OEM Design-in guide

Fortimo LED LLM (linear light module system) – Version 1.0

• Fortimo LED LLM 1100 & 1800 in 3000 & 4000K

PHILIPS

sense and simplicity

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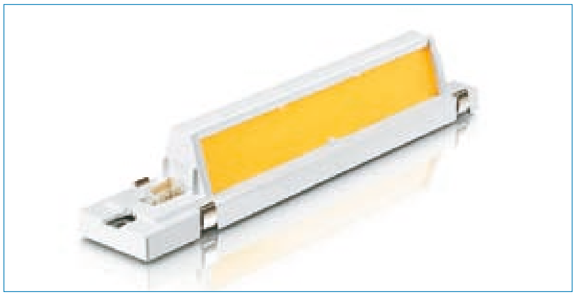
1. Introduction of the Fortimo LED LLM system



Fortimo LED LLM module

Fortimo LED LLM driver

Thank you for choosing the Fortimo LED LLM system.
This guide tells you all about this system. If you require any further information or support please contact your sales representative or visit www.philips.com/fortimo.

Rapid improvements in high-power LED technology mean that LEDs can now be used for the first time in common lighting applications, providing improvements over traditional lighting systems. In contrast to traditional lamps, OEMs have additional design elements to consider when using LEDs. For example, how to design around a technology that is ever evolving; how to provide the necessary heat sinking required for the application, and how to manage variations in flux and/or color. The Fortimo LED LLM system is designed for integration into luminaires. This technical application guide addresses the relevant issues to support and facilitate the work of specifiers and lighting system designers.

The Fortimo LED LLM system can be used for indoor luminaires, and in certain outdoor applications as well as long as this creates no design conflicts with the system and it meets local standards. Please consult us if you wish to deviate from the design rules as described in this application guide. In the application guide you will also find references to heat sinking and reflector manufactures.

1.1 Features and benefits

Features	Benefits
Linear shaped LED module	Easily creates uniform and retangular light patterns
Fortimo technology applied (Remote Phosphor Film layer)	Highly efficient, energy-saving light source (>64lm/W at system level)
Offers the latest in Philips LED technology, ensuring performance and product availability	Reduced LED supply chain complexity for OEMS
No mercury	Environmental friendly
Long lifetime (50,000 hours)	Reliable system performance
Future-proof / easy replacement	Upgradeable

1.2 Applications

- General lighting
- Ambient lighting
- Wall washing

2. LEDs, the heart of the Fortimo LED LLM

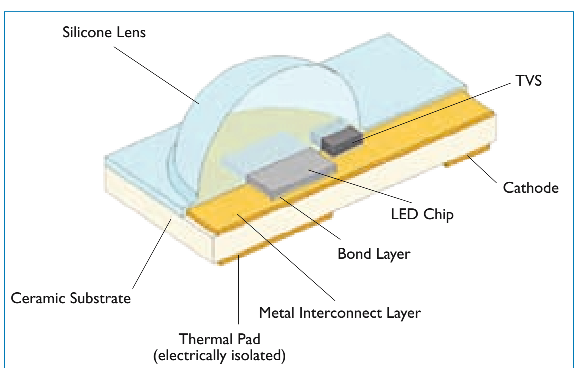
2.1 What is a LED?

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 are 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.

LUXEON Rebel LED

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.



Cutoff section LED

2.3 Binning

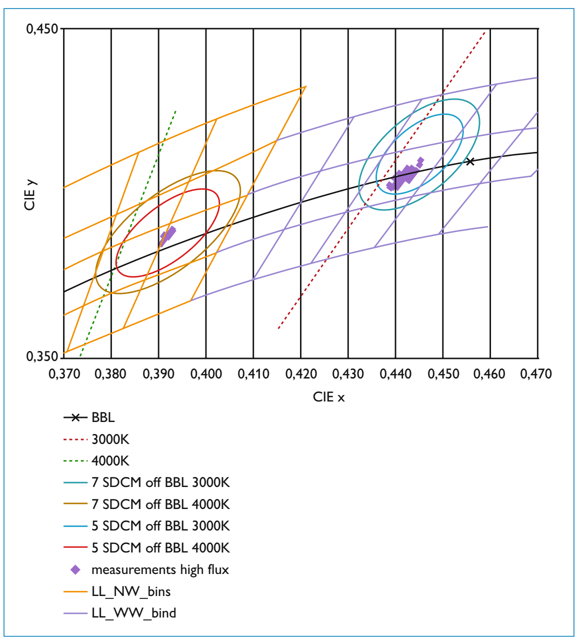
The subject of binning should be explained because of its importance in LED system design. As in other semiconductor manufacturing processes, in LED production the number of parameters of the epitaxy process is very large and the process window small (for example, the temperature must be controlled to 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.

