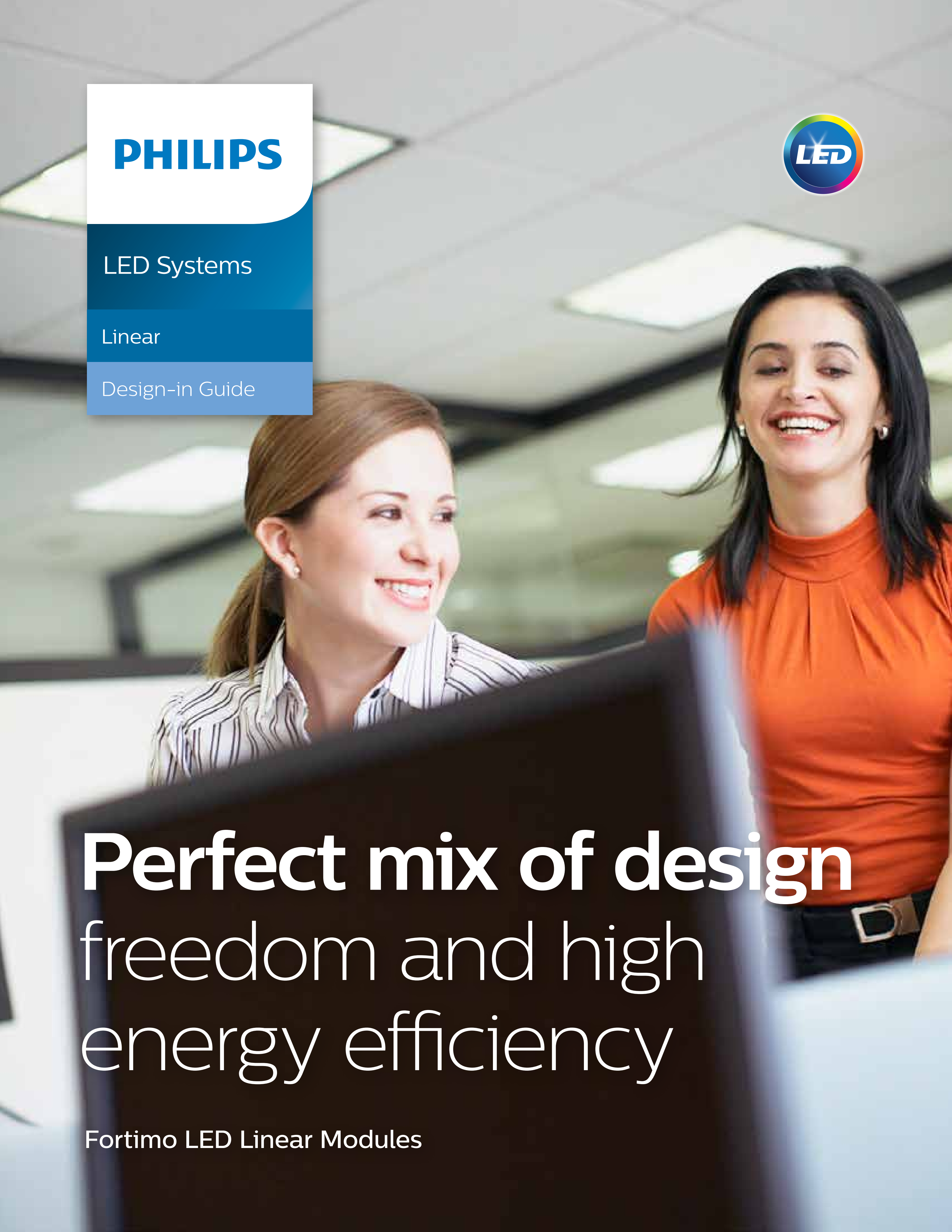


PHILIPS

LED Systems

Linear

Design-in Guide

Perfect mix of design freedom and high energy efficiency

Fortimo LED Linear Modules

Contents

Introduction to this guide

Figure 1. Philips Fortimo LED linear system building blocks.

Thank you for choosing the Philips Fortimo LED linear system. In this guide you will find the information you need to design this system into a luminaire. This edition covers the complete Philips Fortimo LED linear family: LED strip, LED square, LED line, LED LML SE and LED line high flux. We advise you to consult our website for a full portfolio overview and the latest information, www.philips.com/ledmodulesna.

How to determine which documents contain what information

In order to provide information in the best possible and consistent way, Philips' product documentation includes the following.

- Datasheet: detailed product specification.
- Design-in guide: describes how to design-in and apply the products as a system into a luminaire.

These documents can be found in the download section on the OEM website at www.philips.com/ledmodulesna. If you require any further information or support please consult your local Philips sales representative.

Figure 2. Web page.

Warnings and instructions for LV products

When using an UL Class 2 driver, intended for low voltage (LV) products

Warning:
- Avoid touching live parts!
- Avoid touching any bare components on the PCB, e.g., LEDs!
- Do not use damaged LED modules!

Safety warnings and installation instructions

To be followed during design-in and manufacturing.

Figure 3. Safety warning.

Design-in phase

- It is mandatory to use a UL Class 2/IEC compliant SELV driver in combination with the LED linear products.
- The general UL and IEC recommendations for luminaire design and legal safety regulations (ENEC, CE, ANSI, etc.) are also applicable to Philips Fortimo LED linear systems. Luminaire manufacturers are advised to conform to the international standards for luminaire design (e.g., UL1598, IEC 60598-Luminaires).
- It is advised to construct the luminaire in such a way that the LED module cannot be touched by an end-user, both in off state and when live.
- Do take into account the minimum required creepage and clearance distances.
- Do not apply mains power to the LED module directly.
- Connect all electrical components first before switching on mains.
- The LED module shall be powered by a LED driver UL 8750 certified.
- Avoid possibilities of water and dust ingress; use appropriate IP-rating of luminaire with regard to specific conditions of application.

Manufacturing phase

- Do not use damaged or defective LED modules, including damaged connectors or PCB.
- Do not drop the LED module or let any object fall onto the LED module because this may damage the PCB or LEDs and affect proper functioning of the product.
- Connect all electrical components first before switching on mains.
- Take ESD protection measures in your manufacturing environment.

Installation and service for luminaires incorporating the Fortimo LED linear system

- Do not service the luminaire when the mains voltage is connected; this includes connecting or disconnecting the LED module cables.
- Do not use damaged products.

For optimal reliability of the LED module, we advise not to apply an AC electric strength test to the luminaire, as this might damage the LEDs. It is recommended instead to apply an insulation resistance measurement at 500 VDC (noted as Dielectric voltage-withstand test in UL1598).

Philips design-in support

Design-in support is available. Please contact your Philips sales representative for information.

Introduction to the Fortimo LED linear systems

Figure 4. LED line LV3.

Figure 5. LED strip LV3.

Figure 6. LED line high flux LV2.

Figure 7. LML SE.

Applications and luminaire classification

The Philips Fortimo LED linear system is the replacement for linear fluorescent lamps in general lighting. The system features a high level of energy efficiency, which surpasses T5 systems, enabling low total cost of ownership (TCO). It offers high-quality white light with excellent color rendering and color consistency, and, as part of the Fortimo promise, it comes with a limited five-year Philips system limited warranty. (See warranty details at http://www.usa.lighting.philips.com/support/support/warranty.)

The Fortimo LED linear system consists of a range of modules, the Fortimo LED lines, LML SE, strips and square and the associated Xitanium LED drivers. The Philips LED linear module system overview is available with Philips sales representatives. Fortimo LED linear modules feature a variety of different dimensions, lumen packages and color temperatures. In this guide you will find the specific information required to develop a luminaire based on the Philips Fortimo LED linear system. Product specific data can be found in the associated datasheet on www.philips.com/ledmodulesna.

How to use LED linear systems in outdoor luminaires

Neither the Fortimo LED module nor the LED driver has an IP classification. If these products are used in luminaires for outdoor applications, it is up to the OEM to ensure proper protection of the luminaire. Please consult us if you wish to deviate from the design rules described in this guide.

Commercial naming of the Fortimo LED linear modules

The names of Fortimo LED linear are defined as shown in the example below.

Fortimo LED line 1 ft 1100 lm 840 3R LV3

Fortimo	:	Our concept name for efficient, clear and reliable lighting
LED	:	The light source used
Line	:	Linear module (line, sq or strip)
1ft	:	Length of LED module
1100lm	:	1100 lumen output
840	:	8 denotes a color rendering index of 80 (CRI divided by 10); 40 stands for a CCT of 4000 K (CCT divided by 100)
3R	:	Indicates the number of LED rows on a LED line, in this case 3
LV	:	Low voltage; indication of compliance with UL Class 2 requirements
3	:	Generation 3

The range consists of

Fortimo LED line

Designed to replace general fluorescent lighting in new luminaires, the Fortimo LED line system goes into the third generation with improved efficiency and the same Zhaga footprint.

Fortimo LED line high flux

The Fortimo LED line high flux system is ideal for installations at greater application heights where more light output is needed, such as high-bay. It was designed to withstand high ambient temperatures that are common to applications like industry or vapor tight fixtures.

Fortimo LED strip

The Fortimo LED strip system enables design of high-energy efficacy slim linear LED fixtures, which may not be possible with fluorescent lighting or the Fortimo LED line system.

Fortimo LML slim efficiency

The Fortimo LML slim efficiency system enables an economic fixture design that meets DLC requirements for linear lighting applications replacing T8 lamp equivalents.

Fortimo LED line SQ system

The Fortimo LED line SQ system with square outer dimensions is ideal for 2'x2' or 2'x4' recessed office applications that require a very homogeneous (no pixilation) exit surface window and high quality of light.

On top of this broad range in standard settings and building blocks, the Fortimo LED linear portfolio provides the luminaire manufacturer with a high level of flexibility to differentiate a luminaire, design a specific luminaire performance or change settings of a luminaire in the factory, while using the same components.

Cautions during storage and transportation when storing this product for a long time (more than one week)

- Store in a dark place. Do not expose to direct sunlight.
- For Fortimo LED linear modules, do maintain

  - temperature between -40 and +85 °C

  - relative humidity (RH) 5.85 %.

During transportation and storage for a short time

Maintain temperature below 100 °C at normal, non-condensing relative humidity.

Zhaga

Many of the Fortimo LED linear modules are either Zhaga certified or compliant. Please check the associated LED module datasheet for Zhaga details on www.philips.com/ledmodulesna.

Zhaga is an international organization that is enabling the interchangeability of LED light sources made by different manufacturers. The interface specifications for the products covered in this design-in guide designated in Book 7 can now be downloaded from the Zhaga website at www.zhagastandard.org/specifications.

Book 7 covers a variety of rectangular and linear LED modules with different dimensions and with separate electronic control gear that are intended primarily for use in indoor lighting applications. Book 7 modules are typically mounted directly into a luminaire by means of screws.

Optical design-in

Optics on top of or near the LED linear modules

Luminaire manufacturers have the freedom to design their own optics for beam shaping to maximize the lm/W efficiency of the system.

Additional fixation holes are provided in most LED linear modules in order to align electrical non-conductive optics onto the LED module. These are holes without a slit. To allow possible future changes, it is advised to take into account some additional room around the connector when designing optics directly onto the LED module.

Complementary partners for optics

Secondary optics are not part of the Fortimo LED linear system offering. This is an added-value area for OEMs, offering the possibility to differentiate. However, there are many companies offering, for example, reflectors, lenses or bulk diffusers that have a standard portfolio of compatible optics available, enabling quick and easy luminaire creation. Some of these are listed in the complementary partner section in our Fortimo LED System Quick Guide (available in print and digital) or at www.philips.com/ledmodulesna.

Reference to these products does not necessarily mean they are endorsed by Philips. Philips gives no warranties regarding these products and assumes no legal liability or responsibility for any loss or damage resulting from the use of the information given here.

Light distribution

Fortimo LED linear modules generate a Lambertian beam shape. See the light distribution diagram in the product datasheet.

The far field IES (or .ldt) files are available at www.philips.com/ledmodulesna.

Ray sets

Ray set files of the LED modules and of the individual LEDs are available for customer use and can be downloaded at www.philips.com/ledmodulesna.

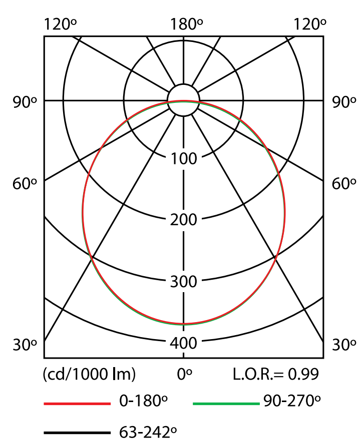


Figure 8. Light distribution.

