LUMITRONIX®
High-Performance LED-Technologies & Solutions

Operation of high power LEDs

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0 Introduction

This summary has been created to summarize and answer the most frequently asked questions about the operation of high power LEDs.

In many applications it isn't necessary to use high power LEDs.
Please check, if there is no possibility to use mid power LEDs in your design.

High power LEDs are ideal for point light sources or for area light sources, in which a high luminous flux is required.

For area illumination in which a moderate luminous flux is required (backlighting, ambient lighting, …) we recommend low and mid power LEDs.

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The user bears the responsibility for conclusions or actions, which are drawn based on this information.

If there may issues remain unresolved, a visit to our forum (**www.ledhilfe.de**) is recommended. There you can find many posts on the basics through to documentations of realized projects.

1 Basics

1.1 What's a high power LED?

A LED driven with a current of 200mA or higher or driven at a power of 1W or more is usually defined as a high power LED. These LEDs are mostly soldered onto star-shaped or 10x10mm aluminium PCBs.

Also CoB-LEDs (Chip on Board) which mostly got a ceramic baseplate and other LED modules (e.g. SmartArrays, PowerBar, etc.) with high power consumption among the high power LEDs.

1.2 Cooling

Every LED needs the ability to transfer the heat away from the chips. High power LEDs or LED modules need an additional cooling element whereas low and mid power LEDs can mostly transfer the heat out of the chip by spreading it do the copper on the PCB.

No one can give a general recommendation for a matching heat sink of an LED since the heat sink always depends on the operation (current, power) and the application (ambient temperature, installation situation) of the LED.

For LEDs in general it can be said: The cooler the LED, the better its performance and lifetime. The perfect operation temperature of a LED is 25°C.

There is a rule of thumb to quickly estimate a heat sink.
In the calculation, however, many factors are ignored, so this is a simple but also inaccurate.

In general, calculated values should never be interpreted as 100% correct.
Therefore a built construction should be thermally monitored in the first hour of operation. The temperature at the T_C-Point (temperature case) should never exceed 85°C.

WARNING:

If there is no proper thermal connection between the LED and the cooling element even the best cooling element is useless.

Cooling elements must never be mounted inside an enclosure since the heat may not be able to escape the enclosure.
Also you must never cover the cooling fins since the cooling otherwise will be deteriorated.

1.2.1 Rule of thumb

A quick estimation of the required heat sink can be done with the following equation:

$$R_{thKK} = \frac{\partial_{LED\,max} - \partial_{U\,max}}{I_{LED} \bullet U_{LED}}$$

R_{thKK} ... thermal resistance of the cooling element (in K/W)
∂_{LEDmax} ... max. LED temperature (mostly 85°C)
∂_{Umax} ... max. ambient temperature
I_{LED} ... operating current of the LED
U_{LED} ... forward voltage of the LED

This estimation is just a rule of thumb and therefore not fully reliable.
The max. ambient temperature may be assumed as 35°C (or more, depending on your region), since the LED should also survive a warm summer without any thermal damage.

When choosing a cooling element it's always a good idea to choose one with a thermal resistance that is less than the calculated value.

In this equation the internal thermal resistance of the LED and the alignment of the cooling element isn't taken to account.

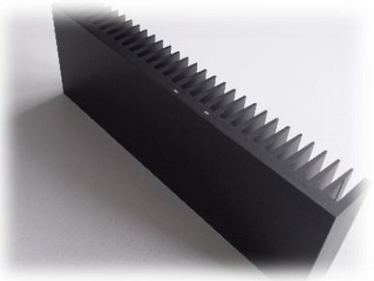
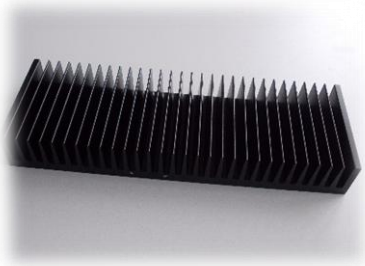
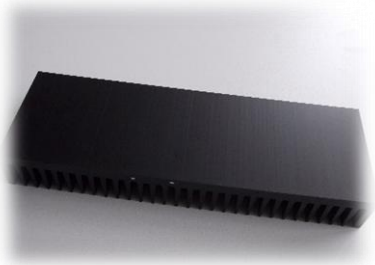
1.3 Full equation

To fully calculate a matching cooling element the following values need to be taken into account:
- Internal thermal resistance of the LED module/the LED and PCB
- Alignment of the cooling element

Also the efficacy of the LED can be also added into the equation, which leads to a smaller cooling element.

The thermal resistance of a LED or a LED module is mostly mentioned in the datasheet.

The efficacy of the cooling element depending on its orientation is about

Orientation	Efficacy (typ.)	Orientation
	100%	70% 
	85%	60% 

Therefore the internal thermal resistance of the LED has to be subtracted from the result of the rule of thumb and the result of that has to be divided by the efficacy of the cooling element.

$$R_{thKK} = \left(\frac{\partial_{LED\,max} - \partial_{U\,max}}{I_{LED} \bullet U_{LED} \bullet (100\% - \eta_{LED})} - R_{thLED}\right) \div \eta_{KK}$$

R_{thKK} … thermal resistance of the cooling element (in K/W)
∂_{LEDmax} … max. LED temperature (mostly 85°C)
∂_{Umax} … max. ambient temperature
I_{LED} … operating current of the LED
U_{LED} … forward voltage of the LED
η_{LED} … efficacy of the LED
R_{thLED} … internal thermal resistance of the LED
η_{KK} … efficacy of the cooling element

As mentioned above the temperature of a construction should be monitored for at least one hour of operation. This measurement should of course be done, when the construction is installed as it will be in further operation.

