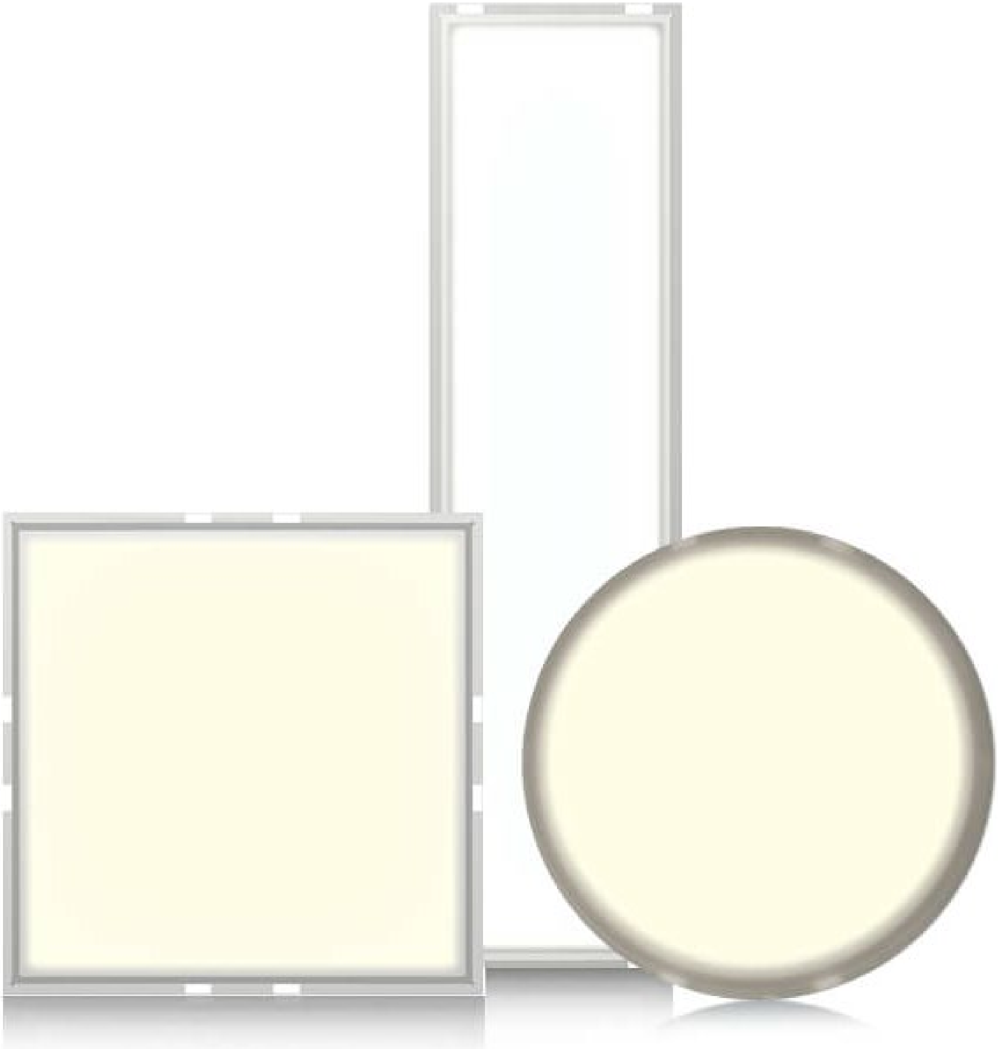
Design-in Guide

OLED Light Technology:
Brite 3 Family



OLEDWorks

Contents

Introduction to this guide

OLED technology offers unique designs in lighting applications.

When it comes to lighting, OLED inspires on a whole different level. The quality of the light itself in combination with its unique design characteristics, OLED lighting can be used to realize innovative applications and designs.

The third generation of the Brite family brings OLED further into functional lighting applications. With the luminous flux of up to 300 lumens, the Brite products are the brightest white OLED panel commercially available worldwide.

The rigid OLED panels are available in three shapes, rectangle, round, and square, and two color temperatures, 3000K and 4000K, making it easy to bring lighting into spaces and products that require high-function and beautiful illumination.

OLED is a human-centric light source.

Lighting affects our well-being in many ways, from physiological impact to emotional response. OLED lighting delivers a positive experience for our health in multiple ways.

OLED light contains longer wavelengths of blue which are safer for our eyes than the high blue peaks found in LED lighting. It delivers the same amount of light as LED, in superior quality, with significantly less hazardous blue light.

Validated through the IEC standard for physiological risk of blue and infrared light – our OLEDs have no risk for skin and eyes and are rated as exempt for all photobiological risks.

OLED light is a naturally diffuse light source.

OLED provides soft, yet bright full spectrum illumination resulting in artificial light that resembles daylight. It emits light from the entire surface area, rather than from one or multiple points. This presents a soft brightness and glare-free experience making it an ideal solution for comforting light able to be placed close to the user. Studies have shown that OLED lighting, in comparison to LED standards, also resulted in lower eye fatigue.

Disclaimer

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

OLEDWorks 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 OLEDWorks or its representatives have been advised of the possibility of such damages.

This Guide

This design-in guide provides the necessary guidelines for configuring the OLED Brite 3 products into a system to meet customer needs. The OLED Panel Brite 3 family is designed to enable integration into final products including, but not limited to, appliances, furniture, machine vision and OLED based luminaires in functional and architectural indoor lighting.

The following sections cover

1. Safety and warnings
2. OLED structure and interfaces
3. Mechanical integration guidelines
4. Optical integration guidelines
5. Electrical integration guidelines
6. Thermal integration guidelines

Many aspects in these six sections are interrelated. We advise reading through all sections before beginning a system design in order to understand how various aspects are interrelated, and to get the best out of the Brite 3 family of products.

SAFETY AND WARNINGS

All products of the OLEDWorks Brite 3 family meet the requirements of IEC 62868 and UL 8752 and are intended for integration into luminaires, et al. Details are provided in the relevant product datasheets. OLED panels are class III electrical appliances (in accordance with IEC 61140, IEC 60598-1) with accessible conductive features. These features require adequate insulation, provided, for example, by SELV/UL class 2 power supplies and the luminaire or system housing.

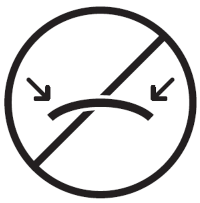
The final product must meet required certification. For example, a luminaire design must follow standards appropriate for the intended use of the luminaire, e.g. UL 1598, UL 153, UL 2108 and/or IEC/EN 60598.

Luminaire design should account for an increase in OLED voltage over life. Data is provided in the relevant technical specifications. The safety standard requirements must also be fulfilled at these increased voltages.

OLED panels are made predominantly of glass. They must be integrated into the luminaire so that all parts of the panel are reliably secured to the final product and cannot become loose. The OLED panel must be installed so that glass splinters cannot cause harm to the user in the event of breakage. Use gloves always when handling the OLEDWorks Brite 3 products in order to avoid potentially sharp edges and to limit fingerprints on surface.

Defective OLED panels or panels with visible damage must not be used. Damaged OLED panels should be disconnected from the power supply and must be either disposed of or returned to the manufacturer. OLED panels are not user serviceable.

Do NOT…
… bend the OLED
… twist the OLED / integrate the OLED so that torsion occurs at either room or other temperatures
… apply point loads to either the front or back of the device
… write on the device with a pen or similar implement
… expose the device to high temperatures
… use defective products
… use products that have been dropped, even if there is no visible alteration
… use products that something has been dropped upon, even if there is no visible alteration



Do not bend

Do not twist

Do not press

STANDARD COMPLIANCE AND SUSTAINABILITY

OLEDWorks products are environmentally friendly and provide efficient illumination without the use of hazardous materials.

This product is RoHS (EU Directive 2011/65/EU) and IEC 62868 (OLED safety) and IEC 62922 (OLED performance) compliant.

These products are compliant with UL8752 (OLED safety). These products are UL recognized in file E353273.

Within the UL report certain 'Conditions of Acceptability' are mentioned as follows. When installed in the end product, the following shall be taken into consideration:

1. These products have been evaluated for connection to an isolated DC Class 2 constant current power source.
   Caution: Do not operate the OLED panel with other than UL-Class 2 power supplies.
2. This product has been evaluated for use in dry or damp locations.
3. The OLED panel temperature shall not exceed 80 °C.
4. Input leads to the OLEDs are intended for factory installation only. Strain relief to be considered in the end-use application if leads are subjected to mechanical stress.
5. Input leads to the OLED panels shall be sufficiently separated from higher voltage conductors in the end-product in compliance with end-product requirements.

STRUCTURE OF AN OLED AND BRITE 3 INTERFACES

The following gives a brief description of the Brite 3 panel.

OLED, a diode, is a solid-state lighting technology. OLED consists of various layers of organic semiconductor materials between two electrodes. Applying voltage to both electrodes activates semiconductor physics that produces light. Light is generated evenly across the entire panel surface, in contrast to point sources of tradition (inorganic) LEDs.

Considerations for optimum performance when integrated in end products include:

- Electrical energy not converted to light will result in heat generation. Since temperature affects the OLED operation (see section ??), management of heat is integral to the OLED panel design and should be maintained during integration.
- Exposing the organic materials to air and water will result in failure. Maintaining the protections incorporated in the panel configuration is vital.

