Efficient LED Heat Management

LEDs are being used in more and more ways. Due to their brightness, high efficiency and long life expectancy, they continue to conquer domains that only recently were reserved for traditional light sources. This means that driver electronics must be adapted to an ever-increasing number of applications.

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This raises the question of how the components' lost heat enters the heat sink. For this, a good thermal transition must be found. Because SMD components are used in most applications, the heat must be brought to the heat sink through a printed circuit board (PCB). This produces two step heat transfers that make up the greater part of the system's overall heat resistance.

Heat transfer characteristics

An LED can have an average lifetime of about 50,000 hours when $T_J = 25°C$. When $T_J = 125°C$, the average lifetime shortens to 25,000 hours. When $T_J = 175°C$, a lifetime of only 100 hours is specified. This is why careful heat management is very important for LEDs.

The printed circuit board is a very bad heat conductor, with heat conductivity (λ) of about 0,3W/m·K when FR4 printed circuit board material is used. The resulting temperature increase through the PCB during induced heat output is calculated as

$$\Delta T = (Q \cdot d) / (\lambda \cdot A)\ [K]$$

where d is the thickness of the PCB in [m], and Q is the heat output in [W].

To increase the PCB's heat conductivity, vias are placed in a hexagonal pattern in the PCB. The vias partially increase the heat conductivity. The costs incurred during PCB production are minimal. If the created heat is high, copper rivets are used. For this, the round notches in the PCB are milled and the copper rivets are inserted. The SMD component is soldered onto the rivet, which has good heat conductivity.

The next important transfer is from the PCB to the heat sink. For this there are several possibilities. One good solution is to lay a heat-conductive film between the PCB and the heat sink. This performs several tasks at the same time. The first task is to conduct heat away continuously. The second task is to even out the irregularities between the printed circuit board and the heat sink. This is achieved by a soft film. The elasticity evens out the various expansion coefficients of the heat sink and the PCB. For example, an aluminum heat sink has an thermal coefficient of expansion (TCE) of $\alpha = 23 \times 10^{-6}$ [1/K], the FR4 PCB of $\alpha = 14 \times 10^{-6}$ in the X, Y direction and of $\alpha = 70 \times 10^{-6}$ in the Z direction. If the PCB is rigidly attached, waves result between the attachment points from the various expansion coefficients. This should even out by the elastic film.

LED module design

When designing the LED module, strict care must be taken to make sure the heat is transferred away. Particularly LEDs are more heat sensitive than IGBTs or FETs, because the maximum junction temperature should not exceed $T_J = 125°C$. The height of the junction temperature influences the LED's lifespan, brightness and emitted light color.

A sample solution is the module shown in Figure 1. The LEDs and the power source are soldered onto a very thin FR4 printed circuit board. The PCB is stuck onto the heat sink with KL 90 heat-conducting film that is self-adhesive on both sides. The KL 90 takes on several tasks. Those are heat conduction, mechanical attachment of the printed circuit board to the heat sink, evening out irregularities, and electrical insulation of the heat sink. It is a very cost-effective solution for producing such a module.

KL 90 is a very soft elastomer film that is filled with heat-conductive ceramic material. It has heat resistance of 0.52K/W and a thickness of 300µm. It reaches a dielectric strength of 3kV. On the other hand, KL 91 film has an inserted fiberglass web, and has more rigid behavior than KL 90. The technical data for KL 91 are almost identical to those of the KL 90 film.