Ray-Set zip file typically contains

Software	File Extension
ASAP	.dis
Light Tools (ASCII)	.ray
TracePro/Oslo (ASCII)	.dat
Zemax	.dat
Explanation & definitions	.ppt
Solid 3D model	.stp

Table 1. Ray-set zip file typically contains.

Color consistency (SDCM)

Color consistency refers to the spread in color points between modules. It is specified in SDCM (Standard Deviation of Color Matching) or MacAdam ellipses, which are identical. The value refers to the size of an ellipse around a point close to the black body locus. Staying within this ellipse results in a consistency of light, which ensures that no color difference is perceivable between one LED module and another with the naked eye in most applications.

SDCM value in the datasheet represents an integrated measurement over the complete LED module.

Please be aware that in applications that are more sensitive for color differences (color consistency of <3 SDCM), such as wall washers (<2 SDCM), we advise you to contact your local Philips sales representative or the Philips design-in team for expertise and support in luminaire design and evaluation.

Spectral light distribution

The typical spectral light distributions of Fortimo LED modules are shown in the respective datasheets on www.philips.com/ledmodulesna.

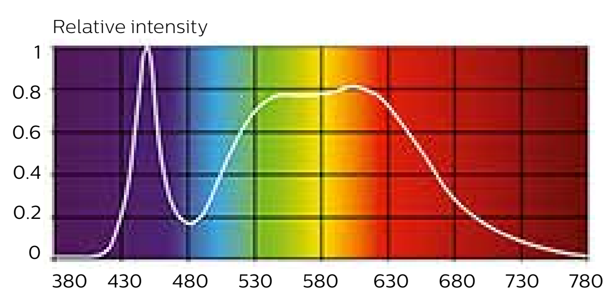


Figure 9. Spectral light distribution.

Compose your luminaire with LED linear

Figure 10. Philips Advance Xitanium indoor linear LED driver.

Figure 11. Resistor.

Figure 12. Wire core.

Figure 13. Fortimo LED linear modules.

In this section you will find all of the product information needed to compose a configuration based on the Fortimo LED linear system.

A LED linear system typically consist of the following building blocks

- Fortimo LED linear modules.
- Philips Advance Xitanium indoor linear LED driver.
- Standard installation wire (solid core, not offered by Philips).
- Optionally a resistor to set the output current (not offered by Philips).
- Optionally MultiOne configurator software and hardware interface to program Simple Set/DALI/programmable drivers (to be purchased separately from Philips).

How to design your typical LED linear system

With below steps we like to provide you with a starting point for designing your LED linear luminaire containing Fortimo LED linear modules, either coming from a conventional lighting solution or starting from scratch.

1. Identify the delivered lumens required from the luminaire.
2. Determine any optical losses that may occur (fixture reflection, lens, etc.).
3. Identify the total lumens or lumen per length (lm/ft) requirement.
4. Select your preferred LED layout (how the LEDs are spread over the fixture body) from the available portfolio.
5. Select the module type best matching above requirements.
6. Determine the amount of modules to use in your system.
7. Determine the electrical specification of the defined system (Voltage [V], current [A] and power [W]).
8. Find your best matching driver (power window, controllability).
9. Set or program the drive current on the driver.

The upcoming sections will help you in more detail to understand how to come to the required answers on above steps.

Compose your LED luminaire with Fortimo LED linear systems

Figure 14. Philips conventional fluorescent tube.

Why replace fluorescent by smart LED building blocks

Instead of replacing hundreds of unique ballast-/fluorescent-lamp-combinations, Philips has chosen to use smart configurable building blocks in its linear LED module portfolio.

These are the Philips Fortimo LED linear modules in combination with the Philips Advance Xitanium window drivers – providing large flexibility with as few components as possible.

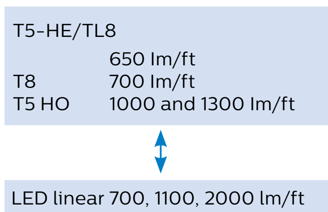


Figure 18. Relation between fluorescent lumen and LED linear lumen.

Characteristics of these building blocks are:

- Lengths mimic fluorescent lamps (1 ft & 2 ft blocks).
- Driver dimensions mimic conventional ballasts.
- Various LED layouts enabling glare and beam control.
- Source flux levels of Fortimo linear LED modules mimic fluorescent equivalents.

By mimicking the mainstream fluorescent light output levels (amount of lumen per unit length [lm/ft]), three main levels of source flux were defined as depicted in Figure 18 (700, 1100 and 2000 lm/ft). For reference please see table in Appendix A.

However, with the ability to select and set the drive current on the LED driver you are able to select a light output (lumen) different than the default or nominal value. This degree of freedom and flexibility is called tuning and will be explained in a later section.

How to convert to your preferred LED linear solution

This section is to help you find your preferred LED linear system solution, starting from your legacy fluorescent system. Please find conversion examples in Appendix B at the end of this document.

	Fluorescent Light Situation	LED Linear Module Consideration
1a	T5-HE / TL8	700 lm/ft
1b	T5-HO	1100 lm/ft
1c	PL-L	2000 lm/ft
2a	Open luminaire	LV system (ease of design-in)
3a	Beam shaping	Narrow LED layout
3b	Glare & luminance control	Wide LED layout

Table 2. Conversion help from fluorescent situation to LED linear system.

In this section you will find all of the electrical design-in information needed to design your configuration based on the Fortimo LED linear system.

Figure 15. SimpleSet driver with programming wand.

Short introduction to operating LEDs

A light-emitting diode (LED) is a semiconductor device. It is a p–n junction diode, which emits light when activated. When a suitable electrical current is applied to the leads and the forward voltage (Vf) is sufficient, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This process is called electroluminescence and results in visible light. The amount of visible light emitted is called luminous flux or lumen [lm] and is proportional to the amount of current applied to the device.

Reasons to set your drive current

Compared to fluorescent lighting, using an LED light source enables a high degree of freedom in tuning luminous flux of the system to the needs of the application.

1. With a generation update, lumen per Watt (lm/W) will improve, hence the required current to achieve its luminous flux (lm) will decrease resulting in a lower required drive current.
2. Opposite to lamps, LED modules allow composition of various light sources into a system, comprising from one to many LED modules in that system. Different combinations require different currents and voltages.
3. Changing the drive current of the system (hence its LEDs) will enable tuning in to a desired light output other than the nominal flux specified at the nominal drive current.

Electrical design-in

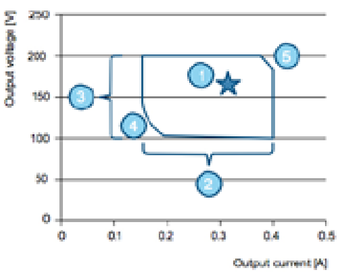


Figure 16. Driver operating window.
Example of a driver operating window:
1. Required set point for the LED solution.
2. Current can be set to needs within range.
3. Driver adapts to required voltage within range.
4. Driver minimum power limit to guard driver performance.
5. Driver maximum power limit to guard driver performance.

Note: Power (W) = Voltage (V) x Current (A).
Note: By means of dimming, it is possible to go below the minimum value of the specified output current.

Xitanium indoor linear LED drivers

For detailed information, please refer to the design-in guide for Philips Advance Xitanium indoor linear LED drivers and the associated driver's datasheet on www.philips.com/leddrivers.

Xitanium driver operating window

LED technology is rapidly evolving. Using more efficient LEDs in a next generation means the same light output can be achieved with less power with reduced drive currents. At the same time, LEDs can be driven at different drive currents based on the application requirement. Typically, LED drivers are available in discrete current levels, e.g., 350 mA, 500 mA or 700 mA. It is often necessary to replace a driver when more efficient LEDs or different LED modules become available.

One of the key features of the Xitanium LED drivers is the adjustable output current (AOC), offering flexibility, differentiation for the OEM and future-proof luminaire design. The Xitanium drivers can operate in a so-called "operating window." See Figure 16. This power window is defined by the maximum and minimum voltage (V), current (A) and power (W) that the driver can handle. The area indicates the possible current/voltage combinations. The current you select will depend on the type and manufacturer of the LEDs, the specific LED configuration of the PCB design and the desired output (lm) per LED.

The voltage required is the sum of the LEDs used (total Vf string). Within the driver window's range the driver will adapt to the voltage requirement. Both the operating window and default current setting of every driver can be found in the datasheets in the download section on www.philips.com/leddrivers. Further information regarding the application and use of AOC and other driver features can be found in the design-in guides for LED drivers. These can be found at www.philips.com/leddrivers.

System configurations with LED linear

As the default current of the drivers does not necessarily match your system drive current requirement, please be sure to check and set the current on the driver, e.g., by means of current measurement. When configuring the system with the Philips Advance Xitanium LED drivers and Philips Fortimo LED modules, the selected driver operating point needs to be within the driver operating window. In case of questions, contact your local Philips sales representative or the Philips design-in team.

For more information on programming these drivers, please check the SimpleSet design-in guide at www.philips.com/simpleset.

How to determine what value the output current should be set at will be explained in the upcoming sections.

Insulation safety indicated by working voltage

UL defines the working voltage as the highest voltage that may occur across any insulation of the module without compromising the safety of the module. Any driver with an open load/circuit voltage below the working voltage (60V DC in case of UL Class 2) of the module can be safely used in combination with the module.

How to select an appropriate driver

For a full overview of available LED driver-module combinations at nominal LED module drive conditions, please refer to the Linear System Overview, which can be found in the download section at www.philips.com/ledmodulesna, as can the datasheets associated with the drivers you intend to use.

Depending on your requirements, several drivers may be a solution for you. The following steps can help you select the preferred driver in the event you wish to deviate from the nominal LED module drive conditions.

1. Determine your required drive current (Idrive) and voltage (Vf) based on the number of LED modules per LED driver and individual LED module specification in the datasheet.
2. Calculate required power via: Pdrive (W) = Vf (V) x Idrive (A).
3. Determine which driver you do need; collect the associated driver datasheets from the website.
4. Does required current fit current range of driver?
   - Idriver minimum ≤ Idrive ≤ Idriver maximum?
5. Does required voltage fit voltage range of driver?
   - Vdriver minimum ≤ Vf ≤ Vdriver maximum?
6. Does required power fit power range of driver?
   - Pdriver minimum ≤ Pdrive ≤ Pdriver maximum?
7. Choose your type of dimming (Dali, 0-10V, step dim, phase dimming or non-dimmable).

Power [W] = Voltage [V] x Current [A]

How to Configure an LV system

Class 2 systems use LV LED modules connected to a UL Class LED driver. LV products make a parallel system. Adding an LED module requires a higher current.

1. Determine the operating current for the desired flux per LED module, using the LED module datasheet. Make sure the operating current does not exceed the specified value for lifetime (Ilife).
2. The required drive current of the driver is the sum of the current required per LED module.
3. Check whether the resulting total current is within the driver's current range. If the current is too low, you can decide to select a driver with a lower output power. If the current is too high for the selected driver, a driver with a higher output power may provide a solution.
4. Connecting too many LV LED modules in a single chain may lead to flux imbalance. Check the advised maximum number of LED modules per chain in the associated LED module datasheet. If the number of LED modules in your system exceeds the specified maximum value, it is advised to create a second chain.

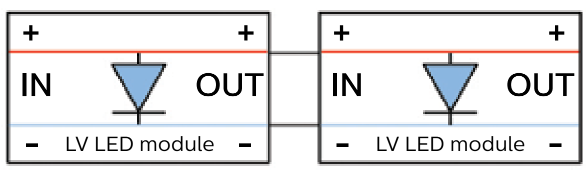


Figure 17. Schematic representation of the wiring of two connected LV LED modules in an LV system, not needing a return-end cable.

Note:
That the number of LED modules per chain does not have to be the same for all chains since all LED modules are electrically connected in parallel.

Some linear drivers come with a duplicate – parallel – output, having 2x "+" and 2x "–" in parallel at the driver output. This means for the 2-chain layout the second chain can be connected either to the "+" and "–" of the first chain or connected to the second set "+" and "–" of the driver.

LV products do not have to be terminated with a return-end connection.

Idrive = Inom [A] x # modules Required drive current equals nominal current of one LED module times number of LED modules. Vdrive = Vf [V] Required drive voltage equals forward voltage of one LED module.