Brite 3 Level 1 configuration is shown in Figure 1 and described below:

1. Functional organic layer: semiconductor carbon-based materials formulated for white light emission
2. Glass substrate: Primary structural element, transparent to visible wavelengths, protects OLED from exposure to environment
3. Optical foil: Scattering layer facilitates light extraction from glass and protects OLED from UV
4. Anode: Transparent Electrode
5. Cathode: Metallic Electrode also acts as reflector
6. Encapsulation: Thin-film encapsulation provides robust protection from environment
7. Metal Foil: Heat spreader to ensure uniform temperature across panel
8. PCB: A frame around panel perimeter, provides electrical interface to anode and cathode
9. Light Emission: Uniform in color, across entire surface, and all viewing angles

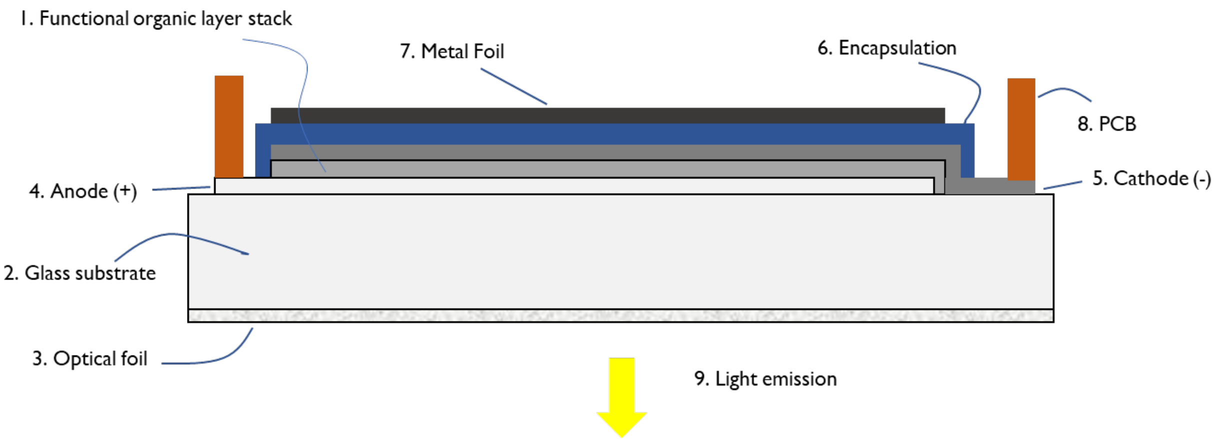


Figure 1: Schematic of Brite 3 Panel, Level 1

Brite 3 Level 2 provides additional thermal and structural support, if needed. The addition of a thermal pad and metal black plate improves heat dissipation through radiation. Notches in the back plate are provided to enable the plate to be mounted with screws.
Brite 3 Level 2 configuration is shown in Figure 2 and described below, staring with level 1 configuration:

10. Heat pad: thermally conductive adhesive element
11. Metal back plate: provides added rigidity and radiative component to heat dissipation
12. Cable: wire attachment to PCB to connect with panel anode and cathode

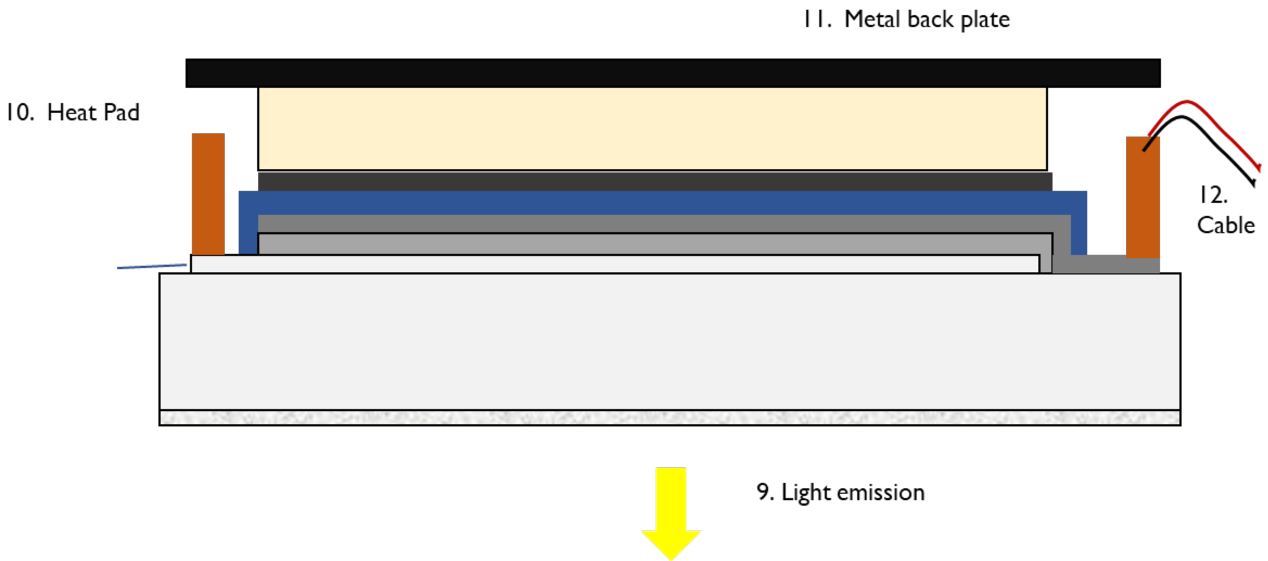


Figure 2: Schematic of Brite 3 Panel, Level 2

Note that integration Level 1.5, not shown, is level 1 with the addition of the cable harness only.

Managing temperature across the panel is important for overall OLED operation, consistency and lifetime. Integration level 1 (and 1.5) and level 2 have slightly different electrical and optical performance due to differences in heat dissipation; notably, level 2 with the metal back-plate potentially has reduced temperature. For most installations, level 1 provides sufficient thermal management.

Three interfaces need to be considered:

- <u>Thermal/mechanical interface:</u>
  the back of the OLED acts as a thermal and mechanical interface. Details are shown in Figures 1 and 2.
- <u>Optical interface:</u>
  the OLED glass front acts as an emission 'window' and performs the function of the substrate on which the OLED is built. It provides a certain (limited) stability to the module but must not be used as a mechanical interface. An optical foil is attached to the glass front of the Brite 3 panel to improve the extraction of light and the color over angle stability.

- <u>Electrical interface:</u>
  the electrical interface for integration level 1 comprises a PCB frame attached to the substrate. The electrical interface for integration levels 1.5 and 2 comprises a cable with a Molex Picoblade plug.

MECHANICAL INTEGRATION

The Brite 3 product range incorporates the newest lighting technology to combine bright, homogeneous lighting with a super-thin and sleek product appearance. This enables the design of unique, innovative and functional luminaires. Several mechanical and handling aspects arise due to the special characteristics of the Brite 3 product family.

With an extreme thinness of 1.4 mm (level 1) to a maximum of 2.1 mm (level 2) the light panels demand careful handling. Brite 3 OLED panels are built on thin glass and encapsulated by thin-film encapsulation, making them sensitive to mechanical impact and ESD. In order to guarantee optimal operation, the panel may not be altered by any means (torsion, pressure, bending, electrical connections, etc.). Awareness of the potentially sharp glass edges and metal back-plate (applicable only to integration levels 2) is also advised.

Integration aspects

When designing a luminaire with a Brite 3 product, please ensure that the following aspects are considered.

General recommendations for Brite 3 product family

<u>Surface integrity: Do not puncture, cut, or otherwise alter or breach the panel integrity. This includes alteration initiated on either the back or the front side of the panel.</u>

<u>Point loads</u>: Prevent exerting point loads on the OLED light source of your luminaire. Point loads of 4N applied with a round shaped tip with a 0.25 mm radius can lead to local damage on the back. This can be caused e.g. by forces to both the light emitting front or the encapsulated back.

Solder joints can locally increase the thickness of the light source and may result in point loads when mounted or temporarily placed into flat, rigid constructions. Figure 3 on page 11 shows how particles or locally increased thicknesses may lead to point loads and/or deformation.

<u>Scratching</u>: Please avoid any type of scratching (e.g. with a pen), pressure or other temporary forces on the light source as this can also result in temporary, local point loads and may damage the product.

<u>Environmental conditions</u>: The Brite 3 product family is designed to operate optimally in indoor luminaire applications as defined in the product datasheet. Any use outside the recommended environmental conditions, including high humidity, high temperature, and/or contact with water or dew, can lead to the product's damage and malfunction. Suitable protection is therefore necessary to help guarantee the product's reliability.

<u>Mechanical fixation</u>: Brite 3 products are designed to be mechanically fixed into luminaire housing units. Due to the fragility of the components the mechanical interfaces need to be designed with care. Please consider the following recommendations:

- Avoid clamping or any other mounting methods that create local forces or cause bending that may damage the light source.
- Design the mounting structure so that it provides additional stability to the fragile light source. Do not design a mechanical fixture that holds the light source with a single touch point.
- The electrical wires are not meant to be used for mechanical fixation and must not be exposed to pulling forces of any kind as no strain relief is provided by the product.
- The use of glue (for all integration levels) or screws (applicable only to integration level 2) is recommended for mounting Brite 3 products to luminaire housing units.

Glue / Adhesives

Gluing is a recommended mounting option for all OLEDWorks Brite 3 products. However, any formation of local forces needs to be avoided.

The glue and thin-film encapsulation need to be chemically compatible. Common adhesives based on epoxy, solvent free urethane, acrylic and vinyl are generally suitable. Specific adhesives can be used according to requirements of flexibility, impact strength, and thermal conductivity. Chemical compatibility of the thin film encapsulation with different types of glues depends significantly on the composition and type of curing/hardening/post processing of the adhesive. This can be generalized but not limited to the following criteria:

- Adhesives should be solvent-free to ensure the compatibility with TFE organics
- If adhesives are processed at a higher temperature (e.g. to induce a chemical reaction or as hot melt) the processing temperature should be as low as possible and must not exceed 85 °C for max 115 min.
- Adhesives should be non-electrically conductive

Avoid any type of glue that shrinks or creates heat during curing or drying as this may result in damage to the light source.

Please ensure that almost the entire area of the metal foil is covered when applying glue to the back of the light source (avoid formation of bubbles or other contamination). This provides safe mechanical mounting and a homogeneous thermal interface (see section on thermal integration on page 20). Avoid gluing the PCB and local gluing as this may result in pull or push forces and point loads. Limit glue application to the area covered by the metal foil taking special care to avoid the glue getting under the metal foil or having contact with the encapsulation and glue below the foil.

