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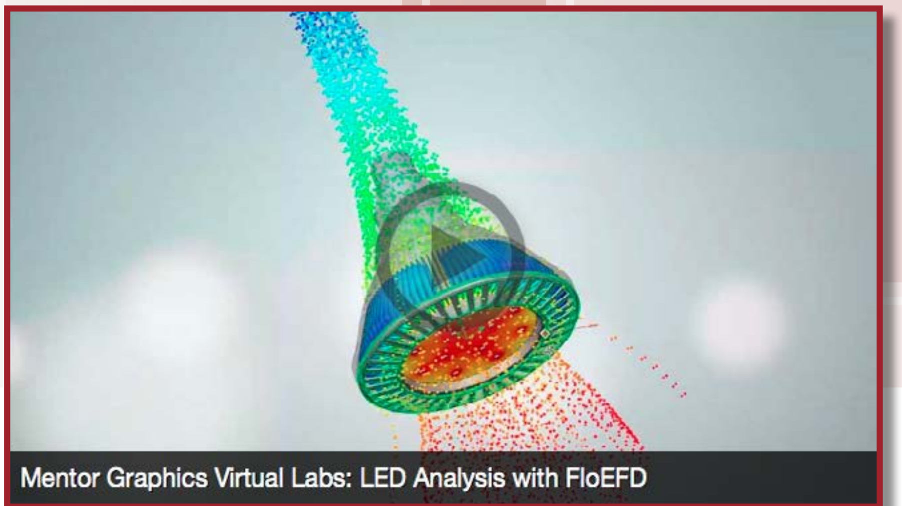

LED Analysis Toolkit

Inside

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LED Analysis & Simulations Explained

Courtesy of Design World

Modern high-power light-emitting diodes (LEDs) today weigh in with power densities of 5 W/mm2 or more. Unfortunately, about 70% the electrical power going to the LED becomes heat rather than light. Getting rid of this heat has become a strategic goal of LED lighting designers. For the sake of reliability and energy efficiency, thermal management of high-power LEDs has become an area of intense research and development.

To ensure good performance of LED lighting products, designers consider all avenues of heat transfer through conduction, convection, and radiation. Thermal management has become a critical design skill because many of the materials used in LED packaging, such as the encapsulating transparent resin, are mediocre thermal conductors at best. Moreover, the thermal path from the LED chip to the outside ambient can be lengthy, further complicating the design.

These difficulties explain why in lighting design, computerized fluid dynamics is a tool that can spell the difference between reliable LED lighting that lasts a long time, and a lighting product that delivers a suboptimal experience for consumers.

Solving The System-Level Thermal Management Challenges of LEDs

Courtesy of Mentor Graphics

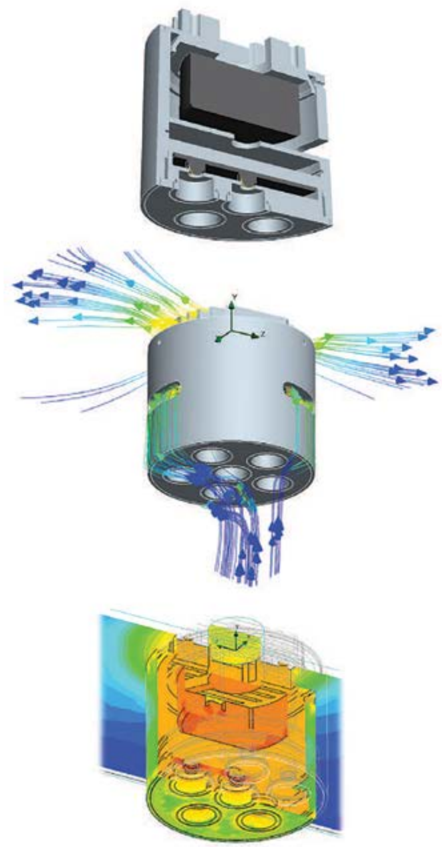
Thermal management is critical to LE D performance and life so mechanical designers need to consider thermal issues from the earliest stages of the development process

In referring to LEDs, the United States Department of Energy (DOE) states that no other lighting technology offers so much potential to save energy and enhance the quality of our building environments. Thermal management is critical to LED performance because the lifetime is a function of junction temperature. Rudi Hechfellner, Applications Manager for Philips Lumileds Lighting, San Jose, California says that thermal management is by far the most critical aspect of LED system 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. Thermal simulation is playing 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.