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 mm^2), 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 within the Fortimo products in order to match required high lumen packages.

2.5 Fortimo 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 for outdoor applications is characterized by a color rendering of minimal 70, popular CCTs in general lighting applications of 3000 K and 4000 K and a color consistency comparable with conventional PLL and HID solutions (five to seven SDCM).



Color consistency (SDCM)

2.6 Color consistency (SDCM)

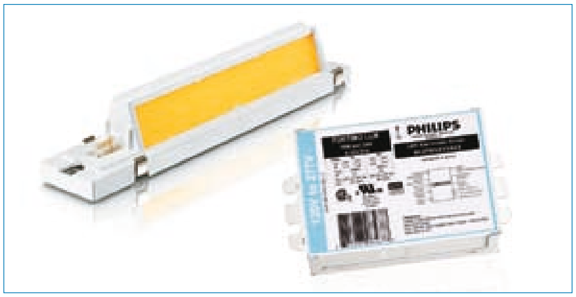
The target specification of Fortimo LED LLM systems for color consistency is 5 SDCM at 0-hours and 7 SDCM at 10K hrs. This is a similar specification as for conventional PLL lamps. SDCM stands for Standard Deviation of Color Matching and the value 5 refers to the size of an ellipse around the black body locus. Staying within this ellipse results in a consistency of light that ensures that from one luminaire to another no difference can be noticed.

In the visual we have plotted > 150 Fortimo LED LLM systems and you can see they all fit within the 5 SDCM ellipse. This really demonstrates the unique quality of the remote phosphor concept. We also plotted these results in a typical bin distribution sheet of Philips Lumileds. As you can see, all of the Fortimo LED LLM system's shown fit within 1 bin. Typically you can buy 6 to 12 bins combinations, not so precise as the 1-bin result of Fortimo LED LLM systems.

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. Fortimo LED LLM system



Fortimo LED LLM System

The Fortimo LED LLM portfolio offers a complete range of linear lighting solutions. It is primarily designed for luminaires for indoor use, but can also be used in certain outdoor applications. Further extensions of the portfolio will be in high lumen packages and programmable dimming features. Future products will make use of the current form factor to build further on the future-proof promise of Fortimo LED LLM systems. As the system is future-proof, it will be possible to replace and upgrade the system without modifying the luminaire.

3.1 The Fortimo LED LLM system components

- Fortimo LED linear light module
- Fortimo LED LLM driver
- Fortimo LED LLM cable (50 cm)

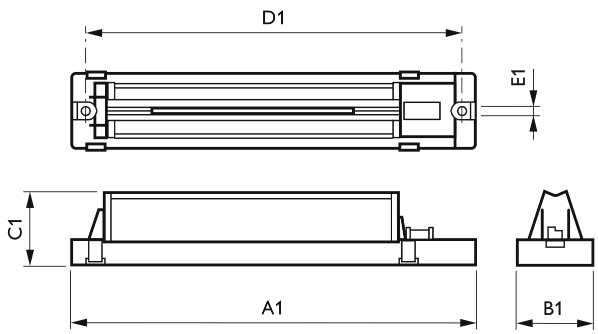
3.2 Nomenclature

Philips Fortimo LED LLM1800 28W/730 120-277V	
Philips	Brand name
Fortimo	Family type
LED	LED system
LLM	Fortimo type descriptor
1800	Light output
28W	Energy consumption system
730	CRI+CCT
120-277V	Voltage range

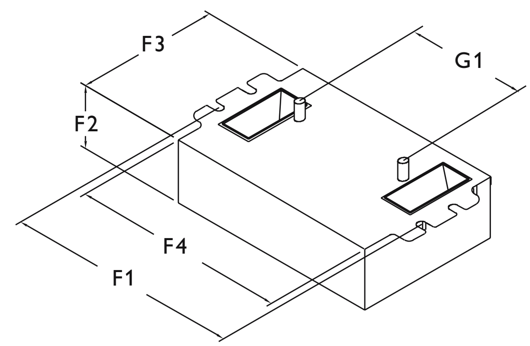
3.3 Fortimo LED linear portfolio

Philips Fortimo LED LLM System (driver, module and cable)	Part Number
3000K	
Fortimo LED LLM US 1800 23W/830	929000497903
Fortimo LED LLM US 1100 14W/830	929000498003
4000K	
Fortimo LED LLM US 1800 22W/740	929000498103
Fortimo LED LLM US 1100 12W/740	929000498203
Driver	
Fortimo LED driver (DLM, LLM, SLM 1100/1800/2000)	913701213402
Cable	
Fortimo LED LLM cable 50 cm without fan	442240069731