When using glue on the front of Brite 3 products, the chemical and mechanical compatibility of the glue with the surface of the optical foil on the light source also need to be ensured. Please refer to Figure 1 which shows the location of the foil. It is attached, using transparent adhesive that is on the mounting side, to the OLED glass primarily for optical performance. It may not be able to withstand the mechanical forces exerted by a housing or other mounting component glued to its surface.

Screws

Screws are another recommended mounting option for integration level 2. In order to avoid bending or delamination of the housing frame while mounting the OLED panel they should not be over-tightened. Please check for deformation of the back-plate.

Only use fitting screw positions as shorter distances between screws (see datasheet) can stress the light source and may lead to damage. Do not use counter-sunk screws because this may also lead to lateral stress on the back-plate and thus damage the OLED.

Use only flat mounting parts; particles, bent and bendable surfaces will lead to point loads, torsion or bend the light source which can cause damage.

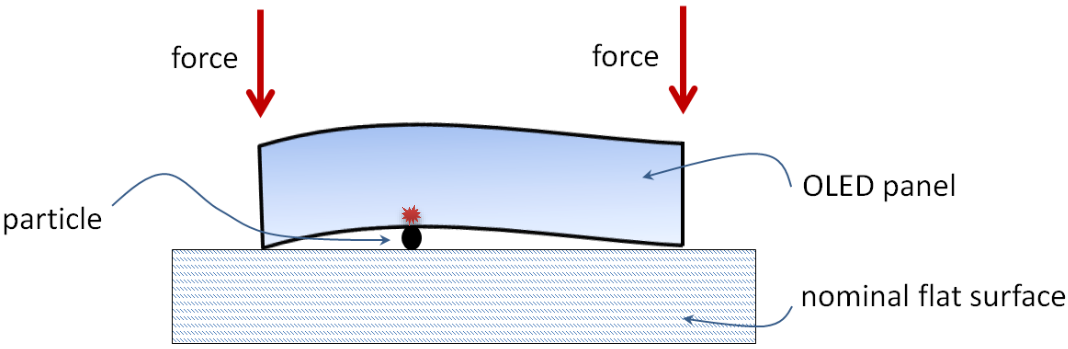


Figure 3 - example of unintended bending due to particles and force to the front

Depending on the mounting surface, insulation may be necessary in order to prevent electric short circuits near the solder joints or to any of the unused, exposed solder pads on the PCB. Care should also be taken to prevent shorting from the PCB to the metal foil.

Specific recommendations for integration levels 1 and 1.5

The Brite 3 panel in integration levels 1 and 1.5 is optimized to enable sleek, virtually seamless luminaire designs. However, special attention should be paid when designing mechanical fixation. This integration level is particularly sensitive to mechanical impacts such as:

- point loads resulting from forces from either side, including front edges caused by a housing unit or frame
- local stress to any component of the device
- any force on the soldering pads
- tension due to torsion or bending caused by the luminaire design

Please provide a gap between the top of the PCB and the mounting component of your luminaire (0.2 mm is recommended) to avoid any kind of torsion or bending of the light source. The OLED panel can be loosely nested in a fixture or frame without glue, taking care to provide gap around the edges.

The luminaire design needs to provide the light source with a good thermal interface (see section on thermal integration on page 27). This may or may not require thermal coupling to end-product housing.

Example solution

A solution involving the aspects mentioned above is given in the following:

The Brite 3 integration level 1 can be glued to a flat surface preferably with a heat pad to improve the heat dissipation. Standard double-sided adhesive can also be used although it may lead to reduced thermal performance.

Assembly: Particles or contamination caught in the glue applied to the metal foil of the OLED panel may cause point loads and damage and should be avoided. The glued area should be slightly smaller than the metal foil (see Figure 5). Localized contact should also be avoided. The PCB frame of the light source needs to be kept free of any fixation material.

Heat pads or double-sided adhesives with enough thickness should be used due to the difference in thickness between the PCB area and the active, light emitting area (refer to the product datasheet). 3M 8708-05 with a thickness of 0.5 mm is recommended. Alternatively, the luminaire's mounting surface should be designed to compensate for the difference in thickness, ensuring a required gap of 0.2 mm between PCB and mounting surface.

A practical example taking all mentioned aspects into consideration is incorporated into the design of integration level 2 (see Figure 2).

Specific recommendations for integration level 2

The Brite 3 products for integration level 2 come with a metal back-plate and cables for improved robustness and easier mechanical and electrical integration.

The following aspects need to be considered:

- prevent point loads from either side including front edges caused by a housing unit or frame
- avoid localized stress to any component
- avoid tugging forces on the cables
- avoid repeated movement of cables which could cause them to break near the soldering points

Integration level 2 can be mounted to a flat surface with four screws. The screw notches are in the corners (please refer to the technical drawings in the product datasheet). Special care must be taken in choosing the correct screws (no counter-sunk screws) and precise screw pitch to prevent mechanical stress to the housing.

Cleaning instructions

Please avoid scratching the front glass with any hard or sharp objects. Use isopropanol or ethanol to remove stains and fingerprints. OLEDs can be cleaned with any soft textile.

For everyday cleaning, the use of a compressed air de-duster is recommended. Should fingerprints or more persistent contamination have occurred, isopropyl alcohol should be applied to a lint-free cloth. Apply a little of the liquid to the cloth and gently wipe the surface of each OLED with a circular movement, beginning at the center and moving towards the edge. Never use water on the OLEDs as this may shorten the lifetime or reliability of the product.

OPTICAL INTEGRATION

In contrast to all other light sources, OLED technology provides diffuse and homogeneous light emission, naturally, without additional optical means nor the efficiency losses associated with diffusers or waveguides. The Brite 3 product family thus enables extremely thin luminaire designs with incomparably uniform light emission.

Luminaire designs or lighting applications using Brite 3 products may include the integration of other optical elements, be it for aesthetical reasons, safety or to intentionally alter the optical performance (e.g. color). These alterations can affect the performance of color, luminance, efficiency, and angular dependency of color and luminance.

This section discusses considerations when integrating additional optical elements. It is not intended to provide quantitative dependencies for a combination of optical elements.

Types of optical elements

Luminaire manufacturers are free to integrate additional optical elements in order to optimize performance with respect to the requirements of the specific application. Properties such as color point, color rendering, color over angle, and off-state appearance can be adjusted by applying additional optical elements.

Please note that the direct attachment of additional optical elements by optical gluing to the diffuser foil could significantly alter the scattering properties of the standard foil of the panels with a standard surface finish.

A small gap left between the panel and the optical element can limit these changes. However, the interfaces towards the gap may also generate losses due to the difference in refractive indices between the OLED, air gap and the optical element.

Combining different optical elements is possible but interactions (see below for different types of optical elements) must be considered in the individual design.

During assembly, inclusions (air bubbles, dust or other contamination must be avoided as they will remain constantly visible and may also alter the performance of the optical element. Please also refer to the precautions in the section on mechanical integration (see page 10).

Scattering elements

Panels with the standard surface finish come with a scattering element in the form of a diffuser foil attached to the glass surface of the OLED panel using an optically clear adhesive (OCA), see Figure 1. This version of the Brite 3 is optimized for high light output and minimal color change over angle.

Refractive elements

Refractive elements like optical plates with dedicated structures can be applied to partially alter the beam shape. Leaving a gap between the optical plate and OLED panel is recommended for this purpose.

Refractive elements can also be used together with scattering elements (taking the recommendations mentioned above into account).

Absorbing elements

Similarly, to colored transparent plates, foils or semitransparent printed layers, absorbing elements can be applied to the front of the OLED to tune the emission color, adjust the color-rendering index, or display graphics. These elements all have the intrinsic drawback of reducing the overall luminous efficacy of the system.

Electrical integration

This chapter introduces basic concepts on how to integrate OLEDWorks Brite 3 panels into a luminaire with respect to driver selection, electrical wiring and contacting recommendations.

Driver selection/ requirements:

1. Current control is recommended
   Current control offers the most stable way of powering OLED panels due to the OLED current-voltage characteristic and the relationship between luminous flux and current.

2. Output current ripple should be low
   The DC current should have a low ripple. High current ripples could lead to inhomogeneity within the OLED, as well as to reduced lifetime and reliability. Typically, switch mode power supplies require a current ripple running through the current sense feedback resistor to work properly. Small ripple values are acceptable. A safe measure would be to keep the peak-to-peak value of the ripple below 30% of the mean value.

3. Avoid transient overshoot
   When turning OLED and power supply on and off and due to other transient conditions, e.g. pulse width modulation (PWM) switching, voltage and current overshoots may occur. These overshoots should be avoided and kept as low as possible. A soft start is recommended.

4. Take varying OLED voltage into account
   The forward voltage of an OLED may vary due to forward current, ambient temperature and self-heating. Additionally, the forward voltage will increase during nominal operational lifetime. Forward voltage data are provided in the OLED panel datasheet. Also account for voltage contributions from system wiring if drive placed remotely.

5. End of Life (EOL) protection
   The driver output voltage increases over lifetime of the OLED in constant current mode. The higher voltage leads to higher power consumption at constant current and hence to higher temperatures. An optional voltage limiter for the protection and safety of the driver and OLED can be used.

OLEDs are a sold-state lighting technology and are compatible with typical control protocols such as DALI, TD, DMX. They are also compatible with 0-10V dimming and PWM dimming systems.

In addition to the guidelines above, please ensure that your application design maintains current, voltage and power within the specified range in order to help protect the OLEDs even in case of misuse of the luminaire, e.g. powering with wrong voltage settings or in fault conditions that exceed the limits given in the datasheet. Both may lead to safety risks or damage of the OLED.

Electrical wiring and contacting

OLEDs can only be operated at DC current and in a forward direction. Reverse polarity will damage the product.