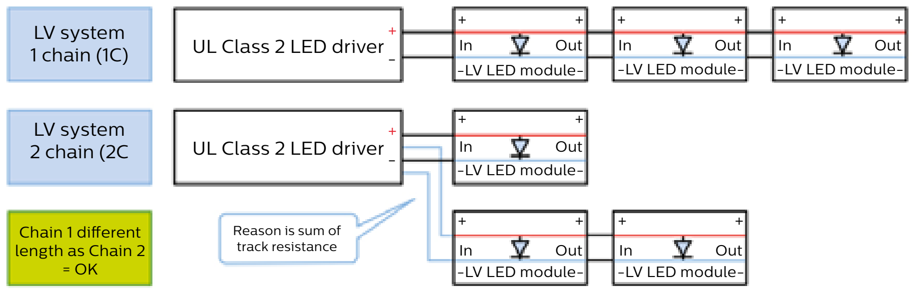


Figure 18. Chain of LED modules.

The LED Linear System Overview is a matrix of LED drivers and linear LED modules released as a system. It shows how many Fortimo LED modules operating at nominal current can be used in combination with a specific Xitanium LED driver. This document gets frequently updated and can be downloaded at www.philips.com/oemna.

How to mix different models of LED modules

Please note that although LED modules of different models can be connected to one another, only modules of the same type (lm/ft & xR & LV) but different length can be mixed. These combinations are also indicated in the datasheet (www.philips.com/ledmodulesna) and are considered a released Fortimo LED linear system. An example is noted below detailing a 5 ft length system composed of 1 ft 1100 lm 1R LV and 2 ft 2200 lm 1R LV LED modules.

What value does the drive current need to be then?

Building a chain of LED modules leads to a derived value for the drive current, as explained in the previous section on how to configure an LED system. To illustrate this please follow the next example.

1. Each module has a requirement for the current linked to the amount of LEDs (2 ft has twice the amount of LEDs as the 1 ft). You simply sum up the currents required per LED module, shown in the drawing below.
    - 5x current for 1 ft, equals.
    - 1x current for 1 ft + 2x current for 2 ft, equals.
    - 3x current for 1 ft + 1x current for 2 ft.

Note:
It is strongly advised to use all LED modules from the same bin to prevent flux imbalance. For more on binning, see “Binning” in section “Tips for assembly and installation.”

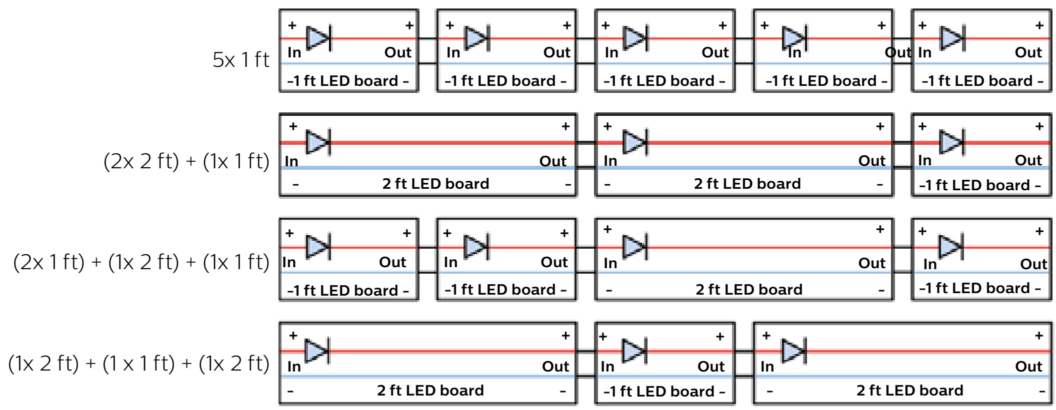


Figure 26. Chain of LED modules.

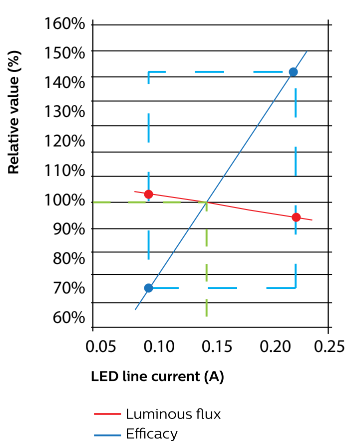


Figure 19. LED line current (A).
Example of tuning flux and efficacy by altering the drive current. For specific details please check the associated datasheet of the LED module you are using.
Example for a given LED module, keeping Tc constant,
- doubling of the drive current (mA)
- leads approximately to a doubling of the flux
- and cost you only 10% efficacy (lm/W).

There is a large degree of freedom to tune to, for example, a desired luminaire lumen output.

Use different LED module generations

When considering mixing LED linear modules of different generations in the same system, use caution. On one driver (making a system), mixing should not be done. The reason is, besides possible interface differences, the different generations have different operation points. Mixing the different generations on one driver would lead to a flux imbalance.

Whole lumen range covered with 3 building blocks

“I need 1200 lm/ft. That is not in the portfolio. Can I order these at Philips?”
“I am designing for even higher efficacy. Can I achieve that with Philips?”

Yes you can!

By means of tuning the drive current for the LED modules, you are able to do this. With only three lumen packages (building blocks 700, 1100 and 2000 lm/ft) the fluorescent tube lumen range is covered.

How to tune the luminaire's flux and efficacy

The LED module specifications are provided under nominal conditions, like nominal flux at nominal current. An example could be 1100 lm at 250 mA. With Philips Fortimo LED linear system, however, it is possible to deviate from the LED module's nominal current. Current (mA) and flux (lm) are approximately linear proportional. By altering the current, the flux will change accordingly. Figure 20 schematically shows the three lumen packages and the indication of the flux as function of the current; tuning. At the same time also the required forward voltage (Vf) changes a bit, leading to a change in efficacy too (lm/W). The next table explains the impact and boundaries.

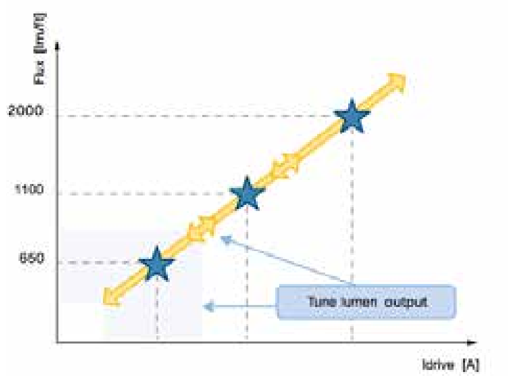


Figure 20. Schematics.
Indicated are the three lumen packages (blue stars: 650, 1100 and 2000 lm/ft). Yellow arrows schematically indicate the flux as function of the current around the nominal value; tuning.

Important

In case the OEM chooses to set the current (either by programming or by applying an Rset resistor) other than nominal, the lifetime and reliability of the LED module must be taken into account. The following current regions can be distinguished:

1. Current < nominal current (mA).
   a. Efficacy (lm/W) higher than nominal value lumen output (lm) lower than nominal value.
   b. Lifetime > 50,000 hours.

2. Current between nominal current and lifetime current (mA).
   a. Efficacy (lm/W) lower than nominal value lumen output (lm) higher than nominal value.
   b. Lifetime > 50,000 hours.

3. Current between lifetime current and absolute maximum current (mA). No warranty applicable in this case.
   a. Efficacy (lm/W) lower than nominal value lumen output (lm) higher than nominal value.
   b. Lifetime < 50,000 hours.

4. Current > absolute maximum current: do not exceed the absolute maximum current as this can lead to LED module failure. No warranty applicable in this case. UL safety limits for approbation are exceeded above this point.

The rated average life is based on engineering data, testing and probability analysis. The hours are at the L70 B50 point.

Values are stated in the associated LED module datasheet at www.philips.com/ledmodulesna.

Fortimo LED Linear Module	**I Nominal***	**I Life****	**I Max*****
	mA	mA	mA
LED Module Example	150	200	250

Table 3. Values for Fortimo LED linear module.

Note:
* Nominal current at which performance is specified
** Value at which lifetime is specified (max current for warranty)
*** Maximum current tested for safety

How to set the output current via Rset to a chosen current

Figure 21. Example of resistor to set the current via Rset.

One resistor value sets the maximum operating current that is chosen as long as it fits within the driver's operating window. That is the same method of operation used for all window drivers.

Why a resistor

1. Worldwide standardized building block.
2. Worldwide availability and well documented.
3. Freedom for OEM to choose the value and supplier.

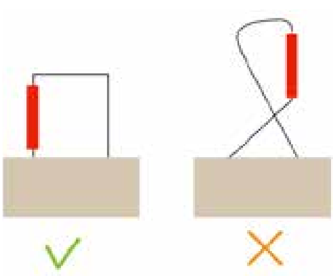
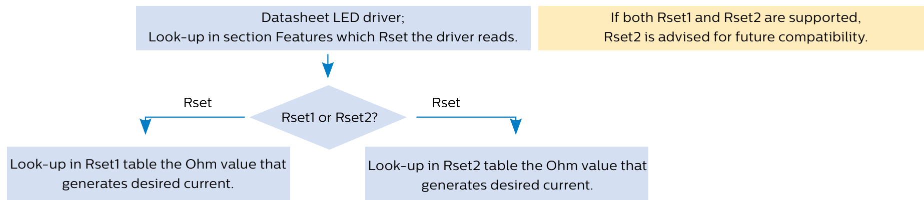


Figure 22: Connect the wires straight into the unit.

Resistor placed into driver enables you to

1. Connect different configurations, not just a unique solution.
2. Drive different type of LED modules, not restricted to one type.
3. Select and tune the current, hence flux or Tc.



Note:
On E-series: in electronics, international standard IEC 60063 defines preferred number series for resistors. It subdivides the interval between subsequent values from 1 to 10 into 6, 12, 24, 48, 96, etc., steps. These subdivisions ensure that when some arbitrary value is replaced with the nearest preferred number, the maximum relative error will be on the order of 20%, 10%, 5%, 1%, etc.
Note:
Next page shows extended Rset2 table: E96 values, stating smaller increments.

Rset1 – E24 Series

Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]
39	200	510	292	6k8	583	91k	690
43	201	560	300	7k5	591	100k	691
47	202	620	309	8k2	599	110k	692
51	203	680	318	9k1	60	120k	693
56	204	750	327	10k	614	130k	693
62	206	820	336	11k	621	150k	695
68	208	910	347	12k	627	160k	695
75	209	1k	358	13k	632	180k	696
82	210	1k1	369	15k	640	200k	696
91	212	1k2	379	16k	643	220k	697
100	215	1k3	388	18k	649	240k	697
110	217	1k5	406	20k	654	270k	698
120	219	1k6	414	22k	658	300k	698
130	221	1k8	429	24k	661	330k	698
150	226	2k	442	27k	665	360k	699
160	228	2k2	455	30k	669	390k	699
180	232	2k4	466	33k	671	430k	699
200	236	2k7	481	36k	674	470k	699
220	240	3k	494	39k	676	510k	699
240	244	3k3	505	43k	678	560k	700
270	250	3k6	517	47k	680	620k	700
300	256	3k9	525	51k	682	680k	700
330	261	4k3	536	56k	683	750k	700
360	267	4k7	546	62k	685	820k	700
390	272	5k1	555	68k	686	910k	700
430	279	5k6	564	75k	688	1M	700
470	286	6k2	574	82k	689	No Rset	default

Table 4. Rset1 – E24 series.

Rset2 – E24 Series

Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]	Ret1 Iset	[Ω] [mA]
short	100	430	245	2k	733	9k1	1558
100	100	470	261	2k2	780	10k	1604
110	106	510	277	2k4	823	11k	1653
120	111	560	297	2k7	884	12k	1694
130	116	620	318	3k	941	13k	1730
150	121	680	340	3k3	993	15k	1793
160	130	750	368	3k6	1042	16k	1817
180	13	820	392	3k9	1086	18k	1864
200	146	910	422	4k3	1143	20k	1902
220	155	1k	452	4k7	1192	22k	1935
240	166	1k1	485	5k1	1238	24k	1965
270	176	1k2	515	5k6	1293	27k	2000
300	190	1k3	545	6k2	1350	No Rset	default
330	204	1k5	602	6k8	1402		
360	215	1k6	632	7k5	1454		
390	228	1k8	684	8k2	1503		

Table 5. Rset2 – E24 series.

Rset priority behavior for drivers that read both Rset1 and Rset2

Rset1	Rset2	Driver status
Open	Open	Driver's default current (see datasheet)
Rset	Open	Rset1
Open	Rset	Rset2
Rset	Rset	Rset2
Short	Open	Rset1 (driver's minimum current, see datasheet)
Short	Short	Rset2 (driver's minimum current, see datasheet)
Open	Short	Rset2 (driver's minimum current, see datasheet)

Table 6. Rset priority behavior for drivers that read both Rset1 and Rset2.

