WhitePaper LED

LED Basics

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Introduction
Light Emitting Diode

Module LLE ADV5

Module SLE G7

Module LLE-FLEX

LED is a semiconductor based light source which significantly differs from conventional light sources. Unlike conventional luminaires where light is produced by a filament or gas, LEDs are tiny electronic chips made of specific semiconductor crystals. This principle of light generation offers many advantages and new opportunities.

The main advantages of LEDs include long lifetime, high efficiency, environmental friendliness, good colour rendering and a wide variety of design options.To make use of its full potential, light designers must be familiar with these new and specific characteristics of the LED. This document explains the most important concepts, techniques and possibilities.

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Parameters to determine the light colour
The different colour spaces of light

The light generated by an LED module can be described by its parameters colour rendering, colour temperature, chromaticity coordinate and colour consistency. The following section explains the relation and differences.

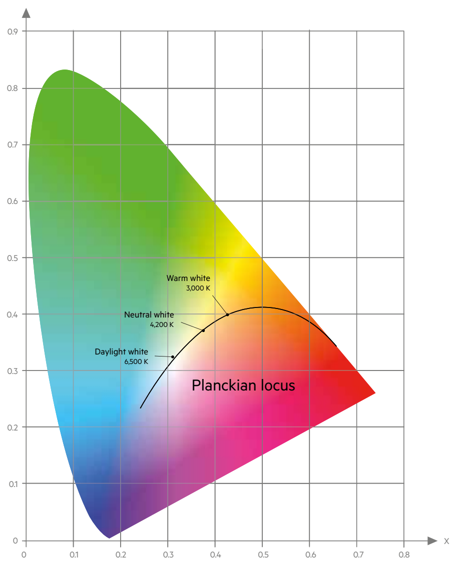
Colour rendering
Colour rendering describes how well a light source reproduces the different colours of an illuminated object. There are different methods for evaluating colour rendering and different parameters which result from that.

Colour Rendering Index (CRI)
The Colour Rendering Index (CRI) is determined using a reference colour chart with 8 standardized test colours. Depending on the deviations between the secondary spectra and the test colours, the light source is assigned to a particular CRI. If the colours are reproduced badly, the deviations are large and the CRI is low. With good colour rendering the deviations are small and the CRI is high.
TM-30 is a newer method which is more detailed and contains more information.
To determine colour fidelity, 99 colour evaluation samples (CES) are used. The resulting Fidelity Index Rf can be between 0 and 100. A value of 100 indicates an exact match with the reference.

A second parameter, the Gamut Index Rg, provides additional information about the average relative saturation.
Various graphics help to interpret the results.
The maximum value of the CRI is 100. This corresponds to a colour rendering without any deviation. Sunlight has a CRI of up to 100, a white LED lies between 70 and 98. For practical use, this means that LED lighting units with a higher CRI reproduce the illuminated colours more naturally and more pleasing to the human eye. In certain applications (e.g. the lighting of works of art in museums), this point is of crucial importance.

Colour temperature
The colour temperature is a measuring unit that describes the colour of a light source. It is measured in Kelvin (K). The most common luminaires have colour temperatures below 3,300 Kelvin (warm white), between 3,300 and 5,000 Kelvin (neutral white) or above 5,000 Kelvin (daylight white).

The colour temperature is determined by comparing the light source with the colour of a black body radiator. This is an idealized body which absorbs all light and has no reflected radiation. If a black body radiator is slowly heated, it passes through a colour scale from dark red, red, orange, yellow, white to light blue. The colour temperature of the light source is the temperature in Kelvin where the black body radiator shows the same colour. If you transfer the different colours of the black body radiator into the chromaticity diagram and connect them, you get a curve which is referred to as "Planckian locus" or "Black body curve".