3.4 Dimensions of Fortimo LED LLM system



Fortimo LED LLM module



Fortimo LED LLM driver

A1	B1	C1	D1	E1	F1	F2	F3	F4	G1
9.05" (230.0)	1.77" (45.0)	1.65" (42.0)	8.44" (214.5)	0.18" (4.5)	4.55" (116.6)	1.18" (30.0)	3.00" (76.4)	4.20" (106.7)	2.0" (50.8)

Dimensions in inches (mm).

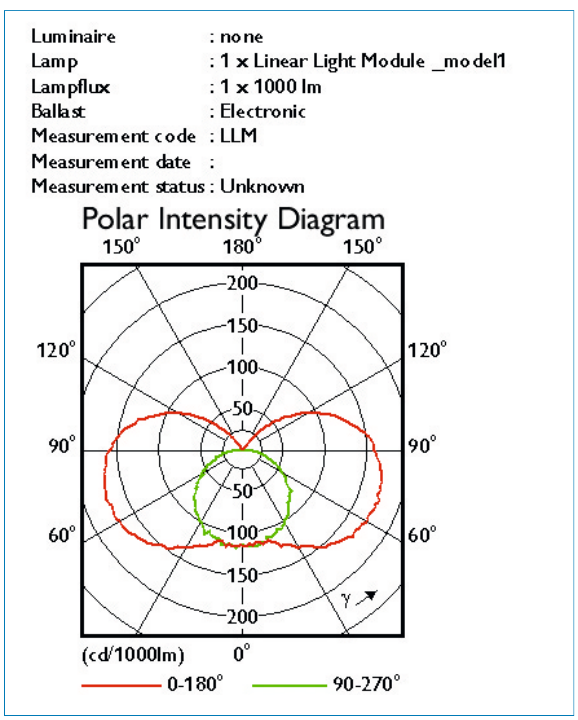
3.5 Fixation (mechanical)

The separate components (Driver and Module) of the Fortimo LED LLM system can be securely fastened by the mounting holes located on the module and driver. Please refer to dimensional drawing for the specific details such a pitch and diameter.

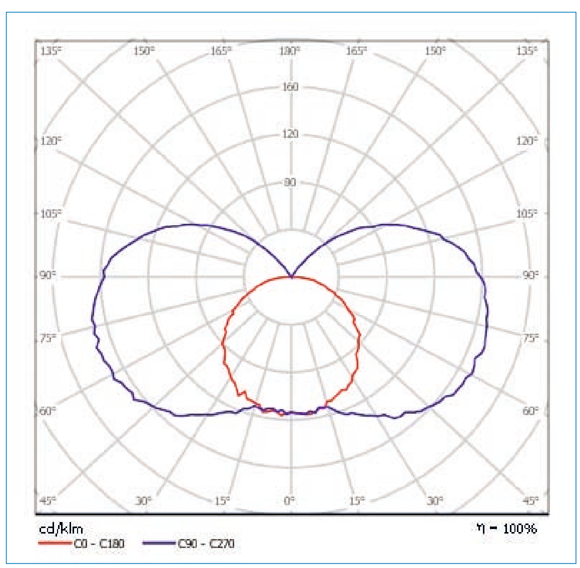
The 3D CAD files will be available for downloading from www.philips.com/fortimo. For fixation of the system, we advise to use hexagon socket head cap screw M4 (DIN 912 / ISO 4762) with cylindrical heads M4 (DIN 7980) of Stainless steel A2 (DIN 1.4301 / AISI 304).

