LED Solutions® by PerkinElmer.

APPLICATION NOTE

Mounting of the ACULED®

The new ACULED VHL (Very High Lumen) delivers outstanding brightness, improved luminous efficacy and excellent thermal management, all in a compact, easy-to-assemble package.

Introduction

PerkinElmer's ACULED® VHL™, with its superior four-chip design and smallest footprint, gives customers the most flexible multi-chip LED on the market. The product family contains various products from UV via VIS to IR with a variety of chip configurations, including sensors and thermistors. PerkinElmer's ACULED® DYO™ even enables customers to put together their own configuration. Please refer to the Custom Design Guide "ACULED DYO - Design-Your-Own" for more details on this product.

The following application note describes how to mount the ACULED product family – ACULED, ACULED VHL and ACULED DYO – to your board and heat sink.

Features and Benefits of the ACULED® VHL Product Family

- Superior color mixing
- Based on multi Chip-on-Board (COB) technology
- 4 separately addressable chips
- Low thermal resistance (as low as 4.5 K/W)
- Best-in-class heat sinking
- Superior "Through-Looking" (TL) mounting design
- Ultra-compact footprint
- Adjustable color temperature
- Outstanding brightness and luminous efficacy
- Designed for high current applications
- Fully RoHS-compliant
- Combination of LED with sensors
- Customized chip configuration

Applications

- Illumination
- Medical lighting
- Aircraft lighting
- Projection lighting
- Signaling

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Technical support

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PerkinElmer®

Scope of the Application Note

This application note describes how to mount the ACULED family of products to your board and heat sink. For more specific information on how to drive the ACULED VHL product family please refer to the application note "Driving the ACULED VHL". To get more information on the thermal management of the ACULED VHL / DYO please refer to the application note "Thermal Management of the ACULED".

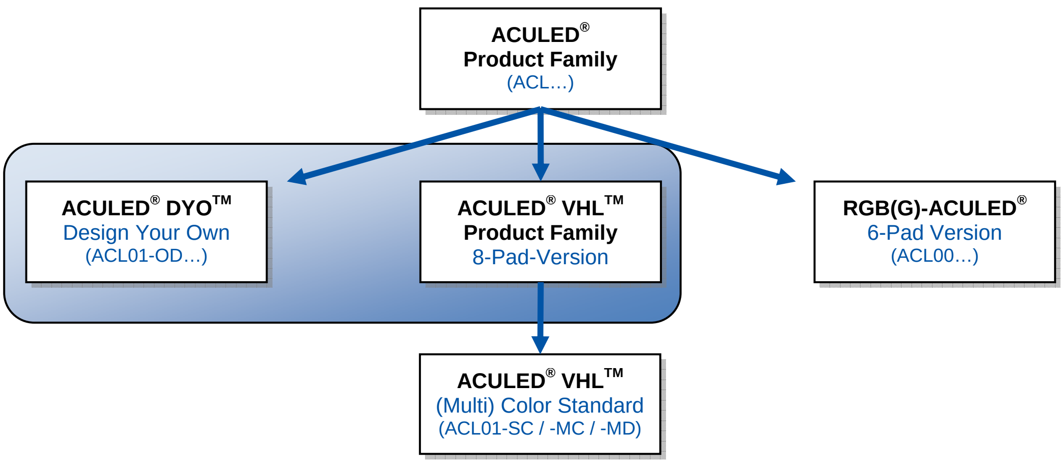
Used Terms

This application note covers different products of the ACULED product family. To differentiate between the particular products of this family, the following terms are therefore used:

- ACULED or ACULED product family: collective term for all PerkinElmer ACULED family products
- ACULED-RGB(G): Standard ACULED with 6-pad-design equipped with red, blue and one or two green LED chips. The particular product numbers start with *ACL00…*
- ACULED VHL product family: Collective term for all ACULEDs with 8-pad-design including all standard single and multi-color ACULED VHLs.
- ACULED VHL: Standard single and multi-color ACULED VHL for highest light output. The specific product numbers of the standard VHL products start with *ACL01-SC…* for the single color VHLs, *ACL01-MC…* for the multi-color VHLs or *ACL01-MD* for multi-die VHLs for example with photo diodes.
- ACULED DYO: All ACULEDs based on the ACULED VHL platform with customized chip selection (Design Your Own). The particular product numbers start with *ACL01-OD…*
- ACULED VHL DYO: Collective term for all ACULEDs with 8-pad-design including the ACULED VHL product family and the ACULED DYO. These products are all based on the same PCB platform. Marked with blue background in the schematic overview below.

While the difference between these products is not relevant to this application note, only the superior terms according to the schematic diagram below will be used as a collective expression within this document.

Schematic ACULED Product Family Overview (Product Tree)



Construction of the ACULED VHL Product Family

The ACULED VHL product family and ACULED DYO board are based on an insulated metal core substrate (IMS) made from copper and a highly sophisticated isolation material with a low thermal resistance between the copper and chip pads. This package provides excellent heat dissipation and thermal management from the chip to the board's backside. The thermal resistance $R_{th\ JB}$ of the entire package is quite low, depending on the chip configuration. To dissipate the heat, adequate cooling must be considered. To avoid damaging the LED chips by overheating when equipped with at least one high-power LED chip, the ACULED must not run without appropriate cooling – even at lower current! Please refer to the application note "Thermal Management of the ACULED VHL" for more information about this issue.

Figure 1 shows the layout of the ACULED VHL / DYO. The chips are placed in the middle of the board, protected by a PPA-based ring and silicone resin encapsulation. The latter is transparent and suitable for a wide range of radiation from ultraviolet (UV) to infrared (IR). It is also more resistant to heat than epoxy resin, and its heat expansion characteristics are closer to those of chips. With the ACULED's high-power LEDs, silicone achieves superior resistance to light radiation, mitigating degradation, and maintaining LED color purity over the LED's lifetime. The mechanical stress applied to the chips is lowest with silicone, as compared to standard encapsulation materials. Due to its softness, pressure to the silicone area within the ring must be avoided. Please refer to the application note "Handling of LED and Sensor Products Encapsulated by Silicone Resin" to learn more about handling silicone-based products such as the ACULED.

