State-of-the-Art Materials Help Keep PCBs, Components Cool

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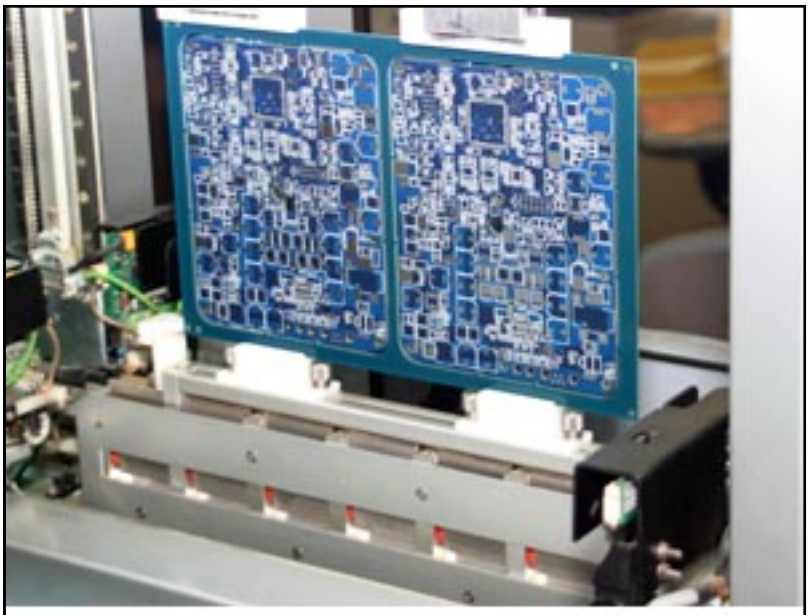
LED lighting provides both promise and challenges for virtually every electric lighting application currently served by earlier illumination technologies such as incandescent and fluorescent lighting. Indeed, the U.S. Department of Energy (DOE) has proclaimed that no other lighting technology offers so much potential to save energy over traditional lighting technologies. LED lighting also offers the potential to improve the quality of living spaces when employed in architectural lighting schemes. But the drawback for LED lighting, in concentrated arrays or in high-power applications, is the dissipation of heat. LEDs in operation generate a great deal of heat in part because they emit light within a narrow spectral band and do not emit infrared energy; thus, according to DOE, fully 75 – 85% of the energy needed to drive high-powered LEDs is converted to heat.

This heat must be conducted away from the die to the underlying circuit board and heat sinks. Allowing the die to overheat “directly affects both short-term and long-term LED performance. The short-term (reversible) effects are color shift and reduced light output while the long-term effect is accelerated lumen depreciation and thus shortened useful life.”1 In addition, white light is the primary component in interior or architectural lighting, and white light-emitting LEDs are the type most dramatically affected by excess heat; “…white LEDs will provide at least 10% less light than the manufacturer's rating, and the reduction in light output for products with inadequate thermal design can be significantly higher.”

Thermal Management by Design

LED system manufacturers are addressing this challenge by seeking out improved heat sink designs, high efficiency circuit boards, high thermal conductivity enclosures and other advanced thermal design techniques.2 Thermal simulation plays an increasingly important role through its ability to evaluate various alternatives and optimize the system-level design from a thermal standpoint prior to the prototype phase, John Parry of Flomerics writes in a recent article. Sometimes, according to Parry, an application may require a cooling system built around the LED device, but this only adds complication to the device and greater

complexity carries with it the greater potential for failure. Ultimately, the responsibility for cooling falls to the circuit board at the base of the device.



Metal core PCBs and other thermal management boards feature unique constructions and laminate materials designed to remove heat from powerful LED devices. Failure to effectively remove heat shortens the life span of LED arrays.