Please refer to the datasheet for the driver you use to determine which Rset or Rsets the driver actually reads.

Rset2 - E96 Series: Extended table with E96 values, stating smaller increments but covering same range as the E24 series on previous page

Rset2 [Ω]	Iset [mA]	Rset2	Iset [mA]	Rset2 [Ω]	Iset [mA]	Rset2 [Ω]	Iset [mA]	Rset2 [Ω]	Iset [mA]	Rset2 [Ω]	Iset [mA]
short	min.	255	171	665	335	1,740	669	4,530	1,171	11,800	1,686
100	100	261	173	681	341	1,780	679	4,640	1,185	12,100	1,698
102	101	267	175	698	347	1,820	689	4,750	1,198	12,400	1,708
105	103	274	178	715	354	1,870	701	4,870	1,212	12,700	1,719
107	104	280	181	732	361	1,910	711	4,910	1,216	13,000	1,730
110	105	287	184	750	368	1,960	724	5,110	1,239	13,300	1,739
113	107	294	187	768	374	2,000	733	5,230	1,253	13,700	1,752
115	108	301	191	787	381	2,050	745	5,360	1,267	14,000	1,761
118	110	309	194	806	387	2,100	757	5,490	1,281	14,300	1,771
121	111	316	197	825	394	2,160	770	5,620	1,295	14,700	1,783
124	113	324	201	845	400	2,210	782	5,760	1,308	15,000	1,793
127	115	332	204	866	407	2,320	806	5,900	1,322	15,400	1,802
130	116	340	207	887	414	2,360	815	6,040	1,335	15,800	1,812
133	118	348	210	909	422	2,370	817	6,190	1,349	16,200	1,822
137	119	357	214	931	429	2,430	829	6,340	1,362	16,500	1,829
140	120	365	217	953	436	2,490	841	6,490	1,375	16,900	1,838
143	122	374	221	976	444	2,550	853	6,650	1,389	17,400	1,850
147	123	383	225	1,000	452	2,610	865	6,810	1,403	17,800	1,859
150	125	392	229	1,020	459	2,670	877	6,980	1,415	18,200	1,867
154	127	402	233	1,050	469	2,740	891	7,150	1,428	18,700	1,877
158	129	412	237	1,070	475	2,800	903	7,320	1,441	19,100	1,885
162	131	422	241	1,100	485	2,870	916	7,500	1,454	19,600	1,894
165	132	432	246	1,130	494	2,940	929	7,680	1,467	20,000	1,902
169	134	442	250	1,150	500	3,010	943	7,870	1,480	20,500	1,910
174	136	453	254	1,180	509	3,090	956	8,060	1,493	21,000	1,918
178	137	464	259	1,210	518	3,160	968	8,250	1,506	21,600	1,928
182	139	475	263	1,240	527	3,240	982	8,450	1,518	22,100	1,936
187	141	487	268	1,270	536	3,320	996	8,660	1,531	23,200	1,952
191	143	491	270	1,300	545	3,400	1,009	8,870	1,544	23,600	1,959
196	145	511	278	1,330	554	3,480	1,022	9,090	1,557	23,700	1,960
200	146	523	282	1,370	565	3,570	1,037	9,310	1,569	24,300	1,968
205	148	536	287	1,400	574	3,650	1,049	9,530	1,580	24,900	1,975
210	151	549	292	1,430	582	3,740	1,062	9,760	1,592	25,500	1,982
216	153	562	297	1,470	594	3,830	1,075	10,000	1,604	26,100	1,989
221	155	576	302	1,500	602	3,920	1,088	10,200	1,614	26,700	1,996
232	161	590	307	1,540	614	4,020	1,103	10,500	1,629	27,000	2,000
236	163	604	313	1,580	626	4,120	1,117	10,700	1,639	open	default
237	164	619	318	1,620	638	4,220	1,131	11,000	1,653		
243	167	634	323	1,650	645	4,320	1,145	11,300	1,666		
249	169	649	329	1,690	656	4,420	1,158	11,500	1,674		

Table 7. Rset2 - E96 Series: Extended table with E96 values, stating smaller increments but covering same range as the E24 series on previous page.

How to program the output current interface – connecting to indoor & outdoor, LED & conventional

Figure 23. MultiOne interface.

The Xitanium programmable drivers offer a full range of controls, enabling customizable luminaire design and performance. It is possible to control light output levels, preset dimming protocols and set system specifications in the factory and even in the complete installations in the field. This can be done with the Philips MultiOne configurator software. The MultiOne configurator software is an intuitive tool that unlocks the full potential of all programmable drivers from Philips, ensuring that the driver performance matches the needs of the lighting solution. It offers unprecedented flexibility, before, during and after the product installation.

There are multiple programming methods (DALI, SimpleSet) being used within the Xitanium programmable portfolio. The DALI method uses hardwired communication whereas the Simpleset method uses wireless communication.

For more information and latest version please visit www.philips.com/multione. This site contains detailed information on how to install the software and how to program the driver using the different methods noted above.

Figure 24. Examples of what solutions could look like for pairing wires.

How to wire - general remarks

Direct wiring between driver and LED modules

Be informed that no components are allowed between the LED driver and LED modules other than connectors and wiring intended to connect the LED driver to the LED module. For example, it is not allowed to install a switch between the driver and LED modules.

Two wires into one connector hole

In some scenarios two wires need to be connected to one connector hole. In this case the pairing has to be done outside the driver, resulting in only one wire going into the driver. Two wires into one connector hole are not supported.

Ferrules

The reliability of twin-wire ferrules (or “wire end stop”), accepting the wire which is inteded to be used, should be checked with the supplier of these ferrules.

Cables and wires

With the current Fortimo LED linear modules, standard solid core installation wire can be used. This approach allows the OEM to choose the preferred supplier, as well as preferred cable properties like color, thickness and lengths, although mains-rated wiring is advised. Please check the LED module and driver datasheet for details like wire thickness and strip length at www.philips.com/ledmodulesna.

Connecting the LED module to the driver

On the LED modules, connectors are marked “IN” or “OUT” together with a “+” or “-” or both. LED linear modules are polarity sensitive. Please assure a correct wiring before switching on the LED driver. In a “2-chain” configuration, 2 plusses and 2 minuses have to be connected to the driver. Currently, Philips offers only single channel linear drivers, meaning that if double “+” and “-” are present at the driver output, these are in parallel. Only one current (mA) can be drawn from the driver. See also the design-in guide for Xitanium indoor linear LED drivers at www.philips.com/leddrivers.

Interconnecting LED modules

By default the cables are connected from the “OUT” connector of a LED module to the “IN” connector of the next in line LED module, keeping the polarity (“+” and “-”) consistent. However, different wiring schemes could be possible (see previous paragraph on wiring). LED linear modules are polarity sensitive. Please assure correct wiring before switching on the LED driver.

Connecting the driver to the mains supply

The mains supply has to be connected to the LED driver, not the LED module.

Warning

If the driver needs to be connected to protective earth, like non-isolated Xitanium LED drivers, then also the luminaire needs to be connected to protective earth in order to comply with safety and EMC regulations. Please also consult the design-in guide for the Xitanium indoor linear LED drivers at www.philips.com/leddrivers.

Electromagnetic compatibility (EMC)

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. In general, LED modules have no effect on the EMC of a luminaire. The Fortimo LED linear family modules are evaluated in combination with a Xitanium driver in a reference luminaire to meet FCC 47 subpart 15 Class A.

Cable length and EMC

Philips has successfully performed EMC tests for a total length of 4 meter (sum of wire length and length of the Fortimo LED linear modules). For longer lengths it is advised to repeat these EMC tests.

How to improve EMC performance

- Minimize the DM loop area of the lamp wires going from the driver to the light source by keeping the wires close together (bundling). This will minimize the magnetic field and reduce the radiated EMI (Electromagnetic Interference). Long linear light sources are also part of that loop.
- Minimize the CM parasitic capacitance of the output wiring + light source to earth by keeping the length of the wires between driver and light source as short as possible. Also minimize the copper cooling area on the LED PCB and keep the length of the incoming mains wire inside the luminaire as short as possible. Remote wiring of the driver and/or LED modules is possible, but the above mentioned capacitance with the addition of resistance caused by the wire creates a voltage drop between the driver and module(s) and must be considered.
- Keep mains and control wires (DALI, 0-10 V) separated from the output wires (do not bundle).
- Ground the lighting system chassis and other internal metal parts to protective earth, and do not let large metal parts “float.” Always use the safety or functional earth connector or wire from the lamp driver. Or use equipotential connecting wires for all internal floating metal parts that are inaccessible. Keep safety and functional earth wires as short as possible to minimize their inductance; use as much as possible large metal areas (chassis, mounting plates, brackets) for earthing purposes instead.
- It is advised to establish a functional earth (FE) connection between all larger conductive, non- accessible luminaire parts and the driver to remedy potential EMC problems.
- Sometimes, radiated EMC compliance cannot be achieved, necessitating the use of a 100 … 300 Ω axial ferrite bead(s) for either mains or lamp wiring (effective for interference between 30 MHz and 300 MHz), or coupling the wires through ferrite cores within the luminaire may improve the overall EMC performance. However, selection of the type and characteristics of the additional filter depends on what frequency components have to be damped and by how much.

Adhering to these rules will help in EMC compliance. For further questions, please contact your local Philips sales representative. Alternatively, the Philips Lighting OEM design-in team could be consulted for a possible solution.

Warning

As mentioned before, the total amount of parasitic current needs to be minimized. For that reason, the preceding practical precautions need to be taken into account in a lighting system to minimize EMI.

Mechanical design-in

Mechanical fixation for LED linear modules

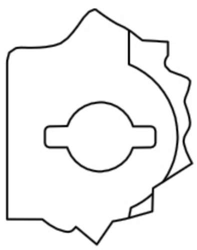


Figure 25. Fixation slit-hole.

To allow product performance achieving the specification, it is advised to use all designated holes on the module indicated for fixation. Optionally, you can omit some fixation points and evaluate the module's performance on mechanical flatness and thermal contact. Make sure the modules are thermally in good contact with the mounting surface. This can be verified by measuring the Tc temperature and visually, or with the use of a gauge, verifying the module is contact with the mounting surface across the entire length of the module. When in good thermal contact, it is likely no additional thermal paste or cooling bodies are required. All fixation holes can be used for mounting purposes although certain features have been added to some to allow for ease in mounting and/or use of specialized fixation hardware. The fixation holes are indicated in each product's datasheet in the download section at www.philips.com/ledmodulesna.

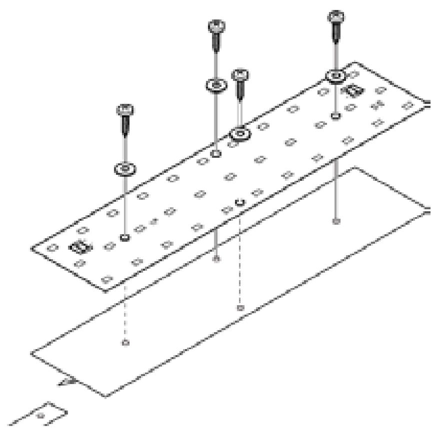


Figure 26. Use of washers.

Screws, washers and fixation holes

Each LED module fixation hole accepts up to a size M4 (or size 6) screw. OEMs may choose different size screws, as long as the creepage and clearance is maintained with respect to the PCB tracks. When using washers, we recommend using insulating washers and not metal washers, as with metal washers the creepage distance of earthed screw connection with respect to the PCB tracks is more difficult to be guaranteed.

To ensure the electrical insulation when using, for example, M4 metal screws, the diameter of the screw head (and optional metal washer) must not exceed 7.5 mm. When using electrically non-conductive materials the size could be allowed larger than 7.5 mm diameter. Small circles around the fixation holes indicate the limit the screw head should stay within.

Some LED linear types have holes available for mounting electrically non-conductive optics. The electrical isolation distance around these holes is not suitable for metal screws. Do not use these holes for mounting and fixating the LED module, as these holes will not meet creepage and clearance requirements. These optic fixation holes are indicated in the applicable product's datasheet in the download section of www.philips.com/ledmodulesna.

Damage of insulation layer by screws or clamps

In general, the surface of the PCB must not be damaged by mounting materials, as this may compromise the electrical isolating layer. However, scratching of the PCB's white top layer in the region that is intended for fixation by screw or clamp will not lead to loss of function or reliability. The area around fixation holes does not carry any copper tracks. This can be seen when looking carefully at the LED module. The mounting materials must still comply with the relevant creepage and clearance.