3.6 Lighting performance characteristics

3.6.1 Photometric diagrams



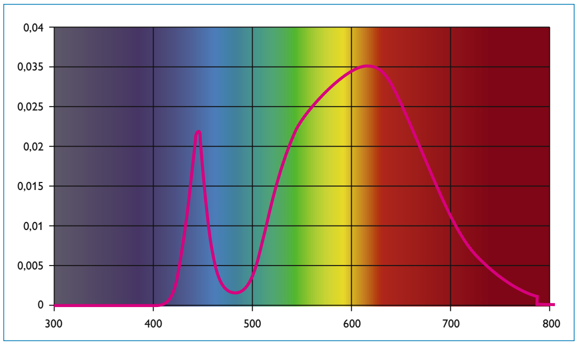
Polar diagrams Fortimo LED LLM



Batwing light distribution

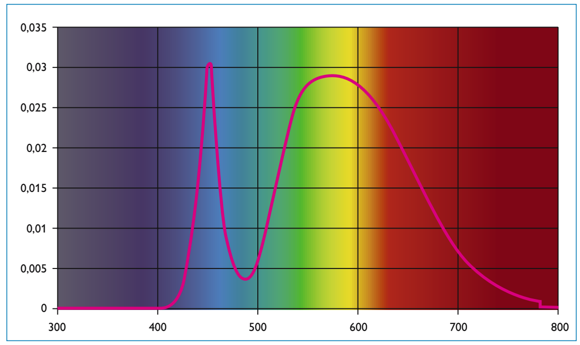
3.6.2 Spectral power distribution Fortimo LED LLM

Special Power Distribution Fortimo LED LLM 3000 K



Wavelength (nm)

Special Power Distribution Fortimo LED LLM 4000 K



Wavelength (nm)

3.6.3 UV and other hazards

PET value >100 hrs./Klux (zero UV)

Damage factor 0.08 at 4100 K

IR (infrared) radiation. As well as being free of UV radiation, the LED modules are also free of infrared radiation in the beam.

3.6.4 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

Hazard Category	Emission Limit
LB	Low (Risk Group 1)
LR	Exempt
LIR	Exempt
ES	Exempt
EUVA	Exempt
EB	Exempt
EIR	Exempt

Emission limit

Note: Exempt = no risk

3.6.5 Measurements on the Fortimo LED LLM

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. For the 1800 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 1800 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.

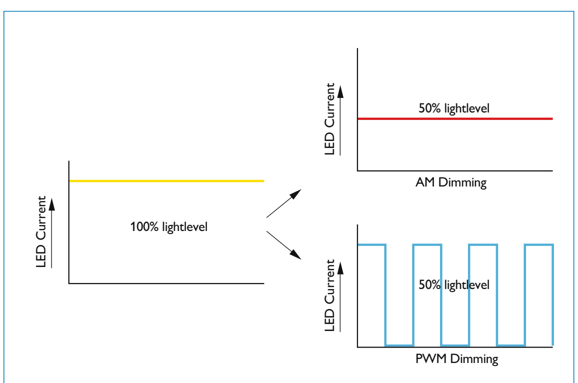
Photobiological safety is not assured if the Fortimo LED module is lit up without the cover. Direct exposure to the blue LED light is dangerous for the eyes.

3.7 Starting characteristics

The system can be switched on in milliseconds, which is a general characteristic of LEDs. It is planned to have a programmable outdoor driver, making it possible to switch in milliseconds to any dimming level for any length of time.

3.8 Luminous flux during start period

In contrast to other light sources, LEDs can be switched on at full power (or at any other dimmed level) instantaneously. The Fortimo LED LLM 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.



3.9 Dimming function of driver

The dimming characteristics of the Fortimo LED LLM makes use of a so called amplitude (AM) dimming protocol. Most LED systems use PWM (pulse width modulation), which means that the current is switched on/off at high frequency. When dimming the time between the on and off switching increases. AM dimming reduces the current through the LEDs to achieve lower light levels and another advantage is that there is no:

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

3.10 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. This system meets FCC Class A requirements in a reference luminare.

3.11 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 LED LLM systems are build-in systems, so this is expected to be negligible.

3.12 Vibration and shocks

Shock resistance: 50 g at 6 ms semi-sinusoidal.
Vibration resistance: Sweep 50-150 Hz, one hour at resonance frequency (all 3 axes) without failure.

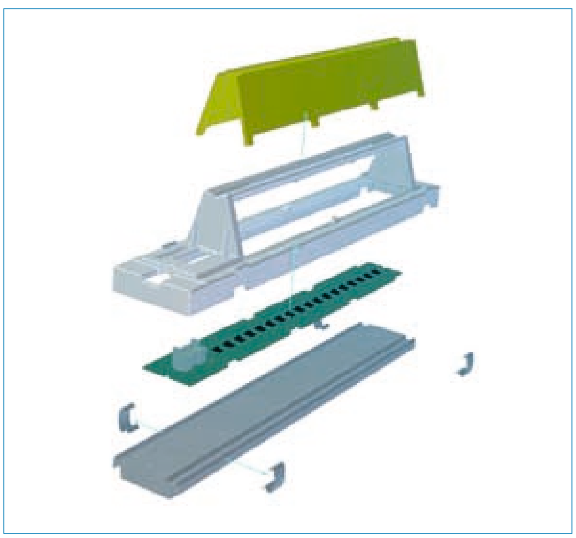
3.13 Standards and approvals

Fortimo LED LLM systems comply with the following rules and regulations:

