

PUBLICLY AVAILABLE SPECIFICATION



Zhaga interface specification Book 1 and Book 10

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PUBLICLY AVAILABLE SPECIFICATION



Zhaga interface specification Book 1 and Book 10

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ZHAGA INTERFACE SPECIFICATION BOOK 1 AND BOOK 10

FOREWORD

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The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
34A/2194/DPAS	34A/2204/RVDPAS

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INTRODUCTION

This PAS is a reproduction of Zhaga Book 1 Edition 1.8 and Book 10 Edition 1.0 with no changes introduced.

The document layout, terms and definitions, etc within this PAS therefore do not follow the normal IEC drafting rules that would be applied for an International Standard.

Subdivision 1 comprises Zhaga Book 10 Edition 1.0 – Circular LED modules for spot lighting.

Subdivision 2 comprises Zhaga Book 1 Edition 1.8 – Overview and common information, which is essential to the interpretation of Zhaga Book 10 (and future Zhaga books).

The future intention is for the content of this PAS to be incorporated within one or more International Standards and at this time any conflict with IEC Directives and drafting rules will be addressed.

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Subdivision 1

Zhaga Interface Specification Book 10

Summary (informative)

Background

The Zhaga Consortium is a global lighting-industry organization that aims to standardize LED light engines and associated components such as LED modules, Holders and electronic control gear (LED drivers).

Zhaga has created a set of interface specifications, known as Books. Each Book defines an LED light engine and/or associated components by means of the mechanical, photometric, electrical, thermal, and control interfaces of the product to its environment. This makes such products interchangeable in the sense that it is easy to replace one product with another, even if they have been made by different manufacturers.

Contents

The LED Modules defined in this Book have an essentially circular outer shape with a small, also preferably circular Light Emitting Surface, so that they are well suited to be used with collimating Luminaire Optics in spot lighting applications. The LED Modules are disc shaped, and are grouped into several size categories, to allow for different LES sizes and flux categories. The LED Modules are intended to be used with a separate Electronic Control Gear, which is specified in Zhaga Book 13.

This Book should be read together with Zhaga Book 1.

Intended Use

The LED module defined in this specification is intended to be screwed to a heat sink and to be connected to a separate electronic control gear. The light output is essentially Lambertian to enable the luminaire optics to shape the application's desired light distribution from a defined input.

The LED modules defined in this Book 10 are intended to be installed and replaced by luminaire manufacturers only.

1 General

1.1 Introduction

The Zhaga Consortium is a global organization that aims to standardize LED Light Engines and associated components. An LED Light Engine is a light source for general lighting that is based on solid state technology, and typically consists of one or more LEDs combined with Electronic Control Gear. Examples of associated components are LED Modules, Electronic Control Gear, and Holders. Zhaga has created a set of interface specifications, known as “Books” defining interfaces between LED Light Engines, associated components and Luminaires.

Book 1 is a special Book that provides common information relevant to all other Books in the series. In addition, Book 1 defines requirements and compliance tests which are applicable across multiple Zhaga Books. The Books refer to these requirements and compliance tests as applicable.

1.2 Scope

This Book 10 defines interfaces between LED Modules, associated components (Holders) and luminaires. Not all interface descriptions are applicable to LED Modules or Holders, but where applicable they are identical.

The scope of the interface descriptions is focused on a range of LED Modules with a circular shape and high luminance LES. A LED Module is intended to be fixed to a luminaire heat sink by means of screws. Its light output distribution is primarily Lambertian, to enable Luminaire Optics to shape an application-specific light distribution independently of that of the LED Module.

Zhaga Book 12 defines an LED (Chip on Board) Array component, which shares certain interface descriptions with this Book 10 (mainly photometric). It is possible to combine a Book 12 compliant LED Array with a Holder that ensures mechanical and electrical fit of the assembly. The Holder provides its own set of mechanical/electrical/thermal interfaces to a luminaire. If these interfaces are compliant with the interface descriptions in this Book 10, the Holder+LED Array assembly can be used in the same way as an LED Module compliant with this Book. Thus this Book can also be used to check compliance of Holders with respect to the Holder-Luminaire interface.

This Book 10 defines several size categories of the LED Module

- 35 mm, 50 mm maximum outer diameter

The size categories can have different LES diameters and different LES categories:

- LES6.3, LES9, LES13.5, LES19, LES23

The LED Modules are intended to be installed and replaced by professionals only.

1.3 Conformance and references

1.3.1 Conformance

All provisions in the Zhaga interface Specifications are mandatory, unless specifically indicated as recommended, optional or informative. Verbal expressions of provisions in the Zhaga interface specifications follow the rules provided in Clause 7 of ISO/IEC Directives, Part 2:2018. For clarity, the word “shall” indicates a requirement that is to be followed strictly in order to conform to the Zhaga interface specifications, and from which no deviation is permitted. The word “should” indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is discouraged but not prohibited. The word “may” indicates a course of action

permissible within the limits of the Zhaga interface specifications. The word “can” indicates a possibility or capability, whether material, physical or causal.

1.3.2 References

For references that are not listed in this section, see [Book 1]. For undated references, the most recently published edition applies.

[Book 1] Zhaga Interface Specification, Book 1: Overview and Common Information

[Book 12] Zhaga Interface Specification, Book 12: Rectangular LED arrays with circular LES and corresponding Holders

[CIE 52] Calculations for interior lighting – Applied Method, CIE 52

1.4 Definitions

This section defines terms that have a specific meaning in the context of this Book 10. Terms that have a specific meaning across all Zhaga Books are defined in [Book 1].

Book-10 LED Module	LED Module according to the specifications in this book.
LED Module Demarcation	The mechanical boundary between an LED Module and its environment.
Spot Application	Application of a Luminaire in which light is to be focused to a beam with FWHM of typically $<40^\circ$.
LED Array	A light source that is supplied as a single unit and intended to be used in combination with a Holder to build a LED Module. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.

1.5 Acronyms

This section defines acronyms that have a specific meaning in the context of this Book 10. Acronyms that have a specific meaning across all Zhaga Books are defined in [Book 1].

TTE-Spot Thermal Test Engine for Spot LED Modules

1.6 Symbols

This section defines symbols that have a specific meaning in the context of this Book 10. Symbols that have a specific meaning across all Zhaga Books are defined in [Book 1].

$\langle H_{OCA} \rangle$	Average height of the OCA (unit: mm)
L_i	Average Luminance in Area i (unit: cd/m^2)
S	Luminance rotational symmetry parameter
U	Luminance uniformity parameter
N	Number of Luminaire camera pixels within LES

1.7 Conventions

This section defines the notations and conventions used in the Zhaga Interface Specifications.

1.7.1 Precedence

In the case of any perceived discrepancy between the definitions provided in Part 1 of this document, Interface Definition and the definitions provided in Part 2 of this document, Compliance Testing, the definitions provided in Part 2 take precedence over the definitions provided in Part 1.

1.7.2 Cross references

Unless indicated otherwise, cross references to sections include the sub sections contained therein.

1.7.3 Informative text

Informative text is set in italics, unless the whole section is marked as informative.

1.7.4 Terms in capitals

Terms that have a specific meaning in the context of this Book 10 are capitalized. See section 1.4.

1.7.5 Units of physical quantities

Physical quantities are expressed in units of the International System of Units. All lengths that omit an explicit unit indication are in millimeters.

1.7.6 Decimal separator

The decimal separator is a comma.

1.7.7 Limits

Values that are indicated as typical, as well as values between parentheses, are informative.

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2 Overview (Informative)

2.1 General

General information with respect to the Zhaga Interface Specifications and certification of products that comply with this Book 10 can be found in [Book 1], section 2.

If components are treated differently in a section, this will be marked at the beginning. Possible components are:

- LED Module
- LED Array Holder which forms an LED Module, using suitable Zhaga compliant LED Arrays

2.2 Description of the LED Module and LED Array Holder

This Book 10 defines an LED Module typically applied in spot lighting applications. The LED Module or Holder is to be mounted onto or into a Luminaire by an OEM Luminaire manufacturer typically by means of M3 screws.

The LED Modules defined in this Book 10 have preferably a circular Light Emitting Surface. In case of a LED Array Holder, the Zhaga compliant LED Array will have this Light Emitting Surface.

The outline of the LED Modules and Holders described is essentially round. Three maximum outer diameters are possible, corresponding to two LED Module categories:

- D35 (35 mm maximum outer diameter)
- D50 (50 mm maximum outer diameter)

Adjacent to the Light Emitting Surface is a mechanical surface, called the Optics Contact Area (OCA) which serves as reference for Luminaire Optics.



Figure 0-1 – Example 3D-drawing of a Book 10 D35 LED Module (informative)

The Luminaire typically includes the means to guide heat away from the LED Module in order to keep the temperature of the LED Module at a level necessary to reach the performance and lifetime specified by the LED Module manufacturer. To ensure this capability, testing procedures as well as certification and marking specifications are defined in this document.

The light output of the LED Module itself does not have a 'spot light' distribution but a general distribution (defined in section 0) which can be tailored into a specific distribution by means of Luminaire Optics. The photometric interface of the LED Module is specified here in such a way that using suitable Luminaire Optics, similar Luminaire performance in spot applications is to be expected using different LED Modules with the same LES category. The specification has been carefully evaluated to yield as similar performance as possible without restricting the inner

structure of the LED Module or the LED technology used inside. This has been done to leave as much room as possible for technical innovation in this field.

2.3 Outline of this Book

This Book 10 consists of two parts:

Part 1, Interface Definition, defines the LED Module-Luminaire interface and LED Array Holder-Luminaire interface in terms of the four sub interfaces:

- The mechanical interface (section 0).
- The photometric interface (section 0).
- The electrical interface (section 0).
- The thermal interface (section 0).

Part 2, Compliance Tests, defines:

- Specific tools, which are used for testing compliance of a LED Module or a Luminaire (section 0).
- The LED Module tests (section 0).
- The Luminaire tests (section 0).

The Annexes to this Book 10 provide the following additional information:

- Requirements on the information that shall be part of the Product Data Set (Annex A).
- Guidelines for mechanical interface test (Annex B)
- Guidelines for LES and Luminance measurement (Annex C)
- Remarks on photometric interchangeability and color effects (Annex D)
- Luminaire test tools (Annex E)

Part 1: Interface Definition

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3 Mechanical interface

3.1 Drawing principles

For the purpose of this section, the provisions in [Book 1] – section 3.1, apply. To simplify drawings and associated text, they are normally labelled only as “LED Module”. Where appropriate (as indicated in the text), the items labelled with “LED Module” can also depict a LED Array Holder for the purposes of this Book.

3.2 Mechanical references

The reference plane and the reference point of a LED Module (or LED Array Holder) with respect to (optional) TIM are defined in Figure 0-1. Dimensions are specified relative to either the reference point or reference plane unless indicated otherwise. Moreover, dimensions are specified with TIM (if present) in compressed state.

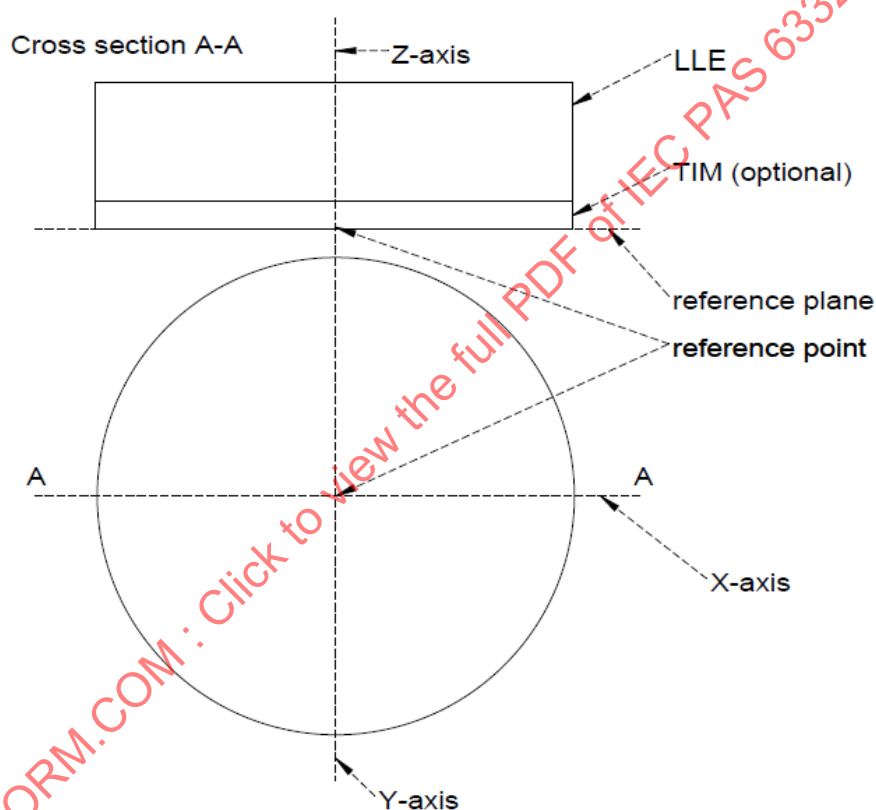


Figure 0-1 – Positions of the reference point and reference plane of the LED Module or LED Array Holder

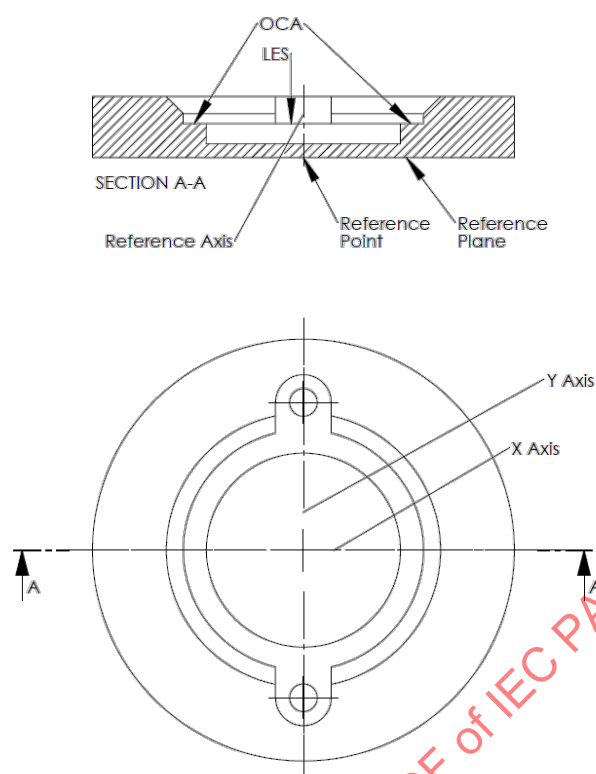


**Figure 0-2 – Positions of the reference point, plane and axis in a sketch of the LED Module (example for D50 category).
Similar for Holders, except that they do not have an LES.**

3.3 Definition of the mechanical interface of the LED Module (and Holder)

3.3.1 LED Module demarcation

The LED Module Demarcations are defined in the following section. In case of a LED Array Holder, the demarcation is verified with a recommended LED Array attached to the Holder. The assembly is treated as an LED Module for this purpose within this section.

No part of the LED Module (excluding interconnect) shall cross the boundaries of the LED Module Demarcation and no part of the Luminaire (excluding interconnect) shall cross the boundaries of the LED Module Demarcation.

In case the LED Module is applied in combination with a Thermal Interface Material, this TIM is defined to be part of the LED Module. Thus the total height of the LED Module + TIM (while compressed according to instruction from the LED Module maker) shall not exceed the maximum height H (D35 category) or g (D50 category).

Additionally, for the purpose of this section, the provisions in [Book 1] – section 3.3, apply.

3.3.1.1 D35 LED Module Demarcation

D35 LED Modules shall have a Demarcation according to the drawing in Figure 0-3 and with dimensions according to Table 0-1.

