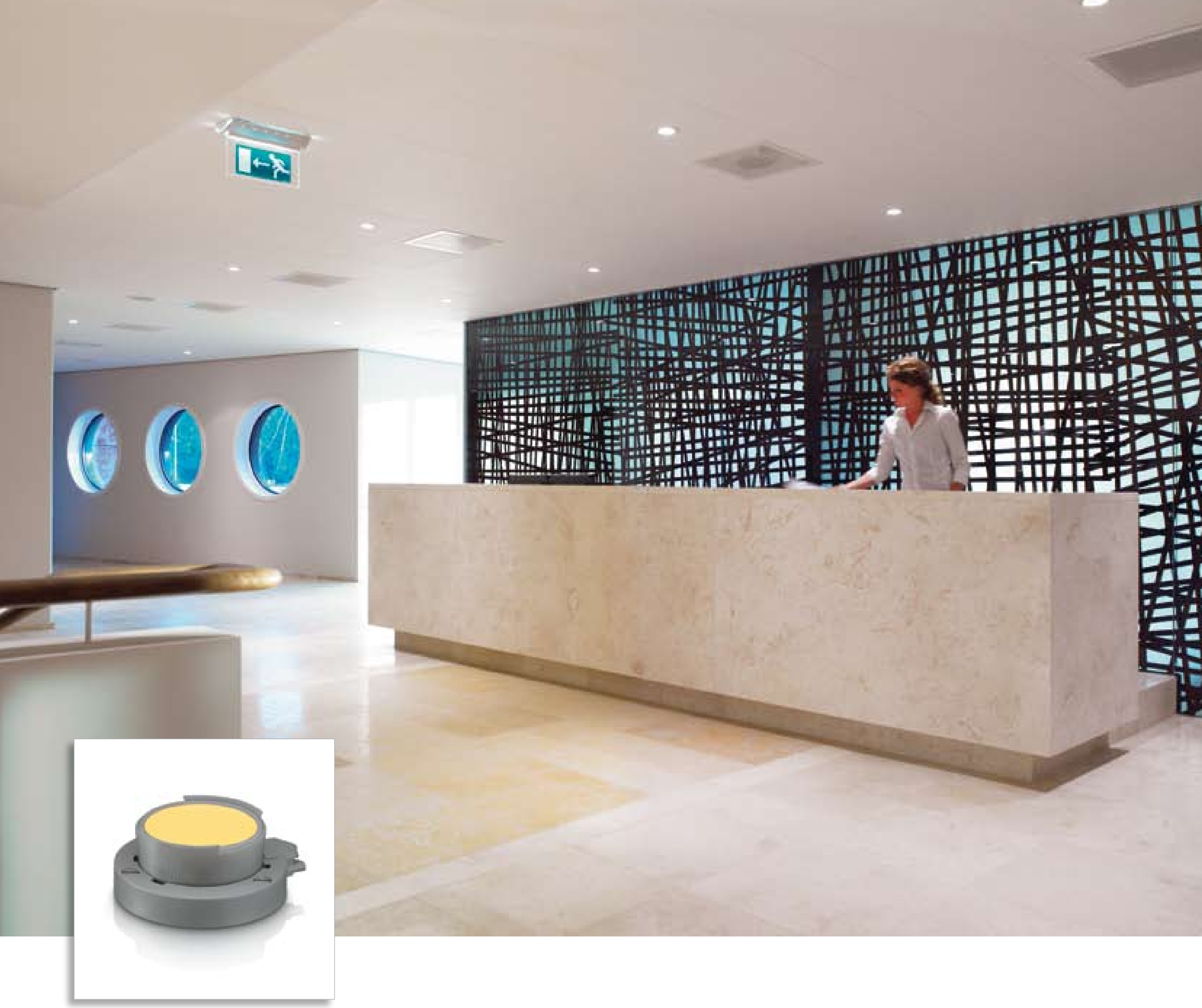


Design-in guide

Fortimo Twistable LED TDLM

asimpleswitch.com

PHILIPS

Contents

1. Introduction

Thank you for choosing the Philips Fortimo Twistable LED TDLM system.
This guide tells you all about this system. If you require any further information or support please consult your local Philips office or visit:
www.philips.com/support or
www.philips.com/fortimo

The advantages of LEDs have been known for 40 years:
- Long life – low maintenance cost
- Robustness – high reliability
- Saturated colors – maximum visual effect
- Cool beam – no heating of illuminated products
- No UV or IR – wide application possibilities
- Low-voltage operation – more safety, ease of use
- Mercury-free – care for the environment

The use of LEDs has implications for lighting manufacturers in terms of differences in solid-state lighting usage compared with traditional lamps: for example how to design given the constant improvements in specifications; how to provide the necessary heat sinking and how to deal with variations in flux and/or color. The Philips Fortimo Twistable LED TDLM system addresses these differences and facilitates easy adoption of LED technology for high lumen packages (1000 lm+). The system is designed for integration in luminaires (system). This technical application guide addresses the relevant issues to support and facilitate the work of specifiers and lighting system designers.

The Philips Fortimo Twistable LED TDLM system is, as the name suggests, designed and intended for downlight luminaires. Other applications can be explored by OEMs as long as this creates no design conflicts with the Fortimo Twistable LED TDLM system and European luminaire standards are respected (EN 60598). Please consult us if you wish to deviate from the design rules as described in this application guide.

Meanwhile also complementary businesses especially for heat sink and reflector design are developing around Fortimo Twistable LED TDLM systems. In the application guide you will also find references by AVC heatsink (passive cooling) and Alux Luxar (reflectors).

1.1 Features and benefits

Features	Benefits
Breakthrough LED L3 energy saving	LED solution enabling savings compared to Halogen solutions
Patented in Remote Phosphor technology	Very high optical efficiency
Superior-quality white LED light	An enabler for entry in General lighting
1100lm CRI 80 2700,3000, 4000K	Competes with CFL and halogen downlight systems
Optimized light mixing chamber	Perfectly mixed light , consistent color quality and lumen output
First replaceable module	
Socket interface design for the module	Peace of mind and easy to work with for OEMs and installer
Easy to mount Heatsink optics	Faster time to market
Dimmable instant light on	Enables further energy savings
Long lifetime from 25 Khrs to 50 Khrs	Low maintenance easy to replace
2700 K, 3000 K	Warmer colour temperature available for replacing halogen downlights in hospitality segment
Integrated driver	For ease of installations mains input directly
Dimmable via trailing edge dimming	Easy to experience and install

1.2 Applications

The Fortimo Twistable LED TDLM system is intended for general lighting applications in the semi professional market for, hospitality and retail and office.