Screw torque

The maximum torque that should be applied depends on the screw type and luminaire material. The fasteners used to secure the LED module to a heat sink must be tightened with a torque in accordance with the table below.

Note:
When tightening the fasteners it is best to start the fasteners into the module to allow the module to be centered and then tighten the fasteners from the center of the module to the ends of the module. This will help to ensure that the module will lie flat on the mounting surface and minimize any gaps that may occur.

Screw Torque	Min	Max
Steel or aluminum, thread forming screws	0.6 Nm	1.0 Nm

Table 8. Maximum screw torque.

Alternative fixation methods

With Fortimo LED linear modules, fixation methods other than screws can be explored, potentially leading to fewer screws and faster mounting times. In order to achieve this, larger copper-free isles have been designed around the mounting holes. This freedom applies to the whole LED line portfolio. Be careful that the clamp pressure on the PCB still enables flat assembly of the LED linear module, so if the clamp somehow prevents the product from taking a flat position to make good thermal contact with the luminaire, it is undesired. Suggestions are made in this section.

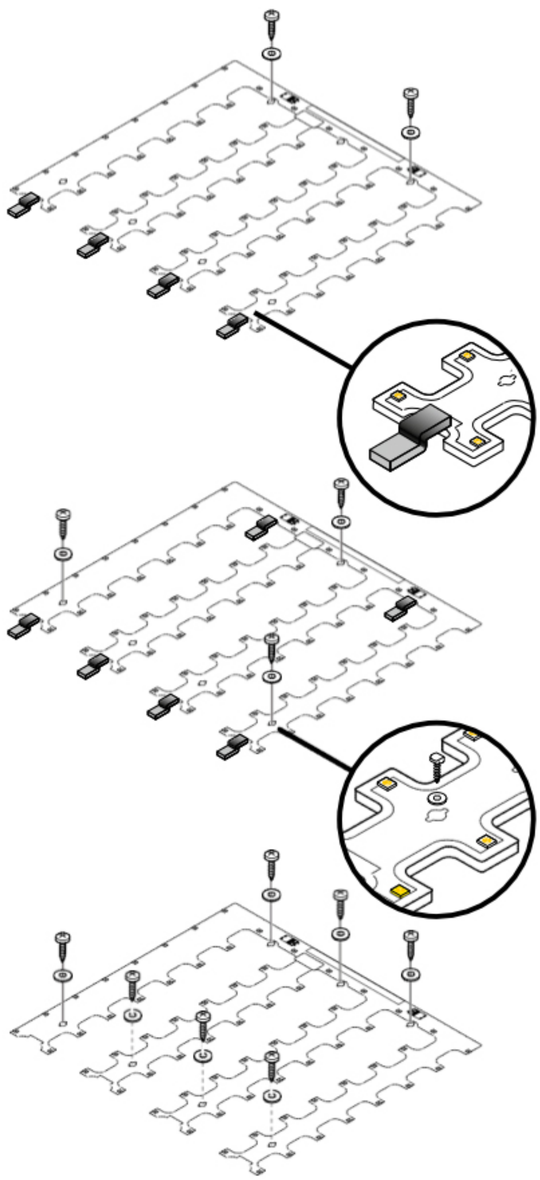


Figure 27 Alternative fixation methods.

Clamps

As an example, for the LED line 1ft SQ module using clamps, three different mounting scenarios are depicted on page 30. Each clamp used must comply with a 0.8 mm distance from clamp to the copper track in all directions on the LED module. A similar approach holds for the linear LED modules, as indicated below.

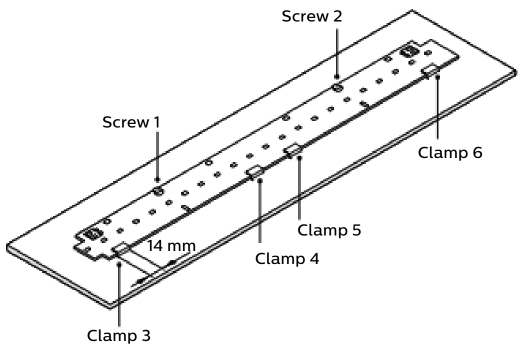


Figure 28. Fixation with 2 screws and 4 clamps.

Tip for scenario 2 of the 1ft SQ modules

Make sure when using two rows of clamps to keep the clamp length of one of the rows slightly shorter, to allow mechanical alignment of those clamps first. Next, lower the 1ft SQ module and slide the module under the second row of clamps. Finally, put in the screws.

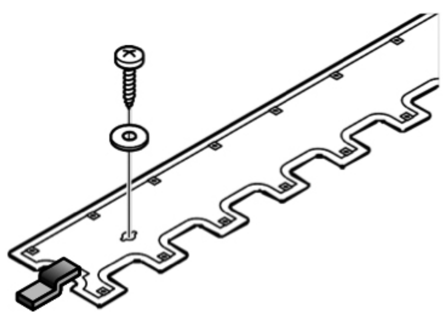


Figure 29. Tip for scenario 2 of the 1ft SQ modules.

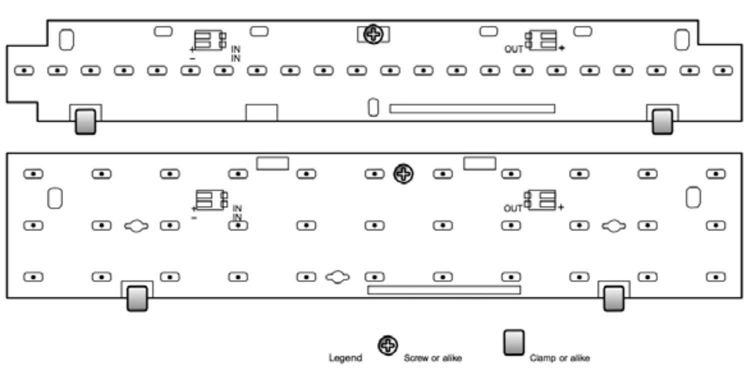


Figure 32. One-screw fixation with clamps for LED lines.

Complementary partners for fixation alternatives

Figure 30. Push to fix component by BJB.

Fixation materials, such as screws, are not part of the Fortimo LED linear system offering. This is an added-value area for OEMs, offering the possibility to differentiate. However, there are several suppliers offering push-and-fix-like components or adhesive tapes, enabling quick and easy luminaire creation. Some of these are listed in the complementary partner section in our LED quick guide (both available printed and digital) or at www.philips.com/ledmodulesna.

Reference to these products does not necessarily mean they are endorsed by Philips. Philips gives no warranties regarding these products and assumes no legal liability or responsibility for any loss or damage resulting from the use of the information given here. We advise not to use bare plastic push-pin fasteners (without any metal parts), as these are likely to wear out before the lifetime of the LED product is reached, reducing the mechanical and thermal contact between the LED module and the luminaire.

Figure 31. Florence Press Fit Screw Replacement component by LEDiL.

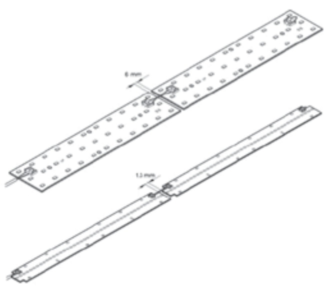


Figure 32. LED line 3R modules.

Continuous LED pitch

To achieve optimal lighting uniformity, it is advised to keep the LED pitch between the modules the same as on the module itself. As an example, for current LED line 3R modules the modules should be ~6 mm apart. For LED line 1R modules that should be ~1.3 mm. This distance can be derived from the measures in the drawings provided in the datasheet of the LED module you use, in the download section on www.philips.com/ledmodulesna.

Reflector design

If a reflector is designed around the LED module, it is essential to allow a proper clearance distance between the LED module and reflector around the LED module surface, LEDs and the connectors (see drawing below). This clearance distance is necessary to ensure safe insulation of the system and is in line with UL 1598/IEC 60598 regulations to prevent short circuiting, damage and an open circuit to the LED module.

Required minimum clearance distance

LV product requires 1 mm minimum.

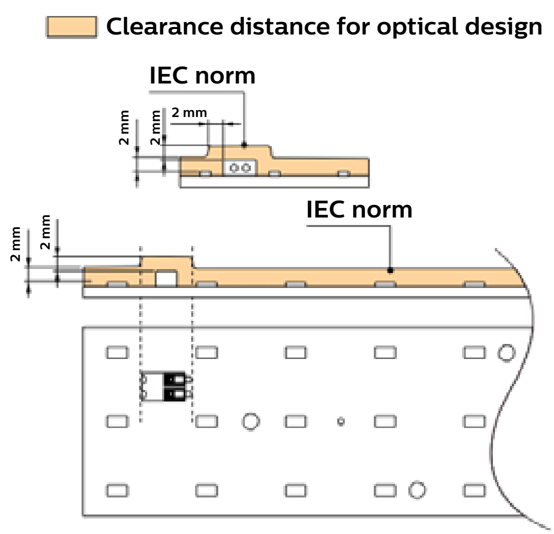


Figure 33. Clearance distances required for optical design around LED linear modules.

Warning

If a luminaire requires protective earth, all conductive parts – like the reflector – must be electrically connected to protective earth in order to prevent hazardous conditions!

Thermal design-in

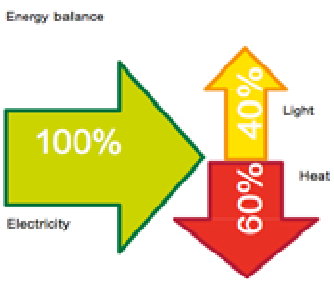


Figure 34. Energy balance of an LED module.

Introduction

To facilitate design-in of Fortimo LED linear systems, the critical thermal management points and case temperature (Tc) of the LED modules and driver are set out in this section. In Philips' product design phase all possible precautions have been taken to keep the component temperature as low as possible. However, the design of the luminaire and the ability to guide the heat out of the luminaire are of utmost importance. If these Tc points are taken into account when designing the fixture, it will ensure the optimum performance and lifetime of the system.

Definitions

- LED module temperature: temperature measured at the Tc point of the LED module.
- Driver temperature: temperature measured at the Tc point of the driver.
- Ambient temperature (Tamb): temperature outside and surrounding the luminaire.

When switched off >2 hours, temperature at Tc point is likely to equal Tamb.

Thermal behavior of Xitanium drivers

Besides the LED modules, another important component is the driver. For specific design-in guidelines, please consult the associated design-in guide for the Philips Advance Xitanium indoor linear LED drivers and the associated driver datasheets, which can be found at www.philips.com/oemna.

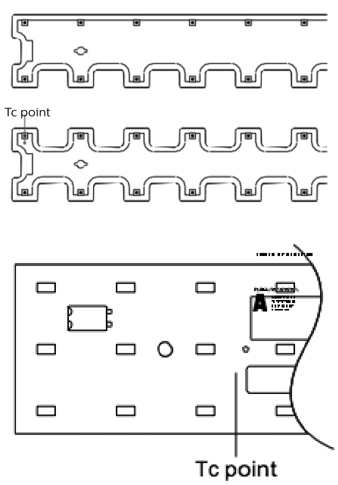


Figure 35. Tc point.

Tc point

The Tc test point indicates a reference point for measuring the LED module's temperature. The Tc test point for each LED module is indicated both on the PCB and in the associated datasheet. This can be used during the luminaire design to verify that the temperature remains below the maximum specified temperature for the Tc test point.

For LEDs it is the junction temperature that is the critical factor for operation and lifetime. Since there is a direct relation between the case temperature and the LED junction temperature, it is intended to only measure the temperature at the Tc point of the LED module. This Tc point must not exceed the maximum values stated in the associated datasheet in the download section on www.philips.com/ledmodulesna.

How to measure Tc at the Tc point

Tc can be measured using, for example, a thermocouple that is firmly glued or taped to the upper surface of the LED module. For a representative measurement the temperature must be stable before any reliable data can be obtained (often minimum 1 hour stabilizing time).

Test requirements

Measurements, e.g., of temperature, luminous flux and power, are reliable once the luminaire is thermally stable, which may take between 0.5 and 2 hours and is defined at least three readings with stability less than 0.5%. Readings are taken every 15 minutes.

Note:
Thermal stability can be considered if the temperature changes are less than 1° C over three measurements taken 15 minutes apart. Measurements must be performed using thermocouples that are firmly glued to the surface (and not, for example, secured with adhesive tape).

Relation between Tc and flux

The flux of the LED module is specified at a nominal Tc, which is a lower value than the Tc corresponding to the lifetime specification (Tc life). Increasing the Tc temperature has an adverse effect on the flux and lifetime of the LED module.

