
# OEM Design-in guide

Fortimo LED DLM System – Version 1.0

• Philips Fortimo LED DLM 1100 & 2000 in 3000 K, 3500 K & 4000 K

PHILIPS

sense and simplicity

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# 1. Introduction

Thank you for choosing the Philips Fortimo LED DLM system.

This guide tells you all about this system. If you require any further information or support please consult your Philips sales representative or visit: 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

Rapid improvements in high-power LED technology mean that LEDs can now be used for the first time in 'real' lighting applications, providing improvements over traditional lighting systems.

Utilizing LED technology has its challenges, such as how to design around constant performance improvement, how to engineer and provide appropriate heat sinking and/or how to deal with variations in flux/color. The Fortimo LED DLM system addresses these differences and facilitates easy adoption of LED technology for high lumen packages (1000 lumens plus). The system is designed for integration in luminaires. This technical application guide addresses the relevant issues to support and facilitate the work of specifiers and lighting system designers.

The Fortimo LED DLM 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 LED DLM system and local standards. Please consult us if you wish to deviate from the design rules as described in this design-in guide.

Reference the Philips web site for complimentary heat sink or reflector product information.

## Features and benefits

| Features | Benefits |
|---|---|
| **Breakthrough LED L3 energy saving** | **LED system suitable for functional lighting applications.** |
| Patented remote phosphor technology | |
| Fortimo driver >85% efficiency | Efficient, easy to meet Energy Star drivers |
| **Superior-quality white LED light** | **An enabler for entry into general lighting** |
| 1100 & 2000 lm modules | Competes with CFL systems |
| CRI = 80, 3000 K, 3500 K, 4000 K | Meets the norms for general lighting |
| Remote phosphor | Very high (optical) luminaire efficiencies |
| Optimized light mixing chamber | Perfectly mixed light, consistent color quality and lumen output |
| Dedicated binning strategy | |
| **Future-proofed, convenient modules** | |
| Fixed form factor | Easy to work with for OEMs |
| Fixed lumen package | Fewer technical barriers |
| Easy-to-mount heat sink/optics | Faster time-to-market |
| Comfortable light | Easy for the end user to experience |
| No heat or UV | More comfortable, no damage to materials |
| Dimmable, instant 100% light | Multiple scene-setting options |
| **Long lifetime of 50,000 hrs** | Low-maintenance |
| Integrated lifetime-preserving method | More reliable, longer life |
| **3000 K, 3500 K & 4000K** | Warm color options available too |
| **Fortimo DLM Driver** | Ease of installation |
| Dimmable via 0–10 V Protocol | Dimming increases efficiency up to 30% |

## Applications

The Fortimo LED DLM system is intended for general lighting applications in the professional market for offices, hospitality and retail. Examples of applications include:

- Offices (representative areas such as receptions, boardrooms, etc.)
- Public buildings (cinemas, restaurants, theaters, airports, exhibition halls)
- High-end shops
- Retail (supermarkets, bakery/butcher areas, leather goods, etc.)

* Use in outdoor luminaires?
Neither the Fortimo LED DLM module nor the LED driver has an IP classification.
If an OEM decides to use the Fortimo system in a luminaire for outdoor application, the OEM is responsible for proper IP protection and approbation of the luminaire.

# 2. LEDs, the heart of the Fortimo 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. Philips 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.

### 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 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 otherlamps, 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.

### 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 lens. This package design now makes high-power LEDs feasible.

### 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.

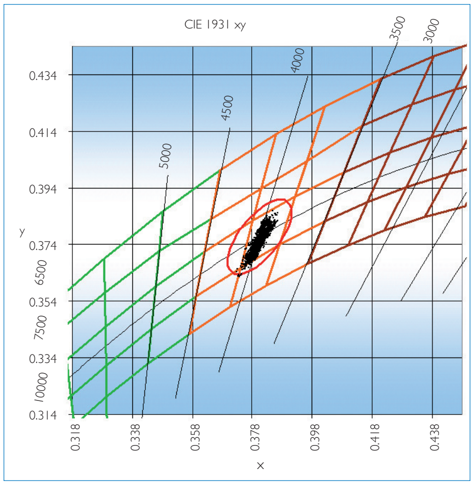
LUXEO Rebel LED

### 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 with the Fortimo products in order to match required high lumen packages.

### Fortimo LED DLM 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, popular CCTs in general lighting applications of 3000 K, 3500 K and 4000 K and a color consistency comparable with conventional CFL and HID solutions (five SDCM).




Color consistency (SDCM)

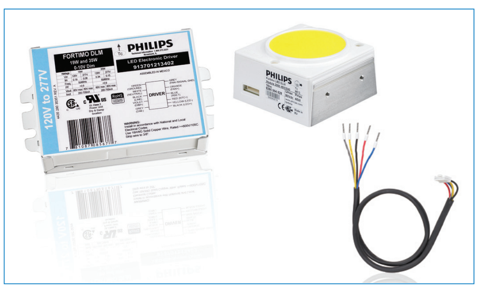
### Color consistency (SDCM)

The target specification of Fortimo LED DLM systems for color consistency is 5 SDCM @ 0-hours and 6 SDCM @ 10 K hrs. 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. In the visual we have plotted >3000 Fortimo LED DLM 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 Fortimo's fit within 1 color bin! Typically you can buy 6 to 12 bins combinations, not so precise as the 1-bin result of Fortimo.

### 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 LED DLM system




Fortimo LED DLM system

### Fortimo LED DLM portfolio

The Fortimo family of products has been ever-evolving since it's introduction in 2008. By maintaining its sleek footprint, OEMs can benefit from the simplicity of it's easy-to-use, future-proof design. The existing portfolio is as follows:

### Fortimo LED DLM "4000 K"

9290098403 Fortimo LED DLM1100 17W/840UL
9290098603 Fortimo LED DLM2000 33W/840UL

### Fortimo LED DLM "3500 K"

9290099603 Fortimo LED DLM1100 18W/835UL
9290099703 Fortimo LED DLM2000 34W/835UL

### Fortimo LED DLM "3000 K"

9290098303 Fortimo LED DLM1100 19W/830UL
9290098503 Fortimo LED DLM2000 36W/830UL

### Fortimo LED DLM cable

442240066181 Fortimo LED DLM cable 500mm w/o fan
442240068381 Fortimo LED DLM cable 500mm w/fan
442240072121 Fortimo LED DLM cable 840mm w/o fan

### Fortimo LED DLM driver

913701213402 Fortimo LED driver (120-277V, 0-10V dim)

## The basic principles of the Fortimo LED DLM system

The Fortimo LED DLM system is designed for downlight applications and contains three components:

- The Fortimo LED DLM (downlight module)
- The Fortimo LED DLM dimmable driver
- The Fortimo LED DLM cable

All products can be ordered separately.