Serial interconnection

Technically, OLEDs can be connected in series. In practice, certain safety standards and regulations need to be considered:

- Connecting multiple OLEDs in series requires a higher output voltage from the driver. If voltages become higher than the safety extra low voltage limits (SELV) additional precautions are necessary. For most applications the limit is 2 panels in series for a combined voltage of 48VDC.

Parallel interconnection

In case of connecting OLEDs in parallel, please note the following: This may result in asymmetrical current distribution to the OLEDs and lead to the variation in panel performance. This can be exacerbated by differences in voltages, panel to panel, due to wiring design. The safety aspects mentioned for general use and serial interconnection still apply.

Establishing electrical connections (soldering recommendations)

Wires should be soldered to the predefined plus and minus pole solder pads to establish an electrical connection (see technical data sheets).

We recommend soldering to establish an electrical contact. As high temperatures may damage the OLED panel, we recommend not exceeding the following parameters:

- maximum temperature of the soldering tip: 370 °C
- maximum soldering time in total: 5 seconds

Keeping the overall soldering time (duration of temperature impact) to a minimum can be achieved by using hot bar soldering equipment that simultaneously solders both contacts (recommended). If individual wires need to be soldered the temperature of the OLED contact area should be left to cool down before this is done.

Do not let solder bridge to metal foil. Do not touch metal foil with hot soldering iron.

Reminder: Insulation may be necessary in order to prevent electric short circuits near the solder joints or to any of the unused, exposed solder pads on the PCB.

Cables

The length and type of cable needs to be considered in the design process of an application. Electrical loss due to the resistivity of the cables affects driver performance.

- Wire resistivity leads to electrical loss and a voltage drop depending on wire lengths. When operating at a constant current the driver increases output voltage to reach the requested target driving current. Device performance is not instantly affected; however, the system will reach end of life more quickly as the upper voltage limit (i.e., 24V DC driver) of the driver output window is reached faster.

In both cases the maximum voltage drop due to the cables should not exceed 1(one) V.

Cables need to be selected in accordance with regulations and safety standards.

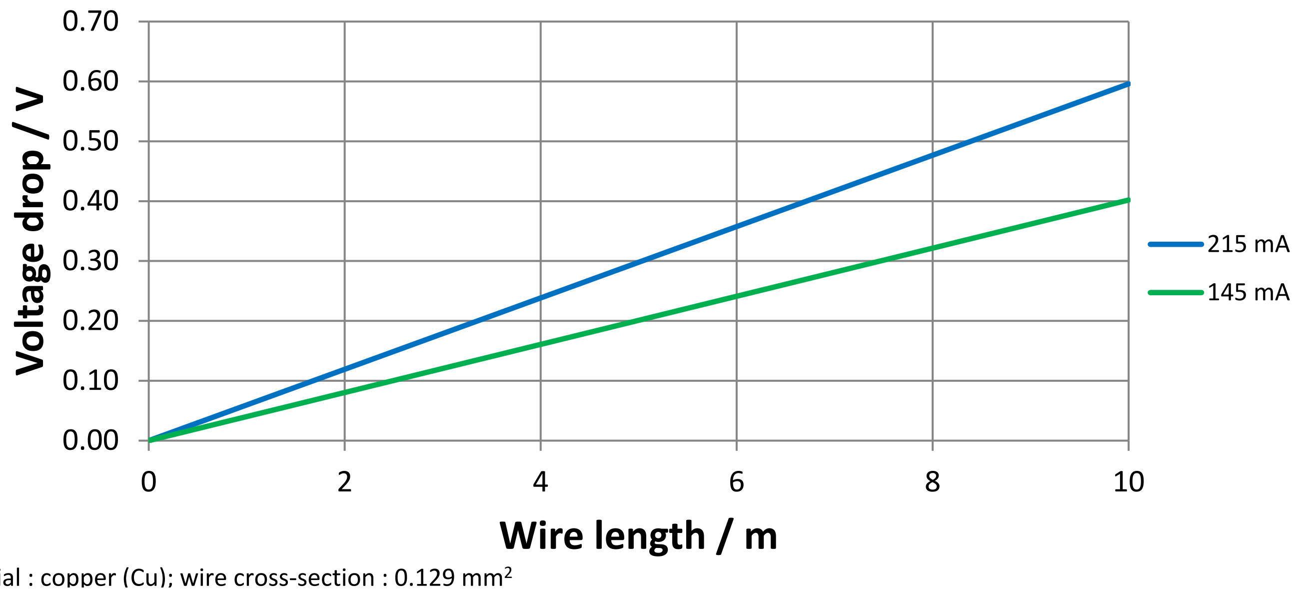


Figure 4 – theoretical estimation of drop voltage vs. wire length for a solid copper wire of 0.129 mm^2 cross-section and $I_{in\ rated}$ = 0.215 A

The resistance (and consequently the voltage drop for a given current) of a cable can be theoretically estimated taking the wire cross-section, the material (specific resistance) and its length into account. An example is given above for a copper wire with a 0.129 mm^2 cross section. Please note that translating AWG values into wire cross-sections is not as dependable if stranded wires are used.

Be aware that it is the overall length of the wires and not the distance between driver and OLED that is relevant.

Assembly

Electrostatic discharge (ESD)

Introduction to ESD

Electro Static Discharge (ESD) can damage electronic components such as LED chips or OLED panels, resulting in early failures. Avoiding ESD damage to finished end products requires extensive measures when implementing electronic components. This is also valid for the implementation of OLED electronic components.

ESD in production environment

Reduction of ESD is required in the production environment, and ESD-vulnerable products should be packaged and delivered in ESD-safe packaging. The purpose of an effective ESD control strategy is the reduction of line failures, final inspection failures and field failures.

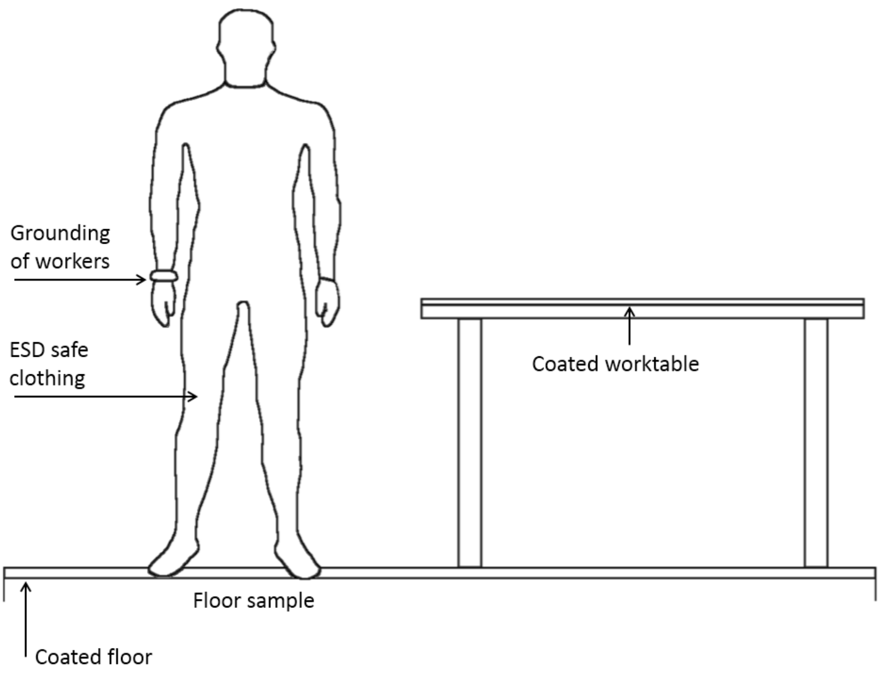


Figure 4 – Protection against ESD in manufacturing environments [source: Philips]

General recommendations in assembly

- Buildup of static friction between the product and surroundings should be minimized and all equipment (including floor, worktops etc.) should be electrically grounded.
- As shown in Figure 7, workers should be grounded and wear ESD-safe clothing

- Low levels of humidity also increase buildup of electrostatic and should be avoided. A level of 50% or more is recommended.
- Use of antistatic packaging for storage and transport is recommended.

For further information, please contact OLEDWorks (see contact details at the end of this guide).

THERMAL INTEGRATION

OLEDs are solid-state lighting components. Like other electronic components the behavior of an OLED depends on its thermal state. The ambient temperature conditions, the OLED driving parameters and the design of the end-product influence the OLED operating temperature.

Operating temperature has an impact on a several parameters including:

- driving voltage at a given current
- achievable lifetime (lumen maintenance)
- achievable reliability [1] (abrupt, catastrophic failures)

Local organic temperature differences in the OLED Panel may result in inhomogeneity. As the OLED itself also generates heat, depending on the driving current, the current directly impacts on the parameters given above.

Thermal requirements must be considered thoroughly in the design of the luminaire to achieve proper optical results and the targeted lifetime.

This section:

- provides information on the general requirements for reliable operation
- gives guidance on how to measure organic temperature
- lists typical aspects that may influence device temperature and performance
- describes the differences between integration level 1 and integration level 2

Integration aspects

General remarks

Description of the Brite 3

Regardless of the integration level, the Brite 3 comprises one major interface on the back which needs to be considered for thermal integration. At integration levels 1 and 1.5 the back is made of thin metal foil (silver-like appearance) while at integration level 2 the back is made of a metal (anodized aluminum) plate of 0.5 mm thickness.

The Brite 3 integration levels 1 and 1.5 comprise basic thermal functionality as they are designed to minimize OLED panel thickness for minimum element thickness and allow the highest degree of freedom in the design of luminaires. The metal foil spreads the heat. The primary mode of heat dissipation is convection cooling across the front of the OLED. Convection cooling depends on fixture design, installation orientation, ambient temperature and ambient airflow. Therefore, it is recommended that

[1] Reliability - the ability of the OLED panel to perform its required functions under stated conditions for a specified period.

additional heat dissipation be integrated in the luminaire or system design. Due to the large panel surface area, this can be readily achieved without heavy, thick heatsinks.