- UL recognized
- CSA

3.14 IP codes, dust and moisture protection

The Fortimo LED LLM modules and drivers are build-in systems and have therefore no IP classification. The Fortimo LED LLM system is not designed for operation in free air. The OEM is responsible for proper IP classification and approbation of the luminaire. The Fortimo LED LLM System is also damp location rated.



Exploded view Fortimo LED LLM (module)

3.15 About the Fortimo LED LLM module

The Fortimo LED LLM module consists basically of four main components:

- PCB with LEDs
- Mixing chamber
- Heat sink
- Diffuser with remote phosphor technology

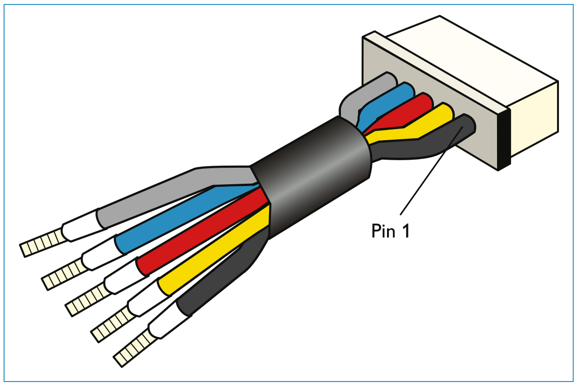
High-quality, white light with high efficiencies is achieved with a plain PCB with LEDs and a remote phosphor film layer. The mixing chamber ensures perfectly mixed light, resulting in uniform colors and good color consistency. The heat sink facilitates optimal heat transfer and helps luminaire manufacturers to design their own heat sink system. The heat sink is equipped with a hole on either side of the module for fixing. The function of the diffuser is to shape the light output, resulting in a batwing distrubution. The luminaire manufacturer has the freedom to design its own secondary optics. The overall dimensions of the Fortimo LED LLM module, i.e. the combination of heat sink and mixing chamber, is optimized for lumen packages varying from 1100 lumen to 4500 lumen.

Fortimo LED driver

3.16 About the Fortimo LED LLM driver

The highly efficient Fortimo LED LLM driver is specially designed to operate the Fortimo LED LLM module. It is designed to operate high-power LEDs.

- Maximum current settings of 700mA
- Maximum 56V enables classification of the system as a UL Class 2 power supply
- High efficiency: 85% at full load
- Tcase life = 75°C
- Class 2 and isolated output
- 0-10V Dimmable
- Connectorized
- Small size



Fortimo LED LLM Cable

Fortimo LED LLM Cable

3.17 About the Fortimo LED LLM cable

For connecting a Fortimo LED LLM driver to a Fortimo LED LLM module a specific cable has been developed. The standard Fortimo LED LLM cable is 500 mm.

JST connector:
Housing JST XAP-05V-1
Contact JST SXA-001T-P0.6
Cable:
5x Wire 24 AWG UL style 1569 (green, blue, red,yellow, black)
Heat shrink tube

Pin 5: Wire 24 AWG UL style 1569 Grey	=	Signal ground
Pin 4: Wirre 24 AWG UL style 1569 Blue	=	LED module setting
Pin 3: Wire 24 AWG UL style 1569 Red	=	NTC (thermal control)
Pin 2: Wire 24 AWG UL style 1569 Yellow	=	Power ground
Pin 1: Wire 24 AWG UL style 1569 Black	=	Current (power utput)

3.18 Fortimo LED LLM system disposal

At the end of their lifetime, appropriate disposal of the Fortimo LED LLM system or its components 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, and can be disposed of with normal care. It is therefore recommended to dispose of these parts as normal electronic waste, according to local regulations.