Relation between Tc and ambient temperature

The Tc increases by approximation linear with the ambient temperature (Tamb). The temperature offset between Tamb and Tc depends on the thermal design of the luminaire. The Fortimo LED linear system has been designed for indoor use. For approved ambient temperature range, please check the associated LED module datasheet on www.philips.com/ledmodulesna.

How to tune for anticipated ambient temperature (°C)

The LED module specifications are provided under nominal conditions, like nominal flux at nominal Tc. In previous sections it has been explained how to determine the temperature at Tc point. It is, however, possible to deviate from the LED module's nominal Tc. As the ambient temperature (Tamb) and Tc are related, thermally designing for a different Tc could allow for, e.g., a higher Tamb or using different housing materials. Deviating Tc from nominal will lead to relative small changes in flux (lm) and efficacy (lm/W). Figure 36 explains the impact and boundaries.

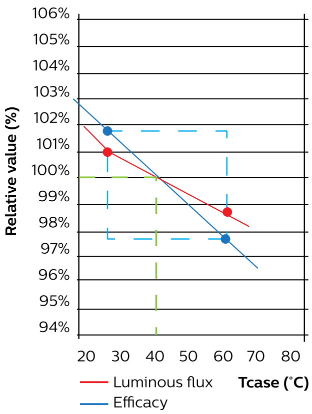


Figure 36. Graph.

Example of altering flux and efficacy by allowing a different Tc. For specific details please check the associated datasheet of the LED module you are using.

Example for a given LED linear module, keeping the drive current constant,

- Allow doubling of Tc (°C).
- Csts only about 5% flux.
- And costs only about 3% efficacy (lm/W).

Example Graph

Case temperature (Tc) has some impact on performance but a clear impact on lifetime. Advice is to stay below Tc-life. The rated average life is based on engineering data testing and probability analysis. The hours are at the L70 B50 point.

An example is given below on how these values are stated in the associated LED module datasheet on www.philips.com/ledmodulesna. Please make sure to look up the corresponding Tc values for the Fortimo LED linear product you are using.

Fortimo LED Linear Module	Tc nominal *	Tc life**	Tc max***
	°C	°C	°C
LED Module Example	45	65	80

Table 9. LED module data.

* Nominal value at which performance is specified
** Value at which lifetime is specified (max current for warranty)
*** Maximum value for safety

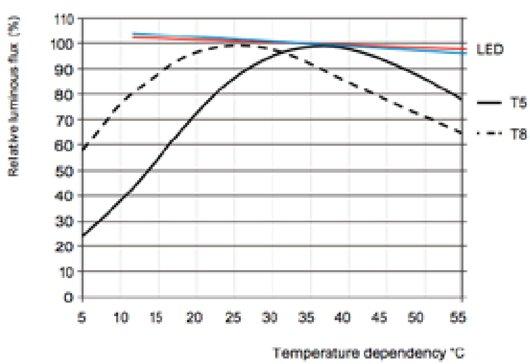


Figure 37. Graph.
With LED there is a stable light performance over a large temperature range, opposed to fluorescent tubes.

Influence of thermal resistance of the luminaire

Retrofitting LED linear modules into existing fluorescent fixtures is possible in many cases. However, in case of a high flux LED line - with a high power density - the luminaire design has to enable sufficient heat transfer from the LED module to the ambient. In other words, the higher the flux density (lm/ft), the lower the total thermal resistance (Rth) from the LED module to the ambient has to be in order to keep the LED module temperature at the specified level. The total Rth is determined by both the LED module and the luminaire design. The lower the Rth, the better the thermal performance of the system.

In case the measured Tc value of the LED module inside the luminaire is higher than specified and the luminaire design cannot be modified, reducing the LED module's current can provide a solution.

The total Rth can be calculated from the measured difference between Tc and Tamb and the LED module's current and voltage by the following formula:

Note:
Pth is approximately 0.6 x Pelectric.

$$R_{th} = \frac{(T_c - T_{amb})}{0.6 \times (V \times I)}$$

Warning

In case the OEM chooses to allow the temperature at Tc other than nominal, the lifetime and reliability of the LED module must be taken into account. Given a constant drive current (mA), following temperature regions can be distinguished:

1. Temperature at Tc < nominal value (°C).
    a. Efficacy (lm/W) higher than nominal value. Light output (lm) higher than nominal value.
    b. Lifetime > 50,000 hours.
2. Temperature at Tc between nominal value and lifetime value (°C).
    a. Efficacy (lm/W) lower than nominal value. Light output (lm) lower than nominal value.
    b. Lifetime > 50,000 hours.
3. Temperature at Tc between lifetime value and absolute maximum value (°C). No warranty applicable in this case.
    a. Efficacy (lm/W) lower than nominal value. Light output (lm) lower than nominal value.
    b. Lifetime < 50,000 hours.
4. Temperature at Tc > absolute maximum value: do not exceed the absolute maximum value as this can lead to LED module failure. No warranty applicable in this case.

How to calculate Tc after changing the drive current

If Tc is known at current "X" mA, what will Tc be if the current is set to "Y" mA?

Alternatively:

How much higher can or lower must the current be to stay below Tc-life?

1. Given Tc and Tambient are obtained correctly in the first place.
2. Assuming linear relation with bias (being the Tambient) is realistic.
3. Once Rth is determined, it becomes: Tc = (Rth * V * I) + Tambient.

This realistic approach is, however, simplified. Use this: For example, calculating Tc within a few degrees Celsius from Tc-life for a reduced current level of 40mA, based on a measurement taken at 200mA, can be very inaccurate.

Advice: For final validation of thermal design, actual measurements are needed.

Cooling via the luminaire housing or cooling plate thermal contact

Preventing an air gap is ensuring the best thermal contact. By ensuring good thermal contact between the bottom surface and the luminaire surface, thermal interface materials (TIM) should not be required.

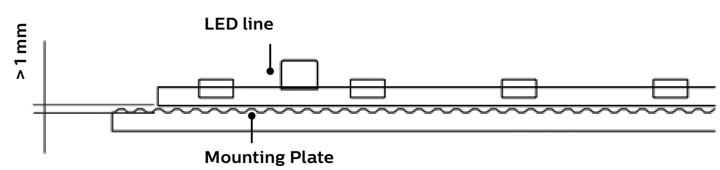


Figure 38. The air gap of the area where the LED module is mounted should not exceed 1 mm along the LED module.

Cooling via the luminaire housing

The Fortimo LED linear module itself has been optimized to spread the generated heat. However, extra cooling can be achieved via the luminaire housing or, if this is not sufficient, via an additional cooling plate. For this to work well, good thermal contact must be achieved. Obviously, the plate must release its heat via the luminaire to the surroundings as well.

Cooling surface area and material

The amount of heat that needs to be transferred away from the LED module to the ambient air is about two-thirds of the electrical power. This heat needs to be dissipated and transferred to ambient air via the luminaire housing.

If the luminaire housing has a good thermal conductivity the effective cooling area is increased. It is therefore recommended to use a material that has high thermal conductivity and is of sufficient thickness. This will lower the module temperature and enable the system to perform better (lifetime and flux). The required size of the luminaire housing area per LED module depends on the design and volume of the luminaire, the thermal properties of the material used and the expected ambient temperature.

Material	k (W/mK)	Equivalent Conductivity
Copper	400	1 cm thickness, could be replaced by
Aluminum	200	2 cm thickness, could be replaced by
Brass	100	4 cm thickness, could be replaced by
Steel	50	8 cm thickness, could be replaced by
Corrosion-resistant steel	15	27 cm thickness

Table 10. Thermal conductivity of different materials.

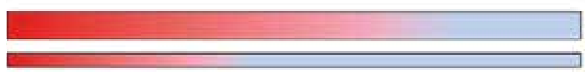


Figure 39. Effective length limited by both conductivity (K/m) and thickness (m).

Aluminum is preferred over steel because of its higher thermal conductivity, although for most applications steel is likely to be adequate. If Tc is exceeding the target value, consider the use of aluminum

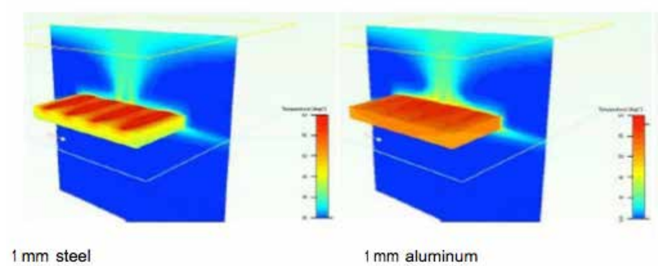


Figure 40. Temperature distribution using different mounting plate materials.

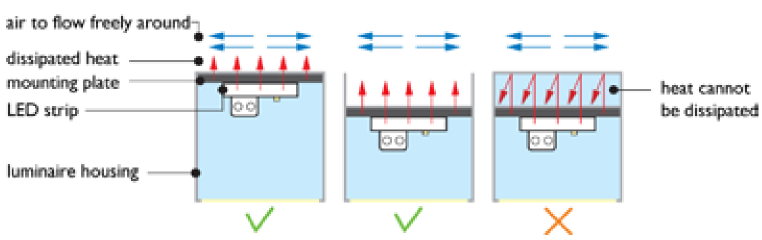


Figure 41. Operation under built-in conditions, applicable for both LED module and driver.

Thermal radiation and emissivity coefficient

Thermal radiation accounts for a substantial part of the total heat transfer. The amount of thermal radiation is highly dependent on the emissivity coefficient of the surface. For example, a polished aluminum surface has a very low emissivity coefficient, while a painted surface has a very high one. A higher emissivity coefficient means more effective heat transfer.

Thermal emissivity coefficients of common material

Material	Finish	Emissivity Coefficient
Aluminum	New/polished	0.04 - 0.06
	Blank	0.20 - 0.30
	Anodized	0.80 - 0.95
Steel	New/polished	0.10
	Painted/coated	0.80 - 0.95

Table 11. Thermal emissivity coefficients of common material.

Tips for small volume and double chamber conditions

The heat produced by the LED modules and LED driver in the luminaire (or similar housing) must be dissipated to the surroundings. If a luminaire is thermally isolated by a ceiling, wall or insulation blanket, the heat produced cannot be easily dissipated. This will result in a higher temperature of the LED driver and LED modules, which will have an adverse effect on system performance and lifetime. For optimum performance and lifetime it is advised that air be allowed to flow freely around the luminaire and that the mounting plate is in direct thermal contact with free air. Designing the luminaire in such a way that air can also flow through it will provide extra cooling, which may be beneficial in certain cases. Any venting provided must meet UL standards for safety.

How to design for good thermal performance

General thermal design guidelines to improve the thermal management and performance of a luminaire:

- Ensure good thermal contact between the module/driver and the coldest part of the luminaire.
- Simplify the heat path from Tc to cold ambient air; fewer interfaces is better.
- Place the module(s) and driver at a distance from each other to obtain a more uniform temperature distribution in the luminaire.
- Avoid sharp folding or bending of metal plate parts.
- Use good thermally conductive materials in the primary heat path.
- Ensure proper heat spreading by using materials with good conductivity and/or sufficient thickness to increase the effective cooling surfaces.
- Anodized, painted surfaces are preferable to blank shiny surfaces in order to increase heat transfer via thermal radiation.
- Use of thermal interface materials (TIM) can be considered to improve thermal contact, i.e., between the LED module and luminaire housing.

Contact Philips at any time if you need advice on your luminaire design (see "Contact details" section).

Reliability

Impact of thermal cycling on product failure

Not only the drive current (mA) and steady state case temperature (Tc °C) have an impact on the lifetime of LEDs. Also the number of full thermal cycles has a significant impact on product failure. A full thermal product cycle means the complete warm up to stabilized Tc of the product in use and full cool down to ambient temperature (Tamb) of the product being switched off. For your convenience the amount of warranted full thermal product cycles of the LED product at a given Tc is stated in the datasheet for the LED module you use, which can be found in the download section on www.philips.com/ledmodulesna. Electrically faster switching, thereby not reaching the thermal limits of a full thermal cycle, will allow for higher numbers.

Note:
Always take the Tc temperature limits into account as stated in the datasheet for the LED module you use.

Warranted number of full thermal product cycles at which the survival rate of the population ≥90%, at 25°C ambient temperature

Case Temperature Tc [°C]	LED Module 1	LED Module 2
35	14,600	
40		
45	14,000	
50		
55	12,000	14,600
60		
65	8,000	14,600
70		
75	6,000	14,000
80	6,000	
85		10,000
90		8,000

Table 12. Warranted number of full thermal cycles at 25C degree ambient.

Example:
LED module 1 with Tc 65 °C at Tamb 25 °C has a warranted number of full thermal product cycles of 8,000.