Emergence of LED lighting

Solid state lighting is a pivotal emerging technology that promises to fundamentally alter lighting in the future. LEDs were originally designed to operate with less than 50 milliwatts of electric power. Over the last decade, the capabilities of power LEDs have improved dramatically to typical levels of 40 to 80 lm/watt. Besides energy efficiency, LEDs also offer longer life, depending on the manufacturer and type, useful life for white LEDs can range from approximately 6,000 hours to more than 50,000 hours compared to 30,000 hours for fluorescent tubes and less than 2,000 hours for incandescent bulbs. LEDs also can emit light of a specific color without filters.

Market analysis firm Yole Développement says that high power LEDs will drive growth in the solid state lighting market by growing from well under $1 billion in revenues in 2007 to approximately $10.3 billion in 2012. Yole projects that high-brightness and ultrahigh-brightness LEDs combined will be responsible for about $4.45 billion of that total, over 5.5 times the $783 million total market size in 2007. “These solid state lighting devices are rapidly becoming the lighting source of choice for diverse applications including traffic signals, interior and exterior lighting in cars and trucks; large screen visual displays, small LCD backlighting and decorative illumination,” a recent iSuppli report states (Ref 1). “And new lighting applications are constantly being discovered.”



Solving The System-Level Thermal Management Challenges of LEDs

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Thermal challenges

High powered LEDs provide greater thermal challenges than most other light sources, largely because LEDs don't generate infrared radiation. According to the U.S. Department of Energy (DOE), 75% to 85% of energy used to drive LEDs is converted to heat "… and must be conducted from the LED die to the underlying circuit board and heat sinks, housings or luminaire frame elements." The US DOE's Office of Energy Efficiency & Renewable Energy has produced a fact sheet on "Thermal Management of White LEDs" (Ref 2). In the short term, the excess heat can reduce an LED's light output and produces a color shift. However, another reason thermal management is so important is the long term effects which include accelerated reduction in light output resulting in a shortened useful life. The DOE says that manufacturers normally test LEDs at a fixed junction temperature of 25oC. On the other hand, under constant operation the junction temperature is typically 60oC or greater and under these conditions the LEDs light output may be 10% or more below the rating and could be even worse for products with inadequate thermal design can be significantly higher.