## Starting characteristics

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

## 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 DLM system requires no initial burning-in time.

## Lumen maintenance

When used within specification, (Tc<65° C; Ta=35° C) lumen maintenance of 70% at 35,000 hours is expected for Fortimo LED DLM. At 50,000 hours lumen maintenance is 50% (average lifetime specification).

## Dimming

To enable the Fortimo LED DLM system to dim, a special Fortimo LED driver has been developed. Due to the use of an Amplitude Modulation (AM) (not PWM) protocol the efficiency of the Fortimo system will increase up to 30% while dimming.

## Future range extensions

As technology quickly advances, the Fortimo family is still growing. The following products are expected soon:

- Fortimo LED DLM upgrades that improve efficiency and lower cost (depending on the product proposition).
- Fortimo with emergency functionality
- Fortimo LED DLM with a 3000 lumen package


Fortimo LED DLM module

## Nomenclature

The names of the products are defined as follows:

• Fortimo LED DLM1100 17W/840UL (CRI of 80 and CCT of 4000 K)
• Fortimo LED DLM2000 33W/840UL (CRI of 80 and CCT of 4000 K)
• Fortimo LED DLM2000 34W/835UL (CRI or 80 and CCT of 3500 K)
• Fortimo LED DLM1100 18W/835UL (CRI of 80 and CCT of 3500 K)
• Fortimo LED DLM1100 19W/830UL (CRI of 80 and CCT of 3000 K)
• Fortimo LED DLM2000 36W/830UL (CRI of 80 and CCT of 3000 K)
• Fortimo LED DLM cable
• Fortimo LED DLM driver

## About the Fortimo LED DLM (downlight module)

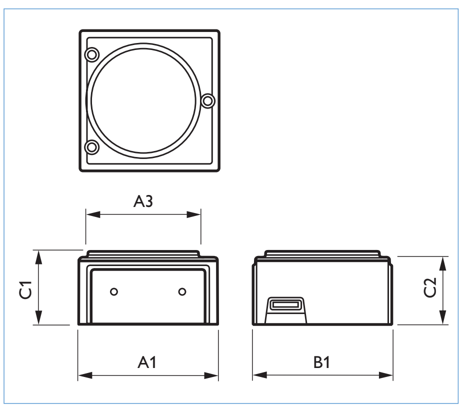
The Fortimo LED DLM consists of four main components:

1. PCB with LEDs
2. Mixing chamber
3. Heat sink
4. Diffuser with remote phosphor technology

## Dimensions of the Fortimo LED DLM module and driver system

(typical data; ± 0.2 mm)

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

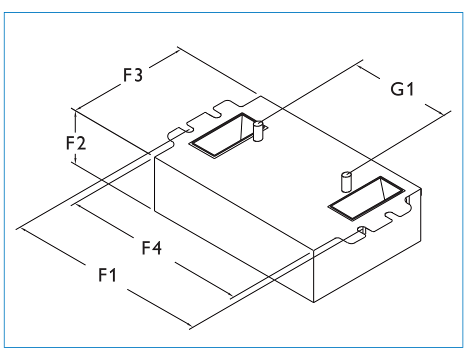



Fortimo LED DLM module - dimensions

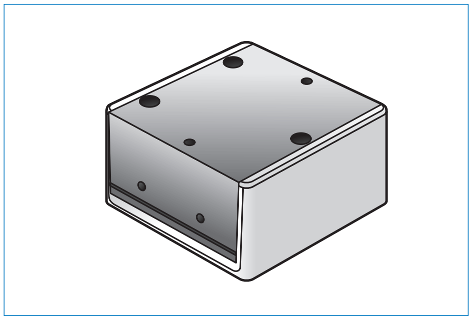
| A1 | A2 | A3 | B1 | C1 | C2 |
|---|---|---|---|---|---|
| 81.6 | - | 66.8 | 82.8 | 43.7 | 40.2 |

| F1 | F2 | F3 | F4 | G1 |
|---|---|---|---|---|
| 116.6 | 30.0 | 76.4 | 106.7 | 50.8 |

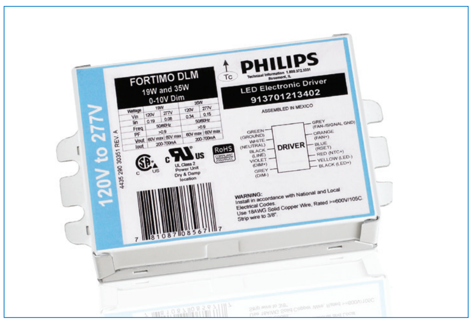
Note: Dimensions are in millimeters (mm)



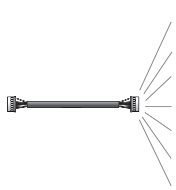

Fortimo LED DLM driver - dimensions



Fortimo LED DLM module, fixing holes and grooves




Fortimo LED driver



| | |
|---|---|
| 1 Black | Led + |
| 2 Yellow | Led - |
| 3 — | Blank |
| 4 Gray | Signal GND/Fan (-) |
| 5 Blue | LED module setting |
| 6 Red | NTC (thermal control) |

Fortimo LED DLM cable

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 square heat sink facilitates optimal heat transfer in three directions and helps luminaire manufactures to design their own heat sink system. The heat sink is equipped with screw holes for fixing the heat sink. Besides facilitating high efficiencies, the remote phosphor technology makes it relatively easy to develop virtually any fluorescent color. The first version will have a light color of 3000 K, 3500 K and 4000 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. The LED module integrates easy mounting options for secondary optics. The overall dimensions of the LED module, i.e. the combination of heat sink and mixing chamber, are optimized for lumen packages varying from 1000 lumen to 2000 lumen.

## Mechanical fixation

The Fortimo LED DLM has screw holes (M4 threaded head size less than 7 mm) at the bottom and sides of the heat sink for fixing the heat sink. As an alternative to screws the Fortimo LED DLM also has grooves at the side of the module so that a heat sink can be clicked in. 2D or 3D CAD drawings are available on the Philips website.

## About the Fortimo LED DLM driver

The highly efficient Fortimo LED driver is specially designed to operate the Fortimo LED DLM module. It is designed to operate high-power LEDs. There are specific versions for Europe (220-240 V) and North America (120-277 V)* because of different housing requirements.
There are meanwhile various Fortimo LED drivers:
• Fixed output; build-in for Europe* (220-240 V) and North America (120-277 V)
Special features for this Intellivolt® dimmable driver are:
• maximum current settings of 700 mA
• max. 56V enables operation of many LEDs in series
• $T_{case}$ = 65° C
• Safety Class 2 system

* A separate design-in guide is available for the European Fortimo DLM system.