Integration level 2 feature a black metal back-plate for additional heat dissipation by radiation coupled with the metal foil by a heat pad for optimal thermal conductivity.

In the following the term ‘thermal interface’ relates to the metal foil (heat spreader) for integration level 1 and the metal back-plate for integration level 2.

Reliable operation

Products must be operated below a certain temperature level to achieve reliable operation throughout the targeted timeframe.

Apart from the likelihood of abrupt failures, (gradual) lumen maintenance is also temperature dependent. The Brite 3 was designed for L70B50[2] = 30,000 hours at an organic temperature of 35°C at 2.08mA/cm2. This temperature is reached when the product is used at the rated current in vertical position at room temperature. Any other temperature results in lower or higher L70B50. The actual organic temperature is affected by power dissipation (driving current), thermal dissipation (thermal design) and ambient temperature.

Reducing temperature can significantly extend the expected lumen maintenance (for more information please see Figures 9, page 30 & 31).

The driving conditions, ambient conditions and the thermal design contribute to the actual organic temperature of the panel, which determines lifetime. This can generally be controlled by:

- control of ambient temperature (of the luminaire, consequently also of the OLED)
- active cooling (within the luminaire)
- reduction of driving current (affects brightness)

Each of these approaches has a drawback:

- ambient temperature control options limited to customer requirements may interfere with the recommended OLED panel temperature.
- active cooling options may add to the thickness of the luminaire design, limiting freedom of design.
- current control affects the amount of light generated and the brightness of the product. While this may be undesirable for some applications it may be a desired for others.

A thorough assessment of customer needs and application requirements and choosing from a combination of the measures mentioned above best suited to the design is therefore recommended.

Thermal management can often be managed by simply:

1. Ensure the front face of the OLED panel is open to convection. Do not block behind insulators such as acrylic layers.

[2] L70B50 describes the point in time when 50 % of the remaining population yields at least 70% of the initial luminous flux.

2. Thermally connect the OLED to the fixture housing
3. Isolate the back of the panel from additional heat sources such as limiting direct contact to drivers or other active components.

Reduction of current may be the only way to reduce temperature for a certain aggressive environments and design.

How to measure organic temperature

The organic temperature is the temperature of the organic layers which determine the lifetime of the product. The temperature at the center of the device should be approximately the same as the temperature on the glass at the front. Therefore, organic temperature is indicated, by proxy, through direct measurement of the front of the panel.

When the term 'organic temperature' is mentioned in this document it always refers to the temperature at the center of the light emitting area on the front measured with a thermo-couple, for example 5TC-TT-KI-36-2M type K (nickel-chrome/nickel) directly attached to the surface (Figure 8, position B, left).

Note: To improve accuracy of measurement a small amount of thermal paste may be used. Be aware that the paste may leave stains on the product.

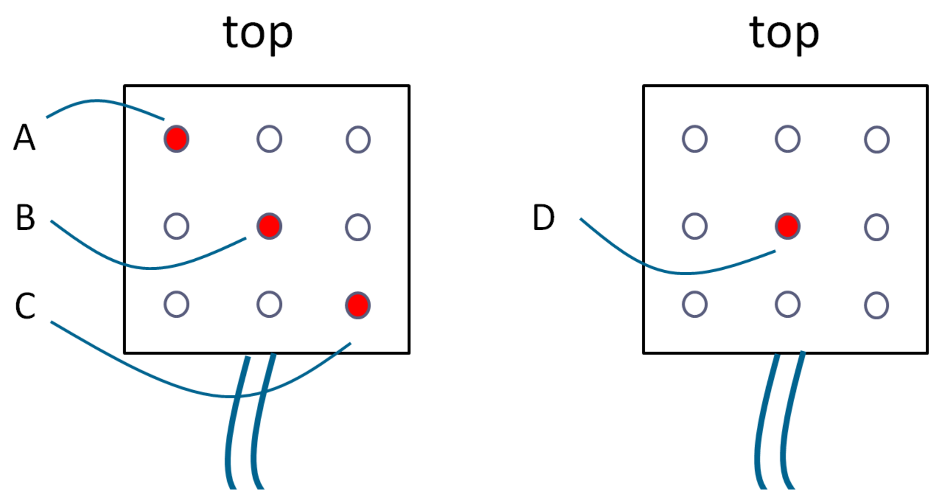


Figure 5 - measurement positions used throughout this guide (left: front view, right: back view)

Please note that mounting the OLED panels in a vertical position when measuring the organic temperature may lead to convective heat dissipation. This is especially true for integration level 1.

If a climate chamber is used to simulate certain ambient conditions be aware that integrated ventilation may alter the results due to forced convection.

A thermo-couple in the vicinity of the device but shielded from temperature created by the device itself should be used to make ambient temperature readings.

Impact factors

Current

The relationship between luminous flux and driving current is almost linear. Increase of driving current also increases temperature (increased power consumption)

Organic temperature

Organic temperature determines lumen maintenance and reliability. Elevated temperatures accelerate the aging of the device which primarily results in lower lumen output and voltage increase. Voltage increase at constant current driving also leads to increased power consumption and increased temperature.

Expected lifetime (lumen maintenance)

Figure 9 show the approximate expected lumen maintenance L70B50 for different points of operation for the different panel versions: luminous flux (as determined by current) and organic temperature. This gives an indication of how an increase in organic temperature at a given current affects lifetime and vice versa.

Current reduction has two effects: It directly increases the lifetime of the OLED due to reduced electrical stress and indirectly extends the lifetime by decreasing the organic temperature.

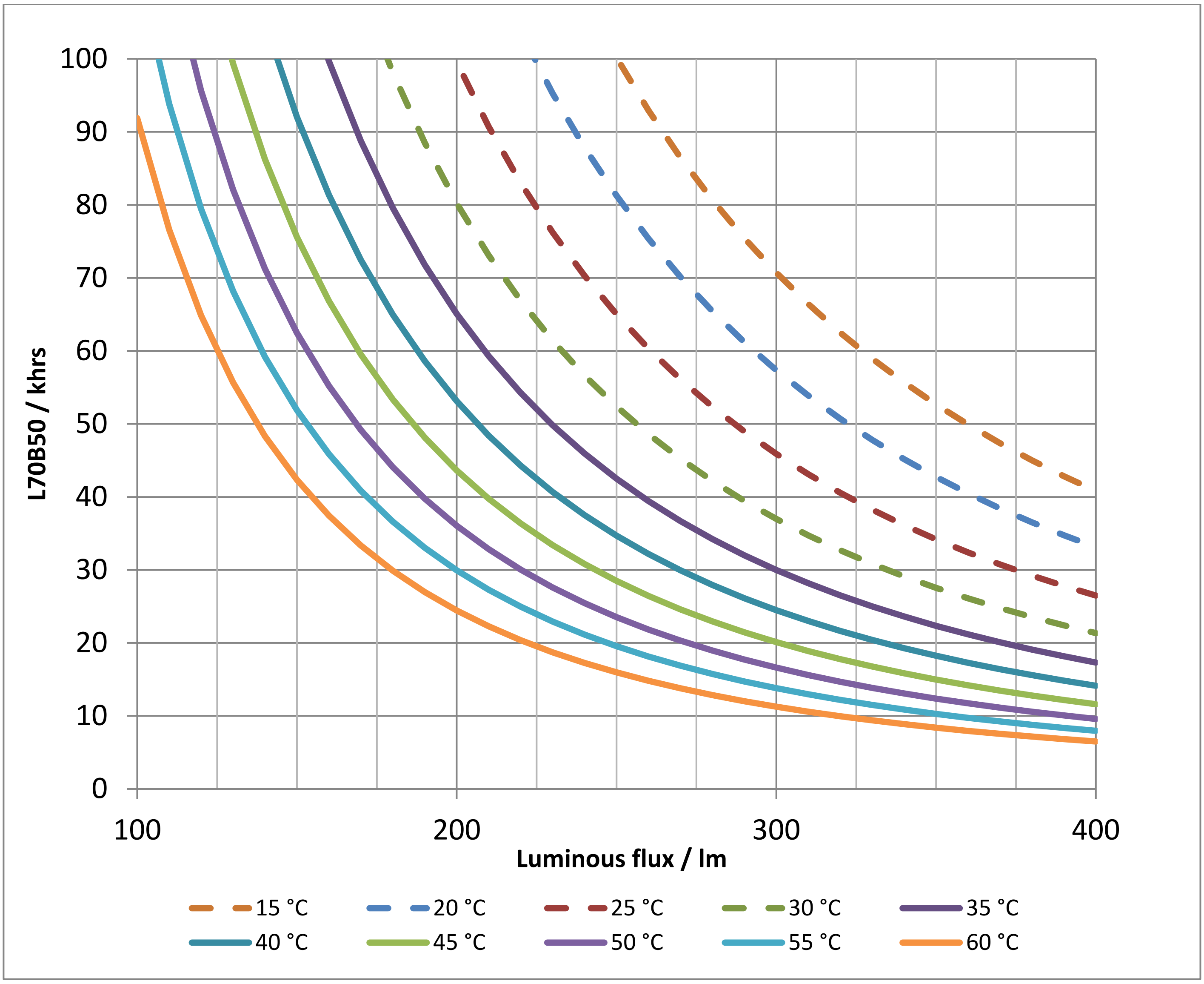


Figure 6.1: Brite 3 Square/Rectangle ww – L70B50 vs. luminous flux and organic temperature