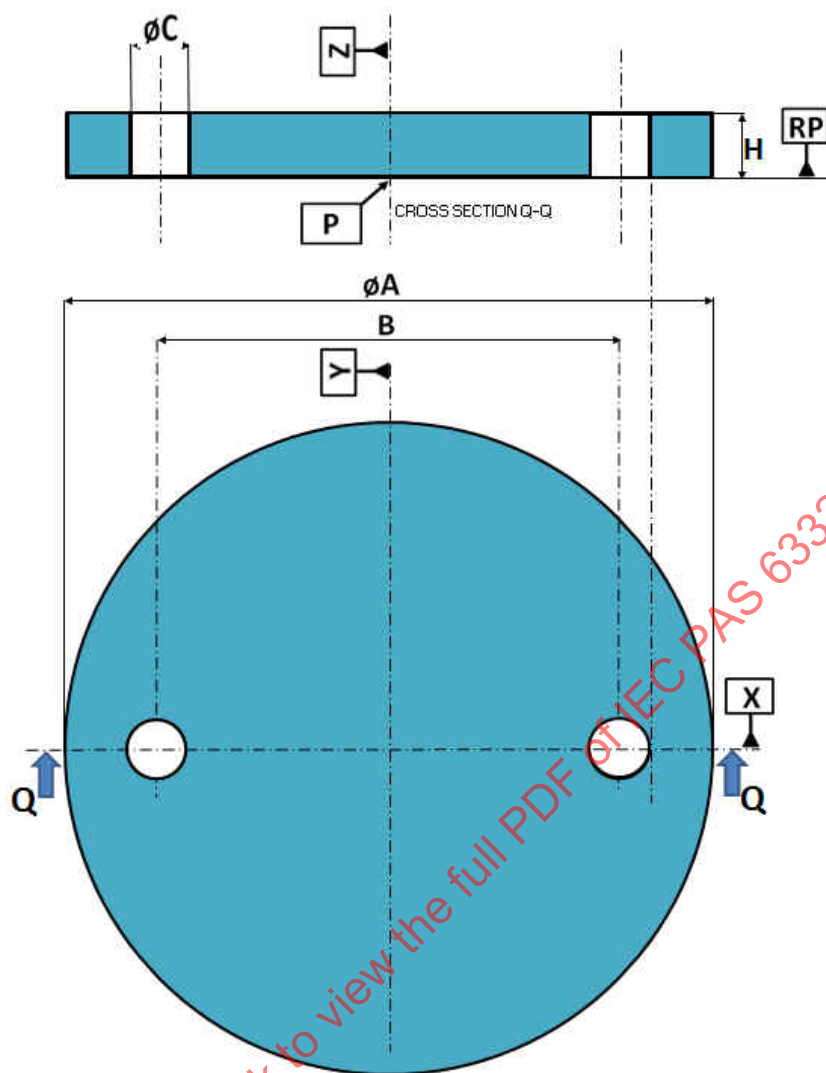


Figure 0-3 – Drawing of the demarcation of the D35 LED Module

Notes to Figure:

- (RP) Reference plane
- (X) Reference X-axis. This is a symmetry axis for the complete model.
- (Y) Reference Y-axis. This is a symmetry axis for the complete model.
- (Z) Reference Z-axis
- (P) Reference point
- The blue area indicates the keep-in zone for the LED Module and the keep-out zone for the Luminaire.

Table 0-1 – Mechanical dimensions of D35 LED Module Demarcation

Dimension	Value
ϕA	35
B	25
ϕC	3,15
H	4,0

3.3.1.2 D50 LED Module Demarcation

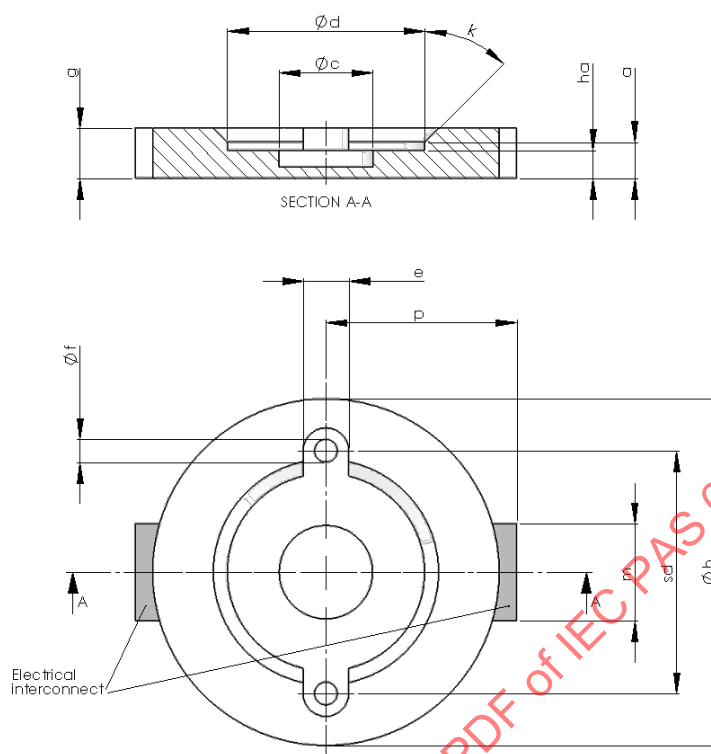


Figure 0-4 – Drawing of the demarcation of the D50 LED Module

Table 0-2 – Mechanical dimensions of D50 LED Module Demarcation

Dimension	Value	Remark
a	5,2	
e	6,4	
f	3,4	
g	7,2	Note that this is the maximum outline height, in contrast to D75
ϕh	50,25	No minimum value specified, in contrast to Book 3
sd	35	
k	45°	
m	15	
p	27,5	
ϕd	28,4	To be evaluated at actual OCA height ($<H_{OCA}>$)
ha	4	
ϕc	See Table 0-3 – Maximum inner OCA diameter	To be evaluated at actual OCA height ($<H_{OCA}>$)

D50 LED Modules including the electrical interconnect shall be within the dimension specified in Figure 0-4 and Table 0-2.

3.3.2 Optics Contact Area

The optics contact area (OCA) is used as a mechanical reference plane for Luminaire Optics. The maximum inner diameter of the OCA is determined by the LES category of the LED Module

and can be seen in Table 0-3. The minimum outer diameter of the OCA depends on the size category of the LED Module. The average height of the OCA is denoted $\langle H_{OCA} \rangle$

For D35 Modules, the minimum outer diameter of the OCA is the outer diameter of the Module (i.e. nominal 35mm). All the module surface is used as the OCA. The OCA of the LED Module features mounting holes and may also show additional recessed features. No such features (e.g. screw heads) are allowed to extend above the OCA. The average height of the OCA ($\langle H_{OCA} \rangle$) shall be in the range given in Table 0-4.

For D50 Modules, there is a fixed minimum outer diameter of the OCA, denoted by $\varnothing d$ in Table 0-2. It is measured at the actual height of the plane surface which extends between the diameters $\varnothing d$ and $\varnothing c$. A simplified image is shown in Figure 0-7. No mechanical features protruding from the OCA are allowed. The average height of the OCA ($\langle H_{OCA} \rangle$) shall be in the range given in Table 0-4.

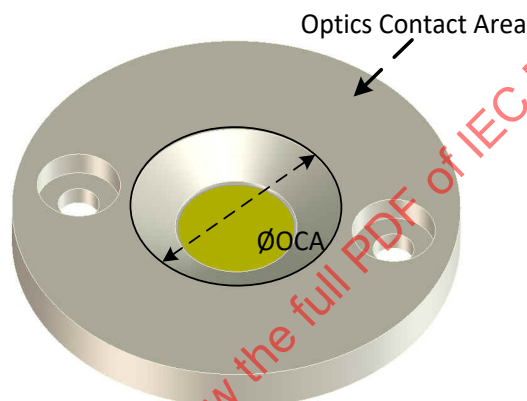


Figure 0-5 – Optics Contact Area of the 35mm LED Module

Position of the OCA in the Z-axis will be determined by the 3 highest points of the LED Module OCA (see Figure 0-6).

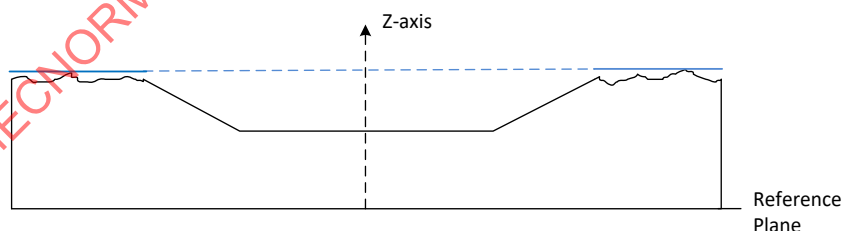


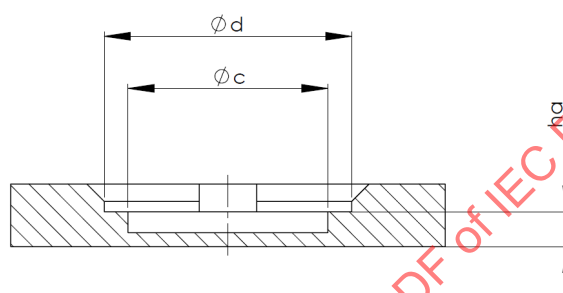
Figure 0-6 – Height of the Optics Contact Area of the D35 LED Module

Table 0-3 – Maximum inner OCA diameter

LES category	$\phi OCA_{max, c}$
LES6.3	11,67
LES9	13,67
LES13.5	19,17
LES19	23,2
LES23	26,2

(informative)

In order to have an effective landing spot for the Luminaire Optics, the OCA should be as flat as possible.

**Figure 0-7 – Dimensions of OCAs for a D50 category****Table 0-4 – Allowed minimum and maximum OCA heights within demarcation**

LED Module category	Relevant dimension in demarcation	Actual OCA height $\langle H_{OCA} \rangle$
D35	H	3,0mm – 4,0mm
D50	ha	3,5mm – 4,0mm

3.3.3 Requirements on screw holes

3.3.3.1 D35 Module

The D35 LED Module shall have either counterbored screw holes or countersunk screw holes. In either case, the LED Module maker shall specify in the PDS the screw type for which the LED Module has been designed by referencing a public standard (for example a DIN standard).

The geometry of the screw holes shall be such that a screw compliant with the specification in the PDS fits in the screw hole and the maximum height of the assembly (LED Module + screws) is less than or equal to $\langle H_{OCA} \rangle$.

3.3.3.2 D50 Module

No special requirements

3.3.4 LED Module Connection

3.3.4.1 D35 Module

No special requirements.

3.3.4.2 D50 Module

An electrical interconnect¹ should be placed symmetrically at the LED Module X axis (see Figure 0-2). The interconnect should not exceed the maximum outline given in Figure 0-4 and Table 0-2. If a Plug is used it should have a width of maximum 14 mm and a length (in plugging direction) of maximum 8 mm.

Any wires exiting the module should be within the dimension m.

3.3.5 Luminaire keepouts for interconnect

3.3.5.1 D35 Module

No special requirements.

3.3.5.2 D50 Module

The Luminaire design should foresee space for a connection as specified in section 3.3.4.

NOTE In addition to these connection keepouts, the thickness of connection wires needs to be taken into account.

3.3.6 Inner Feature

LED Modules may contain any kind of mechanical “inner feature” like light mixing elements, mechanical holding elements, electrical insulation elements, etc., provided they do not exceed a certain height.

Within the diameter ϕ_c defined in Figure 0-4, and Figure 0-8 the LED Module may contain any kind of mechanical “inner feature” provided it does not exceed the height b as defined in Table 0-5 and Figure 0-8. In particular, the inner feature may contain an extension of the OCA or even an OCA of smaller size.

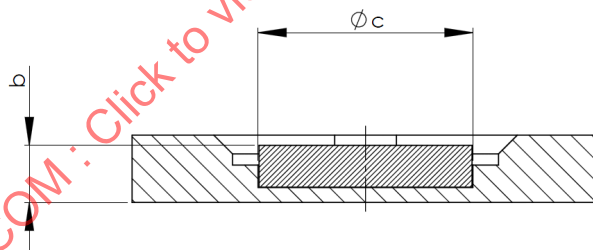


Figure 0-8 – Maximum Inner Feature outlines (dense hatched area)

Table 0-5 – Maximum height of inner feature (b)

LES Category	D35	D50
LES6.3	4,0 mm	
LES9	4,0 mm	5,0 mm
LES13.5	4,0 mm	5,5 mm
LES19		6,4 mm
LES23		7,2 mm

A dome or cover above one or more LEDs shall be allowed to exceed the height b, if optical behaviour is not changed from a similar LES without dome or cover (See section 4.2). The

¹ e.g. by means of a Receptacle / Plug system or a set of wires.

maximum height of the dome or cover shall not exceed 20 mm (measured from the Reference Plane).

3.4 Additional LED Array Holder properties (informative)

A LED Array Holder which complies to this Zhaga Book is required also to comply to the requirements laid out in Zhaga Book 12, such that it is compatible to Zhaga compliant LED Arrays as well as to Zhaga compliant luminaires.

3.5 Luminaire mechanical properties

The Module mounting surface of the Luminaire shall have a diameter of more than the demarcation diameter with means for screwing the LED Module (e.g. M3 threads or holes for self-cutting screws) at points corresponding to the LED Module geometry.

3.6 Optional “Locking Ring System” (LRS)

The 50 mm LED Module may contain features described in this section in order to enable toolless mounting by means of a holder (“locking ring”). The details of the dimensions are described in Zhaga [Book 3] Edition 1.3.

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4 Photometric interface

4.1 General

This section contains the Photometric Interface of the LED Module. LED Array Holders are not affected by the specifications in this section. The LED Module shall emit light of a Lambertian distribution in the direction of the module's reference axis. Associated to the specific light emission of the LED Module is a Light Emitting Surface characterized by its height and diameter.

4.2 Light Emitting Surface

For the purpose of this section, the provisions in [Book 1] – section 4.1, apply. The LES for Book 10 LED Modules shall be described by a circular flat plane parallel to the reference plane defined in Figure 0-1. It has a meaningful physical boundary or it is a virtual surface in the surrounding area of the LED Module.

The LES shall have the smallest possible diameter while complying with the following conditions:

- When seen from above, all light emitting parts (LED, diffuse cover and / or mixing chamber) are covered by the LES.
- It encircles all pixels in the luminance image of the LED Module that have a value >10 % of the maximum (See Annex C).

The height of the LES shall be as small as possible while complying with the condition that all light emitting parts are behind the LES, when seen in a top view. This height should be taken as a reference by the Luminaire manufacturer in designing Luminaire Optics.

The LES categories are defined in [Book 1] – section 4.1. For each LED Module category, the allowed LES categories are shown in Table 0-1. The actual LES of the LED Module shall be within the range defined by its LES category.

Table 0-1 – Association of LES Category to LED Module Category

LES Category	D35	D50
LES6.3	Yes	
LES9	Yes	Yes
LES13.5	Yes	Yes
LES19		Yes
LES23		Yes

4.2.1 Additional hints for LES features to improve interchangeability with Luminaire Optics (Informative)

- The center of the LES should not be off from the Z-axis of the LED Module by more than 1 mm in any direction.
- Inside the circular shaped LES, the LEDs could be placed in a rectangular arrangement. The aspect ratio of this rectangle should be $\geq 0,8$ to produce almost rotational symmetric light distributions even with reflectors for small beam angles. Within any direction mechanical parts of the LEDs may exceed the diameter of the OCA as long as top surface of the OCA is not intersected and all light emitting parts are within the diameter c of the OCA. The area of the light emission should be equal to the area of a circle with the diameter of the LES.
- A dome or cover above one or more LEDs should be allowed to exceed the LES height h_p , keeping the mechanical limits laid down in 3.3.6. This dome / cover should have mainly hemispherical shape.

When designing an optical system for a general Zhaga-compliant module, the typical LES height should be taken as reference. The actual LES height of an individual Zhaga Module is allowed to vary in a range shown in Table 0-2.

Table 0-2 – Categorization of LES height

LED Module Category	D35	D50
Typical LES height	2,0 mm	4,0 mm
Minimum LES height		
Maximum LES height	4,0 mm	7,2 mm

4.3 Operating conditions

For the LED Module defined in this Book 10, the operating conditions defined in [Book 1] section 4.2 apply. In addition, the mounting position of a Spot LED Module is not considered to have a significant influence on the photometric properties and can thus be chosen arbitrarily.