## About the Fortimo LED DLM cables

Standard 500 mm and 840 mm cables without fan and 500 mm cable with fan can be ordered.

# 4. System performance specifications

| Fortimo LED DLM System (driver and module) | Module 12NC | Driver 12 NC | Cable 12NC | Vin (V) | P (W) | pf | THD (%) | Flux |
|---|---|---|---|---|---|---|---|---|
| | | | | Nom | Nom | Nom | Nom | Nom |
| Fortimo LED DLM1100 19W/830 UL | 929000498303 | 913701213402 | 442240066181 | 120-277V | 19 | >0.9 | <20 | 1100 |
| Fortimo LED DLM1100 18W/835 UL | 929000499603 | 913701213402 | 442240066181 | 120-277V | 18 | >0.9 | <20 | 1100 |
| Fortimo LED DLM1100 17W/840 UL | 929000498403 | 913701213402 | 442240066181 | 120-277V | 17 | >0.9 | <20 | 1100 |
| Fortimo LED DLM2000 36W/830 UL | 929000495003 | 913701213402 | 442240066181 | 120-277V | 36 | >0.9 | <20 | 2000 |
| Fortimo LED DLM2000 34W/835 UL | 929000499703 | 913701213402 | 442240066181 | 120-277V | 34 | >0.9 | <20 | 2000 |
| Fortimo LED DLM2000 33W/840UL | 929000498603 | 913701213402 | 442240066181 | 120-277V | 33 | >0.9 | <20 | 2000 |

| Fortimo LED DLM System (driver and module) | 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 | typ | max | typ | max |
| Fortimo LED DLM1100 19W/830 UL | 58 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |
| Fortimo LED DLM1100 18W/835 UL | 61 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |
| Fortimo LED DLM1100 17W/840 UL | 64 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |
| Fortimo LED DLM2000 36W/830 UL | 55 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |
| Fortimo LED DLM2000 34W/835 UL | 58 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |
| Fortimo LED DLM2000 33W/840UL | 61 | 50K hrs | 35K hrs | (-20) to 35 | 55 | 65 | 75 | 85 |

# 5. Lighting performance characteristics

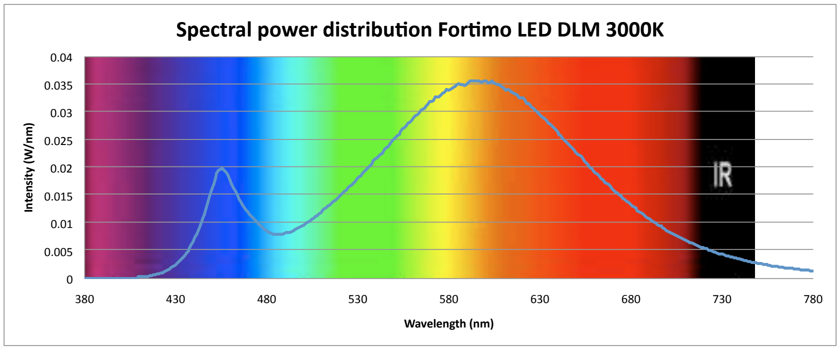
### Specification of the system after 100 hours

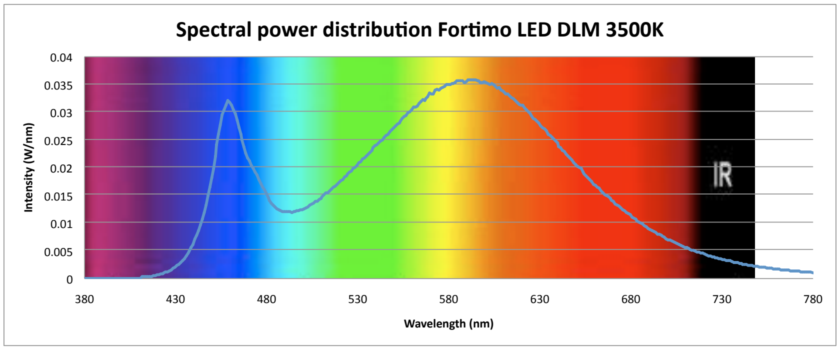
| Fortimo LED DLM System (driver and module) | Light output lm | Color temperature K | Color rendering index Ra | Color consistency initial and at 10K hrs SDCM |
|---|---|---|---|---|
| Fortimo LED DLM1100 19W/830 UL | 1,100 | 3,000 | 80 | 5 / 6 |
| Fortimo LED DLM1100 18W/835 UL | 1,100 | 3,500 | 80 | 5 / 6 |
| Fortimo LED DLM1100 17W/840 UL | 1,100 | 4,000 | 80 | 5 / 6 |
| Fortimo LED DLM2000 36W/830 UL | 2,000 | 3,000 | 80 | 5 / 6 |
| Fortimo LED DLM2000 34W/835 UL | 2,000 | 3,500 | 80 | 5 / 6 |
| Fortimo LED DLM2000 33W/840 UL | 2,000 | 4,000 | 80 | 5 / 6 |

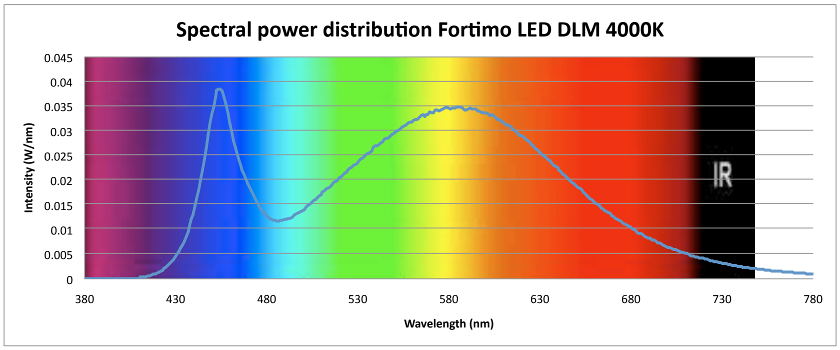
### UV and other hazards

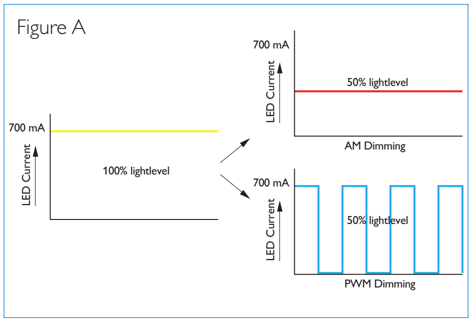
| | |
|---|---|
| PET value | >100 hrs./Klux (zero UV) |
| Damage factor | 0.08 @ 4100 K |
| IR (infrared) radiation | As well as being free of UV radiation, the LED modules are also free of infrared radiation in the beam. |

## Spectral Power Distribution 3000K, 3500K and 4000K




## Dimming characteristics

Fortimo Driver makes use of a so-called amplitude (AM) dimming protocol. Most LED systems work with PWM (pulse width modulation) where the current is cut in parts and 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. At lower currents, LEDs operate more efficiently (Figure A). In addition to this, other advantages of AM dimming are:

• No audible noise during dimming
• No visual interference with other lighting or video sources
• Improvement of overall performance

# 6. Designing a luminaire

In this chapter recommendations and values are given to enable optimal luminaire design.