Examples of applications include:

- Hospitality (hotels representative areas such as receptions, boardrooms, restaurants, etc.)
- Public buildings (cinemas, theaters, swimming pools, exhibition halls)
- High-end shops
- Retail (supermarkets, bakery/butcher areas, leather goods, etc.)
- Urban outdoor lighting (ground lighting, post-top lanterns)
- Use in outdoor luminaires?

Neither the Fortimo Twistable LED TDLM module nor its lamp holder has an IP classification.
If an OEM decides to use the Fortimo Twistable system in a luminaire for outdoor application, the OEM is responsible for proper IP protection and approbation of the luminaire.

2. LEDs at the heart of the Fortimo Twistable downlight module

The development of Light Emitting Diodes (LEDs) is progressing at such a pace that they are rapidly gaining importance for lighting applications. To most people, the term LED still only means the small indicator lights that show whether the TV set is switched on. These tiny light sources barely emit enough light to make themselves visible.
However, breakthroughs made in the last few years now allow LEDs to be used for 'real' lighting applications that have traditionally been the domain of incandescent lamps and discharge lamps.
The Philips/Agilent joint venture Lumileds was the first to bring high power LEDs for lighting applications to the market under the LUXEON trademark. LUXEON emitters are among the highest-performance LEDs in the world, allowing us to offer the brightest solid-state lighting solutions.

2.1 What is LED?

LEDs are solid-state devices, built up from crystalline layers of semiconductor material. The light generation process makes use of the special electronic properties of crystalline semiconductors in a process called injection luminescence. In brief, this means the injection of charged particles by an electric field from one semiconductor layer into another, where they are able to relax to a lower-energy state by emitting visible light. LEDs produce narrow light spectra. The bandwidth remains limited to a few tens of nanometers, and is therefore perceived by the human eye as a single, deeply saturated color. LEDs are now available in all wavelength regions of the visible spectrum; yellow is the only region in which no high-power LED is currently available. White light can be produced by combining LEDs of different colors (for instance red, green and blue), or by applying phosphor coatings on blue or ultraviolet LEDs. Like many other lamps, LEDs cannot be connected directly to the mains. The LEDs have to be operated at a stabilized low voltage, which is provided by Driver electronics.
However, LEDs do not need ignition and can be switched within milliseconds. LEDs do not generate nearly as much heat as many other lamps, but that does not mean that thermal design is not important. LEDs do produce heat when they operate, and are themselves relatively sensitive to temperature. Thermal considerations are therefore very important aspects of LED lighting system design.

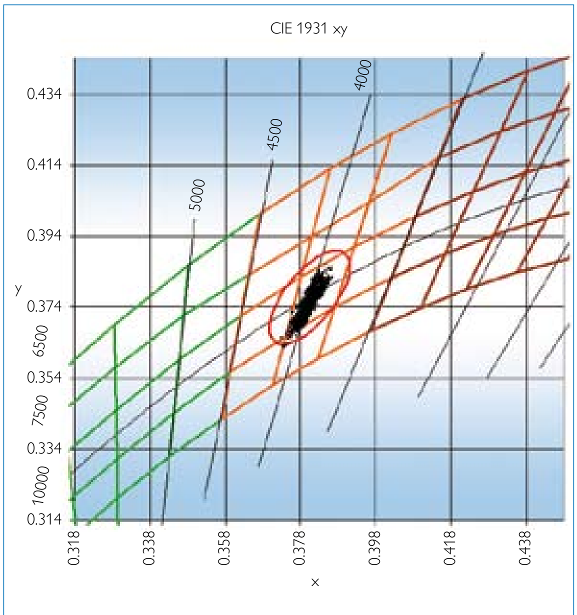
2.2 LED packaging

The bare LED die is still a very sensitive and fragile device that must be handled in a clean room environment. Before bringing them outside, they must be packaged. The light flux of conventional LEDs, for example those used as indicator lights on TV sets, is severely limited by the amount of heat generated. In practice, conventional LED packages are limited to about 0.15 W at most, and emit only a few lumens. Their light is too weak to be used for illumination purposes, and they can only be used for luminance applications (i.e. when the light source is intended to be viewed directly). A breakthrough came with a new package design invented by Philips Lumileds, which guides away the heat generated at the diode junction much more efficiently. LEDs based on this package are sold under the trademark LUXEON. Instead of an epoxy cap, the chip is encapsulated in a silicone gel covered by a polymer lens. Using two different materials for encapsulation and for the primary optics allows better optimization of material properties for heat management and lifetime. The slug is a large metal body that takes up the heat from the chip and provides a low-thermal-resistance route to the outside world. This package design now makes high-power LEDs feasible.

2.3 Binning

The subject of binning should be explained because of its importance in LED system design. As in other semiconductor manufacturing processes, in LED production the number of parameters of the epitaxy process is very large and the process window small (for example, the temperature must be controlled to within 0.5 °C (<1 °F) across the wafer at temperatures of ~800 °C/1470 °F). The difficulty of achieving such a high degree of control means that the properties of the LEDs may vary significantly within single production runs and even on the same wafer. To obtain consistency for a given application, binning (= selection in bins) is mandatory. Binning involves characterization of the LEDs by measurement and subsequently categorizing them into several specific bins. To keep the cost per LED down, LED manufacturers must sell the full production distribution. At the same time they cannot guarantee the availability of all bins at all times. There is a trade-off between logistics and cost price on the one hand, and the application requirements on the other. Setting the specification too tightly will increase the cost price and may lead to logistics problems. System design should therefore try to combine LEDs from different bins intelligently to obtain the required system performance at a reasonable price and with reasonable delivery reliability.

LUXEO Rebel LED



Color consistency (SDCM)

2.4 LUXEON Rebel LEDs

LUXEON Rebel is the smallest surface mountable power LED available today. With the industry's best lumens per package, highest light density (lumens per mm2), and the highest packing density, LUXEON Rebel is ideal for both space constrained and conventional solid lighting applications. Due to the small mounting surface we have been able to use multiple LUXEON Rebel with the Fortimo Twistable in order to match required lumen packages of 1100.