4.4 Luminous flux

For the purpose of this section, the provisions in [Book 1] – section 4.3 apply. The luminous flux of a LED Module shall be measured under the conditions specified in section 4.3.

4.5 Luminous intensity distribution

For the purpose of this section, the provisions in [Book 1] – section 4.4 apply. The luminous intensity distribution of a LED Module shall be measured under the conditions specified in section 4.3 with the exception that Reference Temperature may be stabilized at any temperature as only relative values are considered for the luminous intensity distribution.

It is recommended that the LED Module has a light intensity distribution that is as close as possible to a Lambertian intensity distribution. The light intensity distribution shall comply with the requirements listed in Table 0-3.

Table 0-3 – Requirements for a Lambertian light intensity distribution

γ_1	γ_2	CIE cumulative flux zones [CIE 52]	Relative Partial Luminous Flux	
			Min.	Max.
0°	41,40°	FC1	39 %	56 %
41,40°	60,00°	FC2-FC1	31 %	37 %
60,00°	75,50°	FC3-FC2	11 %	22 %
75,50°	90°	FC4-FC3	0 %	7 %

4.6 Luminance uniformity

For the purpose of this section, the provisions in [Book 1] – section 4.5 apply. The luminance uniformity of a LED Module should be measured under the conditions specified in section 4.3 with the exception that the Reference Temperature may be stabilized at any temperature as only relative values are to be considered for the luminance uniformity.

The luminance of the LED Module should be symmetric with respect to the reference Z-axis. Using the definition of the five segments A_i ($i=1\dots5$) of the LES as shown in Figure 0-1, the following symmetry parameters are defined as follows:

1) Luminance rotational symmetry

The luminance rotational symmetry parameter S is calculated from the average luminance L_i in forward direction in each of the four segments A_i ($i=1\dots4$) as $\frac{\min(L_i)}{\max(L_i)}$. Note that the definition of segments does not have a coupling with the orientation of the module. For that reason, $\frac{\min(L_i)}{\max(L_i)}$ is calculated for different orientation (see C.3) and luminance rotational symmetry (S) is defined as $S = \max(\frac{\min(L_i)}{\max(L_i)})$. The value of S should not be lower than 0,5.

2) Luminance center balance

The Luminance center balance is defined as: $B = \frac{L_5}{\text{Average}(L_1\dots L_4)}$. The value of B should not be higher than 4.

3) Luminance uniformity

The luminance uniformity U is defined as $U = \frac{L_{avg}}{L_{RMS}}$ with

L_{avg} : the average luminance over the actual LES area ².

$L_{RMS} = \sqrt{\frac{1}{N} \sum L_j^2}$: the RMS luminance values over every pixel in the actual LES area.

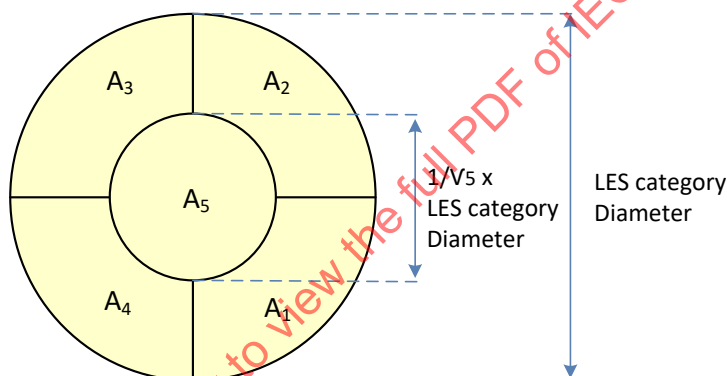


Figure 0-1 – Luminance property evaluation areas

4.7 Correlated color temperature

For the purpose of this section, the provisions in [Book 1] – section 4.6 apply. The correlated color temperature of a LED Module shall be measured under the conditions specified in section 4.3.

4.8 Color rendering index

For the purpose of this section, the provisions in [Book 1] – section 4.7 apply. The color rendering index of a LED Module shall be measured under the conditions specified in section 4.3.

4.9 Luminaire Optics (Informative)

Luminaire Optics (e.g., reflectors) should be designed in such a way that the nominal values of LES diameter and height with a Lambertian emission pattern result in the desired performance.

² For this requirement, not the LES category diameter but the actual LES diameter as given in the PDS or determined according to Annex C shall be used.

Luminaire Optics may be mounted in contact with the OCA corresponding to the LES diameter category it is designed for.

NOTE Due to the compound nature of many LED Module solutions, it is expected that Luminaire Optic designs for Zhaga compliant Spot LLEs take into account the structure of LED clusters, e.g. by using frosted surfaces or faceted structures to achieve the comparable light output with all kinds of module technologies enabled by the Zhaga Specifications. The luminance uniformity factor U of the LED Module can give a hint on the degree of effort necessary to achieve properly distributed light with Luminaire Optics.

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5 Electrical interface

This section addresses the electrical interface of the LED Module. This section does not affect LED Array Holders.

5.1 Electrical interface to the ECG

The LED Module defined in this Book 10 shall comply with the provisions of [LEDset-Inf] and [LEDset-Pow].

(Informative)

A LED Module that is compliant with [LEDset-Inf] can have either a 2-wire electrical interface (2 wires configured to be connected to a current source) or a 3-wire electrical interface (2 wires configured to be connected to a current source and the third wire is used to control the current of that current source. Moreover, such a LED Module may have additional wires and functionality as long as the LED Module can be used in the 2-wire or the 3 wire configuration as defined in [LEDset-Inf].

5.2 Electrical insulation

For the purpose of this section, the provisions in [Book 1] – section 5.1 apply.

The Product Data Set of the LED Module should include a specification of the implemented electrical insulation according to applicable standard(s).

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6 Thermal interface

This section addresses the Thermal Interface of the LED Module. It does not affect LED Array Holders.

6.1 Background information (informative)

For the purpose of this section, the provisions in [Book 1] – section 6.1 apply.

6.2 Generic thermal interface model

6.2.1 General case

For the purpose of this section, the provisions in [Book 1] – section 6.2.1 apply.

6.2.2 Rated Operating Temperature and safety (informative)

For the purpose of this section, the provisions in [Book 1] – section 6.2.3 apply.

6.2.3 Thermal overload protection

For the purpose of this section, the provisions in [Book 1] – section 6.2.4 apply.

6.2.4 Thermal compatibility check

In order to determine whether a particular LED Module is thermally compatible with a particular Luminaire, it should be verified that the LED Module-Luminaire combination will operate at $t_r \leq t_{r,max}$. The value of $t_{r,max}$ is listed in the LED Module Product Data Set. Using the generic thermal model as defined in [Book 1] – section 6.2.1, the operating temperature t_r can be determined by:

$$t_r = t_a + R_{th} \cdot P_{th,rear} \quad \text{EQ. 6-1}$$

The ambient temperature t_a is determined by the application of the LED Module-Luminaire combination. The value of R_{th} is a characteristic of the heat sink. Both t_a and R_{th} should be chosen appropriately by a skilled person.

The value of $P_{th,rear}$ is not listed in the LED Module Product Data Set. However, it can be estimated, using the Rated value of P_{th} in the LED Module Product Data Set.

(Informative)

Depending on the required accuracy of the estimation of $P_{th,rear}$, the following methods may be used.

Method 1 – Ignore $P_{th,front}$

In this case $P_{th,rear} = P_{th}$

Method 2 – Estimate $P_{th,front}$ using a thermal simulation.

In this case, $P_{th,rear}$ is calculated using: $P_{th,rear} = P_{th} - P_{th,front}$ and $P_{th,front}$ is estimated using a thermal simulation of the LED Module in the specific application. This allows the characteristics of the Luminaire also to be taken into account.

6.2.5 Thermal Interface Material

For the purpose of this section, the provisions in [Book 1] – section 6.2.9 apply.

6.2.6 Surface planarity and roughness

For the purpose of this section, the provisions in [Book 1] – section 6.2.10 apply. It is recommended that the surface in the Luminaire which serves as a thermal interface has a surface planarity smaller than 0,1 mm and a surface roughness smaller than 3,2 μm .

6.2.7 Aging of LED Module (informative)

For the purpose of this section, the provisions in [Book 1] – section 6.2.11 apply.

6.3 Luminaire Thermal requirements

The Luminaire is supposed to contain features that enable the heat generated by the LED Module to be conducted to the ambient.

6.4 Compatibility check

The thermal compatibility check including an example is described in section 6.2.7 of [Book 1].

6.5 Ambient temperature and thermal resistance (Informative)

The Ambient Temperature is defined as the average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are:

- In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire.
- In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.

The thermal resistance of the Luminaire ($R_{\text{th,lum}}$) is defined as the thermal resistance from the Thermal Interface Surface to the environment. The environment corresponds to the position where the Ambient Temperature is defined.

As a consequence of these definitions, the thermal resistance of the Luminaire ($R_{\text{th,lum}}$) depends on the application of the Luminaire. The Luminaire manufacturer defines in the PDS (generally in the mounting instructions) how the Luminaire shall be applied. Next to that, the Luminaire manufacturer defines a setup for measuring the thermal resistance of the Luminaire. This setup should be a good model for the actual application of the Luminaire. Note that this measurement setup can be anything ranging from a free air setup to measurement boxes as defined by, for example UL and IEC for safety tests.

Part 2: Compliance Tests

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7 Compliance test tools

7.1 LED Module test tools

7.1.1 Test Fixture PETF (photometric and electrical)

The PETF for Book 10 LED Modules is a temperature controlled heat sink that allows for mounting the LED-Module-under-test and for attachment to the photometric measurement system.

The Thermal Interface Material to be used shall be supplied by the LED Module manufacturer when submitting the LED module for compliance test to the ATC.

7.2 Luminaire test tools

No special luminaire testing tools are defined.

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8 LED Module Compliance and LED Array Holder Tests

This section defines compliance tests to be done on LED Modules. Only the mechanical tests in section 8.1 and the PDS tests in section 8.5 are also relevant for LED Array Holders.

8.1 LED Module and LED Array Holder mechanical interface tests

8.1.1 Test of the mechanical interface of the LED Module or LED Array Holder

The purpose of this test is to verify that the LED-Module-under-test meets the requirements of the demarcation model as defined in section 3.3.1³. LED Array Holders must also pass this test, with a suitable LED Array inserted.

8.1.1.1 Test equipment

The mechanical interface should be tested with (semi) automated 3D measuring equipment such as a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

Alternatively, the mechanical interface may be tested with a gauge made of a material that ensures the accuracy mentioned below (for example 3 mm aluminum). In that case, it shall be verified that the gauge complies with the corresponding demarcation model. This verification shall be done with a (semi) automated 3D measuring equipment such as a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

8.1.1.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25 ± 5 °C.

8.1.1.3 Test procedure

- Verify that the LED-Module-under-test does not cross the LED Module Demarcation as defined in section 3.3.1. Note that such verification includes the outline of the LED-Module-under-test as well as the size, shape and position of the mounting holes within that outline. Additional guidelines for this test are provided in Annex B.
- For a LED Array Holder insert the suitable LED Array in the Holder and treat the assembly as a LED Module for the purpose of this test.

8.1.1.4 Pass criteria

The LED-Module-under-test or Holder passes if the result of the LED Module Demarcation verification is positive. Using (semi) automated 3D measuring equipment, verification of the LED Module Demarcation is positive if all measurement points are in the keep-in zone of the LED Module Demarcation with a tolerance of 0,05 mm. Using a gauge, verification of the LED Module Demarcation is positive if the LED Module or Holder fits in the gauge.

8.1.2 Test OCA of the LED Module or LED Array Holder for the D35 Category

The first purpose of this test is to verify that the LED-Module-under-test (in combination with the TIM) meets the requirements for the OCA as defined in section 3.3.2. The second purpose of this test is to verify whether the LED-Module-under-test meets the requirements for the screw holes as defined in section 3.3.3.1.

8.1.2.1 Test equipment

- Caliper

³ As the TIM is defined to be part of the LED Module, the height of the LED-Module-under-test shall be verified including TIM (in its compressed state). This verification is implemented in the OCA test (section 8.1.2).

- Flat metal ring with an outer-diameter of 35 mm, inner-diameter equal to $\varnothing OCA_{max}$ and a known thickness, constant within $\pm 0,05$ mm.

8.1.2.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25 ± 5 °C. The LED-Module-under-test shall be tested in combination with the TIM and screws which shall be provided with the test sample. The LED Module – TIM combination shall be tested with the TIM in compressed state with a contact pressure or torque as defined in the PDS.

8.1.2.3 Test procedure

- Determine the designation of the LES category from the Product Data Set of the LED-Module-under-test.
- Measure the diameter of the light opening at the top of the LED Module ($\varnothing OCA$).
- Mount the LED Module on a plate by means of the supplied screws with a contact pressure or torque according to the specification in the PDS.
- Position the ring on top of the LED Module such that the center of the ring is concentric with the center of the LED Module.
- Verify that there is visual clearance between the top of the screws and the ring.
- Measure the height of the top of the ring at 4 positions: 0°, 90°, 180° and 270°, on a concentric circle on the ring with a diameter of 20 mm.
- Calculate the average height of the OCA $\langle H_{OCA} \rangle$ as the average height of the 4 measurement points minus the thickness of the ring.
- For a LED Array Holder insert the suitable LED Array in the Holder and treat the Assembly as a LED Module for the purpose of this test.

8.1.2.4 Pass criteria

The LED-Module-under-test or Holder passes if the following conditions are met:

- The inner diameter of the OCA ($\varnothing OCA$) is less or equal than $\varnothing OCA_{max}$ with $\varnothing OCA_{max}$ depending on the LES category according to Table 0-3.
- There is visual clearance between the top of the screws and the ring.
- The average height of the OCA $\langle H_{OCA} \rangle$ is in the range of $3,0 \text{ mm} \leq \langle H_{OCA} \rangle \leq 4,0 \text{ mm}$.

8.1.3 Test OCA of the LED Module or LED Array Holder for the D50 Category

8.2 The OCA requirements as shown in section 3.3.3.2 are already covered by the mechanical verification from section 8.1.1, LED Module photometric interface tests.

8.2.1 Test on luminous flux

For the purpose of this section, the provisions in [Book 1] – section A.0.2.1 apply. The Test Fixture PETF is defined in section 7.1.1. The test conditions are defined in section 4.3.

8.2.2 Test on relative partial luminous flux and beam angle.

For the purpose of this section, the provisions in [Book 1] – section A.0.2.2 apply. The Test Fixture PETF is defined in section 7.1.1. The test conditions are defined in section 4.3. The relative partial luminous flux shall meet the requirements defined in section 4.5.

8.2.3 Test on correlated color temperature (CCT)

For the purpose of this section, the provisions in [Book 1] – section A.0.2.3 apply. The Test Fixture PETF is defined in section 7.1.1. The test conditions are defined in section 4.3.

8.2.4 Test on color rendering index

For the purpose of this section, the provisions in [Book 1] – section A.0.2.4 apply. The Test Fixture PETF is defined in section 7.1.1. The test conditions are defined in section 4.3.

8.3 LED Module thermal interface tests

This section does not apply to LED Array Holders.

8.3.1 Test on thermal power (P_{th})

For the purpose of this section, the provisions in [Book 1] – section A.0.3.1 apply. The Test Fixture PETF is defined in section 7.1.1. The test conditions are defined in section 4.3.

8.3.2 Temperature stabilization

For the purpose of this section, the provisions in [Book 1] – section A.1.3.5 apply.

8.3.3 Position of measurement point for the Reference Temperature

For the purpose of this section, the provisions in [Book 1] – section A.1.3.6 apply.

8.4 LED Module electrical interface tests

All LED Module compliance tests as defined in [LEDset-Pow] shall be conducted and the LED-Module-under-test passes if all these tests pass.

All LED Module compliance tests as defined in [LEDset-Inf] shall be conducted and the LED-Module-under-test passes if all these tests pass.

This section does not apply to LED Array Holders.

8.5 LED Module and LED Array Holder Product Data Set test

For the purpose of this section, the provisions in [Book 1] – section A.0.5 apply.