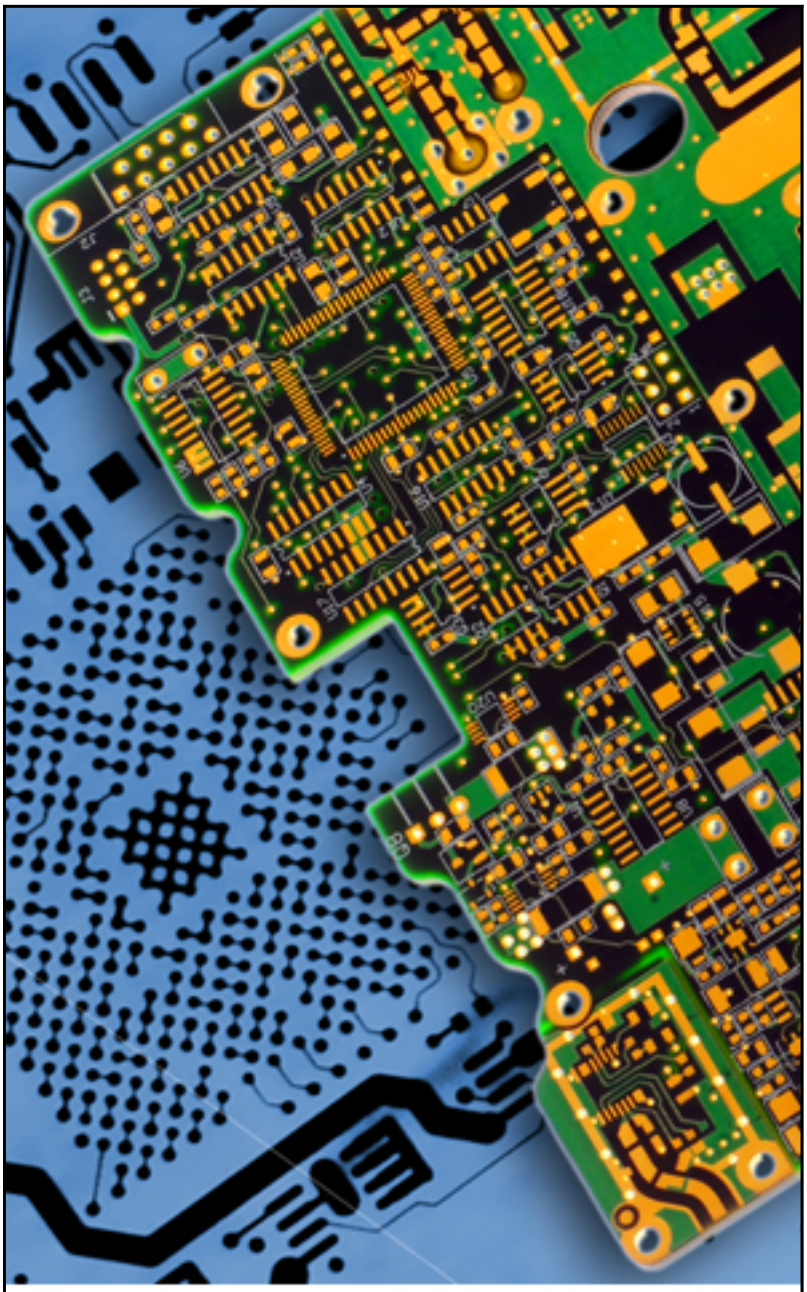
Whenever possible, through built-in thermal management schemes incorporated into the PCB design, adequate cooling should be achieved through conduction through the board. This has much to do with the materials used in the board's design and fabrication, and the thermal path from the die to the circuit board. Generally, the type of printed circuit board used will be a metal-core PCB, or 'MCPCB'. DOE describes the typical high-flux LED system as being comprised of an emitter, a metal-core printed circuit board (MCPCB), and some form of external heat sink. The emitter houses the die, optics, encapsulant, and heat sink slug (used to draw heat away from the die) which is soldered to the MCPCB. The MCPCB is a special form of circuit board with a dielectric layer (non-conductor of current) bonded to a metal substrate (usually aluminum). The MCPCB is then mechanically attached to an external heat sink.

Andy Hill, President of Hill Technical Sales in Arlington Heights, IL, agrees. His company specializes in supplying various components and systems used in LED lighting schemes, and in particular, outdoor and architectural lighting, including sign illumination, channel letters, backlighting, security pathway lighting, architectural, step and border lighting as well as stage, theatre and commercial LED displays.

"High-power LEDs require LED drivers, which are essentially power supplies. Consider, for example, Class II outdoor constant voltage LED drivers, with a range of 90 watts to 400 watts for a total module. These modules of clustered LEDs can get quite warm, especially when you're talking about outdoor signage. In daylight hours, these systems must compete with sunlight, which is of course extremely bright. To overcome that brightness, the LEDs must be arrayed into very powerful clusters, and thus they require an aggressive approach to thermal management

and heat dissipation."