2.5 Fortimo Twistable LED TDLM addresses the issue of binning

High-quality LED light is achieved by mixing the light of blue LEDs and applying a special Fortimo phosphor technology remote from the LEDs. High-quality white light is characterized by a color rendering of 80, a color consistency comparable with conventional CFL and HID solutions (five SDCM)).

2.6 Color consistency (SDCM)

The target specification of Fortimo Twistable LED TDLM systems for color consistency is 5 SDCM @ 0 hours and 6 SDCM @ 10 Khrs. This is a similar specification as for conventional CFL lamps. SDCM stands for Standard Deviation of Color Matching and the value 5 refers to the size of an ellipse around the black body locus. Staying within this ellipse results in a consistency of light that ensures that from one luminaire to another no difference can be noticed.

2.7 Miniaturization

LEDs are typically much smaller than conventional light sources. Lighting designers and specifiers immediately recognized the fact that LEDs allow dramatically different lighting designs that capitalize on these tiny, unobtrusive light sources. This is understandable, but care must also be taken to deal with the heat produced by power LEDs. Proper heat management places limits on miniaturization.

3. Philips Fortimo Twistable LED TDLM system

- Fortimo Twistable LED TDLM range
- Fortimo Twistable LED TDLM 827 230-240 V
- Fortimo Twistable LED TDLM 830 230-240 V
- Fortimo Twistable LED TDLM 840 230-240 V
- Fortimo Twistable LED TDLM lamp holder 230-240 V

3.1 Specifications of Twistable 1100 lm 827

Twistable 1100 lm 827	
Lumen output	1040 lm
CT	2700 K
Module efficacy lm/W	52 lm/W
Colour consistency	5/6 SDCM
CRI	80
Input voltage	220-240 V
PF	>0.9
THD	40%
Frequency	47-63 Hz
Dimming range	10% to 100%
Wattage	20 W
Lifetime	25 Khrs @ Tcase 65 °C
	50 Khrs @ Tcase 55 °C

Specifications of Twistable 1100 lm 827

3.2 Specifications of Twistable 1100 lm 830

Twistable 1100 lm 830	
Lumen output	1100 lm
CT	3000 K
Module efficacy lm/W	55 lm/W
Colour consistency	5/6 SDCM
CRI	80
Input voltage	220-240 V
PF	>0.9
THD	40%
Frequency	47-63 Hz
Dimming range	10% to 100%
Wattage	20 W
Lifetime	25 Khrs @ Tcase 65 °C
	50 Khrs @ Tcase 55 °C

Specifications of Twistable 1100 lm 830

3.3 Specifications of Twistable 1100 lm 840

Twistable 1100 lm 840	
Lumen output	1100 lm
CT	4000 K
Module efficacy lm/W	62 lm/W
Colour consistency	5/6 SDCM
CRI	80
Input voltage	220-240 V
PF	>0.9
THD	40%
Frequency	47-63 Hz
Dimming range	10% to 100%
Wattage	18 W
Lifetime	25 Khrs @ Tcase 65 °C
	50 Khrs @ Tcase 55 °C

Specifications of Twistable 1100 lm 840

3.4 The basic principle of the Fortimo Twistable LED TDLM system

The Fortimo Twistable System includes a socket to create connection between the mains and the led module. The socket can be directly fixed on the heatsink. No need for a separate LED driver since the driver is integrated in the LED module .

3.5 Starting characteristics

The system can be switched on in milliseconds, which is a general characteristic of LEDs.

3.6 Luminous flux during starting period

In contrast to other light sources, LEDs can be switched on at full power (or at any other dimmed level) instantaneously. The Fortimo Twistable LED TDLM system requires an initial burning-in time of 100 hours to reach the listed specifications because of the combination of the LEDs and the remote phosphor used in the modules.

3.7 Lumen maintenance

When used within specification, ($T_c < 65$ °C; $T_a = 35$ °C) lumen maintenance of 70% at 25,000 hours is expected for Fortimo Twistable LED TDLM. IF you wish to reach 50 K hours lifetime with the same lumen maintenance 70% then the Tcase should be at $T_c < 55$ °C.

3.8 Dimming

The Twistable LED TDLM can dim in combination with mostly used conventional dimmers. TRAILING EDGE DIMMERS. There is a very large variety of trailing edge dimmers available with different dimming ranges load and behavior. We recommend OEMS to specify to their end users the following dimmers to be used:
In connection with the dimmer the efficiency will be reduced slightly (10% depending on the dimmer).

List of released dimmers

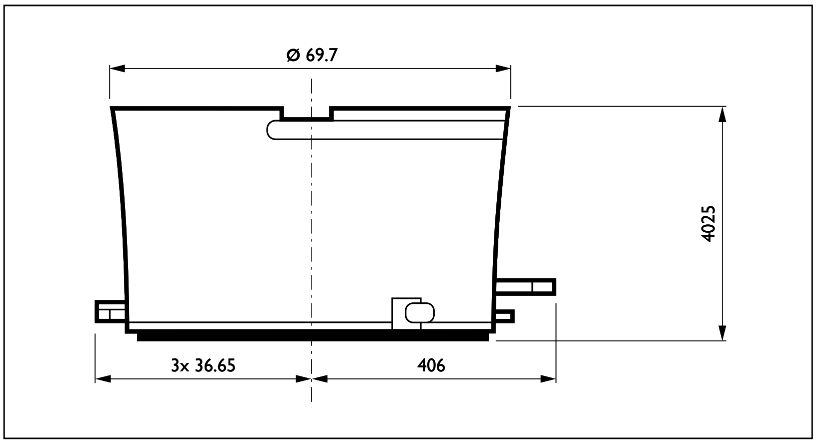
Nr	Brand	ID	Type	Region
1	Jung	225 T DE	RC	EU
2	Bush Jaeger	6513U-102	RC	EU
5	Siemens	5TC8 284	RC	EU
6	Schneider	ATD315	RC	APR

List of released dimmers

These trailing edge dimmers may also be identified by the RC type dimmers. Note that R, RL and RLC dimmers may not work correctly. We suggest the OEM manufacturer to release a dimmer together with the luminaires and to be sold together with the luminaire, when they want to use a dimmer different than in the list mentioned for recommended dimmers.