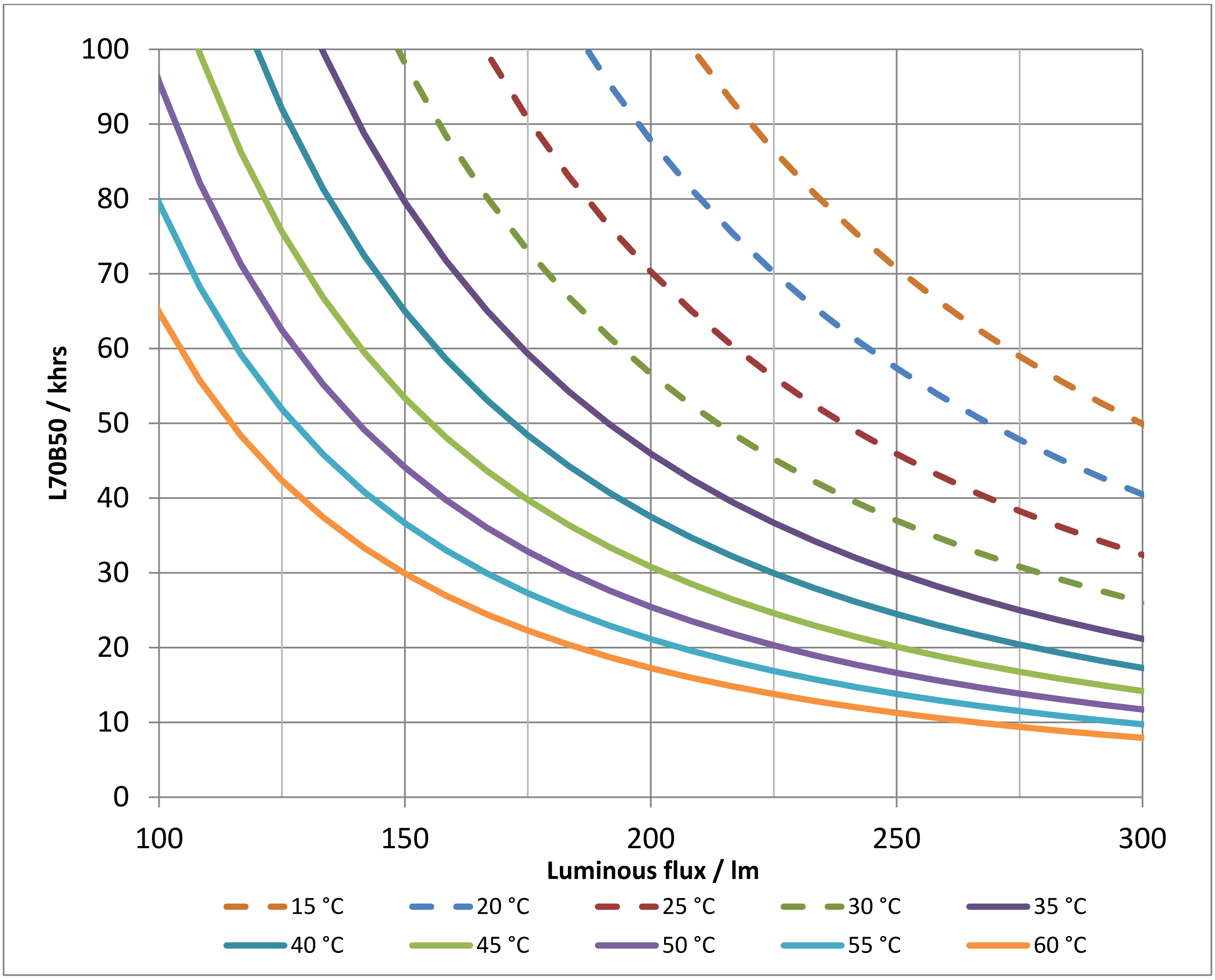


Figure 6.2: Brite 3 Square/Rectangle nw – L70B50 vs. luminous flux and organic temperature

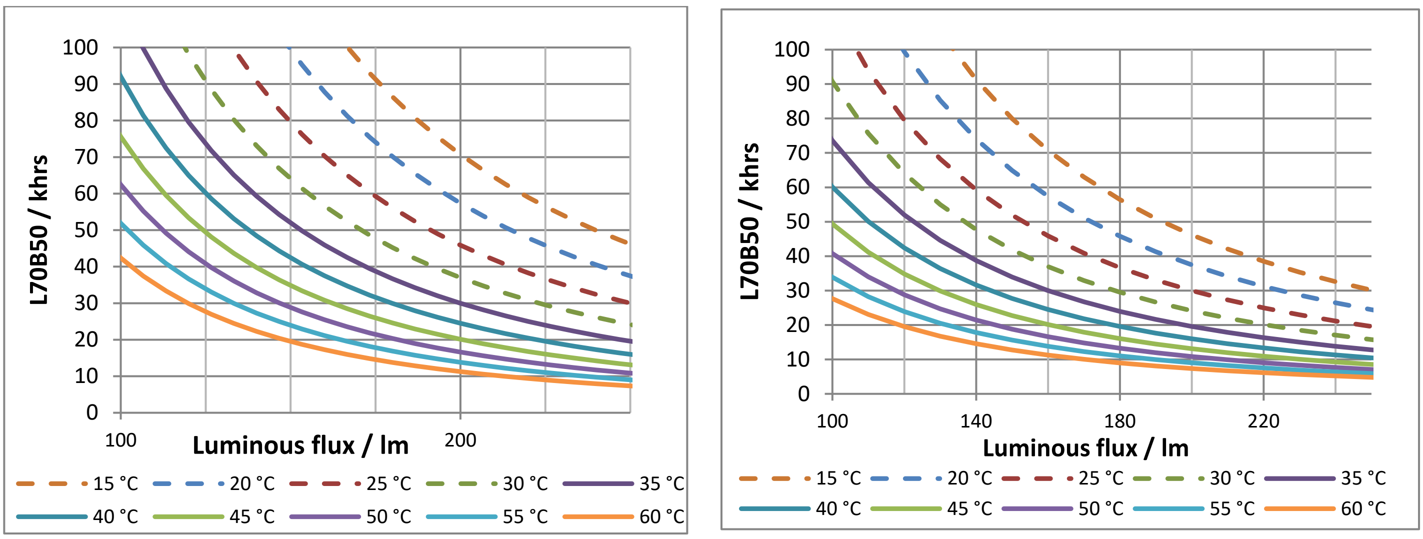


Figure 6.3: Brite 3 Round ww and nw – L70B50 vs. luminous flux and organic temperature

Figure 7 (below) shows the dependency between organic temperature and ambient temperature at different currents. This is only an orientation; air movement, mounting options etc. have a significant impact on resulting organic temperature. The graph shows mean values of temperature measurements taken from Brite 3 ww panels in integration level 1, vertically mounted and measured at spot B on the front. The device had warmed up to steady state before the temperature measurement was made.

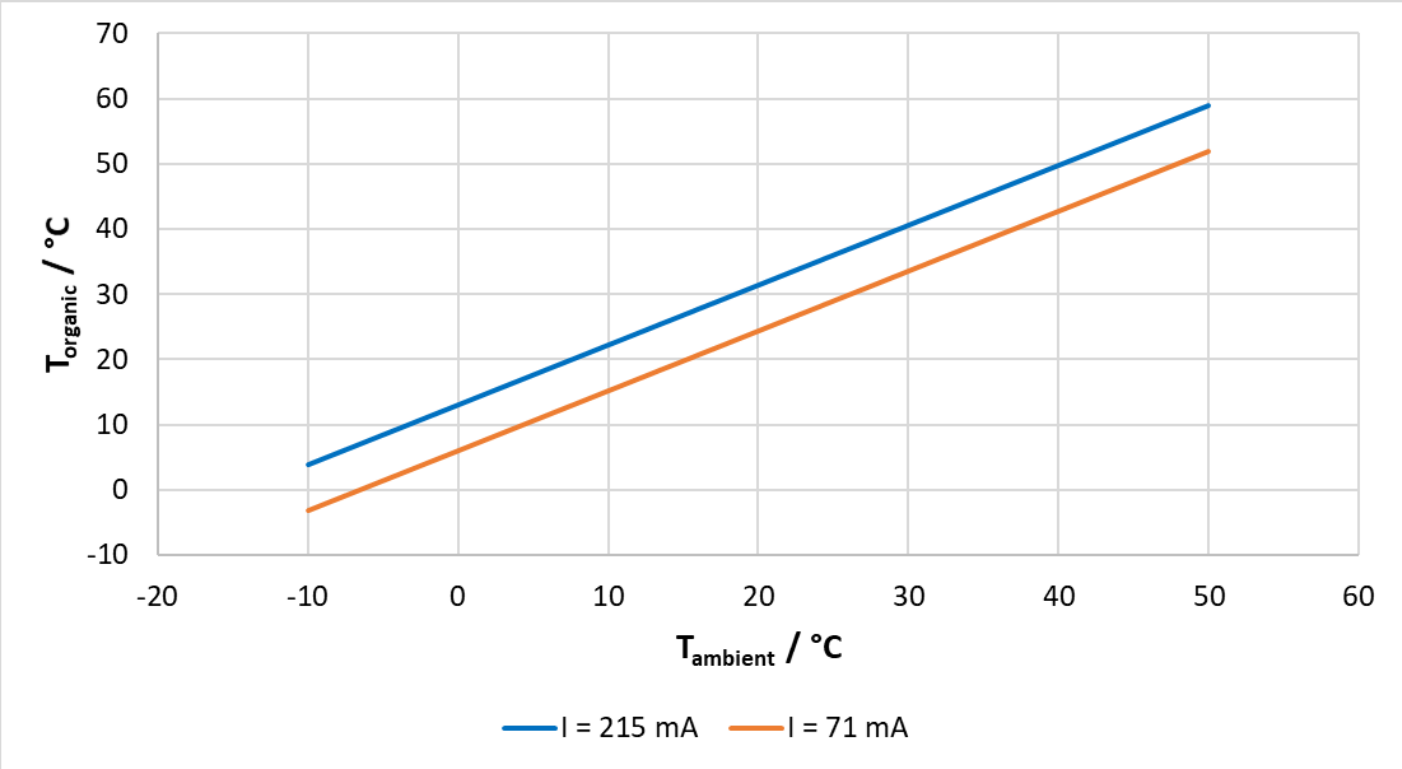


Figure 7 – Indicative relationship between $T_{organic}$ and $T_{ambient}$ at different driving currents (I= 0.085 A, 0.260 A) for integration level 1, mounted vertically in air. Actual relationship strongly depends on thermal interface.