9 Luminaire compliance tests

9.1 Luminaire mechanical interface tests

9.1.1 Test on the mechanical interface of the Luminaire for mounting the LED Module(s)

The purpose of this test is to verify the mechanical LED Module interface of the Luminaire-under-test.

9.1.1.1 Test equipment

The mechanical interface should be tested with a (semi) automated 3D measuring equipment such as a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

Alternatively, the mechanical interface may be tested with a gauge made of a material that ensures the accuracy mentioned below (for example 3 mm aluminum). In that case, it shall be verified that the gauge complies with the corresponding demarcation model. This verification shall be done with a (semi) automated 3D measuring equipment such as a non-contact optical measuring system. The measurement accuracy shall be at least $\pm 0,05$ mm.

9.1.1.2 Test conditions

The mechanical interface shall be verified at a temperature in the range of 25 ± 5 °C.

9.1.1.3 Test procedure

Verify that the Luminaire-under-test, including mounting means such as screws does not cross the LED Module Demarcation as defined in section 3.3. Additional guidelines for this test are provided in Annex B.

9.1.1.4 Pass criteria

The Luminaire-under-test passes if the result of the LED Module Demarcation verification is positive for all LED Module positions in the Luminaire.

9.2 Luminaire Product Data Set test

For the purpose of this section, the provisions in [Book 1] – section A.2.6 apply.

Annexes

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Annex A

Product Data Set requirements

Listed in this section are the requirements with respect to the Product Data Sets of Zhaga products defined in this Book 10.

LED Module Product Data Set

The LED Module Product Data Sets shall contain the following information:

- Book 10 LED Module Category (D35, D50)
- The luminous flux category according to section 4.4
- The CCT and CRI category at the Rated Operating Temperature $t_{r,max}$ using the three digit code as defined in [IEC TR 62732]. Only the nominal CCT categories as specified in [ANSI C78.377] shall be used.
- The LES category according to section 4.2
- The actual LES size according to section 4.2
- The luminance rotational symmetry (S)
- The luminance uniformity (U)
- The Rated Operating Temperature $t_{r,max}$
- The thermal power P_{th}
- The properties or type of TIM to be used with this LED Module
- The contact pressure or torque required for mounting the LED Module
- The type of screws to be used for mounting the LED Module by referencing an international standard (for D35)
- If the LED Module is suited for use with the Locking Ring System, the following statement shall be used: "This LED Module is suited for use with a Locking Ring System according to Book 3 Edition 1.3 of the Zhaga Interface Specification".

On top of the parameters listed above, the LED Module PDS shall also include those parameters related to the electrical interface that are mandated PDS items in [LEDset-inf] and [LEDset-pow].

LED Array Holder Product Data Set

The LED Array Holder Data Sets shall contain the following information:

- Book 10 diameter category (D35, D50)
- The properties or type of TIM to be used with this LED Array Holder
- The contact pressure or torque required for mounting the LED Array Holder
- The type of screws to be used for mounting the LED Array Holder by referencing an international standard (for D35).

Luminaire Product Data Set

- Book 10 diameter category (D35, D50)
- Number of LED Modules if greater than 1.
- The intended operating conditions specifying Luminaire orientation and t_a .
- As it is expected that the Luminaire is only suited up to a maximum LLE power $P_{th,rear,max}$, this maximum shall be stated in the datasheet.

Annex B (informative)

Guidelines for mechanical interface test

The procedure for the compliance test on the mechanical interface of the LED Module or the Luminaire requires verification that the LED Module or the Luminaire does not cross the corresponding LED Module Demarcation. Such verification can be performed using (semi-) automated 3D measuring equipment such as a non-contact optical measuring system. This annex provides some guidelines on the number of measurement points and their positions to be used for such verification. The example in Figure B-1 will be used to provide these guidelines.

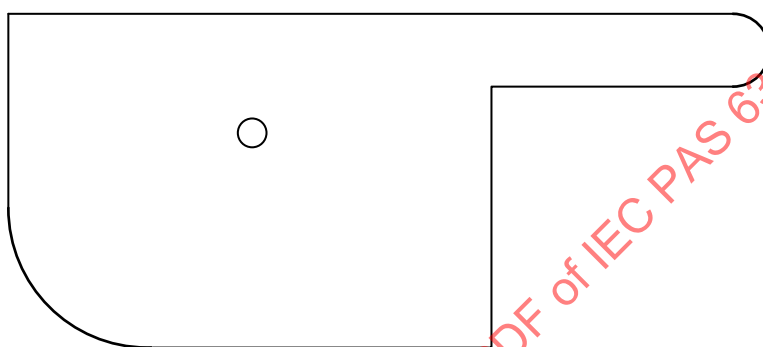


Figure B-1 – Example of a LED Module

As a first step, the outline of the LED Module (including mounting holes) is divided into segments with approximately equal curvature. In each section x , the minimum curvature in that section is denoted by r_x .

As a second step, measurement points are defined at the boundaries between sections. The result of these steps is shown in Figure B-2.

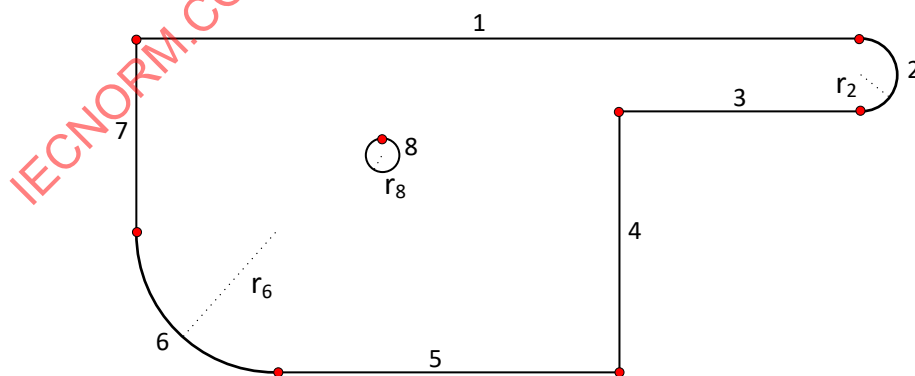


Figure B-2 – Example of a LED Module with sections

As a third and final step, each section is divided into sub-sections with a maximum length d with the value of d fulfilling the following requirements:

- $d \leq \frac{r_x}{2}$ and

- $d \leq 10 \text{ mm}$

Additional measurement points are defined at the boundaries of these subsections. The result of these steps is shown in Figure B-3.

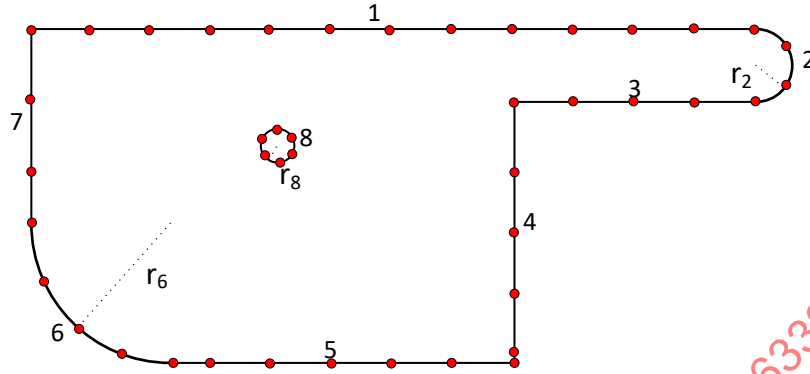


Figure B-3 – Example of a LED Module with measurement points

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Annex C (informative)

Guidelines for LES and Luminance measurements

The Light Emitting Surface and the LES diameter for a Book 10 LED Module are defined in section 4.2 while the luminance uniformity parameters B, S and U are defined in section 4.6. This annex provides guidance on how to measure these parameters. Note that this section is informative only. Other methods to determine the value of these parameters may also be used. As an example one may calculate these values from ray-set data of the device under test.

C.1 Test equipment

The luminance uniformity and the LES diameter can be measured using a setup as depicted in Figure C-1. The luminance camera should have sufficient resolution to measure at least 500 pixels over the actual LES area. The measurement uncertainty for the luminance value should be +/- 10 % or less⁴.

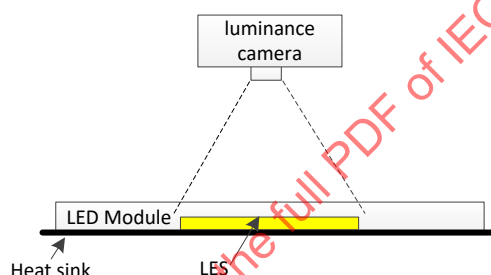


Figure C-1 – Set-up for measurement of luminance uniformity and LES diameter

C.2 Test conditions

See section 4.3.

C.3 Test procedure

- Perform a suitable geometrical calibration to relate the size of the luminance image to the geometrical dimension of the LES. This should be done at least after any modification of the test setup.
- Mount the LED-Module-under-test on a suitable heat sink. The luminance camera should measure the luminance directly looking at the LED-Module-under-test along the Z-axis (Figure 0-1). Ensure that the whole LED-Module-under-test is in the field of vision of the luminance camera.
- Choose the focus of the luminance camera to be in the plane of the OCA, not on the LEDs.
- Turn on the LED-Module-under-test.
- As only relative data is to be taken, it is not necessary to wait for thermal stabilization if the duration of the measurement is less than 1 s. Otherwise, wait for stabilization of the temperature t_r (see [Book 1], section A.0.3.2).

⁴ Evaluation of measurements is always relative in this specification. Thus, the tolerance for the luminance rotational symmetry, center balance and uniformity parameter is expected to be much lower.

- Measure the luminance image of the LED-Module-under-test. Trim the image in such a way that the LED Module is in the center of the image, and that it fills at least 80 % of height and width of the image.
- Determine the center of gravity of the luminance image. The “center of gravity” of a luminance image is by definition the point which has the least summed distance to all pixels in the image. Use only pixels above the background noise level for this determination. A typical threshold level is 10 % of the maximum intensity. Shift the center of the evaluation areas (section 4.6) such that it coincides with the “center of gravity”.
- Evaluate the average luminances L_i in the areas A_i as defined section 4.6. Note that the LES category diameter shall be taken for this evaluation.
- Determine the actual LES diameter as the minimum diameter of the circle around the center of gravity of the luminance image that encloses all pixels with >10 % of the maximum L_i ($i=1..5$).
- Rotate the orientation of the segments diagram defined in section 4.6 with respect to the luminance image by 90° in steps of 5°. For every step, evaluate the rotational symmetry parameter (S). The maximum shall be taken as value for S.
- Evaluate center balance (B) as defined in section 4.6.
- Evaluate the average luminance L_{avg} over the actual LES area.
- Calculate the luminance uniformity (U) as defined in section 4.6. The number of pixels N shall not be less than 500.

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Annex D **(informative)**

Remarks

D.1 Photometric interchangeability

The main objective of the Zhaga Interface Specification is to promote interchangeability of LED Light Engines while allowing maximum design freedom, especially regarding LED technology. Consequently the light emission cannot be defined to the very last detail; in particular, the luminance distribution over the Light Emitting Surface cannot be tightly toleranced.

The definitions in this book have been carefully balanced in order to make the best compromise between freedom in LED technology and a secure platform for Luminaire Optics design.

This compromise has been found using a set of test reflectors with target beam angles of 20° and 40°, using both specular and frosted surface. These reflectors have been optimized for LES 19. Parameters in this specification have been set such that variations in beam angle and center beam intensity are not larger than 12,5 %. This has been verified with all available LES 19 LLEs during phase B testing.

However, it cannot be foreseen whether in a specific reflector design the 12,5 % criterion will be met automatically. Specific optics design for interchangeability is recommended.

As LED technology evolves, there may be solutions that have not been foreseen during the drafting of this specification. New optics solutions should be reviewed regularly by the Zhaga Workgroup and incorporated into newer editions of this specification if they fulfill the 12,5 % criterion.

D.2 Color effects

Current LED technology at the time of finalization of this specification comes in many technical realizations. Some of them show effects of color variation over the emission angle and/or in the luminance distribution. Neither effect has been taken into account in this edition of the specification, as the effects can be managed by proper light mixing properties of the Luminaire Optics. However, it is always recommended to evaluate the performance of a Luminaire Optic using multi-color rayfiles and/or real samples of LLEs to ensure the intended performance is met in a specific combination of LLE and Luminaire Optic.

Annex E (informative)

Luminaire thermal test tools

Thermal Test Engine TTE – Spot (informative)

A Thermal Test Engine TTE-Spot can be used to simulate a general Zhaga Spot module in a luminaire. A typical construction is shown schematically in Figure E-1. A technical drawing of the Aluminium part is shown in Figure E-2. Preferably a device such as a Vishay LTO 100 should be used as a heater. If not available, another heater with sufficient power capability and heat transfer area of approximately 11,5 mm x 14 mm can be used. The heater must be in good thermal contact, for example, by use of thermal grease.

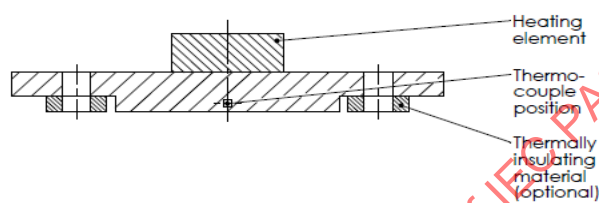


Figure E-1 – Thermal Test Engine TTE-Spot schematic

By applying the TTE – Spot in a luminaire and powering the heater with the same electrical power as the P_{th} of an intended LED Module, the thermal behavior of the Luminaire can be evaluated without the actual LED Module. A comparison of the conditions for different P_{th} is easily possible.

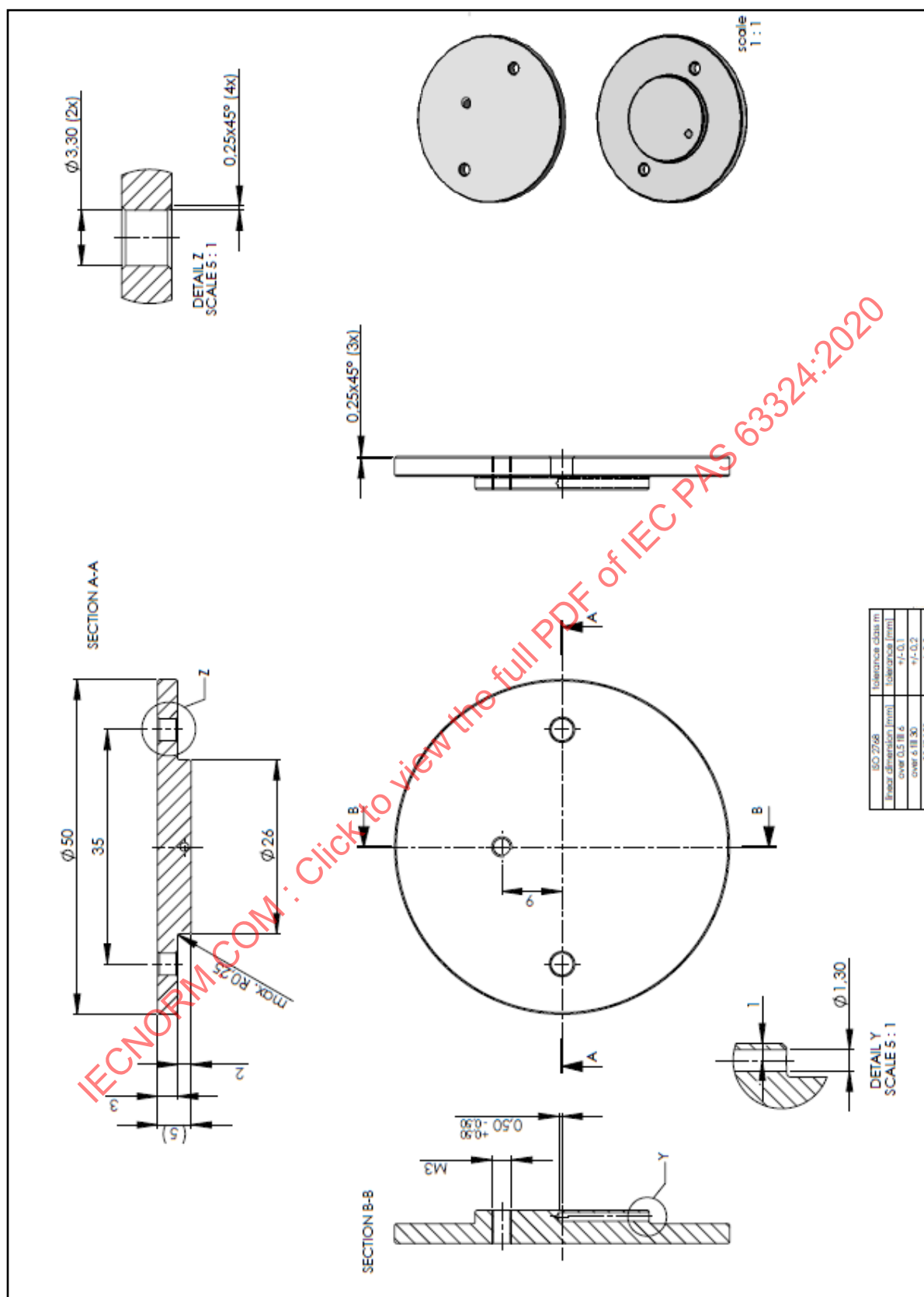


Figure E-2 – Thermal Test Engine TTE-Spot – technical drawing of the aluminum part

Annex F

History of changes

Table F-1 – Changes

Location	Change	Reason
	TCWG Issue of Edition 1.0 – Initial version, thus no changes	

Subdivision 2

Zhaga Interface Specification Book 1

Summary (informative)

Background

The Zhaga Consortium is a global lighting-industry organization that aims to standardize components of LED luminaires, including LED light engines, LED modules, LED arrays, holders, electronic control gear (LED drivers) and connectivity fit systems.