The clockwise numbered pads C1 - C4 inside the encapsulation ring show the pads where the LED chips are placed. The distance between the chips is typically 0.2 mm with a pitch of 1.2 mm. Therefore, the lighting area A_{rad} is approximately 2.2 x 2.2 mm², depending on the particular chip configuration for the specific ACULED product. Some white ACULED products have the whole area inside the ring lighting, leading to an A_{rad} of 23.8 mm² with a diameter of 5.5 mm. Please refer to the according datasheet for more information on a specific product. The numbers of the soldering pads run counter-clockwise from pin 1 to pin 8. The pad numbers 4 and 5 are printed on the board. Pin 1, which can be used as a reference for mounting, can easily be located by the small golden dot. Whether ESD protection diodes are used depends on the ESD sensitivity of the LED chips and is referenced in the specific datasheet of each product.

The tracks on the ACULED are made from copper with a thin gold layer to achieve better bonding results.

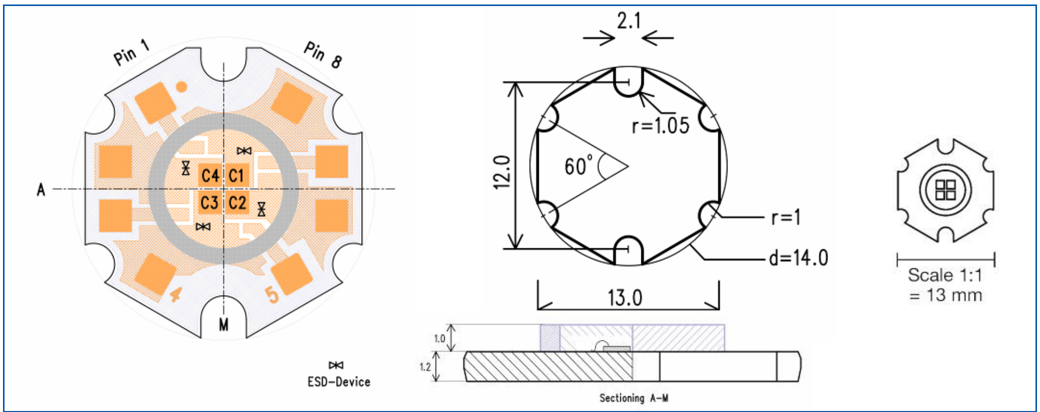


Figure 1
Layout and Dimensions of the ACULED VHL / DYO

Mounting Reference

All products within the ACULED VHL / DYO contain four closely-placed chips to achieve a small but bright light-emitting area and excellent color mixing with multi-color configurations. The high precision of chip placement, with approx. 20 µm tolerance to each other, makes it a superior and reliable light tool, especially when used with optics. The chips and ring are placed with reference to the pads of the board for the narrowest adjustment. Therefore, it is recommended to refer to the solder pads, the golden dot close to pin 1, or the ring when adjusting optics, etc. Do not use the outline or footprint of the ACULED board if high accuracy is required. However, if the accuracy required is less than ± 100 µm, the outline may be used as a reference.

For automatic pick and place processing, the ACULED is supplied in a standard 24 mm blister tape reel as shown in Figure 2. The orientation of your specific ACULED product in the reel can be found in the respective datasheet. Usually it is upside down for all ACULED VHL/DYO products and face up for the 6-pad RGB(G)-ACULED. To recognize the ACULED orientation in an upside down tape by a vision system, the edges at the "upper" long hole between the solder pads #1 and #8 are beveled. Please refer to the left image in figure 1 for details, though the bevels may not appear in all drawings of the ACULED.

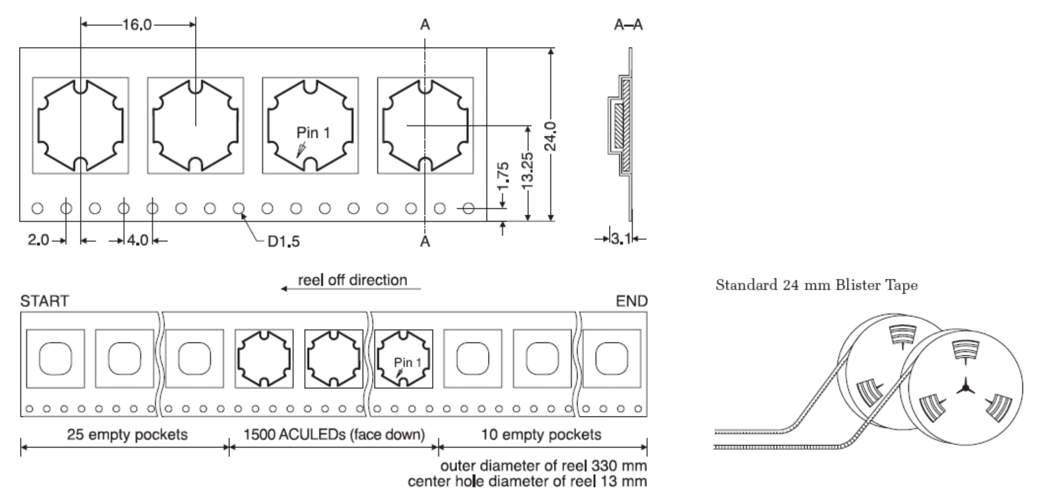


Figure 2
Packaging of the ACULED VHL Product Family

General Mounting Recommendations

The ACULED can be attached to a heat sink or board in various ways. Beside the mechanical stability, cooling is the key point of the assembly. The heat has to be drawn away from the ACULED board by conduction. It is highly recommended to read the application note "Thermal Management of the ACULED VHL" to learn more about cooling the ACULED VHL / DYO properly. The assembly can be done by screwing, gluing or clamping. Either way, a good physical contact between the copper substrate and the heat sink or board must be established for adequate heat transport. This is why screwing usually should be the first choice of mounting if possible. The mounting technique should also consider the stability required by the application; mobile execution with higher vibration for example requires more stability than stationary applications.