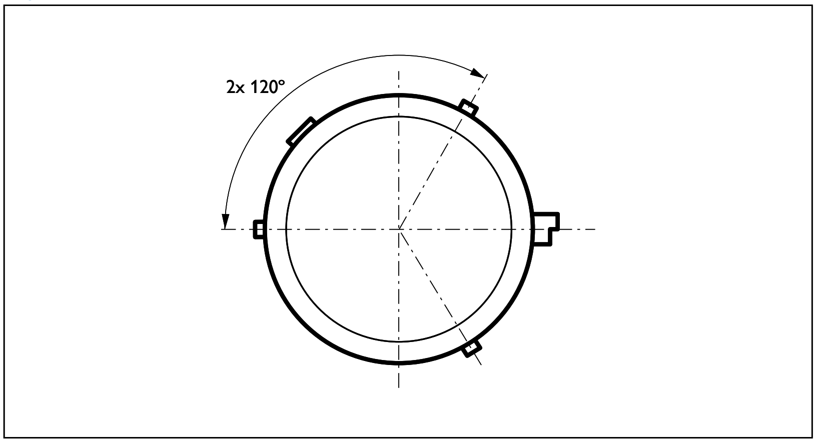
3.9 Dimensions of the Twistable module and lamp holder

Side view Module



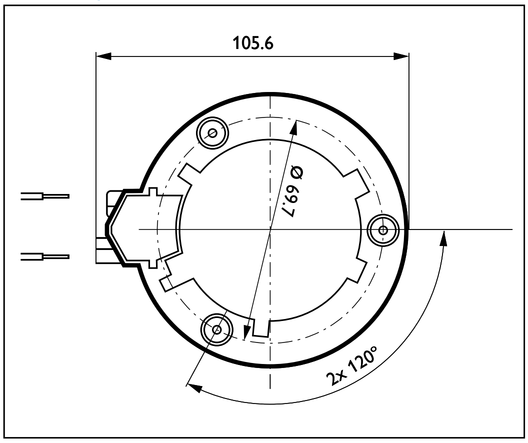
Dimensions Side view Module

Top view module



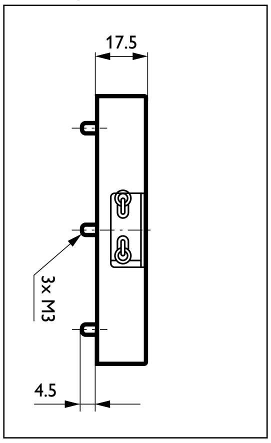
Dimensions Top view module

Socket top view



Dimensions Socket top view

Socket profile view



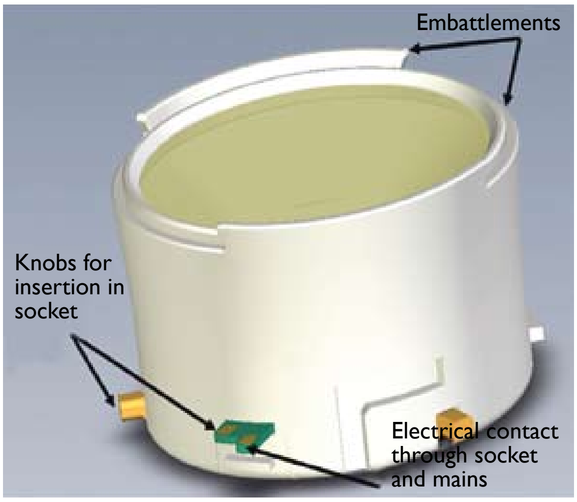
Dimensions Socket profile view

3.10 About the Fortimo Twistable LED TDLM module

- The LED module consists basically of 5 main components:
- PCB with LED Mixing chamber
- Heat spreader
- Diffuser with remote phosphor technology
- TIM thermal interface material at the bottom of the module: not to be removed even for placement in the lamp holder

High-quality white light with high efficiencies is achieved with a plain PCB with LEDs and a remote phosphor film layer. The mixing chamber ensures perfectly mixed light, resulting in uniform colors and good color consistency. The heat spreader facilitates optimal heat transfer and helps luminaire manufacturers to design their own heat sink system. Besides facilitating high efficiencies, the remote phosphor technology makes it relatively easy to develop virtually any fluorescent color. The module will be available from the start in 3 CCTs : 4000 K, 3000 K, 2700 K.

The function of the diffuser is to shape the light distribution, resulting in a Lambertian beam. The luminaire manufacturer has the freedom to design its own secondary optics. On top of the LED module are some embattlements (hooks) which are meant to remove the module out of the fixture by the help of another module. Thus the reflector should be fixed in such a way that embattlements stick out of the reflector. On the bottom side of the module are knobs to insert module in the socket the reflector diameter should also be designed in such a way that the module and its knobs at the bottom can go through the reflector without having to remove the reflector. It is up to the luminaire manufacturer to plan or not a anti-theft mechanism in the luminaire to prevent end users from stealing the LED module.



Fortimo Twistable lamp holder

3.11 About the Fortimo Twistable lamp holder

The Fortimo Twistable lamp holder has been developed in close cooperation between BJB and Philips as a dedicated lamp holder for our Fortimo Twistable LED module. The Lamp holder takes care of the pressure between the LED module and the heatsink thanks to its spring mechanism. With its spring mechanism, the lamp holder pressurizes the interface between module and heatsink for proper thermal contact. 3 screws (3 * M3 screws) are placed in the lamp holder to manage fixation between heatsink or/and reflector to the module and holder.

A connector on the side of the lamp holder makes sure that the mains are correctly connected to the module. The lamp holder is safe for end users according to the standards for lamp holders.

The module can only be twisted out of the lamp holder via a clockwise movement.

3.12 UV and other hazards

- PET value >100 hrs./Klux (zero UV)
- Damage factor 0.08 @ 4100K
- IR (infrared) radiation as well as being free of UV radiation,
- The LED modules are also free of infrared radiation in the beam.