4. System performance specifications

Philips Fortimo LED LLM System (module, driver and cable)	Module 12NC	Driver 12NC	Cable 12NC	Vin (V)	P (W)	Iin(mA) @120V	pf	THD (%)	Flux	Color Temp.
				Nom	Nom	Nom	Nom	Nom	Nom	Nom
Fortimo LED LLM US 1800/830	929000498103	913701213402	442240069731	120-277V	26.5	220	>0.9	<20	1800	4000K
Fortimo LED LLM US 1800/730	929000497903	913701213402	442240069731	120-277V	28	230	>0.9	<20	1800	3000K
Fortimo LED LLM US 1100/740	929000498203	913701213402	442240069731	120-277V	16	135	>0.9	<20	1100	4000K
Fortimo LED LLM US 1100/330	929000498003	913701213402	442240069731	120-277V	18.5	155	>0.9	<20	1100	3000K

Philips Fortimo LED LLM System (module, driver and cable)	CRI	Eff. (lm/W)	B50L70 @TC 55C of Module	B50L70 @TC 65C of Module	Tamb (°C)	Tcase Module (°C)		Tcase Driver (°C)	
	Nom	Nom	Nom	Nom	Nom	Typ	Max	Typ	Max
Fortimo LED LLM US 1800/830	75	71	50K hrs	35K hrs	(-20) to 35	55	65	75	85
Fortimo LED LLM US 1800/730	80	64	50K hrs	35K hrs	(-20) to 35	55	65	75	85
Fortimo LED LLM US 1100/740	75	67	50K hrs	35K hrs	(-20) to 35	55	65	75	85
Fortimo LED LLM US 1100/830	80	59	50K hrs	35K hrs	(-20) to 35	55	65	75	85

5. Designing a luminaire

5.1 UL recommendations

The general recommendations for luminaire design by UL and the national safety regulations are also applicable to Fortimo LED LLM systems. The luminaire manufacturer is advised to conform to local standards of luminaire design.

5.2 Electrostatic device (ESD) measures

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

5.3 Wiring

The sticker on the power supply shows the connections layout for the connection to mains. The system should not be serviced when mains voltage is connected; this includes connecting or disconnecting the Fortimo LED LLM cable. Use only solid 18AWG wire, UL 1452 style.

5.4 Optical design (secondary optics)

The Fortimo LED LLM module generates a batwing beam shape, which is a pragmatic starting point for secondary optic design by OEMs. Secondary optics are not part of the Fortimo LED LLM system offering as this is an added value area for OEMs. A complementary reflector business around the Fortimo LED LLM is being developing by several companies such as Alux Luxar and Jordan. Available by request are Ray-Set Files.

5.5 Thermal management

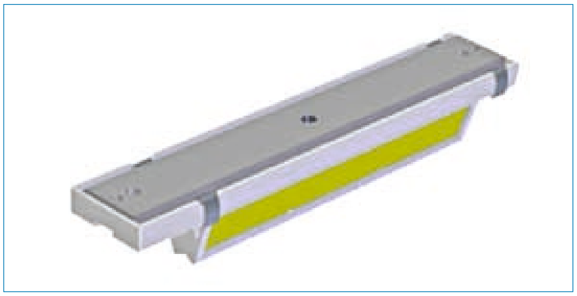
For optimal performance, the Fortimo LED LLM system must operate within specified temperature limits. Depending on the application and luminaire design, a suitable solution for the thermal management should be applied.

5.5.1 Test requirements

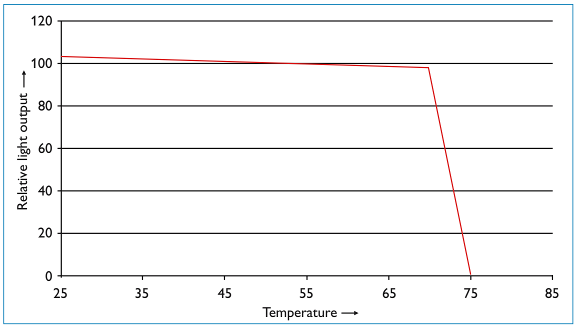
Temperature measurements should only be performed when the luminaire is thermally stable, which may take 0.5 to 2 hours depending on the thermal capacity of the luminaire. For all measurements such as temperature, luminous flux and power, a stabilization period of at least half an hour must be allowed 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).