The ACULED product family is based on two different hexagonal shaped substrate layouts; both containing four-chip pads at closest distance but one with six and the ACULED VHL / DYO with eight contact pads (see Figure 3). The footprint is nearly the same for both, but the handling recommendations are slightly different when screws are used for mounting. Both layouts have six semicircular holes, but only with the six-pad ACULED board can all of these be used to screw the ACULED to the heat sink with M2 screws. It is highly recommended to fix the ACULED symmetrically, e.g. by two screws in opposite holes as shown in Figure 4, three screws with one each second hole, or four screws with two open opposite holes left. Also, the torque should be the same for all used screws to obtain symmetrical pressure. Take care that the screw heads do not touch the solder pads to avoid short cuts and damage of the ACULED.

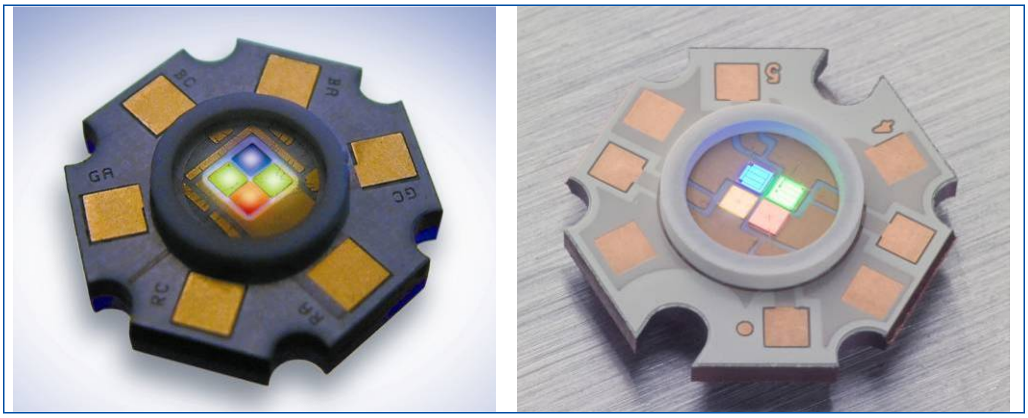


Figure 3
Modules of the ACULED Product Family with Six (Left) and Eight (Right) Lead Pads

With the eight-pad ACULED VHL / DYO, only the two longer holes are suitable for screwing to the heat sink. They are located between contact pad position one and eight, and position four and five. The latter are indicated by small numbers on the top side of the board. Both semicircular long holes should be used with M2 screws at the same torque to achieve a symmetrical pressure to the ACULED. The screw heads must not exceed 4.8 mm in diameter to avoid touching the ring. Do not use the four smaller holes with screws! The screws' head could damage the solder mask and short cut or even damage the ACULED! These holes can be used with pins (2 mm or less) to adjust the ACULED VHL / DYO, e.g. when cascading them to a tight layout as shown schematically in Figure 5. Due to the benefits of TL-Mounting (see next chapter) that allows the use of inexpensive multilayer boards and its small footprint, a very tight mounting with high light output per area can easily be achieved with the ACULED.

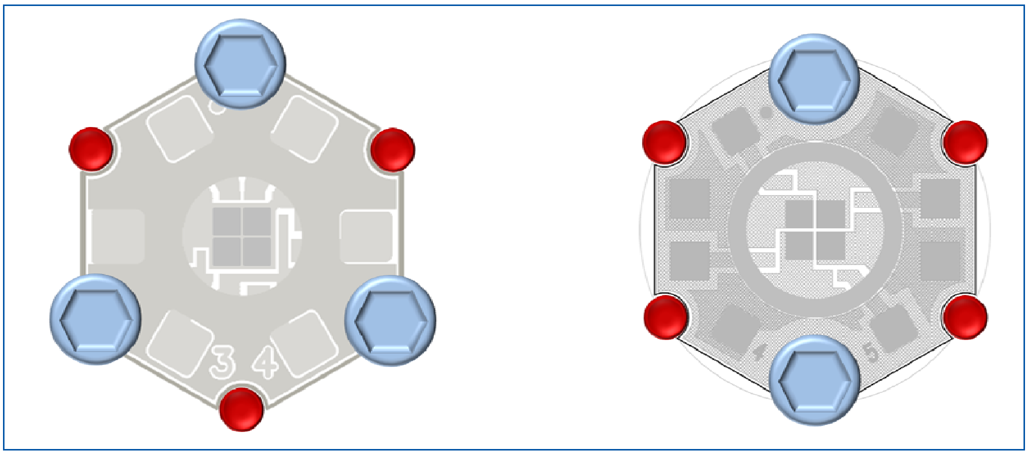


Figure 4
Principle of Mounted ACULEDs Utilizing Adjustment Pins (Red) and Screws (Blue)

Left: 6-pad ACULED
Right: 8-pad ACULED

When using clamps with the ACULED, take care not to short cut the contacts or damage the thin solder mask, which can also lead to short cuts and damage of the ACULED at least. Also, the clamp must not press on the silicone and should not press on the ring. At least the same areas that are covered by screw heads as described in the previous sections can be used for clamping.

Gluing the ACULED to a board or heat sink requires glue or a foil with high mechanical stability and a low thermal resistance. Refer to the application note "Thermal Management of the ACULED VHL" for more information.