Planckian locus with the prevalent colour temperatures within the chromaticity diagram

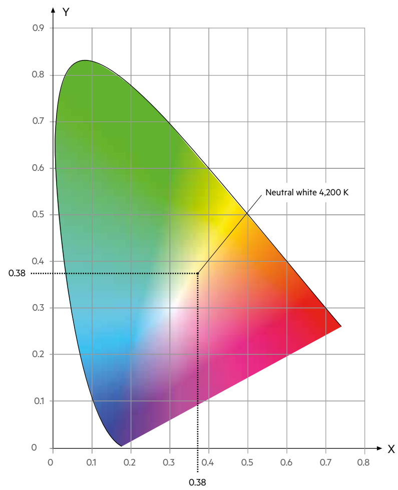
Chromaticity coordinate

The chromaticity coordinate defines a colour by its coordinates within the chromaticity diagram. There are three coordinates (x, y, z). Since the sum of all coordinates always equals 1, two coordinates are sufficient to locate a colour. The chromaticity coordinate allows for a more precise definition of colour than the colour temperature. It can be used to specify a desired colour or to designate undesired deviations between colours. This is specifically important in areas where the lighting must produce a specified and uniform colour and deviations can impair the visual appearance of an installation.

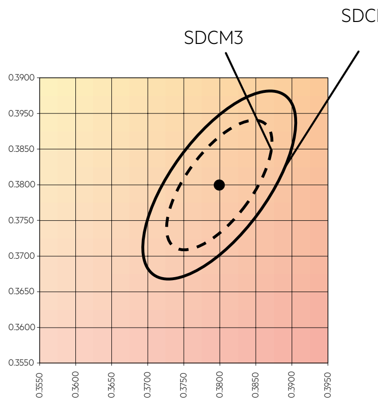
Colour consistency

The colour consistency describes the maximum deviation from a target colour. Its unit is called “SDCM” (short for “Standard Deviation of Colour Matching”). The SDCM value refers to the chromaticity diagram and the MacAdam ellipses.The MacAdam ellipses are named after their discoverer and highlight areas within the chromaticity diagram in which humans can perceive no differences in colour. Different levels of MacAdam ellipses are also used to classify colour deviations. MacAdam1 would be a very small ellipse with a narrow range of different colours. With increasing numbers (MacAdam1, MacAdam2 etc.), the ellipses and the differences between the colours become greater.

SDCM1 or MacAdam1 means that the colour deviations of an LED module must be within a MacAdam1 ellipse around the defined chromaticity coordinate. A larger deviation with a chromaticity coordinate outside the MacAdam1 ellipse (but within the next larger MacAdam2 ellipse) would lead to a classification as SDCM2 or MacAdam2. Colour deviations in the range of SDCM1 are practically imperceptible to humans. A value of SDCM3 represents a good compromise and has established itself as a kind of standard.



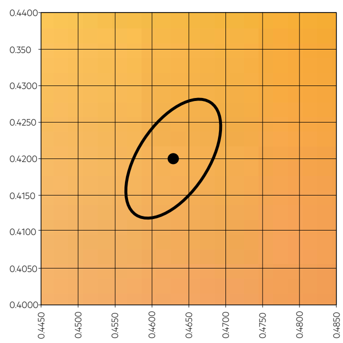
Definition of the colour temperature neutral white by the x and y coordinates (x=0.38; y =0.38) within the chromaticity diagram



Chromaticity coordinate of the colour temperature neutral white (x=0.38; y=0.38) with the MacAdam ellipses SDCM3 and SDCM5

Practical example

Colour-related specifications from the data sheet of a Tridonic LED module: Colour temperature (2,700 K), chromaticity coordinates (defined by the x=0.463; y=0.420 coordinates), colour consistency (SDCM3), and a graphical representation of chromaticity coordinate and MacAdam ellipse.