Zhaga has created a set of interface specifications, known as Books. Each Book defines one or more components of an LED luminaire by means of the mechanical, photometric, electrical, thermal, and control interfaces of the component to its environment. This makes such products interchangeable in the sense that it is easy to replace one product with another, even if they have been made by different manufacturers.

Contents

This Book 1 is a special book, because it does not define components of LED luminaires. Instead, this book gives an overview of the Zhaga terminology as well as common information to explain the general aspects of the interfaces defined by Zhaga. This book also defines a set of generic compliance tests, which are used to verify if a product meets the requirements defined in the relevant Zhaga interface specification.

Intended Use

This book should be read to become familiar with the basic principles of the Zhaga interface specifications. In particular, the other Zhaga interface specifications rely on the information provided in this book. This information is not duplicated in those other books.

1 General

1.1 Introduction

The Zhaga Consortium is a global organization that aims to standardize components of LED luminaires. A LED luminaire is a lighting fixture for general lighting that contains a light source based on solid-state technology. Such light sources, including LED Modules and LED Light Engines, typically consist of one or more LEDs combined with an Electronic Control Gear (LED driver). Other components of LED luminaires include LED Arrays, Holders, and connectivity fit systems.

Zhaga has created a set of interface specifications, known as Books, which define the interfaces between a component and its environment. Book 1 is a special Book in the sense that it provides common information, which is relevant to all other Books in the series. In addition, Book 1 defines requirements and compliance tests, which are applicable across multiple Zhaga books. Such Books refer to those requirements and compliance tests as applicable.

1.2 Scope

This Book 1 defines the common concepts that underlie the Zhaga interface specifications. In addition, this Book 1 specifies general requirements for Zhaga compliant components of LED Luminaires.

Each of the other Zhaga interface specifications details the requirements and the tests for particular types of Zhaga products. These Books are published separately for ease of revision and additional Books will be added as and when a need for them is recognized.

This Book 1 is to provide a set of requirements and compliance tests which are applicable to most Zhaga products and which can be called up as required by the other Books. Accordingly, the provisions of this Book 1 apply only in the specific contexts defined in the other Books. The other Books, in making reference to any of the sections in this Book 1, specify the extent to which that section is applicable. The other Books may also include additional requirements as necessary.

1.3 Conformance and references

1.3.1 Conformance

All provisions in the Zhaga interface specifications are mandatory, unless specifically indicated as recommended, optional or informative. Verbal expressions of provisions in the Zhaga interface specifications follow the rules provided in Clause 7 of ISO/IEC Directives, Part 2:2018. For all clarity, the word “shall” indicates a requirement that is to be followed strictly in order to conform to the Zhaga interface specifications, and from which no deviation is permitted. The word “should” indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

1.3.2 Normative references

[ANSI C78.377]	American National Standard for electric lamps—Specifications for the Chromaticity of Solid State Lighting Products, ANSI NEMA ANSLG C78.377
[CIE 13.3]	Method of measuring and specifying colour rendering properties of light sources, CIE 13.3
[IEC TR 61341:2010]	Method of measurement of centre beam intensity and beam angle(s) of reflector lamps
[IEC TR 62732]	Three-digit code for designation of colour rendering and correlated colour temperature.

[IES LM-79-08]	IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products, IES LM-79-08
[NIST TN 1297]	NIST Technical Note 1297; 1994 Edition—Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results
[Zhaga-ECG]	Zhaga Interface Specification, Book 13 Separate Electronic Control Gear
[LEDset-Inf]	LEDset1 Information Interface Specification, Edition 1.2, November, 2016 available from md-sig.org
[LEDset-Pow]	LEDset Power Interface Specification, Edition 1.1, November, 2016 available from md-sig.org

1.3.3 Informative references

[Zhaga LTLA]	Zhaga Logo Trademark License Agreement
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1.4 Common definitions⁵

Ambient Temperature	Average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are: • In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire. • In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.
Authorized Testing Center	Organization that is authorized by the Zhaga consortium to perform compliance tests for a specific Book.
Book	A Zhaga interface specification.
Built-in ECG	A Separate Electronic Control Gear that is designed for mounting inside an enclosure, such as provided by a Luminaire or a separate box. The use of a Built-in Electronic Control Gear outside a Luminaire without an enclosure can result in relevant standards for electrical product safety being violated.
Compatible	Two or more Zhaga products are Compatible if the combination can function as intended.
Demarcation	A component Demarcation is the boundary between the component and its environment.
Electronic Control Gear	A unit that is located between the external power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.
External Power	The electrical power that is supplied to the LED Light Engine. Typically this is the mains power, but it can also be from another source like a battery or an application specific power grid.
Holder	A component that maintains the LED Light Engine, the LED Module or the LED Array in a functional position, and

⁵ The definitions are possibly further restricted in the other Zhaga Books.

	establishes electrical contact with the LED Light Engine, LED Module or LED Array.
Independent ECG	An ECG consisting of one or more separate elements so designed that it can be mounted separately outside the luminaire, with protection according to the marking of the ECG and without any additional enclosure. This may consist of a Built-in ECG housed in a suitable enclosure which provides all the necessary protections according to its marking.
Integrated ECG	ECG of a LLE that is accommodated in the same housing as the LED module(s) of the LLE. This combination is an Integrated LED Light Engine.
Integrated LED Light Engine	A LED Light Engine that consists of a single housing. This is the same as a “LED Light Engine with Integrated ECG”. Note that a module, complying with a specific Book that describes a LLE with Separate ECG but that is directly connected to external power would be an Integrated LLE and thus would be out of scope of that Book.
Interchangeable	Two Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.
LED Array	A light source that is supplied as a single unit and intended to be used in combination with a Holder. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.
LED Light Engine	A combination of one Electronic Control Gear and one or more LED Modules and means for interconnecting these components. A LED Light Engine may consist of multiple housings.
LED Module	A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.
Light Emitting Surface	A surface of a LLE, LED Module or LED Array with specific dimensions, position and orientation through which the light is emitted.
Luminaire	A lighting fixture which provides an appropriate environment for one or more LLEs and possibly other components.
Luminaire Optics	Set of one or more optical elements, which shape the light output of the LLE, not being part of the LLE itself.
Measurement Uncertainty	Measurement Uncertainty is the same as “expanded uncertainty” as defined in [NIST TN 1297].
Optics Contact Area	Physical surface in the LLE or LED Module with a defined shape and position which allows for a stable and functional positioning of the Luminaire Optics on the LLE or LED Module.
Product Data Set	The combined data in the product data sheet, product label and other public documents related to the product.

Rated <parameter>	The value of the <parameter> as listed in the Product Data Set. Examples: the Rated voltage, the Rated frequency, etcetera.
Rated Operating Temperature	Value of the operating temperature (t_r or t_p) at which the Rated LLE, LED Module or LED Array values are specified.
Reference Temperature	The temperature at a specified position on the Thermal Interface Surface under steady state operating conditions. The exact coordinates of this position are defined for each type of LLE or LED Module in the respective Book.
Relative Partial Luminous Flux	Percentage of the luminous flux that is emitted by a light source into the rotationally symmetric solid angle bounded by two polar angles (see also section 4.4).
Separate ECG	An ECG of an LLE that is accommodated in a housing that is separate from the LED module(s) of the LLE.
Test Engine	A device that is used to define and measure properties of a Luminaire.
Test Fixture	A device that is used to define and measure properties of a LED Light Engine, a LED Module or a LED Array.
Thermal Interface Material	Material at the Thermal Interface Surface which has the purpose to improve the heat transfer from the LLE, LED Module or LED Array to the heat sink of the Luminaire.
Thermal Interface Surface	The surface of the LLE, LED Module, LED Array or Thermal Test Engine that makes physical contact with the surface of the heat sink of the Luminaire.
Zhaga Consumer Product	A Zhaga Consumer Product is intended to be applied and replaced by consumers.
Zhaga Professional Product	A Zhaga Professional Product is intended to be applied by a Luminaire maker.

1.5 Common acronyms

ATC	Authorized Testing Center
CCT	correlated color temperature
CRI	color rendering index
DUT	device-under-test
ECG	Electronic Control Gear
LED	light emitting diode
LES	Light Emitting Surface
LLE	LED Light Engine
NA	not applicable
OCA	Optics Contact Area
PETF	Photometric & electrical Test Fixture
PCB	printed circuit board
PDS	Product Data Set
RMS	root mean square
TIM	Thermal Interface Material
TIS	Thermal Interface Surface
TPTF	thermal power Test Fixture
TTE	thermal Test Engine
TUTF	thermal uniformity Test Fixture

1.6 Common symbols

P_{el}	Electrical power consumed by the LLE (unit: W).
$P_{el,mod}$	Electrical power consumed by the LED Array or LED Module (unit: W).
P_{vis}	Radiant flux of the LLE, LED module or LED Array in the wavelength range from 380nm up to 780nm (unit: W).
P_{th}	Thermal power generated in the LLE, LED Module or LED Array (unit: W).
$P_{th,rear}$	Thermal power that is drained from the LLE, LED Module or LED Array through the Thermal Interface Surface (unit: W).
$P_{th,front}$	Thermal power that is drained from the LLE, LED Module or LED Array by convection and IR radiation (unit: W).
R_{th}	Thermal resistance from the Thermal Interface Surface to the environment (unit: K/W).
$R_{th,max}$	Value of the thermal resistance from the Thermal Interface Surface to the environment for which holds: $t_r = t_{r,rated}$ (unit: K/W).
$R_{sp}(i,j)$	Thermal spreading resistance between measurement points i and j (unit: K/W).
R_{sp}^{max}	Maximum thermal spreading resistance (unit: K/W).
$SPD(\lambda)$	Spectral Power Distribution (unit: W/nm). $SPD(\lambda)$ corresponds to what is expressed as “total spectral radiant flux” in [IES LM-79-08].
t_a	Ambient Temperature (unit: °C).
t_p	The temperature at a specified point on the LLE, LED Module or LED Array under steady state operating conditions (unit: °C). The exact position of this measurement point is defined for each product in its PDS.
t_r	The temperature at a specified point on the Thermal Interface Surface of the LLE, LED Module or LED Array under steady state operating conditions (unit: °C). The exact coordinates of this position are defined for each type of LLE, LED Module or LED Array in the respective Book.
$t_{r,max}$	Rated Operating Temperature (unit: °C) (Used in earlier editions of the specifications; replaced by $t_{r,rated}$).
$t_{r,rated}$	Rated Operating Temperature related to t_r (unit: °C).
$t_{p,rated}$	Rated Operating Temperature related to t_p (unit: °C).

1.7 Common conventions

1.7.1 Cross references

Unless indicated otherwise, cross references to sections in either this document or documents listed in section 1.3, refer to the referenced section as well as the sub sections contained therein.

1.7.2 Informative text

With the exception of sections that are marked as informative, informative text is set in italics.

1.7.3 Terms in capitals

All terms starting with a capital are defined in section 1.4.

1.7.4 Units of physical quantities

Physical quantities are expressed in units of the International System of Units.

1.7.5 Decimal separator

The decimal separator is a comma (“,”).

2 Overview of Zhaga (informative)

2.1 About Zhaga

Zhaga has created a set of interface specifications, known as Books, which define the interfaces between a LED Luminaire component and its environment. Examples of LED Luminaire components are LED Light Engines, LED Modules, LED Arrays, Holders, Electronic Control Gears (LED drivers) and connectivity fit systems. The Zhaga Consortium aims to facilitate easy exchange of components in a LED Luminaire. Replacement may be attractive because of superior characteristics of the new component featuring new technology or for second source choices for optimizing the logistic process or simply to be open for more cost effective alternatives. Another important use case is the replacement of a component by another one with (photometric) properties that better fit a new application. The replacement of components is facilitated by defining the following interfaces between the component and its environment:

- mechanical interface
- photometric interface
- electrical interface
- thermal interface
- control interface

Apart from definitions of the interfaces listed above, each Zhaga book also defines requirements for the information in the Product Data Set (section 2.4).

A Zhaga interface specification defines either a Zhaga Professional Product or Zhaga Consumer Product. A Zhaga Professional Product is intended to be applied by a Luminaire maker while a Zhaga Consumer Product is intended to be applied and replaced by consumers.

The Zhaga interface specifications do not define safety requirements (electrical, thermal etcetera) of Zhaga products. There may be a recommendation to specify in the Product Data Set of the LLE, LED Module or LED Array the implemented electrical insulation.

Note that a LED Luminaire component which is defined in a Book may be categorized in that Book, for example in categories having different dimensions, different external powers or different Optics Contact Areas.

2.2 Zhaga building blocks and interfaces

In this section, the definitions of Zhaga building blocks are elaborated. Each Book defines interfaces between a LED Luminaire component and its environment (see section 2.1).

In the context of the Zhaga interface specifications, a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines and possibly other components (see Figure 2-3 and Figure 2-4). A Luminaire typically (but not necessarily) is comprised of a heat sink to carry away the heat generated in the LLE(s), optical devices to reshape the light beam of the LLE(s), means to supply electrical power to the LLE(s), connectivity fit system to attach an extension module to the Luminaire and means to attach the Luminaire to a wall, ceiling, stand, etcetera.