**U.L. recommendations**

The general recommendations for luminaire design given by the U.L. 1598 and U.L. 8750 are also applicable to LED-based luminaires.

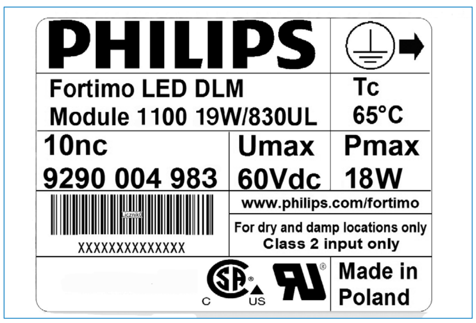
**Electrostatic device (ESD) measures**

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

**Installation instructions**

Fortimo LED DLM systems are build-in systems for integration into luminaires.
There are interfaces for:

• Cabling between LED module, driver and luminaire
• Secondary optics via mounting options in the LED module housing and reflector rim
• Heat sink design




Label Fortimo LED DLM module

**Wiring**

**Connecting to the mains supply**

The mains supply has to be connected to the power supply (L & N can be switched).

**Connecting to protective ground**

The Fortimo LED driver needs to be connected to protective ground for reasons of compliance with safety regulations and EMI.

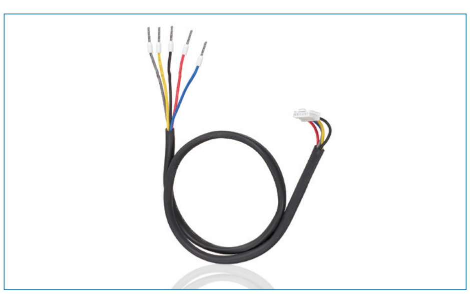
**Connecting to 12 V**

The Fortimo LED DLM version includes also a 12 V output that can be used for various options, like:

• Active cooling of Nuventix SynJet (Universal) DLM Coolers
• Other 12 V operating fans
• Note that when the LED current is <200mA, due to dimming, the 12V output is switched off

**Connecting a Fortimo LED driver to a Fortimo LED module**

A specific cable has been developed to connect the Fortimo LED module and the LED driver; the Fortimo LED DLM cable. This 500 mm cable can be ordered separately to the Fortimo LED DLM systems.



Fortimo LED DLM cable

## Fortimo LED DLM cable

We advise using the Fortimo LED DLM cable. However if an OEM prefers to have a cable with a different length it has to organize this itself. The cable specification should meet UL requirements. However, approval of the Fortimo LED DLM module and LED driver is based on a reference luminaire with the standard cable length of 600 mm. In any case, any luminaire design needs its own approval, organized by the responsible OEM, irrespective of the length of cable used.

If an OEM prefers to have a cable with a different length it can use the following cable/connector specifications:

JST connector at cable to LED module:
- housing JST PAP-06V-S
- contact JST SPHD-001T-P0.5

Ferrule connector at cable to LED driver:
- Wago sire ferrule - 216-201
- Wago Two wire ferrule - 51018076

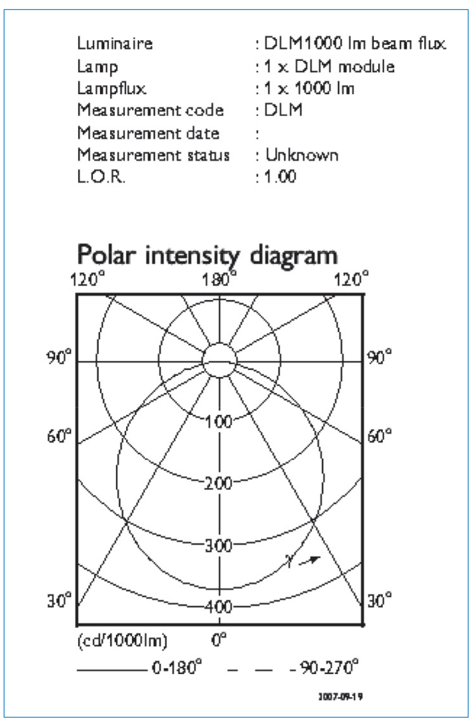
## Outdoor luminaires

Neither the Fortimo LED DLM module nor the LED driver 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.

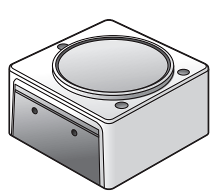
## Secondary optics

The Fortimo LED DLM module generates a Lambertian beam shape 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 (ie. a lens or a filter) within 70 mm of the Fortimo light exit window. When the product is installed according to guidelines, the temperature of the light exit window will be below 105° C. When the customer decides to place 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.



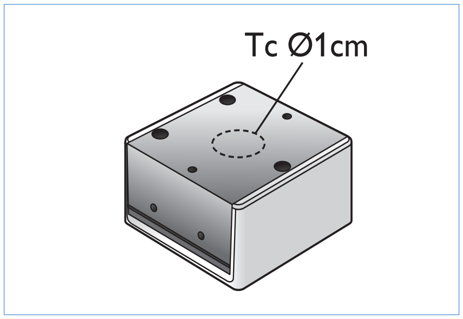

Polar intensity diagram



Position of secundary optics

On top of the Fortimo LED DLM there are mounting options (rim of diffuser and three mounting holes) for positioning secondary optics.

# 7. Heat sink design and temperature measurements




Temperature test point TC

### General

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

### Test requirements

The Fortimo LED DLM systems have no specific measurement for minimum ambient temperature, which may be as low as -20° C. This minimum limit is determined by the Fortimo LED driver. 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).

### 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 sources.

### Critical measurement points

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 LED module at its critical point. 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.

### Operation under built-in conditions

The heat produced by the LED driver and 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 driver and 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
- Airflow through the luminaire and around the modules, must have a positive effect on temperature control and hence on performance and lifetime.