Example:
LED module 2 with Tc 65 °C at Tamb 25 °C has a warranted number of full thermal product cycles of 14,600.

Lumen maintenance of the Fortimo LED linear modules B50L70 @ 50,000 hours

The quality of the LED linear portfolio is underpinned with Philips' claim of B50L70 at 50,000 hours. This means that at 50,000 hours of operation at least 50% of the LED population will emit at least 70% of its original amount of lumens. The decreased lumen level can be a result of less light out of an LED, discrete LEDs failing - leading to a reduced lumen output of the luminaire - or a combination of the two. This is contrary to conventional light sources, where some time after service life hours the conventional light source emits no light at all. In this section the example graphs show the estimated lumen depreciation curves for different percentage of the population and for different Tc temperatures. The actual data for the LED linear modules can be found in the associated datasheet.

Please refer to the associated LED module datasheet for the specific lumen maintenance graphs.

LM-80 data and DLC compliance

The DesignLights Consortium® (DLC) promotes quality, performance and energy-efficient commercial sector lighting solutions through collaboration among its federal, regional, state, utility and energy efficiency program members, luminaire manufacturers, lighting designers and other industry stakeholders throughout the U.S. and Canada. Since 2010, the DLC has administered the Commercial LED Luminaire Qualified Products List (QPL), a leading resource that identifies quality, energy-efficient LED luminaires for the commercial sector. The DLC follows the ENERGY STAR guidance for lumen maintenance testing that includes IES LM-80 test procedures and the application of LM-80 data using the IES TM-21 procedure to determine the long-term lumen maintenance of an LED light source. IES TM- 21 applies an exponential least squares curve-fit through the average values provided in the LM-80 data. The TM-21 calculator that is used to determine the estimated long-term lumen maintenance can be found at http://www.energystar.gov/TM-21calculator. The LM-80 data for the LEDs used for each Philips LED module is available on request from your sales representative. Please contact them for assistance in obtaining this information.

> **Warning**
>
> Lumen maintenance of the LED device is not a proxy for luminaire lifetime as it does not account for other potential failure modes in the luminaire such as driver failure, failure of connections, failure of optical systems, etc. Therefore, it is strongly suggested to not use TM21 predictions and calculations as the sole data point to specify luminaire lifetime.

Note:
TM21 refers to Tc some time as the solder temperature of the LED measured in the insitu-test. This Tc is not equal to the Tc point of the Philips Fortimo LED modules that are used for thermal design-in. However, there is a clear thermal correlation between Ts and Tc designed for within any Fortimo LED Module. The exact temperature difference (dT) depends on fixture design and application conditions.

Lumen maintenance for B10 and B50

Below example graph is showing the lumen maintenance (% of initial lumen over time) for B50 (50% of the population) and B10 (90% of the population).

Please look up the actual lumen maintenance graph in the associated datasheet of the Fortimo LED module you are using.

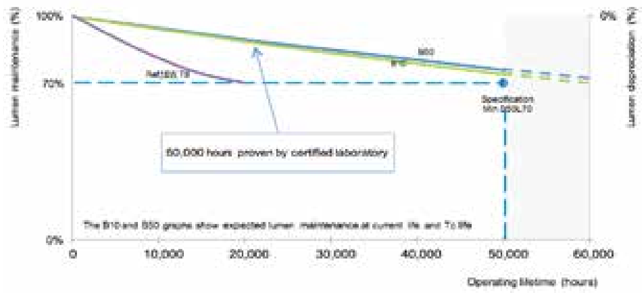


Figure 42. Lumen maintenance as a function of operating hours for B10 and B50.

Lumen maintenance for different Tc temperatures

Lumen maintenance is also affected by temperature. Lowering the Tc will increase the lumen maintenance time. The example graph below (Fig. 43) is showing the lumen maintenance (% of initial lumen over time) for B50 (50% of the population) at I life and three different Tc temperatures (Tc nominal, life and maximum).

Please look up the actual lumen maintenance graph in the associated datasheet of the Fortimo LED module you are using.

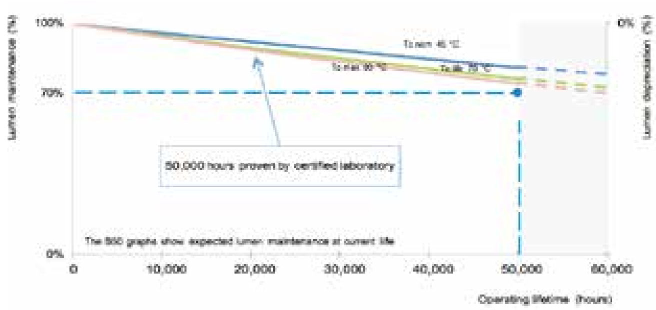


Figure 43. Lumen maintenance as a function of operating hours at different Tc values.

Note:
These graphs are lifetime predictions based on LM80 data; no warranty outside specified lifetime specifications.

Tips for assembly and installation

Warning

Do not service the system when the mains voltage is connected.
This includes connecting or disconnecting the cable.

Inserting and removing the cables

Conductor insertion and release

All wires must be pushed firmly into the contact wire opening. The wire can be released by pushing the release button.

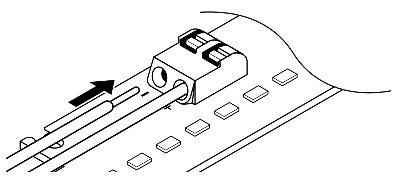


Figure 44. Inserting solid conductor via push-in termination.

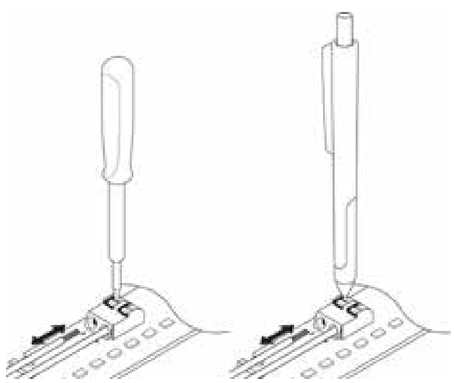


Figure 45. Insert/remove the stranded conductor by lightly pushing on push button, e.g., using a tool or a ball point pen.

Wire insulation

The wires must be fully inserted such that the wire insulation is inserted into and surrounded by the end of the housing (no bare wire should be visible).

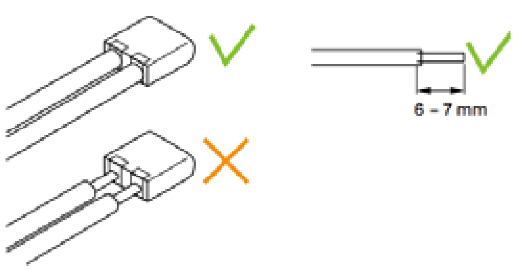


Figure 46. Wire insertion and strip length.

Wire termination depth

The required wire termination depth on the LED module connector is achieved when the wire, with stripped insulation (by hand or machine) to the indicated length stated in the LED module datasheet, ensures a solid connection. For the driver connector the required wire termination depth is stated in the driver datasheet. Check both LED module and driver datasheets for information at www.philips.com/oemna.

Strain relief

It is important to consider the addition of a strain relief to the wiring when the length of the wiring from the connector of the LED linear module is more than 15 cm. The strain relief is meant to prevent high force from being exerted on the wire/connector interface, prevent the connector housing from lifting off the contacts and prevent undue strain on the connector to module solder connection. A strain relief should also be considered when wiring from LED module to LED module if the length of wiring warrants it.

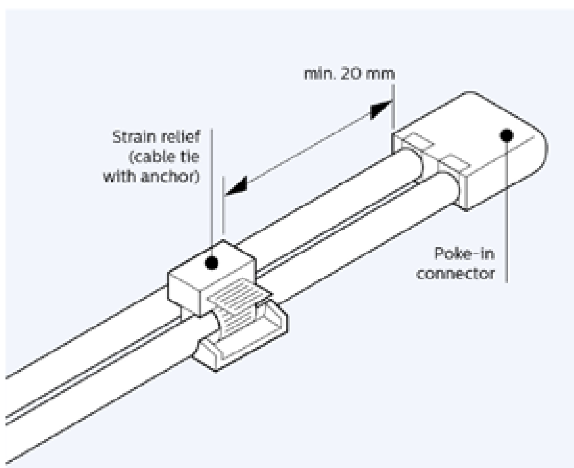


Figure 47. Wire insertion and strip length.

Warning

The electrical connectors are not repairable.

- DO NOT use damaged or defective contacts or housings.
- Do not apply mains power directly to a LED linear module!
- Do not touch, attach or detach LED modules.

Binning

In order to provide an economical high quality LED module product, Philips has established a method for correct mixing of the LED bins within each LED module. For selected LED linear modules there are not one, but two bins, based on forward voltage (Vf) only. Philips Fortimo LED linear does not require bins on flux nor color, which is convenient for stock keeping and assembly. Please check the datasheet of the LED module you use if one or two bins apply.

Why address the issue of LED binning

It is important to understand binning because it is very essential in LED system design. As in other semiconductor manufacturing processes, in the production of LEDs the number of parameters of the epitaxy process is very large and the process window is small (for example, the temperature must be controlled to within 0.5 °C across the wafer at temperatures of ~800 °C). The fact that it is difficult to achieve 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, groups of components like LEDs with similar specifications) is mandatory. Binning involves characterizing the LEDs on the basis of measurement and subsequently categorizing them into several specific bins. To keep the cost per LED down, LED manufacturers need to 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, on the one hand, and the application requirements on the other. The advantage of binning is that there will only be a limited need for LED module pairing by the OEM. In the near future Philips might omit the offering of bins, having only one bin per module type.

Note:
For light quality reasons do not mix different bins in one LED linear system (system being modules on one driver). Luminaires from different bins, but having the same bin within one system (e.g., luminaire), will perform similar on color and lumen. Meaning luminaire X with bin “A” will appear equal to luminaire Y with bin "C."

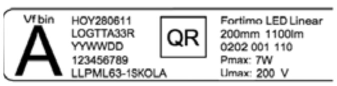


Figure 48. Label on LED linear module indicating bin A.

How to recognize the bin of my LED linear module

Fortimo LED linear modules are labeled and packaged in maximum two voltage bins (Vf). These bins are clearly indicated with letters. For example, "A" and "C" or "E" and "F." In order to ensure optimum flux and color uniformity, we strongly advise not to mix two different bins in the same luminaire (system).

The Vf bin is clearly indicated on the label. All LED modules packaged in one box (MOQ) will be from the same bin.

Introduction to electrostatic discharge (ESD)

It is generally recognized that electrostatic discharge (ESD) can damage electronic components, like LED chips, resulting in early failures. Professional users of electronic components are used to implement extensive and disciplined measures to avoid ESD damage in their finished end products. Now, with the introduction of LED electronic components for lighting, a new breed of users, such as OEMs and installers, are exposed to handling and manufacturing with LED electronic components.

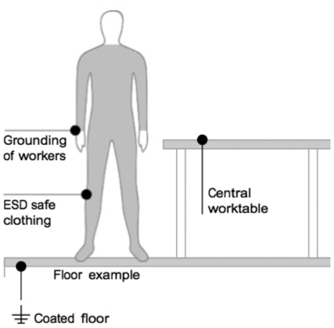


Figure 49. ESD measures, which could contain wrist bands, ESD-safe shoes and floor, ESD friendly materials and ESD-control plan general awareness.

ESD requirement links to product specification

Philips designed their Fortimo LED linear products rather robust against ESD. Specifications of the LED linear module's maximum contact discharge level and air discharge level, according to IEC 61000-4-2 (HBM 150 pF + 330 Ω), are stated in the associated datasheets for the LED modules you use.

ESD in your production environment

The purpose of an effective ESD-control strategy is the reduction of assembly line failures, final inspection failures and field failures. Depending on the immunity level of the LED module (product specification), a minimum set of measures has to be taken when handling LED modules. ESD measures are required in a production environment where handling can exceed the ESD immunity level (product specification). Furthermore, ESD vulnerable products should be packed and shipped in ESD safe packaging.

Note:
Air humidity has an important influence on electrostatic charge build-up.

How to meet the ESD requirement

Advice is to make use of ESD consultancy to determine how the ESD requirement can be met. One should think of an ESD control plan and ESD adequate equipment. Independent ESD consultancy companies can advise and supply adequate tools and protection guidance. For example, Philips Innovation Services can provide that consultancy. More information can be found in the section titled "Contact details."

Servicing and installing luminaires

It is highly recommended that installers are informed that they should not touch the LED components and should use earthed arm-straps to avoid ESD damage during installation and maintenance.