4. Lighting performance characteristics

4.1 Photobiological safety aspects

As of March 2007, LEDs and LED-based products for general lighting are no longer included in the scope of the Eye Safety standard for lasers, IEC 60825-1 'Safety of laser products'. The new lamp standard, IEC 62471 'Photobiological safety of lamps and lamp systems', covering incoherent light sources, is now applicable.
This international standard gives guidance for evaluating the photobiological safety of lamps and lamp systems including luminaires. Specifically it specifies the exposure limits, reference measurement technique and classification scheme for the evaluation and control of photobiological hazards from all electrically powered incoherent broadband sources of optical radiation, including LEDs but excluding lasers, in the wavelength range from 200 nm through 3000 nm.
In the photobiological safety standard, hazard categories are defined as follows:

Radiance-based

- Blue Light LB 300 – 700 nm
- Retinal Thermal LR 380 – 1400 nm
- Retinal Thermal Weak Stimulus LIR 780 – 1400 nm

Irradiance-based

- Actinic UV Skin & Eye ES 200 – 400 nm
- Eye UVA EUVA 315 – 400 nm
- Blue Light Small Sources EB 300 – 700 nm
- Eye IR EIR 780 – 3000 nm

Measurements on the Fortimo Twistable LED TDLM gave the following results:

The following should be taken into account:

- The effective radiance measurement for Blue Light (LB) modules is 'Low', meaning that the LED modules are categorized in Risk Group 1. F=or the 2000 lumen version, the permitted exposure time for Blue Light radiance (relevant when looking into the source) is limited to 1.5 hours, while for the 1100 lumen version it is 3 hours. Because of the Law of Conservation of Radiance, integrating the LED module into a luminaire results in either the same radiance or a reduced radiance. Final assessment of the luminaire is recommended.
- The measured irradiance-based values (E) for the categorized hazards are all within the exempt group (both 1100 and 2000 lumen versions).
- In general the permitted exposure time for irradiance is limited when in the 'low', 'moderate' or 'high' risk group. Limiting the exposure time and/or the distance to the source can reduce the hazard level. However, for the measured LED modules there are no special precautions necessary since they are ranked in the exempt group. Final assessment of the luminaire (including e.g. secondary optics) is recommended.

! Photobiological safety is not assured if the Fortimo Twistable LED module is lit up without the cover. Direct exposure to the blue LED light is dangerous for the eyes.

4.2 Emission limit

Hazard category	Emission Limit
LB	Low (Risk group 1)
LR	Exempt *
LIR	Exempt
ES	Exempt
EUVA	Exempt
EB	Exempt
EIR	Exempt

Emission limit

* *Exempt means 'no risk'.*

4.3 Dimming characteristics

Fortimo Twistable LED TDLM makes use of a so-called amplitude (AM) dimming protocol. Where most LED systems work with PWM (pulse width modulation) where the current is cut in parts and where basically dimming levels are achieved by combining, on high frequency, on/off settings (pulses). AM dimming reduces the current through the LEDs to achieve lower light levels. And here is the big advantage: at lower currents LEDs operate more efficient (graphs on the left). Next to this, other advantages of AM dimming are:

- No audible noise during dimming.
- No visual interference with other lighting or video sources.

5. Designing a luminaire

5.1 IEC recommendations

The general recommendations for luminaire design given by the IEC (IEC 60598) and the national safety regulations are also applicable to LED-based luminaires.

5.2 Electrostatic device measures (ESD)

The Fortimo Twistable LED TDLM systems do not require special ESD measures in a production environment.

5.3 Installation instructions

The Fortimo Twistable LED TDLM systems are build-in systems for integration into luminaries,

There are interfaces for:

- Lamp holder (from the module)
- Mains input via lamp holder
- Heatsink fixation on the lamp holder

Reflector can be connected via the heatsink (standard heatsink from AVC) available with holes for fixation of the reflector.

Note:

The socket only takes care of the mains input no connection to protective earth.
The Fortimo Twistable is class 1 requiring a protective earth connection in the luminaire.
The OEM needs to take care of a proper protective earth connection to the luminaire heatsink. It is highly recommended for safety to ground to the heatsink. Because the Fortimo Twistable LED is class 1, protective ground needs to be connected.

The socket does not take care of the strain relief of the mains cable we recommend to add a strain relief mechanism to make sure the mains cannot be removed and pulled from the lamp holder.

5.4 Wiring

To follow.

5.5 Connecting to Trailing edge dimmer

To follow.

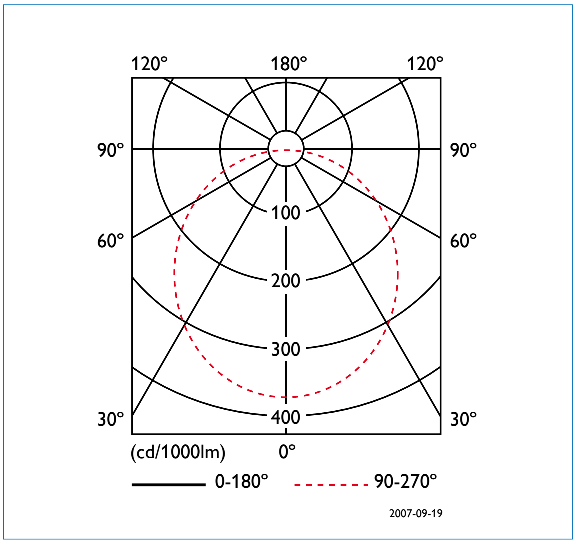
5.6 Outdoor luminaires

Neither the Fortimo Twistable LED TDLM module nor the lamp holder has an IP classification. If an OEM decides to use the Fortimo system in a luminaire for outdoor application, it is responsible for proper IP protection and approval of the luminaire.

5.7 Secondary optics

The Fortimo Twistable LED TDLM module generates a Lambertian beam shape (see polar diagram intensity diagram) which is a pragmatic starting point for secondary optic design by OEMs. Ray-set files are available upon request. The secondary optic design should not cover the exit aperture. "It is not recommended to put a secondary optics within 70 mm of the Fortimo Twistable light exit window. When the product is installed according to the guidelines, temperature of the light exit window will be below 105 °C. When the customer decides to place a secondary optics within 70 mm of the light exit window, the customer should take care that the temperature of the material will not exceed 105 °C for performance and 115 °C for safety. The temperature of the light exit window can be measured with Infrared temperature sensing technique."