5.5.2 Temperature range

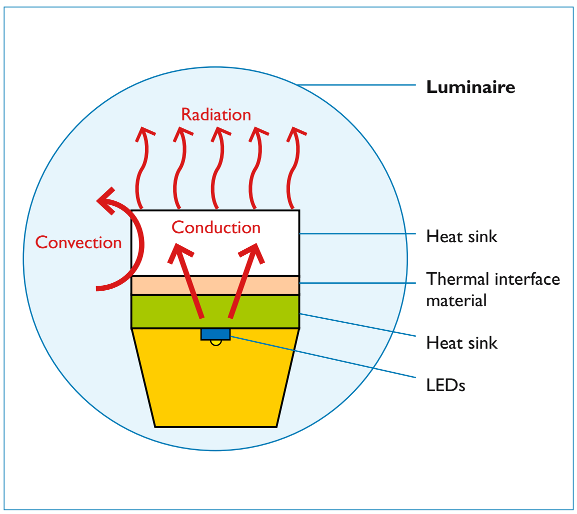
Because LEDs are temperature-sensitive, LED modules require a different approach with respect to thermal management. The system has been designed to operate between -20° C and 65° C at Tcase. The lower and upper limit has been determined by the application and by the components used in direct relation to the performance and reliability of the system.



Tc point light module



Relative light output



3 types of heat transport

5.5.3 Critical temperature points (Tc)

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 aluminum casing of the Fortimo LED LLM module at its critical point (Tc). The Tc point is located on the back surface of the Fortimo LED LLM module and for the driver, it is noted on the label. If the case temperature at the Tc point exceeds the recommended Tc life of 55° C, the performance of the LEDs and the Fortimo LED LLM system will be adversely affected, in terms of light output, lifetime and lumen maintenance.

If due to insufficient thermal management or other circumstances the Tc point reaches 70° C (typ), a thermal circuit* will be engaged. This circuit will start dimming the LED module. The thermal circuit is only a fail safe in order to protect the module against overheating. The optimum performance is only archived if Tc point stays below 55° C. The graph shows the effect on the relative flux as a function of Tc temperature.

**The thermal circuit is applied in all Fortimo LED LLM versions.*

5.5.4 Operation under built-in conditions

The heat produced by the Fortimo LED LLM driver and module in the luminaire (or similar housing) must be dissipated to the surroundings, if this is not taken care of it will have an adverse effect on system performance and lifetime.

5.5.5 Heat sink design

To ensure performance, it is essential that the critical temperature of module and driver stays below 55° C. The thermal management can be done in 3 ways — conduction, radiation and convection or a combination of these (see figure to left).

Note:

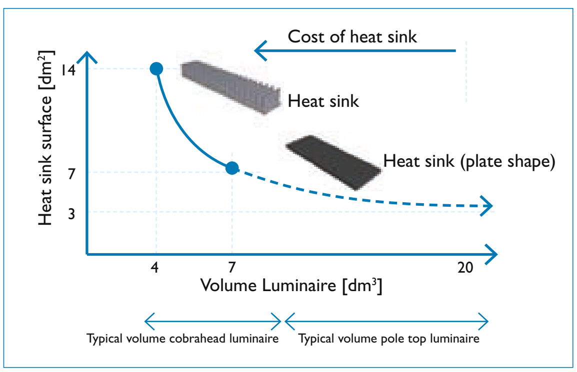
The objective of this chapter is not to indicate exactly how to calculate a heat sink, but to give some guidelines on how to improve its performance.

Material	W/mK
Copper	400
Aluminum	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
	heavily oxidized	0.7 - 0.8

Emission coefficients



Indication of luminaire volume vs. heat sink surface and cost (Fortimo LED LLM 1800 lm)

5.5.6 Heat sink material

The type of material used has a 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 to left) shows that a substantially smaller heat sink can be made with copper. The best material for heat sinks is (soft) aluminum. The thickness (H) of the heat sink is also of major importance. Assuming that we would use the same heat sinks, but made from a different material, a similar effect would be archived with 1 mm copper, 2 mm aluminum, 4 mm brass, 8 mm steel or 26 mm corrosion-resistant steel.

5.5.7 Thermal radiation and emission coefficient

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 to left) 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.

5.5.8 Surface area

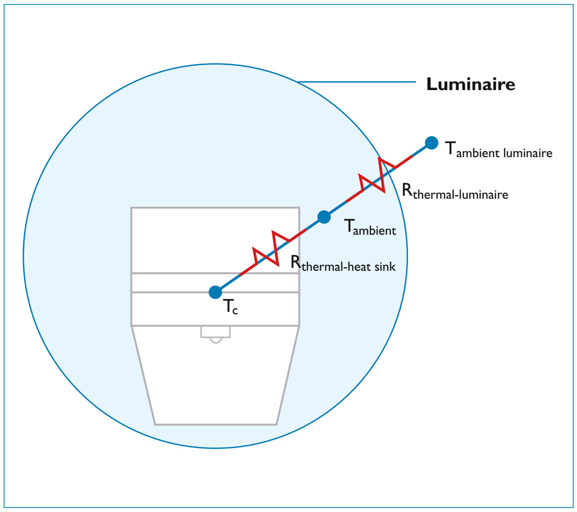
Although a heat sink can have many (complex) shapes, the design will depend on several parameters. Depending on application of the luminaire, surface area, cost, thermal resistance and volume inside of the luminaire can be determined. Here is a differentiation opportunity for luminaire manufacturers.