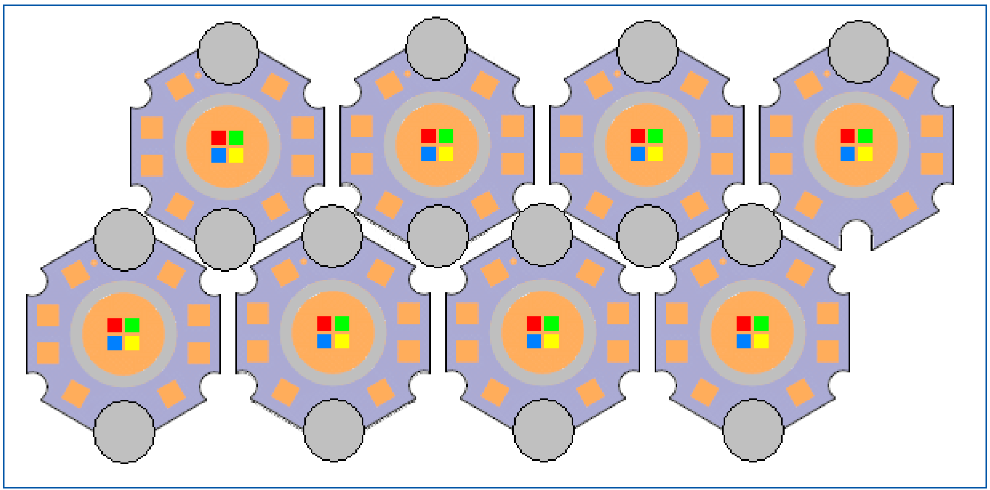


Figure 5
Principle of Tightly Mounted ACULEDs Due to the Hexagonal Shape

TL-Mounting

As shown in Figure 6 there are two different ways of mounting the ACULED, conventional and upside down (TL-Mounting). When mounting it regularly on a heat sink or appropriate board, the pads have to be electrically connected by wires or spring contacts. Therefore, for automatic processing like reflow soldering, the upside down TL-Mounting method is recommended. Here, the ACULED is mounted upside down on a PCB, which can even be made from FR4 and other inexpensive non-heat conductive materials. This PCB needs a cut-out of Ø 7.4 mm, where the ACULED can look through, giving the technology its name TL-Mounting (Through-Looking Mounting). Now the whole package, ACULED with PCB, can easily be mounted on a heat sink. Figure 7 shows the principles of TL-Mounting, whereas Figure 8 shows more details on an example. Please also refer to the chapter "Soldering", where you can find the solder pattern and PCB cut-out for TL-Mounting as shown in Figure 12. TL-Mounting can be done by a conventional SMT process with high reliability. Thus, an official testing institute attested a high reliability to the ACULED after more than thousand temperature cycles from -40 to +90 °C without any failures for TL-Mounting. Since the ACULED VHL / DYO is taped upside down it can easily be picked and placed by a machine without turning when TL-mounted.

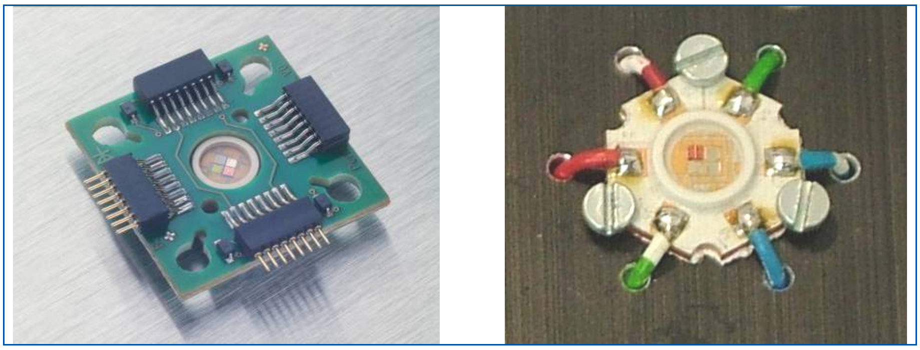


Figure 6
TL-Mounting (Left) and Conventional Connection (Right) of the ACULED

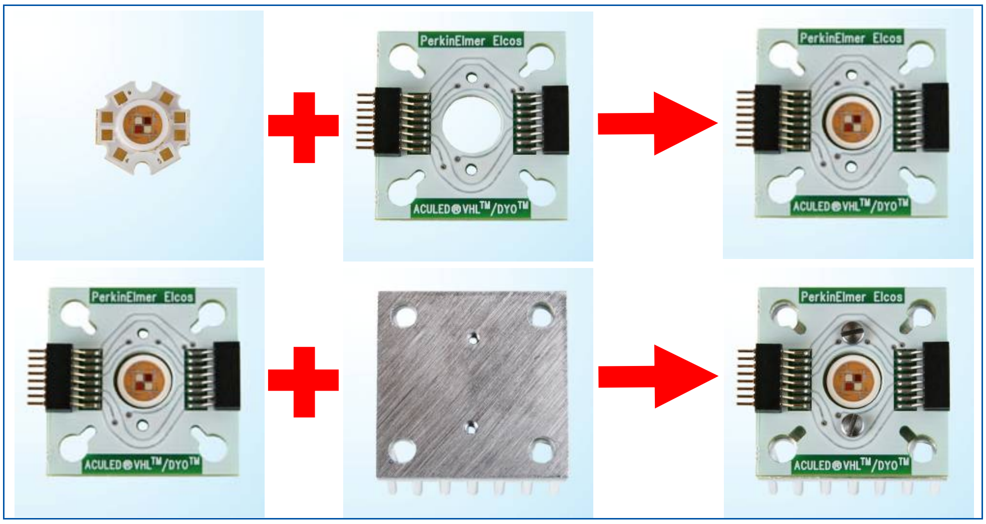


Figure 7
The Principle of TL-Mounting of the ACULED for Easiest Heat Management.

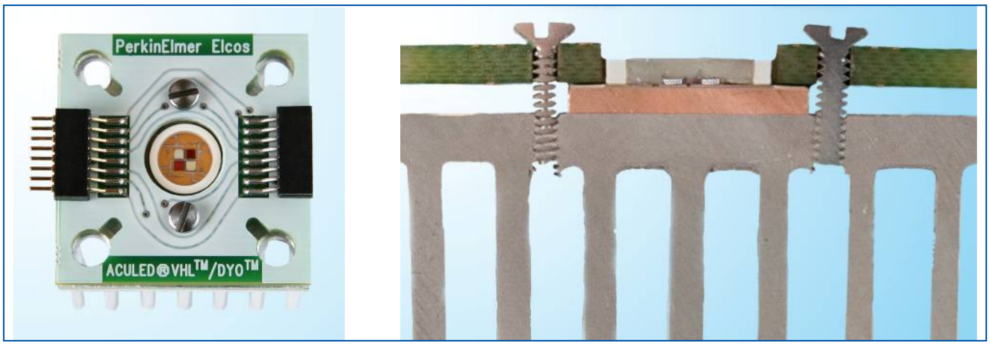


Figure 8
TL-Mounting: ACULED with TL-PCB Mounted on Standard Heat Sink.