Secondary optics are not part of the Fortimo Twistable LED TDLM system offering. This is an added value area for OEMs. Meanwhile a complementary reflector business around the Fortimo Twistable LED TDLM is developing. Companies like Alux Luxar has reflector designs ready for the Fortimo Twistable systems.



Philips LightLabs (simulation) Fortimo Twistable

5.8 Philips LightLabs (simulation) Fortimo Twistable / LDC (Polar)

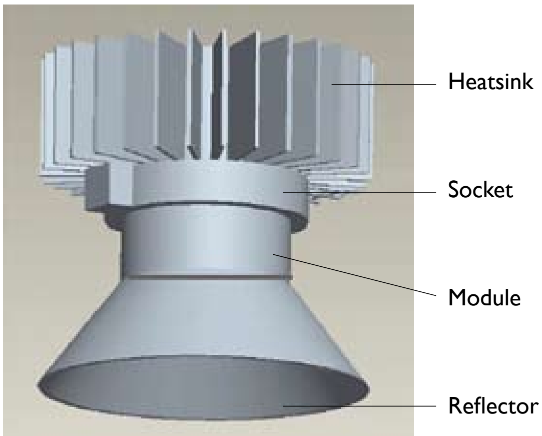
Luminaire: Philips LightLabs (simulation) Fortimo Twistable

Lamps: 7x

5.9 Alux luxar contact details

For a full specification and application assistance please contact Alux Luxar directly:
Alux Luxar GmbH & Co. KG
Schneiderstrasse 76, D-40764 Langenfeld, Germany
Sales: Rene Kaiser, tel. +49 2173 279 - 224
www.alux-luxar.de

6. Heatsink design and temperature measurement



Example of a system with passive heatsink

6.1 General

For optimum performance the Fortimo Twistable LED TDLM system must operate within specified temperature limits.

6.2 Test requirements

Temperature measurements should only be performed when the luminaire is thermally stable, which may take 0.5 to 2 hours depending on the thermal capacity of the luminaire (see also the relevant clauses in IEC 60598). For all measurements such as temperature, luminous flux and power, a stabilization period of at least half an hour must be allowed before any reliable data can be obtained. Measurements must be performed by means of thermocouples that are firmly glued to the surface (and not, for example, secured with adhesive tape).

6.3 Maximum temperature

Because LEDs are temperature-sensitive, LED modules require a different approach with respect to the maximum permissible component temperature. This is different to most other types of light source.

6.4 Critical measurements point

For LEDs the junction temperature is the critical factor for operation. Since there is a direct relation between the case temperature and the LED junction temperature it is sufficient to measure the bottom side of the module. The critical point is on the back surface of the LED module. If the case temperature (Tc) at the critical measurement point is too high (exceeding the recommended maximum temperature), the performance of the LEDs will be adversely affected, for example in terms of light output, lifetime or lumen maintenance.

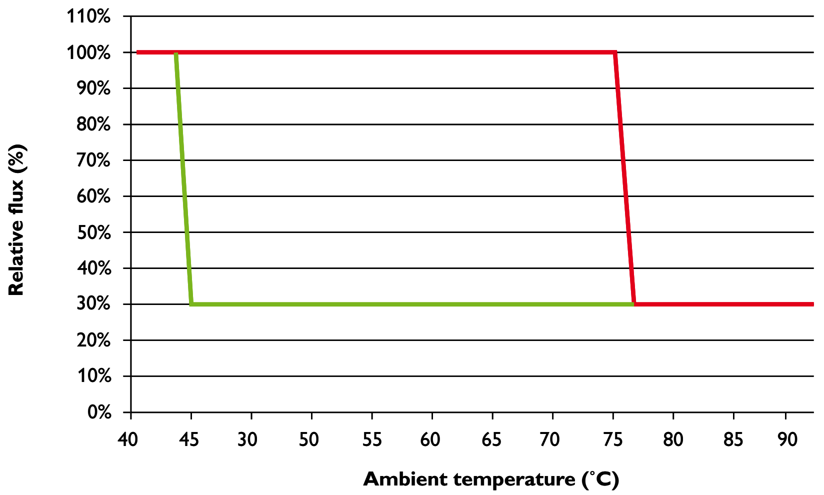
Since the bottom side is covered with a thin plastic foil, the case temperature cannot be measured on the module itself. Instead, it should be measured on the luminaire heatsink on the tcase position. If the heatsink has a hole at the tcase position, the tcase temperature can be measured on the metal side of the wall.

6.5 Operation under built-in conditions

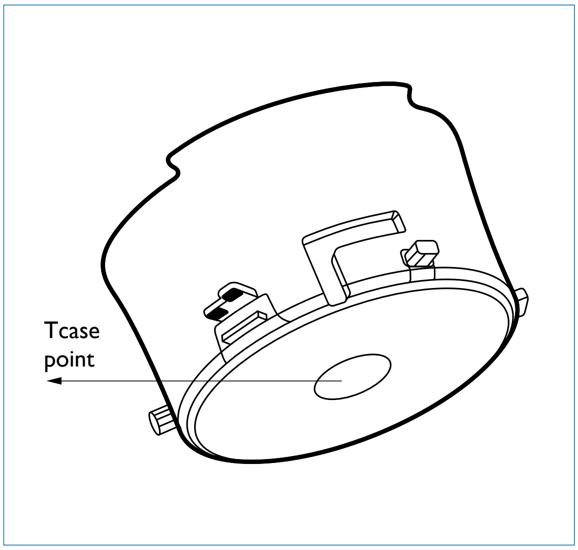
The heat produced by LED module in the luminaire (or similar housing) must be dissipated to the surroundings. If a luminaire is physically insulated by a ceiling, wall or insulation blanket, the heat produced cannot easily be dissipated. This will result in heating of the LED module in the luminaire, which in turn can have an adverse effect on system performance and lifetime. For optimum performance and lifetime it is important that: air can flow freely around the luminaire; and airflow through the luminaire, around the modules, has a positive effect on temperature control and hence on performance and lifetime.

6.6 Case temperature and LED module performance

To ensure the performance of the Fortimo Twistable LED TDLM system we have defined a Tcase at the back surface of the LED module of 65 °C. At that case temperature the junction temperature of the LEDs is assured and the indicated performances (lifetime, light output, lumen maintenance) can be guaranteed. Above a Tc of 65 °C,a thermal circuit will be engaged. This Module will step dim down to a certain level and will switch to normal output when a lower temperature Tcase is reached in the system. The graphs below display the typical case temperature and relative dim level as a function of case temperature.