Fortimo LED LLM products have an energy consumption of 24W for the 1800 lm version and 14W for the 1100 lm warm white version. The amount of heat (energy) that needs to be taken form the module is about 14W for the 1800 lm and 9W for the 1100 version. The heat sink at the back side of the module is the contact area for the external heat sink. The external heat sink transports the heat away from the module.

By improving the thermal management, in other words, lowering the Tc point of the module, the system will perform better (lifetime and light output). Here is another differentiation opportunity for luminaire manufacturers. The size of the heat sink depends on the power rating of the module as well as the design and volume of the luminaire.

A typical surface area of a heat sink, when passively cooled, for a 1800 lm system is 10,40 dm^2 while the 1100 lm module requires a heat sink with a surface area of 6,30 dm^2. This is based on a "standard" heat sink of aluminium with outer dimensions of 250x40x50 mm (LxHxB) and an inside volume of the luminaire at 7 dm^3.

Once LED efficiency upgrades become available, power rating will be reduced and required heat sink size can also be reduced.



Thermal model

5.5.9 Thermal design

If one wants to calculate the required surface area of the heat sink a relatively simple model can be used as shown in the thermal model graph.

5.5.10 Calculation of thermal resistance

The total thermal resistance (Rth_tot) of the system is equal to the thermal resistance of the heat sink (Rth_hs) plus the thermal resistance of the luminaire (Rth_lum). For the reference calculation, we have used the following temperatures: Tc = 55° C and T ambient is 35° C and T ambient luminaire is 15° C.

$$Rth\_total = Rth\_heat\ sink + Rth\_luminiare$$

The Rth_hs is calculated by subtracting Tambient from Tc and devided by the Pdissipation of the Light module.

$$Rth\_heat\ sink = \frac{Tc\_Tambient}{Pdissipated\ light\ module}$$

$$Rth\_heat\ sink = \frac{35°\ C - 15°\ C}{14\ W} = 1.43°\ C/W$$

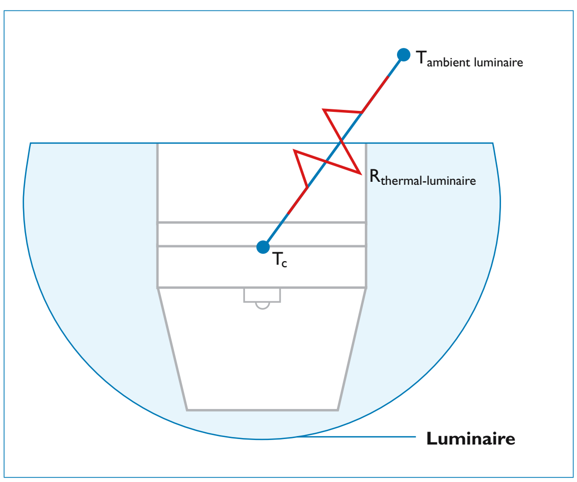
The Rth_lum is calculated

$$Rth\_luminaire = \frac{Tambient - Tambient\ luminaire}{Pdissipated\ light\ module\ \&\ driver}$$

$$Rth\_luminiare = \frac{35°\ C - 15°\ C}{14\ W + 3\ W} = 1.18°\ C/W$$

The Rth_total is then

$$Rth\_total = 1.43 + 1.18 = 2.61°\ C/W$$



Termal model with integrated heat sink

5.5.11 Thermal management

To simplify thermal management, the OEM can design the heat sink in such a way that it becomes one with the luminaire housing. By making the housing of the luminaire an integral part of heat management, the surface area of the internal heat sink is reduced and the calculation is simplified.

5.5.12 Calculating your heat sink

The surface area can than be calculated with:

$$Total\ surface\ area\ heat\ sink = \frac{1}{Rth\_heat\ sink \times h}$$

$$Total\ outer\ surface\ area\ heat\ sink = \frac{1}{1{,}43 \times 7} = 0.099\ m^2$$

The h in the equation is the heat transfer coefficient (W/m²). The typical h value is between 5-10.

5.6 Recommendations

5.6.1 Thermal interface

To increase the conduction of heat it is always advisable to use thermal interface material (TIM).

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