Left: Top View

Right: Sectional View Shows Sandwich of ACULED with TL-PCB Mounted on Standard Heat Sink.

Advantage of TL-Mounting

The advantages of TL-Mounting are easy reflow processing and the easy way of using inexpensive PCB materials and standard heat sinks. Figure 9 shows a packaging comparison between the ACULED utilizing TL-Mounting versus a standard high power SMD LED on top package. The blue parts represent the ACULED respectively the high-power standard SMD LED packages. Respectively we can see that the ACULED is directly mounted on the heat sink, whereas the standard SMD LED needs a high thermal conductive board (orange) to secure a good thermal heat flow from the LED to the heat sink and a proper electrical connection. With the ACULED a simple PCB (green) can be used for driving instead. If space is an issue, the assembly can also be kept thinner than standard on top SMD mounting.

Figure 10 shows the same comparison; now with the thermal bottlenecks (red) highlighted showing that the number of thermal barriers are lower with the through-looking design due to the direct mounting on the heat sink.

We can summarize that the superior ACULED through looking design utilizing TL-Mounting at least has the following advantages versus a conventional SMD-LED package:

- The electrical layout can be done on relatively inexpensive PCB material, no need to use expensive ceramics, IMS or other high thermal conductive boards.
- Double-sided and multilayer boards can easily be applied.
- Less thermal bottlenecks from pn-junction to the heat sink.
- The whole assembly can be made thinner.
- Module costs can be decreased.

The principle of TL-Mounting and through-looking design is also used with the ACULED VHLs provided with the ACULED Designer Kits that can be ordered for testing the ACULED VHL in your engineering environment.

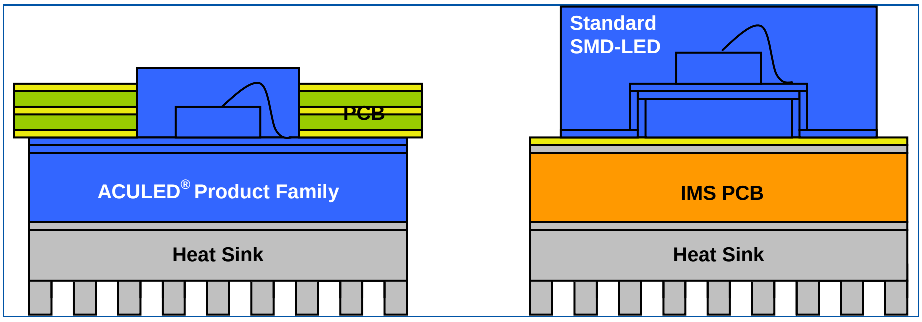


Figure 9
Comparison of TL-Mounting (Left) to Standard SMD Soldering (Right): Cheap PCBs such as FR4 and Multilayer Boards can Easily be Used with TL-Mounting.

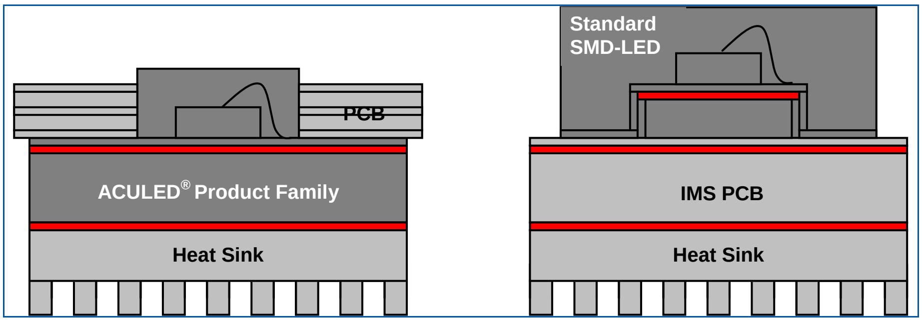


Figure 10
Comparison of TL-Mounting (Left) to Standard SMD Soldering (Right): Less Thermal Bottlenecks (Red Layers) are Necessary with TL-Mounting.

Reflow Soldering

The ACULED is designed for lead-free reflow soldering; Figure 8 shows the recommended reflow profile. The pads are made from copper with a thin gold layer and surrounded by a white solder resist, preventing the solder to short circuit neighbored pads. Figure 12 shows the recommended solder pad geometry of the ACULED VHL / DYO for the PCB side including the cut out for TL-Mounting. An official testing institute attested a high reliability to the ACULED after more than thousand temperature cycles from -40 to +90 °C without any failures for SMD soldering. However, it is recommended to reflow solder each ACULED only one time.