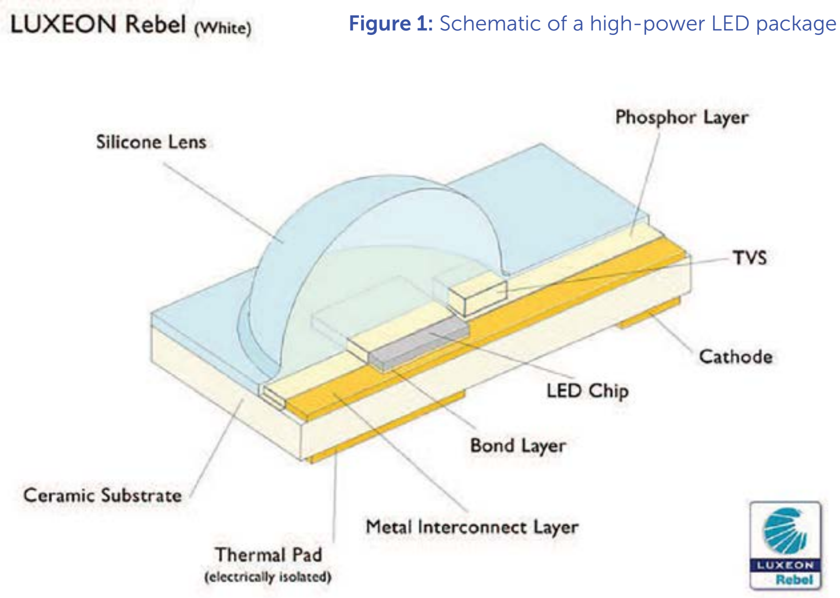
For tungsten light bulbs the heat flow path is direct from the filament to the surroundings by thermal radiation with some participation of the glass. The primary path of heat transfer in an LED device is usually conduction from the junction to the system enclosure. The LED device manufacturer provides the package level thermal management. For the manufacturer, the biggest concern is minimizing the thermal resistance from the junction to the outside of the package. Some LEDs, typically small devices mounted on panels, have leads that form the main thermal conduction path and for these devices the thermal resistance from the junction to the leads is most critical.

Package design varies by manufacturer and type of LED but the concepts between packages are similar. In this example, the LED chip is typically attached with a bond layer to a metal interconnect layer which is then attached to a ceramic substrate and an electrically isolated thermal pad. The entire package is designed to maximize optical output and move heat away from the back of the LED chip.

Hechfellner pointed out that even the most thermally-efficient LED device requires that a cooling system be developed around it. He said that because most traditional lighting methods radiate heat, they do not have that level of thermal issues. Many systems manufacturers have much more experience in the electrical and mechanical than in the thermal aspects of design. "What the engineering community needs is a change of their mindset and think thermal first and electrical later," Hechfellner said. "Thermal represents 90% of today's design challenges for LED systems manufacturers while electrical and mechanical together provide only 10%."

"The biggest challenge facing systems companies is to develop a thermally-efficient socket that will enable an LED device to simply be plugged in while the heat is conducted away to the environment," Hechfellner continued. "To the best of my knowledge, there are no such systems currently on the market. Improved thermal interface materials and design tools are needed to develop

Figure 1: Schematic of a high-power LED package



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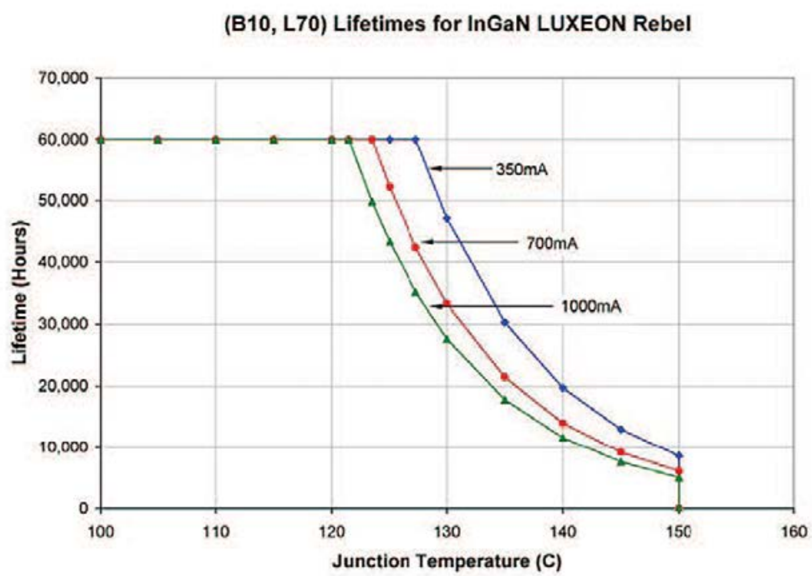

Figure 1: Expected lifetimes for InGaN LUXEON Rebel at various junction temperatures and drive currents at a 90 confidence level.

them. We are focused on creating an infrastructure that helps our customers create a better thermal design - such as simulation tools that enable accurate models of LED devices to be dropped directly into the systems design."