1.4 Assembly

The high power LEDs need to be mounted on the cooling elements.
To do this there are different possibilities:

The LED(s) may be sticked to the cooling element by using thermal adhesive. When the thermal compound has been dried out, the LED cannot be removed from the cooling element without causing damage.

If the LED should be easy to replace they can – depending on the shape of the PCB – hold in place by screws.
To get a proper thermal connection a thin layer of thermal compound shold be used between the LED and the cooling element.

CoB modules should always be sticked on the PCB with thermal adhesive, since the ceramic PCBs often crack and so destroy the CoB modules when the screws are tightened to strongly.

Thermal adhesive or thermal compound don't conduct the heat as good as aluminium does, but it conducts it way better than air. Therefore thermal adhesive and thermal compound should always only be applied very thin so that it can compensate the uneven surface of the materials.

Surplus material can be pressed out by pressing and moving the LED or the LED module on the cooling element.

When there is a bad thermal connection between the cooling element and the LED the LED can overheat without a noticeable temperature rise of the heat sink.

1.5 Selection of the constant current source (CCS)

High power LEDs are always powered by constant current sources (unless they are developed for use on constant voltages). Constant current is delivered by a constant current source at which the High power LEDs are always connected in series so that the current trough all LEDs is the same.
How many LEDs a constant current source can power depends on the output voltage area of the source.

For constant current sources there are at least two information given:
- Constant output current
- Output voltage area
    - minimal output voltage
    - maximal output voltage

To choose the right constant current source for your application you have to define the luminous flux and the matching LED.

By using the technical specifications of the LED you can determine, which current is needed to obtain the desired luminous flux.

LEDs should be driven at their typical current or below, unless this is not possible in your design. The resulting advantages are a better efficacy and also a longer lifetime of the LED.

Usual currents are: 350mA, 700mA, 1050mA, 1400mA, 1750mA

If several LEDs are used, they are connected in series and so the voltage of the LEDs add up.

After this selection a constant current source can be selected.
It has to deliver the required current and the required voltage has to be within the output voltage area of the constant current soured.

Ideally the minimum output voltage is at least 2V below the required voltage.
Also the maximum output voltage should be 2V above the required voltage.

If the construction should be dimmable, the constant current source must support dimming. Further information for dimming can be found in 1.6 Dimm.

TIP: Lower operating currents extend the lifetime of the LEDs.

WARNING: Voltages over 120V(DC) are extremely dangerous!
If such a voltage would be needed to drive all LEDs in series, you should make smaller rows to get below 120V(DC) and power the LEDs from more than one constant current source.

1.6 Dimming

To dim LEDs or LED modules driven by a constant current source it is required, that the constant current source supports the dimming-technique you want to use.
This can be 1-10V, PWM-signal, Resistance, DALI, phase cut or something else.

It is **not** possible to connect a dimming module (e.g. PWM) between the constant current source and the LED.

1.7 Connection

The high power LEDs or LED modules are directly connected to the output of the constant current source. Since the output current is already constant, there are no further components needed.

The installation of the constant current source to the mains has to be done by a electrician.

WARNING:
In general a constant current source should only be powered up, when there is a load (LEDs) connected.
Also you must never connect LEDs to a running constant current source. This may destroy your LEDs instantly, since the constant current source will deliver full power when connecting the LEDs!
Always switch off the power to the current source before handling it.

2 Example

An example will be added soon.

3 FAQ

Q: Why do I need to cool an LED, when a light bulb is getting way hotter?
A: *A light bulb is a so-called thermal radiator and needs the heat to produce light. The temperatures inside such a light bulb can exceed 2.000 °C.*
A LED on the other hand has got a completely different structure and should be kept as cool as possible.

Q: The temperature of my LED exceeds 85°C, is that acceptable?
A: *From 85°C case temperature the lifetime of an LED shortens rapidly.*
T_C means the temperature of the case and is mostly marked on the PCB and is the spot, where the temperature of a Module has to be measured.
If you can accept the decrease of the lifetome (down to a few seconds), you can drive the LED at higher temperatures.

F: Is *this* LED dimmable?
A: *The LED itself is always dimmable. The dimmability is usually only limited by the used constant current soured.*

F: Can I use a PWM module between the constant current source and the LED?
A: *As mentioned above it is not possible to connect a dimmer between the constant current source and the LED(s).*

F: My LEDs are flashing, did I break something?
A: *In most of the cases a flashing LED is the result of a bad chosen constant current source. Please check the output current and the outpult voltage area.*

F: The LED refused to work after a few seconds, whats wrong?
A: *This may be a problem of overheating because of a bad chosen cooling element, a missing cooling element or a bad thermal connection between the LED(s) and the cooling element.*

To be continued …

4 Sicherheitshinweise

- Installationen an 230V dürfen nur von Fachpersonal erfolgen.
- Es sollten nur Konstantstromquellen verwendet werden, deren Ausgangsspannung SELV (= Schutzkleinspannung) ist.
- Wenn Sie sich nicht 100% sicher sind unterlassen Sie den Aufbau und halten Sie Rücksprache mit einer fachkundigen Person.

To be continued …