## Case temperature and thermal circuit

To ensure the performance of the Fortimo LED DLM system, we have defined a Tc 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 realized. Above a Tc of 65° C, a thermal circuit will be engaged. This circuit will dim the LED module. The graphs below display the typical case temperature and relative flux as a function of ambient temperature, for a calculated heat sink performance of 1 K/W. The Fortimo LED driver also has a Tc of 65° C.

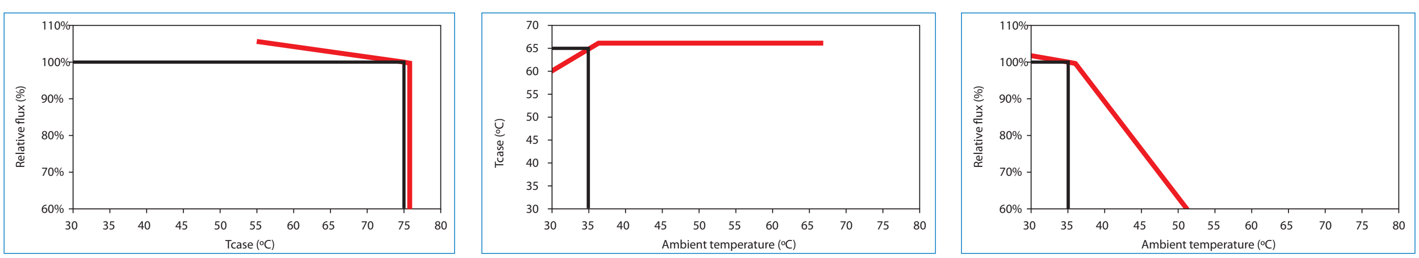
The above-mentioned engagement of the thermal circuit at Tc = 65° C is applicable to both the 1100 and the 2000 lumen versions. The performances of light output, light maintenance and lifetime are related to the Tc value.

## Case temperature and LED module performance

The Fortimo LED module comes in two versions, which are nominally designed for a case temperature of 65° C/149° F. The flux is then 100%. The graphs below show the relative light output (flux) as a % of the nominal case temperature. As you can see, if the operating condition of the Fortimo LED module is lower than the Tc point, performance will increase.

## Operation in free air

The Fortimo LED DLM is not designed for operation in free air. Instead Fortimo LED DLM is a build-in concept for integration into luminaires.




Temperatures Fortimo LED DLM2000

## 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, 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 (below) 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.

### Thermal conductivity

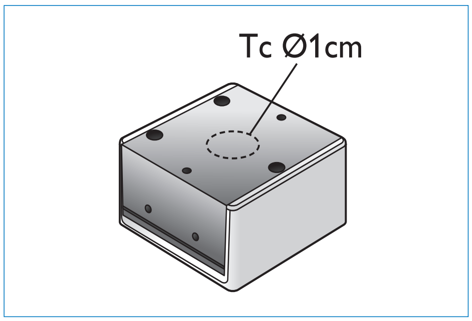
| Material | W/mK |
|---|---|
| Copper | 400 |
| Aluminum | 200 |
| Brass | 100 |
| Steel | 50 |
| Corrosion-resistant steel | 15 |

### Emission coefficients

| 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 |

## Size of heat sink

The first generation Fortimo LED DLM products consume 18 W or 45 W and contain a built-in heat sink. Deducting the driver efficiency and the energy that is effectively giving light leaves a heat dissipation of 15W and 38W, respectively, that needs to be taken away from the module. The sink at the sides and back of the module is the contact area for the external heat sink. The heat sink transports the heat away from the module and is connected to the heat sink, with either the use of the pre-made screw holes or side grooves.



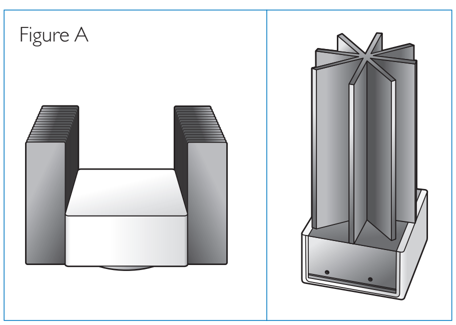

Temperature test point Tc

The performance (lifetime 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 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 dimmed (see also page 21.) So the better the thermal management (low Tc of the LED module), the better the performance of the luminaire (lifetime and light output). Here is a differentiation opportunity for luminaire manufacturers.

## Active and passive cooling

There are two thermal cooling options, passive and active cooling.

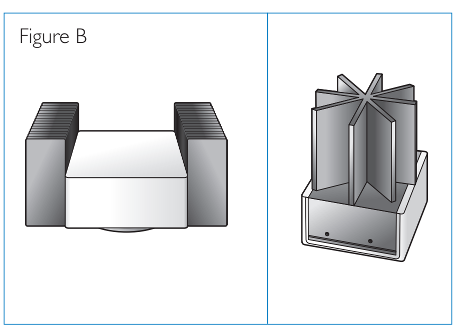
**Passive cooling** systems are made so that hot air moves upwards, and an airflow is created along the surfaces. This is called natural convection.




Passive cooling example for Fortimo LED DLM2000

**Active cooling** systems have airflow that is forced with a fan or SynJet, which enhances the thermal capacity of the heat sink. As a result, a smaller heat sink can be used and orientation of the heat sink is no issue anymore. Negative aspects of active cooling is the possibility of additional noise caused by a fan, as well as incremental energy consumption. Note that the OEM needs to engineer a cooling solution that matches the entire system's lifetime and intended application.

There are many standard heat sinks available which are relatively cost effective. When comparing active cooling, the form factor of the total system is approximately two times larger.




Passive solution directions Fortimo LED DLM1100

## Passive cooling

There are two passive thermal solutions.

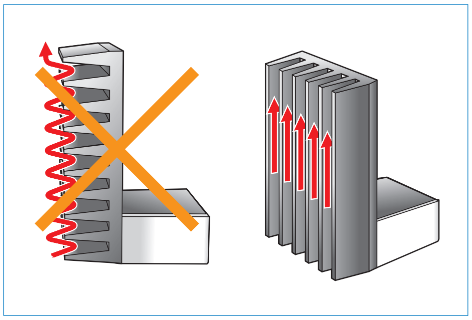
As shown on the left sides of Figure A and B, the solution with the heat sinks connected to the sides of the module has the advantage of lower height, but a larger diameter. The disadvantage is an extra thermal resistance path from test point Tc (in the center of the rear surface) to the sides where the heat sinks are connected.