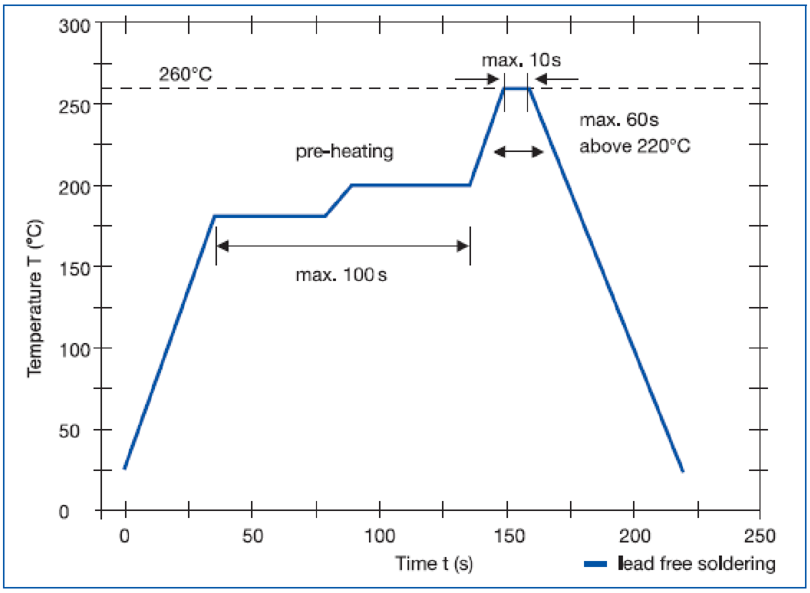


Figure 11
Reflow Soldering Profile

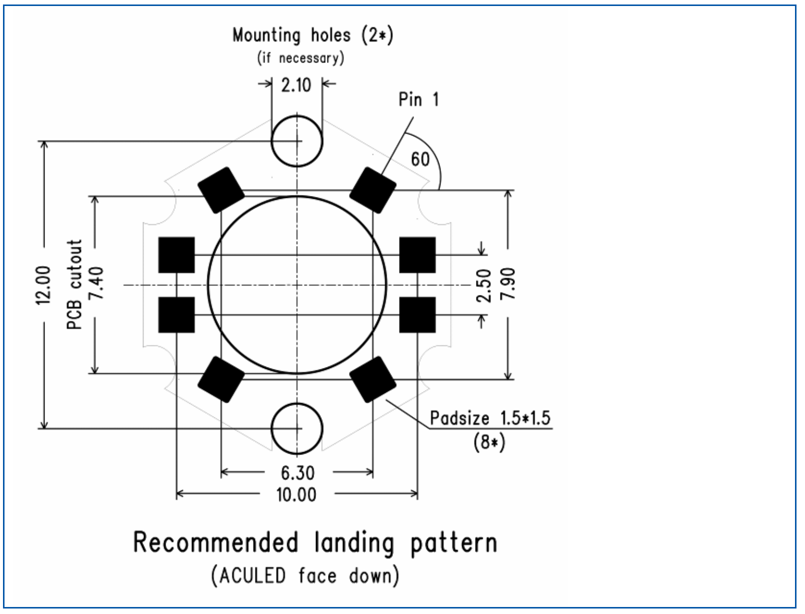


Figure 12
Recommended Solder Pad Geometry for the ACULED VHL Product Family Utilizing TL-Mounting.

Hand Soldering

The ACULED can also be soldered by hand, for example to attach wires for testing. For hand soldering, we recommend to pre-heat the ACULED screwed backside down on a hot plate at 100 °C. With a soldering iron (e.g. 95 W type) you can now solder the ACULED. Please take caution not to apply heat of more than 400 °C for the maximum of 3 seconds to the pads to avoid damaging of the chips by overheating. To avoid solder and solder flux from splashing and contaminating the silicone surface of the ACULED, we recommend protecting it during the hand soldering procedure by a cap or a heat resistant tape that must not stick on the silicone but on the ring of the ACULED only. Figure 13 shows an ACULED during hand soldering of flying wires.

Especially when hand soldering wires to the ACULED take care of avoiding short cuts between the cable and the IMS board copper substrate as shown in Figure 14. Although the white solder resist usually helps avoiding short cuts, improper soldering can lead to tin flowing over the resist and short-circuiting the pad. Too high temperature applied to the ACULED while soldering can be one of the reasons, therefore it is recommended to insert a small cool down break at least after every four wires soldered to the ACULED. It is also highly recommended to do short cut testing once soldering is finished.

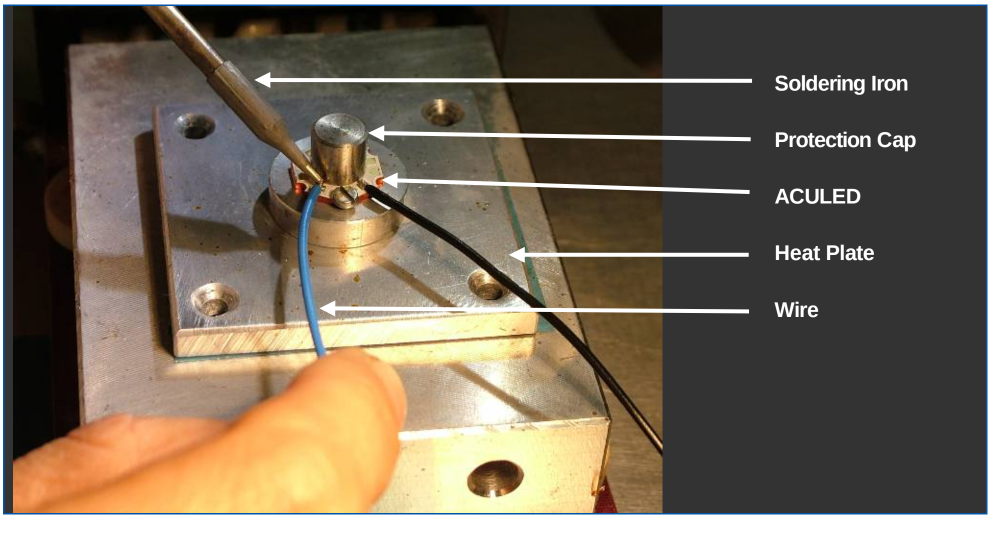


Figure 13
Hand Soldering Flying Wires to the ACULED Utilizing a Heat Plate and a Protection Cap Against Splashing Solder and Flux.

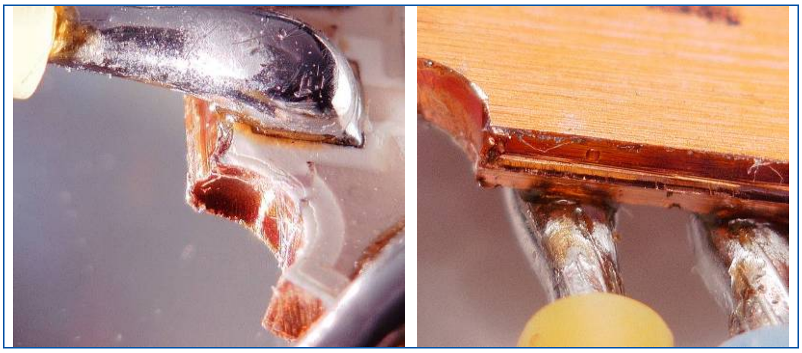


Figure 14
Short Circuits Between IMS Copper Substrate and Soldered Wire Due to Bad Hand Soldering.