Example:

Question: *Is it possible to achieve an L70B50 of 100,000 hours if the current is reduced from 0.215 A?*

Answer: *An ambient temperature of 25 °C with a driving current of 0.215 A (approx. 300 lm for ww) and a resulting organic temperature of approx. 35 °C would result in an expected lumen maintenance of L70B50 = 30,000 hours for a Brite 3 ww panel. By reducing the current to 0.100 A (approx. 150 lm) for example the expected lumen maintenance would be extended to L70B50 = 80,000 hours. This alone seems insufficient for achieving L70B50 = 100,000 hours. However, as the power consumed and therefore the heat generated by the panel is also reduced, the organic temperature decreases to about 30 °C. Selecting the appropriate curve for 30 °C organic temperature (green dotted) results in an L70B50 >100,000 hours. So, the answer to the question is 'yes'. Note that at 150 lm, the brightness level (3000cd/m2) is approximately that of a standard general lighting troffer or panel.*

Device aging

During the lifetime of the OLED panel the voltage increases. Consequently, the power consumed, and heat generated by the OLED panel increases in constant current driving mode.

Ensure that sufficient thermal management is designed into the luminaire to keep the device at required temperature levels, particularly when approaching the end of lifetime. Detailed data on voltage at end of life are given in the relevant datasheets.

As a rule of thumb, expect an increase of ~4 °C in temperature for each additional Watt consumed by the Brite 3 panel at integration levels 1 and 1.5 mounted vertically and exposed directly to air. However, typical voltage increase over the life of the product is about 1 (one) volt. Therefore, at power would be less than 0.25W and temperature increase would be ~1 °C. Integration level 2 increases slightly less in similar mounting conditions.

Device orientation on temperature and homogeneity

Brite 3 integration levels 1 and 1.5 primarily dissipate heat by convection. As device orientation has an impact on convection it also influences the organic temperature distribution and therefore the homogeneity of light emission.

Brite 3 integration level 2 comprises a metal back-plate which improves heat dissipation by radiation. Although some heat dissipation by convection still occurs, the impact of device orientation exposed directly to air on the homogeneity of temperature and light emission is reduced.

In general, all measures to improve heat dissipation by other means than convection (e.g. radiation and conduction) decrease the impact of device orientation on homogeneity and are therefore recommended in the luminaire design.

Mounting components

The Brite 3 main thermal interface is on the back. The main differences between integration levels 1/ 1.5 and level 2 are given above. While levels 1/ 1.5 simply spread heat and require additional measures to remove thermal energy, integration level 2 provides a black back-plate thermally coupled to the metal foil (heat spreader) which improves heat dissipation by radiation.

This section briefly describes the impact that selected mounting components applied to the thermal interface of the Brite 3 may have. The data given are exemplary and to be considered as indicative. To ensure reliable operation the luminaire design itself needs to be assessed with respect to the resulting organic temperature at targeted currents and ambient conditions. See above on how to measure organic temperature.

Comparison of different exemplary counterparts

As a rule, if the mounting component is to function as a heat sink, optimizing the thermal contact between the thermal interface of the Brite 3 and the mounting unit is desirable. In this case mounting towards an element will generally improve performance as it cools the OLEDs or at least keeps it within a certain temperature range. Cooling efficiency is dependent on the quality of the thermal coupling between the panel and the mounting unit. Dedicated heat pads are recommended although from a purely thermal perspective thermal pastes could also be used. Before using pastes please refer to the section on mechanical integration (see page 10).

If mounting components are to function as thermal insulators, other design approaches may need to be considered to keep the OLED working reliably.

For some applications, convection cooling is significant, and no additional thermal dissipation is required.

Typical temperatures for some exemplary mounting materials

This section provides some indicative measurements for an OLED panel mounted on different materials. Measurements have been executed at room temperature ($T_{ambient}$ = RT ~ 25 °C); the organic temperatures are shown below in Figures 11 - 14. Wood and aluminum plates have been chosen as typical mounting material that may be used in luminaire design[3]. Measurement accuracy is about ±1 °C.

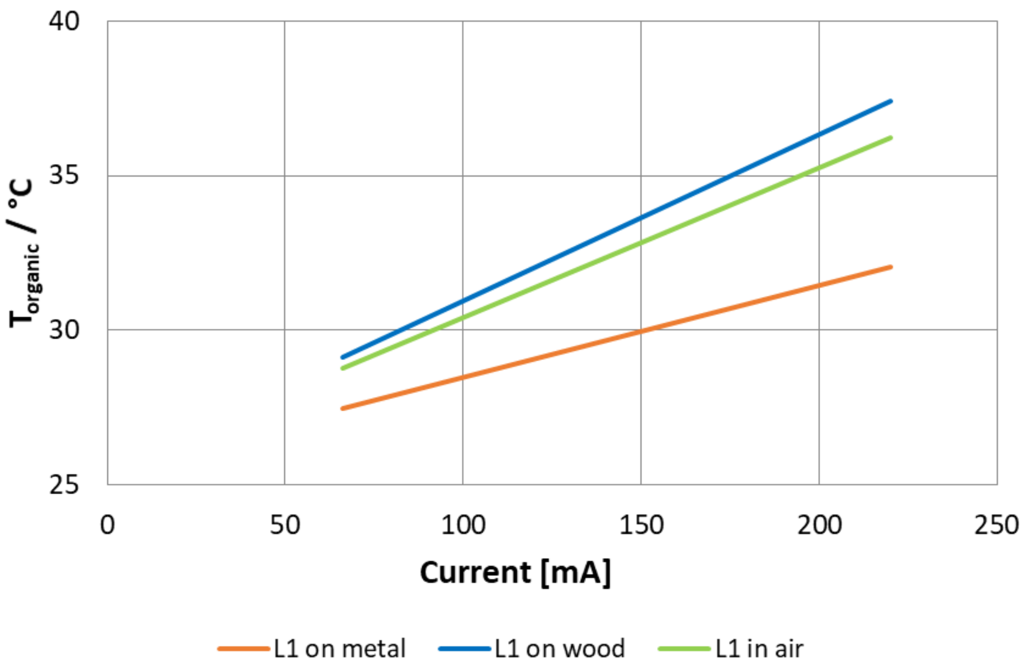


Figure 8 - indicative organic temperature vs. current for different mounting materials – Brite 3 Square ww & nw Level 1

[3] wood: thickness = 16 mm, type = plywood, lateral dimensions = 40 x 40 cm^2; white
aluminum metal: thickness = 1.5 mm, lateral dimensions = 40 x 40 cm^2

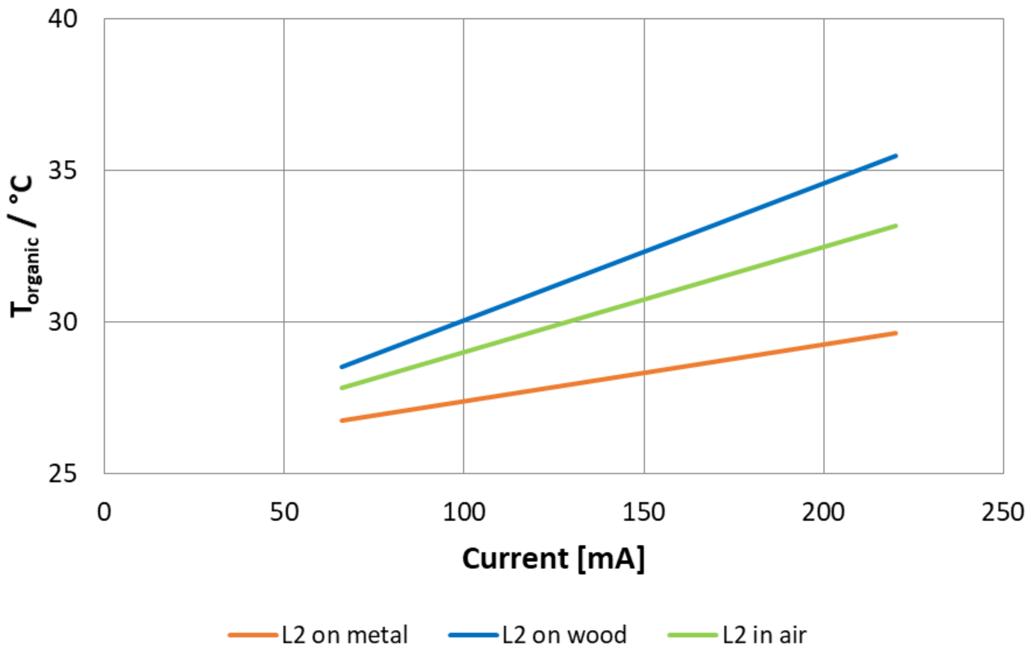


Figure 9 - indicative organic temperature vs. current for different mounting materials – Brite 3 Square ww & nw Level 2