As shown on the right sides of Figure A and B, the heat sink is connected to the backside of module. This configuration provides no extra thermal resistance, though to achieve this same cooling capacity, extra height is required.

For the Fortimo LED DLM1100, the size of the required heat sink is smaller. This all depends on the application, but generally, the Fortimo LED DLM1100 requires a smaller heat sink.

## 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 airlow. In the picture on the left, the 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 indicated in the picture on the right, where the fins are 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.

## Thermal design

There are two main thermal paths to consider — from the temperature test point to the side surfaces and from the heat sink to the ambient temperature (warming up and dynamic behavior are not discussed here, as a static situation is normally found in lighting applications).

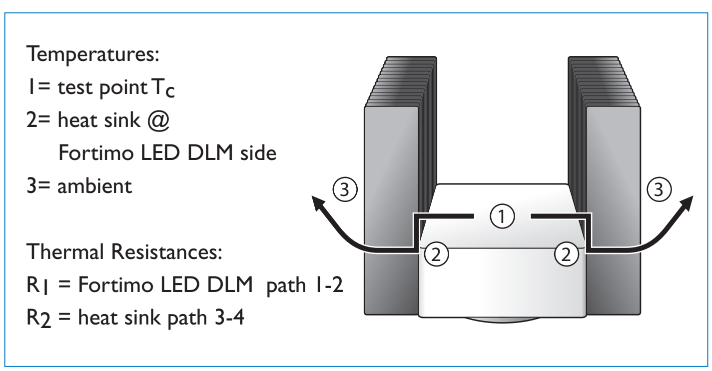
### From the temperature test point Tc (point 1) to the side surfaces (point 2)

- This is already measured by Philips and is 0.2 K/W. Please note that if you attach the heat sink directly to the back of the module, the 0.2 K/W should be considered.

### From the heat sink to ambient (point 3)

The thermal resistance of a heat sink is normally given in a datasheet, but it is based on a few assumptions:

- A certain thermal power has to be applied, as the efficiency of the heat sink is lower at low energy levels
- The temperature of the backside of the heat sink is homogeneous
- An air flow can freely flow over the surfaces




Thermal path basic solutions

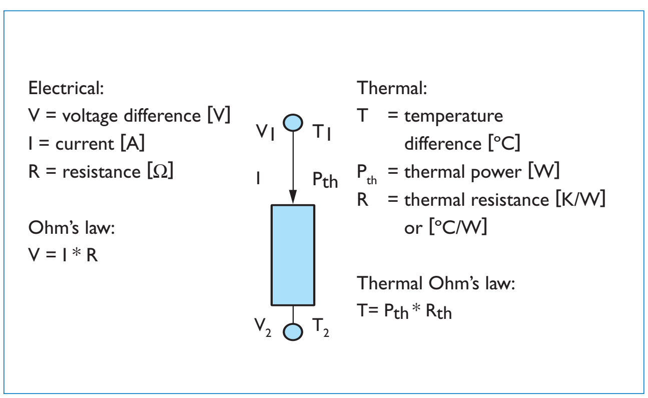
## Thermal model

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. Electrical units are shown on the left, with thermal equivalents shown on the right.

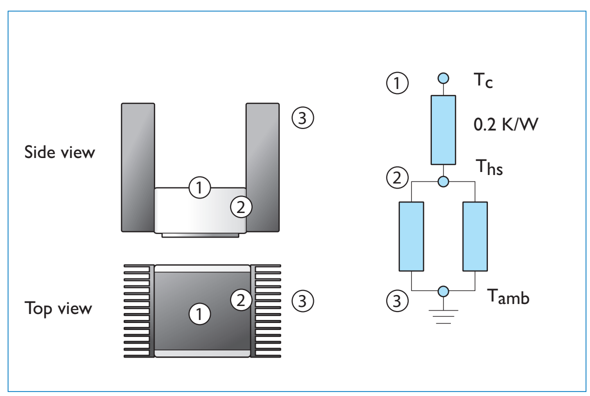
With a known voltage difference at a certain current, it is possible to calculate an electrical resistor with Ohm's law. The same is possible with a thermal resistor. If the temperature difference is known as well as the thermal power, the thermal resistance can be calculated with thermal Ohm's law.

In the figures below you see the two most important thermal resistances. The following are some notable conditions:

- From test point Tc to side surface of the Fortimo LED DLM, where the heat sinks are connected
- From side surface of Fortimo LED DLM to ambient. As we have connected two heat sinks, both will have a similar thermal resistance in parallel
- In the specification the maximum Tc is given, in case of a Fortimo LED DLM2000 system this is 65° C




Electrical and thermal analogy




Thermal resistance of Fortimo LED DLM

## Calculating your heat sink

We start with 3 thermal calculation formulas:

- Formula 1 (f1) is 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.
- Formula 2 (f2) shows how to calculate the replacement of two parallel resistors, with one equivalent.
- Formula 3 (f3) shows the replacement equivalent of 2 resistors in series, simply add the values.

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

## From the datasheet:

| | |
|---|---|
| Maximum test point temperature: | Tc-max = 65° C |
| Thermal power Fortimo LED DLM2000: | Pth = 20 W |
| Thermal resistance from Tc to side surface: | Rth-Tc-to-side-surface = 0.2 K/W |
| Maximum temperature in application: | Tambient-max = 35° C chosen in this case. |
| In this case we install the product below ceiling, which is the ambient temperature of the product. | |

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, so that in worst case scenarios, the maximum temperature of the test point Tc is below its maximum.

**Formulas:**

Thermal: $\Delta T = R_{th} \times P_{th}$ *f1*

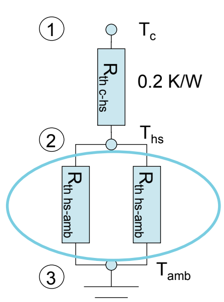
Parallel: $R_{th-R1+R2} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}}$ *f2*

Series: $R_{tot} = R_1 + R_2$ *f3*

**Available information:**

$T_{c\text{-}max}$ = 65°C
$P_{th\text{-}Fortimo2000}$ = 20 W (2000Lm, 3000K)
$R_{th\text{-}Tc\text{-}to\text{-}hs}$ = 0.2 K/W
$T_{ambient\text{-}max}$ = 35°C

**To be calculated:**
$R_{th}$ both heat sinks




Thermal resistance of heat sink

**1. Calculation of total maximum thermal resistance: (f1)**

$\Delta T_{ambient-Tc} = 65 - 35 = 30\ °C$
$R_{th\ Tc-ambient} = (T_{ambient} - T_c) / P_{th} = 30 / 20 = 1.5$ K/W