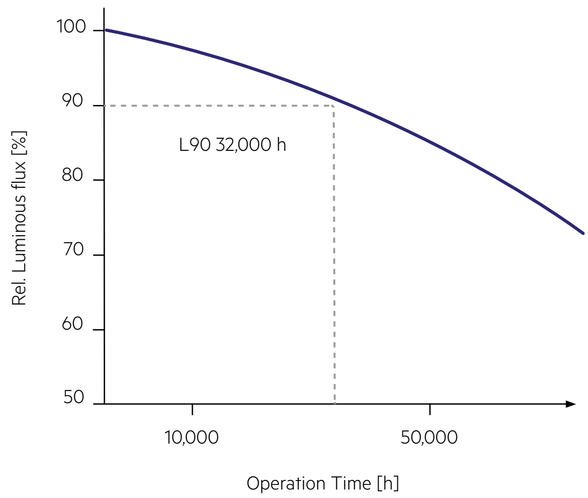


Lifetime of LEDs
High efficiency and a long life span

For conventional technologies, the lifetime is defined as the point at which a certain percentage of lamps show a complete, lights-out failure. For LEDs this definition is not practical. A well designed LED package typically doesn't fail completely. Instead it can operate extensively but will lose luminous flux continuously over time. Accordingly, lifetime definitions for LEDs use different parameters to describe the behaviour of the LED.

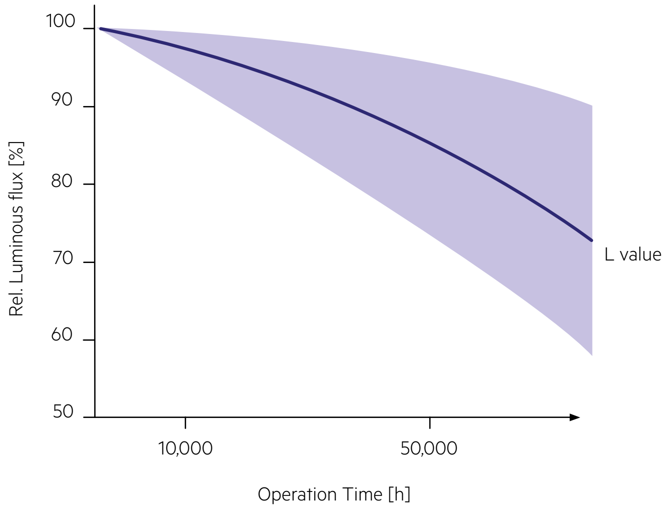
L value (L_p)

L_p defines the remaining luminous flux as a percentage of the original value. L_p is used in combination with a defined operation time. The following graph illustrates this: The cyan-coloured line depicts the luminous flux. This is gradually going down. After 32,000 hours the value has fallen to 90 %. This is defined as L90 at 32,000 hours.

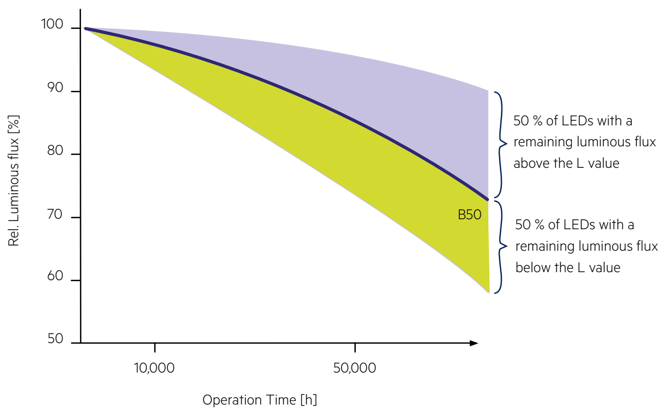


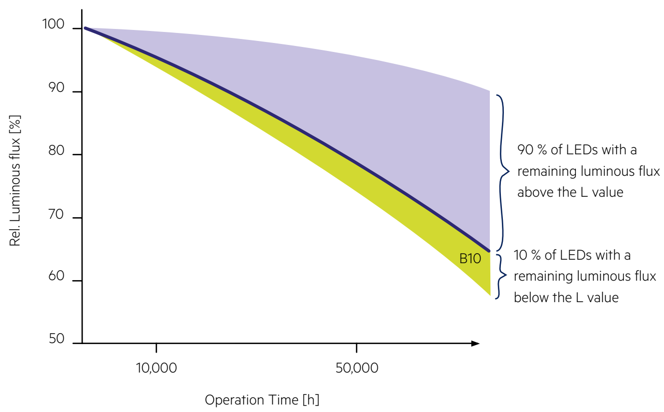
B value (B_p)