Quality, compliance and approval

Chemical compatibility

In the current market medium power LEDs exist, containing a silver-finished (Ag) lead frame. The lead frame finish is sensitive to pollution and/or corrosion when exposed to oxygen and certain Volatile Organic Components [VOCs]. Examples of VOCs are substances containing sulfur or chlorine. In that case parts of the lead frame may blacken, which will impair the lumen output or the color point of the LED light. Materials that are known to have a higher risk to be a source of sulfur and chlorine are, for example, natural rubbers used for cables, cable entries or sealing, or corrugated carton. Also be careful using adhesives, cleaning agents, coatings and applications in aggressive (corrosive) environments.

We recommend ensuring that the direct environment of these LEDs in the luminaire does not contain materials that can be a source of sulfur or chlorine, for optimal reliability of the LED, LED module and/or LED luminaire. Furthermore, make sure that the products with these LEDs are not stored or used in vicinity of sources of sulfur or chlorine and the production environment is also free of these materials. Also avoid cleaning of the LED products with these types of LEDs with abrasive substances, brushes or organic solvents like acetone and TCE.

Applications of the product in industry and heavy traffic environment should be avoided in case of risk of ingress of sulfur and chlorine from the environment.

Chemical Name	Normally Used As
Acetic acid	Acid
Hydrochloric acid	Acid
Nitric acid	Acid
Sulfuric acid	Acid
Ammonia	Alkali
Potassium hydroxide	Alkali
Sodium hydroxide	Alkali
Acetone	Solvent
Benzene	Solvent
Dichloromethane	Solvent
Gasoline	Solvent
MEK (Methyl Ethly Ketone)	Solvent
MIBK (Methyl Isobutyl Ketone)	Solvent
Mineral spirits (turpentine)	Solvent

Chemical Name	Normally Used As
Tetracholorometane	Solvent
Toluene	Solvent
Xylene	Solvent
Castor oil	Oil
Lard	Oil
Linseed oil	Oil
Petroleum	Oil
Silicone oil	Oil
Halogenated hydrocarbons	
(containing F,Cl,Br elements)	Misc
Rosin flux	Solder flux
Acrylic tape	Adhesive
Cyanoacrylate	Adhesive

Table 13. Chemical compatibility.

The Philips LED linear family makes use of LEDs with above explained type of lead frame. Therefore, above recommendations apply for the Fortimo LED linear modules. Philips Fortimo LED linear systems comply with the standards shown in below paragraphs.

A list of chemicals, often found in electronics and construction materials for luminaires that should be avoided, is provided in Table 13. Note that Philips does not warrant that this list is exhaustive since it is impossible to determine all chemicals that may affect LED performance. These chemicals may not be directly used in the final products but some of them may be used in intermediate manufacturing steps (e.g., cleaning agents). Consequently, trace amounts of these chemicals may remain on (sub) components, such as heat sinks. It is recommended to take precautions when designing your application.

In case of questions on compatibility of materials or applications of the product please contact your local Philips sales representative for application support.

Compliance and approval marks

The Fortimo LED linear family is UL/CSA approved. The relevant standards are summarized at the end of this chapter. To ensure luminaire approval, the conditions of acceptance need to be fulfilled. Details can be requested from your local sales representative. All luminaire manufacturers are advised to conform to the international standards of luminaire design (UL1598).

Ingress protection – IP rating, humidity and condensation Photobiological safety

The Fortimo LED Linear systems are build-in systems and therefore have no IP classification. They are not designed for operation in the open air. The OEM is responsible for proper IP classification and approbation of the luminaire. The Fortimo LED linear modules have been developed and released for use in damp locations and not for locations where condensation is present. If there is a possibility that condensation could come into contact with the modules, the system/luminaire builder must take precautions to prevent this.

The lamp standard, IEC 62471 "Photobiological safety of lamps and lamp systems," gives guidance on evaluating the photobiological safety of lamps and lamp systems including luminaires. It specifically defines 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, in the wavelength range from 200 nm to 3000 nm. Measurement results for LED products are given below. Based on these measurements, conclusion is no safety measures are required.

Item	Result: Risk Group
Actinic UV	Exempt
Near-UV	Exempt
Retinal Blue Light	Exempt
Retinal Blue SmallScr	Exempt
Retinal thermal	Exempt
Infrared Eye	Exempt

Table 14. Ingress protection – IP rating, humidity and condensation photobiological safety.

Blue light hazard

From the nature of most LEDs applying blue light, emphasis has been put on the hazard in terms of Photo Biological Safety (PBS). Evaluation by the European lighting industry (ELC, Celma) has concluded LED light sources are safe for customers when used as intended. Nevertheless, luminaire makers have to comply with luminaire standards including PBS. To avoid extensive retesting, the market prefers to build on the test conclusions of the LED (module) suppliers. The testing conclusion then will be expressed in Risk Groups (RG), where RG0 and RG1 do not require marking and/or specific action for the OEM (as compared to RG2 and 3). The certificates with the verdict of the LED products can be found in the download section of www.philips.com/ledmodulesna.

Some facts on blue light.

- All light – visible, IR, UV – causes fading.
- It has long been known that blue light causes fading in yellow pigments.
- LEDs do not produce more blue light than other sources by its nature.
- Blue light content is relative to color temperature, not to light source.

"Often, investigations into the effect of short-wavelength radiation—be it on humans or artwork—suggest that LEDs are dangerous because they emit more blue light than other sources like incandescent bulbs or CFLs. While it is true that most LED products that emit white light include a blue LED pump, the proportion of blue light in the spectrum is not significantly higher for LEDs than it is for any other light source at the same correlated color temperature (CCT)." (Department of Energy).

For more details follow the link for the U.S. Department of Energy: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/opticalsafety_fact-sheet.pdf.

System disposal

We recommend that the Fortimo LED modules and its components are disposed of in an appropriate way at the end of their (economic) lifetime. The modules are in effect normal pieces of electronic equipment containing components that are currently not considered to be harmful to the environment. We, therefore, recommend that these parts are disposed of as normal electronic waste, in accordance with local regulations.

Relevant standards

Safety

UL8750/ CSA C22.2LED modules for general lighting

- safety specifications

IEC 62471 Photobiological safety of lamps and lamp systems

Philips Advance Xitanium driver

UL8750/SSL 7 Lamp control gear

Electromagnetic compatibility

(Tested with LED linear modules, cables and Philips Xitanium driver).

FCC47 subpart 15 Class A Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment.

FCC47 subpart 15 Class A Equipment for general lighting purposes – EMC immunity requirements.

ANSI C82.77 Limits for harmonic current emissions (equipment input current <16 A per phase).

Environmental

The product is compliant with European Directive 2002/95/EC of January 2003 on Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS).

Contact details and suggested suppliers

Philips Fortimo LED linear systems

Product information www.philips.com/ledmodulesna

Or contact your local Philips sales representative.

Philips PInS ESD support

The Philips corporate EMC competence center is a leading provider of approbation and consultancy services.

The following are suggestions of products that can be used with the Philips Fortimo LED linear system. Reference to these products does not constitute their endorsement by Philips. Philips makes no warranties regarding these products and assumes no legal liability or responsibility for loss or damage resulting from the use of the information herein.

www.innovationservices.philips.com/US

Phone: +31 (0) 40 27 46214

+1 9788090483 (east coast)

+1 4154977939 (west coast)

ESD-related material and tool suppliers

Amcatron Technology Co Ltd	www.amcatron.com
Botron Company Inc.	www.botron.com
Desco	www.desco.com
Static Solutions Inc	www.staticsolutions.com

Table 15. ESD-related material and tool suppliers.

Appendix

Appendix A: Fluorecent tube reference table

840	W	mm	ft	lm	lm/ft	lm/W	Tcold
TL5 HE	14	549	2.0	1350	691	96	@35 °C
TL5 HE	21	849	3.0	2100	695	100	@35 °C
TL5 HE	28	1149	4.1	2900	709	104	@35 °C
TL5 HE	35	1449	5.2	3650	708	104	@35 °C
TL5 HO	24	549	2.0	1950	998	89	@35 °C
TL5 HO	39	849	3.0	3500	1158	92	@35 °C
TL5 HO	54	1149	4.1	5000	1223	93	@35 °C
TL5 HO	49	1449	5.2	4900	950	99	@35 °C
TL5 HO	80	1449	5.2	7000	1357	88	@35 °C
TL8	14	375	1.3	860	644	61	@25 °C
TL8	15	437	1.6	1000	643	67	@25 °C
TL8	18	590	2.1	1350	643	75	@25 °C
TL8	30	895	3.2	2400	754	80	@25 °C
TL8	23	970	3.5	2050	594	89	@25 °C
TL8	36	970	3.5	3100	898	86	@25 °C
TL8	38	1047	3.7	3350	899	88	@25 °C
TL8	36	1199	4.3	3350	785	93	@25 °C
TL8	58	1500	5.3	5200	974	90	@25 °C
TL8	70	1764	6.3	6200	988	89	@25 °C
PL-L	18	220	0.8	1200	1533	75	@25 °C
PL-L	24	315	1.1	1800	1606	82	@25 °C
PL-L	36	410	1.5	2900	1988	90	@25 °C
PL-L	40	535	1.9	3500	1838	87	@25 °C
PL-L	55	535	1.9	4800	2521	87	@25 °C
PL-L	80	565	2.0	6000	2984	75	@25 °C

Table 16. Fluorecent tube reference table.

Data gathered from Philips datasheets, available on several websites.

Appendix B: Example wiring schematic

Example: replace 2x 58 W TL-D (or 2x 49 W T5-HO)

Typical specs

- Batten, 5 ft long luminaire
- 5200 lm per lamp, 1040 lm/ft and 90 lm/W
- 10 ft summarized total tube length, 10,400 lm from lamps

Looking into the conversion table, we suggest the following:

- Item 1a, at nominal drive current LED strip 1100 lm/ft

The LED Linear System Overview is a matrix of LED drivers and linear LED modules released as a system. It shows how many Fortimo LED modules can be used in combination with a specific Xitanium LED driver. This document gets frequently updated and can be downloaded at www.philips.com/oemna.

- For LV2, let's choose building block Strip 1100 lm/ft LV. You require 2x 1 ft and 4x 2 ft of these LED strip modules.

For controllability it is possible to select Dali, 0-10V or non-dimmable.

Feel free to explore other combinations and settings as well.

LV Scenario	Strip 2x 1 ft 1100 lm & 4x 2 ft 2200 lm LV2	Spec Fits Driver Window? 75 W
Idrive = Inom x # boards	drive = 0.200 A x 2 + 0.400 A x 4 = 2 A. Rset2 = 27,000 Ω	Iout = 0.7..2 A = ok
Vdrive = Vf	Vdrive = 34 V	Vout = 27..54 V = ok
Power = Idrive x Vdrive	Power = 68 W (@11,000 lm & 162 lm/W)	Pout = 21..75 W = ok

Table 17. Combination of strip 1ft 1100 lm LV with strip 2 ft 2200 lm LV.

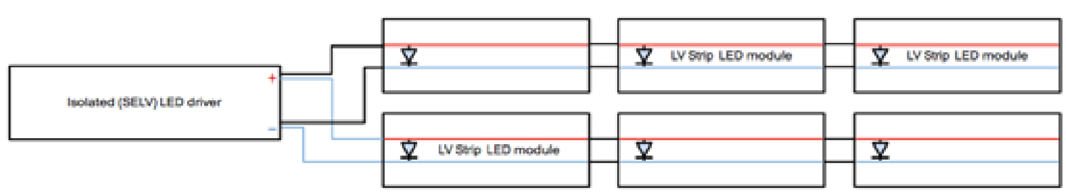


Figure 50. Chain of LED modules.

Disclaimer

The information in this guide is accurate at the time of writing. This guide is provided "as is" without expressed or implied warranty of any kind. Neither Philips nor its agents assume any liability for inaccuracies in this guide or losses incurred by use or misuse of the information in this guide.

Philips will not be liable for any indirect, special, incidental or consequential damages (including damages for loss of business, loss of profits or the like), whether based on breach of contract, tort (including negligence), product liability or otherwise, even if Philips or its representatives have been advised of the possibility of such damages.

PLt-1590DG 11/15 philips.com

Philips Lighting
North America Corporation
10275 W. Higgins Road
Rosemont IL 60018
Tel: 800-322-2086
Fax: 888-423-1882
Customer/Technical Service:
800-372-3331
OEM Support: 866-915-5886

Imported by: Philips Lighting,
A division of Philips Electronics Ltd.
281 Hillmount Rd,
Markham, ON, Canada L6C 2S3
Tel. 800-668-9008