Left: Top View

Right: Back View

Material Mixing

When mounting the ACULED on a heat sink, soldering it to a PCB or adjusting it in housing, different materials are mixed together. Beside the properties in thermal conductivity that are important to consider, a good thermal management (refer to the Application Note “Thermal Management of the ACULED VHL” for more information) is also important to consider their thermal expansions, expressed by the coefficients of thermal expansion (CTE). If materials of very different CTEs are mounted together, cracks and other mechanical stress damages can occur during operation of the ACULED due to its heating. Figure 15 shows typical values of thermal conductivity λ_{th} and CTEs in a matrix for different materials that are typically used in and around modern high power LED products like the ACULED. The colors used in this figure respond to the materials and colors shown in Figure 16 that represent the ACULED in a through-looking package and a standard SMD LED package as described in the previous chapter.

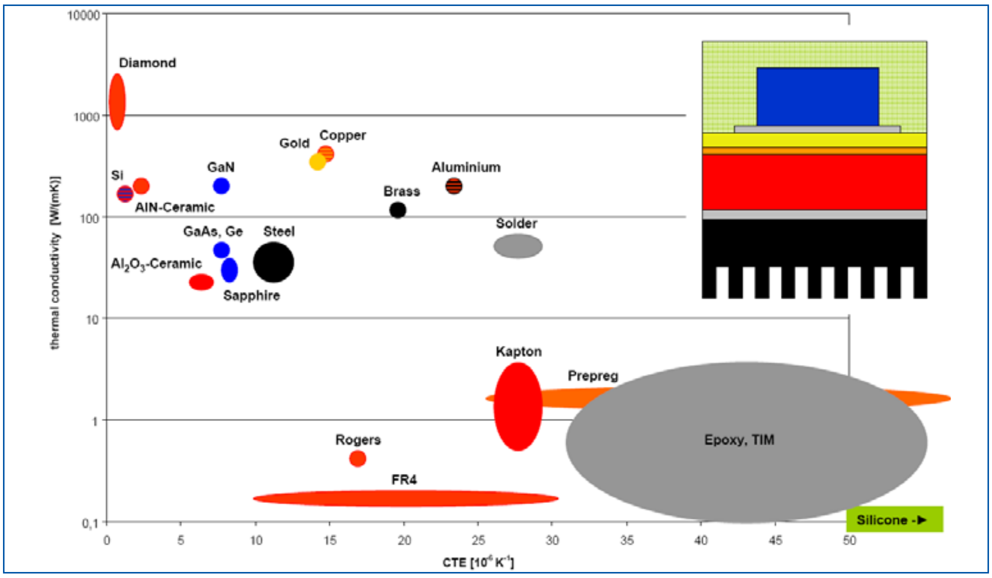


Figure 15
Thermal Conductivity λ_{th} Versus CTE for Different Materials Typically Used with LED Packages and Assemblies. The Colors Correspond to the Schematic LED Package in the Upper Right Corner and in Figure 16

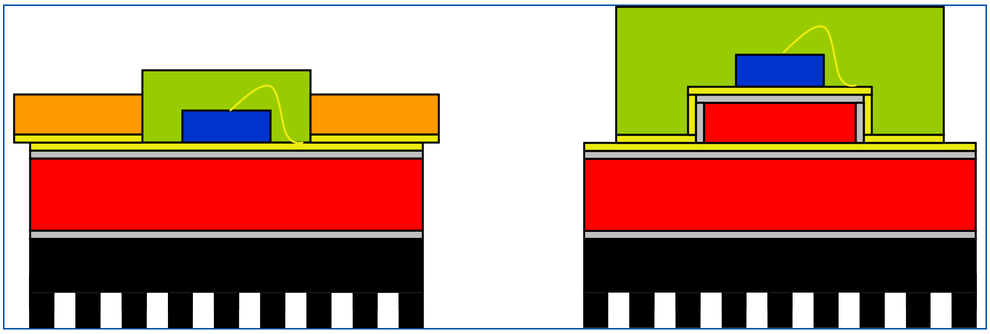


Figure 16
Materials Used According to Figure 15 for the Typical ACULED Through Looking and Standard SMD-LED Assembly as Earlier Introduced in Figures 9 and 10.

Symbols and Units

The following terms and their typical units are used in the application notes and datasheets of the ACULED. Please note that not all of these are used in this particular note.

A	[m²]	area, surface
A_{rad}	[mm²]	radiating surface
E_e	[W/m²]	irradiance
E_V	[lx]	illuminance [lux]
Φ_e	[mW]	radiant flux
Φ_V	[lm]	luminous flux [lumen]
I_e	[W/sr]	radiant intensity
I_F	[mA]	forward current
I_{FM}	[mA]	surge current
I_R	[µA]	reverse current
I_V	[cd]	luminous intensity [candela]
L_e	[W/(m²·sr)]	radiance
L_V	[cd/m²]	luminance
$\Delta\lambda$	[nm]	spectral half bandwidth (usually FWHM)
λ_{dom}	[nm]	dominant wavelength
λ_{peak}	[nm]	peak wavelength
λ_{th}	[W/(m·K)]	thermal conductivity
η	[%]	efficiency
η_{opt}	[lm/W]	optical (luminous) efficacy
P_{Cn}	[W]	power consumption of chip placed on pad *n* of the ACULED
P_{opt}	[mW]	output power (optical)
P_{tot}	[W]	power consumption (electrical) [Watt]
R	[Ω]	(electric) resistance
R_a	[-]	CRI (average value of testing colors R_1 to R_8)
R_{th}	[K/W]	thermal resistance (general) [Kelvin per Watt]
$R_{th\ BA}$	[K/W]	thermal resistance from base (B) backside to ambient surrounding (A)
$R_{th\ JA}$	[K/W]	thermal resistance from junction (J) to ambient air or surrounding (A)
$R_{th\ JB}$	[K/W]	thermal resistance from junction (J) to base (B) backside
RH	[%]	relative humidity
t	[s]	time
t_{Life}	[h]	life time of LED chip or module
T	[°C] or [K]	temperature (general)
T_A	[°C]	ambient temperature
T_B	[°C]	base temperature on back side of package (substrate)