The types and variety of architectural lighting with LEDs is, Hill says, the fastest-growing segment of the LEDs market. "We're seeing everything from warehouse lighting to street lights, toll booths, the exteriors of buildings, and all types of special lighting, often with multiple colored LEDs in the illumination strip. For interior lighting design, we see LEDs used in 'wall washing', wherein the color of a wall changes, for example, and accent lighting; down-lighting, channel-type lighting, airport lighting, roadway illumination." These many emerging applications are creating a whole new LED market for high-powered LEDs, Hill says, but what they all have in common is constantly increasing power density. "LED manufacturers are continually refining their products – becoming more efficient, smaller, concentrating more power into a smaller area, so it is harder to get the heat out of them. They are adding more power per chip, per square inch. Thermal demands are ever-increasing. From die cast heat sinks to more exotic systems, design engineers are doing their best to keep up with it, all the way to a copper heat sink with vanes and a fan on it."



Thermal management circuit boards, especially for LED applications, present manufacturing challenges that affect design. This is an area where the designer and fabricator can effectively collaborate to create designs that will effectively remove the heat generated by ever more powerful LED devices.

Cooperation

In Hill's experience, meeting the demands of emerging LED technology as it moves into new markets requires the cooperation of vendors supplying components for lighting systems. These include Amperor, a supplier of rugged Class II LED power supplies especially suited for high-power outdoor lighting, and Electronic Interconnect (EI), a manufacturer of specialized circuit boards designed and built to handle the heat dissipative requirements of the LED assemblies – plus other vendors of components, heat sinks, and subassemblies.

Amperor's power supplies, mounted in a tough extruded aluminum case,

incorporate a LED driver circuit that is completely encased in a thermally conductive and low expansion coefficient potting compound that completely shuts out the elements, an essential feature for sign lighting and outdoor conditions where a wet environment can be expected.

Role of the PCB Designer and Fabricator

The fabricator wears a lot of different hats, including that of the designer, and must also be flexible enough, knowledgeable enough, and capable of working with a wide range of printed circuit board materials, constructions, and configurations for LED-bearing electronic assemblies requiring heat management characteristics. For example, we have been UL certified for metal-clad PCBs with a standard dielectric, and can work with various thicknesses of aluminum and copper metal cores. These configurations are essential to building effective thermal management properties, and they also require precise machining tolerances and high-quality fabrication services for effective thermal management and long-term board reliability. The application may require everything from simple to complex multilayer constructions, depending on what the customer’s application needs.

LED lighting thermal management really demands the use of state-of-the-art materials including the T-Lam thermal lamination system by Laird, which includes T-Preg thermally conductive dielectric/ Prepreg, DSL or double-sided metal core laminate, and IMPCB's, insulated metal printed circuit boards” Patel adds. Other constructions include 2-layer T-Lam, hybrid IMPCBs with FR-4/T-preg, multilayer metal base construction, and multilayer FR-4/T-preg hybrids.

The design of thermal management type boards can be problematic, which is why it is important for the customer and the fabricator to work together and conduct a thermal analysis of the planned designs, to obtain valuable feedback that helps ensure proper and efficient function as well as long-term product reliability. What we’re trying to do here is simplify the design to build robustness into it, fewer things to go wrong. We want to eliminate the need for fans, heat sinks and heat spreaders. This is not always possible, but quite often it can be done with carefully engineered constructions. Such constructions will dissipate heat effectively, keeping components cool for increased performance and life. Using advanced materials properly will provide outstanding thermal performance.

Conclusion

PCB designers should work in close cooperation with the PCB fabricator in large part because the newer types of materials and construction schemes in thermal management boards present manufacturing challenges that also affect design for manufacturability. Heat dissipation can be handled in a number of ways ranging from heat sinks and even small fans to simply through board materials and design, and this is an area where the designer and fabricator can effectively collaborate, especially since the fabricator’s knowledge may come into play to the benefit of simplifying the design. Since this is an evolving application, there are always emerging challenges and uncharted ground.

Sources

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