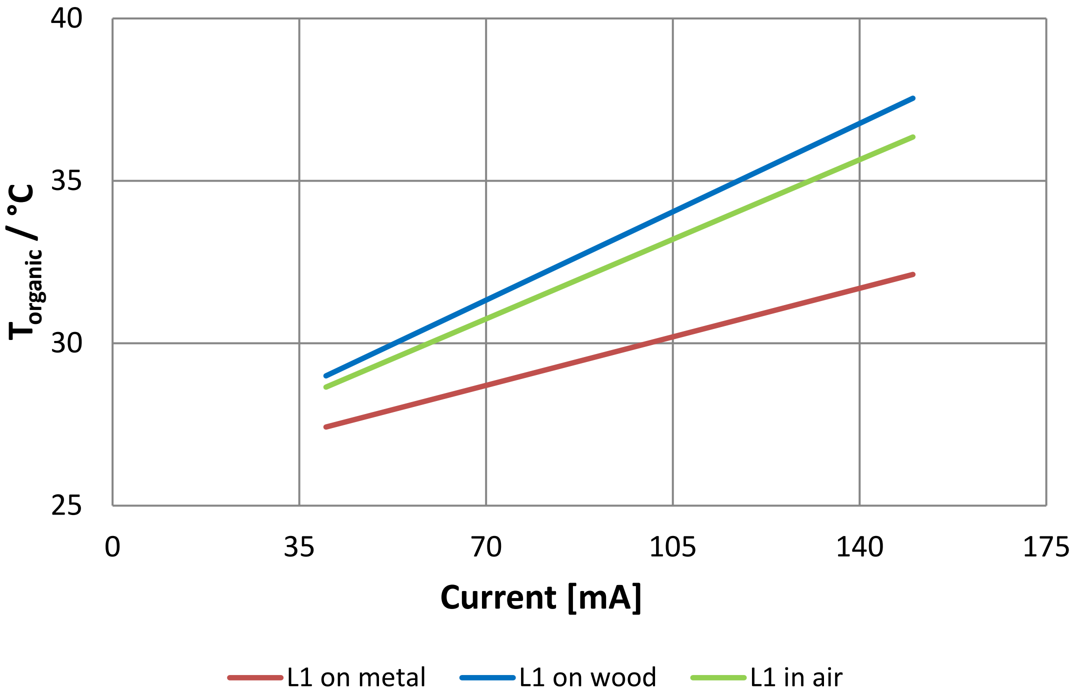


Figure 10 - indicative organic temperature vs. current for different mounting materials – Brite 3 Round ww & nw Level 1

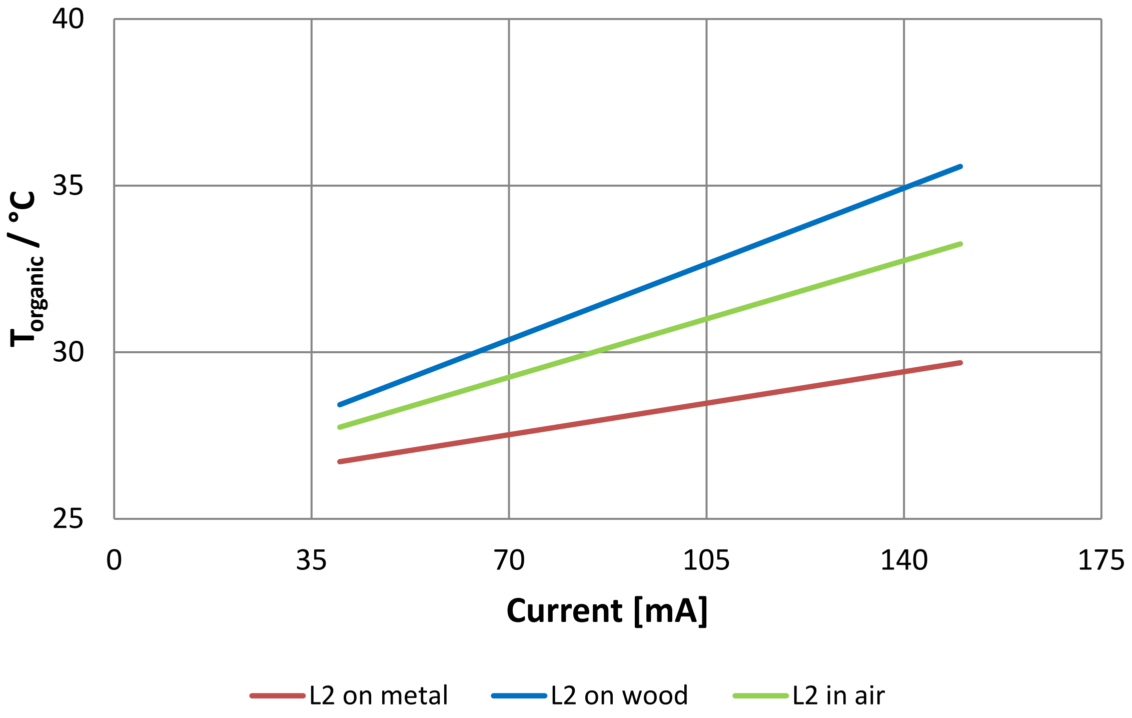


Figure 11 - indicative organic temperature vs. current for different mounting materials – Brite 3 Round ww & nw Level 2

Figures 8-11 show examples for integration levels 1 and 2:

For integration level 2, wood insulates heat dissipation by radiation through the metal back-plate resulting in higher temperatures than when directly exposed to air. This tendency is of varying importance depending on driving conditions (e.g. amount of generated heat).

- Higher integration levels lead to lower temperatures under almost all conditions (mounting units and driving points).
- For all integration levels mounting on a metal unit is always best as it conducts heat efficiently resulting in the lowest possible temperatures.

Please note that the choice of mounting material and the resulting temperatures impact lifetime. See Figure 6.

Notes on thermally active mounting element

So far, the examples given have based on passive mounting units. However, if an active element were mounted directly onto the thermal interface area of the Brite 3, the temperature generated by this component would also need to be considered. An active component, for example a driver, not only limits heat dissipation but also adds thermal energy.

Due to the additional temperature direct contact between thermally active components and an OLED panel is not advisable. Alternatively, organic temperature needs to be reduced by other means (see above).

Also note that Brite 3 panels mounted back-to-back also constitute active components adding to overall heat.

Impact of temperature on electrical properties

The electrical properties of OLEDs change with temperature.

This section describes the general impact of ambient temperature on OLED voltage for a given current. For accurate data on the specific OLED panel in use please refer to the product datasheet.

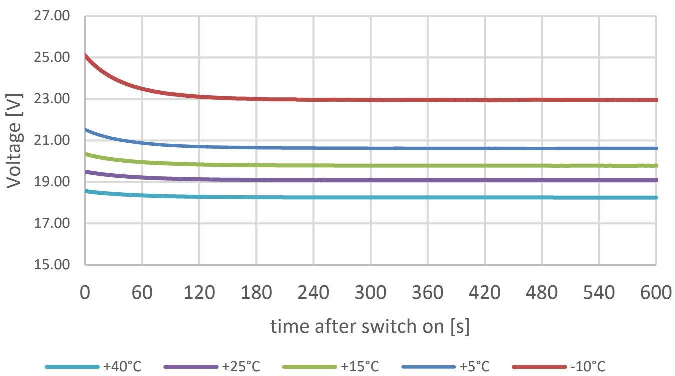
OLED resistivity is reduced with increasing organic temperature. This has two consequences on the voltage in constant current driving mode.

- First, at a given ambient temperature the voltage required to start up the OLED is higher than in a steady state. The voltage drops after turning on the device due to the heat caused by operation. When driving the Brite 3 ww Level 1 at a rated current and room temperature, the drop in voltage is typically around 1 V after the first 10 minutes of operation.
- Second, and in addition to this, the ambient temperature has the same impact on the OLED driving voltage but also leads to differences in the steady state after being turned on.

Figure 12 shows this dependency for the Brite 3 ww. While variation in ambient temperature leads to a shift in the overall voltage curve, this decreases towards a steady state within the first 5 minutes following the device being turned on.

Note that the time to steady state voltage behavior is longer at lower temperatures. If turning on at low temperatures is required, this needs to be considered in the choice of the driver.

This voltage increase adds to the overall voltage increase as the panel ages and may prevent a driver starting up an OLED even though there would be enough power in a steady state.
When Philips Lumiblade OLED drivers are used together with Brite 3 panels proper operation within defined usage is ensured.



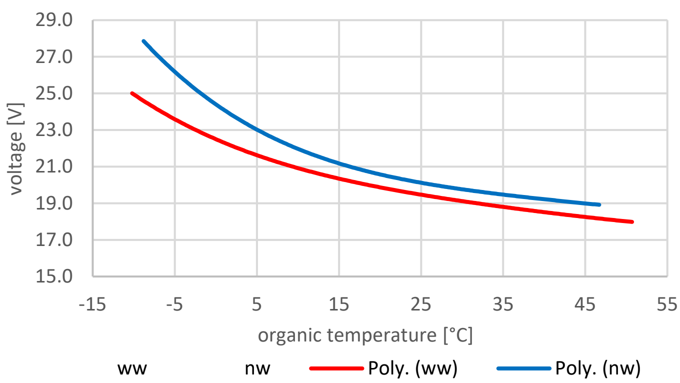


Figure 12 – (left) dependency of driving voltage at constant current (I = 0.215 A) on ambient Temperature $T_{ambient}$; (right) voltage over organic temperature $T_{organic}$

Optical performance changes (color points and luminous flux) during the warm-up phase are negligible.

Additional information

Tc

In contrast to driver electronics there is no Tc mark on the Brite 3 as the entire panel must fulfill the temperature requirements (see datasheet). Inhomogeneity may cause problems (see above). Temperatures should be measured at point B of the panel (see Figure 8).

Moisture / humidity

Be aware that relative humidity may increase if temperature changes to lower values. Recommended usage of the Brite 3 does not account for dew, moisture, water in direct contact with the device as this alters the extent of lifetime (see datasheet for use cases). If the application is exposed to rapidly changing temperatures and high relative humidity levels, please take appropriate precautions.

Contact details

OLEDWorks
1645 Lyell Avenue, Suite 140
Rochester, NY 14606, USA

OLEDWorks GmbH
Philipsstr. 8, 52068 Aachen, Germany

OWinfo@oledworks.com

For more information visit:
www.oledworks.com
www.facebook.com/oledworks
www.twitter.com/oledworks
www.instagram.com/oledworksllc