In real life the luminous flux cannot be described as a single line. There are deviations between different LED modules. The following graph illustrates this: The cyancoloured line depicts the luminous flux of some of the LED modules. The light blue area shows the bandwidth of all LEDs. Some LEDs have values above, some below.



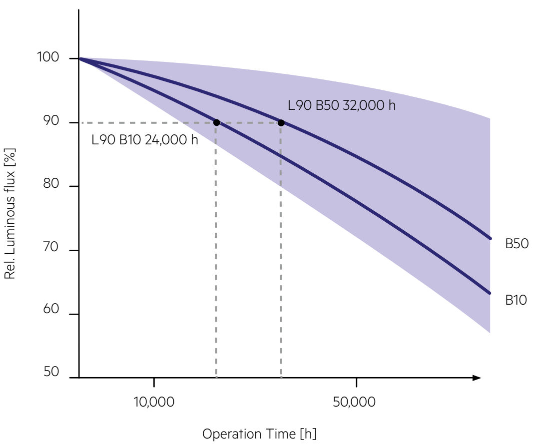
B_p defines the percentage of LED modules that fail to achieve the specified L_p. With a lower B_p the demands for lifetime get higher. For a complete assessment of an LED module both values, L_p and B_p, must be considered equally. The following graphs show the behaviour for two typical values: B50 and B10.





Combination of L_p and B_p

The combination of L_p and B_p can be seen in the following graph. It shows two possible descriptions for the same behaviour, depending on what was chosen as initial value.



When combining L90 B50 32,000 h, 50 % of the LEDs have a remaining luminous flux that is less than 90 % of the original value after 32,000 operating hours. When combining L90 B10 24,000 h, 10 % of the LEDs have a remaining luminous flux that is less than 90 % of the original value after 24,000 operating hours.

There are two more values.

C value (C_p)

C_p depicts the percentage of total failures.

F value (F_p)

F_p depicts the combined failure fraction. This is the combination of both gradual (B_p) and total failures (C_p).

Energy efficiency of LEDs

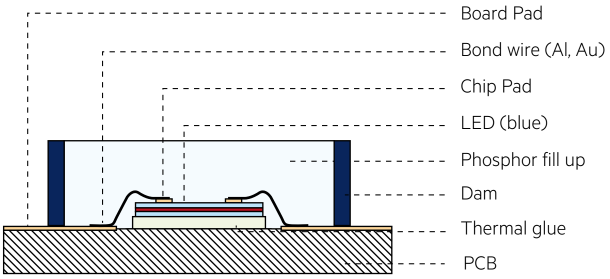
LED luminaires are very energy efficient. The energy efficiency is defined as the quotient of the luminous flux emitted and the electrical power. The measured initial luminous flux is divided by the measured initial input power. The energy efficiency is given in lumens per watt (lm/W). Energy efficiency should always relate to the system as a whole and clarify which temperature was chosen as reference. The temperature strongly influences energy efficiency.

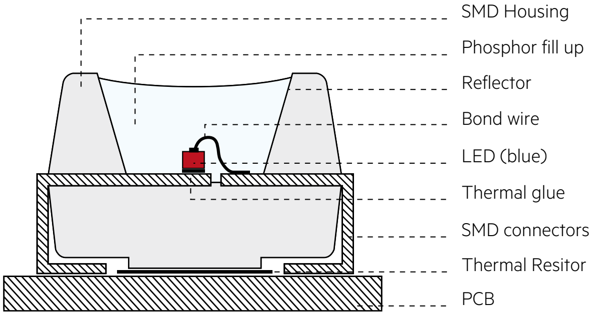
Different LED layouts

Chip on board (COB) and Surface mounted device (SMD)

There are two main techniques for mounting LEDs to the surface of a printed circuit board. Chip on board technology means the different components of the LED (chip, fluorescent converter, wire bond) are built together on the printed circuit board. SMD technology means the different components of the LED are pre-fabricated. The unit is soldered to the printed circuit board as a whole.

