die.

While not a direct comparison, it is possible to see advanced packaging as a micron scale, semiconductor-grade descendant of PCBs, designed to connect, protect, and integrate. This works on the same principles, but shrunk down to a chip scale and used to package semiconductors, helping semiconductor designers overcome traditional PCB limits.

PCBs began as simple platforms for wiring and mounting components. Over time, these boards evolved to handle more complex electronics, adding layers, finer traces, vias, and advanced materials. Through this process, PCB fabrication was adapted, miniaturized, and refined, giving rise to IC substrates, high-density interconnects (HDI), and redistribution layers (RDLs), which are used to help reroute signals. From there, the technology continued to shrink and specialize, eventually evolving into today's 3D advanced packaging.

With advanced packaging, a semiconductor designer can plan more efficiently, decrease cost, increase interconnect density, and design optimal geometry. This approach enables higher system bandwidth while consuming less power, allowing for more diverse designs tailored to each application. As advanced packaging grows in its potential, equipment manufacturers are searching for methods to more easily create these packages. DLP technology enables them to overcome traditional barriers.

Using DMDs for photolithography

At a high level, a DMD, such as the DLP991UUV (Figure 2), is a micro-electro-mechanical system (MEMS) based spatial light modulator made of millions of individually addressable micromirrors, or pixels. These DMDs provide pixel-accurate control across a wide range of wavelengths from 343nm to 2500nm and sizes from 0.1 to 0.99 inches diagonal, allowing for flexibility in system design. Designers can use these devices in a variety of industrial settings from 3D printers and dental scanners to machine vision and maskless lithography systems.

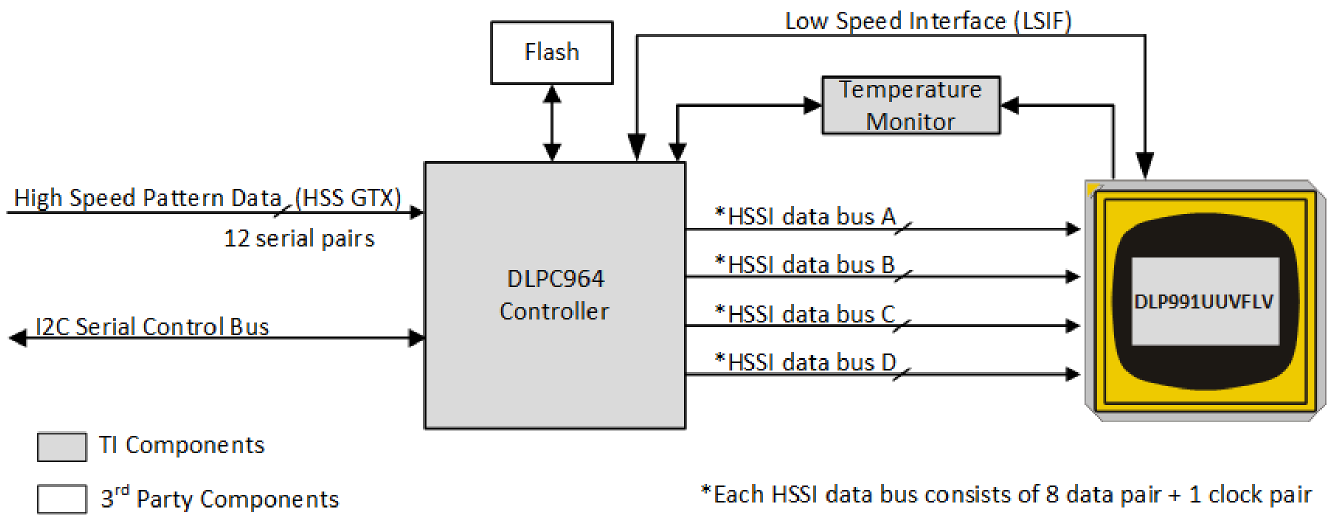

Figure 2. Simplified Block Diagram Featuring the DLP991UUV DMD

DMDs were first used in photolithography systems for printing PCBs before expanding into advanced packaging manufacturing. Acting as programmable photomasks, these DMDs are used to print features such as traces, vias, and solder masks without the need for physical photomasks. A PCB typically consists of an organic laminate with metal layers, often copper, for interconnects. To print traces and features, the copper layer is coated with a photoresist and aligned on a stage. A pattern is then printed onto the photoresist using photolithography methods, the resist is developed, and the excess metal and resist are stripped away to leave behind the circuit features.