Typical case temperature and relative dim level as a function of case temperature



Tcase point

The performances of light output, light maintenance and lifetime is related to the Tc value T case value : Tc = 65 °C for Fortimo Twistable LED TDLM 1100 for all CCTS.

The heat sink design in this case can be reduced as long as the Tc remains under 65 °C. In order to reach 50 k hours lifetime specification one may choose to go for a Tcase of 55 degrees resulting in a bigger size and volume heatsink.

The Fortimo Twistable LED module is designed for a case temperature of 65 °C/149 °F

The flux is then 100%. if the operating condition of the Fortimo Twistable LED module is lower than the Tc point, performance will increase.

6.7 Heat sink design

To ensure that housing temperatures do not exceed the specified maximum values, a luminaire can act as an additional heat sink. The applicable heat transport mechanisms are conduction via the heat sink and convection and thermal radiation to the surroundings. The objective of this chapter is not to indicate exactly how to calculate a heat sink, but to give some guidelines on how to improve its performance. Although a heat sink can have many (complex) shapes, the following discussion is based on a disk type of heat sink. The results for square plates, etc., are more or less the same provided the surface areas are equal. The type of material used has a relatively large influence on the final result. For example, a comparison of the thermal conductivity (k) of copper with that of corrosion-resistant steel (see table left) shows that a substantially smaller heat sink can be made with copper. In practice the best material for heat sinks is (soft) aluminum. The thickness (d) of the heat sink disk is also of major importance. Assuming the use of different heat sinks of the same diameter but made from different materials, the same effect in terms of temperature difference will be achieved if the product of thermal conductivity (k) and disk thickness (d) is constant. This means more or less the same result is obtained with a disk of 1 mm copper, 2 mm aluminum, 4 mm brass, 8 mm steel or 26 mm corrosion-resistant steel. Increasing the diameter, and thereby also the surface area, of the heat sink disk also leads to an improvement, but the effect is smaller for larger diameters and depends on the thermal conductivity (k) of the material and the thickness (d). Thermal radiation can also form a substantial part of the total heat transfer, and is of the same order as for convection. This depends strongly on the emission coefficient (see table) of the surface, which lies between 0 and 1. For example, a polished aluminum surface has a very low emission coefficient, while that of a painted surface is very high.

Material	W/mK
Copper	400
Aluminium	200
Brass	100
Steel	50
Corrosion-resistant steel	15

Thermal conductivity

Material	W/mK	Emission coefficient
Aluminium	New/polished	0.04 – 0.06
	Oxidized	0.2 – 0.3
	Anodized	0.8
Steel	Painted	0.8 – 0.95
	New/polished	0.03 – 0.07
	Heavy oxidized	0.7 – 0.8

Emission coefficients

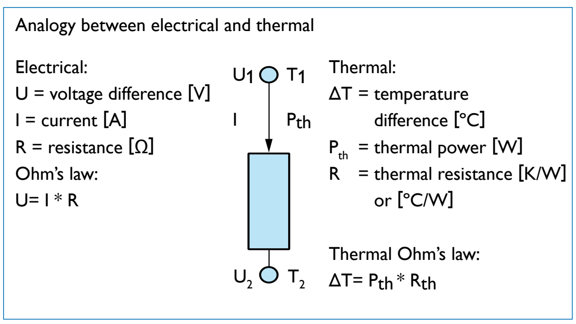
6.8 Size of heat sink

The Fortimo Twistable LED TDLM products consume typically up to 20 W and contains a built-in heat spreader. The module is delivered with a layer at the bottom this should not be removed from the module since it makes sure of a perfect contact between the module and the heatsink without the need for adding thermal paste. This layer has a very limited negative influence on the thermal conductivity and no impact on the behavior of the module. Deducting the driver efficiency and the energy that is effectively giving light leaves a heat of 13,5 W that needs to be taken away from the module. The spreader at the back of the module is the contact area for the external heat sink. The performance (life time and amount of light) of the module depends heavily on the thermal management. Therefore the temperature of the test point (Tc) is important. During the thermal design process, the aim is to keep the Tc temperature below the stated maximum (65 °C). Although the Fortimo Twistable LED module will not fail due to a higher temperature, the effect of insufficient cooling will mean that the light output of the LEDs is automatically step dimmed and lifetime could be reduced.

So the better the thermal management (low Tc of the LED module) the better the performance of the luminaire (life time and light output). Here is a differentiation opportunity for luminaire manufacturers.
The size of the heat sink needed depends on the power rating of the module. The Fortimo Twistable LED TDLM 1100 lm consumes 20 W to produce 1100 lumens. The surface area of a heat sink, when passively cooled, for a 1100 lm system is ~ 0,08 m^2, once LED efficiency upgrades become available, power rating will be reduced and required heat sink size can also be reduced. This is planned for 2011.

6.9 Air flow

Before starting with any calculation, an important point to consider is the airflow. In general hot air is moving upwards with relatively low speed. The form and position of the heat sink is influencing the airflow. If the fins are perpendicular to the airflow which reduces the efficiency of the heat sink. This situation should be avoided.
A better way to position the fins is to have the fins parallel to the airflow direction. Closing the top of the profile will reduce the effectively of the heat sink as well, and should be avoided during design and installation.



Electrical and thermal analogy

6.10 Thermal model

Standard STATIC thermal situations can be modeled with so-called thermal resistances. These resistances behave like electrical resistors. Below the analogy between electrical and thermal resistors is explained. Where on the left the electrical units are mentioned, on the right the thermal equivalent is set. With a known voltage difference at a certain current it is possible to calculate an electrical resistor with Ohm's law. The same is possible with a thermal resistor. If the temperature difference is known and the thermal power, the thermal resistance can be calculated with thermal Ohm's law.

6.11 Calculating your heat sink

We start a thermal calculation formula:

- Formula (f1) the relation between temperature difference, thermal power and thermal resistance. With this formula the needed thermal resistance can be calculated when the thermal power and temperature difference are known.

Formulas:

Thermal:	ΔT = Rth x Pth (f1)

Next we gather all available information, as can be found in the datasheet, application details and design choices.