The question arises as to how the adhesive behaves in combination with

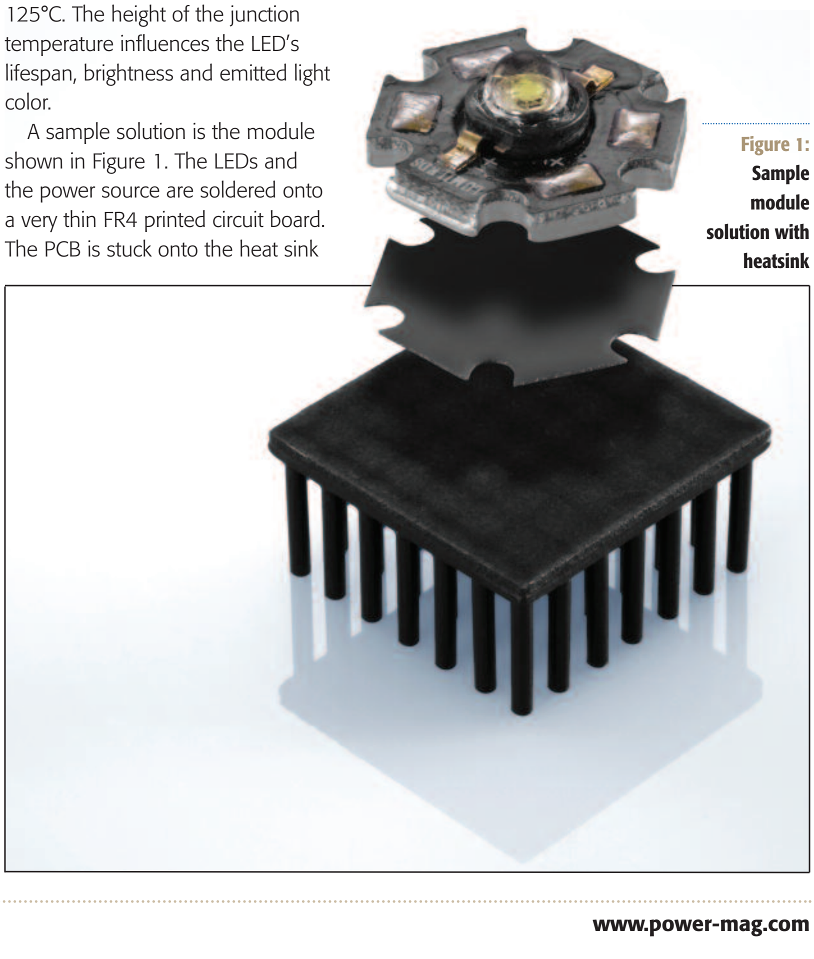

Figure 1: Sample module solution with heatsink

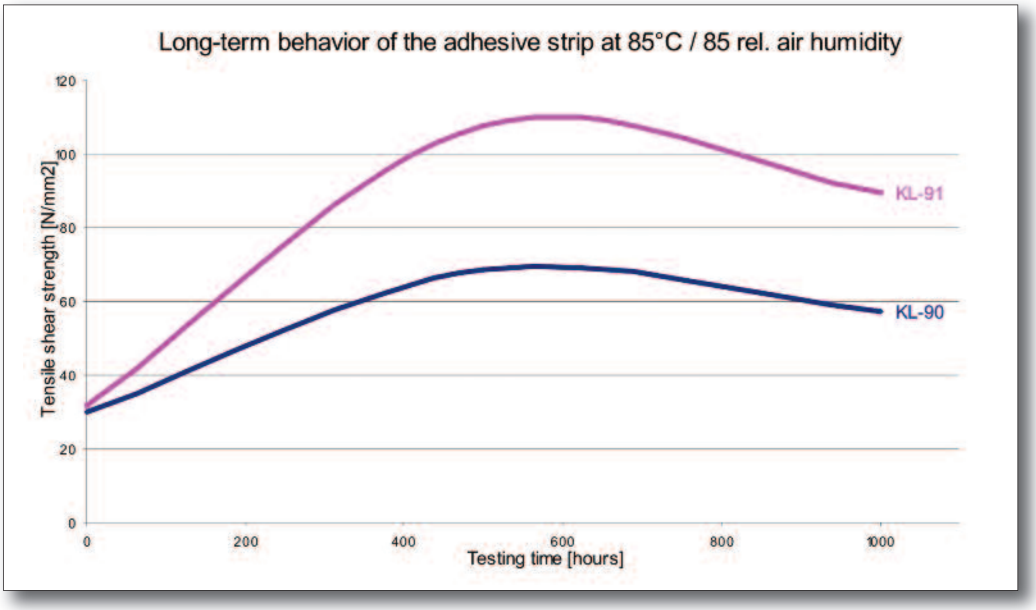

Figure 2: Tensile shear strength at 85°C of materials KL 90/91

heat over time. When the KL 90 and KL 91 films were developed, explicit care was taken to ensure that the adhesive would not degrade with time. Studies have shown that at 150°C, the adhesive has a degradation rate of 4% after 10,000 hours. Thus, the adhesive does not age, and the area of adhesion does not detach from the PCB or the heat sink. After the film is applied, its adhesive strength even increases, as shown in the tensile shear strength curve in Figure 2.

The films even cover applications in which they are exposed to mechanical shocks. Tests according to IEC 60068-2-6 in combination with IEC 60068-2-2 and IEC 60068-2-47 have shown that the KL-90 and KL-91 films withstand accelerations of 50 m/s^2 and 100 m/s^2 in all three axes. The values were determined with a design consisting of a PCB and a CPU aluminum heat sink.

Conclusion

The KL 90 and KL 91 films have very good heat conductivity, with the added advantage of being self-adhesive. The goal in developing these films was to attach the heat-generating components to heat sinks very simply.


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Part Number	Vdss max	ID Tc=25°C	Rds(on) max TJ=25°C	Qg typ	Pd	RthJC max	Package Type
IXFH60N50P3	500V	60A	0.100Ω	96nC	1040W	0.12°C/W	TO-247
IXFK78N50P3	500V	78A	0.068Ω	147nC	1130W	0.11°C/W	TO-264
IXFX98N50P3	500V	98A	0.050Ω	197nC	1300W	0.096°C/W	PLUS247
IXFN132N50P3	500V	112A	0.039Ω	250nC	1500W	0.083°C/W	SOT-227
IXFB132N50P3	500V	132A	0.039Ω	250nC	1890W	0.066°C/W	PLUS264
IXFH50N60P3	600V	50A	0.145Ω	94nC	1040W	0.12°C/W	TO-247
IXFK64N60P3	600V	64A	0.095Ω	145nC	1130W	0.11°C/W	TO-264
IXFX80N60P3	600V	80A	0.070Ω	190nC	1300W	0.096°C/W	PLUS247
IXFN110N60P3	600V	90A	0.056Ω	245nC	1500W	0.083°C/W	SOT-227
IXFB110N60P3	600V	110A	0.056Ω	245nC	1890W	0.066°C/W	PLUS264

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