**2. Calculation of thermal resistance two heat sinks: (f3)**

$R_{th\ hs-ambient} = R_{th\ Tc\text{-}hs} + R_{th\ hs-ambient}$

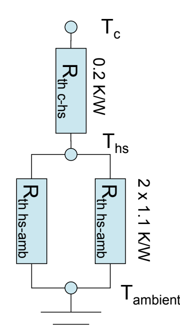
$R_{th\ hs-ambient} = 1.5 - 0.2 = 1.3$ K/W

**3. Calculation of thermal resistance per identical heat sink: (f2)**

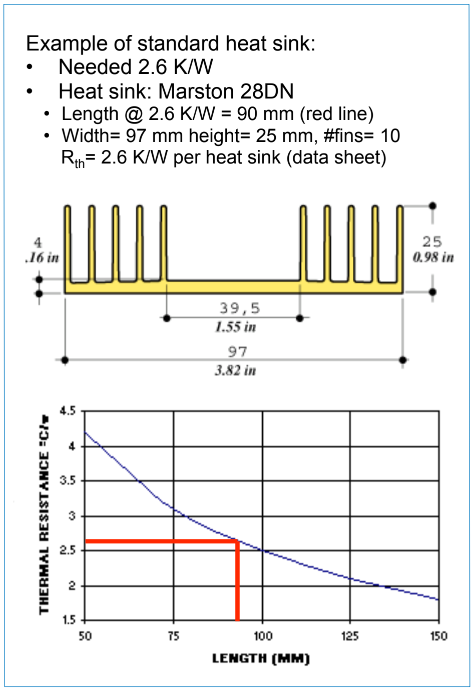
$R_1 = R_2$ and $R_{tot\text{-}hs\text{-}amb} = 1/(1/R_1 + 1/R_2)$

$R_{tot} = 1/(2/R_1) = R_1/2 \;<>\; R_1 = 2R_{tot}$

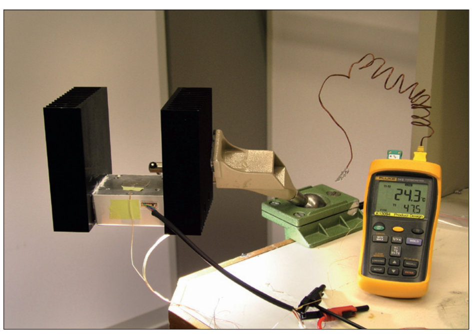
$R_1 = R_{th\ single\ heat\ sink} = 2 * 1.3 = 2.6$ K/W

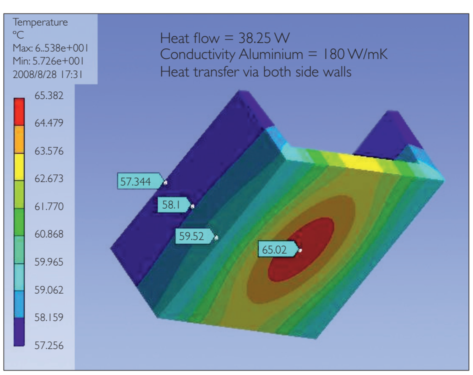



Thermal resistance of heat sink




Thermal resistance of heat sink






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 scenario, which means that normally the test point temperature Tc is lower. This assures lifetime and light output will be according to specifications.

## Shape of heat sink

When looking into heat sink suppliers, remember that the shape is determining the thermal resistance of the heat sink. In this case, the length is a design parameter.

The graph at left, shows the thermal resistance of the heat sink, with increasing length. With the parameters provided in this example, we need a 2.6 K/W heat sink and the red line indicates that this profile has the stated value with a length of approx. 90 mm.

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 thermocouple, all important temperatures can be measured and compared to theoretical values.

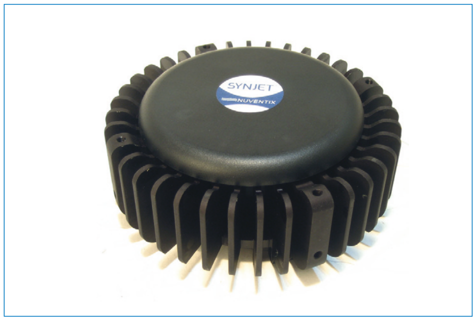
**On the left you see the standard set-up for thermal testing of the Fortimo LED DLM system which includes two connected heat sinks and three thermocouples.**

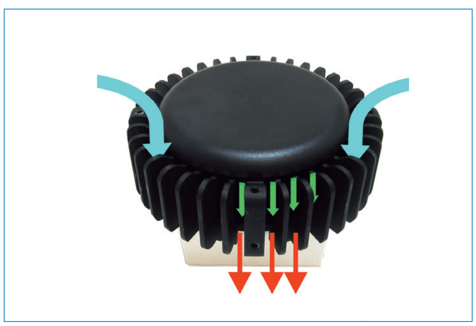
Key thermocouple test points are:
• At test point Tc
• At the heat sink interface of the Fortimo LED DLM module
• At the ambient temperature in situation

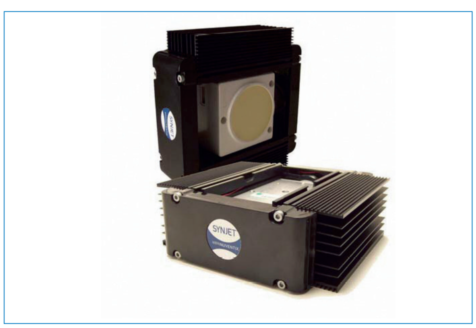
With this simple set-up, all important values can be measured and compared to the theoretical values. It's important to assure good thermal contact between Fortimo LED DLM and the heat sinks. We recommend using thermal pads or thermal paste. Furthermore, it is very important that there is no moving air in the room. This will influence the measurement heavily.

## How to measure Tc

In case you have no direct or easy access to connect a thermo couple to the defined Tc point, we recommend connecting the thermo couple to one of the sides of the Fortimo LED DLM. The heat sink that is integrated in the Fortimo LED DLM module ensures that temperature difference for Tc point to both sides is minimal. In the visual on the left, you see this difference is approximately 8 degrees with a Fortimo LED DLM of 2000 lumens. If a heat sink is connected to the back of the module, this temperature difference will reduce to 4 degrees.





## SynJet cooling from Nuventix

Nuventix has developed a cooling solution utilizing SynJet technology that offers silent operation, long life and robust cooling for Fortimo LED DLM systems. Its small size allows it to be used in tight spaces. SynJet cooling allows for universal mounting, permitting great flexibility in installation. The unit is designed for use with 1100 and 2000 lumen Fortimo LED DLMs, providing long-term thermal solutions for LED lighting.