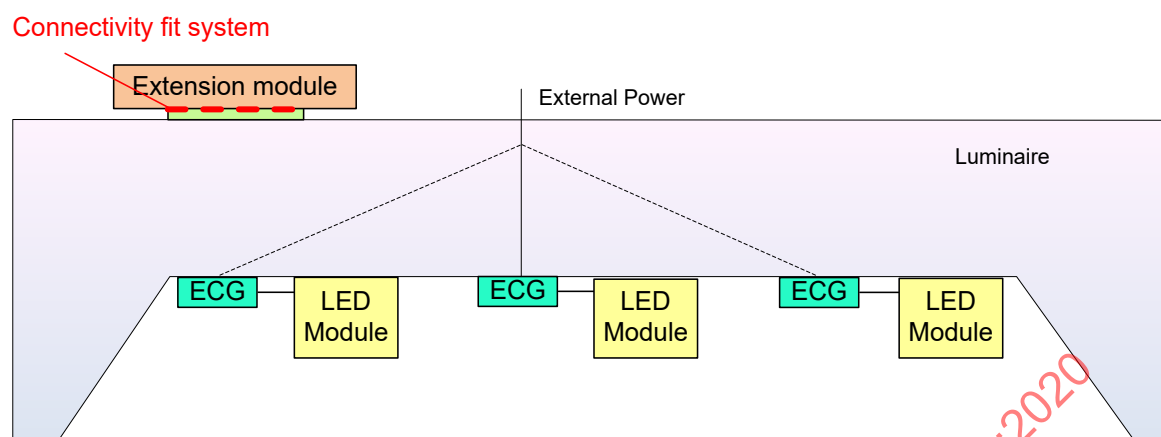


Figure 2-3 – Schematic overview of a Luminaire and one or more non-integrated LED Light Engines

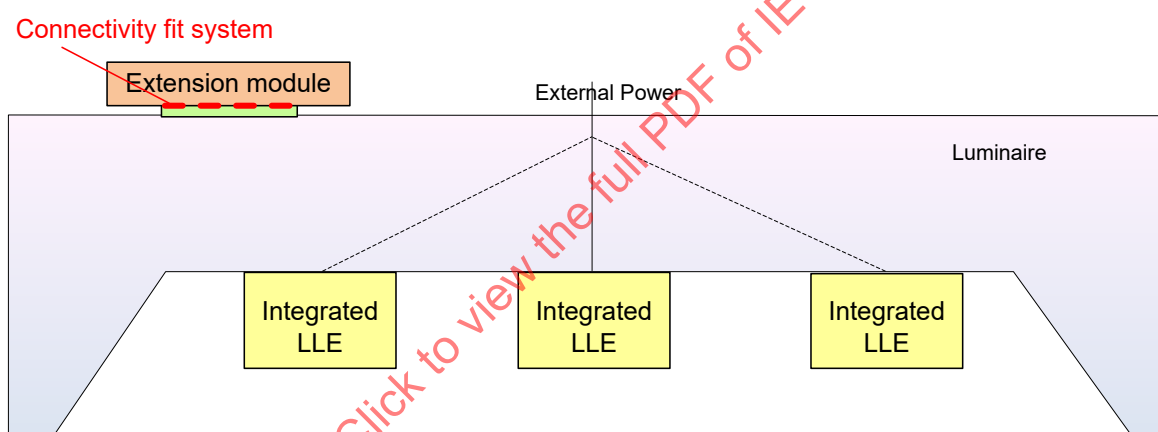


Figure 2-4 – Schematic overview of a Luminaire and one or more integrated LED Light Engines

A LED Light Engine is defined as a combination of one Electronic Control Gear and one or more LED Modules (see Figure 2-5 and Figure 2-6).

A LED Module is defined as a light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its optical, thermal, mechanical and electrical properties, but it does not include the Electronic Control Gear.

The Electronic Control Gear is defined as a unit that is located between the External Power and one or more LED Modules to provide the LED Module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

The LED Module(s) and the Electronic Control Gear can be in one housing as depicted in Figure 2-5. Such a system is denoted as a LED Light Engine with Integrated ECG, or alternatively as an Integrated LED Light Engine.

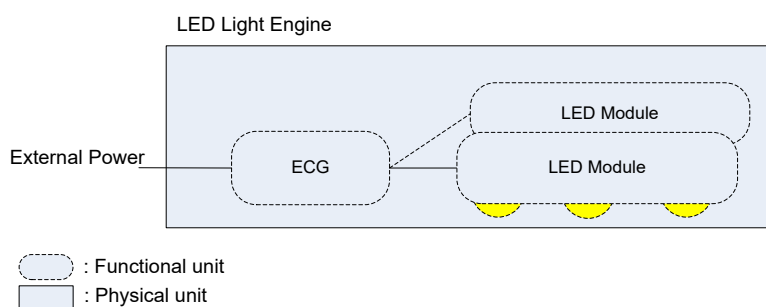


Figure 2-5 – Schematic overview of a LED Light Engine with Integrated ECG

Alternatively, the LED Light Engine consists of an Electronic Control Gear and one or more LED Modules in separate housings as depicted in Figure 2-6. Such a system is denoted as a LED Light Engine with Separate ECG.

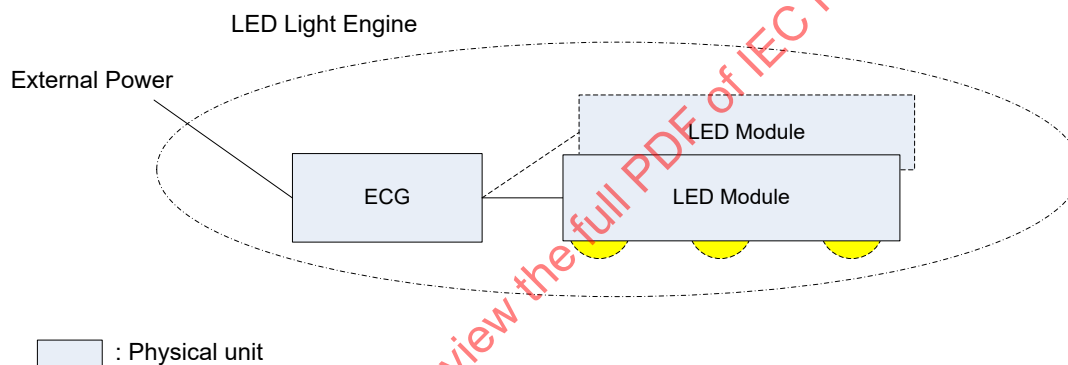


Figure 2-6 – Schematic overview of a LED Light Engine with Separate ECG

2.3 Compatibility and Interchangeability

The Zhaga Consortium aims to define LED Luminaire components which are Interchangeable in the sense that LED Luminaire components, possibly designed by different manufacturers, can be interchanged without complications. Practically speaking this means that a professional lighting expert can replace one component by another one while maintaining essentially the same functionality. The Zhaga defines two concepts which are relevant in this context: Compatibility and Interchangeability:

- Two Zhaga products are Compatible if the combination can function as intended.
- Two or more Zhaga products are Interchangeable if replacement of the first product with the second product in a system results in comparable photometric and dimming properties of that system.

Note that to ensure Interchangeability, the Luminaire also should be designed for Interchangeability. As an example, the Luminaire Optics should incorporate diffusing elements to account for different granularity of light emission by different LLEs or different LED Modules.

2.4 Product Data Set

The Product Data Set is defined as the combined data in the product data sheet, product label and other public documents related to the product. The requirements with respect to the Product

Data Set of a Zhaga product are defined in the applicable Book. These requirements guarantee that the Product Data Sets of Zhaga products contain the information which

- enables a check on Compatibility and
- enables a prediction of the (photometric) properties of a combination of Zhaga products.

2.5 Compliance testing

As an example one manufacturer brings to the market a Zhaga certified product A while another manufacturer brings to the market a Zhaga certified product B. At a later point in time, a professional lighting expert may combine product A and product B in a Luminaire (product C) for a specific application.

One of the challenging issues is that the characteristics of the product A-B-C combination in terms of performance and lifetime depend on the characteristics of all three products and on how these three sets of characteristics match. In order to effectively cope with this situation, Zhaga has defined procedures with tests to be conducted by manufacturers and Authorized Testing Centers and checks to be conducted by the one who intends to use these products. The checks are described in section 2.6 while the test related procedures are described in sections 2.5.1 and 2.5.2.

2.5.1 Certification

Before market introduction of a Zhaga product, the following procedure is conducted. See also Figure 2-7.

- Next to measurements and tests that may be required for internal purposes and regulations, the manufacturer of a Zhaga product performs all measurements that are needed to generate the Product Data Set that is required by the Zhaga interface specification. The measurements are performed as defined in the Zhaga interface specification. The outcome of these tests is laid out in the Product Data Set that is provided with the product.
- The manufacturer sends the product with associated Product Data Set to an Authorized Testing Center. The ATC performs all compliance tests that are listed in the corresponding Zhaga Book and returns a test report and a test report summary to the manufacturer.
- The manufacturer sends the test report summary to the Zhaga Logo License Administrator. If the test report summary indicates that the product has passed all tests, the Zhaga Logo License Administrator certifies the product.

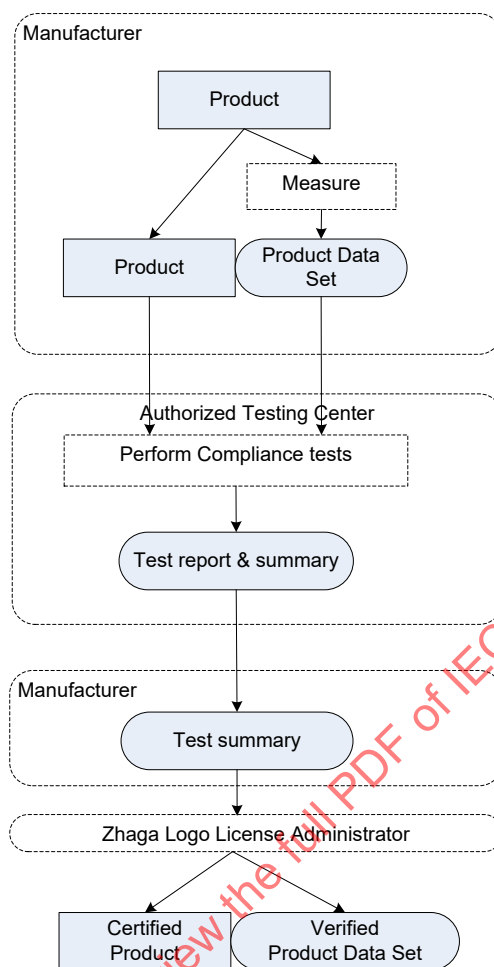


Figure 2-7 – Overview of test and certification of Zhaga products

2.5.2 Market surveillance

After market introduction of a Zhaga product, a market surveillance procedure may be initiated to check for the compliance of the product. For details on the market surveillance procedure and consequences of non-compliance see [Zhaga LTLA].

2.6 Compatibility check

Using the Product Data Set of the Zhaga certified products, the Luminaire maker or, for some LLEs the end-user, can check whether two or more Zhaga products are Compatible.

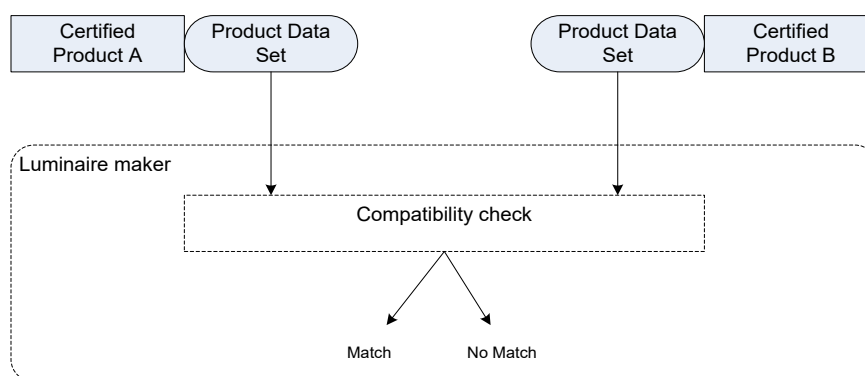


Figure 2-8 – Compatibility check

2.7 Zhaga product certification

The Zhaga Consortium prohibits use of its trademark on products and on product documentation without a trademark license. Members can obtain a conditional trademark license by signing the so-called Zhaga Logo Trademark License Agreement [LTLA]. This agreement licenses the Zhaga Logo for use on products that have certified.

3 Mechanical interface

3.1 Drawing principles

Unless indicated otherwise, the characteristics of the mechanical interface are specified according to the following principles:

- The dimensions are in millimeters.
- The minimum and maximum values provided in tables that accompany the drawings represent absolute limits, without any implied tolerance (neither positive, nor negative).
- Typical values as well as values between parentheses are informative.

3.2 Mechanical interface between Separate ECG and Luminaire

The mechanical interface between the Separate ECG and the Luminaire is defined in [Zhaga-ECG].

3.3 Thermal expansion

The mechanical dimensions are verified at a temperature in the range 25 ± 5 °C. This is the temperature at which a LED Luminaire component is typically mounted in a Luminaire. Manufacturers should take all necessary measures to ensure that thermal expansion or contraction is accommodated for the complete operating temperature range.

3.4 Demarcation (Informative)

In many Zhaga books the mechanical interface of a product, for example a LED Module, a LED array, an LLE or an ECG has been defined by means of a so-called Demarcation model. In this section the principle of the Demarcation model will be elaborated by means of an example.



Figure 3-1 – Example of a Demarcation Model (2-dimensional)

A demarcation model defines a 3-dimensional space. The product shall fit in this space and at the same time the environment of the product (generally the luminaire) shall not intrude this space.

Figure 3-1 shows a Demarcation model. For simplicity, this is a 2-dimensional model rather than a 3-dimensional model but the principle is exactly the same. The green area is the keep-in zone for the product and the keep-out zone for the product's environment. It shows that the product can have any shape as long as it does not cross the outline and it does not cross the boundaries of the screw holes. It also shows that the Luminaire, including screws can have any shape as long as it does not cross the outline and it does not cross the boundaries of the screw holes.

Figure 3-2 shows an example of a product that is compliant with the demarcation model.



Figure 3-2 – Example of a product which is compliant with the Demarcation Model

Figure 3-3 and Figure 3-4 show two examples of products that do not comply with the Demarcation model.

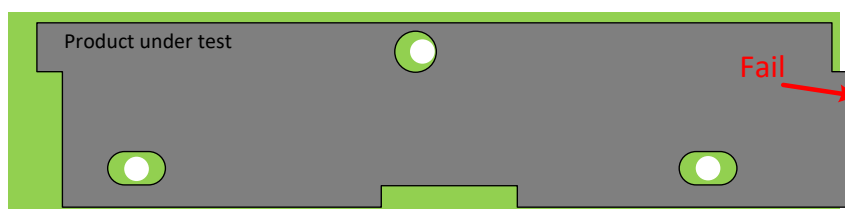


Figure 3-3 – Example of a product which is not compliant with the Demarcation Model

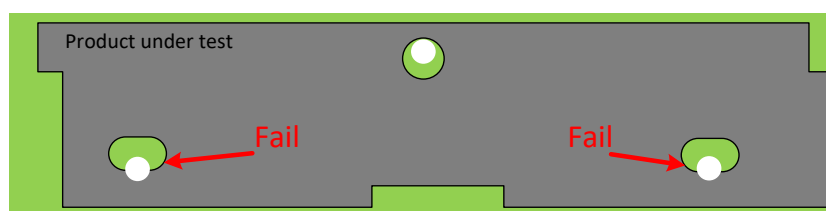


Figure 3-4 – Example of a product which is not compliant with the Demarcation Model

Guidelines for measuring compliance with the Demarcation model are provided in Annex B.

4 Photometric interface

4.1 Light Emitting Surface

A Light Emitting Surface (LES) is a surface associated to a LED Light Engine or a LED Module/LED Array with specific dimensions, position and orientation through which the light is emitted and that has the following characteristics:

- All substantial light generated by the LED Light Engine or the LED Module/LED Array is emitted through this surface.
- The center of the Light Emitting Surface coincides with the reference point of the luminous intensity distribution (See Figure 4-1).
- The LES is generally described by simple geometrical shape, for example a circle or a rectangle. It has a physical boundary or is a virtual surface in the surrounding area of the LLE or the LED Module/LED Array.

(Informative)

For each type of LLE or LED Module/LED Array the definition of the LES may be further restricted in the respective Book according to the following principles:

- When seen along the axis perpendicular to the LES, all parts of the light emitting area (LEDs, diffuse cover and/or mixing chamber) are covered by the LES.
- The position of the LES is chosen in a way, that all light emitting parts are behind the LES, when seen along the axis perpendicular to the LES.
- Inside a circular shaped LES, the LEDs may be placed in any arrangement, for example in a rectangular arrangement.
- A clear dome or cover above one or more LEDs is allowed to exceed the LES height.

Examples LES definitions:

- The LES is the domed cover of a multichip, phosphor covered LLE or LED Module/LED Array.
- The LES is a circle or a rectangle which is large enough to encompass all silicone domes of packaged LEDs in the LLE or LED Module/LED Array completely.
- In case the LEDs are encircled by the nearly vertical walls of a light guiding, mixing or diffusing element, the LES is described by the opening of this element.
- In the case of a diffuse cover covering the LEDs, the LES is described by the light emitting area of the diffuse cover.