Systems based on DLP technology are involved in the photolithography step, where the pattern is printed onto the photoresist using UV light. For this step, there are two main technologies to discuss: traditional mask-based systems and maskless systems.

- **Mask-based systems:** Mask-based systems rely on photomasks, also known as reticles, to transfer circuit patterns. These masks are typically made of glass or quartz and coated with specific materials. These materials block light from passing through, while the uncoated parts remain transparent and allow light to pass through. When UV light is shone onto the mask, the light that passes through hit the photoresist, curing the pattern established by the mask. One challenge of this technology is that a mask cannot change the pattern, instead a new mask must be fabricated to change printed features.
- **Maskless systems:** Maskless systems do not rely on physical masks to transfer patterns. One technique is using DLP technology as a programmable photomask. With this maskless method, UV light is shone onto the DMD and the micromirrors in the DMD then tilt *on* or *off* to modulate the light, creating a pattern that is

projected onto the photoresist of the PCB. Typically, many pulses of light are projected onto the DMD while the mirrors flip and the entire module scans across the surface. Each pulse of light cures the material to create the desired patterns. This allows the pattern to modify with each pulse and adjust to factors such as warpage. By dynamically adjusting the pattern projected onto the resist, a modified software file or feedback loop can be used to change the pattern instead of creating a new mask.

Using DLP technology, digital design can be modified at any time to enable higher yield and scalability while maintaining high throughput and meeting the required printed feature sizes. DMD-based systems also reduce expenses associated with masks, including, but not limited to, mask fabrication, mask inventory management, and mask redesigns.

DLP technology for advanced packaging

A PCB provides board-level support and electric connections between discrete components or packaged chips, routing signals across relatively large areas with moderate density. However, these PCBs have many rules such as arrangement and feature sizes that limit the I/O. For this reason, substrates and interposers become useful to overcome those limits when connecting and routing individual dies. Advanced packaging substrates boost I/O density at the package level by distributing signals from fine-pitch chip pads to larger package pins or balls. Multiple layers allow for a higher number of connections with a compact footprint, further enabling the integration of many dies on one package. Interposers have higher I/O density by providing even finer pitches directly between dies. With substrates and interposers, the traditional PCB limitations can be avoided, allowing final sizes to use less space than an equivalent PCB with individual packages for each die. This increases performance and efficiency due to shorter connections and allows the number of connections to the PCB to be decreased. Essentially, to overcome the large resulting size of directly routing to a PCB, interposers and substrates are used as intermediaries. A DMD can be used to print features on these substrates and interposers in the same way users print PCBs.

Most substrate materials resemble a PCB as well, using alternating layers of dielectric and metal. Interposers tend to consist of three material categories: organic, glass, and silicon. Systems using DLP technology typically focus on organic and glass, especially when pushing to a panel level. Panels can help improve manufacturing efficiency, reduce handling errors and tool costs, and enable high throughput. Panel-level manufacturing allows for greater area efficiency, scalability, and flexibility as more transistors are combined into a single package.

By projecting directly onto the substrate without photomasks, systems with DLP technology allow for greater flexibility and scalability to a panel size while minimizing stitching errors, a common challenge when scaling mask-based systems. With a DMD-based system, panel sizes can have no limit and warpage can be accounted for through real-time corrections. Most modern PCBs are printed at the panel level, further explaining the natural progression from PCB printing with DLP technology to printing substrates, interposers, and RDLs at a panel level for advanced packaging.

As demand is increasing for higher I/O density and the number of layers on advanced and panel-level packages continues to grow, systems with DLP technology are helping system manufacturers meet scalability requirements with high precision and throughput while reducing error accumulation.

The DLP991UUV DMD was designed to support the advanced packaging market. This DMD provides high data rates of up to 110Gbps, enabling real-time corrections with maximum exposure speeds and panels per hour. Featuring a micromirror pitch of 5.4μm, the DLP991UUV features 8.9 million micromirrors in a 0.99-inch diagonal package. With the highest resolution in the DLP portfolio, these devices enable equipment manufacturers to maximize throughput and increase exposure area, while reducing feature sizes to achieve 1μm L/S. Specified down to 343nm, the DLP991UUV can be used in G-line and I-line tools and multiple wavelengths can be tailored to optimize photoresist performance. The DMD helps system manufacturers achieve greater precision and smaller feature sizes in designs, enabling higher I/O density while also reducing costs.

Conclusion

With digital imaging manufacturing processes using DLP technology, system manufacturers can reduce manufacturing costs and cycle times, enable real-time design adjustments in panel-level packaging, manufacture at scale with improved yield, and achieve precision across complex topographies.

Related documentation

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