The decision as to which of the two technologies is used mainly depends on the proposed application. Typically SMD is more often used for area modules whereas COB is used for spot modules. Another factor is production costs. COBs are more complicated and more expensive to produce. This disadvantage is levelled out by better qualities in terms of thermo management and luminous density.





Chip on board technology (COB)

In the case of chip on board technology, "naked" unpackaged semiconductor chips, known as "dies", are attached directly to the circuit board by means of an adhesive with high thermal conductivity and connected to the pads on the circuit board via "wire bonding". Gold wires with cross sections in the micrometre range are used for making electrical contact. The open parts are covered with a potting compound to protect them from mechanical exposure and pollution. For this, the so-called dam and fill technique is used. First, a dam is drawn around the components with a viscous fluid. Subsequently, the intermediate space is filled with a liquid, which hardens afterwards.

Surface mounted device technology (SMD)

SMD LEDs are designed for automatic population of circuit boards and extremely low-profile and narrow modules. Encapsulated SMD LEDs are fixed directly onto the circuit board with adhesive. Electrical contact is made in a solder pot. These components meet the requirements of general lighting applications such as the quality of light and thermal management. The disadvantage of this technology is that the packaging and solder increase their thermal resistance. What's more, the packing density on the LED chip is less than can be achieved with COB technology.

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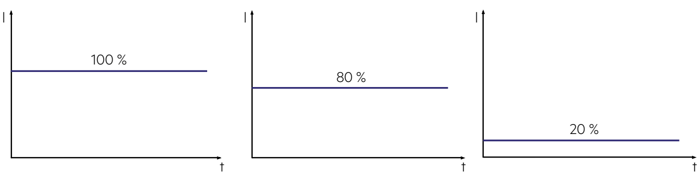
Dimming of LEDs

Analog dimming and pulse width modulation

From a technological point of view, LEDs can be dimming very well in principle. The reduction of the luminous flux is done by reducing the forward current that flows through the LED.

Dimming can show differences in the light output of different LEDs or displacements in the colour location. However, these limitations only occur at low brightness values, are the same for all light points and are practically imperceptible to the human eye.