For each type of LLE, LED Module or LED Array the requirements for the LES are defined in the respective Book.

4.1.1 LES categories

The Zhaga interface specifications define circular LES categories as listed in Table 4-1.

Table 4-1 – Definition of circular LES categories

LES category designation	Minimum LES diameter ⁶	Maximum LES diameter
LES6.3	4,5	6,3
LES9	6,3	9,0
LES13.5	9,0	13,5
LES19	13,5	19,0
LES23	19,0	23,0
LES30	23,0	30,0
LES40	30,0	40,0

4.2 Operating conditions for measuring photometric parameters

In general, the characteristics of the light generated by a LED Light Engine, a LED Module or a LED Array depend on the operating conditions. This section defines the operating conditions that shall be applied when measuring the photometric parameters defined in this chapter.

In case the device-under-test is a LED Module or a LED Array the operating conditions for photometric tests shall be as follows:

- The LED Module/LED Array shall be mounted in Test Fixture PETF according to the manufacturer's mounting instructions.
- The LED Module/LED Array shall be connected to a power source according to the manufacturer's instructions. The input current and voltage shall be within 0,2 % of the Rated values.
- The ambient temperature shall be stable within the range 25 ± 1 °C.
- The heat sink of the test fixture shall maintain the temperature t_r or t_p within the range $t_{r,rated} \pm 1$ °C or $t_{p,rated} \pm 1$ °C respectively.
- The photometric output of the LED Module/LED Array shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LED Module/LED Array and the Test Fixture.

In case the device-under-test is a LED Light Engine the operating conditions for photometric tests shall be as follows:

- The LLE or LED Module(s) in case of an LLE with Separate ECG shall be mounted in Test Fixture(s) according to the manufacturer's mounting instructions.
- The frequency of the External Power of the LLE shall be within 0,2 % of the Rated value. Depending on the Rated voltage range of the LLE, the LLE shall be tested at one or two values of the test voltage as indicated in Table 4-2.

⁶ The range of LES diameter values for a specific LES category is excluding the lower bound and including the upper bound. For example, a LES with a diameter of 9,0 mm shall have a designation LES9.

Table 4-2 – Test voltages for different Rated input voltages of the LLE

Rated voltage	Test voltage(s)
100...127	120 VAC
200...254	230 VAC
250...288	277 VAC
100...288	120 & 277VAC

- The ambient temperature shall be stable within the range 25 ± 1 °C.
- The heat sink(s) of the test fixture(s) shall maintain the temperature t_r or t_p within the range $t_{r, rated} \pm 1$ °C or $t_{p, rated} \pm 1$ °C respectively.
- The photometric output of the LLE shall not be affected in any way by objects (reflectors, glass or plastic windows, heat sink features, etcetera) that are exterior to the LLE and the Test Fixture(s).
- In case of an LLE with Separate ECG, the ECG should be mounted at a distance from the LED Module such that the ECG does not influence the results of the measurement.
- In case of an LLE with Separate ECG, the LED Module(s) shall be electrically connected to the ECG according to the LLE manufacturer's instructions.
- In case the LLE features adjustable settings (for example output current of the ECG or de-rating settings), these settings shall be according to the manufacturer's instructions.
- In case of an LLE with Separate ECG and more than one LED Module, photometric properties shall be measured on one LED Module, while the other LED Modules are also operated according to the manufacturer's instructions to enable equal photometric output. If no instructions are provided, the other LED Modules shall be operated in environmental conditions equal to the conditions of the LED-Module-under-test. The measurement setup should be such that the light output of the other LED Modules has no effect on the measurement result.

4.3 Luminous flux

The Zhaga interface specifications define luminous flux categories as listed in Table 4-3. In case of an LLE with multiple LED Modules, luminous flux is defined per LED Module.

Table 4-3 – Definition of luminous flux categories

Luminous flux category	Minimum luminous flux [lm]	Typical luminous flux [lm]	Maximum luminous flux [lm]
100	90	100	150
150	135	150	250
250	225	250	350
350	315	350	500
500	450	500	800
800	720	800	1000
1000	900	1000	1500
1500	1350	1500	2000
2000	1800	2000	3000
3000	2700	3000	4000
4000	3600	4000	5000
5000	4500	5000	6000
6000	5400	6000	8000
8000	7200	8000	10000
10000	9000	10000	15000
15000	13500	15000	20000
20000	18000	20000	30000
30000	27000	30000	40000
40000	36000	40000	60000
60000	54000	60000	80000
80000	72000	80000	100000

4.4 Luminous intensity distribution

For each type of LLE, LED Module or LED Array, the required luminous intensity distribution may be defined in the respective Book. In case of a LLE with multiple LED Modules, the luminous intensity distribution is defined per LED Module.

The luminous intensity distribution may be defined in terms of Relative Partial Luminous Fluxes. The Relative Partial Luminous Flux is the percentage of the total luminous flux emitted into the rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2 , as shown in Figure 4-1.

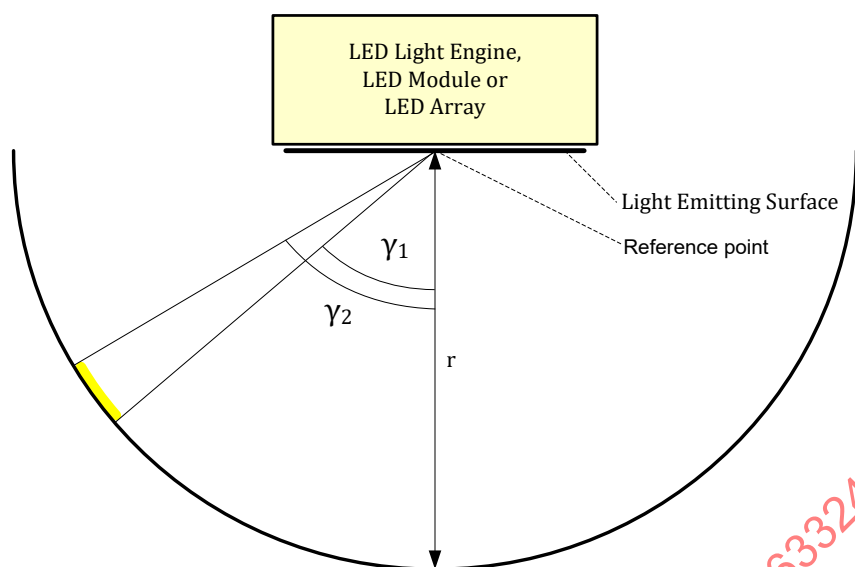


Figure 4-1 – Rotationally symmetric solid angle bounded by the polar angles γ_1 and γ_2 which is used to define the Relative Partial Luminous Flux

4.4.1 Beam angle and beam angle categories

The beam angle shall be defined as in [IEC TR 61341:2010] and the beam angle categories shall be defined as in Table 4-4.

Table 4-4 – Definition of beam angle categories

Beam angle category	Minimum beam angle ($^{\circ}$)	Maximum beam angle ($^{\circ}$)
6	3	9
12	9	15
17,5	15	21
25	21	29
35	29	41
55	41	70
90	70	110
120	110	150

4.5 Luminance uniformity

For each type of LLE, LED Module or LED Array, the required luminance characteristics may be defined in the respective Book. In case of a LLE with multiple LED Modules, luminance characteristics are defined per LED Module.

4.6 Correlated color temperature (CCT)

The CCT category of an LLE, LED Module or LED Array shall comply with the provisions of [ANSI C78.377], with the exception that the target color points may be chosen freely within the quadrangles defined therein. Only the nominal CCT categories as specified in [ANSI C78.377] shall be used. The value, in combination with the CRI value shall be expressed using the three-digit code as defined in [IEC TR 62732]. In case of an LLE with multiple LED Modules, CCT is defined per LED Module.

4.7 Color rendering index (CRI)

The CRI value of the LLE, LED Module or LED Array is defined in [CIE 13.3]. The value, in combination with the CTT value shall be expressed using the three-digit code as defined in [IEC TR 62732]. In case of an LLE with multiple LED Modules, CRI is defined per LED Module.

4.8 Luminaire Optics (informative)

The Luminaire Optics (e.g. reflectors, refractors or diffusers) are not defined in the Zhaga interface specifications. It is recommended to design Luminaire Optics in such a way, that the nominal parameter values of the LES and luminous intensity distribution result in the desired photometric characteristics of the LLE-Luminaire Optics combination. Due to the compound nature of many LED Module solutions, it is expected that Luminaire Optics designed for Zhaga compliant LLEs takes into account the structure of LED clusters, e.g. by using frosted surfaces or faceted structures to achieve comparable light output with all kinds of module technologies enabled by the Zhaga interface specifications. The luminance uniformity of the LED Module can provide information on the measures that need to be taken to achieve proper light distributed with Luminaire Optics. The larger the uniformity the more simple the measures are that need to be taken for a proper light distribution.

5 Electrical interface

5.1 Electrical insulation (informative)

International and national regulations require that products on the market must be compliant with product safety standards (for example UL standards in the USA, EN standards in Europe and JIS-Standard and PSE-Law in Japan) and individual manufacturers are responsible for this.

The electrical insulation of a complete LLE-Luminaire system is a safety item and depends on the electrical insulation implemented in the components and in the Luminaire. Like all other safety requirements, electrical insulation is explicitly out of scope of the Zhaga interface specifications and it is the sole responsibility of the manufacturer that brings the product to the market.

6 Thermal interface

6.1 Background information (informative)

One of the most challenging issues in LED lighting is related to the temperature of the LED. On the one hand this component is made of a semiconductor material and therefore it is sensitive to operating temperature, both in terms of performance and lifetime. On the other hand the operating temperature of the LED is not only determined by the design of the LLE or the LED Module but also by the design of the Luminaire. Manufacturers of Zhaga LLEs or LED Modules have no knowledge in which Luminaire the LLE or LED Module will be used. In order to effectively cope with this situation, a model of LLE-Luminaire or LED Module-Luminaire combination with respect to thermal behavior is defined in this section. This thermal interface model allows prediction of the operating temperature t_r or t_p of a specific LLE – Luminaire combination or LED Module – Luminaire combination.

In section 6.2, the generic thermal interface model is defined whereas a simplified model is defined in section 6.3. The simplified model is applicable when a Luminaire maker applies a LLE or LED Module in a Luminaire.

6.2 Generic thermal interface model

6.2.1 General case

In the thermal interface model, the light generating (and heat generating) component can be any one of the following devices:

- 1) A LLE with Integrated ECG. In this case the thermal interface is defined as the contact surface of the LLE and the Luminaire.
- 2) A LED Module. In this case the thermal interface is defined as the contact surface of the LED Module and the Luminaire.
- 3) A LLE with Separate ECG. In this case the thermal interface is defined as the contact surface of the LED Module and the heat sink the Luminaire and it is assumed that the ECG does not influence the thermal behavior of the Luminaire – LLE combination (See also section 6.1.12). In case of an LLE with multiple LED Modules, each LED Module has its thermal interface with the Luminaire.

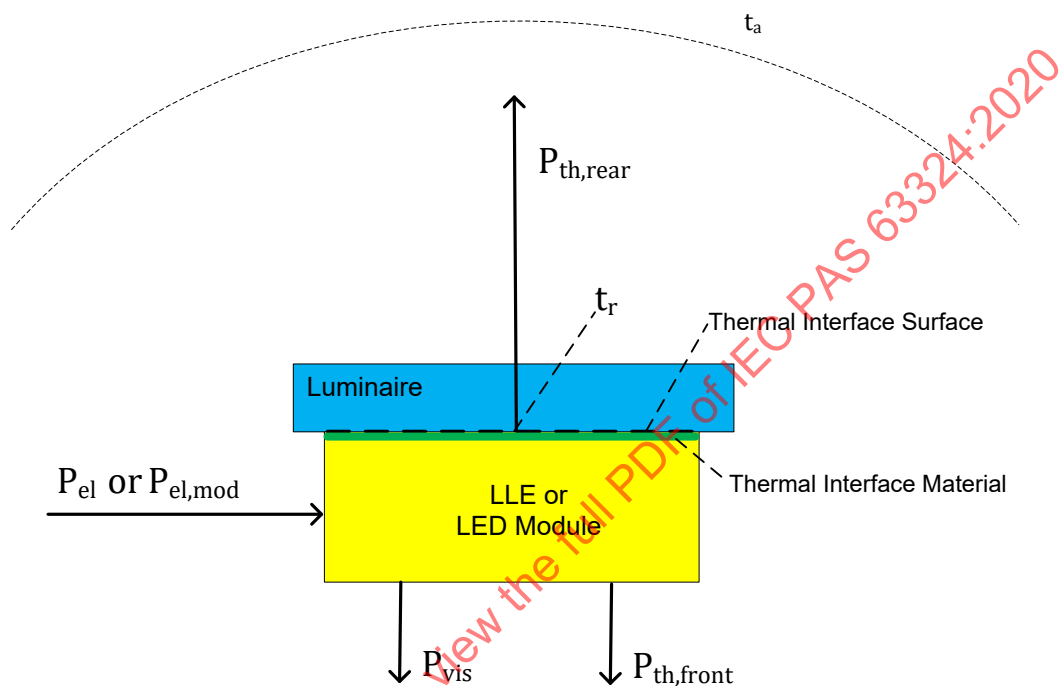


Figure 6-1 – Thermal model of a LLE – Luminaire or a LED Module – Luminaire combination

Figure 6-1 illustrates the model of the thermal interface between the LLE or LED Module and the Luminaire. The LLE or LED Module consumes an amount of electrical power P_{el} and $P_{el,mod}$ respectively. This power is converted into visible light and heat:

$$P_{el} = P_{vis} + P_{th} \quad \text{EQ. 6-1}$$

or

$$P_{el,mod} = P_{vis} + P_{th} \quad \text{EQ. 6-2}$$

Here, P_{vis} is defined as the radiant flux in the visible light spectrum ($380 \text{ nm} < \lambda < 780 \text{ nm}$)⁷.

⁷ IR radiation is not included in P_{vis} and it is assumed that radiation in the range $\lambda < 380 \text{ nm}$ is negligible.

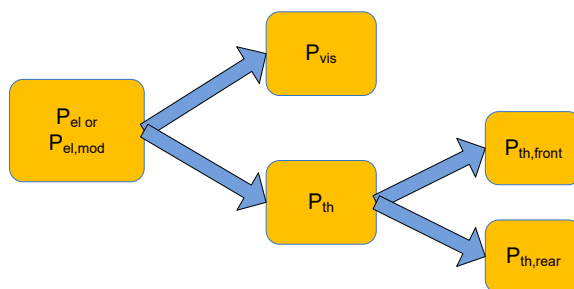


Figure 6-2 – Power conversion

Some of the thermal power P_{th} is drained by convection and infra-red radiation. The sum of the thermal power drained by convection and IR radiation is denoted by $P_{th,front}$ ⁸. Typically a substantial part of the thermal power will be drained through the Thermal Interface Surface to the heat sink of the Luminaire⁹. This portion is denoted by $P_{th,rear}$.

$$P_{th} = P_{th,rear} + P_{th,front} \quad \text{EQ. 6-3}$$

The Thermal Interface Surface is defined as the surface of the LLE or LED Module that makes physical contact with the surface of the heat sink of the Luminaire. The temperature t_r is defined as the temperature at a specified position on the Thermal Interface Surface under steady state operating conditions¹⁰. The exact position of this temperature point is defined for each type of LLE or LED Module in the respective Book.

The Zhaga defines the Rated Operating Temperature ($t_{r,max}$) and the value of $t_{r,max}$ shall be such that if $t_r = t_{r,max}$, a sample of the LLE or LED Module at zero burning hours shows photometric values equal to the Rated values within tolerances defined in the compliance test specifications of the Zhaga interface specifications.