The nature of an LED package is such that even as LEDs increase in efficiency the challenge of thermal management will not disappear. As light output reduces with temperature, a greater proportion of the electrical power is turned into heat, further increasing the temperature. The light output from an LED reduces as it ages, so its heat output may increase over time, accelerating the rate of degradation. A common cause of lumen depreciation in white LEDs is a yellowing of the phosphor which may be heat or environmentally induced but does not necessarily mean that the chip is working less efficiently or that there is more heat being generated. Thermal management solutions will need to be sufficient to remove the heat dissipated by the LED over its useful life.

System-Level Design Considerations

The design considerations are different for every LED and that care must be taken to understand the metrics and performance of the LED being used in the application. The essence of LED system design is transferring the heat efficiently from the LED thermal spreader, slug or wire leads to the ambient. First of all, a secure and thermallyefficient bond must be provided between the slug and the circuit board pad. The thermal connection typically runs through a small thermal via in the PCB to a large copper area on another layer. Heat is typically conducted through this layer to the enclosure or an external heat sink.

An external heat sink may be required in situations where an exceptionally large amount of heat is dissipated within the enclosure. Copper and aluminum are commonly used materials for LED heat sinks. Optimizing the geometry of the heat sink is a critical concern in many applications as the heatsink-to-air thermal resistance is often significant. Heat sink performance varies depending upon factors such as the material, number of fins, fin thickness, base thickness, etc. External heatsinks extend the surface area available for heat to transfer to the ambient air. The optimum design depends on the local air flow conditions that are affected by the introduction of the heat sink, increasing the design challenge.

Copper offers superior thermal conductivity, while aluminium is lighter and less expensive. In some cases PCBs made of materials that improve heat transfer through the board may be used. These boards may be made of ceramic, coated steel or aluminium or several other materials.

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2. http://www.netl.doe.gov/ssl/PDFs/ThermalLED_Feb07_2.pdf
3. http://www.lumileds.com/pdfs/WP12.pdf

Success Story:

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Azonix, a leading provider of computers and displays designed for extremely harsh conditions, used FloEFD CAD-embedded CFD software and reduced the number of thermal prototypes needed for its new Terra computer from up to 12 to only 1.

"FloEFD computational fluid dynamics software enables design engineers without a fluid analysis background to perform thermal simulation. The result is that we got the design right the first time, only had to make one prototype and avoided expensive design changes that typically occur in the late stages of the development process."

James Young, Design Engineer, Azonix

Limited cooling options add challenge

Terra is a new computer designed for use in the transportation industry that is, like other Azonix products, completely sealed from the elements and designed for use in very hot environments.

"As with most of our products, we were limited to conduction and natural convection cooling," said James Young, Design Engineer at Azonix. "This presents a difficult challenge for modern electronics equipment."

Thermal design is addressed early in the process

"We opened the SolidWorks model in FloEFD and defined the heat dissipation sources, material properties and the ambient temperature outside the enclosure at the product's design limit of 60°C," said Young.

"Then we defined the goals and performed a thermal simulation. The software analyzed the CAD model, automatically identified fluid and solid regions, and allowed the entire flow space to be defined and gridded without user interaction and without adding extra objects to the CAD model. The software took about five hours to generate simulation results."

Embedded CAD software saves money and time

After several tests and improvements to the design, they were able to reduce the surface temperatures below the allowable limit.

"The result," Young said, "was that we were able to complete the thermal design prior to building the first prototype. When the prototype was built and tested, the measurements were within 5% of the simulation predictions. As a result, this was the only thermal prototype that needed to be built.

"This is a good example of how the new generation of embedded CAD tools can save money and time by enabling design engineers to optimize the design from a thermal standpoint early in the design process."

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James Young, Design Engineer, Azonix

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