Analog dimming with different dimming levels

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ZHAGA

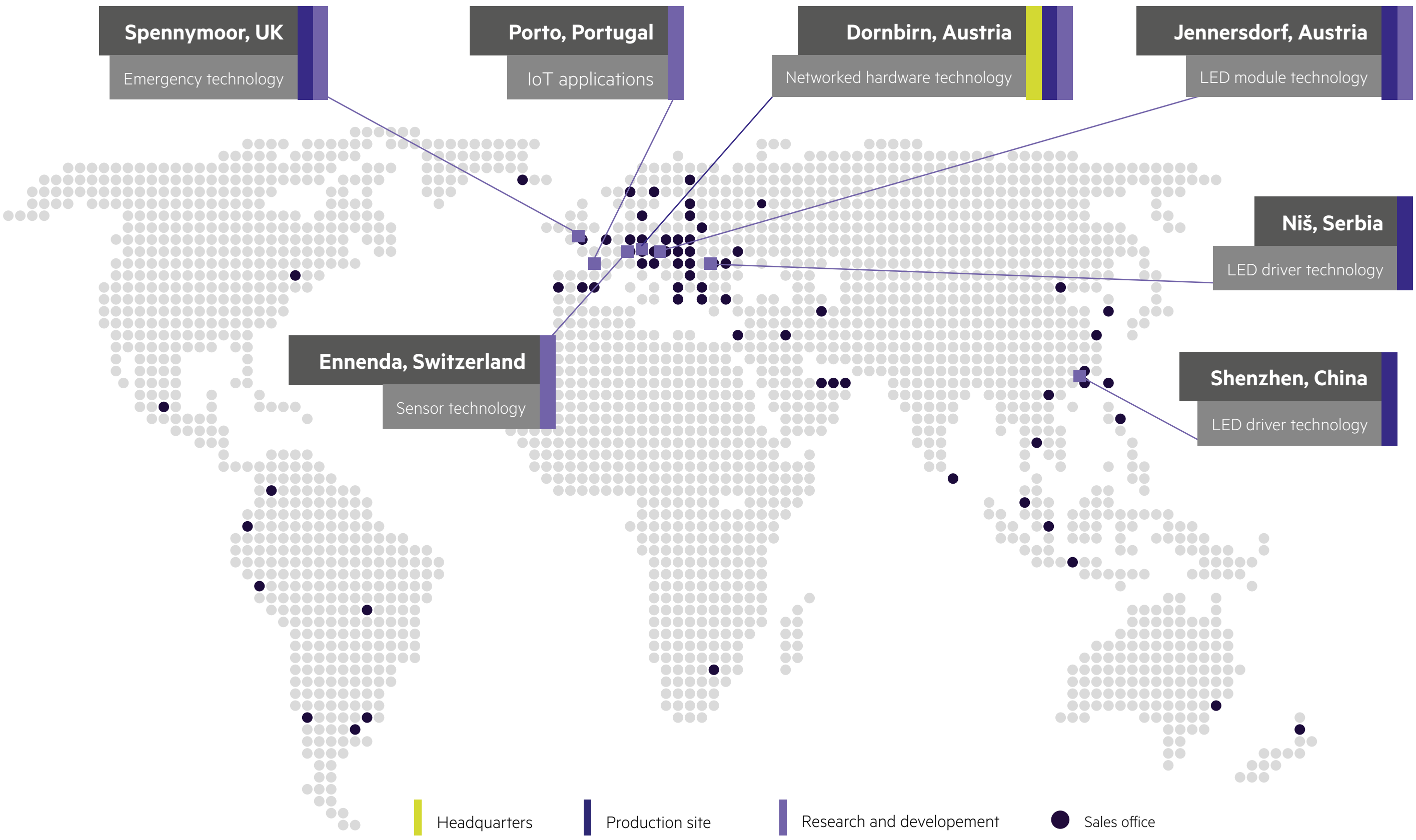
Compatibility of LED light sources

Zhaga is a consortium, initiated in 2010, which takes care of the needs of LED lighting and its standardization. It is active worldwide and has more than 190 member companies.

The aim of the Zhaga consortium is to ensure interchangeability and compatibility of LED luminaires between different manufacturers. To this end, Zhaga defines standards for the interfaces of the various lighting fixtures and holders. This includes the physical dimensions of the lamp base, as well as the photometric, electrical and thermal behavior of LED luminaires. These standardizing measures help to make products comparable, a step that both the manufacturing industry and the consumers benefit from.

Zhaga Making LED light sources interchangeable.

Prepared for the Future
Our Activities and Locations



1.778

Around 1,700 employees throughout the world are committed to helping you with their know-how and creativity to create the perfect light.

6

There are six research and development centres in which new LEDs and networked lighting technologies are being developed.

3

There are three things you can rely on at Tridonic: optimum product quality, decades of expertise and our committed and flexible support.

1

In our unique software competence center in Porto (Portugal), information technology experts are developing new solutions for smart buildings and smart cities. They are working on a range of products from intelligent lighting management and control systems to highly advanced IoT solutions and their matching digital services.

21

With 21 branch offices on five continents we are there for you wherever you are in the world.

2.600

That's how many patents and inventions testify to Tridonic's extraordinary powers of innovation.

Details

For further information, data sheets, product catalogues and ordering details, please go to www.tridonic.com

Close light

We attach great importance to a strong international presence – this allows us to stay sufficiently close to our customers

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