Below we calculate the needed thermal resistance of the heat sink, such that in worst case situations, the maximum temperature of the test point Tc, is below its maximum.

Available information:

Tc-max	= 65 ˚C
Pth-Fortimo Twistable 1100 TDLM	= 13.5 W
Tambient-max	= 35 °C

From the datasheet:

Maximum test point temperature:	Tc-max = 65 °C
Thermal power Fortimo Twistable LED TDLM 1100:	Pth = 13.5 W
Maximum temperature in application. In this case we install the product below ceiling, which is the ambient temperature of the product:	T ambient-max = 35 °C chosen in this case.

The maximum temperature differs per application and can be lower or higher, than the now chosen 35 °C.

Below we calculate the needed thermal resistance of the heat sink, such that in worst case situations, the maximum temperature of the test point Tc, is below its maximum.

Calculation of total maximum thermal resistance: (f1)

ΔT ambient - Tc = 65 – 35 = 30 °C

Rth Tc - ambient = (Ttambient - Tc)/ Pth = 30/13.5 = 2.222 K/W

Calculation of the total thermal resistance : Rth-from-Tc-to-ambient with formula f1. This results in 2.222 K/W.

Now we know the thermal resistance of the needed heat sink. This heat sink dimension is such that at maximum power and maximum ambient temperature, the temperature of the test point Tc is at or below its maximum of 65 °C. This is the worst case situation, which means that normally the test point temperature Tc is lower. This assures lifetime and light output will be according to specifications.

6.12 Shape of heat sink

When looking into catalogs of heat sink suppliers, the shape is determining the thermal resistance of the heat sink. In this case the length is a design parameter. There are many variations in fin number, length of fins, length of heat sink and so on. With special thermal design software, a tailor made solution can be found as well.
With the use of a standard thermo couple all important temperatures can be measured and compared to theoretical values.
It's very important that there is no moving air in the room. This will influence the measurement heavily.

6.13 AVC contact

AVC has developed passive cooling solutions specifically made for the Fortimo Twistable. In different Tcases 65 to achieve a smallest heatsink possible and 25 Khours lifetime and Tcase 55 to achieve the maximum lifetime of the Fortimo Twistable module while compromising on the compactness of the heatsink. Screw holes are placed already on the heatsink to fix the socket as well as a possibility to fix a reflector directly onto the heatsink.

If you need more information please contact AVC:
Jeff Chou
Sales Department, Shang-Hai office
ASIA VITAL COMPONENTS CO., LTD.
cell CN: +86 13916680014
office: +86-21-50270508 ext. 68528
cell TW: +886 920123616
jeff_chou@avc.com.cn
AVC: website http://www.avc.com.tw/

7. Heatsink design and temperature measurement

7.1 Electromagnetic compatibility

Electromagnetic compatibility, EMC, is the ability of a device or system to operate satisfactorily in its electromagnetic environment without causing unacceptable interference in practical situations. Philips Fortimo Twistable LED TDLM systems fulfill the requirements with regard to electromagnetic compatibility as laid down in European Norms EN 55015 and EN/IEC 55022, EN 61000-3-2 and EN/IEC 61547.

7.2 Humidity

Fortimo Twistable LED TDLM modules and LED drivers have no IP classification. The OEM is responsible for proper IP classification and approbation of the luminaire.

7.3 Exposure to direct sunlight

Exposure to direct sunlight during operation may have severe temperature or UV effects. Where this situation is likely, extensive temperature testing is recommended. The Fortimo Twistable LED TDLM systems are a build-in system (except independent versions), so this is expected to be negligible.

7.4 Vibration and shocks

Shock resistance: 50 g @ 6 ms half-sine.

Vibration resistance: sweep 10-500 Hz, 5g, 2 hours at each of all 3 axes without failure.

7.5 Standards and approvals

Philips Fortimo Twistable LED TDLM system complies with the following international rules and regulations, including:

Safety EN/IEC 60598-1 & 2-2, EN/IEC 61347-1 & 2-13

Approvals ENEC 05, CE

Philips Fortimo Twistable LED TDLM systems carry the CE marking. CE is the abbreviation of Conformité Européenne. It expresses conformity of products to mandatory requirements of the European Community Directives. The CE mark acts as a 'passport' that allows goods to circulate freely throughout the European Union.

Furthermore, it simplifies inspection by Market Controlling Bodies. Two European directives cover lighting products: the Electromagnetic Compatibility (EMC) Directive and the Low Voltage Directive (LVD). The Philips Fortimo Twistable LED TDLM system carries the CE marking on the basis of compliance with the following standards: EN/IEC 61547, EN/IEC 61000-3-2, EN 55015.

7.6 IP codes, dust and moisture protection

Philips Fortimo Twistable LED TDLM systems are build-in systems and have therefore no IP rating.

7.7 Glow-wire test

Philips Fortimo Twistable LED TDLM systems conform to the 850 degree glow-wire test. Reference test: according to additional national deviations for clause 13.3 (Annex 2c of EN 60598-1). An exception is made for France, where local regulations are stricter.

7.8 End-of-life behavior

Unlike typical conventional light sources, LEDs are not subject to sudden failure or burnout. There is no time at which the light source will cease to function. Instead, the performance of LEDs shows gradual degradation over time. When used according to specification, Fortimo Twistable LED TDLM modules are predicted to deliver an average of 70% of their initial intensity after 25,000 hours' operation at Tcase 65 (after 50Khours at Tcase 55). The life of the system is therefore more dependent on the other electronic system components and soldering methods. The LEDs in the Fortimo Twistable LED TDLM module are connected in series. If one LED fails, this may be due to an internal short-circuit (character of blue LEDs). In this case it will still conduct current, so that the other LEDs will still operate.

7.9 Fortimo Twistable LED TDLM system disposal

At the end of their (economic) lifetime, appropriate disposal of the Fortimo Twistable LED TDLM is recommended. The modules are basically normal pieces of electronic equipment containing components that at present are not considered to be harmful to the environment, or which can be disposed of with normal care. It is therefore recommended to dispose of these parts as normal electronic waste, according to local regulations.

8. Index of visuals

For more information please visit:
www.philips.com/fortimo
www.asimpleswitch.com
www.philips.com/oem

Document order number: 3222 635 67885
01/2010