The Reference Temperature t_r depends on the Ambient Temperature (t_a), the thermal resistance of the heat sink of the Luminaire (R_{th}) and the thermal power that is transferred through the Thermal Interface Surface ($P_{th,rear}$). Using a simple 1-dimensional model, the following relation is obtained:

$$t_r = t_a + R_{th} \cdot P_{th,rear} \quad \text{EQ. 6-4}$$

For performance equal to or better than the Rated values, the LLE or LED Module should be operated under the condition

$$t_r \leq t_{r,max}$$

Or:

$$R_{th} \leq R_{th,max} \quad \text{with} \quad R_{th,max} = \frac{t_{r,max} - t_a}{P_{th,rear}} \quad \text{EQ. 6-5}$$

⁸ $P_{th,front}$ is defined to be the thermal power that is drained by convection and IR radiation to the environment and not re-absorbed by the LLE, the LED Module or the heat sink.

⁹ Heat transfer via conduction through other parts of the system is assumed to be negligible.

¹⁰ "Steady state" is defined in section A.1.3.5.

6.2.2 Test Fixture TPTF

The relation between the thermal power drained by convection and IR radiation ($P_{th,front}$) on the one hand and the thermal power drained via the heat sink ($P_{th,rear}$) on the other hand depends on the geometry of the LLE-Luminaire system or the LED Module-Luminaire system. For each type of LLE or LED Module a Test Fixture TPTF may be defined in the respective Book. This Test Fixture TPTF shall be used to measure $P_{th,rear}$.

6.2.3 Rated Operating Temperature and safety (informative)

The Rated Operating Temperature ($t_{r,rated}$) or ($t_{p,rated}$) is used to define the conditions for the measurement of the temperature dependent parameters of the LED Light Engine or LED Module. In practical applications the Reference Temperature may be higher or lower than the Rated Operating Temperature. Also, the Rated Operating Temperature is not the absolute maximum temperature related to safety.

In order to comply with safety regulations, the LLE manufacturer has to make sure that the LLE or LED Module operates safely under normal operating conditions. However, this is not mandated by Zhaga and will not be verified by the ATC. In typical products, the maximum temperature related to safety will be considerably higher than the Rated Operating Temperature ($t_{r,rated}$) or ($t_{p,rated}$). This maximum temperature related to safety may be listed in the Product Data Set of the LLE or the LED Module/LED Array. Alternatively the LLE or LED Module/LED Array manufacturer may specify the maximum thermal resistance related to safety in the Product Data Set.

6.2.4 Thermal overload protection (Informative)

The temperature t_r or t_p in a specific LLE-Luminaire or LED Module-Luminaire combination depends on many characteristics of the LLE or the LED Module, the Luminaire and the mounting (for example the TIM and the contact pressure). Zhaga does not mandate a protection in the LLE or LED Module that guarantees the temperature t_r or t_p not to exceed an upper limit (for example by reducing power or shut down).

6.2.5 Ambient Temperature

As indicated in EQ. 6-5, the maximum thermal resistance of the LLE or LED Module ($R_{th,max}$) depends on the Ambient Temperature. With increasing Ambient Temperature $R_{th,max}$ decreases. This effect can be significant and shall be taken into account in the thermal compatibility check (section 6.2.7).

The LLE or LED Module manufacturer may list values of $R_{th,max}$ for several values of the Ambient Temperature. For each type of LLE or LED Module, Product Data Set requirements with respect to $R_{th,max}$ are defined in the respective Book. In case the Ambient Temperature is not listed in the Product Data Set, a value of 25 °C shall be used.

For each type of LLE or LED Module it is defined in the respective Book whether the Ambient Temperature shall be listed on the Luminaire Product Data Set or not.

In case the Ambient Temperature is listed in the Product Data Set of the Luminaire this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or the LED Module.

In case the Ambient Temperature is not listed in the Product Data Set of the Luminaire an independent judgment of the Ambient Temperature shall be made and this value shall be used in the thermal compatibility check (section 6.2.7) to determine the corresponding $R_{th,max}$ of the LLE or LED Module.

6.2.6 Luminaires with multiple LLEs or multiple LED Modules

Within Zhaga, a Luminaire is a lighting fixture which provides an appropriate environment for one or more LED Light Engines. Each LED Light Engine is a combination of one Electronic Control Gear and one or more LED Modules. In this section two cases for Luminaires with multiple LLEs or Multiple LED Modules are described.

6.2.6.1 Separate heat sinks

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on separate heat sinks, it is assumed that the LLEs or LED Modules do not influence each other from a thermal point of view. The general model described in section 6.2.1 can be applied to each LLE or LED Module individually.

6.2.6.2 One heat sink

In case a Luminaire contains more than one LLE or more than one LED Module and these LLEs or LED Modules are mounted on a single heat sink, all LLEs or LED Modules shall be identical¹¹. For such systems, the thermal resistance of the Luminaire is defined as:

$$R_{th} = \frac{MAX(t_{r,i}) - t_a}{P_{th,rear}} \quad \text{EQ. 6-6}$$

with $t_{r,i}$: temperature t_r of a LLE_i or LED Module_i

$P_{th,rear}$: Thermal power per LLE or LED Module

6.2.7 Thermal compatibility check

In general, the thermal resistance of a heat sink depends on the thermal power applied to the Thermal Interface Surface ($P_{th,rear}$). For that reason several values of $P_{th,rear}$ and corresponding values of R_{th} are listed on the Product Data Set of the Luminaire.

In order to determine whether a particular LLE or LED Module is thermally compatible¹² with a particular Luminaire, it should be verify that the applicable thermal resistance R_{th} specified in the Product Data Set of the Luminaire is less than or equal to the applicable maximum thermal resistance $R_{th,max}$ specified in the Product Data Set of the LLE or LED Module. Here, the applicable thermal resistance can be linearly approximated from thermal resistances corresponding to thermal powers above and below the actual LLE or LED Module thermal power. In cases of doubt or incomplete data, the thermal resistance of a power lower than the actual LLE or LED Module power shall be chosen for evaluation. The applicable maximum thermal resistance $R_{th,max}$ is the maximum thermal resistance that corresponds with the Ambient Temperature.

As an example (Informative), consider the information listed in the Product Data Sets of particular LLEs and Luminaires:

¹¹ In case a Luminaire contains more than one LLE or more than one LED Module/LED Array and these LLEs or LED Modules/LED Arrays are mounted on the same heat sink the temperature t_r of each LLE or LED Module/LED Array depends on the characteristics of all LLEs or LED Modules/LED Arrays and on the geometry of the system. In general this will result in a complex dependency matrix that cannot be translated into a simple model characterized by one thermal resistance (R_{th}). For that reason the model has been restricted to Luminaires with identical LLEs or LED Modules/LED Arrays. In later editions of the document the model may be expanded to other configurations.

¹² "thermally compatible" means that the LLE-Luminaire or LED Module/LED Array-Luminaire combination will operate at $t_r \leq t_{r,max}$

Data sheet of LLE #1					Data sheet of LLE #2				
$t_{r,max}$ (°C)	65				$t_{r,max}$ (°C)	80			
$P_{th,rear}$ (W)	18				$P_{th,rear}$ (W)	35			
t_a (°C)		30	40	50	t_a (°C)		30	40	50
$R_{th,max}$ (K/W)		1.9	1.4	0.8	$R_{th,max}$ (K/W)		1.4	1.1	0.9
Data sheet of Luminaire #1					Data sheet of Luminaire #2				
Max. t_a (°C)		30			Max. t_a (°C)		40		
R_{th} at $P_{th,rear} = 10$ W (K/W)		1.8			R_{th} at $P_{th,rear} = 10$ W (K/W)		0.9		
R_{th} at $P_{th,rear} = 20$ W (K/W)		1.6			R_{th} at $P_{th,rear} = 20$ W (K/W)		0.8		
R_{th} at $P_{th,rear} = 30$ W (K/W)		1.5			R_{th} at $P_{th,rear} = 30$ W (K/W)		0.7		
R_{th} at $P_{th,rear} = 40$ W (K/W)		1.4			R_{th} at $P_{th,rear} = 40$ W (K/W)		0.6		

From these numbers it can be concluded that

- LLE #1 is thermally compatible with Luminaire #1 as R_{th} at $P_{th,rear} = 10$ W (1,8 K/W) is less than $R_{th,max}$ at 30 °C (1,9 K/W)
- LLE #1 is thermally compatible with Luminaire #2 as R_{th} at $P_{th,rear} = 10$ W (0,9 K/W) is less than $R_{th,max}$ at 40 °C (1,4 K/W)
- LLE #2 is not thermally compatible with Luminaire #1 as R_{th} at $P_{th,rear} = 30$ W (1,5 K/W) is more than $R_{th,max}$ at 30 °C (1,4 K/W)
- LLE #2 is thermally compatible with Luminaire #2 as R_{th} at $P_{th,rear} = 30$ W (0,7 K/W) is less than $R_{th,max}$ at 40 °C (1,1 K/W)

6.2.8 Thermal uniformity

The thermal interface model defined in section 6.2.1 is a one-dimensional model. Implicitly it is assumed that the temperature across the Thermal Interface Surface is independent of the position. In typical applications this is not exactly the case. When replacing the LED Light Engine or LED Module by a Thermal Test Engine, the thermal interface model can only be used to predict the temperature t_r if the temperature non-uniformity of the LED Light Engine or LED Module and the Thermal Test Engine are limited. The non-uniformity of the temperature distribution across the Thermal Interface Surface depends on:

- the construction of the TTE, LLE, or LED Module and
- the construction of the heat sink of the Luminaire.

The non-uniformity of the temperature distribution across the Thermal Interface Surface is expressed in a set of thermal spreading resistance values. Here, the thermal spreading resistance between two measurement points i and j is defined as:

$$R_{sp}(i,j) = \frac{t_i - t_j}{P_{th,rear}} \quad \text{EQ. 6-7}$$

Here t_i and t_j are the temperatures at the measurement points i and j located on the Thermal Interface Surface. For each type of LLE or LED Module/LED Array the positions of these measurement points may be defined in the respective Book.

The parameter R_{sp}^{max} is defined as the maximum value of all spreading resistance values:

$$R_{sp}^{max} = \text{MAX}(R_{sp}(i,j)) \quad \text{EQ. 6-8}$$

The Zhaga interface specification may restrict the thermal non-uniformity in the case of a LLE or LED Module being operated in a Test Fixture TUTF. For each type of LLE or LED Module the Test Fixture TUTF and the requirements for thermal uniformity in this test case may be defined in the respective Book.

6.2.9 Thermal Interface Material

In order to guarantee good thermal contact between the LLE or LED Module/LED Array and the heat sink, a Thermal Interface Material (TIM) is typically applied to this interface. The TIM is defined to be part of the LLE or LED Module/LED Array and the Thermal Interface Surface is at the interface of the Luminaire and the TIM as depicted in Figure 6-3.

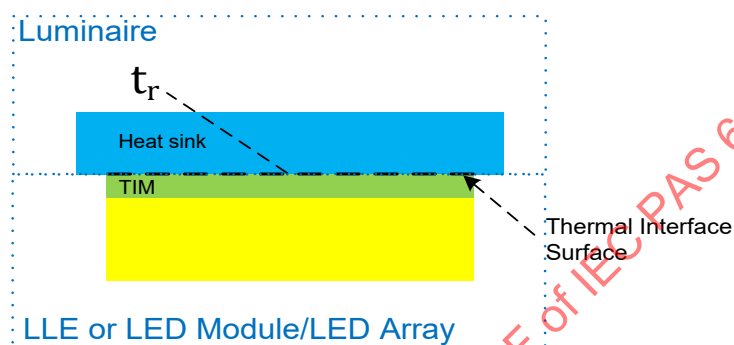


Figure 6-3 – Position of the Thermal Interface Surface in case of a configuration with TIM

The LLE or LED Module/LED Array shall be tested with the TIM prescribed by the LLE or LED Module/LED Array manufacturer, and the LLE or LED Module/LED Array manufacturer shall provide the prescribed TIM to the Zhaga Authorized Testing Center (ATC) when offering the LLE or LED Module/LED Array for Zhaga compliance testing. The Luminaire shall be tested with a TIM that is specified in the test specification of the respective Book.

6.2.10 Surface planarity and roughness

In order to guarantee good thermal contact between the LLE or LED Module/LED Array and the heat sink of the Luminaire, both the surface of the LLE or LED module/LED Array and the surface of the heat sink shall meet planarity and roughness requirements. For each type of LLE or LED Module/LED Array these requirements may be defined in the respective Book.

6.2.11 Aging of LED Light Engine or LED Module/LED Array (informative)

Due to aging of the LED, the radiated power (P_{vis}) will decrease over time and consequently the thermal power will increase. Although this effect is relatively weak it is recommended that the Luminaire manufacturer takes it into account in the design of the Luminaire.

6.2.12 Empty

This section is empty because its contents in a previous version has become obsolete.

6.2.13 Ambient Temperature and thermal resistance (R_{th})

The Ambient Temperature is defined as the average temperature of the air in the environment where the Luminaire (or Test Fixture) is applied. A few typical examples are:

- In case of an outdoor Luminaire or a suspended indoor Luminaire, the Ambient Temperature is the temperature of the air in the vicinity of the Luminaire.
- In case of a recessed Luminaire, the Ambient Temperature is the temperature of the air in the room, below the ceiling and in the vicinity of the Luminaire.

In section 6.2.1, the thermal resistance of the Luminaire (R_{th}) is defined as the thermal resistance from the Thermal Interface Surface to the environment. The environment corresponds to the position where the Ambient Temperature is defined.

As a consequence of these definitions, the thermal resistance of the Luminaire (R_{th}) depends on the mounting conditions of the Luminaire. The Luminaire manufacturer defines in the PDS (generally in the mounting instructions) how the Luminaire shall be mounted. Next to that, the Luminaire manufacturer shall define a setup for measuring the thermal resistance of the Luminaire. This setup should be a good model for the actual application of the Luminaire. Note that this measurement setup can be anything ranging from a free air setup to measurement boxes as defined by, for example UL and IEC for safety tests. It is recommended to use the same test setup for R_{th} measurement as for safety measurement. The ATC will use the setup as defined by the Luminaire manufacturer to measure the thermal resistance of the Luminaire.

6.3 Simplified thermal interface model

6.3.1 General case

See section 6.2.1.

6.3.2 Rated Operating Temperature and safety (informative)

See section 6.2.3.

6.3.3 Thermal overload protection (informative)

See section 6.2.4.

6.3.4 Thermal compatibility check

In order to determine whether a particular LLE or LED Module is thermally compatible with a particular Luminaire, it should be verified that the LLE-Luminaire combination or LED Module-Luminaire combination will operate at $t_r \leq t_r$. The value of t_r is listed in the LLE or LED Module/LED Array Product Data Set. Using the generic thermal model as defined in section 6.2.1, the operating temperature t_r can be determined by:

$$t_r = t_a + R_{th} \cdot P_{th, rear} \quad \text{EQ. 6-9}$$

The ambient temperature t_a is determined by the application of the LLE-Luminaire combination or LED Module-Luminaire combination. The value of R_{th} is a characteristic of the heat sink. Both t_a and R_{th} should be chosen appropriately by a skilled person.

The value of $P_{th, rear}$ is not listed in the LLE or LED Module/LED Array Product Data Set. However, it can be estimated using the Rated value of P_{th} in the LLE or LED Module/LED Array Product Data Set.

(Informative)

Depending on the required accuracy of the estimation of $P_{th, rear}$, the following methods may be used.

Method 1 – Ignore $P_{th,front}$

In this case $P_{th,rear} = P_{th}$

Method 2 – Estimate $P_{th,front}$ using a thermal simulation.

In this case, $P_{th,rear}$ is calculated using: $P_{th,rear} = P_{th} - P_{th,front}$ and $P_{th,front}$ is estimated using a thermal simulation of the LLE or LED Module in the specific application. This allows the characteristics of the Luminaire also to be taken into account.

6.3.5 Thermal Interface Material

See section 6.2.9.

6.3.6 Surface planarity and roughness

See section 6.2.10. It is recommended that the surface in the Luminaire which serves as a thermal interface has a surface planarity smaller than 0,1 mm and a surface roughness smaller than 3,2 μm .

6.3.7 Aging of LED Light Engine or LED Module/LED Array (informative)

See section 6.2.11.

7 Control interface

This edition Book 1 does not define means to control the light output characteristics of the LED Light Engine or the LED Module/LED Array.

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