Nuventix offers these standard versions:
• SynJet DLM Cooler with heat sink (round)
• SynJet Universal DLM Cooler with heat sink (square)

Design and assembly guides are available for both products by request.

## Nuventix contact information

For full specification and application assistance, please contact Nuventix directly:
Jeff Kelley, VP Sales, Americas
E-mail: jkelley@nuventix.com
512. 382. 8116 or 512. 422. 4391
4635 Boston Lane
Austin, TX 78735
www.nuventix.com

Below are some additional references for other fan suppliers:

**Emb Papst,** website: http://www.ebmpapst.com/de/
Emb Papst is a high-end, German-based fan supplier. They cover a broad application range (including automotive applications) and have a lot of experience in fan applications for harsh environments.
**Sunon,** website: http://www.sunon.com/index.htm
Sunon is a large Taiwan-based fan supplier, mainly active in electronics cooling. Their Maglev technology uses a magnetic field to stabilize the fan, resulting in long life and low noise.
Further we would like to mention two Taiwanese suppliers of cooling assemblies (combinations of fan + heat sink):
AVC: website: http://www.avc.com.tw/
CoolerMaster: website: http://www.coolermaster.com/

Both suppliers are active in PC cooling solutions and are starting a business for LED solutions as well. Please check the Fortimo webpage (www.philips.com/fortimo) for the latest info on our complementary partners.

# 8. Lighting installations and the environment

### 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 LED DLM systems enable a FFC Part 15 Class A Luminaire.

### Humidity

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

### 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.

### Vibration and shocks

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

### Standards and approvals

Philips Fortimo LED DLM systems comply with the following international rules and regulations:

| | |
|---|---|
| Electrical Classification | UL Class 2 |
| Approvals | UL 8750, CSA C22.2 No. 250.0 |

### IP codes, dust and moisture protection

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

### 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 LED DLM modules are predicted to deliver an average of 70% of their initial intensity after 35,000 hours of operation at Tc 65° C and 50,000 hours of operation at Tc 55° C. The life of the system is therefore more dependent on the other electronic system components and soldering methods.

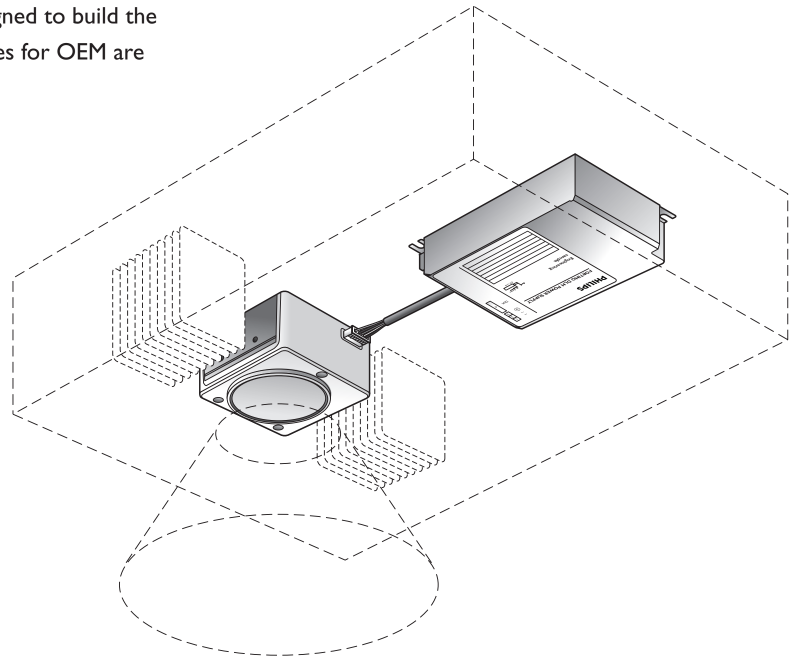
The LEDs in the Fortimo LED DLM module are connected in series. If one LED fails, this will lead to an internal short-circuit (character of blue LEDs). In this case it will still conduct current, so that the other LEDs will still operate.

### Fortimo LED DLM system disposal

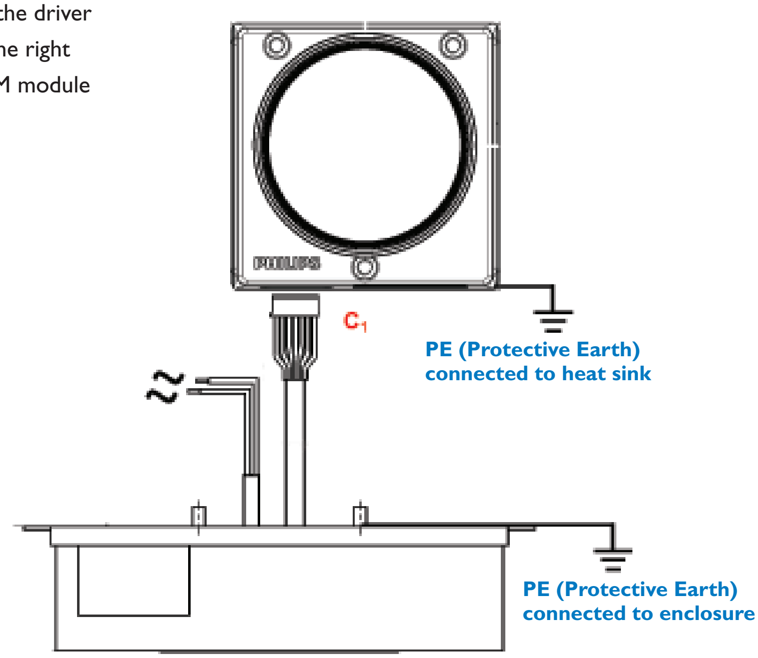
At the end of their (economic) lifetime, appropriate disposal of the Fortimo LED DLM or its components is recommended. The modules are basically normal pieces of electronic equipment containing components that at present are not considered to be harmful to the environment, or which can be disposed of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

# 9. Schematic luminaire with the Fortimo LED DLM system

The first Fortimo LED DLM systems have been designed to build the driver inside the luminaire. Added value opportunities for OEM are optic-, heat sink- and luminaire design (dotted lines).



Fortimo LED DLM systems are class 2 systems that require proper protective earth wiring. It's important that the driver is connected to protective earth. The drawing on the right shows how to properly wire the Fortimo LED DLM module and driver.



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Philips Lighting Electronics N.A.
10275 West Higgins Road
Rosemont IL 60018
Tel: 800-322-2086 Fax: 888-423-1882
Customer Support/Technical Service: 800-372-3331
OEM Support: 866-915-5886
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