T_{CT}	[K]	(correlated) color temperature
T_J	[°C]	junction temperature
T_{op}	[°C]	operating temperature
T_{sold}	[°C]	soldering temperature (at backside of the ACULED VHL)
T_{st}	[°C]	storage temperature
ΔT_{BA}	[K]	difference between base and ambient temperature
ΔT_{JB}	[K]	difference between junction and base temperature [Kelvin]
ΔT_{JA}	[K]	difference between junction and ambient temperature
$TC_{\Phi e}$	[mW/K]	temperature coefficient of radiant flux
$TC_{\Phi V}$	[mlm/K]	temperature coefficient of luminous flux
$TC_{\lambda\ dom}$	[nm/K]	temperature coefficient of dominant wavelength
$TC_{\lambda\ peak}$	[nm/K]	temperature coefficient of peak wavelength
TC_{VF}	[mV/K]	temperature coefficient of forward voltage
V_F	[V]	forward voltage
V_R	[V]	reverse voltage
$x_{n°}$	[-]	x coordinate in CIE color space for *n*-degree observer (usually *n* = 2 is used with light sources like LEDs: $x_{2°}$)
$y_{n°}$	[-]	y coordinate in CIE color space for *n*-degree observer (usually *n* = 2 is used with light sources like LEDs: $y_{2°}$)
2ψ	[°]	viewing angle (usually at half of maximum intensity)

Abbreviations

The following abbreviations are used in the application notes. Please note that not all of these abbreviations are used in this particular note.

ACULED®	The trademarked name for PerkinElmer's range of All Color Ultrabright LEDs.
BOM	Bill of Material
ccw	counter clockwise
CCT	Correlated Color Temperature
CIE	Commission Internationale de l'Eclairage = International Commission on Illumination
COB	Chip on Board
CRI	Color Rendering Index, value to measure the quality of light used for illumination purposes.
CTE	Coefficient of Thermal Expansion
DMX	Digital Multiplex, serial light communication protocol (DMX-512)
DYO™	Design Your Own, indicates an ACULED with customized chip configuration
DUT	Device Under Test
ESD	Electro Static Discharge, Electro Static Damage, Electro Static Sensitive Device

FR4	Flame resistant 4, low cost PCB material made from epoxy resin and fiberglass mat
FWHM	Full Width at Half Maximum
IMS	Insulated Metal Substrate, PCB substrate made from aluminum or copper to provide excellent heat management; also known as MCPCB (Metal Core PCB)
IR	Infra Red, radiation above 700 nm within the scope of this application note
LED	Light Emitting Diode
NTC	Negative Temperature Coefficient, used as acronym for an NTC resistant. Thermistor to control (LED-) temperature
PCB	Printed Circuit Board
PD	Photo Diode
PIN diode	Positive Intrinsic Negative diode; diode with undoped intrinsic semiconductor between positive (p) and negative (n) regions
PMMA	Polymethyl methacrylate, transparent thermoplastic; in optical grade used for lenses
pn junction	Layer in the LED chip, where positive (p) and negative (n) charged carriers recombine to light respectively radiation.
PPA	Polyphtalamide (plastic)
PSU	Power Supply Unit
PT100	Thermistor made from platin with 100 Ω at 0 °C. Has a Positive Temperature Coefficient (PTC)
PWM	Pulse Width Modulation
RH	Relative Humidity
SMD / SMT	Surface Mounted Device / Technology
TIM	Thermal interface material
TL	Through Looking (Mounting)
UV	Ultra Violet, with LEDs radiation below 405 nm within the scope of this application note
VHL™	Very High Lumen. This is the name for the newest generation of standard monochromatic and multi-colored 4-chip ACULEDs
VIS	Visible light, radiation between 405 nm and 700 nm within the scope of this application note
Z-diode	Zener Diode, usually used as ESD protection

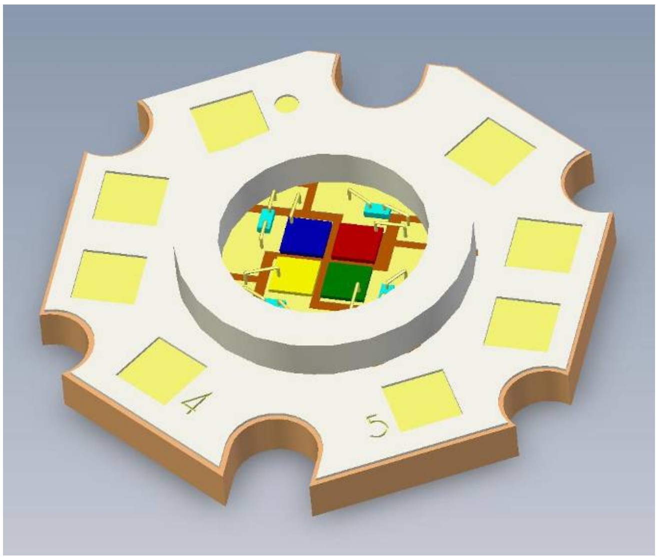
Notes

1. PerkinElmer maintains a tolerance of ± 5% on flux and power measurements.
2. PerkinElmer maintains a tolerance of ± 2 nm for dominant wavelength measurements.
3. PerkinElmer maintains a tolerance of ± 1 nm for peak wavelength measurements.
4. PerkinElmer maintains a tolerance of ± 2 K/W for thermal resistance measurements depending on chip properties.
5. Due to the special conditions of the manufacturing processes of LEDs, the typical data or calculated correlations of technical parameters can only reflect statistical figures. These do not necessarily correspond to the actual parameters of each single product, which could differ from the typical data and calculated correlations or the typical characteristic line. If requested, e.g. because of technical improvements, these typ. data will be changed without any further notice.
6. Proper current derating must be observed to maintain junction temperature below the maximum.
7. LEDs are not designed to be driven in reverse bias.
8. All drawings are not to scale.
9. All dimensions are specified in [mm] if not otherwise noticed.

Revision History

This table provides a summary of the document revisions.

Date	Revision	Description
July 2007	01	Initial release of document to customers
September 2008	02	Additional information on soldering and TL-Mounting



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